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AGE AND GROWTH OF THE BROWN TROUT (*SALMO TRUTTA FARIO* L.) IN THE NORTH BRANCH OF THE AU SABLE RIVER, CRAWFORD COUNTY, MICHIGAN[1]

By

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INTRODUCTION

A review of the literature on brown trout in American waters reveals a lack of information on age and growth relationships. The purpose of this paper is to provide practical data for age and growth comparisons with brown trout in other localities, and with other trout species. This study, however, is in the nature of a preliminary report due to the relatively small sample (175 fish) used in the calculations. As other collections of a similar nature are made it is intended that the results will be incorporated to lend further significance to the information here presented.

COLLECTION OF DATA

The brown trout used in this study were collected by Edwin L. Cooper and Burton P. Hunt during the period of May 13, 1947, to September 19, 1948. The actual collection dates were spaced at approximately one month intervals

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[1] The author was materially aided in this investigation by Edwin L. Cooper of the Institute staff.

throughout 1947, and two month intervals during 1948. All of the fish were wild trout taken in the North Branch of the Au Sable River, Crawford County, chiefly in the vicinity of Twin Bridges.

All but five of the fish taken (flyrod-caught fish) were collected with the conventional electrical fish shocker (Shetter, 1947). An attempt was made to secure fish of all size classes in representative numbers. The collectors were unable, however, to obtain equal numbers of either very large, or very small fish, in comparison with numbers of the intermediate size classes.

A sample of "key scales" (see body-scale relationship section) was taken from all fish over 100 mm. in total length, and data on length, weight, sex, and condition of the sex organs was recorded. All fish under 100 mm. in total length were weighed and preserved intact in a ten percent formalin solution. The stomach of each fish was numbered to correspond with the scale sample and preserved in formalin for use in food habits studies at a later date.

Scale Analysis Procedure

The permanent mount system of scale preparation was deemed most advisable for this study. The scales were first soaked in water and cleaned with a camels hair brush under the low power magnification of a binocular microscope. The scales were then transferred directly to a glycerin-gelatin mixture and mounted on a microscopic slide. (Numbers corresponding to the collection and individual scale sample were printed on the projecting glass portion of the slide with a wax pencil.)

The actual scale analysis, i.e., measurement and age assessment, was made with a micro-projection machine. A magnification of 90 diameters was found to be satisfactory for all sizes of brown trout scales.

Annuli determination was based mainly on the relative approximation of successive circuli. The incompleteness or discontinuity of adjacent groups of circuli and the tendency of circuli to "cut over" were of minor importance in this respect.

The scale measurement used for the body-scale relationship was the anterior scale radius (center of the focus to extreme margin of scale), providing that the point of greatest distance did not fall more than 30 degrees from the center of the anterior portion of the scale.

Measurement of annual growth of the scale was made along the same anterior radius mentioned above. The measurement for each successive year being the distance from the center of the focus to the corresponding annulus.

REGENERATION OF SCALES AND DIFFICULTIES IN THE SCALE ANALYSIS

The practice followed in the selection and mounting of scales was to use three that were intermediate in size and had a normal focus. All scales with an abnormally large focus were interpreted as regenerated, or replacement, scales.

While processing the first few scale samples it was noticed that the number of regenerated scales in the samples, especially from large fish, was very high, the result being that such samples had to be discarded and not used in age and growth calculations. This was especially damaging in the data of the larger size classes, as the collection contained but few such individuals, and many of them were omitted due to insufficient samples of good scales.

Several scale samples from each 50 mm. size class were counted, scale by scale, to determine the percent of regeneration. It was found (Table I)

Table I

Regeneration of scales by size classes

Size class, millimeters	Number of fish	Scales counted	Percent of regeneration	Range in percent
1 - 50	...	...	...	...
51 - 100	14	888	26.4	11.9 - 70.0
101 - 150	9	421	44.4	12.7 - 69.8
151 - 200	10	661	63.7	24.4 - 90.9
201 - 250	10	489	74.8	44.4 - 87.9
251 - 300	12	526	70.7	31.3 - 89.1
301 - 350	10	882	82.9	52.0 - 96.8
351 - 400	10	570	86.5	71.0 - 95.7
401 - 450	10	638	85.1	61.5 - 94.1
451 - 500	2	69	88.4	78.4 - 100.0
500 - up	4	256	94.1	82.8 - 97.6

that as the size of the fish increases the ratio of regenerated scales to good scales also increases.

