AGE AND GROWTH OF THE BLACK AND WHITE CRAPPIES, *POMOXIS NIGRO-MACULATUS* (LE SUEUR) AND *POMOXIS ANNULARIS* RAFINESQUE, IN CLEAR LAKE, IOWA

by

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INTRODUCTION

The black crappie, Pomoxis nigro-maculatus (LeSueur), and the white crappie, Pomoxis annularis Rafinesque, are popular sport fish in the United States east of the Rocky Mountains. Both occur in Clear Lake, Iowa, although the black crappie is by far the more abundant. Black crappie appear in a fairly high percentage of angler's catches, and a few of the fishermen prefer crappie fishing to any other sport the lake offers.

This investigation was carried out as part of a long-range study of the fishes of Clear Lake, which aims to establish a sound knowledge of the lake and the important species of fishes in it as a basis for a management policy to make the best use of the lake's resources. This project, which is sponsored jointly by the Iowa State Conservation Commission and the Industrial Science Research Institute of Iowa State College in cooperation with the U. S. Fish and Wildlife Service, is now in its fifth year.

Data to be used in this study were collected by fisheries students and professors from Iowa State College in the years 1941, 1942, 1943, 1947, 1948, 1949, and 1950. The data from the first three years mentioned are scanty but are quite valuable, since they provide some basis for comparison with the more recent data.

A study of age and growth is basic to the establishment of management policies. In some fish populations, it is necessary to establish the legal size limit at some point above that length at which the fish mature, so that each fish would have a chance to spawn at least once in its life. If a population of fish grows slowly and matures late in life, it may be necessary to take measures which would cut down its numbers so that each fish would have to compete less for food and space. In some populations, one year-class may dominate the catch for several years until it dies out or is fished out. In such a case, an analysis of the years which produced successful hatches of the fish may lead to some method of keeping the population stabilized at an optimum level.

The crappies are subject to overpopulation in many lakes, causing the stunted condition mentioned above, and occasionally they may show year-class dominance.

MATERIALS AND METHODS

Collection of Samples

Clear Lake, which is in western Cerro Gordo county, is 3,643 acres in size, and has a variety of shoreline and bottom types. The first detailed study of Clear Lake (Bailey and Harrison, 1945) gives a description of the lake and lists the 43 species of fish which were found there at that time. Because of the size and shape of the lake, a great variety of gear was necessary to sample the entire area. About 30 per cent of the black crappie were taken by angling; 29 per cent were taken in the gillnets; 24 per cent were taken in small seines; 13 per cent were taken in large seines; and the method of capture is unknown for the remaining 4 per cent (Table 1). Of the white crappie, 64 per cent were taken in the gillnets; 18 per cent were taken in small seines; 11 per cent were taken in large seines; and the method of capture is unknown for the remaining 7 per cent (Table 2).

Angling data were secured by inspection of the catches of the sport fishermen and by the investigators' own efforts. No concerted attempt was made at any time to obtain information concerning the types of tackle and bait used by the anglers.

Several experimental gill nets were used, each 125 feet in length and containing 25 foot lengths of the following mesh sizes: 3/4 inch, 1 inch, 1 1/4 inch, 1 1/2 inch, and 2 inches (bar measure). In 1950, these nets were run in water from three feet deep to approximately six

Table 1. Numbers of Black Crappie Taken by Various Gear, 1941-1950, Clear Lake, Iowa

Year	Angling	Gillnet	Minnow seine	Bag seine	Large seines	Unknown	Total
1941	-	-	-	-	10	-	10
1942	-	-	-	-	1	-	1
1943	-	1	-	-	-	-	1
1947	15	1	6	-	-	-	22
1948	-	30	-	-	-	-	30
1949	54	32	14	-	12	9	112
1950	3	4	14	23	8	-	52
Total	72	68	34	23	31	9	237

Table 2. Numbers of White Crappie Taken by Various Gear, 1948-1950, Clear Lake, Iowa

Year	Gillnet	Small seines	500' seine	Unknown	Total
1948	3	-	-	-	3
1949	10	2	3	3	18
1950	15	6	2	-	23
Total	28	8	5	3	44

feet deep, in an area on the north shore which was virtually free of vegetation and which had a gradually sloping bottom, primarily covered with sand. The nets were lifted every two hours for the removal of the fish, and then were set again. The same and other areas in all parts of the lakes were gillnetted from 1947 to 1949.

Common sense minnow seines of 20 and 30 foot lengths were used along all areas of the littoral zone where such gear could be used effectively. These seines proved useful not only in checking for reproduction, but in securing specimens which might be passed up otherwise because of their size and habits.

In the summer of 1950, a small bag seine was employed to sample those areas of the lake where a gillnet would be difficult to operate, and a minnow seine impossible. This bag seine proved quite successful for crappie: 44 per cent of the black crappie and 26 per cent of the white crappie taken in 1950 were taken by the bag seine. The seine had 1/4 inch mesh, was about 50 feet long, and was operated by 100 foot lengths of sash cord at each end. It could be dropped out of a boat if necessary, and would pull over beds of vegetation with reasonable ease and efficiency.

The large seines mentioned previously consist primarily of gear owned and operated by the Iowa State Conservation Commission for purposes of rough fish removal and lake surveys.

The 1941, 1942, and 1943 specimens were collected by Dr. Reeve M. Bailey and Harry M. Harrison, Jr.. The 1947 specimens were collected by

Mr. James Sieh, the 1948 specimens by Mr. Robert E. Cleary, and the 1949 specimens by Mr. John Parsons. The 1950 specimens were collected by Mr. Thomas S. English and the writer.

