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AGE AND GROWTH STUDIES ON MICHIGAN GAME FISHES*

by

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Since Leeuwenhoek, a Dutch scientist, first looked at fish scales under a microscope, many men have worked on and speculated about fish scales. Leeuwenhoek, in 1684, recorded the fact that there were "rings" on the scales and believed that each ring was a year-mark. Until about 40 years ago, there were many arguments as to the meaning of these rings on the scales. Some claimed that they were year-marks, others that they were not, while some claimed that groups of these rings formed each year. In 1898, a German biologist, Hoffbauer, gave to fishery biology the science of age determinations in fish. He worked with carp which he was raising in ponds. He followed one brood through several years, removed scales from these fish at intervals throughout the period of years, and studied them under the microscope. He discovered the presence of the year-marks or annuli. Following his work, others began an intensive study of fish scales. Gradually an improved technic has been built up. Methods for the calculations of the length of the fish at each year of their life from scale measurements,

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* Revised from discussion presented to the District Fisheries Supervisors Conference at Lansing, 1939.

coefficients of condition, length-weight relationships, and relative rates of growth have all been derived and used.

Fish scales are of three types--ganoid, cycloid, and ctenoid. Ganoid scales are found on gar pike, and are platelike in form. These scales cannot be used for age determinations. The Ctenoid scales are found on black bass, perch, sunfish, bluegills and others. This type is illustrated by a scale from a rock bass (Figure 1). You will note the tooth-like projections on one part. The area on which these teeth are located is the part of the scale which is exposed. It is the part of the scale we see when looking at the fish. The other part of the scale is covered by the overlapping of the scales, similar to shingles on a roof. The trout, ciscoes, whitefish, minnows, etc., have cycloid scales. These scales do not have tooth-like projections on the exposed surface. Figure 2 illustrates this type of scale. It is from a brook trout.

You will notice on the scale (Figure 3, from a yearling bluegill) that in the center of the scale there is a small clear area, the focus, which represents the original scale plate of the young fish. Around this center are numerous ridges or circuli, which represent the successive stages in scale growth, though they seldom correspond exactly with the scale margin. On the anterior, concealed field are the radiating grooves or radii. As has been pointed out previously, the ctenii are on the exposed area.

As the scale grows, each circulus is laid down first along the anterior margin and gradually grows around the scale. A close examination usually will show several incomplete circuli along the dorsal and ventral borders (left and right in the illustration) of the scale. During the winter, growth is retarded or ceases entirely and the circuli do not

Figure 1

Ctenoid scale. From a 3-year-old rock bass, 5 1/4 inches, total length.

