GROWTH CHARACTERISTICS OF A BLUEGILL POPULATION IN A MICHIGAN TROUT LAKE

Thesis for the Degree of M. S.

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Ernest Genrick Karvelis

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This is to certify that the

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Robert C Ball
Major professor

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GROWTH CHARACTERISTICS OF A BLUEGILL POPULATION IN A MICHIGAN TROUT LAKE

by

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INTRODUCTION

Michigan has a large number and a great variety of inland lakes and because of the number and importance of its lakes has become the leading state in the number of licensed fishermen. These lakes can be divided into two general categories on basis of fish-producing potentialities: (1) trout lakes with their colder and usually deeper waters and (2) warm-water lakes with shallower basins and more productive waters.

In the course of fisheries surveys throughout the state many lakes have been found that appear to be thermally and chemically suited to trout but are populated with warm-water species of fish. In such lakes there seldom is satisfactory growth and survival of both types of fish. This appears to be due to the lowered growth rate of the warm-water species in waters below their optimum and inability of the trout to compete successfully with the usually more numerous pan fish.

Since such mixed populations are not successful and because it is desirable to encourage trout production in lakes it has become a part of the lake management procedure to treat lakes to remove such mixed undesirable fish populations.

An opportunity to study such a lake was presented at Ford Lake (T. 32 N., R. 1 W., 8, Otsego County, Michigan) in 1946. This lake was a trout lake having a stunted bluegill

(Lepomis macrochirus) population, (Ball, 1948a) and with a few of the trout planted surviving to harvestable size. The lake was poisoned in 1946 with the intent of removing all fish. This attempt failed as a few bluegills survived the poisoning. This afforded an opportunity to study the establishment of a bluegill population in a lake where the only predator and competitor was the brook trout (Salvelinus fontinalis) and record the interrelationships of these two fishes in competition.

History

Prior to 1936, Ford Lake was a potential trout lake, but as such it was unproductive of trout due to the presence of a stunted population of yellow perch (Perca flavescens). In 1936, the fish population was killed with rotenone and dynamite (Eschmeyer, 1937).

In 1937, a planting of Montana grayling (Thymallus montanus) was made but did not prove successful due to the unauthorized introduction of bluegills (Leonard, 1939, 1940).

By 1939, the bluegill population had become so great that the grayling were not able to compete successfully. Five thousand fingerling brook trout were planted in September 1941, but were unable to thrive due to the bluegill population present.

In September 1943, young-of-the-year walleyes (Stizostedion vitreum) were introduced as a possible means of reducing the large number of stunted bluegills to a point where growth would result in legal-sized fish.

Gill nets set in the lake in the summer of 1945 failed to show any trout remaining (Ball, 1948a).

On August 26, 1946, Ford Lake was poisoned for the second time. In applying the poison, every precaution was made to kill all the fish present so there would be no competition for food, as brook trout were to be planted in the fall of that year.

After the poisoning, an effort was made to recover all of the fish. The introduction of the walleyes proved of no value, since of the 37,383 bluegills recovered, only 18 were legal-sized (6 inches or longer) and the average length of the fish was 3.9 inches. Of the 168 walleyes planted in 1943, only 17 were recovered and had grown from 5.75-10.50 inches to 17.00-19.75 inches (Ball, 1948a).

In the fall of 1946, brook trout were planted, but in 1947, bluegills were found to be present. The bluegills present were believed to have survived the 1946 poisoning.

Ball (1948b) states that of 32 Michigan lakes poisoned with rotenone, during 1934-1942, 18 have been recorded as having a complete kill.

The personnel of the Pigeon River Trout Experimental Station have taken scale samples of the Ford Lake bluegills beginning in 1948 and continuing to 1951. From the material collected, it was possible to calculate the growth rates of the fish for the different year classes and the relationship of this rate to the population density.

An examination of the stomachs of the bluegills and brook trout gave an indication of the food eaten by the fish.

In the bluegill growth studies, it was noted that the majority of fish which survived the 1946 poisoning were fish of the year class 1946. These small fish may have avoided the poison by burying themselves in the dense Chara mats that were on the bottom of the lake. At the time of the poisoning, the lower waters of the lake were devoid of oxygen. A few large fish survived but no scales were available from these, however, the spring following the poisoning the anglers caught a few very large bluegills.

Description of Lake

Eschmeyer (1937b) describes the lake as having a surface area of 10.7 acres, no inlet or outlet, and a maximum depth of 10 meters. The lake is situated in the midst of rolling sandy country covered with jack pine and aspen, and receives a relatively small amount of surface drainage (Leonard, 1939). During a survey conducted by The Institute for Fisheries Research in 1932, the bottom was found to be composed uniformly of pulpy peat. The rather extensive shoal areas, averaging 175 feet in width, are composed of sand on the north, east, and south sides which are separated from the peat by a belt of marl of approximately equal width.

MATERIALS AND METHODS

Field Program

Scale Sampling

Scale samples, and accompanying data for 433 bluegills were collected from Ford Lake during June 1948; June, July, and August 1949; June 1950; and May, June, July, and August 1951. The fish caught did not represent a random sample, but rather a selected sample, since most of the scales collected for this study were obtained from anglers. For this reason all but a few of the fish were 6 inches or longer in total length.

Collection of bluegills by seining was impossible because of a sharp dropoff and aquatic vegetation in the shallow areas along the lake shore.

The scales for the bluegill age and growth studies were removed from the fish in the region between the lateral line and the anterior end of the spinous dorsal fin. These scales were placed in individual envelopes with other pertinent data.

Stomach Sampling

Stomach samples and accompanying data were obtained for 37 bluegills caught with hook and line. The total lengths ranged from 3.5 to 8.0 inches. The date of capture was August 4-5, 1951.

During 1950 and 1951, 37 brook trout with total lengths ranging from 5.0 to 12.1 inches were caught by the same method. Of these, 7 were caught in February 1950, 9 in April, 7 in June, and 12 in August of 1951.

After recording the length, weight, and date of capture, the stomachs were preserved individually in a formalin solution.

Laboratory Examinations

Age and Growth Determination

The scales were mounted on slides with a gelatin-glycerin media and examined with the aid of a scale projection machine. From these observations, the age and growth rate of the bluegills were determined. Growth rates were charted by the use of a nomograph as described by Carlander and Smith (1944).

In the use of a nomograph in growth determinations, it is necessary to know the length of the fish when the scales are laid down. The standard length of bluegills at the time of scale formation was found by Potter (1925) to be 17.0 mm. Using the conversion factor for changing standard lengths to total lengths, as presented by Beckman (1948a), the length of the fish at the time of scale formation was established as 0.8 inches.

As all of the length measurements were taken in inches and the weight in grams, these units were used in all calculations except for those of the "K" factor. This determination required the conversion of length of fish to centimeters.

Fish Food Analysis

The stomach content of each fish was examined with the aid of a binocular microscope. An estimate was made of the percentage of the total volume contributed by each group of food organisms.

GROWTH ANALYSIS

The growth study was carried out to determine whether or not the rate of growth was reduced as the number of bluegills increased. Such a reduction has been noted in many lakes but the rate at which it proceeds has not been recorded nor its relationship to the disappearance of trout in the same waters.

Age groups of the bluegills are represented by the Roman Numerals I, II, and III. These refer to the number of winters through which a fish has lived. Thus, a fish having passed one winter will belong to Age Group I and will show one annulus and be in its second summer.

In making this growth study, a total of 433 scale samples from bluegills were collected, age determinations made, and length at different year classes calculated.

The length of the fish at the time of capture was not used in the growth calculations. If the fish was captured early in the year and had not formed its annulus for that year, that year's growth was omitted and the only reading taken was that of the calculated length at each annulus.

Validity of Scale Method

The scale method for determining the growth rate of the bluegill was used. The validity of the scale method for age and growth determinations for the Centrarchids was demonstrated by Creaser (1926).

The following data are presented to justify the use of the scale method for age and growth determinations for the fish population under consideration. The use of this method is based on the assumption that the length of the scale increases proportionally to that of the fish.

From fish caught in 1951, data were t aken pertaining to the average lengths of the fish and their scales (Table 1). These data represent true (not calculated) lengths at the time of capture. The length of the scales represents the distance from the focus to the anterior edge of the scale.

The data concerning these fish were plotted and the results are shown in Figure 1. In order to have a straight line, there must be a direct relationship between the length of the fish and the length of the scale. This relationship is exhibited by the plotted line of Figure 1. The criteria that the length of the scale increases proportionally with that of the fish is accepted for Ford Lake bluegills.