Records for Individual Specimens

Scale envelopes were the basic recording medium. Scales were placed inside the envelopes, and lengths, weight, sex, maturity, and remarks concerning the internal organs were written on the outside in prescribed blanks. Several scales were removed from the left side of the fish, at a point just caudad of the tip of the pectoral fin as it was extended caudally and dorsally to the lateral line. Standard, fork, and total lengths were measured to the nearest millimeter. Weight was determined by the use of a spring platform scale with a 500 gram capacity. In those cases where investigators had recorded the measurements in inches and the weights in ounces, the data were converted to the metric system for analysis. Sex and maturity were determined by the examination of the gonads. If sex was not immediately obvious, as was the case with some of the smaller fish, they were classed merely as immature. The heart, liver, and kidneys were examined for parasites, and records were made of all parasites that were found. The stomach was opened, and a qualitative analysis of its contents recorded.

Length Conversion Factors

Standard length, measured in a straight line from the tip of the snout to the base of the hypural plate, was used in all growth calculations. In addition, total length, measured from the tip of the snout to the end of the caudal fin with the two lobes compressed, and fork length, measured from the tip of the snout to the center of the fork of the caudal fin, were recorded. Conversion factors were computed by dividing the sums of the total lengths and the fork lengths by the sum of the standard lengths, and by dividing the sum of the total lengths by the sum of the fork lengths. These factors were first computed for separate size groups of 20 mm. range (standard length), but since no definite trend was observed, they are given for the entire group as a unit.

Black Crappie

Fork length = 1.221 standard lengths
Total length = 1.284 standard lengths
Total length = 1.060 fork lengths

White Crappie

Fork length = 1.222 standard lengths
Total length = 1.284 standard lengths
Total length = 1.053 fork lengths

The total length-standard length factor for the black crappie is based on 233 fish; the fork length factors are based on 205 fish. All calculations for the white crappie are based on 44 fish.

Scale Preparation and Projection

The scales were prepared and mounted according to the method described by Lewis and Carlander (1949). If any slime or dirt was adhering to the scales, they were soaked in water and then rubbed between the fingers. The cleaned scales were mounted between two microscope slides, the ends of which were secured with adhesive tape. A microprojector similar to that described by Van Oosten, Deason, and Jobes (1934) was used to examine the scales at a magnification of 42 diameters. Those scales which proved difficult to read because of their lack of transparency were put to soak in distilled water and then read wet. All measurements for the determination of the body-scale relationship were made with dry scales, however. It was apparent that soaking the scales in water changed their diameters.

Determination of Age and Growth

The age of the crappies was determined by counting the number of annuli on the scales. An annulus is distinguished on a ctenoid scale by the anastomosis or cutting over of circuli on the posterior portion of the scale, accompanied by an area where the circuli are extremely close together, and generally followed by an area where the circuli are relatively far apart. The latter two situations were occasionally found in an area of the scale where the circuli did not anastomose, in which case they were not regarded as annular rings, but merely indications of a short slowing of the growth rate.

A fish with no annulus on its scales is said to belong to the O-age group, a fish with one annulus to the I-age group, and so on. All specimens are listed by Roman numerals corresponding to the number of annular rings on their scales. The year-class designation of a particular fish; that is, the year in which it was hatched, is calculated by subtracting the number of annuli on its scales from the year in which it was captured.

Validity of the Annulus as a Year-mark

Although the validity of the annulus as a year-mark has never been proved experimentally for the crappie, several investigators (Schoffman, 1940; Hansen, 1937; Lewis, 1950; Johnson, 1945; and others) have used it as such successfully, and we have empirical evidence to support it. Van Oosten (1929) has summarized the available information both supporting and refuting the scale method. The evidence indicates that the scale method usually is satisfactory for growth studies of Centrarchids. Creaser (1926) studied the structure and growth of the scales of the sunfish, Lepomis gibbosus, and his conclusions, which support the scale method, may be applicable to other Centrarchids. The annuli of the Clear Lake crappies are in most cases easily recognizable and the fact that these annuli are truly year-marks is supported by the following facts, some of which are based on the growth data to be given in a later discussion:

1. An analysis of the year-class data given in Table 3 shows that those fish which were identified by their annuli as belonging to the 1948 year-class were not abundant in any year's collection. This cannot be explained on the basis of the sampling techniques (Table 1), as similar sampling techniques were employed in all cases. The 1948 investigator used the same type minnow seine in checking for young-of-the-year crappies as that which proved successful in locating them in 1949 and 1950. The 1949 investigator made use of gillnets and seines, both of which are shown by a comparison of Tables 1 and 3 to be effective in capturing yearling crappies, yet he captured only seven crappies

Table 3. Numbers of Black Crappie of the Various Year-Classes Taken in Clear Lake, Iowa, 1941-1950

Year Class	Year of Capture 1941	1942	1943	1947	1948	1949	1950
1934	1	-	-	-	-	-	-
1935	4	-	-	-	-	-	-
1936	1	1	-	-	-	-	-
1937	-	-	1	-	-	-	-
1938	4	-	-	-	-	-	-
1939	-	-	-	-	-	-	-
1940	-	-	-	-	-	-	-
1941	-	-	-	1	-	-	-
1942	-	-	-	1	-	-	-
1943	-	-	129	2	-	-	-
1944	-	-	-	4	-	1	-
1945	-	-	-	8	-	8	1
1946	-	-	-	6	4	42	2
1947	-	-	-	43	22	59	7
1948	-	-	-	-	-	7	4
1949	-	-	-	-	-	66	37
1950	-	-	-	-	-	-	102

of the 1948 year-class. In 1950, several types of gear of proven value failed to capture more than four specimens of the 1948 year-class. This follow-through of a scarce year-class through three years of life lends support to the assumption that the annulus is truly a year-mark.

