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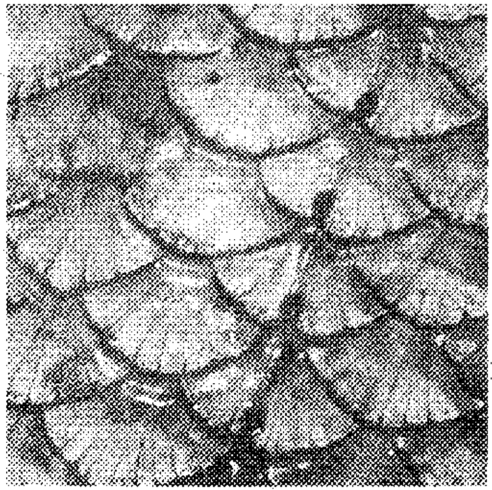


Alberta
FORESTRY, LANDS
AND WILDLIFE
Fish and Wildlife

University
of
Alberta

FISH AGEING METHODS FOR ALBERTA

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Edited
by

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PREFACE

This Manual brings together knowledge concerning fish ageing which has accumulated in Alberta over the past twenty years or so. Our goal in assembling this knowledge was to produce a succinct, "how to" guide to ageing those species of fish which are of wide interest to fisheries biologists in Alberta. This Manual is written for aquatic resource managers with technical school, college, or university training in biology.

It is our intention to update this manual in a few years. We therefore ask fisheries workers to inform us of developments or improvements in ageing techniques. High quality photographs of structures used for ageing, both clear and difficult to "read", would also be appreciated.

This Manual is the result of a Workshop on Fish Ageing sponsored by the Fish and Wildlife Division of Alberta Forestry, Lands, and Wildlife at the Alberta Forestry Training School, Hinton, on September 10 & 11, 1986. The workshop was organized by a Steering Committee consisting of representatives from: Alberta Fish and Wildlife Division (Doug Lowe, Ken Zelt and Hugh Norris), the private sector (Gary Ash and Jim O'Neil), and the University of Alberta (Bill Mackay). Workshop participants were chosen on the basis of their experience in ageing fish, each participant being responsible for presentation of the techniques used to age one or more species of fish. A list of the participants and their affiliation is given below.

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ACKNOWLEDGMENTS

This manual could not have been produced without the concerted effort of the large number of people who participated in the workshop which lead to this manual and who wrote the methods for the various species. We thank: Doug Lowe, Ken Zelt, and Jim O'Neil who assisted us on the Steering Committee to organize the workshop; Ken Zelt who made the logistical arrangements for the workshop; the Fisheries Branch of the Alberta Fish and Wildlife Division for financing the workshop; Gerry Wilde of the Alberta Forestry Training School who ensured that our needs were met while we were in Hinton so that we could concentrate on the workshop; and Thomas Diefenbach who produced the outline drawings and figures used in this manual.

We also wish to thank the people and organizations who assisted with the production of this manual: Alberta Recreation, Parks and Wildlife Foundation and their executive director, Chuck Moser, for financial support through a grant to R.L. & L. Environmental Services Ltd., Fish and Wildlife Regional clerical staff for typing the first draft of the manual and the Fisheries Branch for providing additional photographic services, and Carol Henderson of R.L. & L. Environmental Services Ltd. for final typing and layout.

RECREATION, PARKS AND WILDLIFE FOUNDATION

CHAPTER 1

INTRODUCTION

Fisheries management in Alberta has developed rapidly over the past twenty years. The data being collected today will serve as a bench mark in the future. It is important, therefore, that these data be gathered, stored, and reported in ways which facilitate their use by fisheries biologists other than those who collected them. Anyone who has attempted to compare data from different sources in the province is struck with the multiplicity of ways in which the data have been gathered and reported. We attempt to alleviate this problem.

The management of fish populations depends on accurate knowledge concerning the growth rate of fish in the population. Without accurate knowledge of the annual production of fish, it is impossible to estimate the sustainable harvest that a population will support. Thus the focus of this manual is the accurate determination of the age of fish species which are found in Alberta.

This manual consists of three parts. The first part, Chapters 2 through 5, deal with general issues pertaining to ageing fish. These include standardization of how data are reported, the use of data in mathematical models to characterize growth of fish from different populations, general approaches to ageing fish, and a consideration of criteria for the validation of an ageing technique. The second part, Chapter 6, consists of a discussion of ageing techniques for individual species. The third part, Chapter 7, is a general account of the use of different structures for ageing fish.

Before any samples are collected, both Chapters 6 and 7 should be consulted -- Chapter 6 to decide what structure will be used to age the species of interest, and Chapter 7 to identify critical aspects concerning handling and storage of that structure. In addition Chapter 2 should be consulted to decide what data you will obtain and how you will record those data. The technique used to age fish must be validated for the population being studied so Chapter 5 should also be consulted before you go to the field to collect specimens.

CHAPTER 2

STANDARDS FOR REPORTING DATA ON AGE AND SIZE OF FISH

A rationale can be developed for a wide range of standards with regard to measurements made and units used for reporting data on fish age and growth. The standards suggested here were chosen on the basis of using SI (metric) units, and minimization of the potential for error or systematic variation between investigators.

Fish Species Names and Abbreviations

The common and Latin species names used follow the standards set by the American Fisheries Society (1980) and Kendall (1988). The species found in Alberta are listed in Table 1.

The assignment of standard abbreviations for fish species in the province generated considerable controversy. This is not surprising considering some of the common literal abbreviations in use. For example: ARGR for Arctic grayling used the first two letters of each word. MTWF for mountain whitefish used the first letter of each syllable. RBTR for rainbow trout used a combination of the previous two methods. LKCH for lake chub and TRPR for trout perch is a different system again and it is reversed just between these two species.

Lack of a consistent system of abbreviations means that workers have to memorize each individual abbreviation rather than learning a single system. After evaluation of four different systems, the following one was judged easiest to use and resulted in the fewest conflicts for fish found in Alberta. It is recommended for use in all future fisheries work done in Alberta.

The system recommended is based on the following four simple rules:

a) use four letter base abbreviation
b) one word name - use the first four letters
   e.g., GOLD for goldeye
c) two word names - use the first letter in each word plus the next consonant in each word.
   e.g., ARGR for Arctic grayling
   LKWH for lake whitefish and
   WHSC for white sucker
d) three word names - use the first letter in the first two words and the first letter and next consonant in the last word
   e.g., NRDC for northern redbelly dace

Using the above system the only four letter conflict that occurred was BRTR for both brook and brown trout. These were arbitrarily sorted as BKTR for brook trout and BNTR for brown trout. Table 1 lists the Alberta fish species and recommended abbreviations.

Data Collection and Reporting

"The Fishes of Alberta" by Paetz and Nelson (1970) will give you a good idea of which species you should expect in the field. When field samples are collected it is important to make as complete and unambiguous a record as possible. For each specimen collected the following information should be included: sample number, species designation, location of collection (name or code for water body and location, i.e., Section, Township, Range, Meridian), date of collection (year, month, day), and sex/maturity. These data also should be included in any computer record or report which is produced of the collection. To avoid ambiguity, species, location, and date of collection must be included with all copies or summaries of the data. The species designation should use the standard abbreviation or full name for the species listed in Table 1. Data should be recorded in a standard format. Two examples for field data recording are shown in Tables 2 and 3. The preferred computer format is shown in Table 4, and the preferred data summary is shown in Table 5.

Table 1. Common and scientific names of Alberta fish species, and recommended species abbreviations.

Common Name	Scientific Name	Species Abbreviations
Family Petromyzontidae		
Arctic lamprey	*Lampetra japonica* (Martens)	ARLM
Family Acipenseridae		
lake sturgeon	*Acipenser fulvescens* Rafinesque	LKST
Family Salmonidae		
Arctic grayling	*Thymallus arcticus* (Pallas)	ARGR
cisco, lake herring	*Coregonus artedii* Lesueur	CISC
shortjaw cisco	*C. zenithicus* (Jordan and Evermann)	SHCS
lake whitefish	*C. clupeaformis* (Mitchill)	LKWH
mountain whitefish	*Prosopium williamsoni* (Girard)	MNWH
lake trout	*Salvelinus namaycush* (Walbaum)	LKTR
bull trout	*S. confluentus* (Suckley)	BLTR
brook trout	*S. fontinalis* (Mitchill)	BKTR
brown trout	*Salmo trutta* Linnaeus	BNTR
cutthroat trout	†*Oncorhynchus clarki* (Richardson)	CTTR
rainbow trout	†*O. mykiss* (Walbaum)*	RNTR
golden trout	†*O. aguabonita* Jordan	GLTR
Family Esocidae		
northern pike	*Esox lucius* Linnaeus	NRPK
Family Hiodontidae		
goldeye	*Hiodon alosoides* (Rafinesque)	GOLD
mooneye	*H. tergisus* Lesueur	MOON
Family Cyprinidae		
longnose dace	*Rhinichthys cataractae* (Valenciennes)	LNDC
flathead chub	*Hybopsis gracilis* (Richardson)	FLCH
lake chub	*Couesius plumbeus* (Agassiz)	LKCH
pearl dace	*Semotilus margarita* (Cope)	PRDC
northern squawfish	*Ptychocheilus oregonensis* (Richardson)	NRSQ
redside shiner	*Richardsonius balteatus* (Richardson)	RDSH
northern redbelly dace	*Phoxinus eos* (Cope)	NRDC
finescale dace	*Chrosomus neogaeus* Cope	FNDC
fathead minnow	*Pimephales promelas* Rafinesque	FTMN
emerald shiner	*Notropis atherinoides* Rafinesque	EMSH

*formerly *Salmo gairdneri*

†formerly *Salmo*

Table 1. Cont'd.

Common Name	Scientific Name	Species Abbreviations
river shiner	*Notropis blennius* (Girard)	RVSH
spottail shiner	*N. hudsonius* (Clinton)	SPSH
brassy minnow	*Hybognathus hankinsoni* Hubbs	BRMN
silvery minnow	*H. nuchalis* Agassiz	SLMN
Family Catostomidae		
quillback	*Carpiodes cyprinus* (Lesueur)	QUIL
silver redhorse	*Moxostoma anisurum* (Rafinesque)	SLRD
shorthead redhorse	*M. macrolepidotum* (Lesueur)	SHRD
longnose sucker	*Catostomus catostomus* (Forster)	LNSC
white sucker	*C. commersoni* (Lacepède)	WHSC
largescale sucker	*C. macrocheilus* Girard	LRSC
mountain sucker	*C. platyrhynchus* (Cope)	MNSC
Family Ictaluridae		
stonecat	*Noturus flavus* Rafinesque	STON
Family Gadidae		
burbot	*Lota lota* (Linnaeus)	BURB
Family Percopsidae		
trout-perch	*Percopsis omiscomaycus* (Walbaum)	TRPR
Family Gasterosteidae		
brook stickleback	*Culaea inconstans* (Kirtland)	BRST
ninespine stickleback	*Pungitius pungitius* (Linnaeus)	NNST
threespine stickleback	*Gasterosteus aculeatus* Linnaeus	THST
Family Centrarchidae		
smallmouth bass	*Micropterus dolomieui* Lacepède	SMBS
Family Percidae		
Iowa darter	*Etheostoma exile* (Girard)	IWDR
yellow perch	*Perca flavescens* (Mitchill)	YLPR
sauger	*Stizostedion canadense* (Smith)	SAUG
walleye	*S. vitreum vitreum* (Mitchill)	WALL
logperch	*Percina caprodes* (Rafinesque)	LGPR
Family Cottidae		
shorthead sculpin*	*Cottus confusus* Bailey and Bond	SHSC
slimy sculpin	*C. cognatus* Richardson	SLSC
spoonhead sculpin	*C. ricei* (Nelson)	SPSC
prickly sculpin	*C. asper* Richardson	PRSC
deepwater sculpin	*Myoxocephalus thompsoni* (Gerard)	DPSC

*previously misidentified as mottled sculpin (see Roberts 1988, 1989).

Table 2. Example of data form currently used by Alberta Fish and Wildlife Division for recording data in the field.

Alberta
ENERGY AND
NATURAL RESOURCES

Form WFR 2
SAMPLE RECORD CARD
Fish and Wildlife Division

♀		Maturity	♂
	1	Immature	6
	2	Maturing	7
	3	Mature	8
	4	Ripe	9
	5	Spent	10

Lake or Stream ______ Date ______
Species ______ Time ______
Mesh Size ______ Depth of Set ______
Location of Set ______
Sample ______ Recorder ______

NUMBER	SAMPLE NUMBER	FORK LENGTH Inch. ☐ Mm. ☐	WEIGHT Oz. ☐ Gms. ☐	AGE	MATURITY	CYST COUNT	REMARKS
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
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25							
26							
27							
28							
29							
30							

Table 3. Example of data form currently used by R.L. & L. Environmental Services Ltd. for recording data in the field.

Fish Sample Record — R.L. & L. Environmental Services Ltd.

	Sample No.	Species Code	Length (mm)	Weight (g)	Sex & Mat	Gonad Wt. (g)	Age: Age	Age: Meth	Capt Meth	Net Mesh Size(cm)	C	Tag Number	Date: Yr.	Date: Mo.	Date: Day	Lake or River Name	Site Location	Capt. Code	Preserve	Comments
	5	6	13	18	19 21	24 25	27	29	31	33	34	40	42	44	46	47	56	57	58	80
1																				
2																				
3																				
4																				
5																				
6																				
7																				
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9																				
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21																				
22																				
23																				
24																				
25																				

Recorder ____________ **Project No.** ____________

Table 4. Fisheries Computer Use Guidelines

1) All standard fish data (weight, length, age, sex, etc.) should be entered in columns using LOTUS 1-2-3, dBASE, or another spread sheet program that is readable in ASCII format.

2) Store a copy of the data on disks, not on hard drive. Make a hard copy of all data.

3) Descriptive statistics (means, variances, frequency distributions) can be done on LOTUS or dBASE. Use SPSS or other statistical software for comparative tests (*t*-tests, non-parametric tests, etc.).

4) Include an appendix in reports that is a floppy disk with the raw data. As a minimum, this should be attached to your library copy of the report. Make sure your data are properly documented so they can be accessed by others.

5) Make backup copies of all your software and data on a regular basis (monthly or weekly if using heavily). Practice restoring data to make sure your backup is functioning correctly.

