AN INVESTIGATION OF THE BLUEGILL POPULATION IN FORD LAKE, MICHIGAN - MICHAEL W. FABIAN

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AN INVESTIGATION OF THE BLUEGILL POPULATION IN FORD LAKE, MICHIGAN

by

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INTRODUCTION

The total fish population in lakes has been of increasing interest to the practical fish manager in recent years as a knowledge of the species composition, abundance, size and growth rate is of value in fisheries management. Powdered derris root has been used most effectively in gaining information on these factors by removing undesirable species or reducing an overpopulated area.

Studies made by Beckman (1950) to determine the effect of reduction in numbers of fish by winterkill found that the increase in the rate of growth was not maintained for longer than a year in most species.

Ford Lake, in the north central part of lower Michigan, is an example of one of the several Michigan lakes which was poisoned and stocked with trout, only to become repopulated with warm-water fish. This may have been due to incomplete kill or unauthorized introduction of live fish. From 1946 to 1952 the population of Ford Lake became predominantly one of stunted bluegills (Lepomis macrochirus macrochirus Rafinesque). Ford Lake was poisoned for the third time in August, 1952, offering an opportunity to study the total population in comparison with other years.

Trap nets play an important part in fisheries research and certainly affect the analysis of any data resulting from the catch. In this investigation the results of the catch from three types of nets were analyzed to determine the effect of net construction and size on the number and size of bluegills caught.

Data on the growth of the bluegills were obtained from those bluegills caught in the trap nets during 1952. This information was used to study the effect of increasing population density on the growth rates of an almost pure bluegill population with little if any predation to reduce the population.

An attempt was made to determine the effect of size on the time of annulus formation and also to determine the date at which half the population had formed the annulus.

Description of Ford Lake

In 1931 and 1932, a physical, chemical, and biological survey was made of Ford Lake. According to Eschmeyer (1937), the surface area is 11.7 acres with no inlet or outlet. Vegetation on the shoal areas is abundant. The dominant soil types were found to be: sand, peat, and marl in the shoal areas; marl on the slope areas, and peat in the deep zones.

The north and north-east end of the lake has a peat bottom with *Scirpus* and beds of *Chara*. The west end is very shallow with beds of *Scirpus*.

Field work by Schneider in 1939 showed the dominant soil condition in Ford Lake region to be sand on the surface with a sub-stratum of brownish-yellow sand with occasional gravel pockets. The major soil types are Rubicon and Roselawn sand.

Soil analyses revealed the drainage to be extremely rapid. The physiography of the region is pitted outwash plains and subdued moraines with local relief of twenty to fifty feet. Eighty per cent of the area has up to seven per cent slopes with twenty per cent of the area having slopes from 7-25 per cent.

The original vegetation was white (*Pinus strobus*, L.) and red pine (*Pinus resinosa*, Ait.) with second growth aspen (*Populus sp.*), fire cherry (*Prunus pensylvanica*), service berry (*Amelancher sp.*), and jack pine (*Pinus banksiana*, Lamb.).

There are present large open areas of bracken fern (*Pteriduim* *sp.*), sweet fern (*Comptonia* *sp.*), bluegrass (*Poa* *sp.*), and blueberries (*Vaccinium* *sp.*). This area was given a general agricultural rating of fourth class land because it was very droughty and has low natural fertility.

History

Ford Lake lies in the Pigeon River State Forest area in the north central part of the Lower Peninsula of Michigan. It is located in Otsego County, (R. 1 W., T. 32 N., Section 8) and seems to have been formed either from the isolation of an ice block or from the dissolving away of limestone beneath the soil. Physical, chemical, and biological inventories in 1931 and 1932 by the Institute for Fisheries Research, revealed that several pit lakes in the area were suitable for trout production. At that time the species composition of Ford Lake was limited to a stunted population of yellow perch (Perca flavescens).

Ford Lake, like the others in the area was found to be alkaline in nature, thermally stratified, with abundant vegetation, and sufficient oxygen for fish life available below the thermocline in warm weather.

A program for experimental management, as stated by Eschmeyer (1937), was set up to improve fishing by stocking the lake in 1933 with brook trout. In 1934 when it was found that the stocked fish still were not doing well, the perch population was heavily netted. In 1934 and 1935, the lake was stocked with brook, brown, and rainbow trout. In 1936, due to the poor condition of the trout, it was decided to remove the fish by poison and dynamite. The lake was then restocked in October, 1936 with 5000 Montana grayling fingerlings, (Thymallus montanus).

The experiment (Leonard, 1940) on feeding habits of the grayling was complicated by the unauthorized introduction of bluegills. It was shown that the grayling were not able to compete for food with the more aggressive bluegills.

In 1941, plantings of 5000 fingerling brook trout, (*Salvelinus fontinalis*), proved to be unsuccessful as none were recovered in gill nets set in 1945.

With the possibility that a predatory fish might reduce the bluegill population, walleyes, (*Stizostedion vitreum*), were introduced in 1943 (Ball, 1948).

On August 26, 1946, Ford Lake was again poisoned with rotenone in order to compare the standing crop with that recovered in 1936. In the fall of 1946, brook trout were again introduced. In 1947, bluegills, believed to have survived the 1946 poisoning, were found to be present in the lake. Karvelis (1952) found that the majority of fish that survived the 1946 poisoning were of the 1946 year class.

Plantings of 5,800 three inch brook trout were made each fall from 1947 to 1951 with each planting being identified by removal of a particular fin.

Due to the large numbers of stunted bluegills and very poor survival of brook trout, Ford Lake was again poisoned on August 22, 1952. During the several days following, every effort was made to recover all fish that came to the surface or were washed up on shore. On September 5th the count was discontinued when there were only nine bluegills found on the entire lake shore.

FIELD PROGRAM

Materials and Methods

Recovery of Poisoned Fish in 1952.

In order to compare the brook trout-bluegill relationships, Ford Lake was poisoned with rotenone on August 22, 1952. It was desirable to obtain a complete pickup of fish following the poisoning to compare with previous studies. In order to check the recovery, 342 marked bluegills were placed in the lake prior to poisoning. A test cage with a few bluegills were placed in the lake just before poisoning to test the toxicity at the twenty foot level. On August 29, the test cage was lifted and all the fish were dead. It is not known whether there was a complete kill at the twenty foot level but it is possible that the repeated lifting of the trap through the surface layers killed these test fish. The personnel of the Pigeon River Trout Research Area quit picking up fish on September 5th when the count reached nine bluegills for the entire lake shore. Very few fish were still visible on the bottom but the known recovery rate was little less than 75 per cent.

Only five species of fish were recovered after the lake was poisoned: bluegills, brook trout (Salvelinus fontinalis), bluntnose minnow (Hyborhynchus notatus), mudminnow (Umbra limi), and the shiner (Notropis sp.). All but one brook trout recovered were characterized by removal of the right pectoral fin. This would indicate that the brook trout recovered were those planted in 1947. One brook trout was recorded as having the dorsal fin removed, this fish then belonged, presumably, to the 1946 planting. In the test trap nets one fish was alive four days after application of the poison.

Use of Trap Nets

From February through August, 1952, the personnel of the Pigeon River Trout Research Area maintained and checked the trap nets set in Ford Lake. The results of the metal trap net catch were tabulated and an attempt was made to determine the effect of net construction on catch per net hour. The method used was the analysis of variance test as given by Snedecor (1950). Most of the scale sampling data were obtained from these trap nets although a few were caught by hook and line.

Scale Sampling

The scales used in the age and growth studies were obtained largely from fish caught in the trap nets. The scale data from the trap nets were recorded in the metric system, in grams, and millimeters. The length data obtained from anglers were recorded in the English system, and converted to millimeters by use of a conversion table (Lagler, 1952).

The scale data were obtained from January 28, through August 14, 1952.

It should be noted that the scale data do not represent a random sample because of the selectivity of gear used. The larger fish were caught by anglers and no fish from year classes 1946-1951, or 1952 were collected.

The ages 0, 1, 2, 3, etc., refer to the number of winters through which the fish have lived. Thus a fish in the summer in which it has been hatched belongs to the 0 age group, for it has passed no winters and shows no annuli. In the second summer after hatching, it has passed one winter and therefore belongs to the age group one.

The scales obtained were cleaned in water with a stiff bristled brush and mounted on slides in a gelatin-glycerin media. The scales were then enlarged 45.5 X on the scale projection machine and the annuli recorded on Keysort cards. In every case the scale was read from the focus to the anterior edge of the scale. The annuli were recorded on the cards at the point a complete circulus was being formed. The growth rates were then calculated by means of a nomograph as described by Carlander and Smith (1944).

In order to use the nomograph it is necessary to know the length of the fish at the point the scales begin to form.

Potter (1925) found the standard length of bluegills at the time of scale formation to be 17 millimeters. Using the conversion factor as presented by Beckman (1948) the total length was found to be twenty millimeters at the time of scale formation. Twenty millimeters was then used as the point at which the scale began to form.

The "K", or condition factor was computed from the alinement chart as developed by Phenicie and Bishop (1950). The alinement chart used was a graphical, mechanical representation of the relationship between length and weight. This chart proved convenient as the condition index could be read directly at the point the straight edge crossed the calibrated line.

COMPARISON OF THE STANDING CROP IN THE 1936, 1946, and 1952 FISH POPULATIONS

According to Ball (1948) a complete kill of the fish population was reported for 1936. All fish were accounted for by counting or close estimates. In 1946, every effort was made to recover all fish that came to the surface or were within reach of the surface, but apparently some of the younger fish survived. The poisoning in 1952 was believed to have been a complete kill as no fish were found in trap nets set as soon as the waters became non-toxic.

The fish population of Ford Lake as determined in 1936 consisted of brook trout, four species of minnows, and a stunted population of perch. The weight of the total fish population in 1936 was about 521 pounds. The total number of fish present was 41,703.

At the time of the 1946 poisoning the bluegill was the dominant species with no yellow perch present. The only brook trout present were those stocked immediately prior to poisoning. Only 17 walleyes were recovered from the young planted in 1943. The total number of fish recovered in the second poisoning was 41,693 with a total weight of 1,293 pounds.

The population in 1952 differed from the previous two poisonings as would be expected. Only six years had elapsed since the previous poisoning and there were 11,622 fish

TABLE 1

A COMPARISON OF THE STANDING CROP OF FISH RECOVERED AT THREE POISONINGS

	1952 *	1946 1/	1936 2/
Total number recovered	11,622 3/	41,693	41,703
Total weight recovered (pounds)	726.8 4/	1,293	521
Percentage by number of bluegills recoverd	94.7	89.6	--
Percentage by weight of bluegills recovered	79.9	94.5	--
Number of bluegills recovered	11,001	37,383	--
Bluegills per acre	1,028	3,494	--
Total number of fish per acre	1,086	3,897	3,567
Weight of bluegills per acre (pounds)	54.3	114.2	--
Pounds of fish per acre	67.9	121	44
Number of legal sized bluegills recovered per acre	24	1.68	--
Average weight of the bluegills recovered (ounces)	0.85	0.52	--

1/ Ball (1948)

2/ Ball (1948)

3/ Doesn't include the number of small fish recovered.