2. An analysis of the growth increment from the time of formation of the last annulus to the time of capture (Tables 4 and 5) shows a consistent increase in the increment through the spring, summer, and early autumn. The results of this analysis conform to the theory that the annulus is formed in the spring when the season's growth begins. The figures for the black crappie indicate that a majority (seven out of nine) of the fish taken in the first two weeks in June had not formed the annulus as yet. Possibly three of the forty-nine taken in the last two weeks in June had not yet formed the annulus.

3. There is a correlation between the age of a fish and its size. Tables 6 and 7 show that, although there is considerable variation in the size of fish of the same age group, the general trend is one which shows an increase in size along with an increase in the number of annuli.

Table 4. Growth Increment Since Last Annulus of Clear Lake Black Crappie, by Age Classes and Time of Capture, 1941-1950

Date of Capture	Age I N	Age I Mean Increment	Age II N	Age II Mean Increment	Age III N	Age III Mean Increment
June 1-15	0	-	7	36	2	38
June 16-30	2	30	22	31	19	16
July 1-15	18	44	12	36	7	19
July 16-31	28	46	13	40	8	23
Aug. 1-15	14	56	12	48	10	25
Aug. 16-31	6	68	5	54	9	26
Sept. 23-24	4	63	1	22	1	29
Oct. 13	0	-	0	-	4	38

Table 5. Growth Increment Since Last Annulus of Clear Lake White Crappie of Age-Class I, by Time of Capture, 1941-1950

Date of Capture	N	Mean Increment
June 17-22	2	46
July 6-14	3	65
July 16-28	21	70
Aug. 1-11	7	79
Aug. 17-29	3	93

Table 6. Standard Lengths and Weights of Clear Lake Black Crappie of the Various Age Classes at the Time of Capture, 1941-1950

Age Class	Number of Fish	Mean Standard Length	Range	Number of Fish	Mean Weight
0	340	30	9-66	-	-
I	72	95	64-145	63	30
II	72	140	103-183	60	92
III	60	167	128-246	53	149
IV	12	187	142-231	9	223
V	7	234	177-259	5	348
VI	5	251	247-256	1	312
VII	1	248	-	-	-

Table 7. Standard Lengths and Weights of Clear Lake White Crappie of the Various Age Classes at the Time of Capture, 1948-1950

Age Class	Number of Fish	Mean Standard Length	Range	Number of Fish	Mean Weight
I	36	110	82-157	36	40
II	4	153	140-182	3	110
III	4	176	165-186	3	171

AGE AND GROWTH OF THE BLACK CRAPPIE

Body-Scale Relationship

Use of the scale method for the calculation of the growth of fish requires an assumption "that the annual increment in the length (or some other dimension which must then be used) of the scale maintains, throughout the life of the fish, a constant ratio with the annual increment in body length." (Van Oosten, 1929: 278). In order to show how closely this assumption has been met, the 229 black crappie from Clear Lake were placed into 20 mm. groups and the mean standard length was plotted against the mean anterior scale radius (x42), and a line was fitted to the data by the least squares method. A straight line with an intercept of 8.785 and a slope of 0.957 best fit the scatter diagram (Figure 1). On the basis of this evidence, growth was calculated on a direct proportion basis using the approximate value of a, or 9 mm. as a base rather than zero (Carlander and Smith, 1944). The deviations from the straight line suggest a sigmoid curve but the straight line is believed to give as accurate a fit as is justified by the data.

Growth Rate

The growth for each year of life was determined for each individual fish by use of tagboard strips and a nomograph like that described by Carlander and Smith (1944); then the average standard length at each annulus was calculated for each age group. When such figures were complete for each age group, the average standard length at each annulus could be calculated for the entire group. The observations contributing