To determine the frequency of occurrence of scale regeneration, the data was further grouped by age classes (Table II). The amount of regeneration is very high during the first two years of life, after which it tapers off gradually. It is interesting that over half of the scales were regenerated by the end of the second year of life.

From the sample analyses it appears that the regeneration of scales in the brown trout takes place at a fairly well defined rate (Fig. I) throughout the life of the fish in the North Branch of the Au Sable. Further work is needed to determine whether the same relationship exists in the brown trout of other waters, or in the other species of trout. Very little is known at the present time about the underlying physiological or ecological conditions relating to the high rate of scale regeneration. As the amount of scale regeneration is also correlated to size of fish, it is possible to provide a guide for the size of sample needed to produce a desired number of good scales, with reasonable assurance, from fish of different sizes. Based on the above fish from the North Branch, the following guide gives the number of scales needed in a sample to produce five good scales within a safety margin of ten percent.

Fish length (total length) inches	Number of scales needed in sample
1 - 4	10
4 - 8	20
8 - 12	35
12 - 20	55
20 - up	110

Table II

Regeneration of scales by age classes

Age class	Number of fish	Scales counted	Percent of regeneration	Range in percent
0	18	1,071	25.9	11.9 - 70.0
I	19	1,114	65.7	24.4 - 90.9
II	29	1,749	78.7	44.4 - 96.8
III	15	972	83.8	61.5 - 95.7
IV	5	238	87.4	66.7 - 95.6
V	2	110	89.1	82.8 - 91.4
VI	1	83	97.6	...