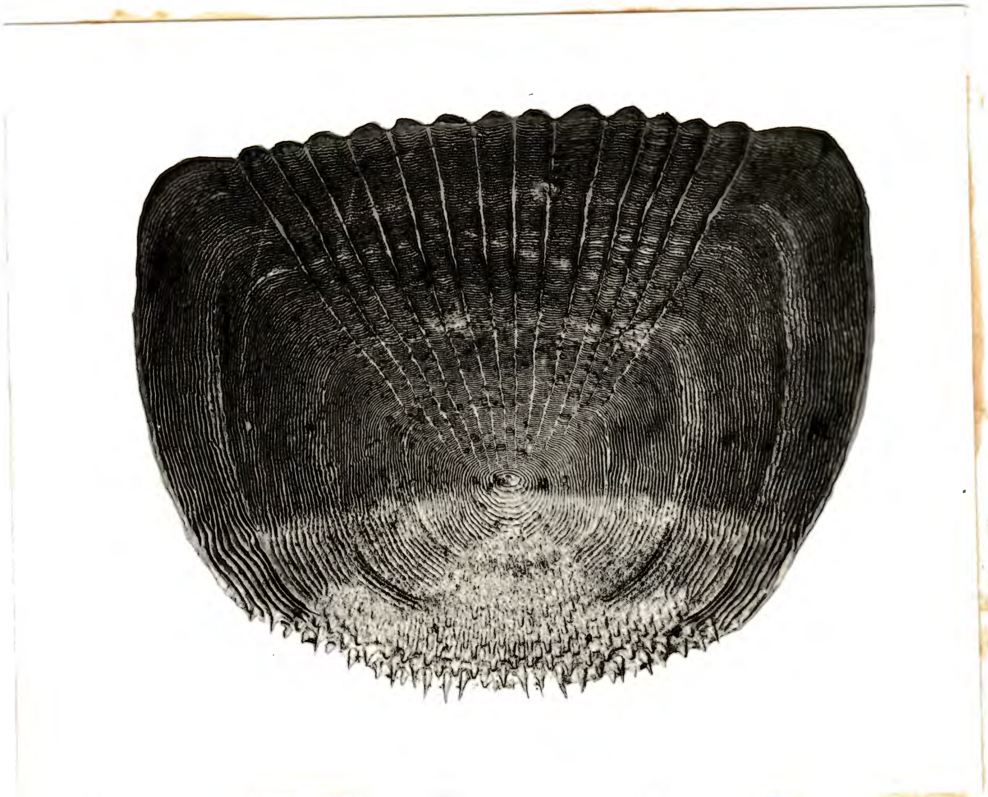


Figure 2

Cycloid scale. From a 3-year-old brook trout, 15 1/8 inches, total length.

Figure 3

Scale from a yearling bluegill,
4 1/4 inches, total length.

grow to completion. With the resumption of rapid growth in the spring, a new circulus is laid down which soon grows around the entire scale margin, just outside the incomplete circuli of the previous growing season, which remain as they were in the winter. The new circulus therefore cuts across these incomplete circuli and this "cutting across" is one of the most conspicuous and trustworthy characteristics of the annulus or year-mark.

It is by locating and counting the number of these annuli or year-marks that the age of a fish is determined.

The scale method is based upon the following propositions as outlined by Van Oosten (1929):

1. "That the scales remain constant in number and retain their identity throughout the life of the fish."

2. "That the annual increment in length of the scale maintains, throughout the life of the fish, a constant ratio with the annual increment in body length."

3. "That the annuli are formed yearly."

During the years 1939 and 1940, collections were made by the writer from eight lakes situated in different parts of the state in order to determine the time of year at which the annuli are formed. It was found that in the lower one-third of the Lower Peninsula, the annulus was formed on the average by the middle of May in all species of fish studied. In the upper two-thirds of the Lower Peninsula, the annulus was formed by the first part of June, and in the Upper Peninsula by the end of June.

It is important to know the time of year at which the annulus is formed in order to determine more accurately the ages of fish caught in the spring and early summer. For example, a collection of fish was made during the first part of May. On many of the scales it would be difficult to determine whether the growth beyond the last annulus represented the new season's increment or the entire past year's growth. With the knowledge of the time of annulus formation, the worker can decide by the width of the band whether or not it is the new or old season's growth.

Fish, like race horses, have a birthday the first of January. A year is added to the age of all fish taken between January 1 and the time of annulus formation. This is done in order to permit comparisons on a calendar year basis. Samples may be collected from a lake during the winter and before the annulus forms in the spring. Other samples are taken from the same body of water after the annulus has formed. These later samples will have one more visible annulus than the winter collections. For example, a $6\frac{1}{2}$-inch bluegill caught in April before the annulus of that year is formed, would have three visible annuli on the scales. However, bluegills of the same size collected a month later, after the annulus has formed, will have one more annulus on their scales, and thus would be IV years old. Therefore, it would appear that there were two age groups for the same size range of fish. In order to avoid this discrepancy, one year is added to those samples taken after January 1 and prior to the time of annulus formation.

Not all scales can be used for age determinations. Some scales may be lost accidentally, and others grow to replace them. These scales, called "regenerated", are easily detected because they have an opaque center approximately equal to the size of the scale at the time it was lost (Figure 4). No circuli are present in the regenerated area

Figure 4

Regenerated scale from a pumpkinseed, 3 7/8 inches, total length.

and thus the scale is useless for age determinations. Other scales may have peculiar marks so that they cannot be used. From one to ten per cent of the scales, depending on the species, are discarded by experienced workers, and less experienced workers should discard an even greater percentage.

Some species of fish have scales much easier to read than others. Among the easiest are the rock bass and bluegills, while the northern pike, perch, and walleye are among the hardest.

