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THE USE OF BRANCHIOSTEGAL RAYS TO DETERMINE AGE OF LAKE TROUT

SALVELINUS NAMAYCUSH WALBAUM

by

Ross Vivian Bulkley

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Fisheries Management

Utah State Agricultural College
Logan, Utah

1957

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Ross V. Bulkley

TABLE OF CONTENTS

	Page
Introduction	1
Description of study area	3
Collection and analysis of data	4
Definition of annuli	7
Calculation of past growth	9
Evaluation of method	12
Ray and body length	13
Annuli number and body size	13
New growth on rays	13
Similarity of rays on same fish	17
Measured and calculated body length	17
Branchiostegal rays versus scales	19
Age of maturity	22
Direct evidence	26
Conclusions	29
Summary	30
Literature cited	31

LIST OF TABLES

Table	Page
1. Mean calculated standard lengths and increments of length for Fish Lake lake trout collected during the summer of 1956, with no differentiation by sex	10
2. Increase in width of new growth on branchiostegal rays of Fish Lake lake trout with the progress of the season . . .	16
3. Comparison of measured lengths of 305 Fish Lake lake trout with calculated lengths determined by use of branchiostegal rays	20
4. Agreement in age assessment of 305 Fish Lake trout by scale and branchiostegal ray reading	24
5. Amount of disagreement in age between branchiostegal ray method and scale method of 8 Fish Lake lake trout 11 years of age and older	25

LIST OF FIGURES

Figure	Page
1. Method used to measure distance from focus (f) of ray to each annulus	6
2. Body-branchiostegal ray relationship of Fish Lake lake trout as determined from 305 fish, collected in 1956 . . .	11
3. Range in length and weight of Fish Lake lake trout for each age class as determined from 305 fish	14
4. Outer branchiostegal rays from the left and right side of a Fish Lake lake trout aged at 3 years	18
5. Branchiostegal rays and scale from a Fish Lake lake trout whose age was estimated at 6 years	23
6. Branchiostegal ray from Lake Michigan lake trout whose known age is 4 years	28

INTRODUCTION

Any method used in aging fish must fulfill certain requirements to be satisfactory. If the method is inaccurate, naturally little reliance can be placed upon its use. If considerable study of the method and much practice are required before accurate readings can be obtained, the method will not come into widespread use. The requirements of an aging method, then are that it must be accurate and comparatively easy. The scale method for aging lake trout (Salvelinus namaycush Walbaum) unfortunately does not fulfill these requirements. It has always been difficult to tell the age of lake trout by the examination of scales--the standard method of aging most fish. Although a few researchers have successfully aged lake trout by the scale method, much training is necessary to be proficient. Older fish are particularly difficult to age by the scales.

This lack of an easy and dependable aging method is hampering growth studies of lake trout in Utah lakes. Hence, in 1956, the Department of Wildlife Management at the Utah State Agricultural College and the Utah Department of Fish and Game began a study at Fish Lake, Utah, to determine the value of branchiostegal rays as growth indicators of lake trout. The branchiostegal rays are small semi-transparent bones located in the branchiostegal membrane, a ventral extension of the operculum. The number of these rays varies according to species of fish.

Various bony structures have been used in place of scales for determining age and growth rates. LeCren (1947) and McConnell (1951) used the opercular bone to age perch and carp. Appelget and Smith (1951), Lewis (1949), and Zarbock (1951) used the vertebrae. Boyko (1946) and Guerrier (1951) used fin rays to determine age of fish. Otoliths have also been used occasionally. Menon (1949) presented a complete list of the different bones that have been used for age determination in fishes, together with the names of the workers who have used them.

Of the bones considered for use in aging lake trout, the branchiostegal

rays were considered most promising. Different bones in the head were checked for markings which might be growth indicators. Markings on the branchiostegals were found to have all of the characteristics of annuli and were used, therefore, in this study.