Growth Increment

Table 2 and Figure 2 show the growth increments for the various year classes during the time considered by this study. From these data there is noted a definite decrease in the growth increments as the age of the fish increased, also the

TABLE 1

NUMBER, AVERAGE LENGTH OF FISH, AVERAGE LENGTH OF SCALES X 46

Class interval (inches)	Number of fish	Average length fish (inches)	Average length (inches) scales X 46
3.1-3.5	7	3.36	2.25
3.6-4.0	17	3.80	2.70
4.1-4.5	14	4.18	3.03
4.6-5.0	10	4.89	3.44
5.1-5.5	19	5.38	4.00
5.6-6.0	41	5.83	4.39
6.1-6.5	111	6.33	4.77
6.6-7.0	46	6.69	4.98
7.1-7.5	7	7.37	5.19
7.6-8.0	7	7.80	5.96
8.1-8.5	4	8.30	6.60

increments for the same age groups decreased as the number of fish increased.

Calculated Lengths for Each Age Group

The average calculated lengths for bluegills in each age group for each year class are presented in Table 3 and Figure 3.

Figure 1 Fish and scale length relationship for Ford Lake bluegills

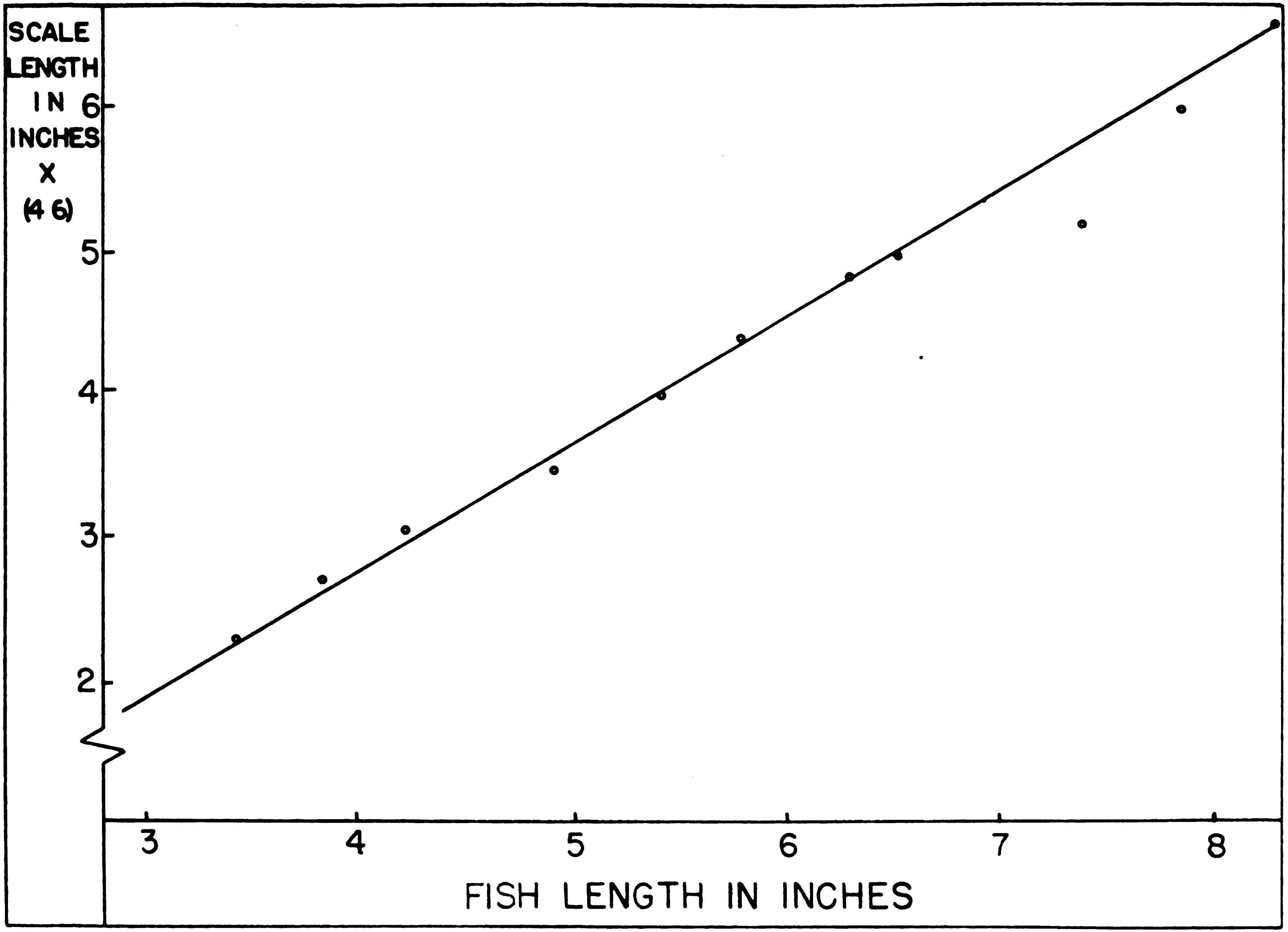

SCALE LENGTH IN INCHES X (4 6)
6
5
4
3
2
3
4
5
6
7
8
FISH LENGTH IN INCHES

TABLE 2

GROWTH INCREMENTS IN INCHES FOR DIFFERENT YEAR CLASSES

	Age Groups		
Year Class	I	II	III
1946	4.4	2.5	
1947	4.0	2.5	1.3
1948	4.0	1.5	0.6
1949	3.9	1.7	
1950	3.1		

The growth analysis revealed a decrease in the growth rate of the Ford Lake bluegills. The decrease from Year Class 1946 to 1950 is too great to be attributed to normal fluctuations of growth from year to year, but is presumably due to the number of fish in the lake increasing thus causing a competition for food which resulted in lower growth rates.

Figure 2 Average growth increment for the year classes and age groups of bluegills from Ford Lake.

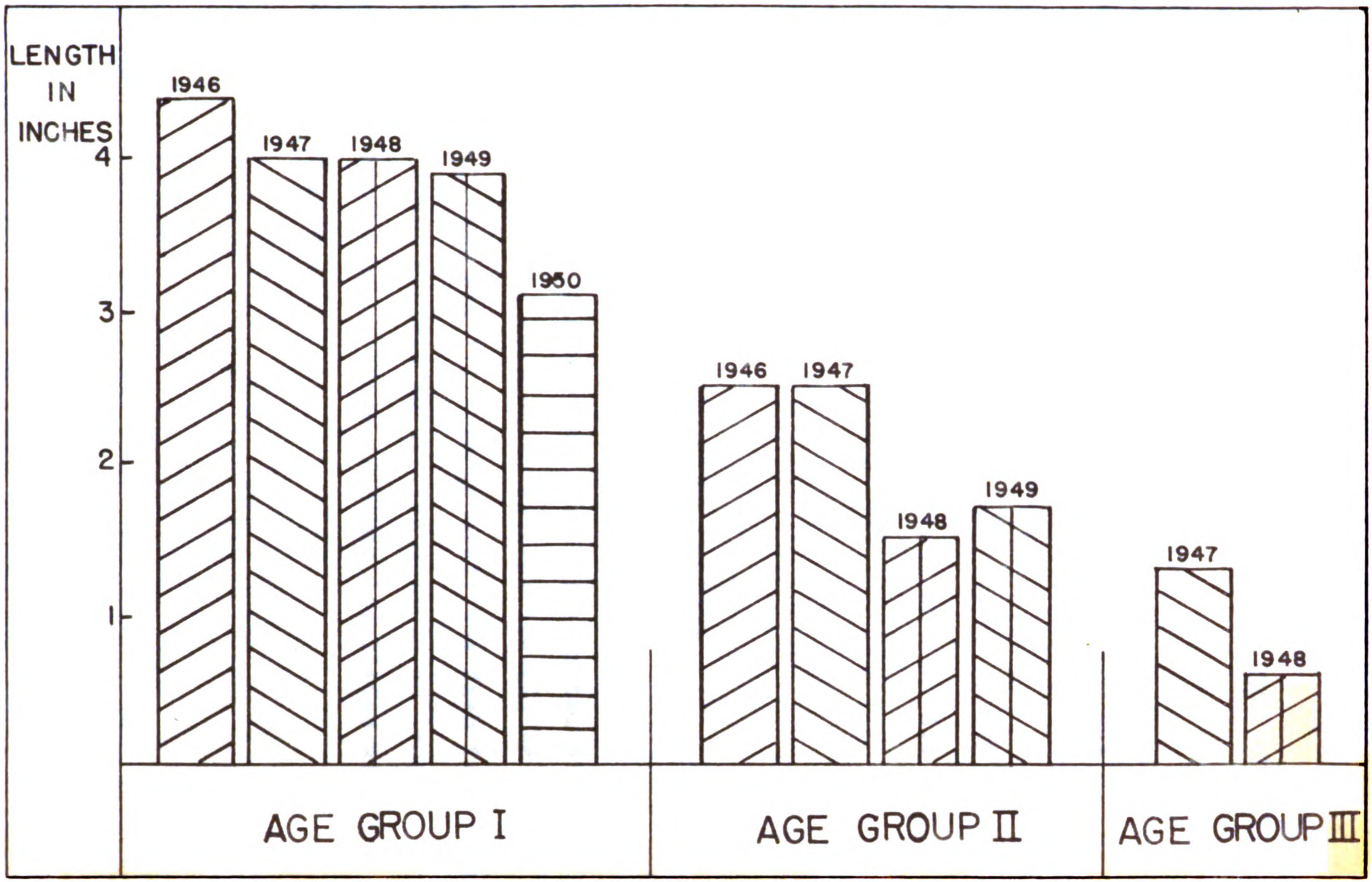

LENGTH IN INCHES
4
3
2
1
1946
1947
1948
1949
1950
AGE GROUP I
1946
1947
1948
1949
AGE GROUP II
1947
1948
AGE GROUP III

TABLE 3

AVERAGE LENGTH IN INCHES OF FISH FOR DIFFERENT YEAR CLASSES

	Age Groups		
Year Class	I	II	III
1946	4.4	6.9	
1947	4.0	6.5	7.8
1948	4.0	5.5	6.1
1949	3.9	5.6	
1950	3.1		