The scale sample which we take from the fish for age determination is scraped off just below the dorsal fin and usually below the lateral line on spiny-rayed fishes, and just above the lateral line in the soft-rayed fishes (Figure 5). It has been found that the scales on these areas are the most uniform in size.

These scales are placed in a scale envelope on which is recorded the necessary data such as species, weight, length, sex, state of sexual maturity, and method of capture, and locality. In the laboratory, the scales are soaked in water, and cleaned with small brushes under a microscope. From three to six of the scales are placed on a glass slide and covered with a gelatin-glycerin compound, and then a cover-glass is placed on top. The mounting medium is applied hot, and upon cooling becomes hardened, and will last indefinitely.

The scale-mounts are then studied on a specially designed micro-projection apparatus (Figure 6) at magnifications from 29 to 90 diameters, depending upon the size of the scale.

The age of fishes upon reaching legal size has been tentatively determined (Figure 7). These figures were derived from the tabulations of the ages from a large series of fish. Age determinations have been

Figure 5

Scale sample area.

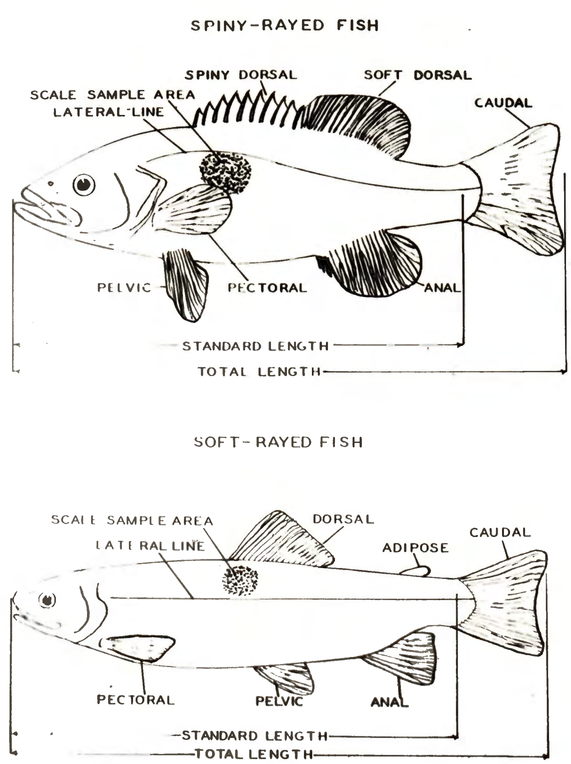


Figure 6

Micro-projection apparatus used in determining ages of fish from scales.

