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D. S. Shetter
Region II-Fish
E. L. Cooper

March 4, 1952

Report No. 1319

GROWTH OF BROOK TROUT (SALVELINUS FONTINALIS) AND BROWN TROUT (SALMO TRUTTA) IN THE PIGEON RIVER, OTSEGO COUNTY, MICHIGAN

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by

Edwin L. Cooper

Abstract

The examination of scales of brook and brown trout of known ages validated the method of determining age by means of annular markings on the scales. Annulus formation takes place during late April or early May depending upon the seasonal differences in water temperature.

A determination of the body-scale relationship of both species was made following the method outlined by Monastyrsky.

For the brook trout: log ASR = 0.99217 + 0.8723 log L.

For the brown trout: log ASR = 1.25377 + 0.8968 log L.

Each of these solutions gave an adequate fit of the original data. The use of the direct-proportion method, or the direct-proportion method plus a correction for the body length at the time of scale formation, would result in errors as much as 78 per cent in growth calculations of the brook and brown trout populations described.

A comparison of the brook trout population of the Pigeon River with those of Moosehead Lake, Maine, and the Nelson River, Manitoba, indicates that the Pigeon River population is short-lived. Very few brook trout in the Pigeon River live to be four years old. This rapid disappearance of older brook trout is associated with a high rate of

exploitation. Brown trout in the Pigeon River are also short-lived although a few reach an age of five years.

Angling for brook trout selects the faster growing individuals from each age-group. The high rate of exploitation together with angling selectivity invalidates the method of comparing growth rate by sampling methods once the fish attain a size vulnerable to angling.

Brown trout do not show this angling selectivity, and growth comparisons are less biased from this factor.

Compensation in growth, after the first year, takes place in both species. However, it is not sufficient to overcome the initial difference in growth, and the large yearlings maintain their superiority in size. Under a low minimum size limit, such as 7 inches, the fish with the best chances of becoming large, prize-winning individuals are sacrificed first at a small size. Also, a low minimum size limit favors the survival of the slowly growing runts of each age-group as spawning stock. Our wild trout are thus being continually selected for slow growth under present laws which permit excessive removal of the stock and at too small a size.

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by

Edwin L. Cooper

Introduction

The Pigeon River Trout Research Area was established in April, 1949, by the Michigan Department of Conservation. This includes 4.8 miles of trout stream and seven small lakes. The stream has been divided into four experimental sections and fishing is allowed only on a daily permit basis. This method of creel census assures an examination and record by trained fisheries workers of the total catch. Most of the scale samples upon which this study is based were taken from the portion of the stream in the research area. The fish were collected by two different methods; hook and line and by electrofishing. In all, samples were obtained from 4,439 brook trout and 1,429 brown trout older than one year during the period from April 20, 1949, to November 30, 1951.

Validity of Age Determination by Scales

Evidence in favor of the method of determining age of brook trout by means of scales was presented in an earlier publication

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* Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation.

(Cooper, 1951). Further confirmation of this method is given here because of the availability of known-age material and also because the trout in this stream usually form quite distinct annuli, making the interpretation of age a relatively simple task (Figure 1). In all instances involving fish of known age there has been agreement between the age as determined by scales and the known calendar age of the fish.

For the brown trout, the validity of age-assessment using scales seems to be well established (Dahl, 1918; and others). In the Pigeon River, formation of annuli on scales of this species is also quite distinct, and studies of the available known-age material through the formation of the first two annuli have validated the method (Figure 2). In this stream, the resumption of fish activity, growth, and the accompanying annulus formation of the scales takes place during late April or early May depending upon the seasonal differences in water temperature.

Body-Scale Relationship and the Calculation of Growth

Calculation of previous growth of fishes by means of scale measurements has been summarized by Ralph Hile (In Lagler, 1949). Of the various methods used by the early workers in this field, that of Monastyrsky (1930) seemed to be most practicable to both the brook and brown trout populations in the Pigeon River. This assumption holds that the logarithms of scale length and fish length exhibit a straight line relationship, that $ASR = CL^n$, or $\log ASR = \log C + n \log L$,

where ASR = anterior scale radius,
L = total fish length, and
C and n are constants to be determined empirically.