Comparison with Other Regions

An attempt is made to compare the growth of Ford Lake bluegills with those of other regions of the United States. Table 4 illustrates the average calculated lengths of fish in Age Groups I, II, and III. In general, the fish from Ford Lake, through 1951, exhibit an average calculated length equal to, or better than, those of other localities with the exception of California.

Figure 3 Average length of Ford Lake bluegills at each annulus for the different year classes.

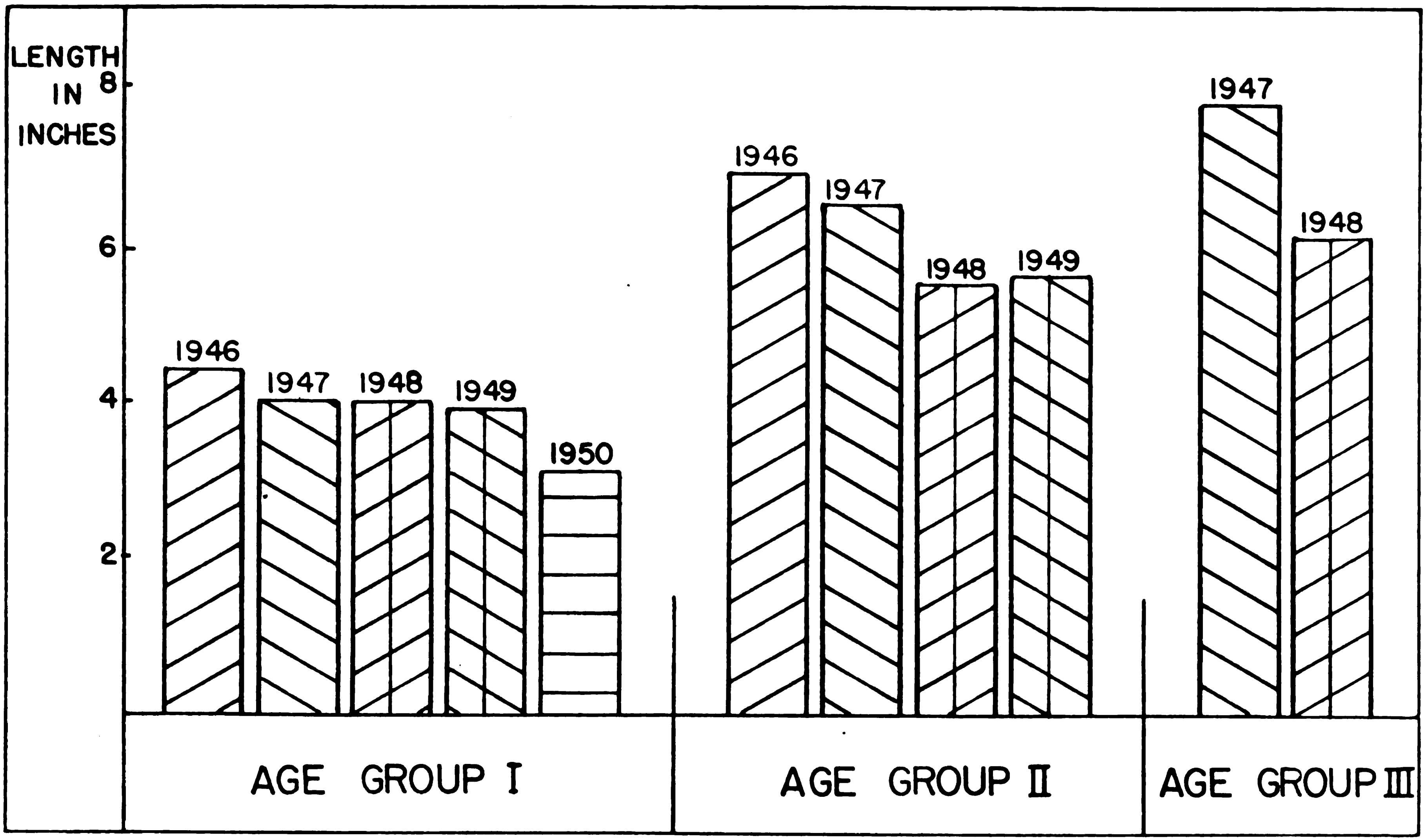

LENGTH IN INCHES
8
6
4
2
1946
1947
1948
1949
1950
AGE GROUP I
1946
1947
1948
1949
AGE GROUP II
1947
1948
AGE GROUP III

TABLE 4

COMPARISON OF THE AVERAGE LENGTH IN INCHES OF FORD LAKE BLUEGILLS, AT EACH AGE GROUP, WITH OTHER REGIONS OF THE UNITED STATES

Age group	Ford Lake, Michigan	Michigan average[1]	South Wisconsin[2]	Buckeye Lake, Ohio[3]	Clear Lake, California[4]	Red Haw Lake, Iowa[5]	East Lake, Iowa[6]
I	3.9*	3.1	4.9	1.6	4.1	1.4	1.7
II	5.7**	4.3	5.5	2.9	6.5	3.4	3.6
III	6.3***	5.4	6.3	4.1	8.1	6.1	5.6

* Year classes 1946-1950 combined.
** Year classes 1946-1949 combined.
*** Year classes 1947-1948 combined.

1. Beckman (1949).
2. Mackenthun (1947).
3. Morgan (1951).
4. Murphy (1951) (fork length).
5. Lewis (1950).
6. Lewis (1950).

EVALUATION OF CHANGES IN LENGTH, WEIGHT, AND CONDITION OF THE BLUEGILL

The data on growth rates from the calculated lengths of bluegill scales revealed that the growth rate had declined. The scale method for determining the growth rate of fish is accepted, and the following investigations were made to determine whether or not other calculations may be used for growth determinations.

In this section of the study a determination of the age of the fish at the time of capture was necessary. At the time of capture, some of the fish had not formed their annulus for that year. Thus, the number of annuli present could not be used for the age determination of the fish.

The policy for determination of the age of fish was as follows; if the fish was caught early in the year and had not formed its annulus, it was placed in the same age group as fish of the same age that were caught later and had formed their annuli. A fish with one annulus caught in May or June, and not having formed an annulus for that year, was placed in Age Group II. The average length of the fish was calculated for each age group and year of capture with no reference to year class.

These fish were caught during the following periods: June 1948; June, July, and August 1949; June 1950; and May, June, July, and August 1951.

Average Length at Time of Capture

The average length of the fish at the time of capture (Table 5) reveals that the average length of the fish in Age Groups I and III for the different years of capture declined. This is not the case for the fish in Age Group II, for the fish captured in 1949 were longer than those caught in 1948, and those in 1951 were longer than in 1950. The reason for this may be that the fish in 1949 and 1951 were caught as late as August, and thus had a longer growing season than the fish caught in 1949 and 1950, which were captured during June.

The data from Table 5 are presented as a graph in Figure 4. There is only one age group represented in the catch of 1948 and is represented by the symbol ⊙ on the graph.

From the above data, it can be seen that the growth of the fish decreased from 1948 to 1951. This paralleled an increase in the number of fish.

Age of Fish to Reach 6 Inches

Beckman (1948b) found that the average Michigan bluegill reaches 6 inches sometime during its fourth summer of life.