Branchiostegal rays were also chosen because of the ease of obtaining specimens. Most lake trout samples must come from the fisherman's creel, and fishermen do not want their fish defaced by the removal of large or deeply-centered bones in the head or body. This is especially true for fish which the fisherman wishes to mount or photograph. Hence neither the opercular bone nor the vertebrae would be suitable. The small size and surface location of the branchiostegal rays eliminate this difficulty in obtaining specimens. One ray on either side of the head can be removed and only a small deformation results. Also many fishermen remove the isthmus and branchiostegal membrane when cleaning the fish. Thus the rays can be obtained easily.

Another possible advantage in using the branchiostegal rays is that the careful removal of a single ray apparently does not cause serious injury to the living fish. This would make it possible to check the age of a fish without killing it--one of the advantages of using scales. Limited observation of small fish of several species indicates that fish have a good chance of survival after removal of a single branchiostegal ray. However, this possibility was not explored in the present study. More investigation is necessary to determine the long-range effects of branchiostegal ray removal from lake trout before it is attempted on large numbers of fish.

DESCRIPTION OF STUDY AREA

The fish of unknown age used in this study were taken from creels of fishermen at Fish Lake, Utah. Fish Lake is perhaps the best habitat for lake trout in Utah. It is located in Fish Lake National Forest, Sevier County, and lies at an elevation of 8,800 feet. The lake was formed by a graben and is oligotrophic in nature. It is $5\frac{1}{4}$ miles in length and has an average width of three-fourths of a mile. The surface is roughly 2,500 acres. The long axis of the lake extends in a northeast-southwest direction. The shore on the southeast side is precipitous and rocky, and a few yards offshore a shelf drops off to a depth of 90 feet or more. This area of the lake provides a suitable spawning grounds for the lake trout.

Water temperatures were taken regularly during the summer of 1956 with a bathythermograph. Surface temperatures varied from 51° to 63° F. during this period (June 16 to September 17). A distinct thermocline extended to a depth of 60 feet where the temperature was 45° F. The hypolimnion remained at a fairly constant temperature of 43° to 44° F. These temperatures differ slightly from those recorded by Hazzard (1935). However, they still fall between 40° and 45° F., the temperature necessary for a suitable lake trout habitat.

The lake trout was first introduced into Fish Lake along with the brook trout Salvelinus fontinalis (Mitchell) in 1906. It was not immediately successful, but since that time the lake trout has adapted to the lake, and the population is now quite numerous. It is now one of the lake's main attractions to fishermen because of its large size.

COLLECTION AND ANALYSIS OF DATA

The fork, standard, and total length of 305 lake trout captured in 1956 at Fish Lake were recorded. Measurements were taken to the nearest one-eighth of an inch with a steel tape. Weights were recorded to the nearest ounce. These measurements were considered sufficiently accurate because of the large size of the fish examined and also because of the difficulty in carrying more accurate equipment in the field.

Samples of scales from the standard location between the anterior end of the dorsal fin and the lateral line were taken from each fish. Fish were classified as mature if the eggs were grossly visible in the ovaries or if the testes showed development. Some of the fish listed as mature would not have spawned, therefore, for another year. Fish with undeveloped gonads were listed as immature, and no attempt was made to sex them.

The outer branchiostegal rays adjacent to the left and right opercular bones were taken for this study. Both rays were taken because occasionally one ray was deformed or broken. Using a particular ray employs all the advantages obtained by using key scales. There is no variation in size or development due to taking the structures from different areas of the body. To remove the rays, a sharp knife was inserted along each side of the ray to sever the connecting skin. It was necessary to remove the ray carefully so that the base of the ray containing the focus was not cut off. Best results were obtained by promptly removing the skin covering the ray before it dried out. The flesh and skin were readily peeled off from rays of the smaller fish with the fingernail. A better method was to insert the ray in boiling water for 30-60 seconds. The flesh was then pulled away very easily. It was difficult to remove the flesh from large branchiostegal rays in any other way. No other preparation of the rays was necessary before reading.