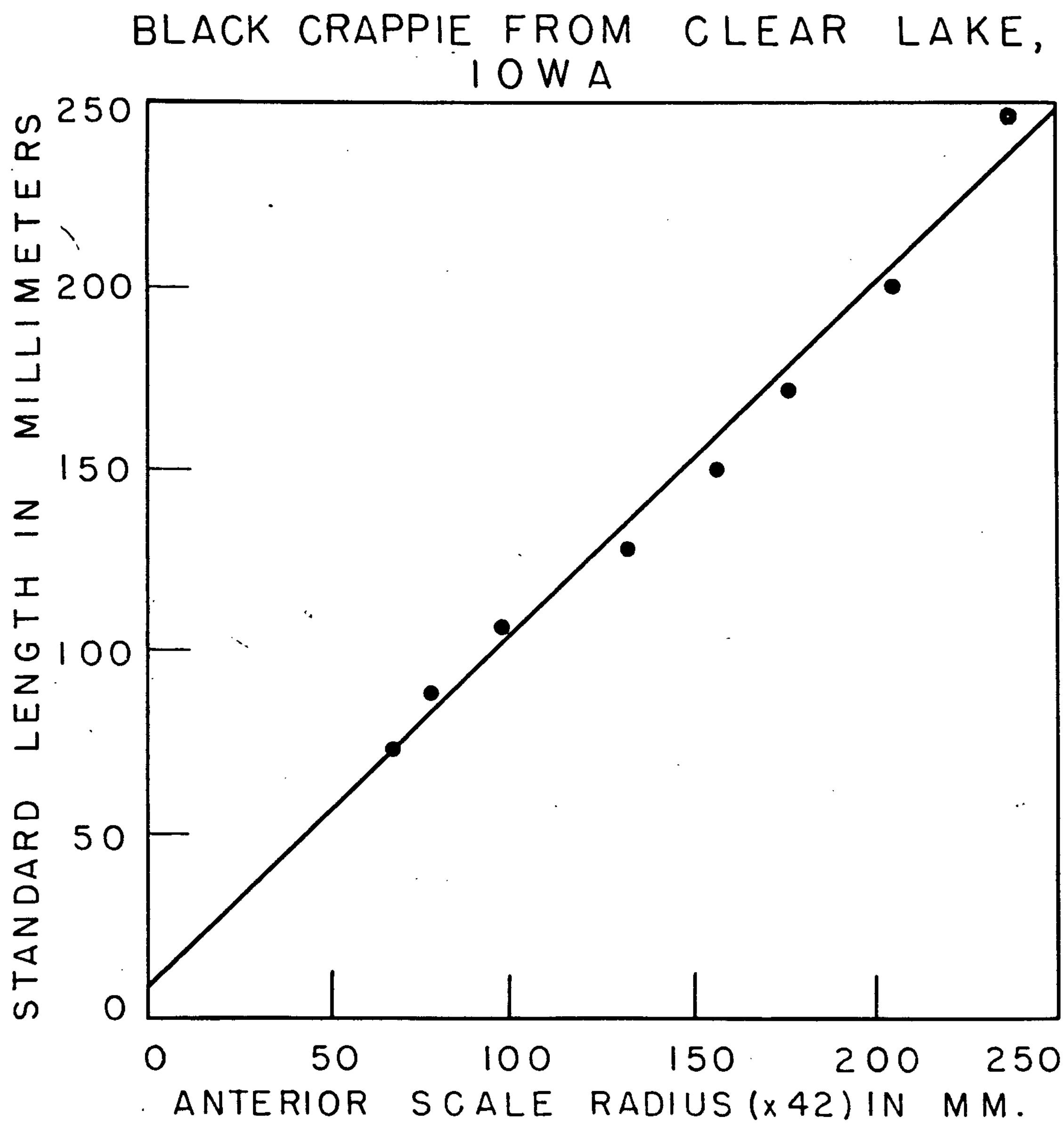

Fig. 1. Body-Scale Relationship of Black Crappie from Clear Lake, Iowa

to this overall average were each weighted according to the number of fish involved. The average annual increment, which is a measure of how much the fish grew on the average in each succeeding year of life, was calculated by subtracting one weighted average from the one for the year following it; however, the averages used in calculating this average annual increment were obtained only from those fish which had completed the year of life for which an average increment was to be computed.

Since there was virtually no difference between the growth rates of the fish collected in the different years, the data are presented for the entire collection as a body (Table 8). The average annual increments show that the fish added more length in their second year than in their first; the tendency in succeeding years is one of gradual decrease in the increment. A possible explanation for this greater growth in the second year can be obtained from an examination of the time of hatching. Eddy and Surber (1947) give the spawning time for the black crappie in Minnesota as May and June, and occasionally in July. Table 9 shows that no investigator found young crappie in Clear Lake before the first of July, which would indicate that they seldom spawn in that lake earlier than June. It seems reasonable to conclude from this that the average black crappie does not have a complete year in his first season, and thus would not be expected to grow as much as in the second. The gradual nature of the decrease in the average annual increment through later years of life is quite typical of the growth of fishes.

Table 8. Average Calculated Lengths of Black Crappie in Each Age Group Collected at Clear Lake, Iowa, 1941-1950

Age Class	Number Examined	Standard Length in mm. at Each Annulus							Standard Length at Capture
		1	2	3	4	5	6	7	
I	72	45							95
II	72	46	103						140
III	60	46	103	144					167
IV	12	51	101	139	166				187
V	7	46	91	142	183	212			234
VI	5	45	78	136	181	206	231		251
VII	1	36	70	128	155	190	226	235	248

Grand Averages from Above Table (229 fish)

	1	2	3	4	5	6	7
Standard Length	46	101	142	173	208	230	235
Average Annual Increment	46	55	43	35	28	27	9
Corresponding Total Length in Inches	2.3	5.1	7.2	8.7	10.5	11.6	11.9
Average Weight in Grams *	3	33	92	166	288	391	415
Weight Increment *	3	30	61	81	101	122	45
Average Weight in Ounces *	0.1	1.2	3.2	5.9	10.1	13.8	14.6

* Computed by length-weight formula presented in later discussion.

Table 9. Growth of Black Crappie Young-of-the-Year from Clear Lake, Iowa, 1943-1950

Date of Capture	Number of Fish	Standard Length in mm. at Capture	
		Mean	Range
1943 (Bailey, 1943)			
July 10	15	22.8	18-26
July 21	40	28.2	23-33
Aug. 6	27	39.1	34-51
Oct. 29	47	53.0	44-66
1947 (Carlander, 1949)			
July 13	18	18.7	
July 18	3	26.5	
July 26	8	27.3	
Aug. 1 & 2	4	28.0	
Aug. 5	6	35.8	
Aug. 9	4	37.4	
1949 (Carlander and Parsons, 1949)			
July 2-16	25	28.6	21-31
Aug. 2-16	15	45.4	41-54
Aug. 17-Sept. 1	26	49.1	44-54
1950			
July 18	5	14.0	9-19
July 25	29	12.4	9-19
July 28	7	15.7	9-25
July 31	28	15.5	9-19
Aug. 2	24	12.7	9-19
Aug. 8	2	17.7	16-19
Aug. 13-15	5	20.2	16-21
Aug. 24	2	19.9	16-21

Lee's phenomenon of apparent change in growth shows up in the calculated lengths at all the annuli except the first and the fourth. This phenomenon appears in many growth studies of fish and has been explained in many different ways (Van Oosten, 1929). The only explanation which seems plausible in this case is that possibly the faster growing fish die at a younger age, leaving a predominance of slow growing fish in the sample of fish of advanced ages. No proof can be offered for this explanation.