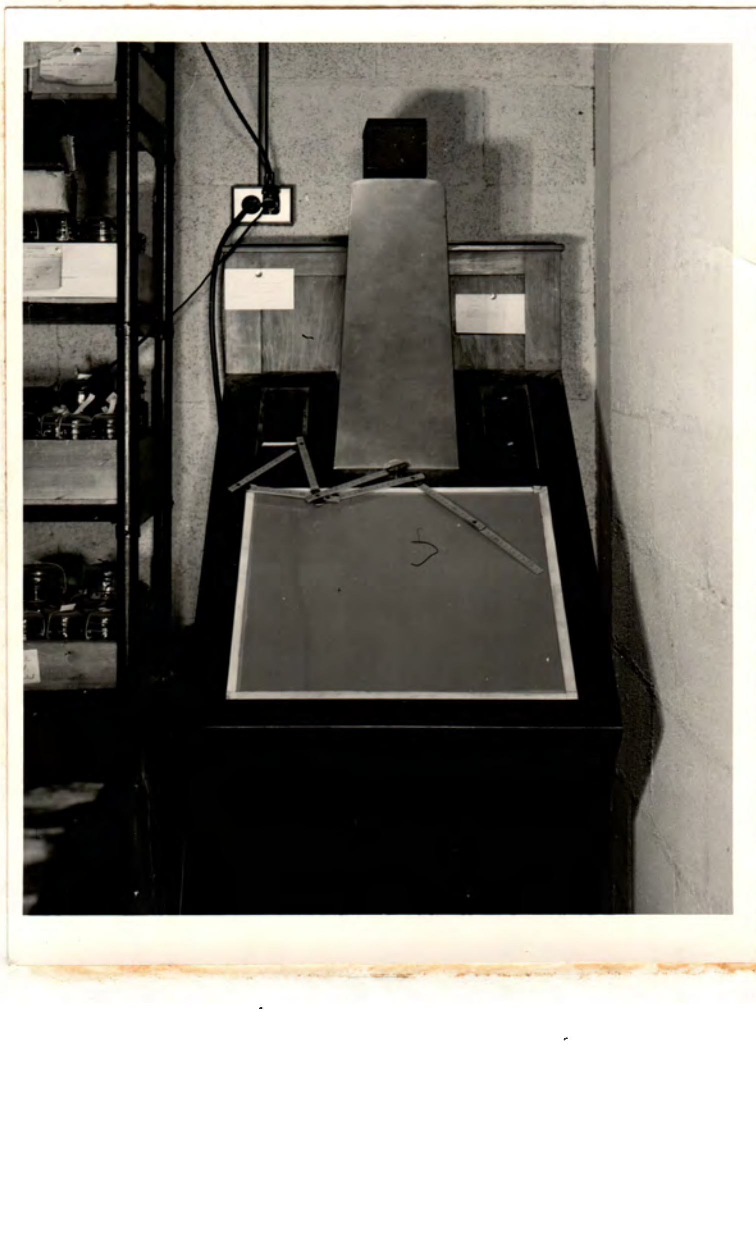


Figure 7

Age of fishes upon reaching legal size
(Tentative)

Age of fish upon reaching legal size

(tentative)

Species	Legal length	Age	
		Number of annuli	Summer of life
Bluegill	6 inches	III	4th
Pumpkinseed	6 inches	III	4th
Rock bass	6 inches	IV	5th
Black crappie	6 inches	II	3rd
Yellow perch	6 inches	II	3rd
Largemouth black bass	10 inches	II	3rd
Smallmouth black bass	10 inches	II	3rd
Northern pike	14 inches	I	2nd
Walleyed pike	14 inches	II	3rd

made on approximately 30,000 samples, and when the remaining 30,000 have been determined, the tables will be revised. General growth curves have also been determined by taking the average length for the various age groups and plotting the data on a graph (Figure 8).

In order to increase the value of the data by increasing the numbers upon which the averages are based, growth calculations can be made from scale measurements. The measurements for growth calculations are made on the magnified scale image.

It has been stated that the number of scales on a fish remain constant throughout the life of the fish, and that the scales grow in the same proportion as the fish grows. Thus there is a definite ratio between the body length and the scale length. This ratio is determined by measuring the size of key scales. These key scales are specially chosen scales. For our work, we use the three scales found by counting ten scales back along the lateral line, three rows down, and the three scales back from that point. The scales are thus taken from the same location on all fish and can be compared directly.

By means of mathematical procedure, the body-scale relationship is determined. The body-scale relationship for the rock bass from Booth Lake is illustrated (Figure 9). This relationship is determined in order to see whether the direct proportion method for size calculation can be used, or whether a correction factor must be added.

By measurement we know the length of the fish at the time of capture, the length of the scale is measured, and the length of the scale to each annulus is measured (Figure 10). If the scale is directly proportional to the body, we can determine the size of the fish at any year by the following formula:

Figure 8

General growth curve for bluegills.