This assumption fails to give a satisfactory fit to the data from very small fish since it assumes that scale growth and body growth begin at

Figure 1. Scales of brook trout from Pigeon River, Otsego County, Michigan. July-O: 3.0 inches, July 9, 1949; December-O: 4.6 inches, December 28, 1949; March-I*: 3.8 inches, March 13, 1950; April-I*: 4.5 inches, April 14, 1950; May-I: 3.9 inches, May 19, 1950; June-I: 5.0 inches, June 19, 1950; August-I: 5.6 inches, August 17, 1949; October-I: 6.0 inches, October 24, 1949; March-II*: 6.1 inches, March 13, 1950; May-II 6.8 inches, May 19, 1950; June-II: 7.0 inches, June 19, 1950; May-III: 10.2 inches, May 30, 1949; July-III: 10.0 inches, July 3, 1949.

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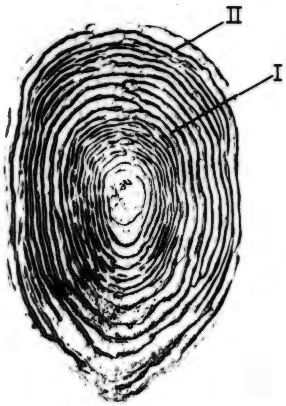

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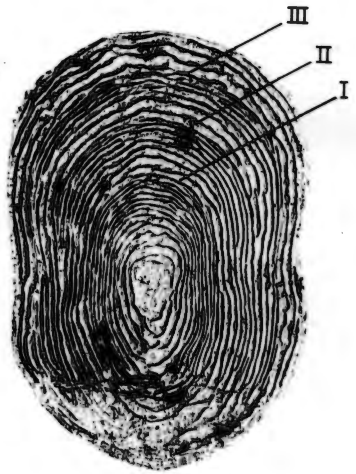

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Figure 2. Scales of brown trout from Pigeon River, Otsego County, Michigan. August-0: 2.9 inches, August 10, 1949; May-I*: 3.3 inches, May 5, 1950; August-I: 5.9 inches, August 9, 1950; September-I: 7.7 inches, September 24, 1950; March-II*: 6.1 inches, March 27, 1951; May-II: 9.5 inches, May 21, 1951; June-II: 8.4 inches, June 20, 1951; August-IV: 19.5 inches, August 12, 1949; November-V: 21.4 inches, November 14, 1950.

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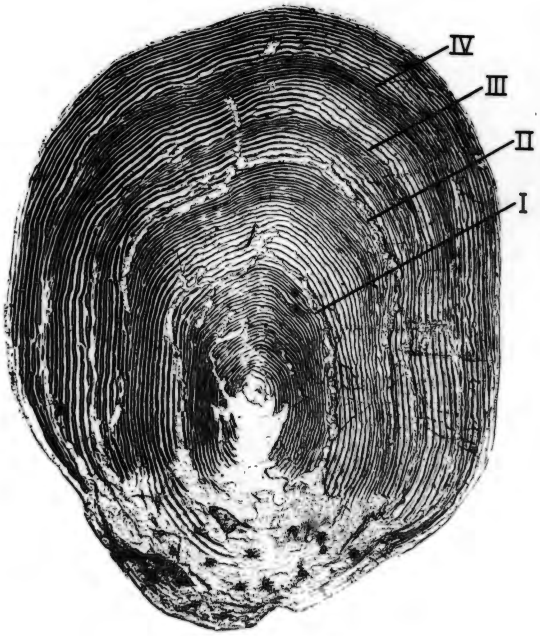

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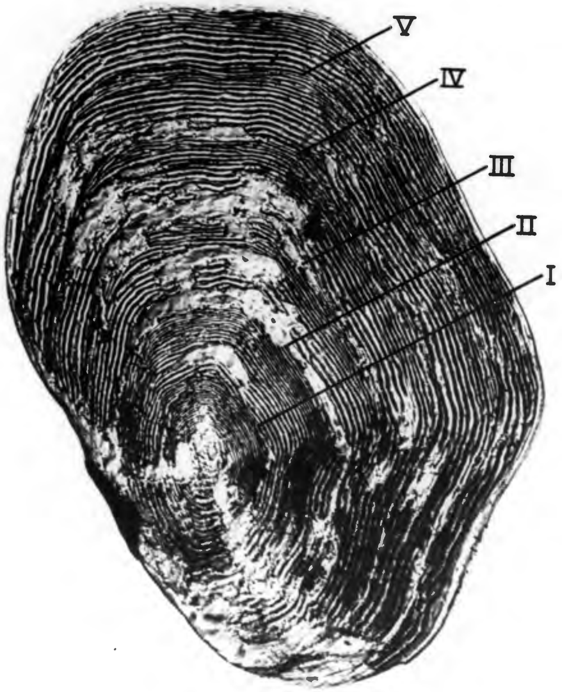

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the same time. Actually scales do not begin to form until the fish are about 40 mm. in total length. Scale growth then proceeds very rapidly but at a diminishing rate. However, from the time the fish are one year old, Monastyrsky's method gives a very satisfactory fit to the data and renders growth calculations at completed years of growth quite accurate.