The growth histories of some of the individual fish present an interesting picture of individual variation. The fish which was the longest of the entire group at the end of the first year of life was a two-year-old, and was longer than average at the end of the second year. The fish which was the longest at the end of the second year of life was a three-year-old, and had grown fast through all its three years, being longer at the end of its third year than the average crappie was at the end of the fourth. The fish which was longest at the end of its third year had quite a different history, however; it was smaller than average at the end of the first year, a little larger than average at the end of the second year, and, at the end of the third year it was as long as the average crappie at the end of the fifth year. Of the three which showed the greatest length by the end of the fourth year, two were considerably larger than average through their first three years also, but the third was below the average in every one of the first three years. The last mentioned fish was a six-year-old, and, although it continued to be longer than average, it gained less than the average annual increment in succeeding years.

Growth of the Young

A comparison of the lengths of the young-of-the-year fish through the growing seasons of 1943, 1947, 1949, and 1950 (Table 9) shows that the young were growing quite similarly in the first three years, but the 1950 young were very retarded. The lengths when first captured in early July indicate that the 1950 hatch was probably later than that of former years. The data in Table 9 also suggest that the spawning may have been sporadic. This is not surprising when one considers that Clear Lake is large and has a variety of bays and shore-line types.

A comparison of the growth of the young-of-the-year black crappies collected from the Ventura Marsh (Table 10) with that of the young in the main lake (Table 9) gives a possible explanation of the slow growth of the 1950 young-of-the year in the lake.

Table 10. Growth of Black Crappie Young-of-the-Year from Ventura Marsh for the Summer of 1950

Date of Capture	Number of fish	Standard Length in mm. at Capture	
		Mean	Range
July 28	18	35.4	22-47
August 1-2	39	45.6	36-51
August 15	58	48.2	36-55
September 24	17	60.5	51-70

The Ventura Marsh is situated at the extreme west end of Clear Lake, and was cut off from the lake in the summer of 1950 by a gate and a rough fish trap. The marsh is composed primarily of very shallow water, and its maximum depth is about eight feet, whereas the lake has considerable quantities of deeper water, with a maximum depth of about twenty-one feet. The water in the marsh warms up earlier in the summer than does that of the lake. It is difficult to set any positive time of spawning from the data from Ventura Marsh, but it is apparent that the crappies were hatched earlier than those in Clear Lake. A comparison of the sizes of the young from the two bodies of water indicates that they grew faster in the marsh as well as hatched earlier. With this information, an explanation of the relatively slow growth of the 1950 year-class in Clear Lake can be postulated. The summer of 1950 was unusually cold and windy, so it can safely be concluded that the overall water temperature was much lower than it was at similar times in former years. This caused the adult crappies to spawn later and the young to grow more slowly.

Comparison of Growth with Other Areas

Carlander (1950) has summarized growth data for black crappies from various parts of the country, and the majority of these show faster growth than the Clear Lake black crappie; however, the differences are not great in some of the cases. The averages for Minnesota, Indiana, Ohio, and Iowa are relatively close to those for Clear Lake. There appears to be a much greater difference in the growth of crappies in the South, where they grow both faster and larger than they do farther north. There is some suggestion, however, that they live longer in the North.

The only available data on growth of black crappie in Iowa is contained in a study of two artificial lakes in southern Iowa (Lewis, 1950). The black crappies from both East Lake and Red Haw Lake grow larger in a shorter time than do those of Clear Lake; however, a comparison of the average annual increments shows that the growth tends to drop off more abruptly in both Red Haw Lake and East Lake than it does in Clear Lake. The oldest black crappie from Red Haw Lake was eight years old; from Clear Lake, seven years old. Although the single specimens of six and eight-year-olds taken from Red Haw Lake were smaller at capture than the one seven-year-old taken from Clear Lake, the average of the three five-year-olds from Red Haw Lake is greater than the length of any of the specimens from Clear Lake.

Eddy and Carlander (1942) have calculated average growth for black crappies from seventy lakes in Minnesota, using a statistical system designed to give averages for the state as a whole. The average annual increments and the calculated lengths at the end of each year of life are consistently equal to or greater than those of the black crappies of Clear Lake.

Size and Age at Maturity

Information on sex and condition of the gonads is available on only forty-three black crappies, so it is impossible to establish any positive time of maturity; however, the nature of the available information makes it worthy of discussion. The black crappie in Iowa is reported to mature in its third year at about seven to eight inches (Harlan and Speaker, 1951). Of the immature females in the sample of Clear Lake black crappies, the largest was 5.6 inches in total length and was in its second year; the largest of the immature males was 9.0 inches and was in its fourth year. The latter may have been mature earlier, but the gonads were not developed at the time of capture, August 17, 1950. Of the mature fish, the smallest female was 5.35 inches and in its second year, and the smallest male was 7.4 inches and in its third year. These are, of course, the extremes and not the averages. Perhaps a word of explanation regarding the smallest mature female is in order: she was captured in late August, and had eggs forming in the ovaries. She probably had not spawned in the spring of her second year, but would have been ready to spawn in the spring of her third year.