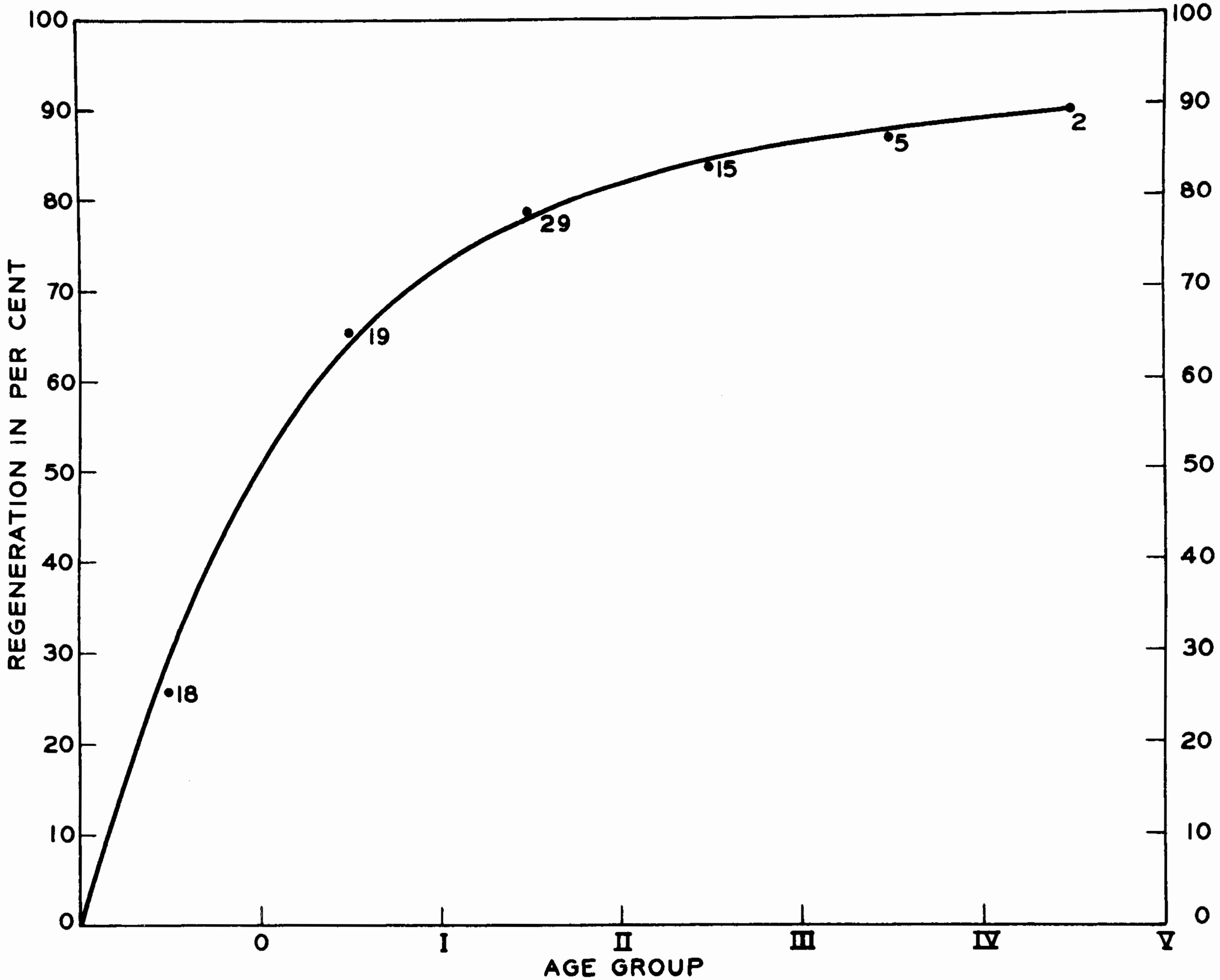

FIGURE 1. REGENERATION OF SCALES OF BROWN TROUT IN NORTH BRANCH OF THE AU SABLE RIVER. VALUES OPPOSITE BLACK DOTS ARE NUMBERS OF INDIVIDUAL FISH UPON WHICH AVERAGES ARE BASED.

A further difficulty encountered in the reading of the scales occurred in the interpretation of annuli. Some of the scales exhibited circuli near the scale margin with a relative approximation that resembled a true annulus. As all such fish were collected during the latter phase of the annual period of rapid growth, i.e., October and November, the wider spacing of the circuli was attributed to an increase in the growth rate due to a cooling of the water in the autumn period, and was not read as a true annulus (Fig. II).

BODY-SCALE RELATIONSHIP AND COMPUTATION OF GROWTH RATE

All scales used in this study were taken from a "key" region on the fish. For this study the collectors assumed the gross morphometry of scales on the brook and brown trout to be similar. The region of the largest and most uniform scales, or key region, as determined by Cooper (oral communication) for the brook trout, is the three or four rows of scales immediately below the lateral line, located between the most posterior portion of the dorsal fin and the most anterior portion of the anal fin.

Three scales were measured from each fish whenever possible. These measurements were then grouped by one inch size classes - relating to the total length of the fish, and the mean of each size class was determined. Plotting this original data on an absolute scale indicated that the body-scale relationship would best be described by the equation for the parabola:

$$ASR = CL^n$$ where: ASR is anterior scale radius, L is the total body length, C and n are constants.

An equation of this type was then fitted to the empirical data on body length and anterior scale radius. The resulting equation was:

$$ASR = 15.59\ L^{.88461}$$

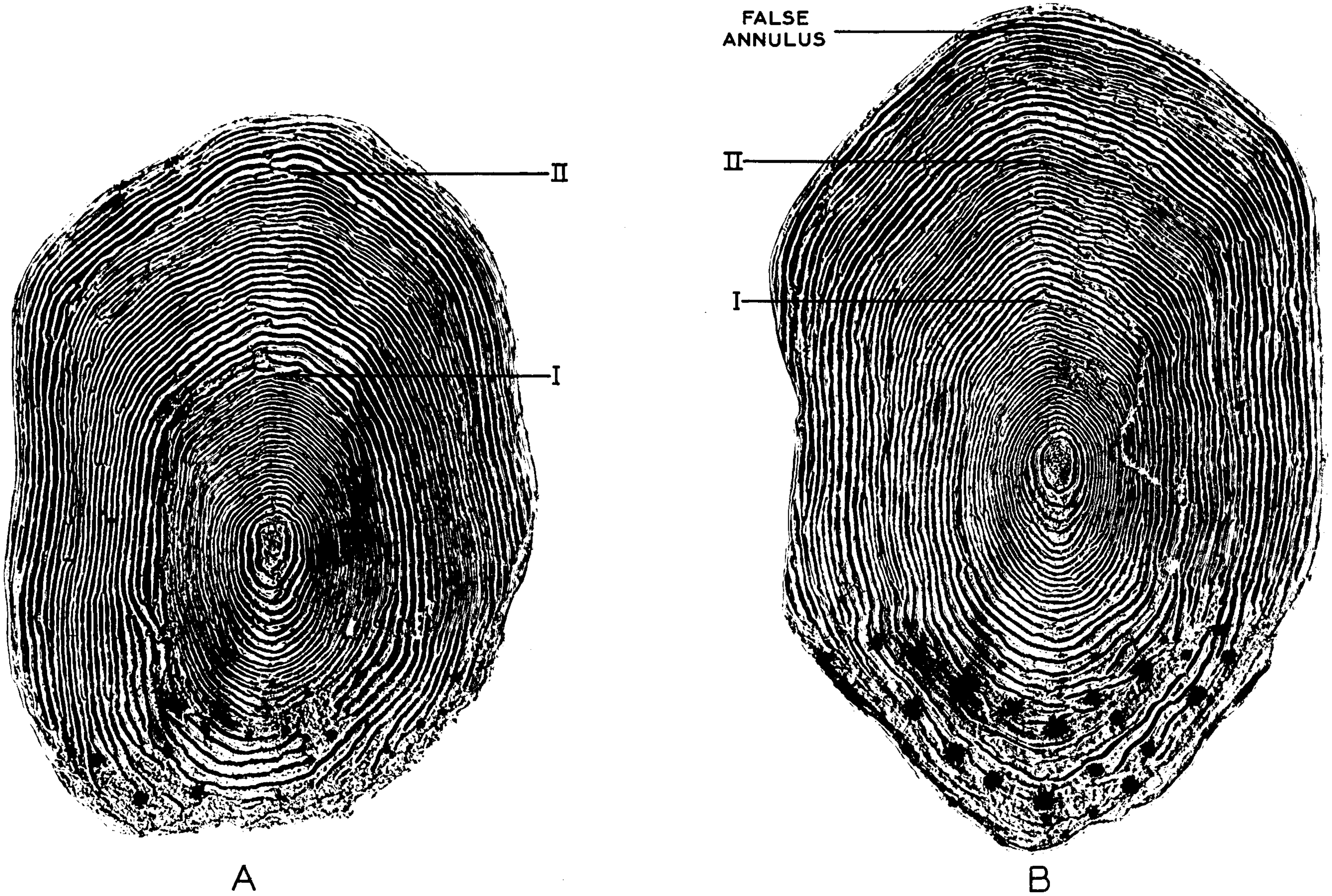

FIGURE II. SCALES FROM AGE-GROUP II BROWN TROUT FROM A NOVEMBER COLLECTION. SCALE A HAS TWO NORMAL ANNULI. SCALE B HAS TWO NORMAL ANNULI WITH A FALSE ANNULUS NEAR THE MARGIN DUE TO INCREASED LATE FALL GROWTH.

A comparison of the computed curve with the empirical data was then made (Fig. III) and found to satisfactorily represent the body-scale relationship. The procedure followed in this computation was derived from Hile (1941).

Individual growth histories were computed with the aid of a nomograph. The nomograph used in this study allows the computed lengths to be read directly without consultation to a table of solutions of the above parabolic equation (Carlander and Smith, 1944).

AGE AND RATE OF GROWTH

The total length in inches of the brown trout at the end of each year of life was calculated and the mean lengths of the age groups attained (Table III, and Figure IV). The rate of growth exhibited by this population in the North Branch of the Au Sable is very rapid and exceeds that of brook trout in the same stream (Cooper, 1949 MS). Growth is very fast for the first three years of life, declining somewhat during the fourth year. Fish five years old and older were too rare in the collections to use in calculating the growth rate.

The age composition of the brown trout in the collections was studied and the average total length of each age group computed (Table IV). This limited series indicates that relatively few fish live longer than four years, at which time they are about 17 inches in total length.

Further credence is given the calculated growth data because the empirical year class averages fall between the corresponding calculated lengths at the end of each year of life (compare Tables III and IV). Because of the extended period throughout the year when these samples were obtained, the empirical averages alone mean little in growth comparisons.