In the actual reading, each ray was read independently three times to determine the age of the fish. The annuli on most rays were easily discernible without optical equipment. Doubtful rays were observed with a large reading glass or a hand lens. When the correct age was decided upon, the annuli were marked with a dot of india ink to aid in re-locating them for measurement.

Annuli near the edge of the ray on older fish were bunched closely together. This made it difficult to measure directly the distance between the focus and annuli without enlarging the ray. The rays were marked, therefore, with india ink in the general location of each annulus and then enlarged 3.4 times by projecting with a lantern-slide projector. This particular enlargement was chosen so that there would be minimum loss of distinctness of the markings, and also so the lengths obtained would fit directly on an ordinary nomograph. The rays were placed in a transparent plastic envelope for inserting into the projector. This method worked satisfactorily for rays of all sizes.

Oak tag strips were used for recording the projected ray length and distance from the focus to each annulus. A plastic ruler would also be satisfactory if lengths to each annulus in millimeters were desired. The oak tag was bent so that it lay parallel to the curved inner edge of the ray enlargement for measurements as illustrated in figure 1. (Notice that the focus is at the very base of the ray.) The curved measurement was assumed to be closer to the correct growth lengths than a straight-line measurement. Allowance for curvature in the other plane was unnecessary because the rays were almost flat. The measurement of growth to each annulus was made from the focus to the posterior-most part of the annulus. This maximum distance of each annulus from the focus was used so that all measurements would be uniform.

Figure 1. Method used to measure distance from focus (f) of ray to each annulus

DEFINITION OF ANNULI

Linear growth in the branchiostegal rays of fish is in one direction only---posteriorly. It is postulated that the ray is lengthened by the deposition of cells on the posterior edge. As this edge grows outward, a complete history of growth is recorded there just as on the scales. Thus the branchiostegal rays of lake trout are marked by a series of white opaque bands divided by sharp transparent lines that run parallel to the outer edge of the ray. These lines were the outer edge of the ray at one time. The number of markings on the ray increases directly with an increase in the length of the fish.

The annuli are defined as narrow transparent lines located in the posterior end of the ray and extending also along the full length of the lateral field. These narrow lines of winter growth contrast sharply with the broad white bands of summer growth on most rays. Occasionally on older fish, the white area obscures these transparent lines, but another characteristic also helps to locate the annuli. A slight ripple of varying distinctness in the structure of the ray is present at each annulus. The direction of growth of the ray appears to change immediately after the annulus is laid down. This wave or ripple is important in locating the true annulus. If the ray is held so that light reflects from it to the eye, these waves stand out distinctly enough to mark all annuli on most rays. False annuli were often present in the rays examined, but were incomplete and did not extend far into the lateral field of the ray. The false annuli also did not have the characteristic ripple in the ray structure. The annuli of fish aged as 3 years or younger were not as distinct as the annuli on the rays of fish older than 3 years. It was easier, therefore, to age the mature fish. Markings on the rays of old fish were especially distinct. This is in direct contrast to the process of aging lake trout by scales which become worn and indistinct with age.

McConnell (1951) in working with the opercular bone of carp had some difficulty in locating the first annulus because of thickening of the bone around the fulcrum. Only occasionally did this occur with the branchiostegal rays of lake trout because branchiostegal rays are much thinner than the opercular bone. Most rays even in older fish retained the first characteristic ripple of the annulus, and usually the transparent line also, as the ray increased in size. Very little obscuring due to thickening of the ray occurred.

The annuli were seen most easily against a dark background in reflected light. A bright cloudy day provided the best conditions for reading the rays. Light from a tungsten lamp was inferior to diffused sunlight and fluorescent lighting. The use of X-ray was considered as a check of the method, but it was not tried because of the costs involved.

In an effort to make the markings more distinct, various stains were tested. Among these were basic fuchsin and alizarin red S. Alizarin red was used successfully by Galtsoff (1952) to stain the growth rings in the vertebrae of tuna. This made the annuli more distinct. It was thought that branchiostegal rays would absorb the stain in a manner similar to the tuna vertebrae. However, none of the stains tested were of any value in making the annuli on the rays more distinct. Unstained rays were the easiest to read.