Length-Weight Relationship

It has been shown (Hile, 1941) that the length-weight relationship of various fish may in general be expressed by the following equation: $W = CL^n$; where W is the weight, L is the length, and C and n are constants. For the sake of computation of these constants, the standard lengths and weights of the Clear Lake black crappie were converted to logarithms and a straight line fitted to the data by the least squares method. This length-weight relationship was computed separately for each year's collection and for the sexes, when such data were available. An analysis of covariance was computed to determine if the various regression coefficients, or b values, were significantly different from each other (Table 11). Lot 1 in the table includes the male black crappies collected in 1950, which had a regression coefficient of 3.021; Lot 2 includes the females of the 1950 collection, which had a regression coefficient of 3.017; Lot 3 includes the rest of the 1950 collection of undetermined sex, which had a regression coefficient of 3.058; Lot 4 includes the entire 1949 collection, which had a regression coefficient of 2.916; Lot 5 includes the 1947 collection, which had a regression coefficient of 3.114. The F value of 1.050 with degrees of freedom 4 and 157 shows the differences in these regression coefficients to be not significant at the 5 per cent level. On the basis of this analysis, the length-weight relationship is presented for the entire collection of 169 fish (Table 12). Two fish could not be included in the analysis of covariance because they were the single representatives of the 1942 and 1943 collection; but since they did not appear to vary greatly from the average, they are included in the computation of the length-weight relationship of the entire group.

The straight line which best fit the scatter diagram of the logarithms of the lengths and weights of the Clear Lake black crappie had an intercept of -4.459 and a slope of 2.985. Thus the formula $\text{Log } W = -4.459 + 2.985 \text{ Log } L$ can be used to estimate unknown weights of fish from the same population.

Table 11. Analysis of Covariance for the Length-Weight Relationship of Clear Lake Black Crappie, 1947, 1949, 1950.

Lot	d.f.	Sums of Squares and Cross-Products Sx^2	Sxy	Sy^2	b	Errors of Estimate Sum of Squares	d.f.	Mean Square
1	13	0.243	0.734	2.253	3.021	0.036	12	
2	16	0.162	0.488	1.491	3.017	0.021	15	
3	15	0.238	0.726	2.238	3.058	0.023	14	
4	106	0.576	1.680	5.063	2.916	0.163	105	
5	12	0.238	0.740	2.357	3.114	0.056	11	
						0.299	157	0.001904
Sums	162	1.457	4.368	13.402		0.307	161	
Difference						0.008	4	0.002000

F = 0.002000/0.001904 = 1.050, not significant

Table 12. The Length-Weight Relationship of Clear Lake Black Crappie, 1942-1950

Average Standard Length in Millimeters	Number of Fish	Average Weights in Grams: Observed	Average Weights in Grams: Computed[1]
77	5	14	15
86	11	20	21
94	12	28	27
104	9	36	36
114	5	48	48
125	25	64	63
135	11	80	79
144	20	100	96
155	20	123	120
164	14	146	142
173	15	167	166
184	7	203	200
191	4	222	224
203	4	280	269
214	2	251	313
231	1	345	396
246	3	440	476
252	1	524	510

[1] $\text{Log } W = -4.459 + 2.985 \text{ Log } L$

The value of b, 2.985, shows that the length-weight relationship approaches that in which the weight increases as the cube of the length; which is to be expected if the fish retains the same body shape throughout life. To substantiate this assumption of cubic relationship, the standard deviation of the b value, the 95 per cent confidence interval estimate, and a t-test were computed. The standard deviation of the b value, s_b, is 0.0358. The 95 per cent confidence limits are 3.056 and 2.914. The t-test, which is computed from the formula $t = b - 3.000/s_b$, gave a value of $t = 0.419$; which is not significant at the 5 per cent level with 166 degrees of freedom.

The coefficient of condition, or K factor, is a numerical representation of the relation of a fish's weight to its length; a thin fish will have a lower K value than a plump one. The coefficient of condition is computed by the formula

$$K = \frac{W\, 10^5}{L^3}$$

where W is the weight in grams and L is the standard length in millimeters.

The average K of the Clear Lake black crappie taken in 1942 (1 fish) was 3.44; in 1943 (1 fish), 3.32; in 1947 (13 fish), 3.28; in 1949 (107 fish), 3.22; in 1950 (47 fish), 3.31; giving a grand average for 169 fish of 3.25. Since this value is higher than that reported for Minnesota (Carlander, 1950), and for southern Iowa (Lewis, 1950), we could presume that, although the Clear Lake black crappie grew slower in length than did those from some other comparable areas, they maintained a better than average relative weight.

To determine if the fish collected in various years differed significantly as to plumpness, another analysis of covariance was computed (Mottley, 1941). This analysis is presented in Table 13.

Table 13. Analysis of Covariance for Test of Significance of Differences Among Adjusted Group Means of Clear Lake Black Crappie, 1947, 1949, 1950.

Source of Variation	d.f.	Sums of Squares and Cross-Products			Errors of Estimate		
		Sx^2	Sxy	Sy^2	Sum of Squares	d.f.	Mean Square
Total	166	1.457	4.368	13.402	0.307	165	
Lots	4	0.735	2.164	6.372			
Within Lots	162	0.722	2.204	7.030	0.302	161	.00188
Difference					0.005	4	.00125

F = 0.00125/0.00188 = 0.665, not significant

The F value of 0.665 with degrees of freedom 4 and 161 shows that the differences in plumpness in the various lots, adjusted to a constant length, are not significant at the 5 per cent level.

The yearly weight increments (Table 8) show that the fish put on more weight each year through the first six years of life. The apparent decline in the increment in the seventh year may be partly due to the small size of the sample; but it is to be expected that a crappie would gain less in weight as well as length by the time it reaches its seventh year, due to senility.