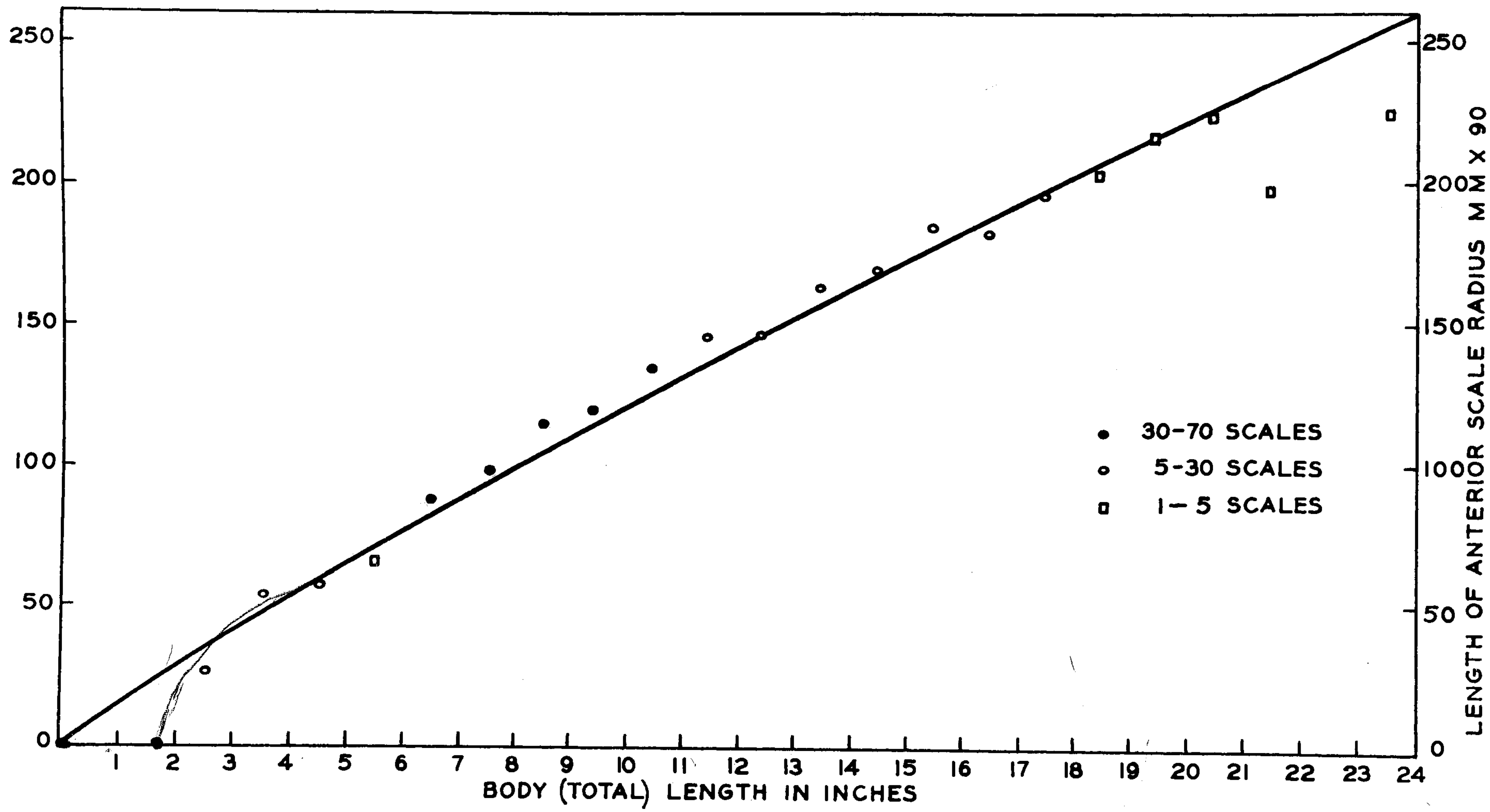

FIGURE 3. BODY-SCALE RELATIONSHIP OF BROWN TROUT IN THE NORTH BRANCH OF AU SABLE RIVER BASED ON MEASUREMENTS FROM 438 SCALES.