CALCULATION OF PAST GROWTH

The relationship between body length and branchiostegal-ray length of Fish Lake lake trout was determined from 305 specimens. This relationship is adequately expressed by the straight-line formula:

$$L = 7.19 + 4.45 R,$$

where L is the standard length in millimeters and R is the total curved length ($\times 3.4$) of the ray in millimeters (figure 2).

Actual calculations of past growth (table 1) were made with the aid of a nomograph as described by Hile (1950).

Table 1. Mean calculated standard lengths and increments of length for Fish Lake lake trout collected during summer, 1956

Age Class	No. of Fish	Standard Length	Calculated Length (mm) at End of Each Year of Life															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	213	172															
2	9	278	177	249														
3	12	328	182	257	305													
4	68	358	168	247	299	340												
5	57	396	171	243	303	349	380											
6	94	428	164	242	301	345	383	413										
7	33	487	186	276	330	373	411	445	471									
8	10	548	188	277	352	393	432	470	504	532								
9	6	585	206	302	358	407	443	488	525	552	575							
10	1	709	210	311	396	490	546	576	613	643	676	698						
11	2	669	209	304	371	422	473	523	567	596	621	644	657					
12	2	744	171	269	357	402	465	543	584	621	655	682	702	724				
13	1	750	181	252	336	378	416	455	504	559	607	646	684	710	739			
14	3	686	220	316	374	437	483	519	551	579	603	626	643	657	670	697		
15	3	725	203	279	339	423	483	522	564	600	622	646	663	676	694	707	719	
16	3	779	153	251	352	415	476	537	595	628	654	674	696	713	737	748	762	772
Weighted Grand Average			173	252	310	355	397	437	504	571	615	655	672	691	704	711	741	772
Growth Increments			173	80	58	45	37	34	33	31	26	28	20	17	19	11	13	10
Equivalent Total Length in Inches			9	12	15	18	20	21	25	28	30	32	33	34	35	35	36	28
Number of Fish			305	304	295	283	215	158	64	31	21	15	14	12	10	9	6	3

Figure 2. Body-branchiostegal ray relationship of Fish Lake lake trout as determined from 305 fish, collected in 1956

EVALUATION OF THE METHOD

Before an aging method can be used confidently in life history studies of fish, evidence must be obtained to prove that the method is valid. Direct evidence may be obtained that proves the method without doubt; or indirect evidence can be used which suggests that the method is valid.

Direct evidence may be obtained by the use of known-age fish or by comparing length frequencies in the same fish population for 2 or more consecutive years. As this study was conducted over a 1-year period only, the latter method was not used. However, branchiostegal rays from 37 lake trout of known age were used in this study to substantiate the evidence obtained from fish of unknown age. The known-age fish were part of the collection used by Louella E. Cable in her study on the validity of aging lake trout by the scale method (Cable, 1956). The fish were marked and planted as fingerlings in Lake Michigan and recovered when 3, 4, or 5 years of age.

Indirect evidence was obtained from 305 lake trout of unknown age captured at Fish Lake, Utah. This indirect evidence, which will be given first, was adapted from Van Oosten (1929) and is as follows:

1. There is correlation between the length of the aging structure (branchiostegal rays) and the length of the fish. The ray grows longer at a constant ratio as the body grows longer.
2. The number of annuli on the ray increases directly with fish size. The length and weight increases in gradual steps with the assigned age class.
3. The ray margin grows out from the last annulus as the growing season progresses.
4. Different rays from the same fish are similar in size and number of annuli present.
5. Calculated lengths obtained from the rays agree with empirical lengths

of younger fish.

6. Age data acquired by the ray method agree with similar data from the scales.

7. Age assigned from branchiostegal ray reading agrees with the normal age when lake trout mature.

Ray and body length

In order for the branchiostegal rays to be accurate indicators of age, they must be closely correlated with body size. There was a high correlation ($r = 0.961$) between the length of branchiostegal rays and body length (figure 2). The body and the rays grew longer, therefore, at a constant ratio. The average ray length ($\times 3.4$) for fish in the 200-225 millimeter length group was 49 millimeters. This ray length increased for each length group up until the 850-875 millimeter length group which had a ray length ($\times 3.4$) of 175 millimeters.