A determination of the body-scale relationship for the brook trout in the Pigeon River was made on 532 individuals ranging in total length from 2.5 inches to 8.0 inches, as follows:

$$\log ASR = 0.99217 + 0.8723 \log L.$$

For the brown trout 1,291 individuals ranging in total length from 2.5 inches to 23.7 inches, revealed a body-scale relationship as follows:

$$\log ASR = 1.25377 + 0.8968 \log L.$$

Nomographs patterned after the one described by Hile (1950) were constructed and used for all calculations presented here.

The body-scale relationship of the brook trout in the Pigeon River was published earlier (Cooper, in press) along with data from four other populations of brook trout in Michigan. The body-scale relationships of all of these populations could be best described by the use of the Monastyrsky method given above although minor variations did occur between different populations. The use of the direct-proportion method or the direct-proportion method plus a correction for the body length at the time of scale formation would result in errors as much as 78 per cent in growth calculations of the brook and brown trout populations described here.

Age Composition

Sampling, either by hook and line or by electric shocking, indicates very few old fish in the population of both brook trout and brown trout

(Table I). Few individuals live to be four years old, and over 95 per cent of the catch by anglers is composed of fish less than three years old. The actual age composition of the Pigeon River population undoubtedly is represented by many more individuals of the age-group I than suggested by the collections, since electric shockers are selective in capturing a greater proportion of the larger fish. Collections taken by hook and line are also selective because of the 7-inch minimum size limit. No information on the abundance of age-group 0 is given because only the largest individuals of this class were sampled.

A comparison of these brook trout data with collections made in Maine (Cooper and Fuller, 1945) and Manitoba (Doan, 1948), where brook trout in their 5th, 6th, 7th and 8th summers were represented in rather small collections, indicates that the Pigeon River population is short-lived. This rapid disappearance of older brook trout in the population is associated with a high rate of exploitation. For the brook trout, three fish were caught by anglers each year for every one left of legal size at the end of the season (Cooper, in press). Whether fishing alone is responsible for the difference in age composition between the Michigan population and those of Maine and Manitoba is unknown because of the absence of any age composition data from unfished or lightly fished populations in Michigan.

Brown trout populations are not so easily exploited as are brook trout (Cooper, op. cit.) and also show greater numbers of old and large fish in the population. There is also some evidence that the brown trout normally has a longer normal life span than brook trout. Dahl (op. cit.) gives the age of brown trout in Norway as reaching twelve to fifteen years; less complete information on the maximum age of brook trout indicates a life span of about ten years.

Table I

Age Composition of Brook Trout and Brown Trout in the Pigeon River

Species and collection method	Age-group					Total fish sampled
	I	II	III	IV	V	
Brook trout						
Hook and line	509	1,241	79	...	...	1,829
Electric shocker	2,006	562	41	1	...	2,610
Brown trout						
Hook and line	222	376	31	4	...	633
Electric shocker	547	210	33	4	2	796

Selectivity of Gear on Calculations of the Rate of Growth

In any discussion of the rate of growth of fish, the question of selectivity of the gear used in collecting must be considered. Is the sample taken representative of the population as a whole? An example of selectivity was demonstrated for hook-and-line fishing in Gangle Lake, Montmorency County, Michigan. In this lake, brook trout collections were made by hook and line for a period of about two years. All fish caught, regardless of size, were scale sampled. At the end of this period, the residual population was treated with rotenone and all of the fish then available were sampled. An examination of the growth rate data of the fish collected by these two methods indicated that hook-and-line fishing was apparently selective in capturing the faster growing members of each age-group regardless of size (Table II).

This selective effect of angling was also noted for grayling (Gustafson, 1949). Studies of this species in Lake Storsjö, Sweden, suggested a selection by angling to the third year of life with young grayling with a rapid growth rate being captured first.

Because of these indications that hook-and-line fishing might be selective, data from the two collecting methods, i.e., hook and line and shocking, were analyzed separately for the Pigeon River. They show that hook-and-line fishing for brook trout selects the faster growing individuals of each age-group. However, angling is not selective to the same degree for brown trout in the Pigeon River. The calculated lengths of brown trout caught with the electric shocker exceed slightly those of fish taken by hook and line, but the differences probably are not significant (Table III).