$ASR = CL^n = 15.59 L^{.88641}$

Table III

Calculated lengths and growth increments for brown trout in the North Branch of the Au Sable River

Age group	Number of fish	Average total length
0	16	3.2
I	57	7.7
II	57	11.6
III	20	15.8
IV	8	17.8

Table IV

Age composition and average total lengths of brown trout in the North Branch of the Au Sable River

Age in years	Calculated total lengths	Calculated annual increment
1	3.9	3.9
2	9.3	5.4
3	13.9	4.6
4	16.5	2.6

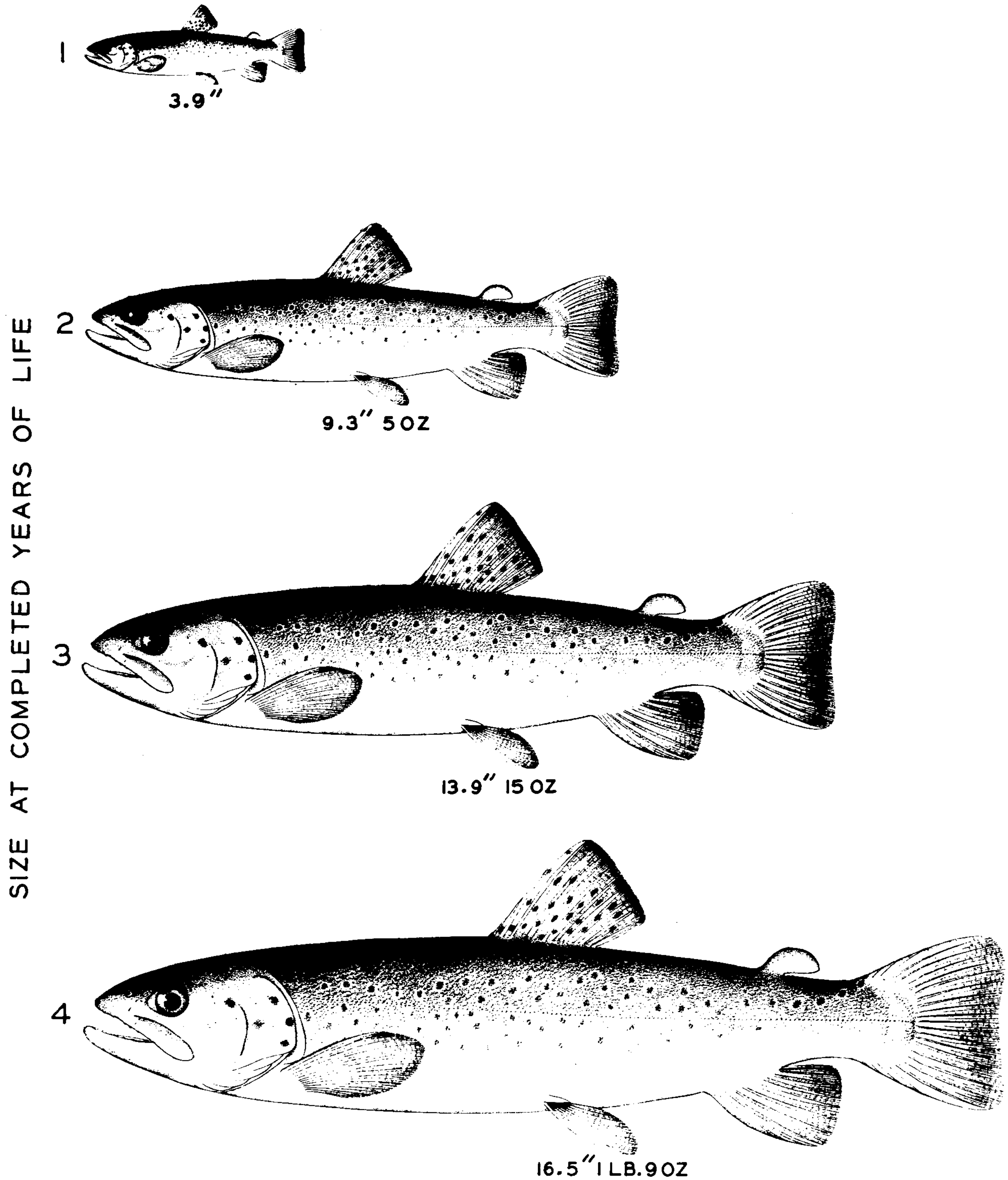

FIGURE 4. CALCULATED LENGTHS AND WEIGHTS OF BROWN TROUT IN THE NORTH BRANCH OF THE AU SABLE RIVER AT COMPLETED YEARS OF LIFE. LEGAL SIZE SEVEN INCHES.