4/ Includes weight of the small fish.

recovered as compared to approximately 41,700 recovered the previous two poisonings. Ball (1948) stated that the average length of the bluegills recovered in 1946 was 3.9 inches and the average weight about one-half ounce. No data were

TABLE 2

WEIGHT AND NUMBER OF BROOK TROUT AND OTHER FISH RECOVERED AT POISONING IN 1952

	Brook Trout	Small Fish
Total weight (pounds)	24.4	121.3
Pounds per acre	2.3	11.3
Per cent of total weight recovered	3.3	16.6
Total number	621	--
Per cent of total number of fish recovered 1/	5.3	--
Number per acre	58	--
Average weight (ounces)	.628	--

1/ Excluding the numbers of small fish

available on the average length of the bluegills recovered in the 1952 poisoning but the average weight was 0.85 ounces. The average weight of the bluegills from the scale data was 35.2 grams as compared to the average weight of 24 grams for those recovered in the poisoning operations. This is

TABLE 3

NUMBER AND WEIGHT OF POISONED FISH RECOVERED PER DAY

	August								Sept.	
	22	23	24	25	26	27	28	29	1	5
Legal sized bluegills (Number)	99	114	20	16	6	2	0	0	0	0
Brook trout (Number)	189	364	27	26	11	3	0	1	0	0
Sub legal bluegills (Number)	2015	5580	807	1369	559	254	79	64 *	14	8
Sub legal bluegills (Pounds)	116	287	43	70	27	13	4	0	0	0
Small fish (Pounds)	64	57								

probably due to the size selectivity of the trap nets. There were 11,001 bluegills recovered with a total weight of 581.1 pounds. Six hundred and twenty one brook trout weighed 24.4 pounds. Approximately 94.7 per cent of the number of fish recovered, i.e. brook trout and bluegills, were bluegills. By weight, bluegills consisted of 79.95 per cent of the total weight. The minnows that were recovered during the poisoning operation were weighed but not counted. In 1952, 257 legal sized bluegills were recovered as compared to 18 in 1946.

Within ten days prior to the poisoning 342 bluegills were marked and returned to the lake. After the poisoning 254 were recovered which would indicate that there was approximately 74.3 per cent recovery of poisoned fish in the lake, presuming the mortality was very low. Ball (1948), after the poisoning of Ford Lake in 1946, reported a 58.9 per cent recovery of all marked bluegills, and 44.7 per cent of the marked trout were recovered.

A study by Krumholz (1944) estimated the fish population in Twin Lake, Michigan, by means of recovery of marked fish in nets. The lake was then poisoned and 86 per cent of the marked fish presumed to be alive were recovered. One of the main items of uncertainty in such an operation is the completeness of recovery of poisoned fish.

Day Lake, a small soft water lake in Wisconsin, that is naturally divided into two basins by a shallow narrow constriction, was considered ideal for a population and growth study. The fish population was considered stunted and to increase the growth rate, the population from one basin was removed by fyke nets and rotenone. The left fins of numerous fish were clipped and of the fish known to be present in the lake shortly before poisoning, only 47.5 per cent were recovered (Williamson and Brusch, 1947).

This would seem to indicate that the recovery at Ford Lake was higher than the recovery in most lakes.

UTILIZATION OF TRAP NETS IN FORD LAKE IN 1952

Use

From February 27 through August 20, trap nets were set in Ford Lake to obtain scale samples and length-weight data for growth analysis. These nets were maintained, checked, and moved about the lake periodically by personnel of the Pigeon River Trout Research Station.

Construction

Eight nets were used during the entire netting operation in 1952, but only three nets were used from March through July 26.

Net No. 1 was constructed of one inch chicken wire mesh. The net had a length of 52 inches with 36 inch triangular sides. Funnel depth was 20 inches with a 3 1/2 inch opening. The funnel was reconstructed June 25th with a new depth of 38 inches, and replaced on June 28. Nets 2, 4, 5, 6, 7, and 8 were each constructed of one inch chicken wire mesh with a length of 48 inches and 36 inch triangular sides. Funnel depth was 20 inches with a 3 1/2 inch opening.

Net No. 3 was constructed of 1/2 inch mesh hardware cloth--length 48 inches with 36 inch triangular sides. The funnel depth was 20 inches with a 3 1/2 inch opening.

The data on the metal trap nets indicated that there was a difference in the catch due to net construction. To substantiate this assumption a statistical test was made to determine whether or not the traps had the same catch-ability. Nets 1 and 2 have the same size wire mesh but each has a different length. The funnel depth was the same until it was changed on June 25th and the net reset on June 28. Nets 2 and 3, although of the same dimensions, are constructed respectively of one inch chicken wire mesh and one half inch mesh hardware cloth.

TABLE 4

CATCH PER NET PER 100 HOURS

Nets	No. 1	No. 2	No. 3
March	2.8	5.0	5.2
April	2.6	6.9	11.6
May	0.8	21.3	13.8
Through June 25	1.2	18.2	9.1
Totals	7.4	51.4	39.7

The statistical test was the variance ratio, "F", as shown by Snedecor (1950). If the "F" test showed significant differences, there was a difference in the catch per net hour. The value of the variance was calculated for nets 1, 2, and 3 from March through June 25 (Table four). The value revealed a significant difference in catch for the three nets, at the five per cent level. That is, up to June 25, net 2 was the most effective trap net.

TABLE 5

COMPARISON OF CATCH FROM JULY 28
THROUGH AUGUST 20

Nets	Hours Fished	Fish per 100 Net Hours
1	600	18.2
4	600	14.2
5	600	11.0
6	600	11.2

From July 28 through August 20 (Table 5), a comparable number of hours were fished. The data from Table 5 showed that net No. 1 seemed to have a substantially increased catch over previous months. The catch was also greater than in nets 4, 5, and 6. This increase is thought to be due to the new funnel depth of 38 inches, as compared to 20 inches previously.

Nets 1, 2, and 3 seem to show a declining catch per unit of time set toward summer which might be accounted for by the increased water temperature. Perhaps the increased yield of net No. 1 can be explained in that it may be an increase due only to net construction and comparison with previous months.

TABLE 6

COMPARISON OF THE MONTHLY TRAP NET CATCH
IN FORD LAKE IN 1952

Month	Total Hrs. Fished	Total No. Fish	Catch per 100 Net Hrs.	Size Range (Inches)
Net No. 1		*		
Feb.	96	14	14.5	4.3-6.0
Mar.	672	19	2.8	4.3-8.2
April	768	20	2.6	4.4-7.0
May	624	5	0.8	4.2-4.7
June	504	6	1.2	4.2-4.5
July	720	71	9.9	4.2-8.4
Aug.	552	102	18.4	4.1-6.4
	3936	237	6.0	4.1-8.4
Net No. 2				
Mar.	672	34	5.0	4.5-7.7
April	768	53	6.9	4.5-8.1
May	624	133	21.3	4.2-8.4
June	720	131	18.2	--
July	672	0	0.0	--
Aug.	96	1	1.0	5.0
	3552	352	9.9	4.2-8.4
Net No. 3				
March	672	35	5.2	4.1-6.7
April	768	89	11.6	3.5-6.1
May	600	83	13.8	3.4-6.1
June	720	46	6.4	3.3-5.9
July	720	3	0.4	4.1-5.8
August	96	0	0.0	--
	3576	256	7.2	2.6-6.7

TABLE 7

A COMPARISON OF THE CATCH OF NETS
WITH THE SAME CONSTRUCTION

Nets	Total Hours Fished	Total No. Fish	Catch per 100 Net Hours	Size Range (Inches)
4	696	128	18.4	4.2-8.9
5	696	106	15.2	4.4-6.8
6	696	100	14.4	4.2-6.6
7	192	52	27.1	4.1-6.4
8	96	13	13.5	4.3-6.7
	2376	399	16.8	

As water temperature increases during the spring, the fish become more active and more food is required to maintain bodily demands. Morgan (1951) found that extreme rises in temperature may also cause bluegills to stop eating. He also found the test net catch was a good record of when the fish were biting. In Buckeye Lake, Ohio, the average number caught increased rapidly from March to May when the temperature rose to 70 degrees Fahrenheit but declined sharply from June to August when the temperature rose as high as 80 degrees Fahrenheit.

This assumption does not always seem to hold true as Belding (1928) stated that trout decreased their activity as the water temperature rose into the seventies whereas the bullheads did not seem to mind the increase.

TABLE 8

TOTAL CATCH, SIZE RANGE FOR EACH TRAP NET

Nets	Total Hours Fished	Total No. Fish	Catch per 100 Net Hours	Size Range (Inches)
1	3936	237	6.0	4.1-8.4
2	3552	352	9.9	4.2-8.4
3	3576	256	7.2	2.6-6.7
4	696	128	18.4	4.2-8.9
5	696	106	15.2	4.4-6.8
6	696	100	14.4	4.2-6.6
7	192	52	27.1	4.1-6.4
8	96	13	13.5	4.3-6.7
	13,440	1,244	9.3	2.6-8.9

Table 6 and Table 8 show that net No. 3 had the smallest size range of all the nets. This is believed to be due to the one half inch mesh hardware cloth construction.