AGE AND GROWTH OF THE WHITE CRAPPIE

Body-Scale Relationship

The 44 white crappie from Clear Lake were placed into 40 mm. groups and the mean standard length was plotted against the mean anterior scale radius (x42), and a line was fitted to the data by the least squares method. A straight line with an intercept at a standard length of 30.048 mm. and a slope of 0.960 gave the best fit to the scatter diagram, but since such a line would obviously give too large an increment for the first year, the growth rates were determined on the basis of a direct proportion, as with the Dahl-Lea formula (Lagler, 1950).

Growth Rate

Growth was calculated in the same manner as that previously described for the black crappie, except that 0 was used as a base on the nomograph instead of the 9 mm. intercept. The average growth rate of those white crappie collected in 1948, 1949, and 1950 is presented in Table 14.

An explanation of the greater increment in the second year would follow the same lines as that given previously for the black crappie: the fish do not always have a complete season in the first year due to the time of hatching. However, the greater increment in the third year can probably best be explained by sampling error. The figures are based on only four fish, and probably do not give a true picture of the growth of the population.

Table 14. Average Calculated Lengths of White Crappie in Each Age Group Collected at Clear Lake, Iowa, 1948-1950

Age Class	Number Examined	Standard Length in mm. at Each Annulus 1	2	3	Standard Length at Capture
I	36	38			110
II	4	41	113		153
III	4	45	86	146	176

Grand Averages (44 fish)

Standard Length	39	100	146
Average Annual Increment	39	57	60
Corresponding Total Length in Inches	2.0	5.1	7.4
Average Weight in Grams	1	28	100
Weight Increment	1	26	83
Average Weight in Ounces	.04	1.0	3.5

The individual fish do not vary greatly in growth, although one of the one-year-olds showed quite rapid growth from the time of annulus formation until the time of capture. This fish was 46 mm. long at the time of formation of the first annulus, and had grown to a length of 157 mm. when it was captured in late August. This particular specimen was larger at capture than three of the four two-year-olds.

The 1948 collection of white crappie consisted of three fish. One of these was a three-year-old and the other two were two-year-olds. The 1949 collection consisted of eighteen fish, fourteen of which were one-year-olds. The 1950 collection consisted of twenty-three fish, twenty-two of which were one-year-olds. The twenty-third fish in the 1950 collection was a three-year-old; not one fish of the 1948 year-class, which was so predominant in the 1949 collection, showed up in the 1950 collection. This indicates that, although some of the Clear Lake white crappie live more than one year, a large percentage of them do not survive through two years.

Since there are no records of any young-of-the-year white crappie ever having been taken in Clear Lake, no comparison can be made as to good and bad growing seasons for the young compared with the growth of the adults in those same seasons.

Comparison of Growth with Other Areas

When compared to growth of the same species in other parts of the country (Carlander, 1950), the white crappies of Clear Lake seem to be a slow growing population; but the white crappies do not appear to be as much below average as the black crappies. There is little evidence to indicate different growth in the North and the South.

Data from two artificial lakes in southern Iowa (Lewis, 1950) show that the white crappies in Red Haw Lake grew considerably faster than those of Clear Lake, although the age distribution was quite similar. The East Lake white crappies, which were generally older and more numerous than those of Red Haw Lake or Clear Lake, showed quite similar growth to the white crappies of Clear Lake in their first two years, and grew less their third year, on the average, than did the Clear Lake white crappies.

The white crappie in Minnesota is confined largely to the southern part of the state (Eddy and Surber, 1947). A small sample of white crappies from two Minnesota lakes (Eddy and Carlander, 1942) was composed of fish three years old and younger. The average standard lengths at the end of each year in this sample were: at the end of the first year, 52 mm.; at the end of the second, 93 mm.; at the end of the third, 134 mm.. A comparison with Table 14 will show that those fish were slightly larger than the Clear Lake white crappies at the end of the first year, but were smaller at the ends of the second and third years.

Size and Age at Maturity

Condition of the gonads was recorded for 23 white crappies collected in the summer of 1950. Of these, 22 were yearlings and were immature. The twenty-third was a three-year-old male, and was apparently spent.

This fish was 186 mm. in standard length, or 9.4 inches in total length.

Length-Weight Relationship

The length-weight relationship of the white crappie was calculated in the same manner as that described previously for the black crappie: the lengths and weights were converted to logarithms and a straight line fitted to the data by the least squares method. Since the sample was so small, no attempt was made to keep the sexes or the time of collection separate in the computations.

The straight line which best fit the scatter diagram of the logarithms of the lengths and weights of the Clear Lake white crappie had an intercept of -5.308 and a slope of 3.376. These values can be substituted into the formula $\text{Log } W = -5.308 + 3.376 \text{ Log } L$, which may be used to estimate unknown weights of fish from the same population (Table 15). The weight appears to increase more rapidly than the cube of the length.

The average K value for the 42 white crappie was 2.95. This, like the comparable value for the black crappie, is higher than that reported for southern Iowa (Lewis, 1950), and for Minnesota (Carlander, 1950). Although they are not as plump or as long-lived as the black crappie, it appears that the Clear Lake white crappie compare quite favorably to fish of the same species from other lakes in nearby areas.

Table 15. The Length-Weight Relationship of Clear Lake White Crappie, 1948-1950

Average Standard Length in Millimeters	Number of Fish	Average Weights in Grams	
		Observed	Calculated[1]
86	3	20	17
98	6	26	26
107	14	36	35
116	7	47	46
127	3	49	62
134	2	71	75
144	3	111	95
157	1	107	128
165	1	168	150
184	2	172	218

[1] $\text{Log } W = -5.308 + 3.376 \text{ Log } L.$

FOOD AND PARASITES

Food of the Black Crappie

In the summer of 1950, 57 stomachs of black crappie were examined. Records were kept of the types of food found, the size of the specimen and the date of capture. No attempt was made to determine the volume of the food or the percentage of various organisms in the stomach, as the food was found in various stages of digestion. Of the 57 stomachs, 26 contained entomostraca, 16 were empty, 4 contained insects, 3 contained vegetation, 3 contained *Hyalella* sp., 3 contained fish, and 1 contained only unidentifiable debris.