The calculated lengths are superior as they represent the size of the fish at definite times. The empirical averages cannot take into consideration the amount of the yearly growth increment that has occurred prior to the time of capture.

The only other American studies on growth in brown trout available to the author, however, are based on empirical averages, so a comparison was made and is presented in Table V. The first study concerns wild brown trout in Crystal Creek, New York (Schuck, 1943). The data presented represent the average size, by age groups, for September collections. The second study concerns average lengths attained, by age groups, of wild brown trout from various Michigan waters (dates of collections not known). (Shetter, 1942.)

It is significant that growth in the North Branch brown trout is consistently greater after the first year of life, than of the other collections. Admittedly, however, the samples are limited for significant comparisons of growth between these localities.

A separate tabulation of the data by males and females from the North Branch of the Au Sable was made using both empirical and calculated data. There was no significant difference by sex in the growth rate, or size attained, during the first four years of life.

It is apparent from these data that some individuals of the population in the North Branch of the Au Sable reach the legal size of seven inches in the second summer of life, and that by the third summer the average length is well over the legal limit.

Shetter (1942) states "It may be of interest to fishermen to know that the ages presented in the table represent, for the brook and brown

Table V

A comparison of age and size attained of brown trout from the North Branch of the Au Sable, with collections from various Michigan waters, (Shetter, 1942), and Crystal Creek, New York (Schuck, 1943)

North Branch, Au Sable				Various waters, Michigan		Crystal Creek, New York	
Empirical average		Calculated lengths		Empirical average		Empirical average	
Age group	Total length	End of year	Total length	Age group	Total length	Age group	Total length
0	3.2	1	3.9	0	3.7	0	3.09
I	7.7	2	9.3	I	6.8	I	5.69
II	11.6	3	13.9	II	8.1	II	7.56
III	15.8	4	16.5	III	10.6	III	10.15
IV	17.8	...	...	IV	...	IV	11.65

trout, the maximum known ages for these species in Michigan waters." The brown trout referred to was in the eighth year of life and had attained a length of 19.9 inches. One of the female brown trout from the North Branch collection was in the eleventh year of life, and had attained a length of 23.75 inches and a weight of 4 pounds 9 1/2 ounces. It would be of considerable interest to have age and growth data on some of the brown trout caught annually that are much larger than either of the above mentioned fish.

LENGTH-WEIGHT RELATIONSHIP

The method used in computing the length-weight relationship was the same as that used by Hile (1936) and Beckman (1948). The weights were tabulated by one inch size classes, and the means determined. An equation of the general parabola: $W=CL^n$, was then fitted to the empirical data. Logarithms were used in the computation of this relationship. The resulting equation was:

$$W = .1862\ L^{2.94665}$$

The computed curve of the length-weight relationship is presented graphically in Figure V, and compared with the empirical data. The curve fits the data satisfactorily. The discrepancies in the larger size classes are attributed to the small numbers of fish involved in the empirical means plotted. Brown trout used in this computation represent all size classes, were collected at all times of the year, and in all stages of sexual maturity and condition. A previous collection of brown trout from the same locality on the North Branch was also incorporated in the data.