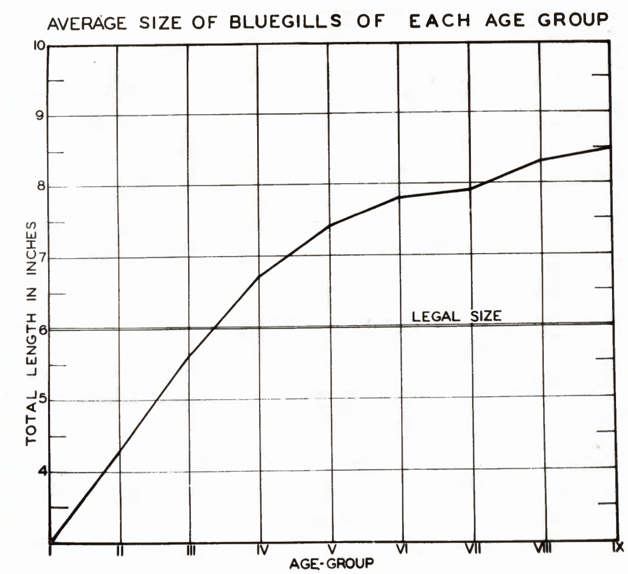


Figure 9

Body-scale relationship graph
for rock bass

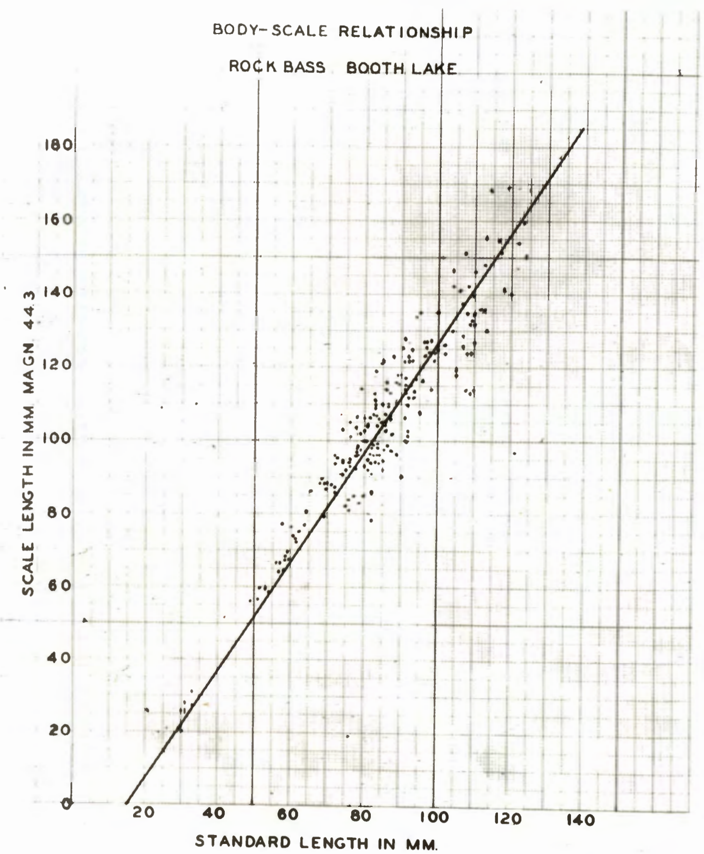
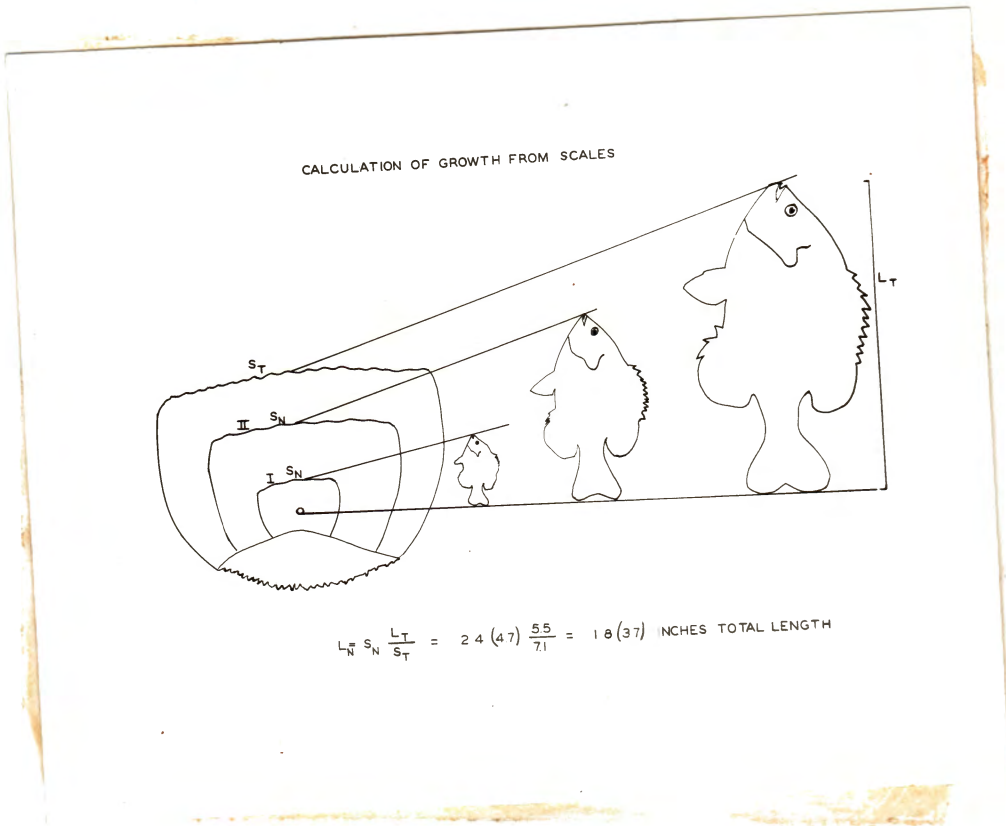