SCALE METHOD

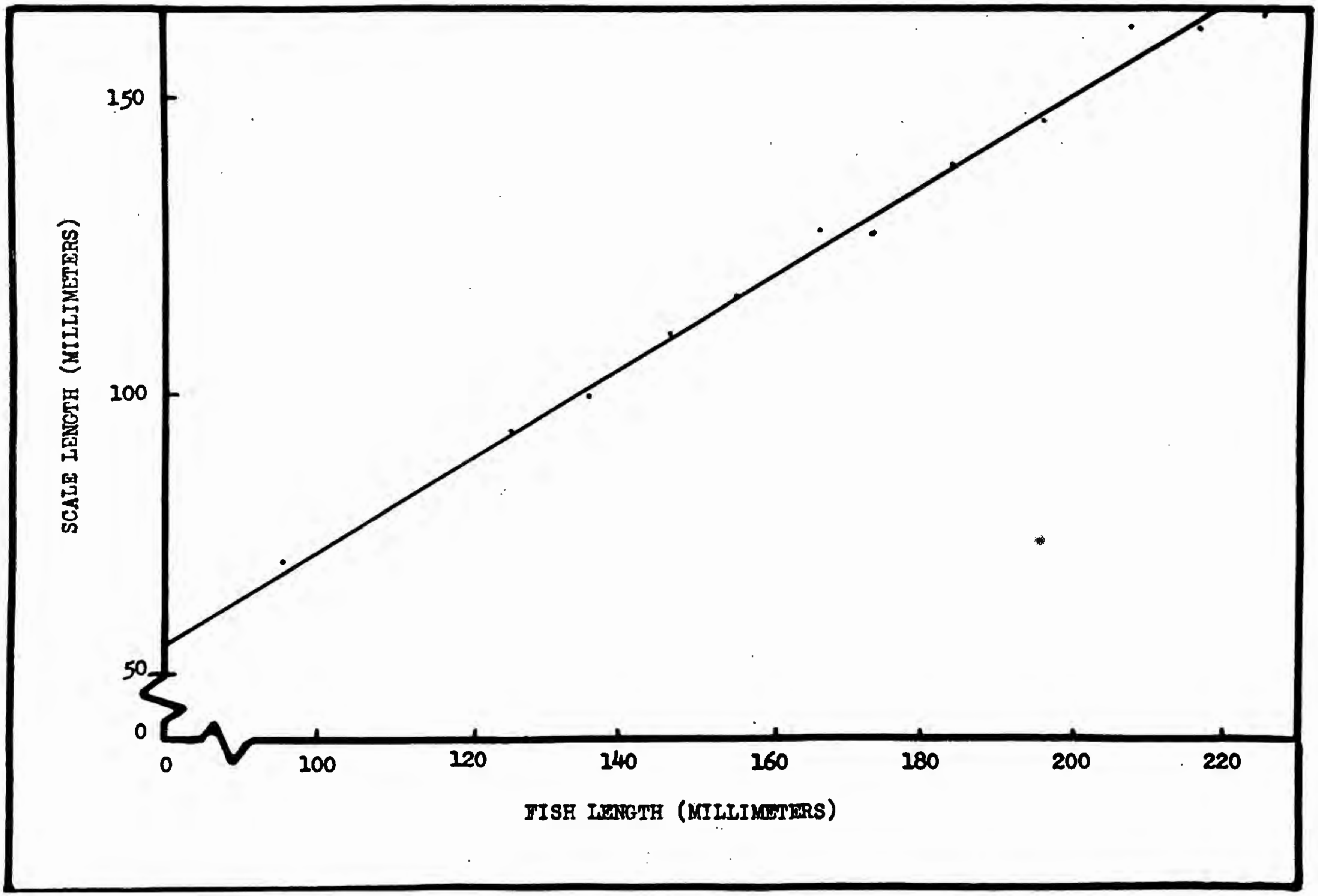
Scales are a protective exoskeleton found on fish which until recently were not studied extensively. Ctenoid scales, found usually in the higher teleosts, such as the bluegill, and perch, are similar to cycloid scales, but the part which extends out from neighboring scales has small spines.

Creaser (1926) found that tested scale data might be used effectively in the study of the life history of fishes. Three types of marks have been described in the fixation of the pattern on scales, those of the cessation of scale growth, those of variation in the rate of scale growth, and those of regeneration.

Van Oosten (1928) reported that it was possible to determine by scale analysis the approximate length attained by the fish at the end of each year of its life, and its rate of growth for each year of life.

The age of bluegills in this study was obtained by counting the annuli, which appear to be visible marks produced at about the time growth was resumed following semidormancy. The use of the scale method is based on the assumption that the scale length increases directly proportional to the length of the fish. In order to check this for Ford Lake bluegills, the data were grouped in ten millimeter intervals (Table 15) and plotted as seen in Figure 1.

Figure 1 The scale length-fish length relationships of the bluegills collected in 1952.



SCALE LENGTH (MILLIMETERS)
150
100
50
0
0
100
120
140
160
180
200
220
FISH LENGTH (MILLIMETERS)

Sex Differences of Ford Lake Bluegills

A comparison of the sex ratio of bluegills in Ford Lake (Table 9) showed that there were 107 females for every 100 males.

Beckman (1949) in a study of 8,159 bluegills, had a ratio of 120 females for every 100 males.

Hansen (1951) in a study of the white crappie, (*Pomoxis annularis*, Rafinesque), found 105 females for every 100 males.

TABLE 9

SEX RATIOS OF BLUEGILLS IN FORD LAKE IN 1952

Annulus	Number of Males	Number of Females	Number of Females per 100 Males
2	19	23	121
3	77	126	164
4	60	20	33
5	3	1	33
TOTALS	159	170	107

In the Ford Lake samples most of the young bluegills were females (Table 10), and most of the older ones were males. The sex ratio was equal, apparently, between the third and fourth year of life. The unbalanced sex ratio may have been due to the selectivity of the trap nets for a particular year class, or variation in the natural mortality for each sex.

Figure 2 The average calculated growth increments at each annulus for each year class collected during 1952.

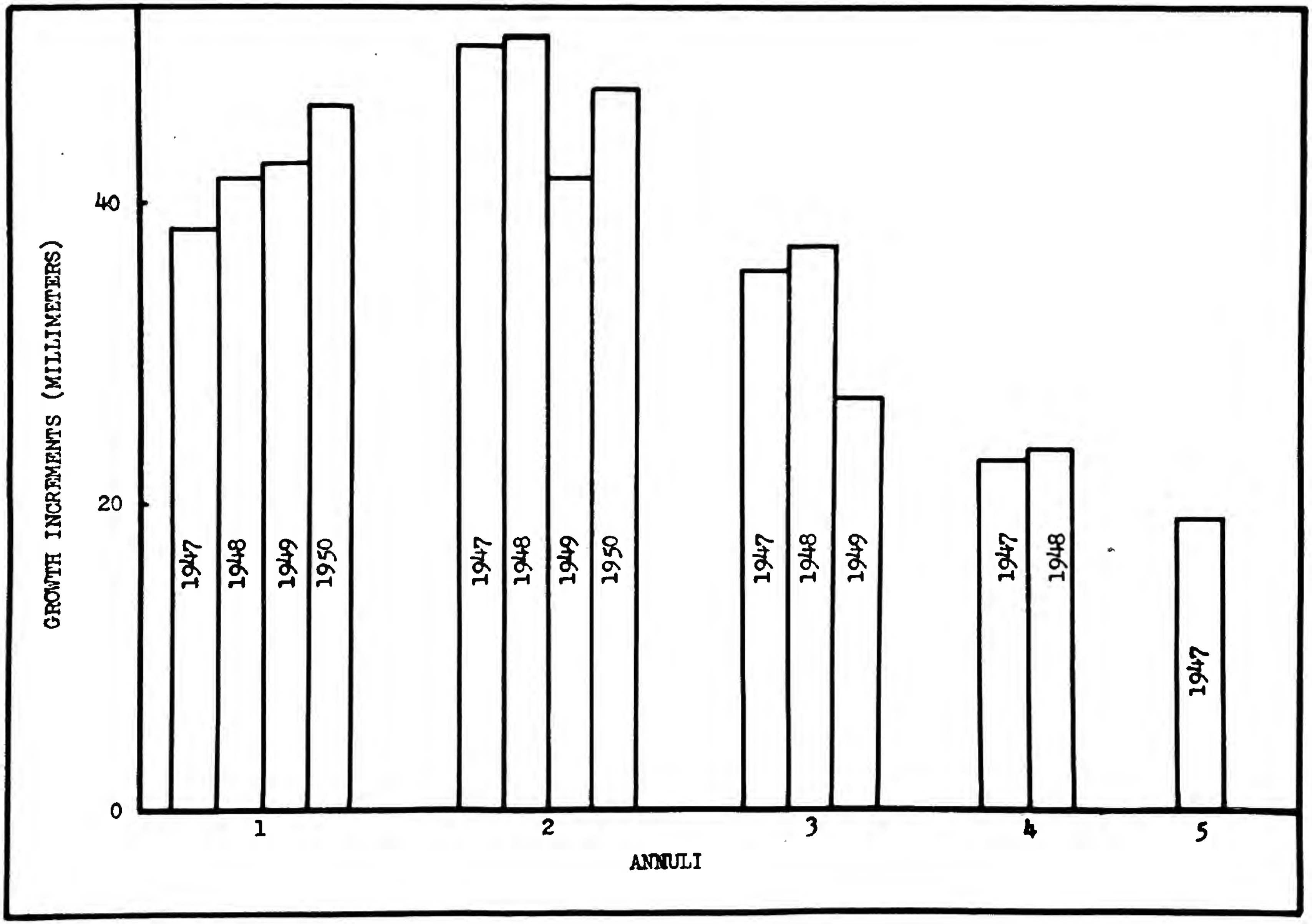
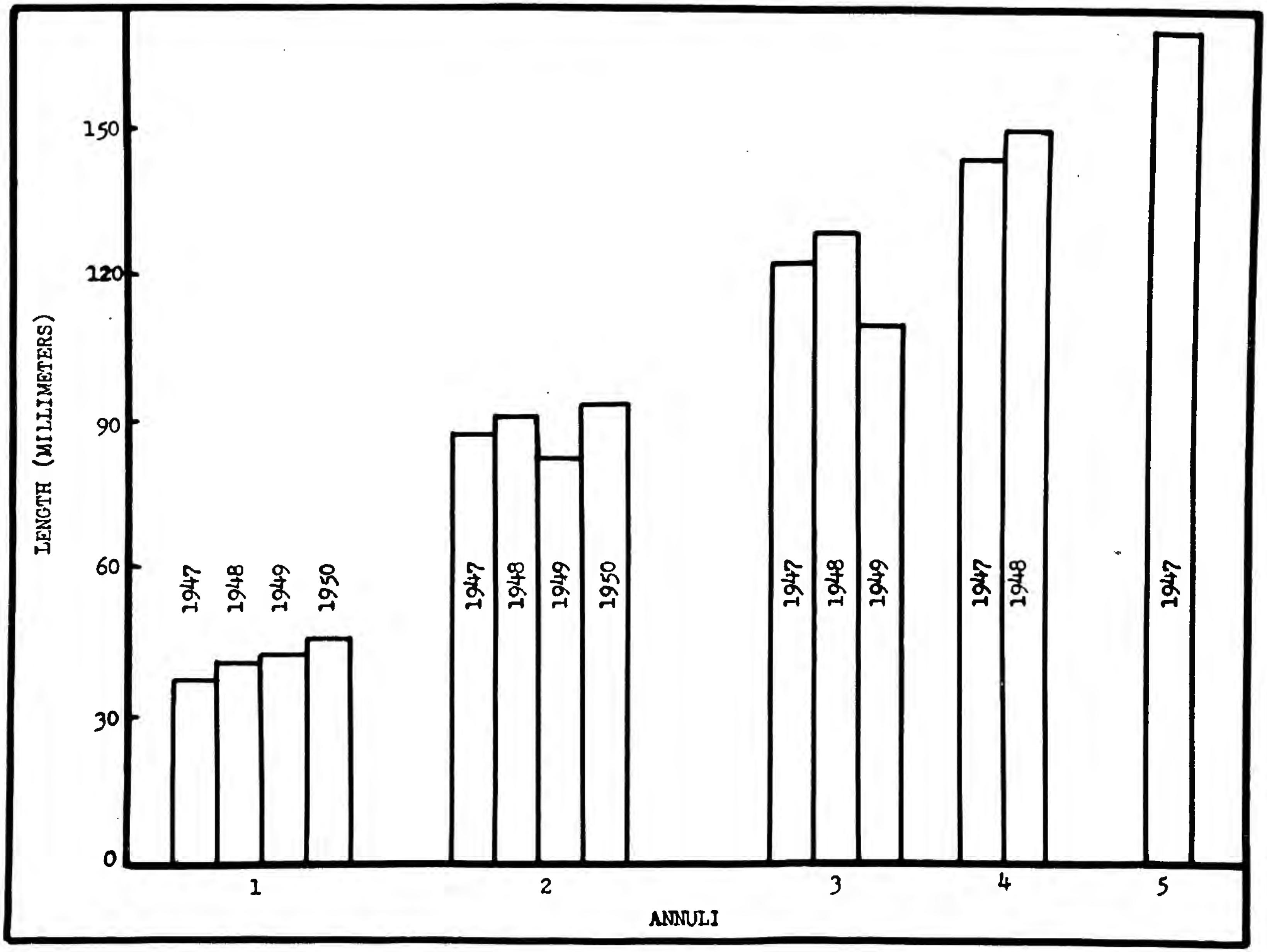