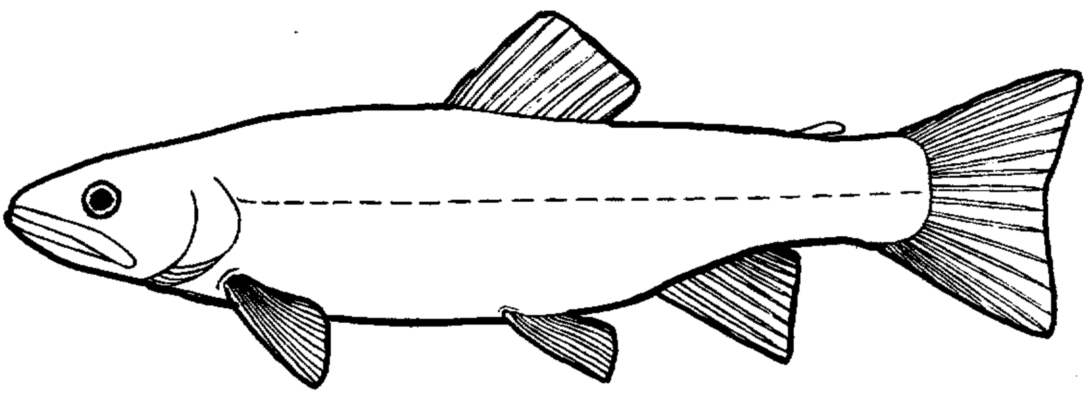

Table 5. **Age-Growth Data Summary Sheet.**

Species ____________________

Lake/Stream ____________________

Data Source ____________________

Sample Date ____________________
(Day Month Year)

Method of Ageing ____________________

Ageing done by ____________________ Date ____________________
(Year Month Day)

Length-Weight Relationship:

Log_{10} Weight = ________ Log_{10} Length - ____________

or Weight = ________ Length to the power ____________

N = ________, r^2 = ____________

Year-class	Age	N	% of Sample	Mean Length (mm) Fork ☐ Total ☐	Range	S.E.	Mean Weight (g)	Range	S.E.
	0								
	1								
	2								
	3								
	4								
	5								
	6								
	7								
	8								
	9								
	10								
	11								
	12								
	13								
	14								
	15								

***Comments:** all ages standardized to a 1 January birthdate.*

Measurement of Length

- Standard measurement: FORK LENGTH
- Standard unit: MILLIMETRE (abbreviation - **mm**)

The standard measurement of length will be fork length (Figure 1) for all species except burbot, sculpins, sticklebacks and darters which do not have a fork in their caudal fin. For these species the standard unit will be total length (Figure 1).

There are three common types of measurement of the whole body length of fish: fork length, standard length, and maximum or total length (Anderson and Gutreuter 1983). Each offers some advantage and some disadvantage (Carlander and Smith 1945).

- **Fork Length**, the measurement most commonly used in Canada, is the distance from the most anterior point on the head to the tip of the median caudal fin rays.
- **Standard Length** is the length from the tip of the upper jaw to the posterior end of the hypural bone. This measure is not recommended for use in Alberta.
- **Maximum or Total Length**, the most common measure of length in the United States, is the distance from the most anterior part of the fish to the tip of the longest caudal fin ray when the lobes of the caudal fin are compressed dorso-ventrally so that the caudal fin is at its greatest length.

To compare data with different length measurements it is necessary to calculate a conversion factor for your data. Measure the fork length and other length you need to compare, from a sufficient number of fish (i.e. 30 to 50) so that a relationship between the two measurements can be derived for the particular population. The mathematical relationship between the two measures of length should be determined by doing a least squares linear regression on the pairs of length measurements collected. A much less desirable alternative is to use published relationships (conversion factors) between the two measurements (e.g., Carlander 1969, 1977); for the most part, published relationships are derived for populations located geographically far from Alberta and are likely less accurate for our populations than conversion factors derived for local fish stocks. Examples of fish length conversion factors that have been derived for

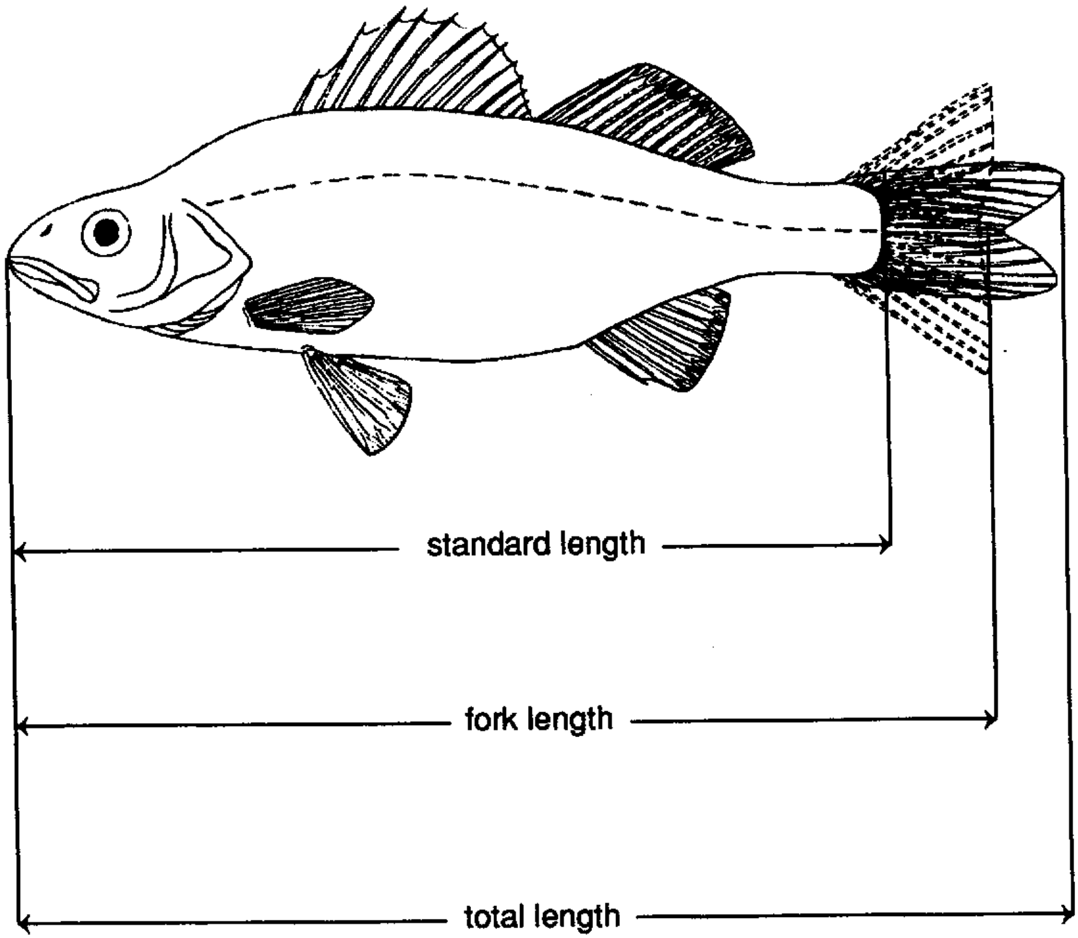

Figure 1. Three measures of length of fish.

Alberta fish are provided in Table 6.

Table 6. Relationship between fork length, total length, and standard length of some freshwater fish from Alberta.

Species	Location	Reference	TL to FL	SL to FL
mountain whitefish	Sheep River	Thompson (1974)*	FL = 0.914·TL	FL = 1.087·SL
yellow perch	Pine Lake	Norris (1984)	FL = 0.960 TL - 0.077 r = 0.999	FL = 1.133 SL + 1.754 r = 0.999
	Mayatan Lake	Mackay (unpubl.)	FL = 0.97 TL - 0.41	
northern pike	Lac Ste. Anne	Mackay (unpubl.)	FL = 0.96 TL - 1.02	FL = 1.06 SL + 1.17

*recalculated from Thompson (1974).

Fish should be measured fresh, if possible since drying, freezing and various preservatives (Leslie and Moore 1986; Theilacker 1980) may result in shrinkage.

Measurement of Weight

- Standard measurement: TOTAL BODY WEIGHT
- Standard unit: GRAM (abbreviation - g)

Fish should be weighed as soon as possible after capture. Excess water should be removed by blotting small specimens or allowing water to drain from large specimens. Snow and ice should be removed from fish collected in winter. The stomach contents should be removed prior to weighing. This is particularly important for piscivorous species. Food in the stomachs of piscivores such as northern pike can be equal to 20% or more of their body weight; thus, if stomach contents are not removed, body weight could be grossly over-estimated for some specimens. Record the method used with your data.

The gram (g) is the preferred unit of weight since decimal points are not normally required for the sport species. Although it is not always practical in field situations, workers should strive to achieve three significant digits in recording data for fish weight. Fish larger than 100 g should be weighed to the nearest gram. Fish between 10 and 100 g should be weighed to 0.1 g and fish between 0 and 10 g should be weighed to 0.01 g. Where conditions do not allow measurement to the above level of precision be sure to note this in the methods section of your report.

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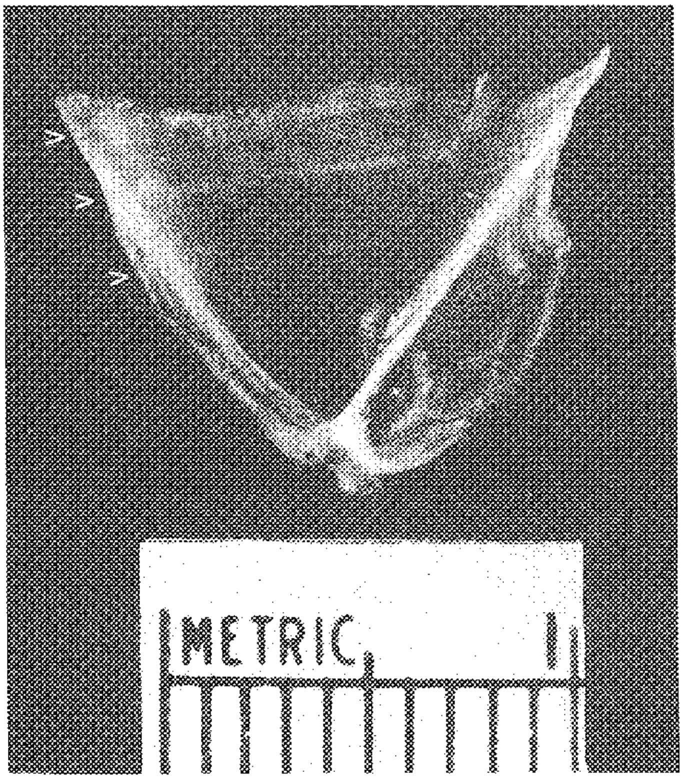

CHAPTER 3

MATHEMATICS OF FISH GROWTH

Fish show indeterminate growth, that is, they continue to grow throughout their lives. This is in contrast to the determinate growth shown by higher vertebrates such as birds and mammals which reach some 'adult size' and then stop growing. These two types of growth are shown graphically in Figure 2. In both cases growth is asymptotic, that is, the rate of growth decreases with increasing age approaching some maximum value (asymptote) for the individual or population. The fundamental difference between fish and higher vertebrates such as mammals is that mammals reach maxiumum size at about the time of sexual maturity while animals which show indeterminant growth continue to grow throughout life, their body size approaching some theoretical asymptote. Therefore, the asymptote is the theoretical maximum size which one could expect for the population at the maximum (infinite) age.

From the point of view of fisheries managment, this population maximum size tells the manager how large fish can be expected to get in that population. A second number which is useful is the growth constant, *k*, which is the rate at which a particular population grows toward the maximum size for that population. In the section that follows we will describe techniques for calculating maximum size (L_∞ value) and the growth constant for fish populations.

Growth of fish over their lifetime can be best described by a sigmoid or S-shaped mathematical function; however, the accelerating portion of growth occurs very early in life, often during the first few weeks. Figure 3 shows this phase of the growth curve for yellow perch. The curve starts with the size of the fish at 'hatching' or emergence from the egg, not at zero. The initial phase of the sigmoid curve is not apparent in most studies of fish growth because they estimate the size of the fish starting at age one, the time of formation of the first annulus. Thus, the accelerating portion of the sigmoid curve is completely missed and the remaining, decelerating portion of the

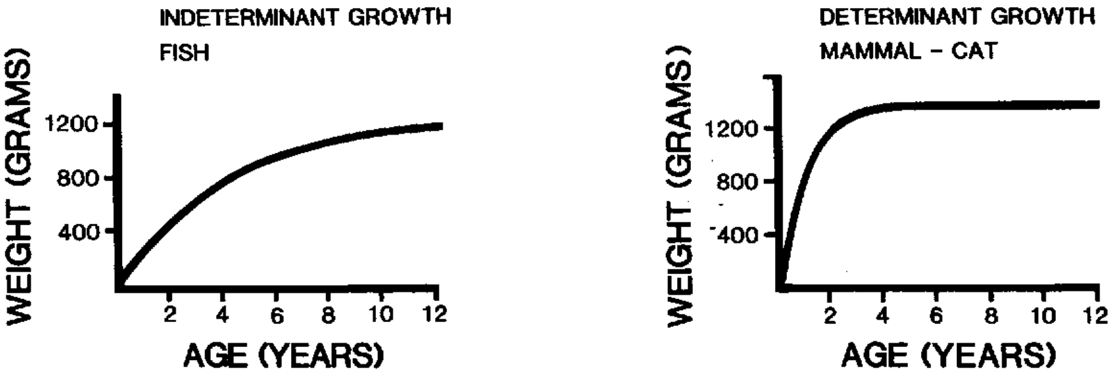

Figure 2. Two types of growth.

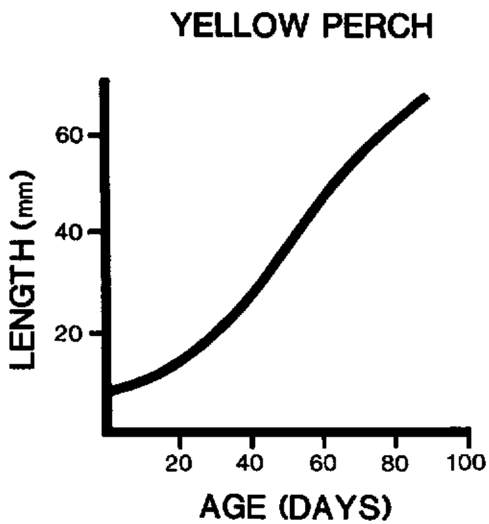

Figure 3. Growth of young-of-the-year yellow perch showing sigmoid curve.

growth curve has the form of a simple exponential function which can be described by the general equation:

$$Y = ae^{-kt} \qquad (1)$$

where: Y is the size (length or weight) of the fish at time t;
a is a constant characteristic of the population and,
k is the growth constant for the population.

Mathematical descriptions of fish growth are useful because they allow fisheries biologists to calculate parameters which are characteristic of the population being studied; these parameters can be used to compare different populations of fish. In order to make comparisons accurate, the populations should all be compared at the same time. The most appropriate time for such comparison is at the time of annulus formation; however, since it is unlikely that fish will be collected at the precise time of annulus formation, their size at this time is determined indirectly using a technique called back-calculation (Hile 1950; see page 21 of this manual).

Mathematical Parameters for Comparing Populations

Two parameters related to growth rate are of particular interest in comparing the growth of different fish populations. These are the maximum size, L_∞, which is possible for fish in that population and the rate, k, at which this maximum size is achieved. The L_∞ value indicates whether the population is stunted; here stunted refers to populations of fish that do not have the potential to reach the normal maximum size for the species. It distinguishes between populations which are not capable of producing large fish (stunted) and those which never acheive their L_∞ because of a short life span. If the L_∞ for a population of apparently small fish is within the 'normal range' for the species then the population is slow growing; if it is significantly smaller than the 'normal range', then the population is stunted.