Figure 10

Calculation of growth from scales.



$$L_n = S_n \frac{L_T}{S_T},$$

where L_n = the length of the fish in inches (or millimeters) at the end of the n^{th} year of life,

S_n = the scale radius within the n^{th} annulus,

L_T = the length of the fish in inches (or millimeters) at the time of capture,

S_T = the total scale measurement.

For example,

L_n = 2.4 (4.7) $\frac{5.5}{7.1}$ = 1.8 (3.7) inches total length at end of first (second) year.

If the body-scale relationship is not a direct proportion, as was the example of the rock bass in Booth Lake, a correction factor is added. This was determined in Booth Lake to be a correction of 15. Then the following formula was used in growth calculations for Booth Lake.

$$L_n = 15 + S_n \frac{L_T - 15}{S_T}$$

The correction factor may vary for the various species, and must be determined for each if the calculated lengths are to be used.

The relationship between the length of the fish and its weight can also be determined. From the data an average is established for a large series of fish from all over the state. When a collection of fish is made from a lake, the average weight and length are determined for each age-group. These averages can then be compared with the data from the length-weight relationship curve or table, and an evaluation made as to whether or not the population in the particular lake is up to, above, or below the state average. The length-weight curve is illustrated by the data for the bluegill for the state (Figure 11).

Now the question arises as to the value of this information to the fish culturist, fishery biologist, and the fishermen.

Throughout the state there are many lakes in which the fish are numerous but small. Some of these lakes have had samples of the fish collected from them. On examination of the scales, it was often found that these fish were much older for their size than a normal growing fish of that species is expected to be. One such lake was Booth Lake, at the corner of Charlevoix and Otsego Counties. This lake was divided into two basins of nearly equal size by a shallow channel. In September, 1937, following a lake inventory, the south basin of this lake was treated with chemicals. The channel was blocked off with sand bags to prevent the fish in the north basin from entering the south basin while the killing power of the chemicals was still potent. After the potency had disappeared, the bags were removed, permitting free movement of the remaining fish from the north basin throughout the entire lake. The south basin has an area of 16 acres, and a maximum depth of 31 feet. A total of 20,192 fish were recovered from the basin. Perch and rock bass were the only game fish present. Of the 6,060 game fish recovered, there were just 42 legal-sized fish in the 16 acres. This is less than two limit catches. There were 37 perch, and 5 rock bass of legal size.

Collections have been made from this lake to see what effect the reduction in numbers had on the remaining fish. The scales have been studied and it has been found that all age-groups of the rock bass have shown an increase in growth rate since the poisoning (Figure 12).

Figure 11

Length-weight curve for bluegills

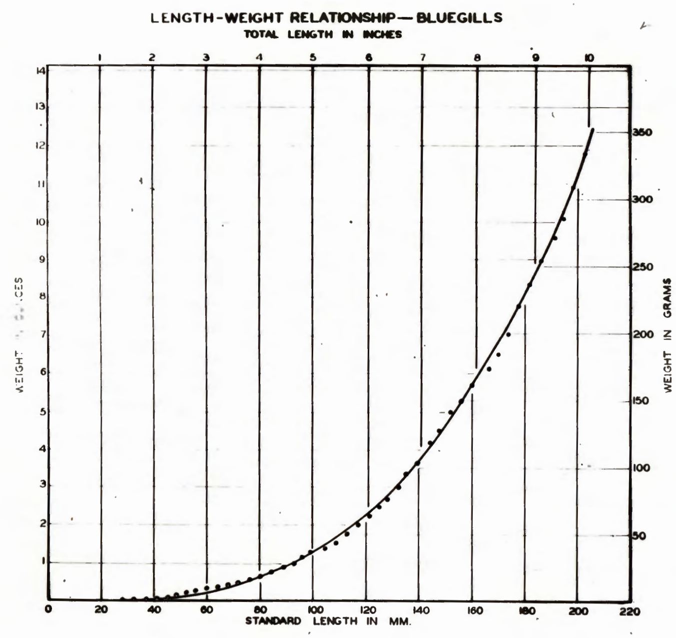


Figure 12

Size of rock bass in Standard (Booth) Lake at time of capture.