GROWTH INCREMENTS (MILLIMETERS)
40
20
0
1947
1948
1949
1950
1947
1948
1949
1950
1947
1948
1949
1947
1948
1947
1
2
3
4
5
ANNULI

TABLE 10

AVERAGE CALCULATED TOTAL LENGTHS (MILLIMETERS) OF MALE AND FEMALE BLUEGILLS

Year Class	Sex		Annulus 1	2	3	4	5
1947	Male	Total length	38.1	88.7	124.0	148.2	158.7
		Number examined	29	29	29	29	3
	Female	Total length	38.4	88.9	126.6	144.7	211.0
		Number examined	7	7	7	7	1
1948	Male	Total length	41.4	92.4	128.5	151.2	
		Number examined	89	89	89	34	
	Female	Total length	42.4	94.1	133.4	161.2	
		Number examined	70	70	70	14	
1949	Male	Total length	42.3	91.2	127.3		
		Number examined	40	40	22		
	Female	Total length	42.7	87.0	116.6		
		Number examined	90	90	70		
1950	Male	Total length	53.0	120.0			
		Number examined	1	1			
	Female	Total length	46.0	89.3			
		Number examined	3	3			

Figure 3 The average calculated length at each annulus for each year class.



LENGTH (MILLIMETERS)
150
120
90
60
30
0
1947
1948
1949
1950
1947
1948
1949
1950
1947
1948
1949
1947
1948
1947
1
2
3
4
5
ANNULI

Beckman (1949) found that in Michigan waters there was a general trend toward a decreased percentage of male bluegills with increase in age. Hubbs and Cooper (1935) found that data on the sex ratio in the green sunfish (Apomotis cyannellus), show an increasing percentage of males among the older fish, thus constrasting with the condition found in the long-eared sunfish (Xenotis megalotis peltastes).

A comparison of the growth rates of females and males was of particular interest. The total lengths of each sex, within each year class or brood, were calculated for each annulus. The 1947 brood, the oldest in the sample, shows that the female was larger at each annulus except the fourth.

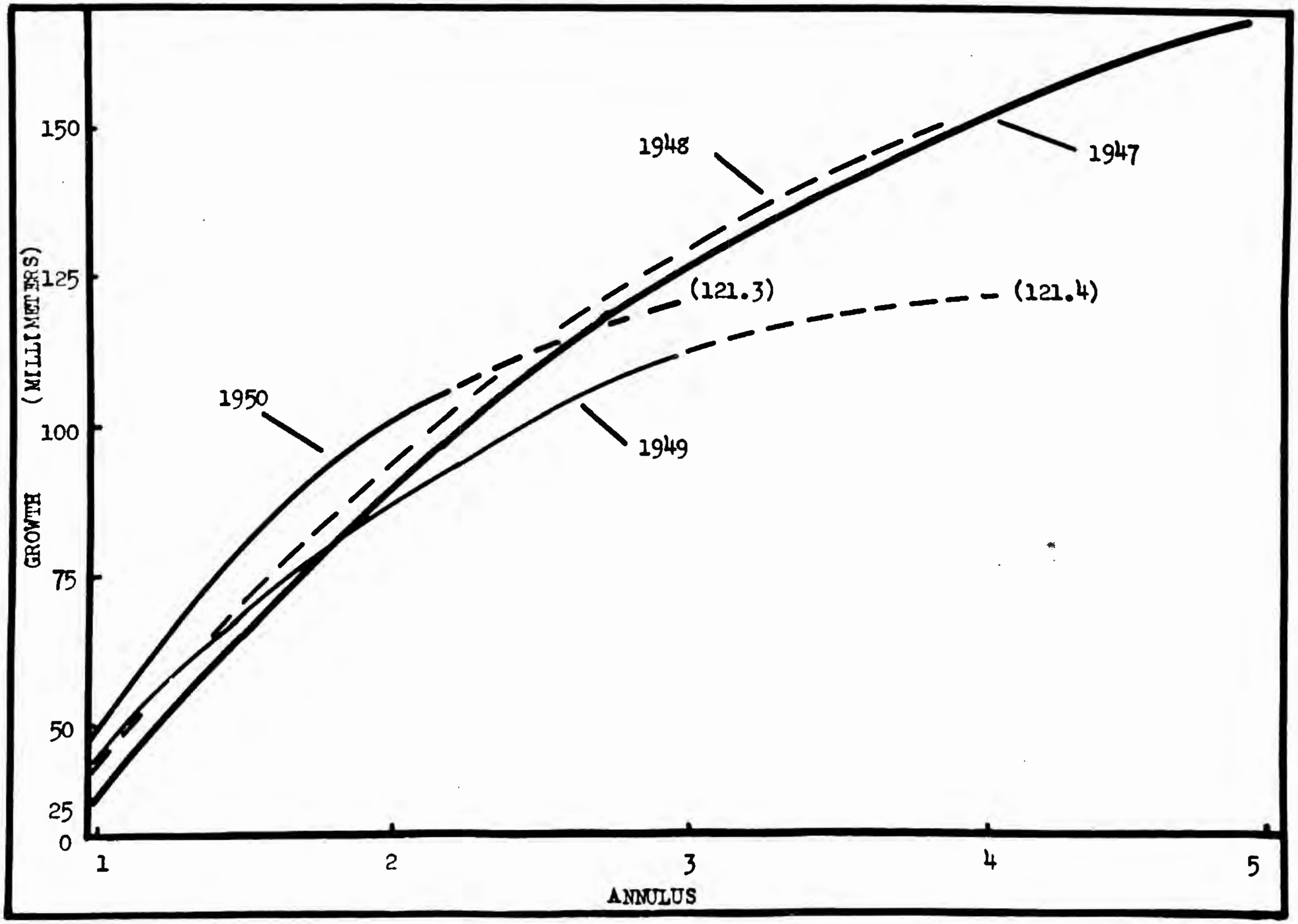
Morgan (1951), combining year classes, found that the average length of the female bluegill was consistently larger than the male.

The females from the 1948 year class were larger at each annulus, whereas the males from the 1949 and 1950 year class showed a more rapid growth than the females during 1951 and 1952.

Growth Increments

Table 11 and Figure 2 were obtained by determining the length of the fish at each annulus and subtracting the previous calculated length from it. For example, if the calculated lengths at each annulus were 35, 80, and 100

Figure 4 The average calculated lengths for each year class at each annulus.


GROWTH (MILLIMETERS)
150
125
100
75
50
25
0
1950
1948
1947
1949
(121.3)
(121.4)
1
2
3
4
5
ANNULUS

millimeters, then the fish grew 35 millimeters to the first annulus, 45 millimeters to the second, etc.

TABLE 11

AVERAGE GROWTH INCREMENTS (MILLIMETERS) FOR THE DIFFERENT YEAR CLASSES OF BLUEGILLS

Year Class		Annulus 1	2	3	4	5
1947	Growth	38.3	50.0	35.6	23.1	19.0
	No. of fish	39	39	39	39	4
1948	Growth	41.8	50.3	37.1	23.6	
	No. of fish	187	186	186	56	
1949	Growth	42.6	41.0	27.9		
	No. of fish	400	400	327		
1950	Growth	46.2	47.4			
	No. of fish	6	5			

Table 11 shows that the 1947, 1948, and 1950 year class reached their maximum growth during the second year of life, thereafter the decline is rapid. Unfortunately there were no fish in the samples from the 1946 year class. However, the growth of the 1947 year class closely approximates the growth of bluegills from Batteese Lake, Michigan, following winterkill (Beckman, 1950). During the winter of 1944 and 1945, a severe winterkill reduced the population of bluegills in Batteese Lake, subsequently, the growth of the fish increased sharply immediately following the winterkill and then slowed down.