A study of the total lengths of the fish which had eaten the various organisms shows that entomostraca was eaten by fish ranging from 3.7 inches to 8.6 inches; insects were eaten by fish from 4.8 inches to 5.6 inches; vegetation appeared in stomachs of fish from 4.8 to 8.0 inches long; *Hyalella* sp., in fish from 5.4 to 5.8 inches long; fish remains were found in black crappies from 5.3 to 7.4 inches long.

The dates when the various foods were found point further to the importance of entomostraca in the diet of the black crappie; those organisms were found in stomachs throughout the entire summer and into September. Vegetation appeared in the diet only between the 18th and the 28th of July. Insects, as noted above, were not common in the diet, but they were found from July 28th until September 24th. Fish were found in the diet only during one week in mid-August. The *Hyalella* sp. were found only on the 24th of September.

Food studies by other investigators show quite similar food preferences by black crappies in other sections of the country. Pearse (1919) found entomostraca to compose 43.7 per cent of the food of 276 black crappies from inland lakes of Wisconsin. Insect larvae, pupae, and adults composed 38.6 per cent of the food of those fish; amphipods, 7.4 per cent; and fish, 6.4 per cent. This shows a higher precentage of insects than were found in the black crappies of Clear Lake, but the other items compare quite closely. Lewis (1950) gives insects and entomostraca as important items in the food of crappies in two artificial lakes in southern Iowa.

Parasites of the Black Crappie

The same 57 black crappies which were examined for food were examined also for parasites. The heart, liver, and kidneys were inspected in each of them. Of these 57, four were found to have white grubs, probably Posthodiplostomum minimum, in the liver.

Food of the White Crappie

Twenty-three stomachs of white crappies were examined in the summer of 1950. Ten stomachs were empty, 8 contained entomostraca, 4 contained insects, and 2 contained vegetation.

The total lengths of the fish in relation to their food choices do not vary greatly. Those which had eaten insects ranged from 5.5 to 5.8 inches; those which had eaten entomostraca ranged between 4.2 inches and 6.0 inches; and those which had eaten vegetation were 4.6 and 6.0 inches long.

The times of finding the various food items in the stomachs do not indicate any definite time for the entomostraca and the vegetation. Entomostraca were found in stomachs all through the period of investigation, and vegetation was found once in the early part of the investigation and once in the later part. Insects were found solely in late July.

SUMMARY AND CONCLUSIONS

Black Crappie

1. The study of Clear Lake black crappie was based on 237 adult fish and 340 young-of-the-year fish collected in 1941, 1942, 1943, 1947, 1948, 1949, and 1950.

2. Various types of gear were used in capturing specimens, each sampling a different habitat or size range of fish. A small bag seine used in 1950 proved very useful in capturing black crappies.

3. The 1948 year-class was found to be consistently scarce through three years of collection.

4. The majority of the specimens had apparently not formed the annulus by the middle of June, but all had formed it by the first of July.

5. The body-scale relationship can best be described by a straight line having an intercept of 8.785 mm. and a slope of of 0.957.

6. The greatest growth in length was in the second year. The increment decreased gradually each year thereafter.

7. Data from young-of-the-year collections indicate that spawning probably takes place sometime in June.

8. Lee's phenomenon of apparent change in growth shows up in the calculated lengths at all the annuli except the first and the fourth.

9. The 1950 young-of-the-year were noticeably retarded in growth, probably because of the unusually late spring and cool summer.

10. The rate of growth of the Clear Lake black crappies is slightly slower than that in other parts of the Midwest, and considerably slower than in the South.

11. Maturity is usually reached by the third spring when the fish just becomes a member of age-group II.

12. The relationship between standard length (L) and weight (W) can best be described by the formula: $\text{Log } W = -4.459 + 2.985 \text{ Log } L$.

13. An analysis of covariance failed to show significant differences between the regression coefficients of the length-weight relationships for the fish captured in different years.

14. The average coefficient of condition, K, for 169 fish was 3.25, which is higher than that reported for black crappie in nearby waters.

15. The yearly weight increment increases steadily through the first six years of life, and declines in the seventh.

16. Fifty-seven stomachs were examined for food. Entomostraca appeared to be a basic part of the diet at all times and for all sizes of black crappie.

17. Four of 57 black crappie were found to have white grubs, probably Posthodiplostomum minimum, in the liver.

White Crappie

1. The study of Clear Lake white crappie was based on 44 adult fish collected in 1948, 1949, and 1950.

2. The average annual increment in length increases steadily through the three years of life; but, the growth during the third year may be overestimated as the sample size is quite small.

3. There is some evidence to indicate a high mortality between the end of the first year and the end of the second year of life, and no specimen was taken which was four years old.

4. Clear Lake white crappies grow somewhat slower than those from some other regions of the Midwest, but seem to pass up most of them by the end of the third year.

5. The formula for the length-weight relationship describes a straight line: $\text{Log } W = -5.308 + 3.376 \text{ Log } L$.

6. The average K for 42 white crappies was 2.95, which is higher than that reported for white crappies in nearby waters.

7. Twenty-three stomachs were examined for food. Entomostraca was the major item found, followed by insects.

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