Fish grow toward an asymptote; calculation of the asymptote allows one to predict the theoretical maximum length fish will reach in a particular population. The rate at which a given population grows (rate constant for growth) toward the asymptote can also be calculated.

The most common technique used to calculate these two parameters is the Walford plot or the Ford-Walford plot (Ford 1933; Walford 1946). This is also useful for checking the validity of the ageing technique used. If the growth of a population follows a single mathematical function, then all the data points should fall on or very near a straight line, and the y-intercept of the Walford plot should be equal to the length of fish when they are one year old. The Walford plot is most useful when growth rates are back-calculated since most fisheries biologists and technicians are seldom able to collect sufficient one year old fish for a representative sample.

Walford Plot

A Walford plot is simply the relationship of l_t, the length at age t, to the length, l_{t+1}, the following year. The length at age t is plotted on the x axis and the length at age $t+1$ is plotted on the y axis. A straight line is fitted to the data using a least squares linear regression. The L_∞ value is calcuated as:

$$L_\infty = y \text{ intercept}/(1\text{-slope}) \qquad (2)$$

The y intercept should be equal to the average length of the fish at age one. If the y intercept differs significantly from the observed length at age one, the ageing technique should be reassessed, particularly if all of the data points in the plot fall on a straight line.

The von Bertalanffy growth coefficient, K, is equal to the negative natural logarithm of the slope:

$$K = -\ell n \text{ slope} \qquad (3)$$

and the age, t_0, at size zero can be calculated from the relationship:

$$t_o = (\text{intercept} - \ell n\, L_\infty)/K \qquad (4)$$

Table 7 gives a data set for the length of northern pike at various ages. Figure 4 shows how these data can be used to calculate L_∞, K, and t_o for this population.

Two other plots which can be used to determine the L_∞ and growth constant are the Gulland plot (Gulland 1955) and the Brody plot

Table 7 **Fork length (mm) of northern pike from Lac Ste. Anne.**

Age (years)	1	2	3	4	5	6	7
Length (mm)	198	331	426	478	514	543	578

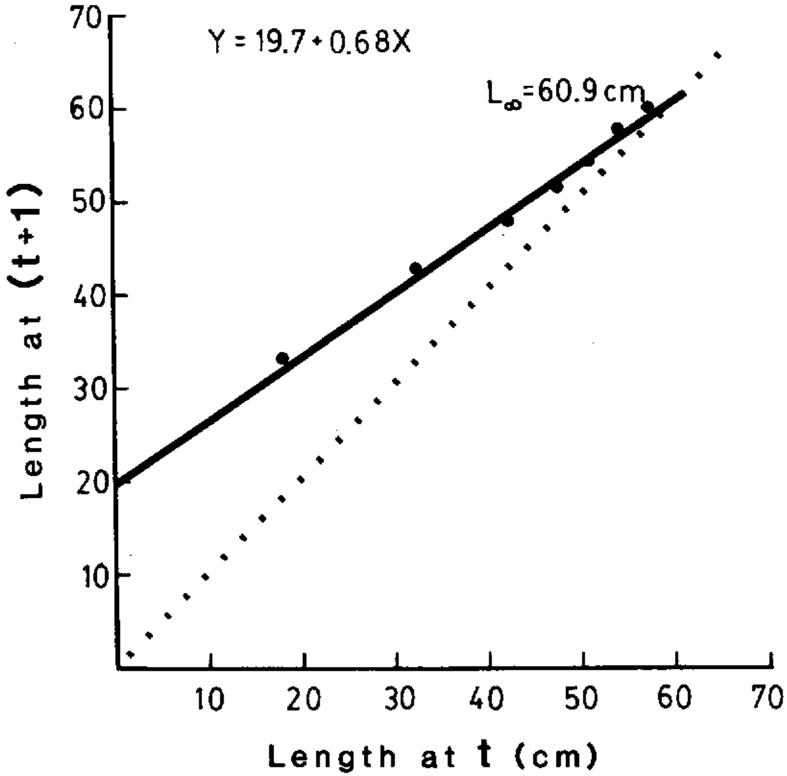

Figure 4. **Walford plot of the data from Table 7 for growth of northern pike in Lac Ste. Anne. The growth coefficient, K, is 0.39 and the L_∞ is 609 mm.**

(Brody 1945). All three methods (Ford-Walford, Gulland and Brody) assume exponential growth. In order to obtain an L_∞ value, one must first do a Walford or a Gulland plot. These two plots use the same data in slightly different ways. The resulting values for L_∞, K and t_0 are slightly different.

The von Bertalanffy growth equation (von Bertalanffy 1938) describes the asymptotic growth of fish. It has been widely used in fisheries management (Allen 1969).

$$l_t = L_\infty\{1 - \exp[-K(t-t_0)]\} \qquad (5)$$

where: l_t = length at age t
L_∞ = the asymptote or final maximum size,
K = the rate at which the growth curve approaches the asymptote, and
t_0 = a time scaler, the hypothetical time when the fish was size zero.

Graphical Fitting of the Growth Curve to the von Bertalanffy Equation

By taking logarithms of equation (5) above, we get:

$$\ell n(L_\infty - l_t) = (\ell n\, L_\infty + Kt_0) - Kt \qquad (6)$$

If you know L_∞, plot $\ell n(L_\infty - l_t)$ against t; the slope of the regression equation is equal to $-K$, and the y intercept is equal to $(\ell n\, L_\infty + Kt_0)$. To calculate t_0:

$$t_0 = (a - \ell n\, L_\infty)/K \qquad (7)$$

L_∞ can be determined from a Walford plot (l_{t+1} vs l_t). The slope of the Walford plot is e^{-k}.

See Misra (1986) for a method of comparing growth curves from different populations. A method for fitting growth curves to the von Bertalanffy equation has been described by Allen (1966).

Back-Calculation

Back-calculation involves estimating the size (usually length) of a fish at the time of formation of each annulus. This is equivalent to determining the length at each year of age for each fish sampled. This techinique has several advantages in studies of fish populations:

- It allows the biologist to obtain the maximum amount of data from each fish killed.
- It averages growth for each age over many year-classes of fish so that the data obtained are not for a single age-class as would be the case if samples were collected in one year and the size at age of collection were the only data obtained.
- The disadvantage, which is relatively minor, is that from a statistical point of view, the data obtained (i.e., length at each age for a single fish) are not independent; that is, several data points are obtained for each fish and these data points are not strictly independent of one another. Therefore, when one does statistical tests with the back-calculated data, the degrees of freedom used are based on the number of fish examined, not the number of observations (data points).
- Back-calculation is done by deriving a mathematical relationship between size and some linear dimension of the structure used for ageing the fish. The distance between the origin or focus of the ageing structure and the margin of the structure is measured for the population of fish being examined. This distance is plotted against length for each fish and a 'best fit' relationship is determined for the data using a least squares linear regression. Usually the length of the fish is plotted against distance from origin to margin of the ageing structure. Theoretically this relationship will be linear; and hence, a 'best fit' relationship between the two parameters can be determined using a least squares linear regression. The relationship between a linear dimension of the structure used for ageing and the weight of a fish theoretically is exponential so that a best fit relationship for this parameter would not be linear.

Once the relationship between fish length and some distance on the ageing structure has been determined, the length of the fish at the time of formation of each annulus can be determined from the distance between the origin of the ageing structure and the annulus using the equation derived above. All distances must be measured along the same plane of all the ageing structures and along the same plane as that used to determine the relationship between fish length and size of the ageing structure. A plane should be chosen which is perpendicular to the annuli (Figure 5).

The weight of individual fish at any age is much more variable than the length (Table 8); hence, if one wishes to determine mean weight at a given age, it is most accurate to back-calculate length at that age and then to calculate weight from a length-weight regression for the population.

Lee's Phenomenon

It has long been recognized that there are general relationships between growth rate and longevity. In general, fast growing individuals, and fast growing populations have shorter life spans (higher mortality rates) than slow growing individuals and populations. Lee (1912) first described this phenomenon for individuals within a population. He showed that in some populations the longest lived individuals had significantly slower growth rates than short lived individuals. Lee's phenomenon was reviewed by Ricker (1975). The implications of Lee's phenomenon for back-calculation of growth rate is that if Lee's phenomeon is present (it is not present in many populations), then the growth rates determined from back-calculation will be significantly slower than those for the population as a whole. The way to test for Lee's phenomenon in a population is to compare the back-calculated length of old individuals at some early age, two or three years old, to the average length of individuals at that age from the population. Use a Students' *t*-test to statistically test for differences. The population sample may be difficult to obtain since it should be collected at the time of annulus formation if the comparison is to be valid. In addition the collection techniques often used do not result in the capture of large numbers of young individuals. A less desirable but perhaps more practical alternative to the above test is to compare the lengths at a given age (e.g., age 3) back-calculated from younger individuals (say fish aged 4 to 6), to those back-calculated from older fish (e.g., age 7 years or older).

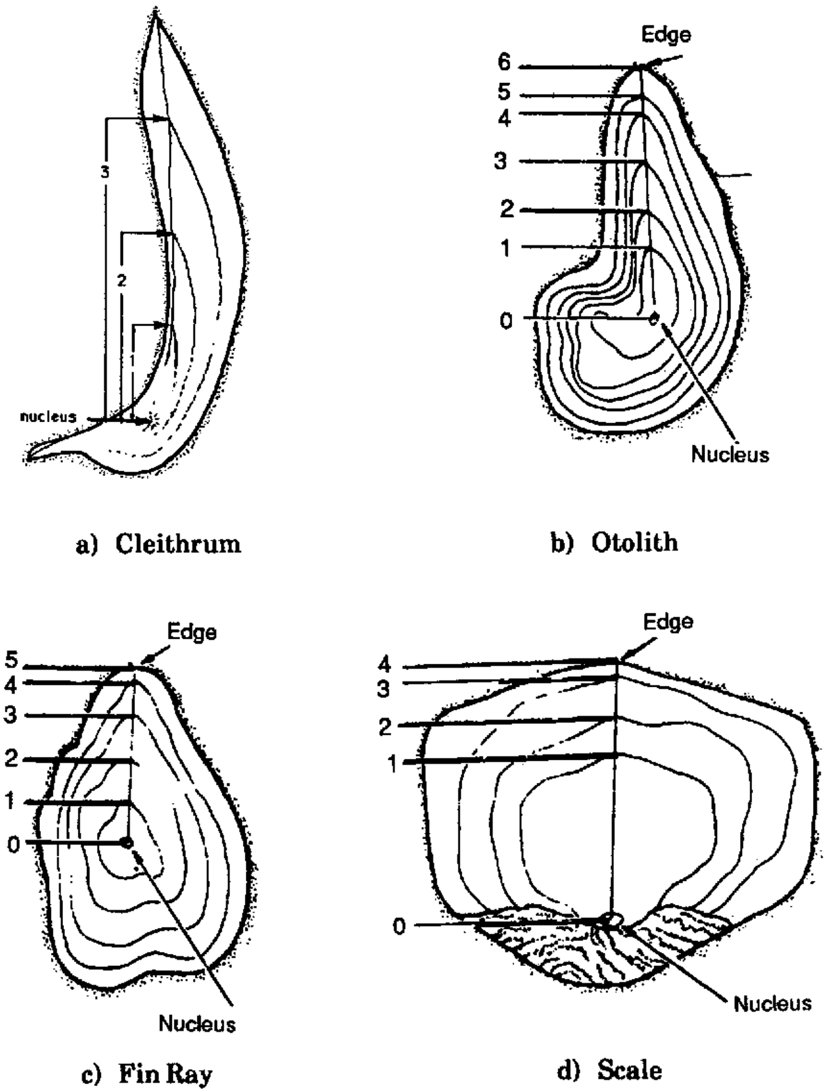

Figure 5. Structures used for back-calculating growth rate of fish.

a) cleithrum
b) otolith
c) fin ray
d) scale

Black line on each structure indicates the axis along which distance from origin of each annulus is measured.

Table 8. Growth in length and weight of yellow perch from Mink Lake, Alberta.

	Age								
	1	2	3	4	5	6	7	8	9
Total Length (mm) ± S.D.	96 ±12	128 ±14	142 ±20	159 ±23	183 ±46	208 ±44	234 ±21	239 ±20	240 ±44
Total Weight (g) ± S.D.	8.4 ±3.2	20.8 ±7.9	31.5 ±14.3	44.0 ±20.2	72.1 ±36.2	104.3 ±35.5	138.0 ±40.2	144.6 ±37.1	146.3 ±56.5
N	26	58	77	93	106	117	78	40	9

	Standard Deviation as % of Mean								
Length	11	8	14	13	28	19	9	8	17
Weight	38	38	44	45	51	35	29	26	39

Mean standard deviation in length = 14.1%.
Mean standard deviation in weight = 38.3%.

Length-Weight Relationships

For management purposes, it is often useful to compare the condition or 'fatness' of fish in a population to other populations, or to that in previous years, to assess the state of well-being of the population. As a fish population size increases and/or food resources decline, individual fish become thinner and the ratio of weight to length declines. This may indicate that the population is being underharvested (e.g., commercial fish harvest could be increased) or that some factor is affecting the food source (e.g., pollution, a major development, etc.).

The relationship between fish length and body weight is curvilinear, and normally follows the power function:

$$W = aL^b$$

where W = weight, L = length, and 'a' and 'b' are constants which are characteristic of the population being examined. The parameter 'b' reflects the rotundness of the fish or the rate at which weight increases for a given increase in length. In general, a value of 'b' less than 3.0 represents fish becoming less rotund as length increases, and 'b' greater than 3.0 represents fish that become more rotund as length increases. If 'b' is equal to 3.0, growth is isometric, meaning that shape does not change as fish grow.

The parameters 'a' and 'b' can most easily be calculated by making the relationship linear using a $\log_{10}$ or ℓn transformation of both length and weight; thus, the relationship between length and weight becomes:

$$\log_{10} W = \log_{10} a + b \log_{10} L$$

where $\log_{10} a$ is the *y*-intercept of the regression line, and b is the slope. These parameters can be estimated from a sample of lengths and weights from individual fish using a least squares or geometric (GM) regression technique. Ricker (1975) describes the methodology for the GM regression technique, and recommends its use. In practice, however, the least squares technique is most often used since it can be done easily on most scientific calculators or simple statistical programs on a computer. Since differences often exist in the body weight to length relationship for males and females, the length-weight regression should be calculated separately for the two sexes. The relationship also changes throughout the growing season (especially for females) as gonad weight increases, so care should be taken when comparing various data sets.