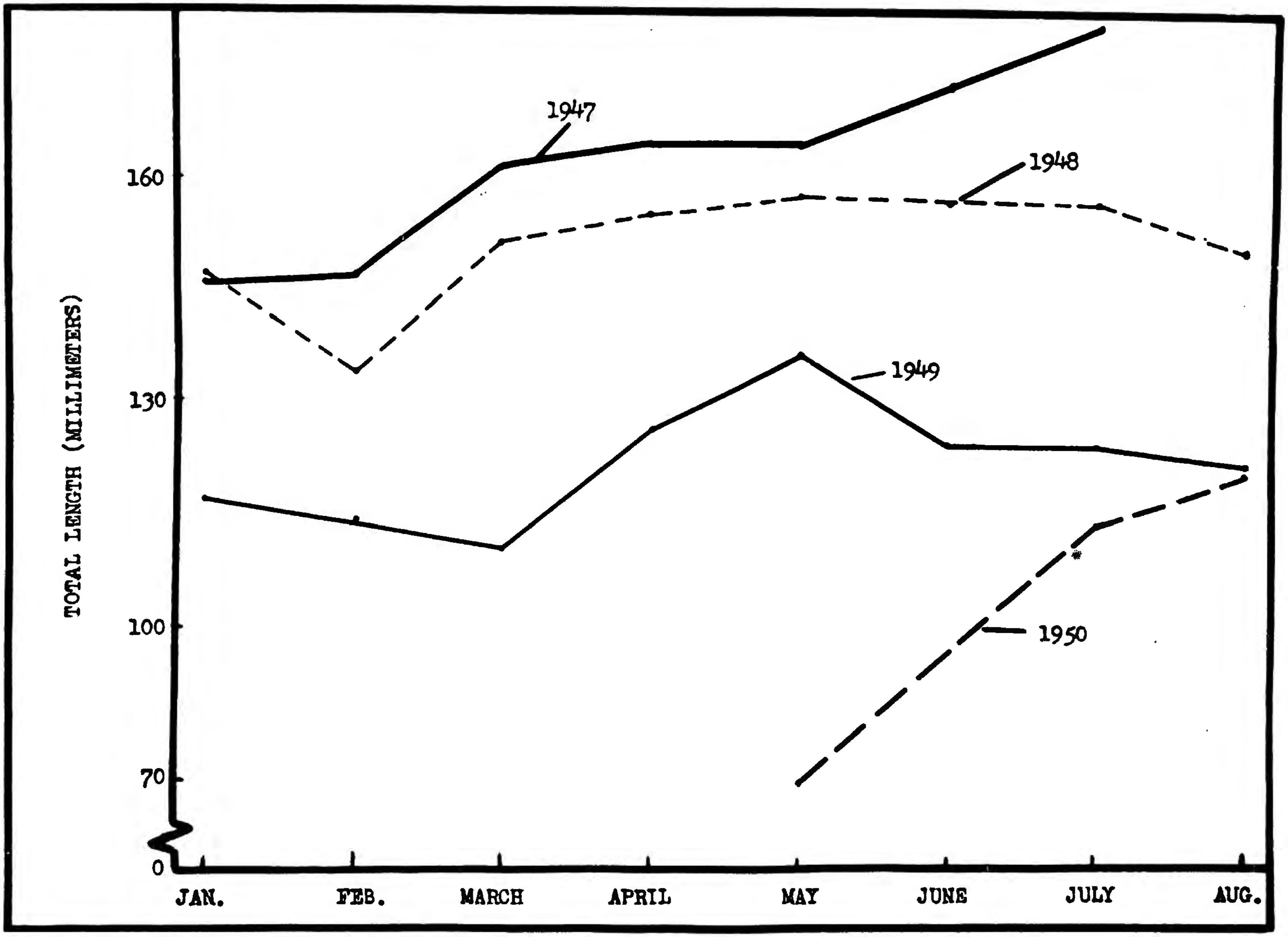
TABLE 12

AVERAGE CALCULATED LENGTHS (MILLIMETERS) OF BLUEGILLS FOR EACH YEAR CLASS

Year Class		Annulus 1	2	3	4	5
1947	Average length	38.3	88.4	123.9	146.9	171.8
	Number of fish	39	39	39	39	4
1948	Average length	41.8	92.0	129.1	151.8	--
	Number of fish	186	186	186	56	--
1949	Average length	42.6	83.7	110.8	--	--
	Number of fish	400	400	327	--	--
1950	Average length	46.2	94.2	--	--	--
	Number of fish	6	5	--	--	--

Figure 2 shows that the 1947 year class grew less than the 1948 year class during the third year of life. Also it was noted that the 1949 year class, though having an initial years growth larger than the preceding two year classes, declined much more rapidly. It should be noted that the 1950

Figure 5 Average total lengths at the time of capture for each year class collected in 1952.



TOTAL LENGTH (MILLIMETERS)
160
130
100
70
0
1947
1948
1949
1950
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.

TABLE 13

VARIATIONS IN GROWTH RATES DUE TO THE TIME OF THE YEAR

Month		Year Class			
		1947	1948	1949	1950
Jan.	Average Total Length (mm.)	145.8	147.4	117.0	--
	No. of Fish	5	17	1	--
Feb.	Average Total Length (mm.)	147.5	134.0	114.7	--
	No. of Fish	2	3	10	--
March	Average Total Length (mm.)	160.9	150.6	109.9	--
	No. of Fish	10	37	39	--
April	Average Total Length (mm.)	164.3	155.4	126.3	--
	No. of Fish	3	34	15	--
May	Average Total Length (mm.)	164.0	157.6	136.2	69
	No. of Fish	7	24	22	1
June	Average Total Length (mm.)	172.0	156.5	124.4	--
	No. of Fish	9	22	18	--
July	Average Total Length (mm.)	180.3	156.4	124.5	114
	No. of Fish	3	33	145	1
Aug.	Average Total Length (mm.)	--	150.4	121.4	121.3
	No. of Fish	--	16	150	4
TOTALS	Average Total Length (mm.)	163.2	153.5	122.3	111.3
	No. of Fish	39	186	400	6

year class, whose growth increments were approximately the same at each annulus, were above the state average for age group II at time of capture.

Calculated Growth Rates

Figure 3 shows that the average growth of the 1948 year class to the first annulus was greater than the 1947 year class. They maintained this initial growth through the formation of the third annulus. The 1949 year class, though having an initial growth at the first annulus larger than the previous two, grew much less from the second to the third annulus. The 1950 year class had a calculated growth rate slightly higher for the first two annuli. This may be due to the type of food eaten by the various year classes. Bennett, Thompson, and Parr (1940) stated that the older bluegills were less active than the yearling fish in seeking the animal foods.

In an effort to determine whether the growth rates of the 1949 and 1950 year classes were declining, the average total lengths for August were plotted in Figure 3. Spoor (1938) found that suckers (Catostomus commersonnii) in Muskellunge Lake, Wisconsin completed 92 per cent of their growth by mid-July. Karvelis (1952) found that the growth of the 1949 and 1950 year classes in Ford Lake would be less than the growth of the 1947 or 1948 year class at the third and fourth annuli. It is believed the 1950 year class does not represent a true sample because of the small numbers.

Variation in Growth Rates

Figure 5 and Table 13 show the differences in monthly average total lengths. From this table it is shown that the average total length of each year class increases as the summer progresses. The fish caught during January, February, and March were smaller than those caught in June, July, and August.

TABLE 14

AVERAGE WEIGHT OF BLUEGILLS AT THE TIME OF CAPTURE IN 1952 FOR EACH YEAR CLASS

	Number				Weight (Grams)			
	1947	1948	1949	1950	1947	1948	1949	1950
Jan.	5	17	1	--	38.4	41.1	19.0	--
Feb.	2	3	10	--	42.5	33.7	18.3	--
March	10	37	39	--	64.6	50.9	16.2	--
April	3	34	15	--	62.3	56.7	28.4	--
May	7	24	22	1	70.4	59.9	41.4	4
June	9	22	18	--	75.1	50.9	27.5	--
July	3	33	145	1	104.3	56.2	24.0	19.0
Through August 14	--	16	150	4	--	42.7	23.8	23.8
	39	186	400	6	66.5	52.2	24.3	19.7

Figure 6 The average total weight for each year class collected monthly in 1952.

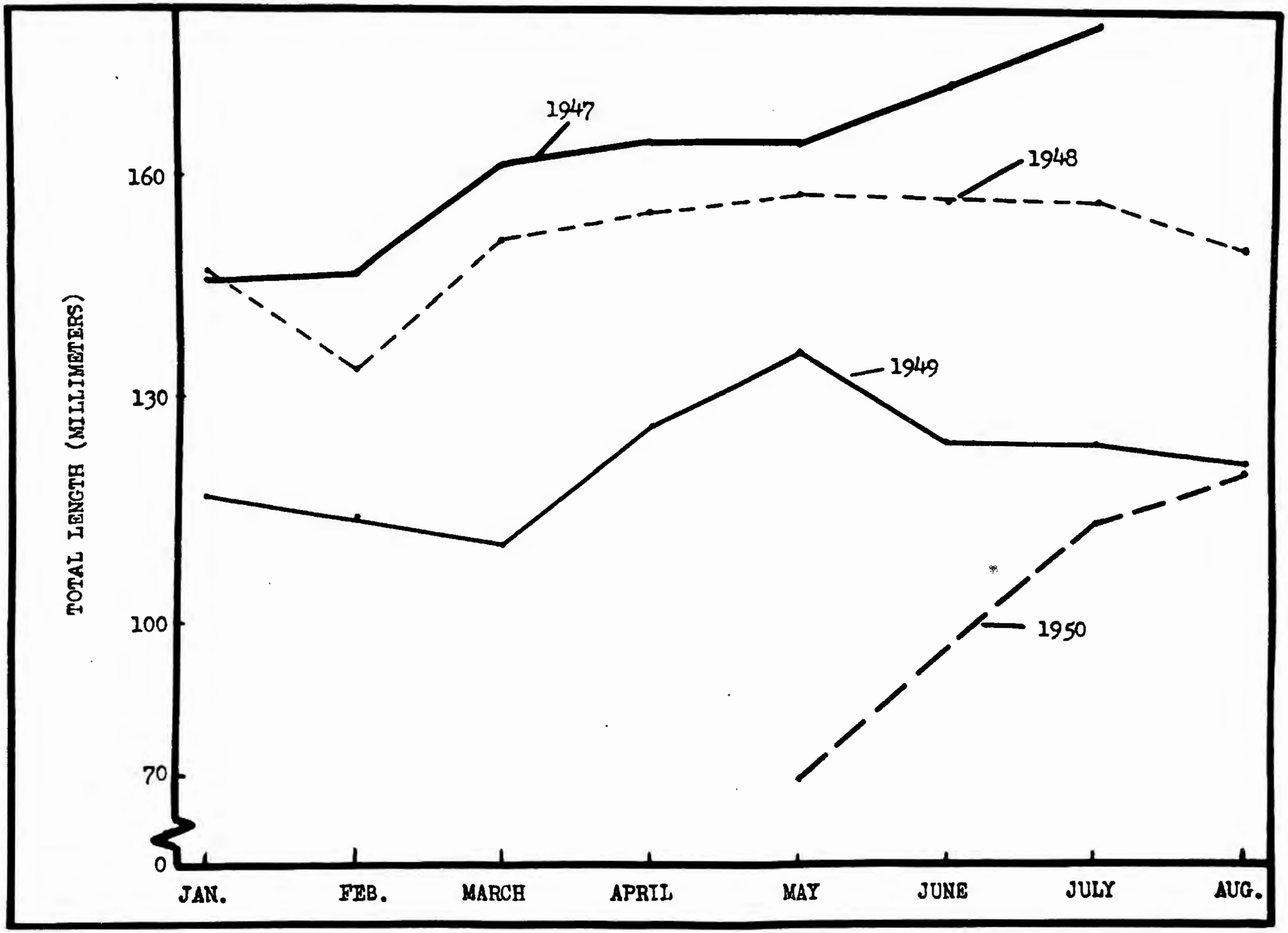

1947
1948
1949
1950
160
130
100
70
0
TOTAL LENGTH (MILLIMETERS)
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.