Annuli number and body size

The number of annuli present on the branchiostegal rays also increased directly with the size of the fish. A comparison was made between the number of annuli counted on the ray and the length and weight of the fish. Both the length and weight increased in gradual steps with increases in assigned age (figure 3). This relationship is not as distinct in some age groups such as the XV-year group, where the number of fish in the group is very small. This particular weight range does not fall in the regular pattern of gradual increase, but the exception is assumed to be due to the small number of fish in this group. There is wide variation in the weight of older fish in many species, so this is not unusual. The over-all pattern does show an increase in size with an increase in number of annuli on the branchiostegal rays.

New growth on rays

Another method of indirectly verifying an aging method is to follow the growth history of the marginal portion of a scale or bony structure throughout all or part of the year. As the body growth continues, the

Figure 3. Range in length and weight of Fish Lake lake trout for each age class as determined from 305 fish

outer edge of the scale grows progressively further from the last annulus. Finally, after a full year, another annulus is laid down and the cycle repeats itself. Hence, the width of the scale beyond the outer annulus increases as the year progresses. If the aging structures of a fish, such as scales, were examined early in the growing season and then examined again later in the year, this band of summer growth would have increased in width. As all accurate aging structures with annulus-like markings exhibit this characteristic, the branchiostegal rays were examined for indications of this growth pattern.

Cable (1956) found that new growth was visible on scales of a few Lake Michigan lake trout as early as the latter part of March. The percentages of lake trout with new growth on their scales increased slowly through April and May, but rose rapidly through June and July. Fifty percent of the fish showed scale growth by the last week in June and the 100-percent mark was reached by the latter part of August.

Lake trout from Fish Lake, Utah, probably have growth conditions similar to those from Lake Michigan. New growth should be visible, therefore, on many of the branchiostegal rays of Fish Lake lake trout by June. Examination of the rays revealed that new growth was present on rays of most of the fish captured during this month. The rays of the lake trout aged as 4-6 years in this study were examined to see if this new growth increased as the summer progressed. Only the 4, 5 and 6 year age classes were used to reduce variation in rate of growth of very young or very old fish. The trout in these three age classes were separated according to month of capture. The average width of the branchiostegal rays from the outer annulus to the ray edge for all fish captured in each month was then determined (table 2).

The average widths of new growth for July and August were found to be the same. This would seem to invalidate the aging method. However, the use of different fish instead of the same individual over the whole

Table 2. Increase in width of new growth on branchiostegal rays of Fish Lake lake trout with the progress of the season

Month	June	July	August	September
Average distance from annulus to ray edge (mm)	0.101	0.116	0.116	0.126
Number of fish captured in each month	84	59	55	18

growing season introduces an error due to individual variations in growth.

Theoretically all fish of the same age should grow at the same rate. As Cable (1956) indicated, though, some Lake Michigan lake trout showed evidence of growth on the scales as early as March, but others did not show growth until August. This may account for the same average width of new growth for July and August in this study. Perhaps more of the fish captured in August had just commenced growing than those captured in July. If the growth of individual fish over the whole summer could be observed, this error would not be present. Even with the error due to using different fish, the growth pattern over the 4 months does seem to indicate that the markings on the branchiostegal rays are true annuli. Average growth for June is less than for any of the succeeding months, and September has the largest average width of new growth on the rays.

Similarity of rays on the same fish

The branchiostegal rays on lake trout are included in the branchiostegal membrane which is a ventral extension of the operculum. In this study the two branchiostegal rays adjacent to the opercular bones were used as they are the largest in the branchiostegal membrane. Apparently they are also the first to be ossified in the young fish. These two rays from the opposite sides of the head were compared to determine if the number of annuli were the same on each. Observation showed that the rays were very similar (figure 4). The number of annuli was always the same on each pair examined. Occasionally an annulus on one ray would be more distinct than that on its mate, but after comparison both annuli could be located. As both rays were so similar, the one showing the more distinct annuli was used in this study. Some error may have been introduced by not using the same ray at all times, but if so, it would probably be small.