Prior to conducting a length-weight regression analysis, the length and weight data (or $\log_{10}$ length and $\log_{10}$ weight data) should be plotted in a scatter diagram to spot 'outliers'. These are values that are outside the normal scattering of the data points. These values should first be checked for accuracy (e.g., did someone forget a trailing zero in the weight or possibly a leading '1'?). If the data are found to be accurate, a decision will have to be made to determine if the data for the fish in question should be excluded. Is the individual fish a sick (e.g., very skinny) or a very fat (possibly sterile) animal which is not representative of the population? One such value in a data set, particularly if it is at the high end or low end of the range, can have a substantial effect on the regression equation. One method that is helpful may be to calculate the regression equation both with and without the 'outliers' and judge the effect on the regression equation.

In calculating a regression equation, care should be taken to ensure that a large enough sample is used (a rule of thumb often used is that $n \geq 30$). Also, the range of the size of fish used in calculating the relationship should be as wide as possible (e.g., use data from young-of-the-year up to the largest size fish wherever possible). There should also be a uniform distribution of fish over the whole size range of the population. Data that are clumped should be avoided. Always report the sample size used (n), and the coefficient of determination (r^2) which is a measure of how well the regression line explains the scattering of the data points.

Another index that has been used in the past to compare the well-being or condition of a fish population is the Fulton-type Condition Factor which is calculated as follows:

$$K = \frac{W \times 10^5}{L^3}$$

where K = condition factor (metric units), W = weight in grams, L = length in millimetres, and 10^5 is the metric scaling factor to bring the index to near 1.0. Note that C has been used in the past instead of K where imperial units (i.e., lbs and inches) were used, and 10^4 was used as the scaling factor. Normally this parameter is expressed as the mean K for a group of fish (e.g., a given age-class, males or females, etc.) along with the related statistical parameters (e.g., SD, SE, or 95% CI).

Several other indices of well-being have also been used in specific studies (e.g., relative condition factor; relative weight); however, their limited use precludes presentation in this document. For further discussion on these, see Nielsen and Johnson (1983) or Ricker (1975).

Comparisons of Length-Weight Relationships Between Populations

Comparisons of well being of fish populations have traditionally used mean condition factors. Recent trends in Alberta have been to use analysis of covariance to statistically compare the regression equations for the length-weight relationships between populations. This analysis determines whether the regression lines are statistically different, and so involves the test of both the slopes (i.e., is the 'b' value from one population significantly higher or lower than from the other test population) and the intercepts (i.e., is the $\log_{10}$ 'a' value from one significantly different from the other).

To perform analysis of covariance, a number of additional parameters used in the calculation of the least squares regression must be recorded during the calculations. For a more complete discussion of the mathematics of the analysis of covariance to determine differences in linear-regression equations, see Appendix A.

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CHAPTER 4

APPROACHES TO AGEING FISH

The ageing technique(s) chosen for a particular study will be dictated by the purpose of the project or study and the population being studied. In order to compare data collected at different times or from different places, common conventions must be established for reporting age. The purpose of this chapter is to establish appropriate criteria and to develop conventions for reporting age. Careful consideration of the techniques to be used will facilitate the gathering of data and optimize the quality of the data obtained. Other references which should be consulted when undertaking a study of fish growth are: 'Fisheries Techniques' (Nielsen and Johnson 1983) and 'Methods for Assessment of Fish Production in Fresh Waters' (Bagenal 1978).

Empirical

This method relies on the direct measurement of fish growth over some known period of time, in specimens that are either held in aquaria or are marked, released and later recaptured.

Due to the physical and financial constraints of holding fish in aquaria, only small numbers of specimens can be kept. The measured growth of small numbers of fish must be extrapolated to the full size range of the species under natural conditions. This technique is further troubled by the impossibility of duplicating conditions experienced by fish in nature.

More useful data can be obtained from fish stocked into natural water bodies where successful reproduction of those fish will not occur. In this case the fish stocked are of known and similar size and age. Growth rate can be determined by sampling the population at any time following stocking. In Alberta, this technique could be applied to situations in which large numbers of trout or walleye of one size and age are stocked into a waterbody which is barren of that species.

Typical examples where this technique might apply are trout stocked into aquatic habitats as varied as prairie potholes and subalpine mountain lakes. Caution must be exercised when interpreting data from such populations because growth rates are affected by the density of fish in the water body. Variations in size can also occur if the 'grading' and 'sorting' of the fish was not carefully controlled prior to stocking.

Growth rates can also be obtained from wild fish which are captured, length and weight recorded, tagged and released back into their natural habitat. When tagged fish are recaptured at a later date their growth rate in the interval can be determined. Studies of tagged wild fish are difficult to interpret over the whole range of fish lengths. Typically these studies are done on large old fish which show the relatively small growth increments in length or weight that are normal in adult fish. These studies will be deficient if they do not define the growth that occurs during the first year of life as this is the value which is most difficult to determine and verify in studies of growth.

Length-Frequency Distribution

The simplest method of determining age, and hence growth rate using length-frequency analysis is called the Petersen method (Petersen 1892; Bagenal and Tesch 1978). Length intervals are plotted along the x-axis of suitable graph paper and the numbers of fish, from a totally random sample of the population is plotted on the y-axis. For this technique to be useful all sizes of fish must be sampled in proportion to their numbers in the population. When the data are plotted in this way, a peak will be present for each of the first few year-classes. The peak closest to the y-axis would represent age zero fish and each peak after that should represent another year-class. The size intervals chosen for plotting these data are particularly important in this analysis. If the size intervals are too large peaks will be obscured; too small and they will also be obscured.

This technique requires a large number of fish which are an unbiased sample of the population (Majkowski and Hampton 1983). Appropriate collection methods must be used to obtain an unbiased representative sample of the population. This technique is plagued by a number of problems. Small, age zero (young-of-the-year) fish may easily be missed by even fine meshed seines while larger fish may segregate between habitats and hence be missed. Dominant year-classes may obscure the small peaks of weaker year-classes. Divergent growth rates of male and female fish complicate the analysis as does the small incremental changes in length which occur in mature fish.

Nevertheless, the Petersen technique is often useful in determining growth rates during the first few years of life, particularly where methods are available which allow for the collection of large numbers of small, young fish. Inclusion of fish which are known to be age zero (young-of-the-year) is crucial to this and all ageing studies.

A summary of additional graphical and statistical methods that can be used to sort length-frequency data sets can be found in Nielsen and Johnson (1983, page 320).

Anatomical Structures

Counting bands (annuli) on hard structures is the most common method of determining fish age. It relies on the use of bony structures in which mineralized layers of different density are deposited during the course of the annual growth cycle. In general, a dense layer is formed during each summer growth phase and this alternates with a less dense band which is deposited during the winter when growth is very slow or undetectable. The overall result of this sort of growth pattern is a series of alternating light and dark bands on the fish's hard body structures similar to the rings seen on tree trunks.

There are probably few hard structures on fish that have not been examined in order to determine fish age. In this manual we describe the use of many different hard structures. However, determining the age of a fish or a population of fish requires more than just counting the bands or annuli seen on the hard structures. Criteria must be established which define an annulus and when it is formed.

Annulus Definition

Rapid summer growth in fish is correlated with the deposition of dense, wide mineral bands in bones and by widely spaced circuli on scales. Slow winter growth appears as narrow, less dense bands in bone and as

Summer Growth

- opaque zone
- wider bands
- dark under transmitted light
- white under reflected light

Winter Growth

- hyaline zone
- narrow bands
- white under transmitted light
- dark under reflected light

crowded, narrow, often incomplete circuli on scales. Summer growth bands will appear white or opaque when viewed against a dark background under reflected light, that is, light shone directly onto the surface being viewed from the same side as it is being viewed. Winter bands will appear dark and narrow under the same conditions. This appearance will be reversed when the bone is viewed with transmitted light, that is, light which passes through the bone toward the viewer. With transmitted light, the wide bands deposited during the summer appear dark while the narrower bands laid down during the winter are light. As a result of this reversal in appearance of the bands depending on the nature of the illumination used to view them, the summer growth band is called the *opaque zone* and the band laid down during the winter is called the *hyaline zone*. The terms light and dark bands or light and dark zones should not be used because of the ambiguity which can arise (Bagenal and Tesch 1978).

The yearly annulus is defined as having been formed or as being complete when new summer growth is visible beyond the hyaline band that was laid down during the winter. New summer growth appears more quickly in cleithra, opercular bones and scales than in fin ray sections. This is not because of differential growth but rather it is an artifact of the preparation of the different structures. All soft tissue is removed from cleithra, opercular bones and scales before they are examined while in the case of fin rays, soft material is not removed thus, it is more difficult to clearly observe new growth on fin rays than on the former structures. Such factors are particularly important if one of the objectives of your study is to determine the time of annulus formation.

Young fish typically deposit new growth on these hard structures earlier than older fish. This may be due to the great metabolic input required in the adult fish to bring their bodies, particularly of spring spawners, back to the level of condition which existed when they were in peak condition during the winter.

Reporting Ages of Fish

- **Standard**: January 1 should be used as the 'birth date' of fish in Alberta. Ages should be reported in Arabic numerals (e.g., Age 2) and the year of hatching should be reported.

It is important to know the year-class (year of hatching) in order to compare growth rates, survival, etc. Since there is annual and geographic variation in the time of annulus formation, standardization of birth date to January 1 avoids confusion when comparing data sets, and ensures that all fish hatched in a single calendar year would be given the same age. Fish caught after January 1 but prior to annulus formation would be assigned an age which was one year greater than the number of annuli present. Using this method, a fish caught in February (prior to annulus formation) would be assigned the same age as if it had been caught in July (after annulus formation). It is very difficult to identify new growth on old fish because annuli are crowded at the margin; hence, very careful counting of annuli is required if accurate ages are to be obtained for old fish. Whenever possible it is preferable to collect samples very early in the spring or in late fall after the water temperatures have cooled and growth has slowed. By collecting samples very early or late in the growing season, the period of annulus formation will be avoided. This would also avoid the general period of rapid growth and thus samples would be more uniform.

The following example of age assignment for a fish hatched in spring 1988 (i.e., 1988 year-class) is based on the January 1 standard 'birth date' discussed above.

Date Caught	Age
December 25, 1988	0
January 2, 1989	1
May 1, 1989	1
September 30, 1989	1
December 31, 1989	1
January 1, 1990	2

Although some investigators use the '+' designation to indicate that new growth has occurred, the use of a standardized birth date eliminates the need for the '+' designation unless the specific timing of annulus formation is being determined.

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CHAPTER 5

AGE VALIDATION TECHNIQUES

Accurate age determination is essential for assessment of growth and maturity to enable comparison of fish populations, and ultimately for the formulation of management strategies. The most useful body structures for ageing fish are ones that:

- are easy to collect and prepare,
- do not require excessive equipment for examination,
- show distinct annuli with a minimum of false annuli, and
- can be used to back-calculate length-at-age (i.e., structures where size can be mathematically related to fish length).

For most fish species, scales are the easiest structures to remove and prepare for ageing. They have remained the standard ageing structure for many fish species in North America despite some major negative characteristics. These include the presence of false annuli, scale resorption and regeneration (Bagenal and Tesch 1978; Deelder and Willemse 1973; Ottaway and Simkiss 1977; Joeris 1956), and failure to form annuli on the scales (Schneider 1972). Some of these problems are probably due to the ability of teleosts to demineralize the scales if calcium is required for other body functions; however, fish are not able to recycle calcium deposited in their acellular bones (Simkiss 1974). Since formation of the hyaline and opaque zones of fish bones is partially due to the incorporation of different amounts of calcium (Casselman 1974), these structures sometimes hold more promise than scales for accurate ageing results.

The best method of validation is to collect and analyze the ageing structure of choice from known young-of-the-year fish either in the fall or very early in their second spring. Fish raised in hatcheries and then stocked can have very unusual 'annulus' patterns. The best way to avoid this problem is to keep samples from a few fish at the time of stocking.

Other common age validation techniques to check your data include:

- comparison with the growth of tagged or captive raised known-age fish,
- comparison with other published results of fish growth from similar habitats,
- comparison with a length-frequency analysis of your data,
- comparison of your data with the data from the same fish aged with a different structure,
- back-calculation of size, or
- Walford plots.

For a description of the use of back-calculation and Walford plots, see Chapter 3 of this manual.

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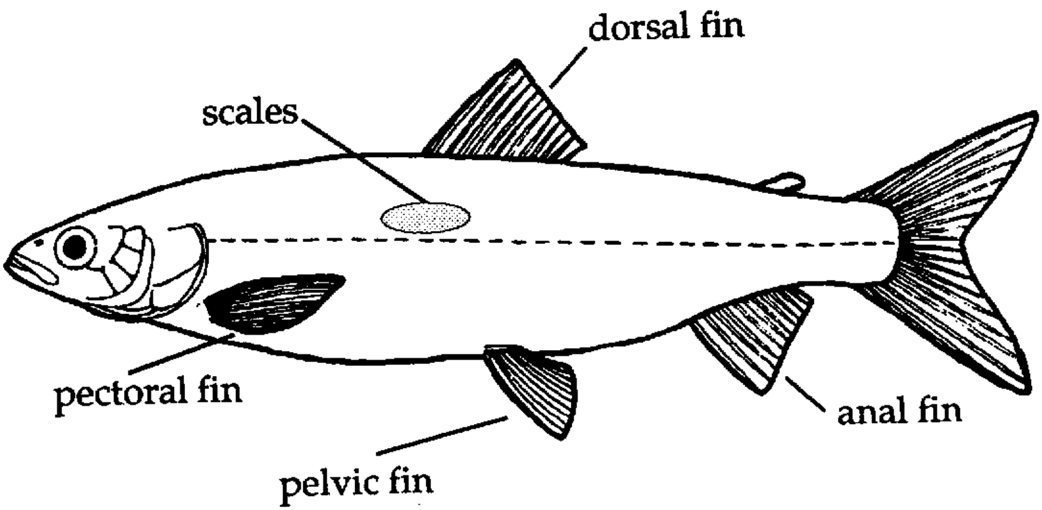
CHAPTER 6

FISH AGEING TECHNIQUES

Species Recommendation

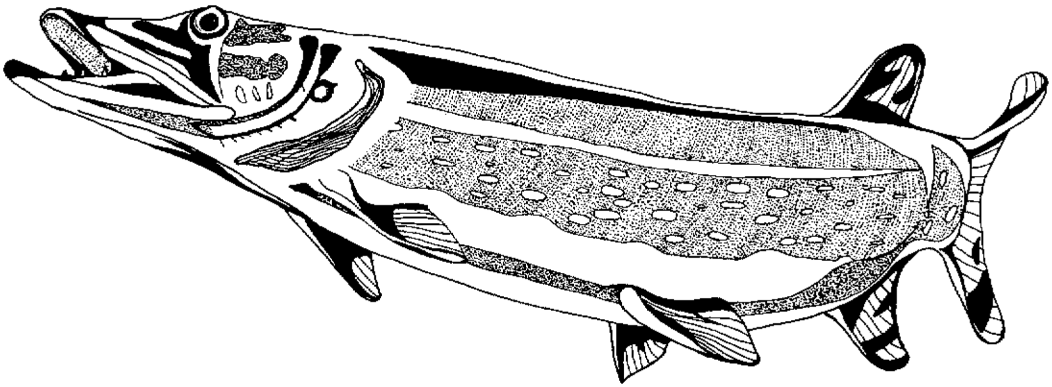
A variety of structures are recommended in this manual for ageing fish.