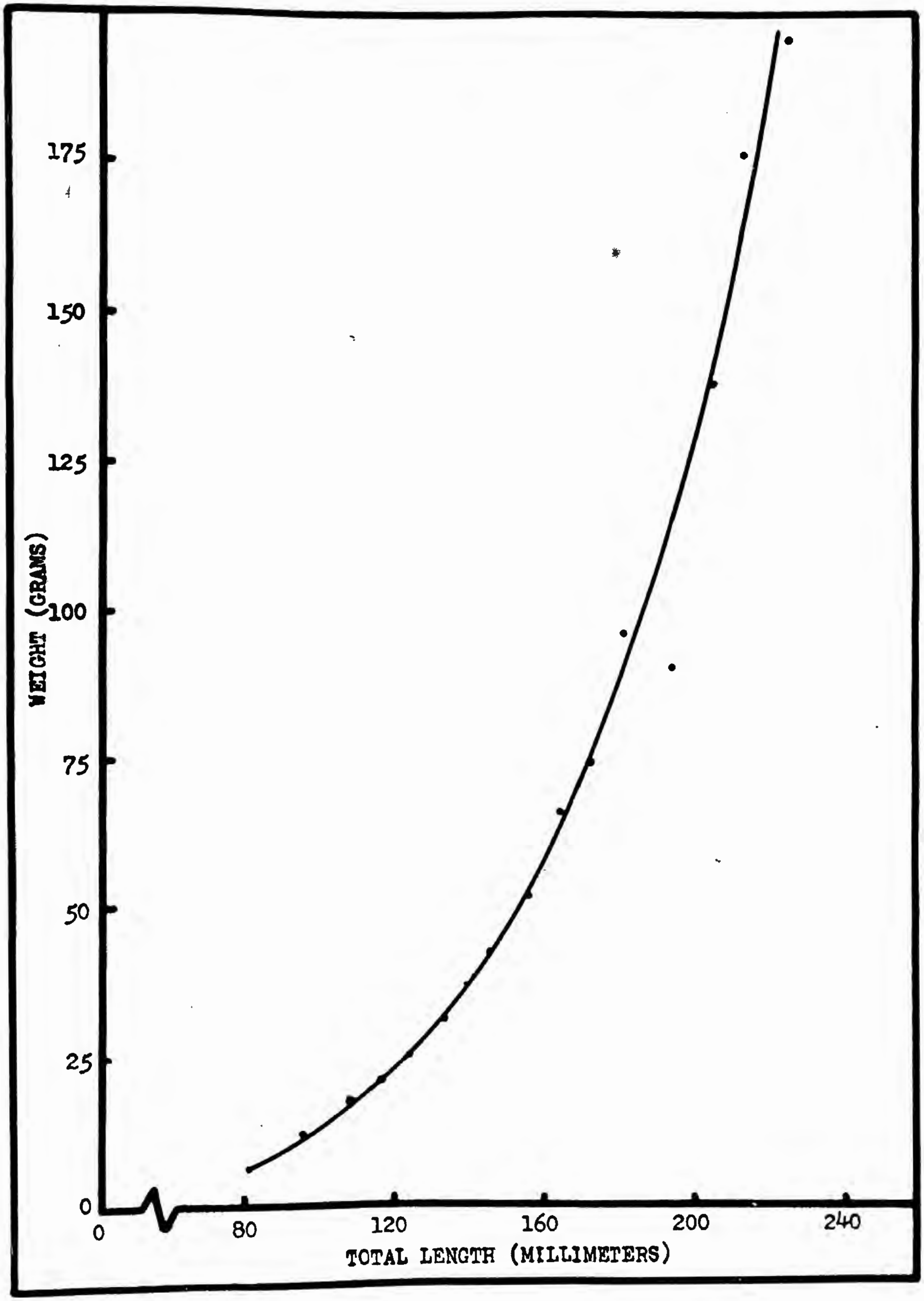
TABLE 15

THE RELATIONSHIP OF TOTAL LENGTH AND AVERAGE WEIGHT TO THE LENGTH OF THE SCALES 45.5X

Class Interval (mm.)	Number of Fish	Average Length (mm.)	Average Length of Scales (mm.)	Average Weight (grams)
81-90	3	82.3	50.7	6.7
91-100	8	95.5	73.3	11.6
101-110	27	107.1	79.1	15.8
111-120	178	116.5	86.5	20.2
121-130	149	124.9	92.6	24.3
131-140	41	135	99.9	31.3
141-150	81	146.4	110.4	41.9
151-160	68	155.6	116.2	51.7
161-170	51	165.7	127.6	66.1
171-180	9	173.1	127.1	74.2
181-190	2	182.5	139.0	96.0
191-200	8	194.3	148.8	89.9
201-210	2	206.0	162.5	137.5
211-220	5	215.0	163.6	176.0
221-230	1	226.0	167.0	195.0

The average weight of the bluegills showed a corresponding increase in length with several exceptions. The 1947, 1948, and 1949 year classes showed a decrease in average weight during June (Table 14). This decrease may have been

Figure 7 Length-weight relationships of the Ford Lake bluegills collected during 1952.



WEIGHT (GRAMS)
175
150
125
100
75
50
25
0
0
80
120
160
200
240
TOTAL LENGTH (MILLIMETERS)

due to spawning activities since Karvelis (1952) reports that the peak of the bluegill spawning had passed as of June 18, in Ford Lake.

Statistical Test for Population Differences

An effort was made to determine whether there was a difference between the average total lengths of the 1948 and the 1949 year classes during June. The "T" test as given by Snedecor (1950) was 6.46 with 38 degrees of freedom. This is statistically significant at the one per cent level. In June the standard deviation for the 1948 year class was 11.6 millimeters and 19.3 millimeters for the 1949 year class. A similar test was used for the March catch which was also significant at the one per cent level.

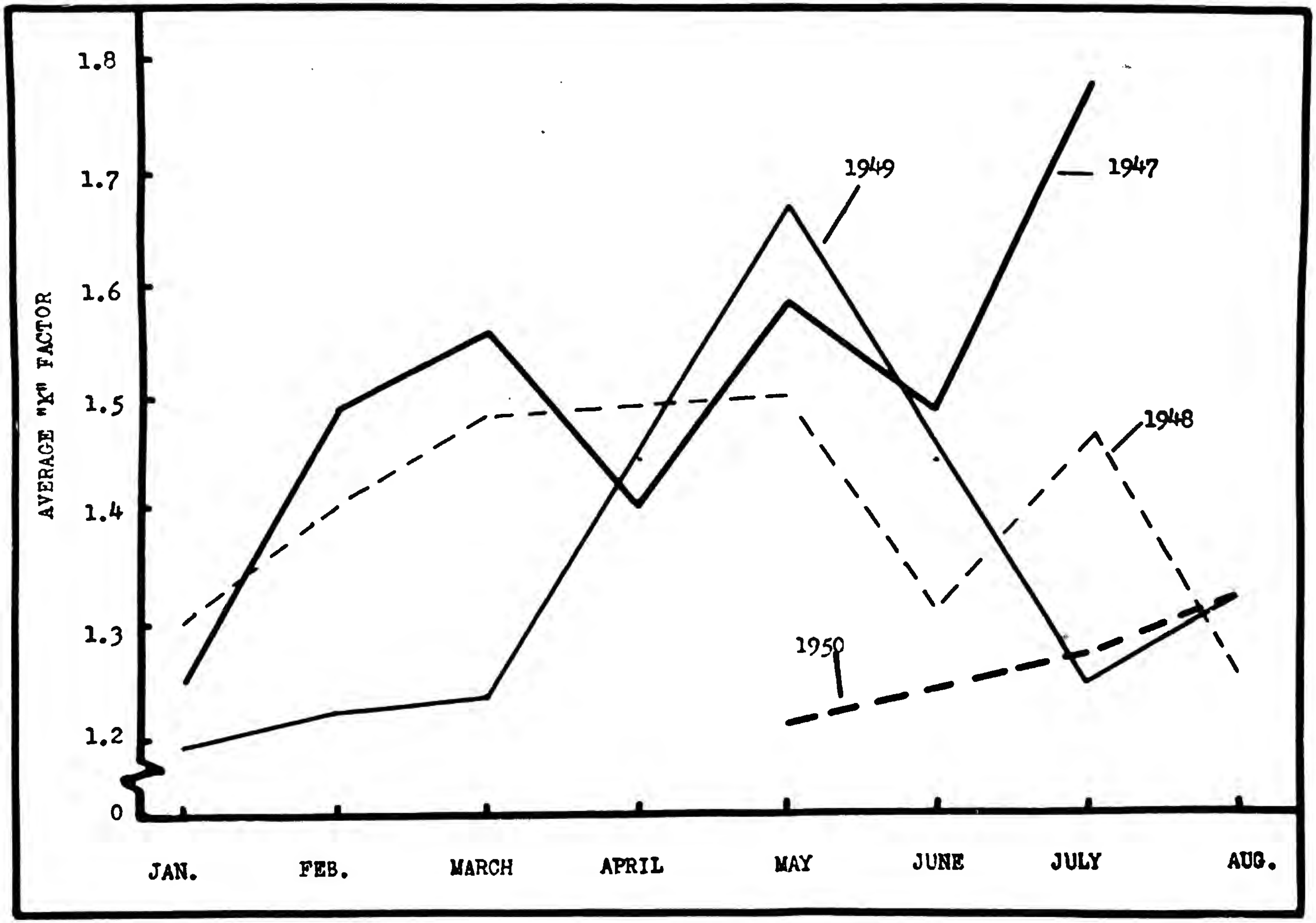
The 1949 population had an average deviation in June from 105.1 to 143.7 millimeters, whereas the average deviation for the 1948 year class varied from 144.9 to 168.1 millimeters.

The "T" test was used to determine whether the 1948 and 1949 year classes were essentially different populations. In June, for example, a bluegill approximately 124 millimeters in length probably belonged to the 1949 year class.

Condition and Length-weight Relationships

Table 15 shows that over 50 per cent of the fish caught

Figure 8 Variation in the "K" factor due to the time of the year for each year class.


AVERAGE "K" FACTOR
1.8
1.7
1.6
1.5
1.4
1.3
1.2
0
1949
1947
1948
1950
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.

were from 111 to 130 millimeters in length and these weighed about 22.3 grams. It should also be noted that two-thirds of the sample were from the 1949 year class.