In Table 5 and Figure 5, the average lengths of bluegills at the time of capture are shown. All of the fish caught in 1948 and 1949 attained a length of 6 inches sometime during their second summer of life. Those caught in

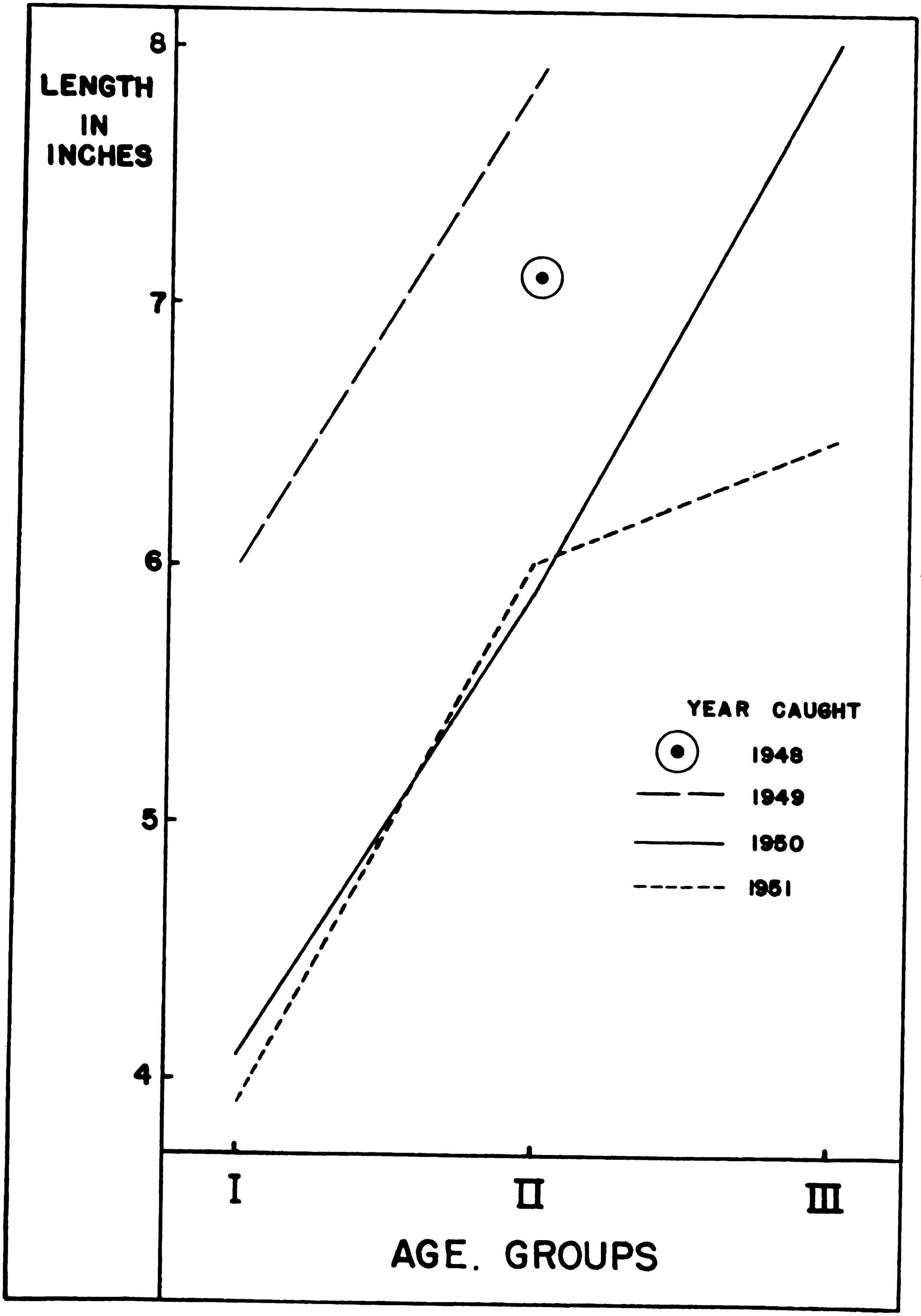
TABLE 5

STANDARD DEVIATION, STANDARD ERROR, AND AVERAGE TOTAL LENGTH FOR BLUEGILLS

Age group	Year capture	Standard deviation	Standard error	Average length (inches)
I	1949	.14	.05	6.0
I	1950	.14	.05	4.1
I	1951	.50	.08	3.9
II	1948	.14	.03	7.25
II	1949	.26	.03	7.89
II	1950	.44	.06	5.88
II	1951	.70	.07	6.00
III	1950	.38	.17	8.04
III	1951	.54	.04	6.46

1950 and 1951 did not reach this length until their third summer. If this trend persists, it may take four or more summers for the fish to reach the length of 6 inches. All of the fish caught up to 1951 had a better growth rate than the average Michigan bluegill. With the fish requiring a longer period of time to reach 6 inches this indicates a decrease in the growth rate.

Figure 4 Average length of Ford Lake bluegills at the time of capture for the different age groups.


LENGTH IN INCHES
8
7
6
5
4
YEAR CAUGHT
1948
1949
1950
1951
I
II
III
AGE. GROUPS

Average Weight at the Time of Capture

Table 6 gives the mean weight, standard deviation, and standard error for the different age groups at the time of capture. The average weights of the fish are presented graphically by Figure 5. As the only fish caught in 1948 were in Age Group II, they are represented by the symbol $\odot$.

From Table 6 it can be seen that the average weight of the fish in Age Groups I and III for the different years of capture declined. This does not hold true for the fish in Age Group II. The fish captured in 1949 were heavier than those caught in 1948, and those in 1951 were heavier than those captured in 1950. This same pattern applies to the lengths, and the reason for the greater weights of fish for 1949 and 1951 may be due to the later dates of capture than the fish caught in 1948 and 1950.

In comparing Figure 4 with Figure 5, it can be seen that as the fish increased in length from year to year, they also increased proportionally in weight.

Length-Weight Relationship

The length-weight relationship of the bluegills at the time of capture for each age group is presented in Figure 6. The data for length (Table 5) are plotted as the abscissa and weights (Table 6) as the ordinate. From the graph, it can be seen that the relationship between the lengths and

TABLE 6

STANDARD DEVIATION, STANDARD ERROR, AND AVERAGE TOTAL WEIGHT FOR BLUEGILLS

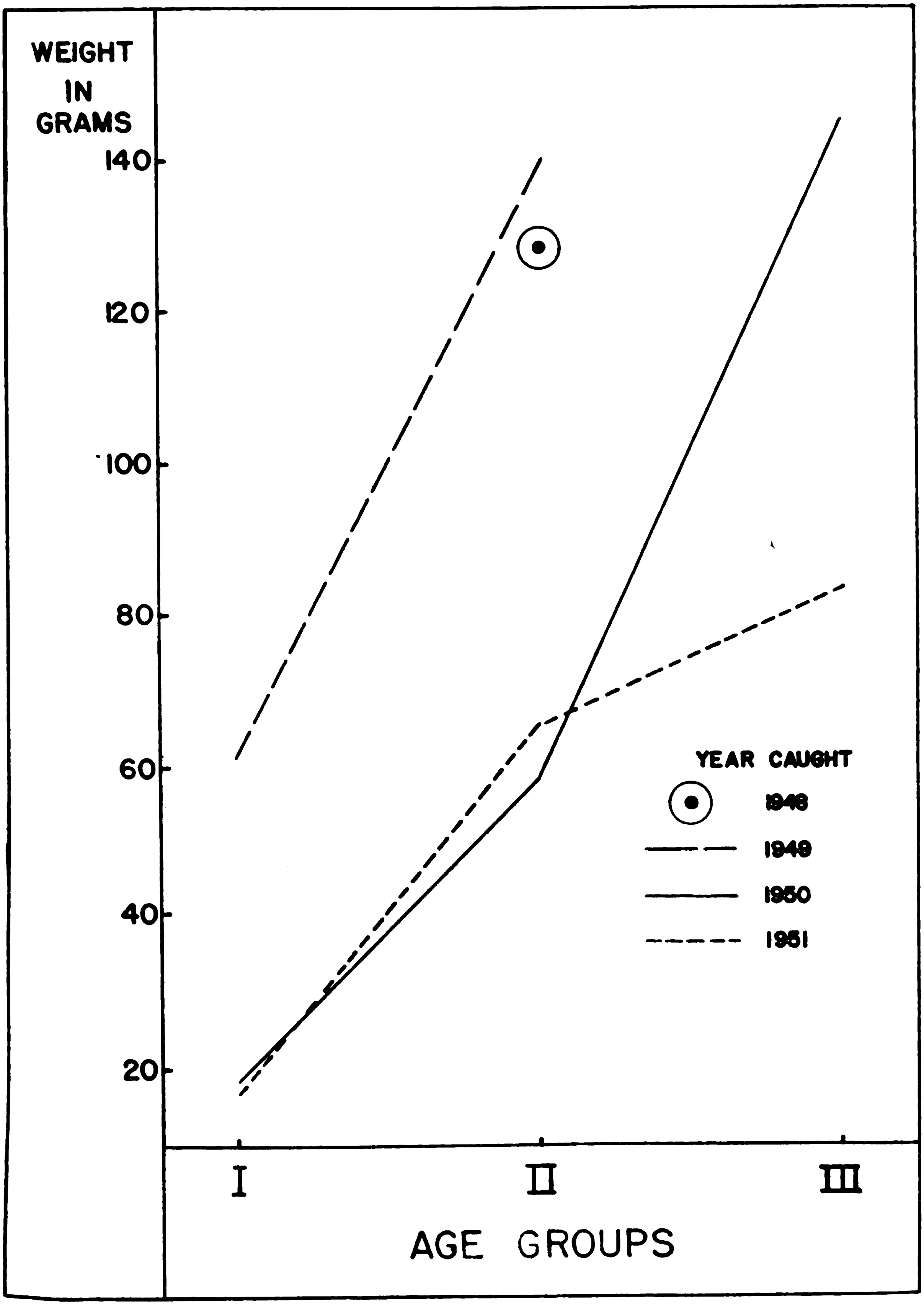
Age group	Year capture	Standard deviation	Standard error	Average weight (grams)
I	1949	2.64	.93	61.2
I	1950	2.64	1.00	18.3
I	1951	7.35	1.23	16.5
II	1948	25.20	5.16	128.53
II	1949	20.10	2.69	138.89
II	1950	14.20	1.88	58.46
II	1951	17.03	1.81	65.60
III	1950	30.20	13.51	145.00
III	1951	22.90	1.83	83.10