Measured and calculated body length

Comparison was also made between calculated body lengths determined

Figure 4. Outer branchiostegal rays from the left and right side of a Fish Lake lake trout aged at 3 years

from the branchiostegal rays and measured length of younger fish. An aging method is based on the premise that some correlation exists between the body growth rate and growth rate of certain body structures used in aging. Hence, calculated lengths as determined by an aging method should agree well with empirical lengths of younger fish. If there is wide disagreement between calculated length of younger fish and observed length of these fish, then the particular aging method is not valid. The growth of the structure used in aging would not be correlated with body growth. As indicated in the body-branchiostegal ray relationship, there is high correlation in growth between the two. The product moment correlation coefficient is 0.961. This correlation is substantiated further by the comparison between calculated length determined from the rays and observed length of younger fish (table 3).

It should be noted that agreement is closest where the number of fish is largest. A larger number of fish in a group would naturally tend to cancel out wide variations, and the average would be closer to the true mean. The average of a small number of fish might differ greatly from the true population mean. It is assumed that much of the error in the smaller groups was due to the small size of sample. The over-all comparison was close enough to state that the calculated length as determined by the branchiostegal rays is a good estimate for practical purposes of the true average length of the fish.

Branchiostegal rays versus scales

The use of an aging method should also give results that are comparable to that obtained by other methods of determining age. There must be agreement if both methods are valid. Age determined by the branchiostegal rays should agree, then, with the age read from scales of the same fish. Scales of the lake trout obtained at Fish Lake were mounted and read for this comparison.

Scales were mounted in a sodium silicate-glycerin base, and then

Table 3. Comparison of measured lengths of 305 Fish Lake lake trout with calculated lengths determined by use of the branchiostegal rays

Age of fish (years)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Number of fish	1	9	12	68	57	94	33	10	6	1	2	2	2	3	3	3
Measured standard length (mm)	213	278	327	358	396	428	487	548	585	709	669	744	750	686	725	779
Calculated standard length	172	252	310	355	397	437	503	571	615	655	872	791	704	711	741	772
Numerical difference	40	26	17	3	1	9	17	23	30	54	3	53	46	25	16	6

studied in detail to set up criteria for the recognition of annuli. Annuli on the scales of lake trout are difficult to find as they are not always indicated by the same characteristics. It was necessary, therefore, to decide what determined an annulus.

The most frequent characteristic indicating the presence of an annulus was the gradual bunching together of the circuli followed by an abrupt increase in spacing. These bands often were quite distinct on some scales. However, this characteristic alone was not sufficient for locating all annuli. Some were characterized by crossing over of the circuli where growth had resumed again. The location of others was indicated by incomplete circuli that did not extend completely around the scale. An annulus usually was located by use of all three criteria. These criteria, arrived at independently, are essentially the same as those listed by Cable (1956) for the recognition of annuli on the scales of Lake Michigan lake trout.

Success in reading a scale hinged upon the proper interpretation of the area around the focus. Interpretation of the circuli in this area was the most difficult, but once solved, reading the rest of the scale was relatively easy. A check was located near the focus on all scales. This was defined as an annulus at first, but after applying the above criteria on a number of scales, it was rejected. Cable (1956) found this central check on the scales of both stocked and wild lake trout from Lake Michigan. She designated it as the O-mark.

After the aging criteria were established, the scales were read independently two times. Where first and second readings disagreed, the scale was read again until an age was decided upon. Scales of the older fish were difficult to read, and the accuracy of the age assigned to these fish is doubtful. However, for purposes of comparison, all scales were assigned an age.