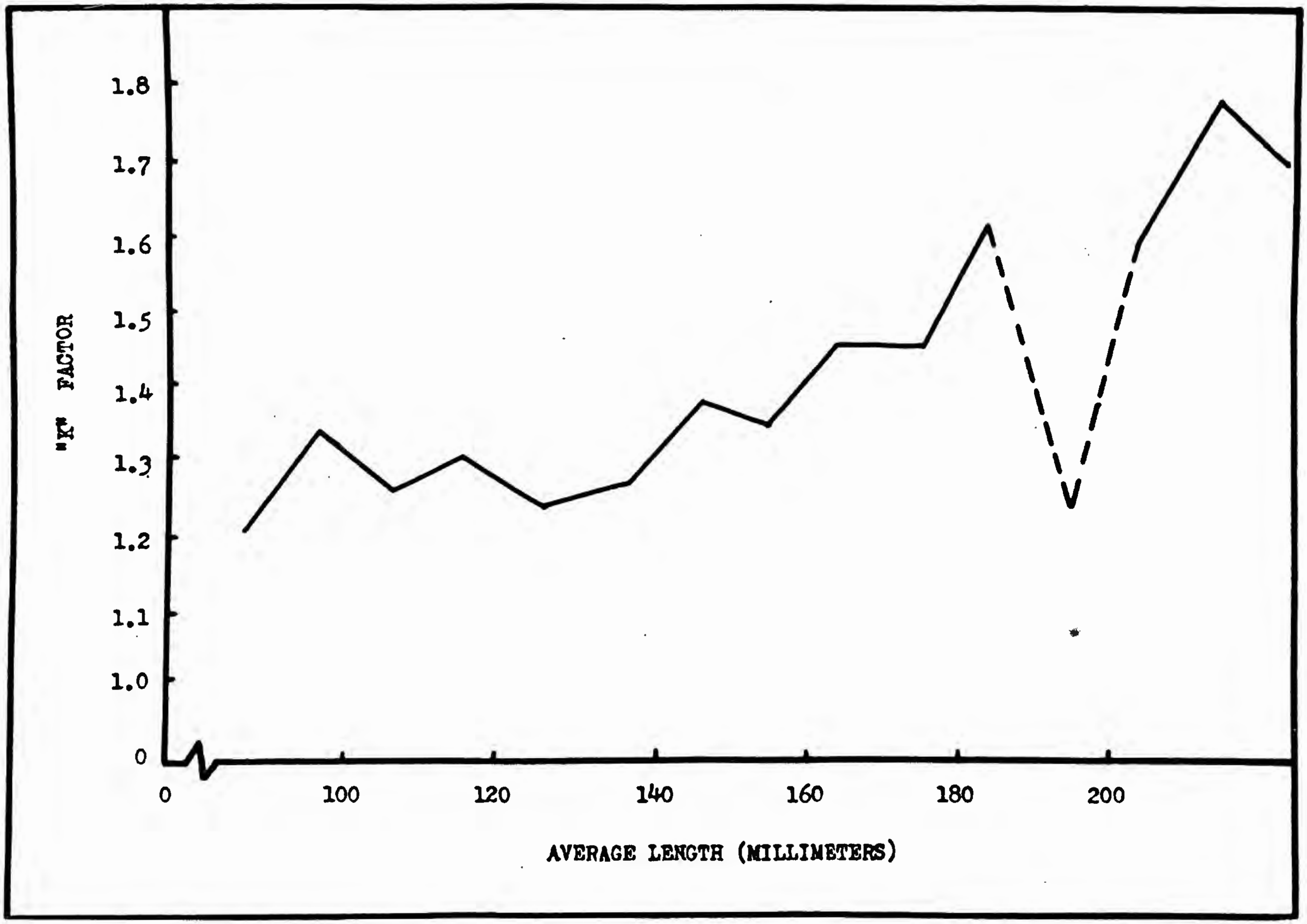
TABLE 16

VARIATION IN "K" FACTOR DUE TO THE TIME OF THE YEAR FOR EACH YEAR CLASS

	Year Class			
Month	1947	1948	1949	1950
January	1.25	1.30	1.19	--
February	1.48	1.40	1.22	--
March	1.54	1.48	1.23	--
April	1.40	1.49	1.44	--
May	1.59	1.50	1.67	1.21
June	1.48	1.31	1.44	--
July	1.78	1.46	1.25	1.28
August	--	1.26	1.32	1.32
TOTAL AVERAGE	1.50	1.40	1.34	1.27

Weight in fishes may be considered a function of the length. The values of "K" have been used to express this relative well-being of the fishes. As fish grow older they tend to gain proportionately more in weight than in length. Abrupt changes occur in the condition of a fish at spawning. Preceding spawning there is a rise in the "K" factor due to

Figure 9 Average "K" factor for each average class interval in length collected during 1952.



"K" FACTOR
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0
0
100
120
140
160
180
200
AVERAGE LENGTH (MILLIMETERS)

enlarging gonads. Following spawning there is a rapid decrease in the "K" factor due to loss of weight. It has also been noted that the "K" values increase with age because the older fish tend to gain in weight faster than length (Hile, 1936).

TABLE 17

AVERAGE "K" FACTOR FOR EACH CLASS INTERVAL IN LENGTH COLLECTED IN 1952

Class Interval (mm.)	Average "K" Factor	Number of Fish
81-90	1.21	3
91-100	1.34	8
101-110	1.26	27
111-120	1.30	178
121-130	1.24	149
131-140	1.27	41
141-150	1.37	81
151-160	1.35	68
161-170	1.45	51
171-180	1.45	9
181-190	1.61	2
191-200	1.23	8
201-210	1.58	2
211-220	1.77	5
221-230	1.69	1

Table 16 shows that the "K" factor is greater for the older age groups although the value for each year class is less than the Michigan average. Each year class, except 1950, showed a decline in condition during June, probably due to spawning activities. The 1949 year class continued to decline in condition in July, possibly meaning that spawning took place in July. Bluegills of the 1949 year class averaged 4.9 inches in length during June and July. The females outnumbered the males 2 1/2:1 in the collections of this period. It is believed that the 1948 year class increased in condition in July because of an increase in weight, whereas the average length did not increase.

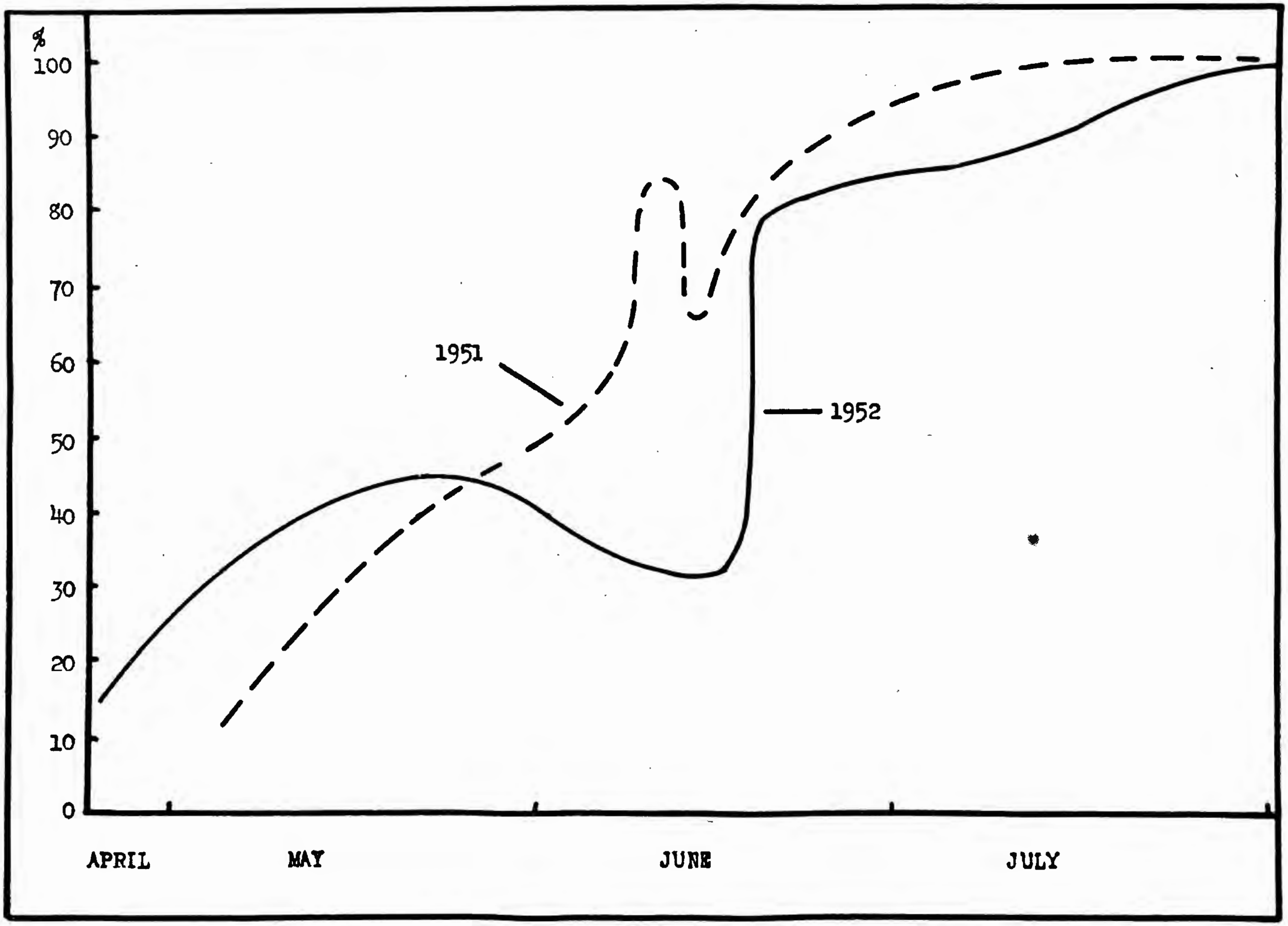
Table 17 shows that the average "K" factor for over fifty per cent of the bluegills was approximately 1.28. Figure 9 shows a drop in the "K" factor for those fish in the 191-200 millimeter group. Although the sample was taken throughout the collection period, seven out of the eight fish in this group were females. It is believed that this sample was not representative of the group.

Time of Annulus Formation

An effort was made to determine the relationship of the length and the weight to the time of annulus formation. Table 18 shows that there was not much difference in the average weight at each collection date. In most cases, however, it

Figure 10 The percentage of bluegills having the annulus formed by the collection date in 1951[1] and 1952.

[1] Adapted from Karvelis (1952)



%
100
90
80
70
60
50
40
30
20
10
0
1951
1952
APRIL
MAY
JUNE
JULY

was the longer fish, during each collection period, that had formed the annulus. Table 19 shows that for three collection periods out of four, the average weight of the bluegills having the annulus formed was larger than those not having the 1952 annulus formed.