weights during the four years is not significantly different. As there was only one age group in the catch for 1948, this relationship is presented by the symbol ⊙ .

Condition of Ford Lake Bluegills

Fish that have a poor growth rate generally have a low condition factor ("K" factor). Taube (1948) states that bluegills in a stunting experiment reflected stunting more clearly by sub-normal weights than by sub-normal lengths.

Figure 5 Average weight of different age groups of Ford Lake bluegills at the time of capture.



WEIGHT IN GRAMS
140
120
100
80
60
40
20
YEAR CAUGHT
1948
1949
1950
1951
I
II
III
AGE GROUPS

Parsons (1950) also found that perch caught in Clear Lake, Iowa followed the same pattern. This is true only when the weight of the fish declines more rapidly than the length.

"K" Factors from 1948 to 1951

The average "K" factors for the different age groups and years of capture were computed by the use of the formula described by Beckman (1948a) and are presented in Table 7.

The average "K" factor for the one year old fish declined during each year of sampling. The "K" value for the two year old fish declined from 1948 to 1949. However, an increase was noted during 1950 and 1951. The three year old fish captured in 1951 had a higher "K" factor than those caught in 1950.

It was found that fish of the same age caught in later years may be in better "condition" even though their average lengths and weights were less. This is due to a smaller decrease in weight than in length. The reason for this may be that the "K" factor of the fish is not stable but fluctuates throughout the year.

"K" Factors for 1951

In support of the theory that the "K" factor changes throughout the year, an attempt was made to calculate the "K" factor over an extended period. The only collections

Figure 6 Length-weight relationship of Ford Lake bluegills at the time of capture for each age group.

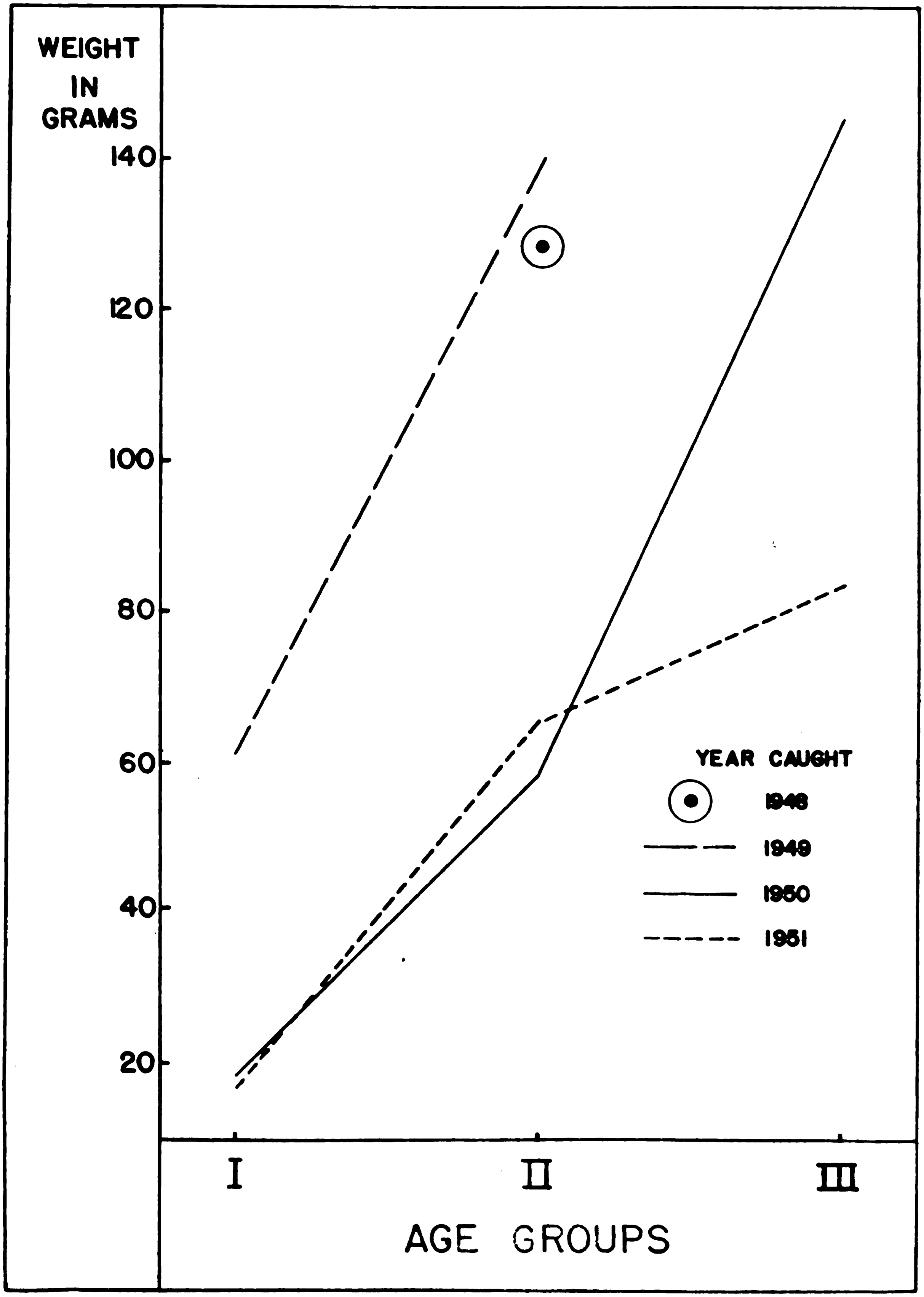

WEIGHT IN GRAMS
140
120
100
80
60
40
20
I
II
III
AGE GROUPS
YEAR CAUGHT
1948
1949
1950
1951

TABLE 7

YEAR CAUGHT, AGE GROUP, AVERAGE LENGTH, WEIGHT, AND "K" FACTOR FOR FORD LAKE BLUEGILLS

Year caught	Age group	Number of fish	Average length (mm.)	Range in mm.	Average weight (grams)	Range in gms.	Average "K" factor	Range "K"
1948	II	19	184.15	165.1-203.2	128.53	90.0-176.0	2.03	1.78-2.18
1949	I	8	152.4	147.2-157.5	61.00	58.0- 66.0	1.70	1.66-1.75
1949	II	56	200.5	187.9-221.0	138.89	112.0-214.0	1.71	1.48-2.10
1950	I	7	104.0	96.4-134.5	18.30	13.0- 21.0	1.62	1.45-1.69
1950	II	57	149.5	127.0-170.2	58.46	32.0- 90.0	1.72	1.45-2.02
1950	III	5	203.5	195.6-215.9	145.0	123.0-192.0	1.66	1.54-1.91
1951	I	36	99.0	81.1-157.5	16.5	7.0- 50.0	1.61	1.03-2.88
1951	II	89	152.5	114.3-203.2	65.6	34.0-115.0	1.82	1.23-2.32
1951	III	156	165.0	129.5-215.9	83.1	39.0-218.0	1.84	1.42-2.49

of bluegills that covered a considerable period of time were the 282 caught in 1951. The "condition" was calculated for each date of capture and the results are presented in Table 8.

TABLE 8

DATE OF CAPTURE, NUMBER, AVERAGE "K" FACTOR, AND PERCENT OF BLUEGILLS HAVING ANNULUS FORMED FOR 1951.