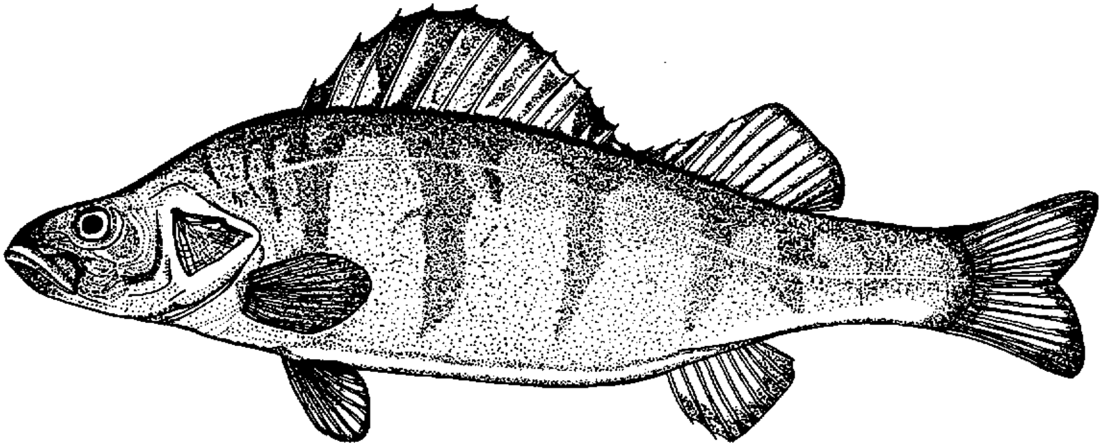
a) Cisco

Figure 6. Location of structures used for ageing fish.
- a) fins and site of scale collection
- b) cleithrum
- c) operculum

For location of otolith, see plate 17 on page 87



b) Northern pike



c) Yellow perch

LAKE STURGEON

(*Acipenser fulvescens*)

Key Contributors: Curtiss McLeod, Larry Hildebrand, Gary Ash

Preferred Structure:

Proximal end of the first pectoral fin ray (non-lethal). Slit the integument between the marginal and the second fin ray with a knife and use a bone cutter to severe the marginal fin ray. Care must be taken in removal of the fin ray; if taken too close to the fin articulation the fin artery will be cut and excessive bleeding can occur. Recent studies on lake sturgeon recommend severing the fin ray 3-5 mm from the point of articulation with the body wall to maximize reliability of age data (Wilson 1987).

For collecting pectoral fin ray samples from live fish we prefer the method employed by Beamesderfer et al. (1989) for white sturgeon. This technique collects a piece of the leading pectoral fin ray by making two cuts with a fine-tooth hacksaw, the first within 5 mm of the articulation of the fin, and the second approximately 10 mm distal to the first cut. The integument is slit behind this piece, and it can be twisted free with pliers. This section of the fin will heal over and regenerate.

Secondary Structure:

Viable alternate structures for validation of fin ray ages of live sturgeon do not exist. Other bones that have been used to age sturgeon (lethal) include otoliths, cleithra, clavicles, and scutes (Cuerrier 1951). Because of calcium resorption, otoliths are the only other reliable bony structure for ageing sturgeon, and have been successfully used by several investigators (Harkness 1923; Schneberger and Woodbury 1944).

Time of Annulus Formation:

Presumed to be June-July (Sunde 1961; Nelson River, northern Manitoba). In Alberta, annulus formation probably occurs in mid to late June.

Special Preparation and Storage:

Fin rays should be thoroughly dried before sectioning. For fin rays that have been removed at the articulation, the first section should be taken from the point where the flared portions of the joint narrow to form the solid ray. For fin rays removed above the articulation, the first section should be taken as close to the cut as possible. Sections from older individuals should be 0.3 to 0.5 mm thick, although sections up to 1.0 mm thick are readable in younger specimens. Wilson (1987) indicated that fin ray sections mounted using a permanent mounting medium tended to become opaque over time; however, sections mounted with Diatex medium in 1985 and stored dry were readable up to three years later (R.L. & L. Environmental Services Ltd., unpubl. data). Beamesderfer et al. (1989) mounted readable sections on glass microscope slides using clear fingernail polish, leaving the exposed side without a coating of polish.

Ageing Considerations:

The first annulus is a distinctive star shape (Plate 1). If the section was taken too far from the articulation, the first annulus may not be visible, but can usually be identified by the presence (under transmitted light) of lighter patches that form the points of the star. Best ageing result are obtained by reading along the posterio-lateral region of the section where the annuli are spaced farthest apart. Double annuli and false or incomplete annuli are common, and it is often necessary to follow the annulus around the section to determine if it is one annulus or two separate annuli. False annuli have a tendency to fade out and are not as continuous as true annuli. Wilson (1987) suggests cutting sections of varying thickness, especially in older fish, and using more than one section to determine age.

Roussow (1957) reports that bonding or clumping (several years of closely spaced annuli) of annuli in sections from older sturgeon was common. He attributed these patterns to differences in growth prior to and after spawning. From fin ray sections, he was able to not only determine age and periods of unfavourable growth but also intervals between spawning periods, age of first spawning, and the sex (due to different maturation rates between sexes). In sturgeon from the South Saskatchewan River, the first narrow band of slow (i.e., pre-spawning) growth is easy to identify, but the number of annuli in subsequent bands is difficult to determine (i.e., several narrow annuli may appear as one thick annulus) (R.L. & L. Environmental Services Ltd., unpubl. data). Ages of older individuals, therefore, should be considered as minimum ages.

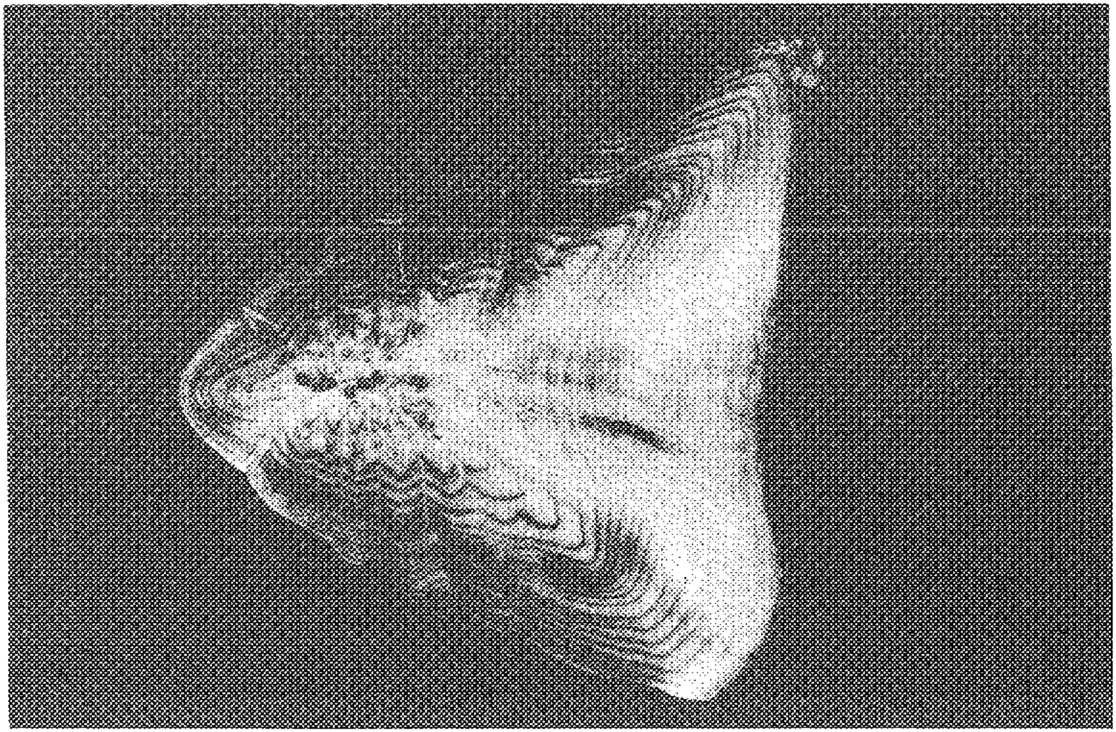


Plate 1. Cross section of a fin ray from a 20 year old lake sturgeon from the South Saskatchewan River (photo by Don Fritts).

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ARCTIC GRAYLING

(*Thymallus arcticus*)

Key Contributor: Don Schroeder

Preferred Structure:

Scales (non-lethal) (Plate 2) from the left side of the fish between the front edge of the dorsal fin and the lateral line. Take 10-15 scales. Old fish may be difficult to age with scales. Harper (1948) caught young fish in Neultin Lake, N.W.T., that were 64 mm long by late August but still did not have scales. If scale formation does not occur during the first year, then the older Arctic grayling will be under aged by one year.

Secondary Structures:

Sagittal otoliths (lethal) or pectoral fin rays (non-lethal).

Time of Annulus Formation:

Mid-May to mid-June.

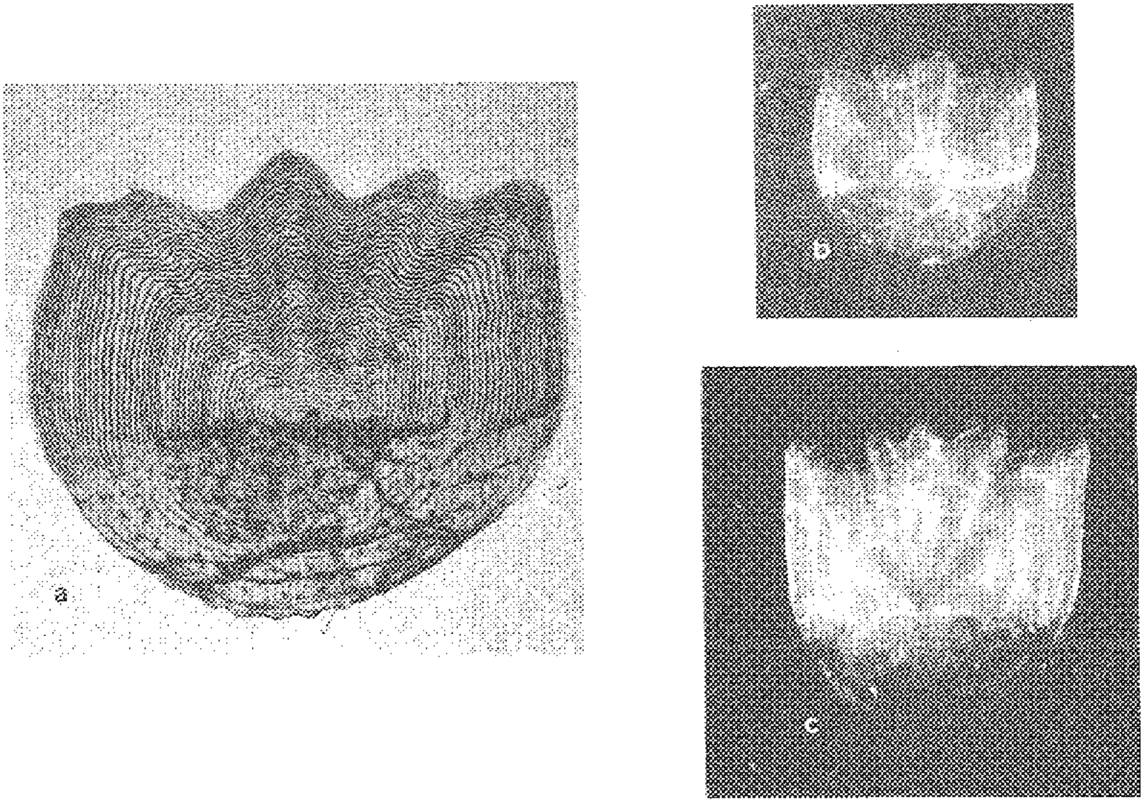

Plate 2. **Scales of Arctic grayling.**
a. an easily read three year old fish caught in mid August.
b. a four year old fish from the Kakwa River caught in mid September.
c. a seven year old fish from the Otter River caught in mid May.

Note how the use of appropriate magnification makes the first scale much easier to read.

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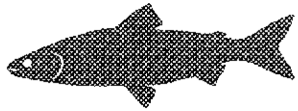
CISCO[1]



Cisco; lake herring: *Coregonus artedii*
Shortjaw cisco: *Coregonus zenithicus*

Key Contributors: Don Schroeder and Jim Stelfox

Preferred Structure:

Slow-growing fish - sagittal otoliths (lethal) require breaking and toasting when the peripheral annuli become crowded (Plate 3).

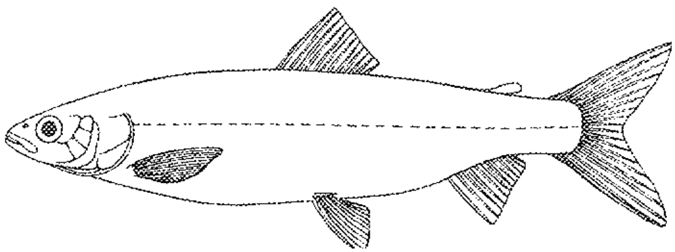
Fast-growing fish - scales (non-lethal) from the left side of the fish between the front edge of the dorsal fin and the lateral line. Take 10-15 scales. Old fish may be difficult to age with scales (Plate 3).

Secondary Structures:

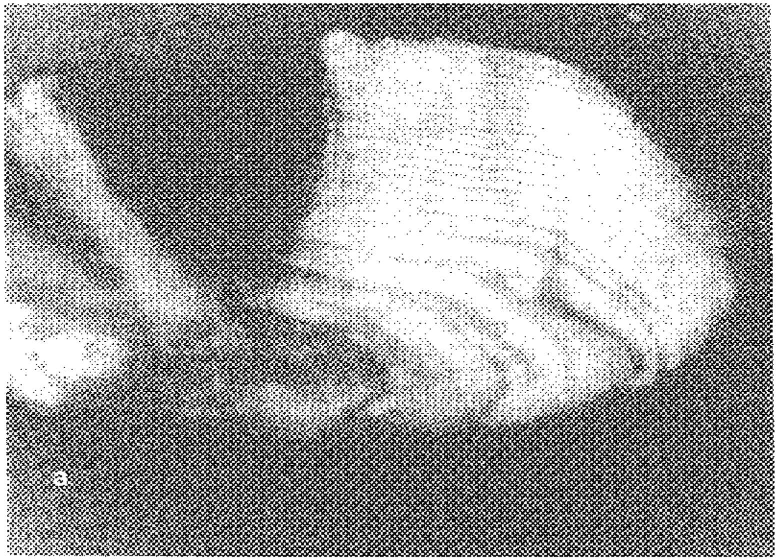
Sagittal otoliths (lethal).

Time of Annulus Formation:

Mid-May to mid-June.