Comparison was then made between age determined by reading

branchiostegal rays and age assigned by reading scales (figure 5). With those fish where the assigned age by the two methods disagreed, both the rays and scales were again studied independently. Any errors found in previous readings were corrected. If no definite errors were located, the ages assigned were not changed. Almost all of the errors found were in scale readings.

In the first comparison 70.6 percent of the scales agreed in age with the branchiostegal rays. After an independent re-reading of scales and rays, agreement was much closer (table 4). Table 5 shows the area of disagreement between the two readings. As can be seen, where the two readings disagreed, the fish were aged younger by scale readings than by ray readings. On scales of older fish it is difficult to locate all annuli.

From this comparison, it would seem that the branchiostegal-ray method is at least as accurate as the scale method for determining age of lake trout. The branchiostegal rays have the added advantage of retaining a clear pattern on older fish because the rays do not become worn and defaced with age as scales do.

Age of maturity

To see if age assigned from the branchiostegal-ray readings agreed with the normal age when lake trout mature, the gonads of the lake trout from Fish Lake were examined to determine sex and stage of maturity. The classification used was that described by Lagler (1950). As the collection was made during the summer, at a time when the lake trout were not spawning, the fish were classified as either mature or immature. If eggs were grossly visible or if the testes showed much development, the fish were classified as mature.

As the fall spawning period approached, it was noticed that some of the young female fish classified as mature were not ready to spawn. Eggs were visible but not developed sufficiently for spawning in 1956. In this classification, then, maturity as indicated by gonad development

Figure 5. Branchiostegal rays and scale from a Fish Lake lake trout whose age was estimated at 6 years
(It should be recognized that the untouched photographs of branchiostegal rays cannot give the same degree of legibility attainable in practice by tilting the surface of the rays and altering the lighting.)

Table 4. Agreement in age of 305 Fish Lake lake trout by scale and branchiostegal-ray reading

Assigned age from rays (years)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Number of fish	1	9	12	68	57	94	33	10	6	1	2	2	1	3	3	3
Percent agreement of rays and scales -	90	92	98	98	97	97	97	90	100	100	66	66	33	66	75	-

Table 5. Amount of disagreement in age between branchiostegal-ray method and scale method of 8 Fish Lake lake trout 11 years of age and older

Age according to ray readings (years)	11	12	14	14	15	16	16	16
Age according to scale readings (years)	8	11	13	15	13	15	15	15
Difference	-3	-1	-1	1	-2	-1	-1	-1

may occur a year before spawning actually takes place. This would place the age of true maturity as indicated by spawning at one year later.

Under the classification used, no fish under an assigned age of $4\frac{1}{2}$ years had noticeable gonadal development. Forty-one percent of the $4\frac{1}{2}$ -year-old fish, 81 percent of the $5\frac{1}{2}$ -year-old fish, and 86 percent of the $6\frac{1}{2}$ -year-old fish were mature. All fish over an assigned age of $6\frac{1}{2}$ years were mature.

This age of reaching maturity agrees favorably with other studies on lake trout. Surber (1933) raised lake trout to maturity in a fish hatchery. He secured his first eggs from females $4\frac{1}{2}$ years old. These fish were 18 to 26 inches in length. Only a very few fish were mature at this early age. Royce (1943) found that very few male lake trout from Seneca Lake, New York, matured before their sixth year. Few females matured before their seventh year. Fry and Kennedy, as quoted by Royce, estimated the minimum age at maturity of lake trout of Lake Opeongo, Algonquin Park, Canada, as the fifth year of life. According to the age determined by the branchiostegal rays, lake trout from Fish Lake would mature, therefore, at about the same average age as lake trout from many other waters.

Direct evidence

The evidence presented thus far has been of an indirect nature, but in the final analysis, definite proof of any aging method must rely on the use of known-age fish. The assigned age must agree with the known age of the fish if the method is accurate.