Date of capture	Number	Average "K" factor	Percent having annulus formed for 1951
May 5	24	1.54	12.5
May 19	12	1.71	41.6
June 3 & 4	21	1.86	52.4
June 6	50	1.80	54.0
June 7	40	1.88	57.5
June 10	41	1.93	85.0
June 14	44	2.07	65.9
June 17	4	1.33	80.0
July 10	5	1.44	100.0
August 4 & 5	40	1.56	100.0

From the table it can be seen that the "K" factor increases from May 5, to a peak on June 14. A sharp drop then occurred on June 17, followed by a gradual increase to August 4 and 5.

The "K" factors for June 17 and July 10, cannot be relied upon because of their small numbers, but they indicate an upward trend.

The rise in the "K" factor to June 14 may have been due to enlarging gonads as the spawning season approached. The sharp drop on June 17 could have been caused by spawning. This may be substantiated by the fact that the peak of spawning had passed by June 18, 1951, (as reported by observers at the lake). Lagler (1949) states that a sharp change in the "K" value may be expected at spawning. Deason and Hile (1947) found that the weight loss of male kiyis (*Leucichthys kiyi*) at spawning was unimportant, but the loss of weight for the females at spawning was considerable. Any rapid loss in the weight of the fish would have a marked effect on the condition factor of the fish.

The reason the bluegills in Age Group III, caught in 1950, have a lower "K" value than fish of the same age group, but caught in 1951, may be that they were all taken just after spawning. This is the time when the condition of the fish is the lowest. The fish of the same age group for 1951 were caught over an extended period of time masking the low values of "K" at the time of spawning.

The date of capture appears to have a marked effect on the condition ("K" factor) of the fish.

Statistical Test for a Homogeneous Population

The data, on the growth rate of the bluegills, indicate that the growth was probably declining. To substantiate this supposition, a statistical test was made to determine whether or not the populations are homogeneous.

The statistical test was the "t" test as shown by Snedecor (1946). If the "t" test shows significant differences, the populations for those age groups and their dates of capture can be said to represent two different populations.

"t" Test for Lengths

The value of "t" for the lengths (Table 9) reveals a significant difference for all age groups and years of capture with the exceptions of Age Groups I and II for the 1950-1951 dates of capture.

"t" Test for Weights

Table 10 shows the "t" values for the weights of bluegills and reveals a significant difference for all age groups and years of capture. The exceptions to this are for Age Group I for the 1950-1951 dates of capture and Age Group II for the 1948-1949 dates.

If the "t" value was significantly different for the lengths, it was also significantly different for the weights

TABLE 9

"t" TESTS FOR LENGTHS OF FORD LAKE BLUEGILLS
LENGTHS

Age Group I

Years Caught	"t" Value
1949-1950	27.55 **
1949-1951	11.51 **
1950-1951	1.02

Age Group II

Years Caught	"t" Value
1948-1949	7.89 **
1948-1950	12.11 **
1948-1951	8.66 **
1949-1950	28.94 **
1949-1951	13.92 **
1950-1951	1.30

Age Group III

Years Caught	"t" Value
1950-1951	6.50 **

** Significant at 99 percent level.

TABLE 10

"t" TEST FOR THE WEIGHTS OF FORD LAKE BLUEGILLS

Age Group I

Years Caught	"t" Value
1949-1950	31.80 **
1949-1951	16.85 **
1950-1951	.63

Age Group II

Years Caught	"t" Value
1948-1949	.58
1948-1950	14.99 **
1948-1951	11.94 **
1949-1950	24.54 **
1949-1951	21.55 **
1950-1951	2.29 *

Age Group III

Years Caught	"t" Value
1950-1951	5.88 **

** Significant at 99 percent level.

* Significant at 95 percent level.

of the bluegills in Age Groups I and III. In Age Group II this is not true. For 1948-1949, the "t" value of the lengths was found to be significant while that of the weights was insignificant, but for 1950-1951, the opposite was found to be true. These data indicate that the population of Ford Lake bluegills during the period of the investigation is not homogeneous. The "t" test does not indicate whether or not the growth rate is declining. The non-homogeneous population in the lake supports the previous findings that the growth rate of the bluegills declined.

Time of Annulus Formation

The annulus is formed in the spring of the year when growth is resumed after a winter period of little or no growth. An attempt was made to determine the date of annulus formation for the Ford Lake bluegills.

Since collections for the years 1948, 1949, and 1950 were made after annulus formation, no conclusions as to the time of annulus formation for these years could be made.

The date of annulus formation for Ford Lake bluegills for the year 1951 is presented in Table 8. From the data available 80 percent had formed annuli by June 17 and 100 percent by July 10.

The rapid increase in the percentage of fish having formed their annuli by June 10 may be due to a larger number

of Age Group I fish (3.4-3.8 inches long) present in this collection than in earlier or later collections. Hansen (1936) found that the date of annulus formation for the white crappie (Pomoxis annularis) in Illinois is quite variable, varying from May to June or even later. Also, fish from 3.6-5.5 inches long had a peak in annulus formation about the middle of June, while on the same date larger fish (5.6-9.5 inches) had barely begun. He also found that the peak in the annulus formation for the larger fish came a month later than that of the smaller fish.

Carlander (1950) working with saugers (Stizostedion canadense canadense) from Lake of the Woods, Minnesota, found the annulus formed in May and early June. Beckman (1943) found that fish of the same region of Michigan as Ford Lake had laid down their annulus by the first part of June.

The date for annulus formation of Ford Lake bluegills varies, and a specific date for their formation cannot be given. However, for the year 1951, it can be said that the annulus of the fish was formed during the month of June.

Time of Spawning for Ford Lake Bluegills

In the food analysis of the brook trout, the fish caught in February, 1950 were found to be eating small bluegills ranging in length from 1.0-1.6 inches.

The growth rate of the bluegills shows that the average calculated length of the bluegills at the first annulus was 4.4 inches for the fish hatched in 1946 and 3.1 inches for those of 1950. The smallest calculated length at the first annulus for the fish hatched in 1950 was 2.7 inches and 3.0 inches for 1949. The finding of fish of such small size in the stomachs of the brook trout, indicates that spawning must have occurred late in the summer.

With the indication that there must have been a wide range in the time of bluegill spawning, an attempt was made to establish the approximate date of the peak.

As very little material was available for the years 1948, 1949, and 1950, no attempt was made to determine the time of spawning for those years; however for the year 1951 there is sufficient data to establish the approximate date for the peak of spawning.

The Pigeon River Trout Experimental Station reported that the peak of the bluegill spawning had passed as of June 18, 1951. Table 8 gives the average "K" factor of 2.07 for fish caught June 14, 1951 and 1.33 for June 17, 1951. The reason for the rapid decrease may be due to loss in weight because of the spawning of the fish. Deason and Hile (1947) found the loss of weight for the female kiyis at spawning to be considerable. If this is true it would indicate that the peak of the spawning occurred sometime between the dates of June 14 and June 17, 1951.

Morgan (1951), who worked with the bluegills of Buckeye Lake, Ohio, found the fish spawning from early May to the middle of August. Carbine (1939), in his studies of the spawning habits of fish in Deep Lake, Michigan, found the bluegills spawning from June 18 to August 18.

With the report from the Pigeon River Trout Experimental Station that the peak of bluegill spawning had passed by June 18, 1951, there is no other definite proof that the bluegills spawned at a later date for this year. The only indication that this may have happened is the presence of the small bluegills in the stomachs of the brook trout caught in February, 1950. The work of Morgan and Carbine also confirms this supposition.

The bluegills spawned over a prolonged period with a fairly rapid increase to a peak, and then declined to a point where a few fish spawned sporadically.

Length of Growing Season

The length of the growing season of fish is variable. An attempt to determine the length of the growing season for the Ford Lake bluegills was made. It was possible to observe the differences in the length of the growing seasons for the years 1949 and 1951.

The growing season for fish starts with an annulus formation, then for a short time there is a period of rapid growth which later tapers off. Spoor (1938) observed that suckers (*Catostomus commersonnii*) in Muskellunge Lake, Wisconsin completed 92 percent of their growth by mid-July.

The average growth for each collection date was calculated for bluegills caught in 1949 and 1951. This was accomplished by calculating the amount of growth from the time of the last annulus formation to date of capture.

Growing Season for 1949

The average length of fish for each date of capture is presented by Table 11. The earliest collection date was late June, which is well into the growing season, so no date for when growth started can be given, but the leveling-off period occurred some time in August.

Growing Season for 1951

The results for 1951 (Table 12) are more reliable because of the greater numbers taken at each collection date. The earliest date of capture was May 5, which was before growth had started, and the latest date of capture was August 4.