[1] often called tullibee in Alberta but this is not a common name recognized by the American Fisheries Society.



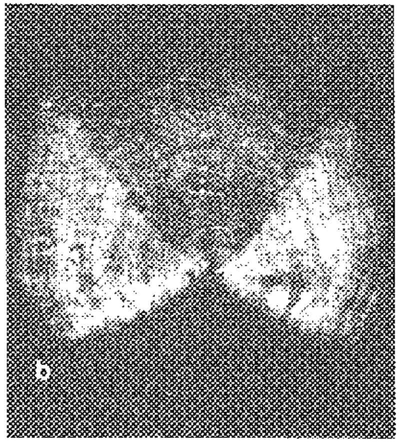


Plate 3. Otolith and scale from cisco.

a. otolith from a 25 year old cisco from Whitemans Pond (June 6, 1986). The last annulus is at the outer edge.

b. scale impression of an eight year old cisco from Utikuma Lake (March 6, 1979).

References:

Aass, P. 1972. Age determination and year-class fluctuations of cisco *Coregonus albula* L. in the Mjosa hydroelectric reservoir. Rep. Inst. Freshwater Res. Drottningholm 52: 5-22.

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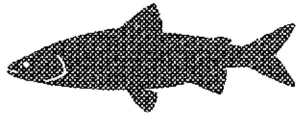
LAKE WHITEFISH



(*Coregonus clupeaformis*)

Key Contributors: Dave Berry and Dick Brown

Preferred Structure:

Slow-growing fish - sagittal otoliths (lethal).

Fast-growing fish - scales (non-lethal) from the left side between the front edge of the dorsal fin and the lateral line. Take 10-15 scales. Old fish may be difficult to age with scales. Some populations in which problems have been encountered using scales include Lesser Slave Lake (slow growth), Lake Athabasca (migrate in lake and river habitats), Wabamun Lake (possibly influenced by heated effluent), and probably some southern populations with access to irrigation canals.

Secondary Structures:

Use pelvic fin rays for non-lethal samples but sagittal otoliths are preferred. The latter may require grinding, or breaking and toasting. Opercular bones also appear to be promising structures for ageing lake whitefish.

Time of Annulus Formation:

May - June.

References:

Barnes, M.A., and G. Power. 1984. A comparison of otolith and scale ages for western Labrador lake whitefish. Environmental Biology of Fishes 10: 297-299.

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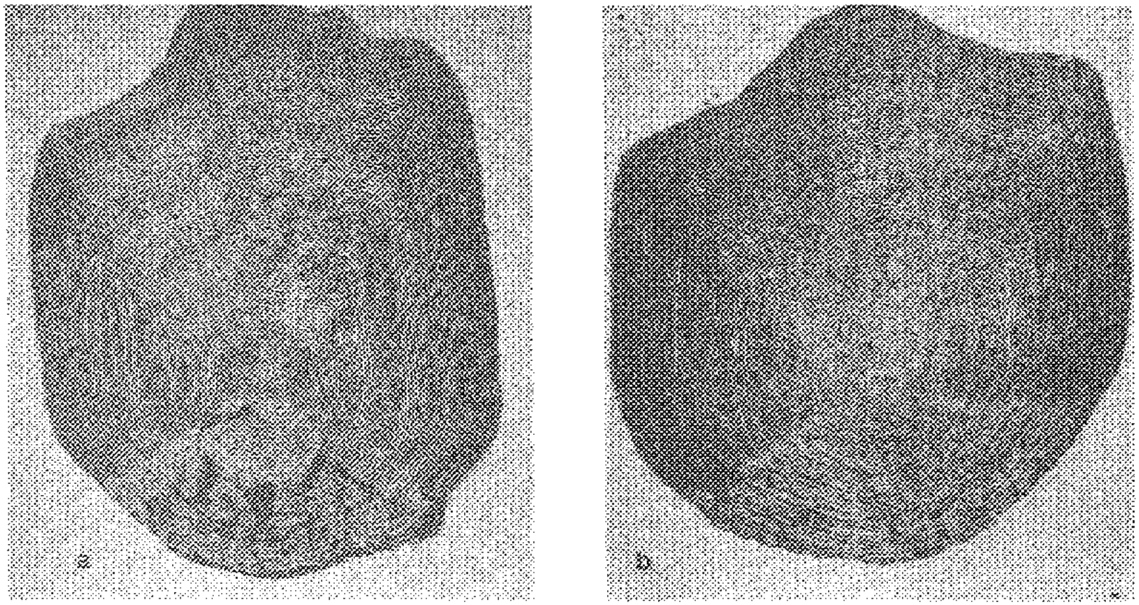
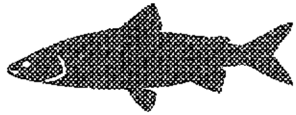


Plate 4. Scales from a five year old, fast growing, and an eight year old, slow growing, lake whitefish (August 25, 1979).

MOUNTAIN WHITEFISH



(Prosopium williamsoni)

Key Contributor: Wes English

Preferred Structure:

Scales (non-lethal) from left side between the dorsal fin and the lateral line. Take 10-15 scales. Thompson (1974) found that young mountain whitefish from the Sheep River, Alberta, had complete scale development when they reached a length of 50-65 mm. These fish grew to a length of 80 mm by mid-October. Larger (100 mm) young fish that were also caught were believed to have been migrating upstream from richer, warmer downstream waters. The mean back-calculated length from over 300 fish was 71 mm at first annulus.

Thompson (1974) found excellent agreement between scale and otolith readings for 30 fish between 200 and 415 mm in length.

Thompson's (1974) and Sigler's (1951) respective factors for converting from fork length to total length were 1.0936 and 1.0599, and from fork length to standard length were 0.9202 and 0.9099.

Secondary Structure:

Sagittal otolith (lethal). These may require grinding, or breaking and toasting. Fin rays may work for a non-lethal sample.

Time of Annulus Formation:

Thompson found that it was complete by the end of May and one fish had formed its annulus by April 24.

References:

Thompson, G.E. 1974. The ecology and life history of the mountain whitefish *Prosopium williamsoni* (Girard) in the Sheep River, Alberta. M.Sc. Thesis, Univ. of

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Sigler, W.F. 1951. The life history and management of the mountain whitefish, *Prosopium williamsoni* (Girard) in Logan River, Utah. Bull. 347. Utah State Agr. Coll. Logan, Utah. 21 p.

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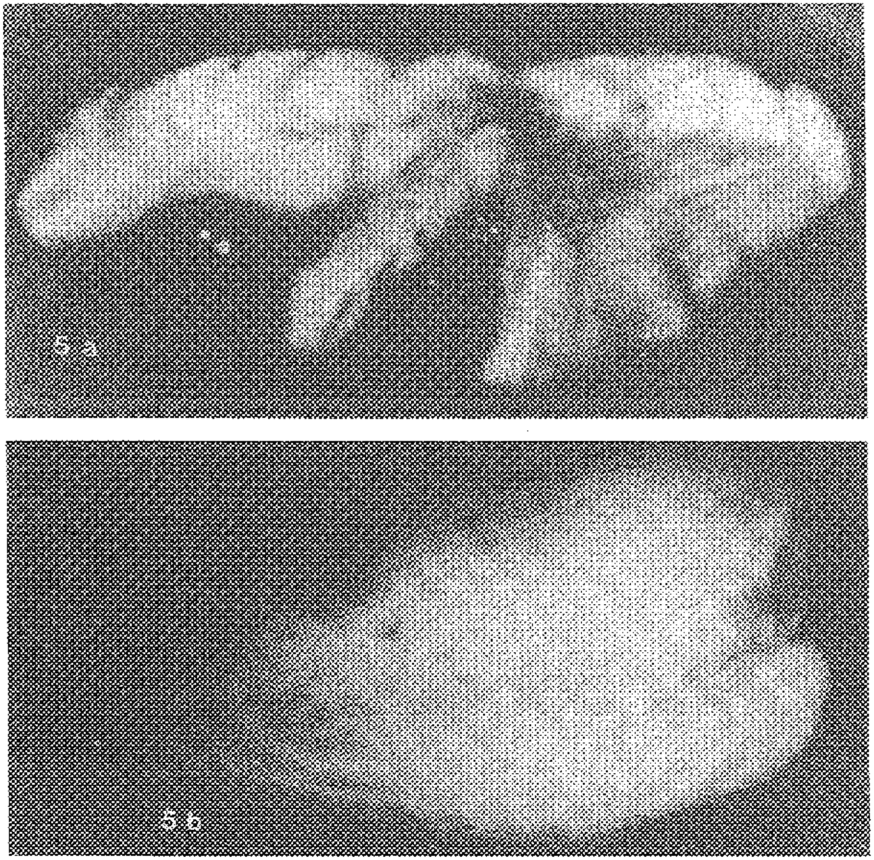

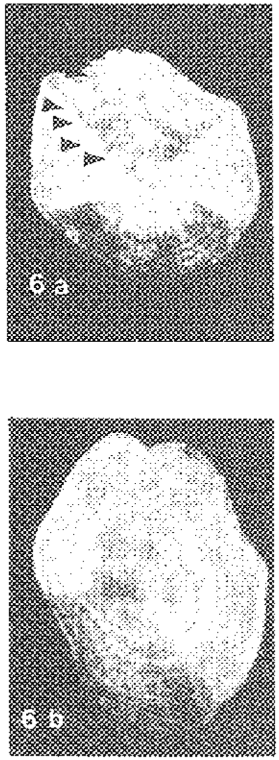

Plate 5. Otolith from 26 year old mountain whitefish from Spray Lakes (September 17, 1986).
a. cross-section of toasted otolith.
b. whole otolith.

Plate 6. Scale of a five year old mountain whitefish from the Oldman River (August 16, 1985).

LAKE TROUT

(*Salvelinus namaycush*)

Key Contributors: Gary Ash, Jim O'Neil, and George Walker

Preferred Structures:

Non-lethal - proximal end of the first three pelvic fin rays.

Lethal - sagittal otoliths that will require grinding or sectioning.

Secondary Structure:

Scales are useful for ageing immature lake trout (Sharp and Bernard 1988).

Time of Annulus Formation:

Presumed to be early summer. Cable (1956) found that only 50% of Lake Michigan lake trout show new growth on scales by June.

Plates for lake trout unavailable. Please refer to the plates for the lake whitefish, mountain whitefish and for the trout species that follow.

References:

Bulkley, R.V. 1960. Use of branchiostegal rays to determine age of lake trout, *Salvelinus namaycush* (Walbaum). Trans. Am. Fish. Soc. 89(4): 344-350.

Cable, L.E. 1956. Validity of age determination from scales, and growth of marked Lake Michigan lake trout. U.S. Fish and Wildl. Serv., Fish. Bull. 107, 57: 1-59.

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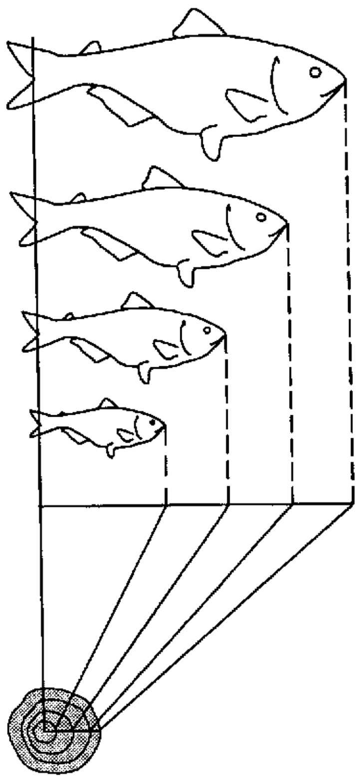
Dubois, A., and R. Lagueux. 1968. Comparative study of the age as determined by scales and otoliths of the lake trout (*Salvelinus namaycush*) of Lake Mistassini, Quebec. Nat. Can. 95: 907-928. Fish. Res. Board Can. Trans. Series. 2883.

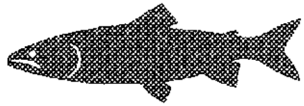
Kennedy, W.A. 1954. Growth, maturity and mortality in the relatively unexploited lake trout, *Cristivomer namaycush*, of Great Slave Lake. J. Fish. Res. Board Can. 11: 827-852.

Power, G. 1978. Fish population structure in Arctic lakes. J. Fish. Res. Board Can. 35 (1): 53-59.

Sharp, D., and D.R. Bernard. 1988. Precision of estimated ages of lake trout from five calcified structures. N. Am. J. Fish. Manage. 8(3): 367-372.



BULL TROUT[1]



(*Salvelinus confluentus*)

Key Contributors: Jim Allan, Rudy Hawryluk, and Don Hildebrandt.

Preferred Structure:

Otolith - may require grinding or sectioning (Plate 7).

Time of Annulus Formation:

Time of formation is probably mid-May to mid-June; however, it may occur even later in high altitude lakes where break-up doesn't occur until late June.

General Comments:

Ageing of bull trout using otoliths has a major disadvantage in that the fish must be sacrificed. Careful consideration, therefore, must be given to the possible benefits in better managing bull trout populations before such sampling is undertaken. If and when lethal sampling is justified, otoliths are the best method for age determination, particularly in younger fish; however, problems may be encountered with larger, older fish when the annuli are close together. Scales generally are not suitable for ageing bull trout.

References:

Hildebrandt, D. 1982. Preliminary survey of Mystery Lake (24-48-26-5). Alta. Fish and Wildl. Div., Edson. MS. Rep.

__________. 1986. A preliminary biology survey of an unnamed (Saracen) lake (SW8-43-20-5). Alta. Fish and Wildl. Div., Edson. MS. Rep.

__________. 1989. Preliminary investigation of bull trout spawning activity in an unnamed lake (23-55-12-6). Alta. Fish and Wildl. Div., Edson. MS. Rep.

Sterling, G.L. 1978. Population dynamics, age and growth of rainbow trout and Dolly Varden in the Tri-Creek Watershed, 1971-1977, Alta. Fish and Wildl. Div., Tri-Creeks Watershed Study Rep. No. 2. Alta. Fish and Wildl. Div.

[1]Previously called Dolly Varden.