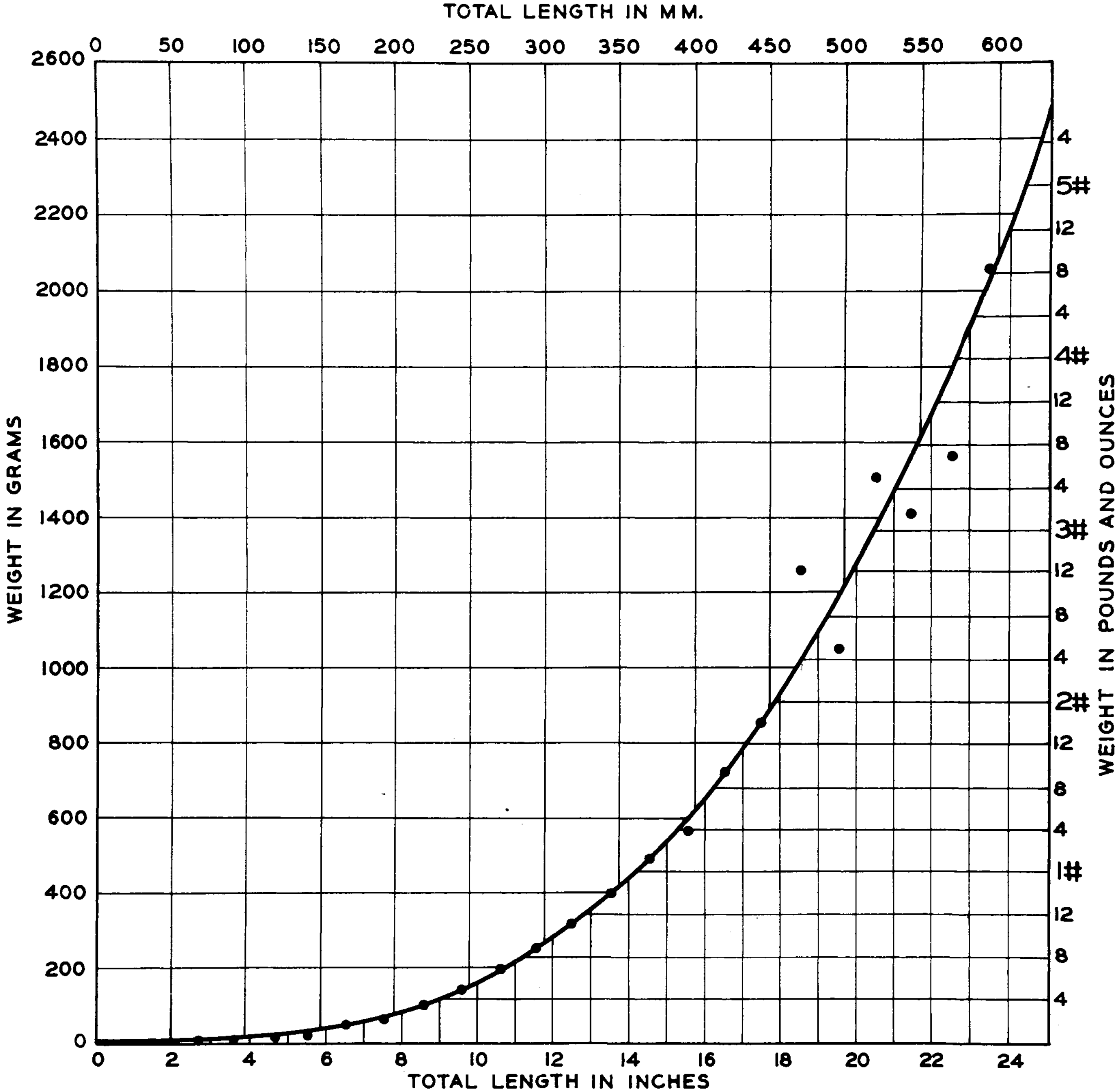

FIGURE 5. LENGTH–WEIGHT RELATIONSHIP OF BROWN TROUT IN THE NORTH BRANCH OF THE AU SABLE RIVER. BLACK DOTS REPRESENT EMPERICAL DATA. LINE OF BEST FIT CALCULATED FROM EQUATION $W = CL^{n} = .1862L^{2.94665}$

AGE AT SEXUAL MATURITY

Information was taken on all fish in the field relating to sexual maturity. All fish in age group 0 were found to be immature, and all fish in age group IV and higher were found to be mature.

Of the males, two individuals were mature at age group I, over half were mature at age group II, and two individuals remained immature at age group III.

All of the females examined were found to be immature until age group II when over two thirds of them were mature. None of the females in age group III were immature.

Examination of age group 0 (over two inches in length) fish in the laboratory proved that it was possible to "sex" them, as the appearance of the gonads were markedly different. In the males the testes were paired, ribbon-like, and smooth textured. The ovaries of the females were enlarged anteriorly, and eggs were visible at low magnification.

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