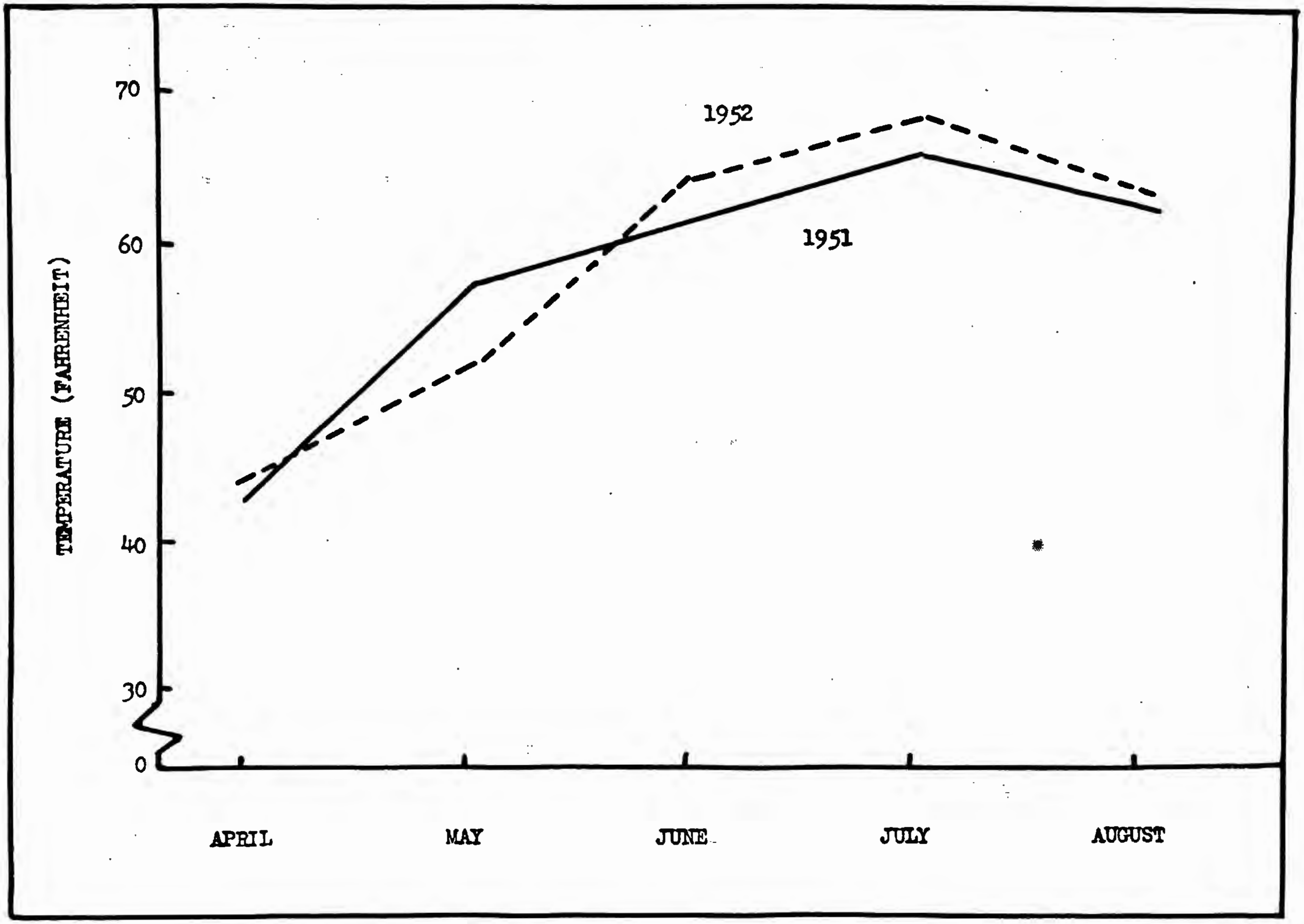
TABLE 18

THE RELATIONSHIP OF LENGTH AND WEIGHT TO THE TIME OF THE 1952 ANNULUS FORMATION FOR THE 1948 YEAR CLASS

Collection Date	Average Weight (grams) Without Annulus	Average Weight (grams) With Annulus	Average Length (mm.) Without Annulus	Average Length (mm.) With Annulus	Per Cent with Annulus Formed	No. Fish Examined
4/23-4/27	56.0	62.2	153.0	160.7	20.7	29
5/1-5/16	49.6	94.8	148.8	183.3	35.0	14
5/17-6/1	54.5	50.0	154.5	155.0	11.1	9
6/2-6/17	56.0	53.5	154.0	151.5	50.0	4
6/18-7/2	49.5	51.8	156.6	160.3	22.2	18
7/3-7/18	42.5	41.0	145.5	150.0	66.7	6
7/19-8/2	35.6	63.5	146.2	159.5	72.7	33
8/3-8/14	--	44.3	--	153.3	100	10

A comparison of Table 18 and Table 19 shows that the majority of the 1949 year class formed the annulus sooner than the 1948 year class. This is believed to be due to the increased growth of younger age groups.

Figure 11 The average monthly air temperature (Fahrenheit) recorded at the Vanderbilt Trout Research Station.



TEMPERATURE (FAHRENHEIT)
70
60
50
40
30
0
1952
1951
APRIL
MAY
JUNE
JULY
AUGUST

TABLE 19

THE RELATIONSHIP OF LENGTH AND WEIGHT TO THE TIME OF THE 1952 ANNULUS FORMATION FOR THE 1949 YEAR CLASS

Collection Date	Average Weight (grams)		Average Length (mm.)		Per Cent with Annulus Formed	No. Fish Examined
	Without Annulus	With Annulus	Without Annulus	With Annulus		
4/23-4/30	26.5	--	126.4	--	0.0	11
5/1-5/16	82.8	56.7	162.3	153.4	42.9	7
5/17-6/1	18.7	37.0	115.0	135.1	53.3	15
6/2-6/17	--	50.0	--	155.0	100	1
6/18-7/2	18.0	27.3	110.0	124.3	88.8	17
7/3-7/18	17.0	25.1	114.0	123.0	95.0	20
7/19-8/2	--	23.9	--	123.3	100	180
8/3-8/14	--	23.9	--	122.4	100	95

Figure 10 compares the time of annulus formation for all fish collected in 1951 and 1952. Table 20 shows that approximately 50% of the fish collected in 1952 had formed the annulus before June 23. Karvelis (1952), working on Ford Lake in 1951, found that 52.4 per cent of the fish had formed the annulus by June 4, 1951. It should also be noted (Figure 10) that the average monthly air temperature in the vicinity of Ford Lake in May, 1951, was 5.3 degrees above that in May, 1952. This early increase in temperature for 1951 may partly account for the rapid increase in annulus formation in early June. The average monthly air temperature during

TABLE 20

PERCENTAGE OF BLUEGILLS HAVING FORMED THE ANNULUS BY EACH COLLECTION DATE IN 1952

Date	Number Examined	Percentage Having Annulus Formed
4/23	38	15.8
4/27	4	25.0
5/2	3	0.0
5/4	16	31.3
5/9	10	40.0
5/22	19	47.4
5/25	6	33.3
6/4	5	40.0
6/19	28	32.1
6/23	16	81.3
7/12	9	88.9
7/14	16	87.5
7/21	2	100
7/26	155	98.1

June was higher in 1952, which may possibly account for the rapid increase in annulus formation from June 19 to June 23.

The average air temperature was computed for the period preceding each collection date in 1951 and 1952. The only similarity between 1952 and 1951 was a period of average air temperature of 55 degrees Fahrenheit for a period of approximately 12 days preceding the June 4, 1952 collection period. By this time 40 per cent of the bluegills had formed an annulus. For ten days preceding the May 19, 1951 collection, the average air temperature was also 55 degrees Fahrenheit and 41.6 per cent of the bluegills had formed an annulus.

TABLE 21

AVERAGE MONTHLY AIR TEMPERATURE (FAHRENHEIT) AT THE VANDERBILT TROUT RESEARCH STATION

Year	Month				
	April	May	June	July	August
1951	42.0	56.3	60.6	65.2	61.8
1952	43.4	51.0	63.5	68.6	63.8

DISCUSSION

Ford Lake was one of the lakes that became part of a fish management plan to expand trout production in Michigan. This planning began in 1931 and extends through the present.

In twenty years Ford Lake has been stocked with brook, brown, and rainbow trout, and Montana grayling. The lake has been poisoned three times, the last in August, 1952. This poisoning offered an opportunity to compare the standing crop with that found following previous poisonings.

Data on the trap nets used in Ford Lake were suitable for an analysis of variance test to determine whether small differences in construction would alter the catch. The test indicated that the funnel depth influenced the number of bluegills caught.

Karvelis (1952) found insects to be the predominant food of the brook trout in Ford Lake. He also found that over half the food of the larger bluegills was insects. This competition for the food utilized by trout was evident by the relatively few numbers and low weight of brook trout during poisoning. At least 29,000 fingerling brook trout had been planted in Ford Lake since 1947 but only 621 were recovered following poisoning in 1952. In 1949, 1950, and 1951, a total of 197 brook trout were caught by anglers. This relatively low return seems to indicate that brook trout cannot survive in competition with the bluegill.

Although a few small bluegills were found in trout stomachs, the bluegills were not limited in population by predation. Essentially the main species in Ford Lake was the bluegill, limited in growth and population by food and natural mortality. It was found that the average bluegill from the 1948 brood reached the legal length of 6 inches in four years. The bluegills from the 1947 and 1949 year classes averaged respectively, 6.4 and 4.8 inches in 1952.

It was found that the bluegills grew faster during the first year or two of life, but the growth rate declined rapidly in later years.

The biological pattern of Ford Lake indicates several possibilities or combination of possibilities. Sexually mature or near mature bluegills survived the 1946 poisoning and spawned in 1947 or later years. This would probably mean a very large population survival of bluegills from the 1947 year class. It is also possible that some "young of the year" fish survived the poisoning and spawned in 1949, which may have resulted in the very large sample of the 1949 year class. Morgan (1951) proposed that the date of spawning, whether it was the third or fourth summer, depended on the hatching date being early or late in the summer.

The average total lengths of age groups 3, 4, and 5 were below the Michigan average total length at time of capture. The average weight of the bluegills recovered from poisoning in 1952 was little more than 0.3 of an ounce larger than those recovered in 1946. It is believed, therefore, that the period of time from the last poisoning was adequate to produce stunting tendencies in an almost pure bluegill population.

SUMMARY

1. The known recovery rate at time of poisoning of bluegills marked before poisoning was slightly less than 75 per cent.
2. Bluegills constituted 80 per cent of the total weight and 95 per cent of the number of fish recovered.
3. The average weight of the brook trout was slightly more than half an ounce.
4. The funnel depth of a trap net influenced the yield of bluegills.
5. The wire mesh on trap nets apparently was a selective factor in the size of catch.
6. The sex ratio revealed that the majority of the younger bluegills were females while the older ones were predominantly males.
7. The average calculated total length of the 1948 year class showed that the female was larger than the male at each annulus formation.
8. The growth rates of the 1949 and 1950 year classes were declining following formation of the first annulus.
9. Over 50 per cent of the bluegills caught were from 111 to 130 millimeters in length.
10. During each collection period it was the larger and heavier bluegill that had formed the 1952 annulus.
11. The 1949 year class formed the 1952 annulus earlier than the 1948 year class.

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