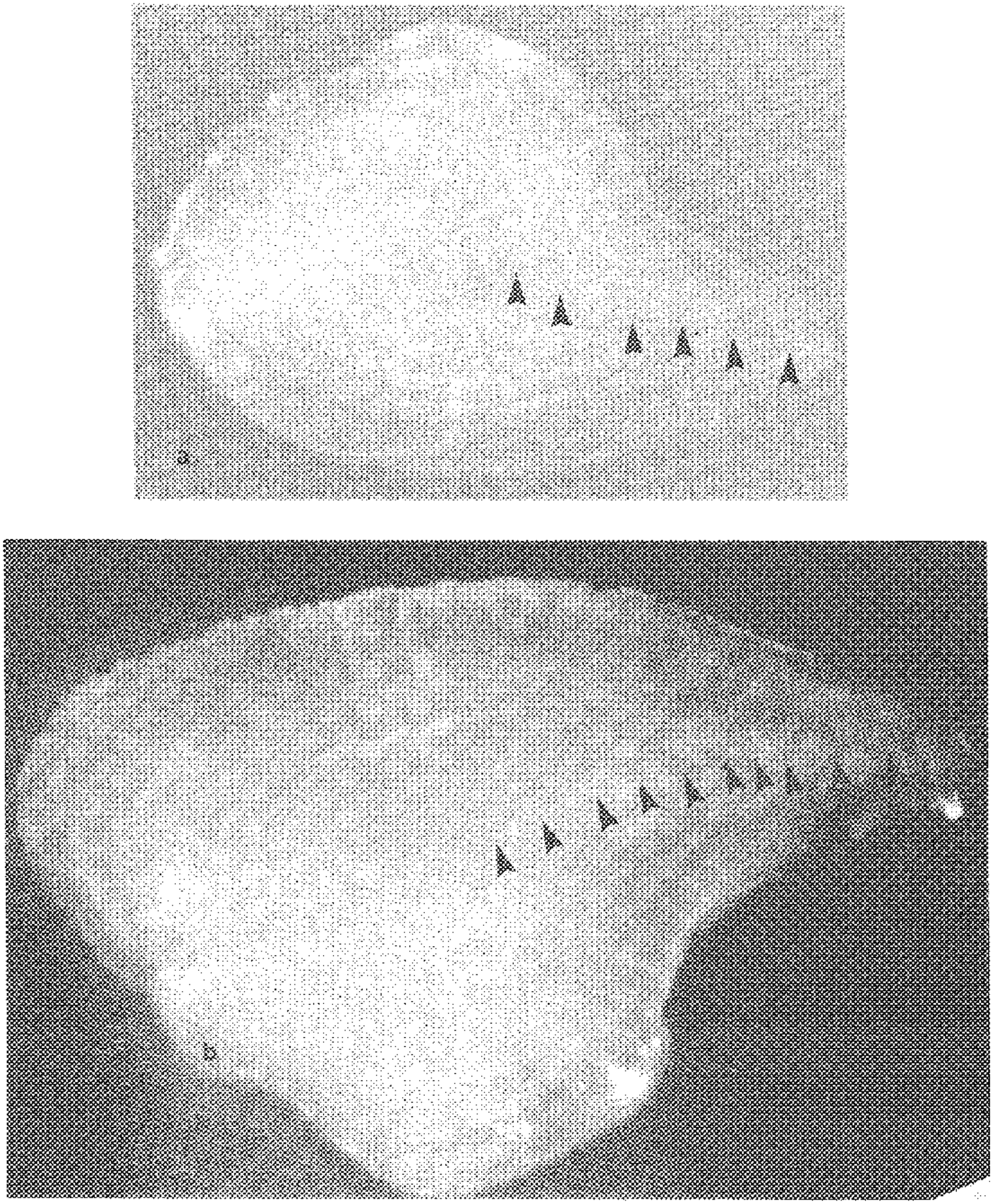


Plate 7. Whole otoliths of bull trout from Mystery Lake (October 17, 1982).
a. 6 year old fish.
b. 12 year old fish.

BROOK TROUT

(*Salvelinus fontinalis*)

Key Contributors: Larry Rhude and Jim Stelfox

Preferred Structure:

Otoliths (lethal) which are viewed laterally for young fish but may require grinding, or breaking and toasting for old fish. Note - if you are dealing with stocked populations, it is best to sacrifice a few fish at the time of stocking. Keep the ageing structures from these known-age fish for comparison with future samples.

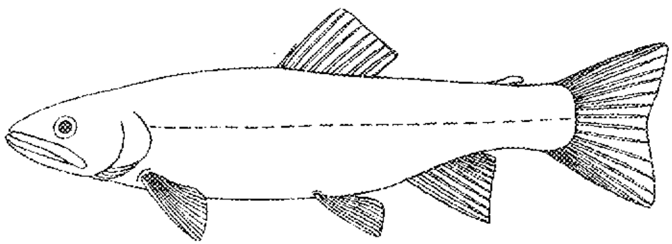
Secondary Structure:

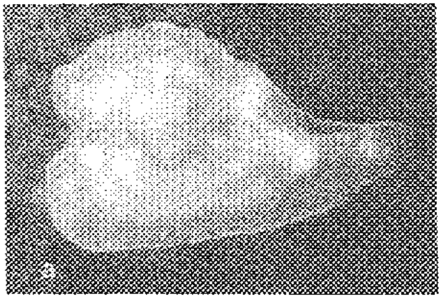
Scales (non-lethal) taken from the left side of the fish between the dorsal fin and the lateral line. Due to their small size they are generally only reliable for young, fast growing trout. This method should not be used to age trout older than three years of age.

Time of Annulus Formation:

Presumed to be May - June.

McFadden (1959) found that in Wisconsin, over half of the brook trout had laid down an annulus on scales by mid-April, and that younger fish appeared to lay down an annulus earlier in the spring than older trout.





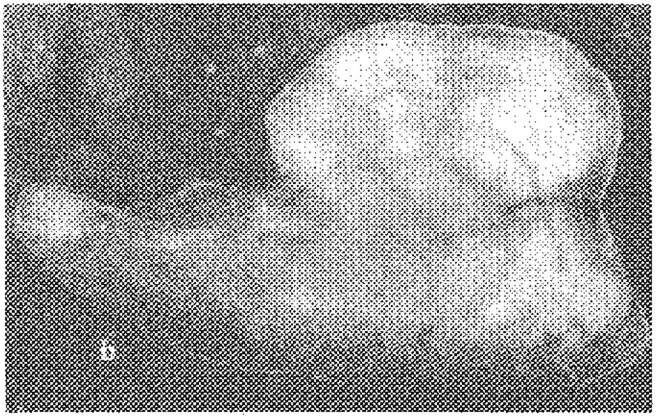


Plate 8. Otoliths of brook trout collected from Elbow Lake (July 7, 1986).

a. three year old. Note band around nucleus which is not an annulus; 3rd annulus is at margin of otolith.

b. nine year old fish. Note dark nucleus at centre of otolith.

References:

Allen, G.H. 1956. Age and growth of the brook trout in a Wyoming beaver pond. Copeia, 1956 (1): 1-9.

Alvord, W. 1954. Validity of age determinations from scales of brown trout, rainbow trout, and brook trout. Trans. Am. Fish. Soc. 83: 91-103.

Cooper, E.L. 1951. Validation of the use of scales of brook trout, *Salvelinus fontinalis*, for age determination. Copeia, 1951 (2): 141-148.

Dutil, J.D., and G. Power. 1977. Validity of reading otoliths in comparison with reading of scales for the determination of the age of brook trout, *Salvelinus fontinalis*. Nat. Can. (Quebec) 104: 361-368.

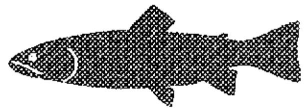
Grand, M. 1965. Age determinations from scales and otoliths in the brook trout (*Salvelinus fontinalis* Mitchell). Nytt Mag. Zool. 12: 35-37.

Hatch, R.W. 1961. Regular occurrence of false annuli in four brook trout populations. Trans. Am. Fish. Soc. 90(1): 6-12.

McFadden, J.T. 1959. Relationship of size and age to time of annulus formation in brook trout. Trans. Am. Fish. Soc. 88(3): 176-177.

Reimers, N. 1979. A history of a stunted brook trout population in an alpine lake: a lifespan of 24 years. Calif. Fish and Game 65 (4): 196-215.

BROWN TROUT



(*Salmo trutta*)

Key Contributors: Jim Allan, Steve Herman, and Al Sosiak

Preferred Structure:

Otolith. Note: - if you are dealing with stocked populations it is best to sacrifice a few fish at the time of stocking. Keep the otoliths from these known age fish for comparison with future samples.

Secondary Structure:

Scales should only be used for fast-growing populations no older than age 3 (Plate 9). The scales are taken from above the lateral line and just posterior to the dorsal fin. Fin rays have been tried but cannot be recommended until more work has been done on soft fin rays.

Time of Annulus Formation:

Bow River - presumed to be late spring; Foothills streams - May/June; High mountain lakes - June/July

References:

Alvord, W. 1954. Validity of age determinations from scales of brown trout, rainbow trout, and brook trout. Trans. Am. Fish. Soc. 83: 91-103.

Burnet, A.M.R. 1969. An examination of the use of scales and fin rays for age determination in brown trout. N. Z. J. Sci. 4(1): 151-161.

Hesthagen, T. 1985. Validity of the age determination from scales of brown trout (*Salmo trutta* L.). Instit. of Freshwater Res., Drottningholm Rep. 62: 65-70.

Konynenbelt, R.D. N.D. A comparison of scales and otoliths in the age determination of Bow River trout. Alta. Fish and Wildl. Div., Calgary, MS. Rep. 26 p.

Newman, R.M., and S. Weisberg. 1987. Among- and within- fish variation of scale growth increments in brown trout. p. 159-167. IN: R.C. Summerfelt and G.E. Hall (eds.). Age and growth of fish. Univ. Iowa Press. Ames, Iowa. 544 p.

Shirvell, C.S. 1981. Validity of fin ray ageing for brown trout. J. Fish Biol. 18:377-383.

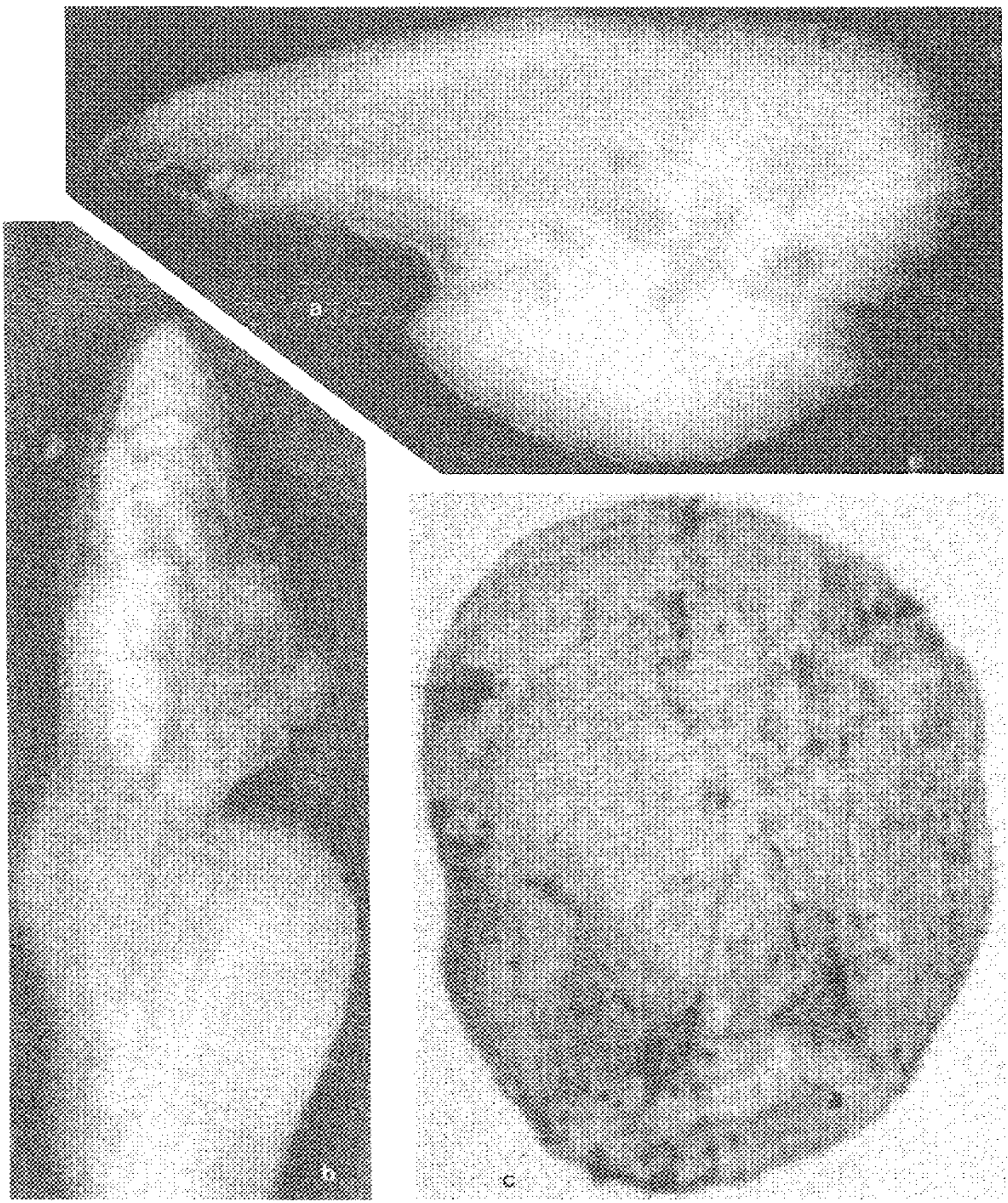


Plate 9. Whole otolith (a), split and toasted otolith (b), and scale (c) of an eight year old brown trout from the Bow River.

RAINBOW TROUT

(*Oncorhynchus mykiss*[1])

Key Contributors: Al Sosiak and George Sterling

Preferred Structure:

Slow-growing populations - sagittal otoliths (lethal) (Plate 10). Annuli on otoliths from trout older than the age of maturity may be clearest when the otolith is split and toasted. Otoliths from younger trout can often be aged by lateral view. Annuli should be determined on the distal side from the focus (nucleus) to the dorsal tip edge. Young-of-the-year and yearling fish should be used to establish location of the first annulus as it is often missed when ageing older fish.

Fast-growing populations - scales taken from the first few rows of scales dorsal to the lateral line, between the posterior margin of the dorsal fin and the anterior margin of the anal fin. Scales from fish older than age of maturity may under-estimate age, especially where growth is slow. In all cases this method should be carefully validated.

Secondary Structure:

A. Sosiak tried to age rainbow trout from the Bow River using cross sections from all their fins but found them inadequate because either one or two annuli could occur at the centre. These annuli were easily missed by cutting the fin too far from the body.

Time of Annulus Formation:

Mid to late June for east slope headwater tributaries. Apparently late spring for the Bow River.

[1] Formerly *Salmo gairdneri*.