Table II

Comparison of Calculated Total Lengths in Inches of Brook Trout from Gangle Lake Taken by Different Methods

Sampling method and date	Calculated lengths at end of year of life:					
	1		2		3	
	Length	Number of fish	Length	Number of fish	Length	Number of fish
Hook and line						
1947	2.5	152	4.4	130	5.8	47
1948	2.5	226	4.5	206	5.8	83
Poison						
1948	2.3	416	3.8	209	5.0	50

Table III

Comparison of Calculated Total Lengths in Inches of Brook Trout and Brown Trout from the Pigeon River

Species and sampling method	Age-group	Number of fish	Calculated lengths at end of year of life:				
			1	2	3	4	5
Brook trout							
Hook and line	I	509	4.31	...	...	...	...
	II	1,241	3.30	6.26	...	...	...
	III	79	3.12	5.81	8.12	...	...
Electric shocker	I	2,006	3.58	...	...	...	...
	II	562	3.09	5.76	...	...	...
	III	41	2.90	5.33	7.69	...	...
	IV	1	2.80	5.90	7.50	8.90	...
Brown trout							
Hook and line	I	222	4.11	...	...	...	...
	II	376	3.47	7.82	...	...	...
	III	31	3.68	8.15	10.66	...	...
	IV	4	4.40	8.58	11.63	13.55	...
Electric shocker	I	547	3.77	...	...	...	...
	II	210	3.63	7.90	...	...	...
	III	33	3.78	8.31	11.00	...	...
	IV	4	4.08	8.28	10.55	13.63	...
	V	2	3.80	8.75	13.30	16.45	19.10

Lee's Phenomenon

The phenomenon of the "apparent change in growth rate" was first described from studies of the scales of herring, haddock and brown trout (Lee, 1912). It was noted that calculated lengths of the first few years of growth tend to decrease with the age of the fish sampled, i.e., that the growth rate is apparently increasing each year. The most logical explanation for this phenomenon advanced by the author was the selective mortality of fast growing individuals of each year class. With the known high rate of exploitation for the brook trout in the Pigeon River and also the selective effect of angling on faster growing individuals, the growth data might be expected to show Lee's phenomenon to a marked degree. For the brook trout, this is not only true for samples drawn from successively older age-groups (Table III), but also applies to samples from the same year class taken at successive monthly periods (Table IV).

Brown trout in the Pigeon River do not show this phenomenon to as great an extent as do brook trout. This is probably associated with the lesser degree of exploitation of this species.

Growth Compensation

In studies of the growth of fish involving calculated lengths based on scale measurements, many workers studying various species have found that slowly growing members of an age-group grow faster in later years than do the fast growing members of that same group. This phenomenon referred to as the "law of growth compensation" was first described by Gilbert (1914) working on the sockeye salmon (*Oncorhynchus nerka*).

Table IV

Lee's Phenomenon in Brook and Brown Trout Caught by Hook and Line from Pigeon River, 1949 to 1951. 1948 Year Class Compared as to Calculated Total Lengths in Inches at End of 1st and 2nd Years

Species and date of collection	Length at: Annulus 1	Length at: Annulus 2	Number of fish sampled
Brook trout			
July, 1949	4.36	...	45
August - September, 1949	4.27	...	51
April - May, 1950	3.71	6.81	268
June, 1950	3.14	5.89	224
July, 1950	3.08	5.76	121
August - September, 1950	3.08	5.68	99
Brown trout			
July, 1949	4.20	...	22
August - September, 1949	4.09	...	43
April - May, 1950	3.58	7.76	67
June, 1950	3.30	7.33	65
July, 1950	3.48	7.43	36
August - September, 1950	3.45	7.47	22

Other workers have not found this compensation in growth to hold in other species to the same extent.

Growth compensation does occur in both the brook trout and brown trout in the Pigeon River based on calculated lengths of two-year-old and three-year-old fish. Although growth increments of different sized fish are similar, the relative growth of the small yearlings is greater than that of the larger fish of that group (Tables V and VI). However, this growth compensation is not sufficient to overcome the original difference in growth exhibited during the first year, and the large yearlings maintain their superiority in size throughout the first three years. The lack of old fish in the population does not permit analysis of this phenomenon past the first three years.

Discussion

One of the principal advantages for the method of using calculated lengths from scale measurements to compare growth rates is the assumption that average growth rates thus obtained are directly comparable regardless of the time of collection because the calculated lengths of individual fish represent increments at completed seasons of growth. To compare average growth rates the age-groups sampled at different times should not have undergone any marked differential mortality between collection dates. Also, it is necessary that the collecting method ensures a random sample of the population.