The calculated growth on May 5, 1951 was 1.0 inches, while on June 10, the growth had decreased to 0.5 inches. The reason being that during May, the fish had not formed their annulus, and as the number of fish forming their annu-

TABLE 11

AVERAGE GROWTH FROM THE TIME OF THE LAST ANNULUS FORMATION TO THE TIME OF CAPTURE OF BLUEGILLS CAUGHT IN 1949

Collection date	Total growth of all fish (inches)	Number of fish	Average growth (inches)
June 29	6.1	5	1.2
July 1	3.2	2	1.6
July 4	6.0	4	1.5
July 7	27.9	20	1.4
July 10	17.3	14	1.2
July 17	4.9	4	1.2
July 24	11.5	8	1.4
August 17	1.1	1	1.1
August 23	6.3	4	1.6
August 28	3.1	2	1.6
Totals	87.4	64	1.4*

* Average growth for all fish.

lus increased, the calculated growth declined until the peak of annulus formation was reached (Table 8 shows June 10 as the peak of annulus formation). The growth increased to 0.9 inches by July 19, then leveled off so that it appeared that the growing season for 1951 was complete.

For the year 1951, the growing season appeared to be

TABLE 12

AVERAGE GROWTH FROM THE TIME OF THE LAST ANNULUS FORMATION TO THE TIME OF CAPTURE OF BLUEGILLS CAUGHT IN 1951

Collection date	Total growth of all fish (inches)	Number of fish	Average growth (inches)
May 5	23.6	24	1.0
May 19	8.6	12	0.7
June 3 & 4	12.2	21	0.6
June 6 & 7	51.6	89	0.6
June 10	20.7	41	0.5
June 14	24.8	44	0.6
June 17	3.0	5	0.6
July 19	5.2	6	0.9
August 3 & 4	35.4	39	0.9
Totals	185.1	281	0.7*

* Average growth for all fish.

from the middle of June to the latter half of July.

Due to the late collection dates for the year 1949, there was no basis for comparing the start of the growing season with that of 1951. The termination of growth for 1949 was in the latter half of August, while that for 1951 was in the latter half of July. The length of the growing season may regulate the amount of growth for the two years.

During 1949, the average growth was 1.4 inches and during 1951, 0.7 inches.

Effect of Temperature on Growth

Temperature may have had an effect on the length of the growing season. Table 13 shows the average monthly air temperatures of the Ford Lake area from May through August for 1949 and 1951. May 1951 was warmer than May 1949, but the rest of the months during 1951 were cooler than in 1949.

TABLE 13

AVERAGE MONTHLY AIR TEMPERATURE (FAHRENHEIT) FROM MAY THROUGH AUGUST FOR 1949 AND 1951

Year	Month			
	May	June	July	August
1949	52.96	67.44	67.91	64.99
1951	56.25	60.55	65.20	61.80

Beckman (1943) states the time of annulus formation is correlated roughly with the mean monthly air temperature. If this is true, the fish caught in 1951 started growing before those caught in 1949, but the warmer temperatures during June, July, and August of 1949 may account for the later growing season.

CATCH OF BROOK TROUT

During 1946, 1947, and 1951 brook trout were planted in Ford Lake at the rate of 500 fingerlings per acre or a total of 17,400 fish. As there was no compulsory creel census before 1949, there is no record of the number of trout caught before this date.

During the trout season of 1949, 139 brook trout were caught having an average total length of 8.6 inches and an average weight of 133 grams.

In 1950, only 11 trout were caught during the open season. Their average total length was 10.3 inches and their average weight was 222.5 grams. However, on February 9, 1950, a total of 31 brook trout were caught. These fish had an average total length of 9.7 inches and an average weight of 198.1 grams.

In 1951, the total catch consisted of 16 legal-sized brook trout with an average total length of 9.6 inches and an average weight of 164.4 grams. During the summer, numerous trout below the legal-size of 7 inches were caught but are not included in the tabulation.

17,400 brook trout were planted of which only 197 were known to have been caught, thus revealing a very low return.

FEEDING HABITS

The feeding habits of the bluegill and brook trout were studied to determine whether or not they competed for food.

Food of the Bluegill

During August 4 and 5, 1951 while obtaining scale samples for bluegills, 37 stomachs were collected for food analysis. The fish were of two length groups, 3.5 to 4.5 inches and 5.5 to 8.0 inches. For the fish in the smaller length group, the results of the food analysis are presented in Table 14, while the results for the fish in the larger length group are presented in Table 15.

Table 16 shows the major food groups eaten by the two groups of fish. The food of the smaller sized fish consists primarily of plankton crustaceans (Entomostraca), and insects in very small numbers. Ball and Tanner (1951), Ewers and Boesel (1935), and Leonard (1940) who worked with bluegills of a smaller size found the fish to be feeding on a similar diet.

The food of the large fish presented in Table 16, shows insects making up over one half of the total food eaten and plants accounting for a little under one third of the total. The plankton crustaceans (Entomostraca), mollusks, and fish make up the remainder of the total. Morgan (1946), Morgan

Table 14 Results of stomach analysis of 16 bluegills, 3.5 to 4.5 inches total length, average total length 3.9 inches, shown as percent of total food volume.

Date of capture August 4-5, 1951

Organism	Number of stomachs containing organisms	Percent of total stomachs containing organisms	Greatest percent of total volume in any stomach	Least percent of total volume in any stomach	Average percent of total volume in stomachs containing the organisms	Average percent of total volume for all stomachs
Entomostraca						
Cladocera	16	100	100	70	96	96
Copepoda	2	13.5	5	2	4	trace
Ostracoda	1	6	10	10	10	1
Insecta						
Diptera						
Chironomidae	4	25	30	5	14	3

Table 15 Results of stomach analysis of 21 bluegills (one empty), 5.5 to 8.0 inches total length, average total length 6.6 inches, shown as percent of total food volume. Date of collection August 4-5, 1951.

Organism	Number of stomachs containing organisms	Percent of total stomachs containing organisms	Greatest percent of total volume in any stomach	Least percent of total volume in any stomach	Average percent of total volume in stomachs containing the organisms	Average percent of total volume for all stomachs
Entomostraca						
Cladocera	10	50	25	0.5	4	2
Ostracoda	6	30	25	2	9	3
Insecta						
Diptera						
Chironomidae	15	75	95	5	51	39
Culicidae	3	15	40	5	18	3
Odonata						
Anisoptera	1	5	100	100	100	5
Trichoptera	1	5	25	25	25	1
Hemiptera	1	5	5	5	5	trace
Hymenoptera*	1	5	40	40	40	2
Coleoptera*	1	5	100	100	100	5
Mollusca						
Gastropoda	2	10	70	5	38	4
Plant						
Chara	4	20	95	20	56	11
Higher aquatic	5	25	90	5	64	16
Fil. algae	3	15	10	5	8	1
Debris	2	10	45	20	33	3
Fish						
Mud minnow	1	5	100	100	100	5

*Terrestrial.

(1951), and Ball and Tanner (1951) also found bluegills of comparable size feeding largely upon insects and plants.

TABLE 16

PERCENTAGE OF TOTAL FOOD ORGANISMS FOR TWO SIZE GROUPS OF BLUEGILLS, (AUGUST 4 and 5, 1951)

Food organisms	3.5 to 4.5 inches	5.5 to 8.0 inches
Entomostraca	97*	5
Insecta	3	54
Plant	0	31
Mollusca	0	4
Fish	0	5

* Percent of total food.

The above investigation of the food of the Ford Lake bluegill, is based on collections of fish taken in a short span of time and the only conclusion that can be made is that there is a definite difference in the food eaten by the two size groups of fish, at the time of capture. Hile (1931) states that the feeding habits of fish change with their growth. As the fish becomes larger, it is capable of seizing and devouring larger prey. This may be the reason for the difference in the food eaten by the two size groups of fish.

Food of the Brook Trout

Stomach samples of 37 brook trout were collected at the following dates, 9 during February 1950, 9 during April 1951, 7 during May-June 1951, and 12 during August 1951. A small number of fish were examined and can only give an indication as to the food eaten. The food for the four dates of capture are presented in Tables 17, 18, 19, and 20.

Table 21 presents the major food groups. No plankton crustaceans (Entomostraca) were found in any of the stomachs. Insects made up the bulk of the food for all dates of capture with the exception of February. Plants contributed very little to the food of the fish although small quantities were found in the February and August collections. Mollusks were not found in large numbers. Few were taken during February, and for the other collection dates, their volume varied up to almost one third of the total volume. The stomach analysis for February showed a predominance of fish; whereas relatively few were found in the stomach samples of other months with the exception of August, when none were found. In northern and southern Ontario lakes fish were found to be the main diet for speckled trout (brook trout) over 10.0 inches in length (Ricker, 1930).

Insects accounted for the greatest part of the food of brook trout in East Fish Lake, Michigan (Leonard, 1941). This is in agreement with the stomach analysis of the trout in Ford Lake during April, May-June, and August.

Table 17 Results of stomach analysis of 9 brook trout, 8.7 to 11.1 inches total length*, average total length 10.0 inches*, shown as percent of total food volume. Date of capture February, 1951.

* For 4 fish.