Table 3. Size of Rock Bass in Standard Lake at Time of Capture

Age Group	Average standard length in millimeters at time of capture (Number of specimens in parentheses)					
	Males			Females		
	[1] 1937	[2] 1939	[2] 1940	1937	1939	1940
[3] I	57 (10)	88 (16)	— —	57 (8)	84 (22)	— —
II	73 (12)	89 (20)	91 (11)	70 (10)	85 (11)	85 (6)
III	84 (13)	105 (16)	— —	80 (17)	89 (19)	— —
IV	88 (22)	108 (20)	140 (1)	83 (19)	102 (31)	— —
V	— —	114 (17)	— —	90 (2)	115 (23)	126 (1)
VI	— —	118 (5)	— —	— —	— —	135 (1)

[1] All of the fish of the 1937 collection were taken on September 6.

[2] In 1939 the specimens were taken in May, June, and October--about two-thirds in May and June; the 1940 specimens were taken in July.

[3] The 1939 data for age-group I are considered unreliable due to gear selectivity.

Weight and condition of the fish has also improved. The details of this study were published in a paper by the writer in the Transactions of the American Fisheries Society (1941).

The knowledge that the fish in the lake are not maintaining the expected normal growth can be used in making stocking recommendations. Generally the cause of the slow growth is an overabundance of fish in the lake. By way of illustration, a lake may be compared with a pasture. Let us assume that an acre of pasture will support one cow in excellent condition. Then we place 10 cows in the same area. These ten cows may continue to live, but will be in poor condition, or at least will produce very little milk or beef. Similarly a lake can produce enough food to maintain a certain number of fish in good condition and in normal rate of growth. If this number is doubled or even trebled, the fish can continue to live, but will be slow growing and usually in poor condition. Thus the number of larger fish, which the sportsman desires, cannot be increased by planting more small fish into these lakes. In fact, it might be the wiser plan to remove some, and give the others an opportunity to grow just as a gardener thins his plants in order to get a good crop.

Thumb Lake, now called Lake Louise, in Charlevoix County, gives an example of this by naturally occurring factors. There seems to be a cycle in this lake. About every six or seven years an extremely heavy mortality is reported to occur among the yellow perch. Following this loss, the perch increase greatly in size. Fishing seems to improve for a period of three or four years, then smaller and smaller perch are caught, and then the heavy loss occurs, and the cycle begins again. A study of the scales and growth rate of these perch each year could establish when the fish begin their slowing down in growth. Then by removing some of the fish by some means, the cycle of increased growth might be hastened and the heavy loss avoided.

On the other hand, a lake may be found where the fish show a much greater growth than normally expected. This might indicate that plantings would improve the fishing if spawning conditions, small brood stock or some other factor is limiting the number of fish in the lake. When a lake is found of this superior type, a close check could be made to determine just what makes it a good lake. By comparing the limnological and biological data gathered by the Lake Inventory Party with the data from other lakes known to be poor, the limiting factor or factors in poor lakes may be found. Then by treating these defects in the poorer lakes, better fishing may result.

Dr. Ralph Hile (1936) of the U. S. Fish and Wildlife Service, suggests that where hatchery brood stock are taken from natural waters, that age determination to see if the fish are of normal growth is advisable. "Rapid growth indicates favorable environmental conditions, and fish taken from good waters may be expected to be healthier and more virile than those taken from poor waters where growth is slow." However, it has been shown by Bennett, Thompson and Parr (1940) that stunted bluegills make excellent growth when transplanted into a lake having a good food supply. Thus from the much "cussed" fish scales a large amount of information can be obtained, and by applying this information, better fishing may result.

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