It has already been shown for brook trout that angling selects the fast growing individuals of each age-group as soon as those individuals are available in the legal catch, and that samples drawn from the same age-group show a decreasing trend in growth rate. Thus, the main advantage of using scale measurements is nullified by a selective

Table V

Growth Compensation of Brook Trout and Brown Trout from the Pigeon River. All fish are from Age-group II

Size group at end of first year	Number of individuals	Mean length at end of first year	Growth increment between first and second years
Brook trout			
1.6 - 2.0	42	1.90	2.90
2.1 - 2.5	202	2.35	2.88
2.6 - 3.0	437	2.81	2.87
3.1 - 3.5	458	3.29	2.84
3.6 - 4.0	314	3.78	2.90
4.1 - 4.5	142	4.27	2.92
4.6 - 5.0	50	4.73	2.67
5.1 - 5.5	8	5.30	2.44
Brown trout			
1.6 - 2.0	14	1.89	4.29
2.1 - 2.5	33	2.35	4.44
2.6 - 3.0	99	2.84	4.32
3.1 - 3.5	155	3.32	4.45
3.6 - 4.0	143	3.80	4.23
4.1 - 4.5	89	4.29	4.13
4.6 - 5.0	33	4.77	4.15
5.1 - 5.5	13	5.24	3.80

Table VI

Growth Compensation of Brook Trout and Brown Trout from the Pigeon River. All Fish are from Age-group III

Size group at end of first year	Number of individuals	Mean length at end of first year	Growth increment between first and second years	Growth increment between second and third years
Brook trout				
1.5 - 2.9	42	2.52	2.63	2.49
3.0 - 3.9	50	3.40	2.71	1.96
4.0 - 5.0	10	4.30	2.22	2.49
Brown trout				
1.5 - 2.9	12	2.53	4.42	2.89
3.0 - 3.9	27	3.54	4.52	2.37
4.0 - 5.0	23	4.50	4.48	2.47

angling of high intensity. It follows that growth rates from different localities might not only reflect growing conditions *per se* but also differences in the degree of exploitation of the stocks. Actual lengths of each age-group offer no advantage in obtaining an unbiased index of growth rate, since selective angling would operate in the same manner in removing the larger individuals of each age-group. For populations subjected to fishing there appears to be no way of obtaining an unbiased estimate of the growth rate of brook trout once the fish reach a size vulnerable to angling. In many of the populations exhibiting a fast rate of growth, calculations of growth to even the first annulus are greatly biased because of the 7-inch minimum size limit in effect in Michigan. Mortality of sublegal trout due to angling may also be a factor if a sizeable number of fish are killed in this manner. Up to the present time in Michigan, it has been impossible to obtain growth rate information on wild brook trout populations from which angling has been excluded.

Brown trout growth rate studies are apt to be less biased from this factor due to a smaller rate of exploitation and the apparent absence of this selective angling phenomenon. Information from the Pigeon River does not show any consistent differences in growth of brown trout from samples taken by angling or by the electric shocker. An exception occurs in the few fish of the age-group I taken early in the season when the fast growing members of that group are first reaching the minimum size limit. However, the rate of exploitation is not high enough to deplete these fast growing members in the population, and later samples from this group show no serious decline in growth rate.

The marked difference in the rate of exploitation between brook trout and brown trout plus the selective effect of angling on the brook trout prevents a valid comparison of the growth rate of the two species. If we compare the calculated lengths at annulus 1 of the first individuals of an age-group caught by fishermen (Table IV), the two species seem to be growing at similar rates. However, if two-year-old fish are used as a basis of comparison, it appears that the brown trout are growing much the faster. The greater portion of this difference is probably more correctly explained by the selective harvesting of the fast growing brook trout rather than by a difference in growth rate between the species.

The lack of sufficient growth compensation, demonstrated for both the brook and brown trout in the Pigeon River, to overcome the initial difference in growth rate has important management implications. Under a low minimum size limit, the fish with the best chances of becoming large prize-winning individuals are sacrificed first at a small size. Also, a low minimum size limit favors the survival of the slowly growing runts of each age-group as spawning stock. If the effect of selective breeding applies to wild fish as it does in hatchery fish (Embody and Hayford, 1925; Hayford and Embody, 1930), the wild stock is being continually selected for slow growth under present laws which permit excessive removal of the stock and at too small a size.

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