Organism	Number of stomachs containing organisms	Percent of total stomachs containing organisms	Greatest percent of total volume in any stomach	Least percent of total volume in any stomach	Average percent of total volume in stomachs containing the organisms	Average percent of total volume for all stomachs
Insecta						
Diptera						
Chironomidae	1	11	0.2	0.2	0.2	trace
Odonata						
Anisoptera	3	33	5	3	4	1
Coleoptera	1	11	3	3	3	trace
Mollusca						
Gastropoda	4	44	22	5	10	5
Plant						
Chara	3	33	10	1	5	2
Debris	1	11	3	3	3	trace
Fish						
Bluegill	9	100	100	30	52	52
Mud minnow	7	78	70	30	50	39

Table 18 Results of stomach analysis of 9 brook trout, 7.8 to 11.3 inches total length, average total length 9.8 inches, shown as percent of total volume. Date of capture April, 1951.

Organism	Number of stomachs containing organisms	Percent of total stomachs containing organisms	Greatest percent of total volume in any stomach	Least percent of total volume in any stomach	Average percent of total volume in stomachs containing the organisms	Average percent of total volume for all stomachs
Insecta						
Diptera						
Culicidae	4	44	20	5	13	6
Phoridae	4	44	30	5	18	8
Chironomidae*	2	22	20	10	15	3
Mycetophilidae*	1	11	5	5	5	1
Chironomidae	1	11	20	20	20	2
Coleoptera	5	56	60	10	29	16
Coleoptera*	5	56	50	10	30	17
Hemiptera	4	44	20	10	15	7
Orthoptera*	1	11	10	10	10	1
Hymenoptera	1	11	20	20	20	2
Mollusca						
Gastropoda	4	44	70	15	36	16
Fish						
Mud minnow	3	33	70	60	65	21

*Terrestrial.

Table 19 Results of stomach analysis of 7 brook trout, 5.0 to 12.1 inches total length, average total length 8.3 inches, shown as percent of total voluem. Date of capture May and June, 1951.

Organism	Number of stomachs containing organisms	Percent of total stomachs containing organisms	Greatest percent of total volume in any stomach	Least percent of total volume in any stomach	Average percent of total volume in stomachs containing the organisms	Average percent of total volume for all stomachs
Insecta						
Diptera						
Empididae*	3	43	100	10	43	18
Culicidae[1]	3	43	100	8	52	22
Dolicho-podidae*	2	28	10	5	8	2
Choronomidae	1	14	2	2	2	trace
Coleoptera	1	14	5	5	5	trace
Coleoptera*	2	28	15	10	13	4
Homoptera*	1	14	20	20	20	9
Hymenoptera*	2	28	20	15	18	5
Debris	1	14	75	75	75	11
Mollusca						
Gastropoda	2	28	60	25	43	12
Fish						
Mud minnow	2	28	50	50	50	14
Debris	1	14	20	20	20	3

* Terrestrial.
1 Larva and pupa combined.

Table 20 Results of stomach analysis of 12 brook trout*, 5.6 to 7.0 inches total length, average total length 6.3 inches, shown as percent of total volume. Date of collection August 4-5, 1951.

* 7 stomachs empty not included in tabulation.

Organism	Number of stomachs containing organisms	Percent of total stomachs containing organisms	Greatest percent of total volume in any stomach	Least percent of total volume in any stomach	Average percent of total volume in stomachs containing the organisms	Average percent of total volume for all stomachs
Insecta						
Diptera						
Chironomidae	2	40	100	10	55	22
Chironomidae*	2	40	20	15	18	7
Coleoptera	1	20	5	5	5	1
Hemiptera	1	20	80	80	80	16
Debris	1	20	90	90	90	18
Mollusca						
Gastropoda	2	40	80	75	78	31
Plant						
Higher aquatic	1	20	25	25	25	5

* Terrestrial.

TABLE 21

DATE OF CAPTURE OF BROOK TROUT WITH THE PERCENTAGE OF TOTAL FOOD FOR EACH MAJOR GROUP

Major food groups	Date of capture			
	February 1950	April 1951	May and June 1951	August 1951
Entomostraca	0*	0	0	0
Insecta	1	63	71	64
Plant	2	0	0	5
Mollusca	5	16	12	31
Fish	91	21	17	0

* Percent of total food.

Needham (1931) and Morofsky (1940), found insects to be the predominate food of the brook trout in streams.

Table 22 illustrates the amount of aquatic and terrestrial food taken by the brook trout. The terrestrial foods include the adult forms which have aquatic larvae or nymphs. The water organisms contribute the largest percentage of the food. During the winter when the lake was covered with ice, only aquatic food was taken. As more terrestrial forms of life became present, they were taken in larger numbers.

The bluegills have an advantage over the brook trout in that they have a high breeding potential and reproduce naturally in lakes, whereas the trout do not and have to be planted. The only predator of the bluegill is the brook trout which does not seem to be great enough to control their numbers. As the bluegills increase in numbers, they compete strongly with the trout for the same foods. This competition results in a poor showing of the trout.

TABLE 22

PERCENT OF TOTAL FOOD AND DATE OF CAPTURE FOR FORD LAKE BROOK TROUT

Food types	Date caught			
	February 1950	April 1951	May and June 1951	August 1951
Aquatic	100*	68	60	93
Terrestrial	0	32	40	7

* Percent of total food.

DISCUSSION

Michigan with its large number and great variety of inland waters has been placing greater attention on the lakes that are suitable for trout.

Many of the lakes that are suited for trout have a large population of small warm-water fish. In lakes where trout and warm-water fish live together such mixed populations are not successful.

In the northern part of the lower peninsula of Michigan the accepted lake management procedure is to encourage trout production. In carrying out this policy it is necessary to remove the undesirable fish population and restock with trout.

Ford Lake is a lake that is thermally and chemically suited to trout but has been over populated with small bluegills. In August of 1946 the lake was poisoned, to remove the fish population for a fall planting of brook trout. After the poisoning it was believed that the bluegill population was eliminated, however, in the spring of 1947 it was discovered that a few of the bluegills survived the poisoning. This situation gave the opportunity to study the growth rate of the bluegills as they repopulated the lake.

The growth studies were made from 433 bluegill scale samples, collected from 1948 to 1951. The scales were mounted on slides with a gelatin-glycerin media and examined with the aid of a scale projection machine.

The growth rate of the bluegills was found to decrease as the age of the fish increased. The growth rate for the same age groups of fish also decreased as the number of fish increased.

During the investigation an attempt was made to determine whether or not other calculations besides the scale method may be used for growth determinations. It was found that these calculations could not be used. However, with the scale method they help substantiate the findings.

From the creel census it was found that very few brook trout were caught, indicating that the growth and survival of the trout was very poor.

Stomach samples of 37 bluegills and 37 brook trout were analyzed and it was found that the larger sized bluegills competed for food with the brook trout.

The relationship between the bluegill and brook trout is one in which the bluegill becomes the numerically dominant fish and the trout eventually disappears from the lake.

If a lake is to have a good trout production it is necessary to keep the warm-water fish out of the lake.

SUMMARY

1. Growth analysis of the bluegill revealed a decrease in the growth rate as the age of the fish increased, also the growth rate of the same age groups decreased as the number of fish in the lake increased.
2. The bluegills caught in 1948 and 1949 attained a length of 6 inches some time during their second summer of life. Those caught in 1950 and 1951 did not reach this length until the third summer.
3. The lengths and weights of Ford Lake bluegills increased proportionally.
4. The condition ("K" factor) of a fish population does not indicate whether there is poor growth by a low "K" value.
5. The date of capture has a marked effect on the "K" factor of the fish. Increasing from the start of the growing season to spawning, accounting for the sharp drop, then increasing for the remainder of the growing season.
6. Ford Lake bluegills laid down their annulus during the month of June.
7. Bluegills spawned over a prolonged period of time with a fairly rapid increase to a peak, and then declining to a point where a few fish spawned sporadically.
8. For the year 1951, the growing season was from the middle of June to the latter half of July.
9. Of 17,400 brook trout planted in Ford Lake, the records

reveal only 197 legal-sized trout caught.

10. Food of bluegills in the length group, 3.5 to 4.5 inches, was almost exclusively plankton crustaceans (Entomostraca) with a few insects.

11. Food of the larger sized bluegills, 5.5 to 8.0 inches, was chiefly insects, which accounted for over one half of the total amount of food taken, plants a little under one third, with plankton crustacenas (Entomostraca), mollusks, and fish almost equally divided for the remainder.

12. The food of the brook trout for February consisted of fish (bluegills) in such numbers as to almost exclude all other organisms. In April insects made up the greatest percent of the total food taken, with mollusks second. May and June collections had a greater percentage of insects than the April collection but had a smaller percentage of fish and mollusks. In the August sampling, insects were the dominate food followed by mollusks and plants.

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