Examination of several hundred fish with all age groups well represented would be ideal. However, mature lake trout of known age are very scarce in this country. Most of the fish which are available have been reared in hatcheries and are unsuitable, therefore, for aging studies because of unnatural growth conditions. Fortunately, branchiostegal rays from a small number of wild lake trout of known age were obtained from Lake Michigan. These fish, captured in 1949 and 1950, had been preserved

in formalin originally and then transferred to alcohol. Hence, a certain amount of deterioration of the rays had taken place and the markings on the rays were not as clear as those found on branchiostegal rays of fresh fish. However, the characteristic ripples marking the annuli were plainly visible so that the rays could be aged with confidence. Figure 6 illustrates the branchiostegal ray from a lake trout whose known age was 4 years.

Branchiostegal rays from 37 Lake Michigan fish ranging from 3 to 5 years of age were examined without a knowledge of the age of any particular fish. Every effort was made to make an unbiased reading of the rays. The number of annuli on 30 of the 37 rays agreed with the known age of the fish. The reason for this apparent disagreement in the age of 7 fish was found by checking the date of capture of these fish. All 7 were captured between February 4 and May 7, which is prior to the main growing season of lake trout. As Cable (1956) indicated, only 50 percent of Lake Michigan lake trout show new growth on the scales by June. This being true, it is not unusual to find fish captured before May without new growth visible on the rays. The final annulus of these 7 fish was assumed, therefore, to be on the edge of the ray, but that new growth was insufficient to mark its location. Under this assumption, all assigned ages agreed with the known age of the 37 fish, and hence, the fish were aged correctly by the branchiostegal ray method.

Figure 6. Branchiostegal ray from a Lake Michigan lake trout whose known age is 4 years

CONCLUSIONS

From the above information, aging of lake trout by branchiostegal rays appears to be a reliable method for the particular populations studied. As the fish examined came from Fish Lake and Lake Michigan only, further study would have to be made to see if this method is valid for lake trout from other areas.

Using the criteria given, the annuli can be located with little difficulty on most rays. The rays are easily cleaned and require no preservation or further preparation for reading. Age of the fish can be determined directly from the rays either without magnification or with a hand lens. For calculations of growth or more detailed study, the rays may be projected, but expensive microprojection equipment is unnecessary. A common 35-millimeter slide projector is suitable for all except the largest rays, and a lantern-slide projector is satisfactory for rays of any size.

The branchiostegal rays of older fish are easier to read than the scales; this is a definite advantage. Further study should be made, however, with senile lake trout of known age when such fish are available. Further investigation is needed of the effects of spawning on the branchiostegal rays. The available information suggests that branchiostegal rays appear to be the answer to the question of deteriorating scales on older lake trout.

Age assigned to known-age fish agreed with their actual age, and all indirect evidence obtained from a population of unknown age agreed with the ages assigned. In comparison to the scales, the rays are relatively easy to read as the annuli are usually quite distinct. Thus the branchiostegal ray method of aging lake trout fulfills the requirements of a suitable aging method, and the possibilities of its general use should be investigated.

SUMMARY

1. Branchiostegal rays of 342 lake trout were examined to determine their value as age and growth indicators. Three hundred and five fish of unknown age from Fish Lake, Utah, and 37 lake trout of known age from Lake Michigan were examined.

2. The annuli on the rays were defined as narrow transparent lines extending from the posterior end of the ray well into the lateral field. Annuli were also marked by a wave or ripple in the structure of the ray.

3. The relationship between body length and branchiostegal ray length was expressed by the formula:

$$L = 7.19 \div 4.45 R.$$

4. Indirect evidence supports the method. This included correlation between length of ray and body length, correlation between number of annuli and size of fish, comparison of scales and branchiostegal rays from the same fish, and comparison of calculated lengths and measured length.

5. According to the age assigned from ray reading, Fish Lake lake trout mature between $4\frac{1}{2}$ and $6\frac{1}{2}$ years of age.

6. Direct evidence was obtained from 37 known-age fish, whose assigned age was determined from the branchiostegal rays, agreed with the actual age of the fish.

7. It is concluded that the branchiostegal-ray method is accurate and is relatively easy to use for the populations studied, and should be generally applicable.

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