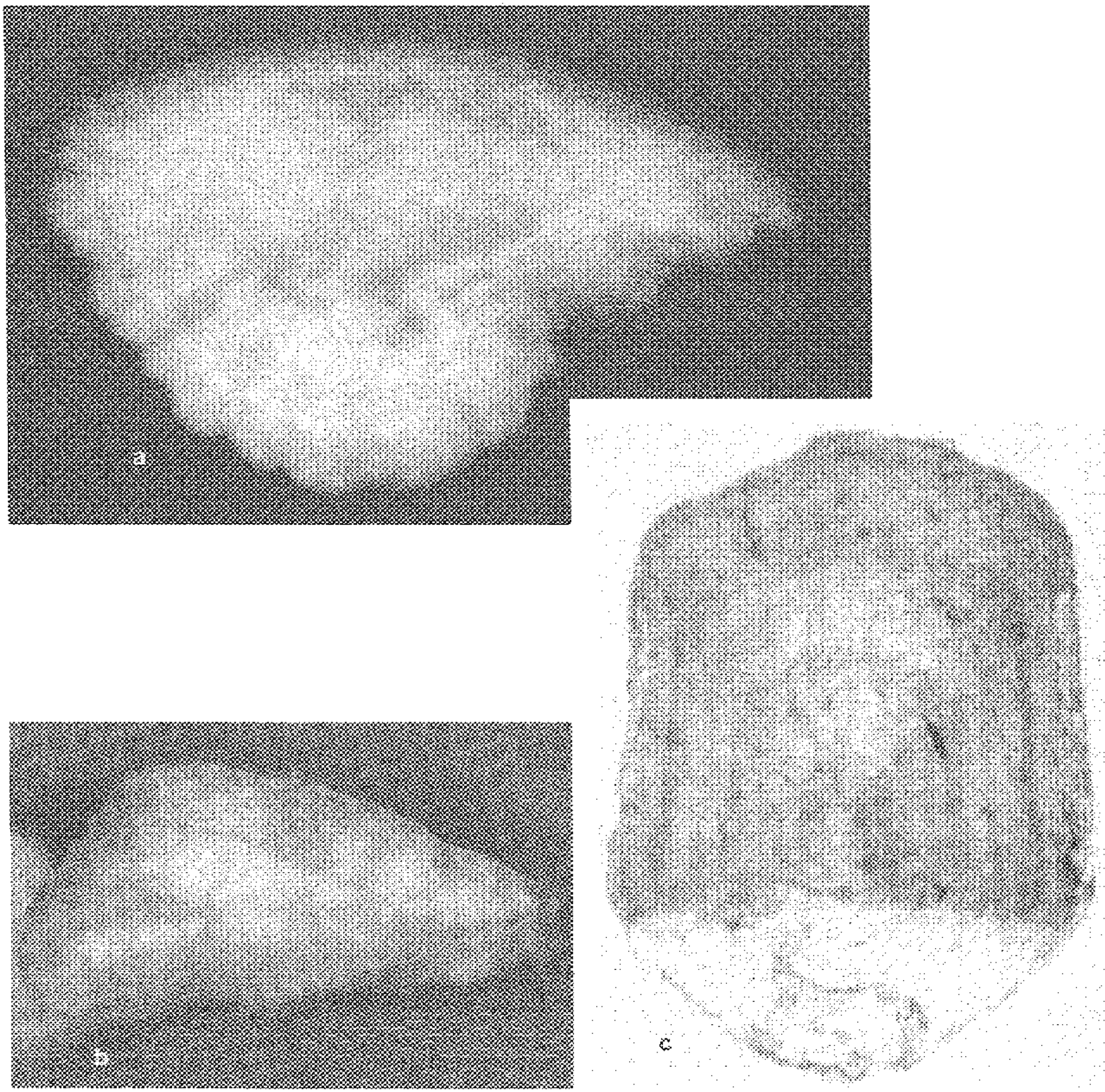


Plate 10. Ageing structures for rainbow trout.

a. whole otolith.
b. split and toasted otolith.
c. scale.

(a–c: four year old rainbow trout from the Bow River)

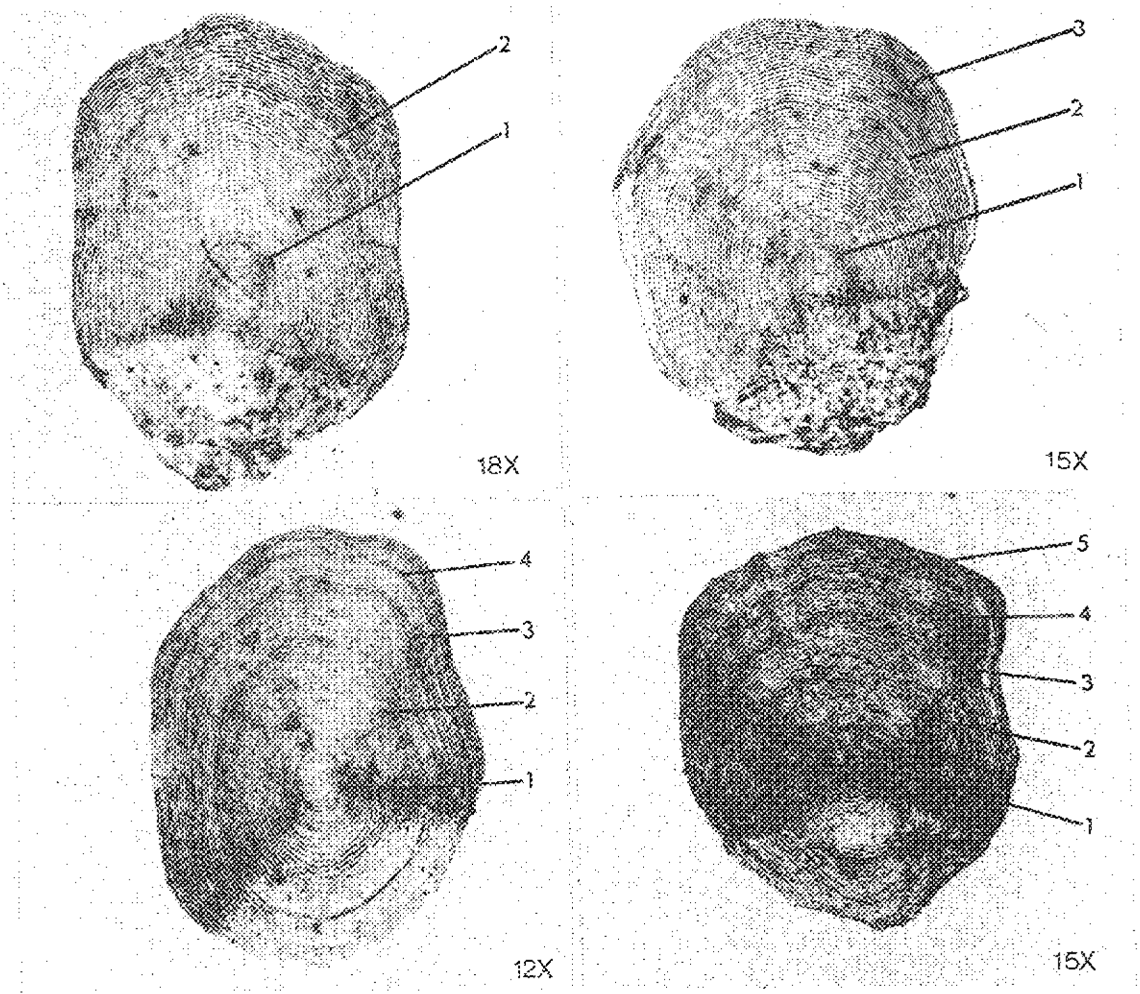


Plate 10. Continued.
d. representative rainbow trout scales from the Bow River - age 2 to 5.

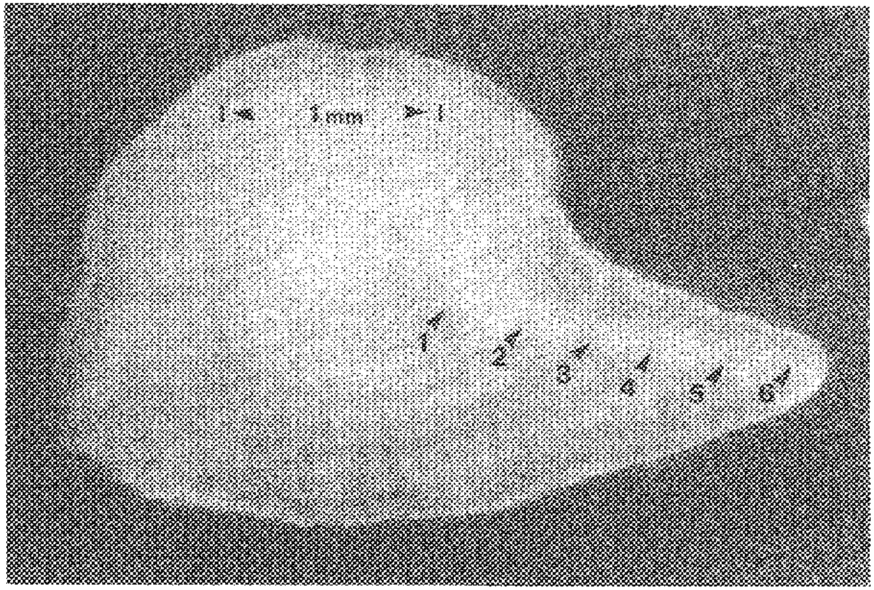


Plate 10. Continued.
e. otolith of a six year old rainbow trout from Wampus Creek (16 August).

References:

Alford, W. 1954. Validity of age determinations from scales of brown trout, rainbow trout, and brook trout. Trans. Am. Fish. Soc. 83: 91-103.

Bhatia, D. 1931. On production of annual zones in the scales of rainbow trout (*Salmo irideus*). J. of Exp. Zool. Philadelphia 59:45-59.

_________. 1932. Factors involved in the production of annual zones on the scales of rainbow trout (*Salmo irideus*). J. Exp. Biol. London 9:6-11.

Bilton, H.M., and D.W. Jenkinson. 1968. Comparison of the otolith and scale methods for ageing sockeye (*Oncorhynchus nerka*) and chum (*O. keta*) salmon. J. Fish. Res. Board Can. 25: 1067-1069.

Dietz, Karl G. 1971. The rainbow trout populations (*Salmo gairdneri*) and other fish of three streams in the foothills of Alberta. M.Sc. Thesis, Dep. of Zool., Univ. of Alta., Edmonton, Alberta. 71 p.

Konynenbelt, R.D. N.D. A comparison of scales and otoliths in the age determination of Bow River trout. Alta. Fish and Wildl. Div., Calgary, MS. Rep. 26 p.

CUTTHROAT and GOLDEN TROUT

Cutthroat trout: *Oncorhynchus clarki*[1]
Golden trout: *O. aguabonita*[2]

Key Contributor: Wes English

Preferred Structure:

Otolith - Note, however, golden trout may have calcium deposits on the otoliths (W. English).

Secondary Structure:

Scales have been used to age cutthroat trout but one must recognize limitations such as crowded annuli in old fish and the fact that many cutthroat trout will not form scales during their first year. It is not considered feasible to use scales to age golden trout.

Time of Annulus Formation:

In the Southern Region east slope streams and high mountain lakes of southern Alberta, the annulus is clearly visible (preceding the opaque zone) on the otolith after August 1. It's formation must begin earlier (i.e., post spawning in late June or July).

The annuli on golden trout are apparent by mid-July.

References:

Fitch, L. 1979. The life history of the golden trout (*Salmo aquabonita*) in Rainy Ridge Lake, Alberta, with particular references to observations on spawning. Alta. Fish and Wildl. Div., Lethbridge. MS. Rep.

Baughman, J. 1985. A brief history of the golden trout. Fish. 10(2): 2.

[1]Formerly *Salmo clarki*.
[2]Formerly *Salmo aguabonita*.

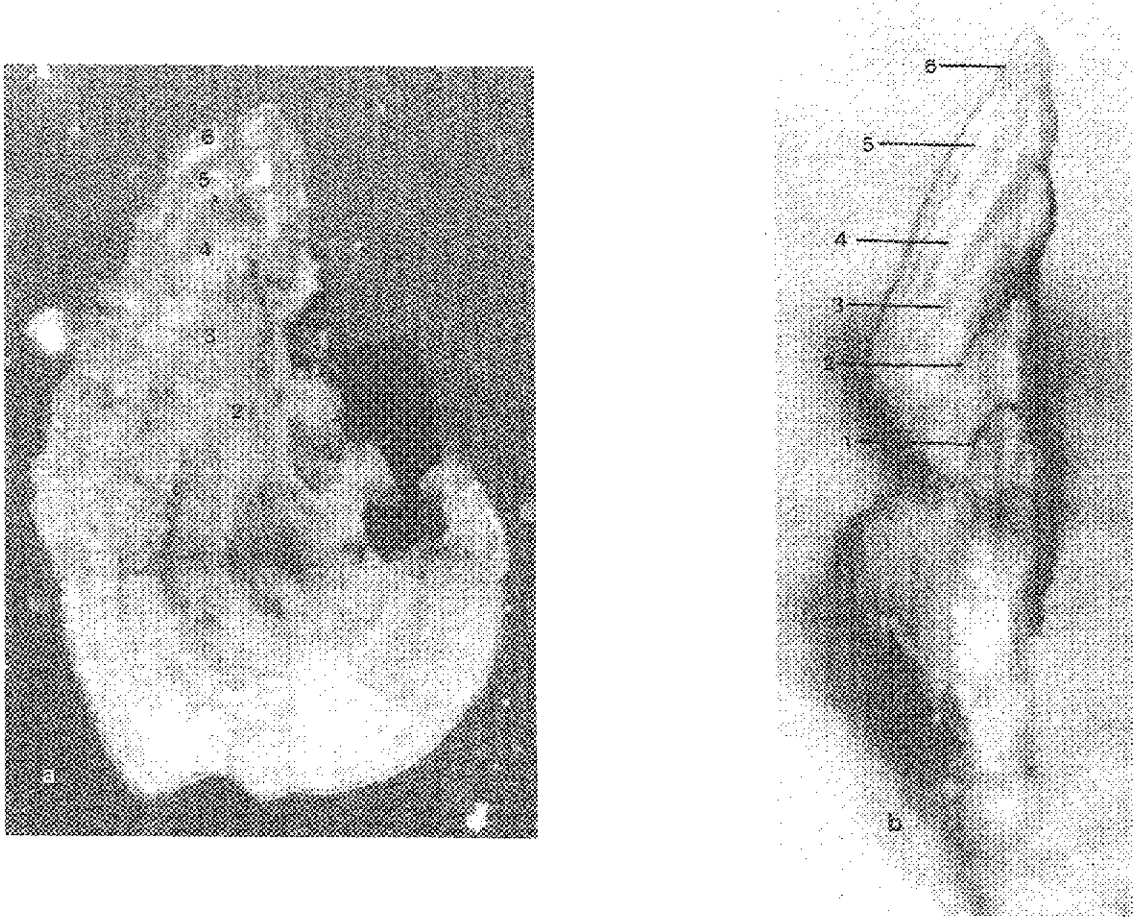


Plate 11. Whole otolith (a) and broken and toasted otolith (b) of a six year old cutthroat trout from Job Lake (May 23, 1985).

NORTHERN PIKE

(*Esox lucius*)

Key Contributors: Jim Allan, Bill Mackay, and Daryl Watters

Preferred Structure:

Cleithrum (lethal sample) (Plate 12). However, after two weeks, dried cleithra lose their bleached white appearance and annuli become fuzzy; therefore, cleithra should be kept frozen until time of preparation for ageing. Accurate ageing by cleithra is definitely influenced by the experience of the reader.

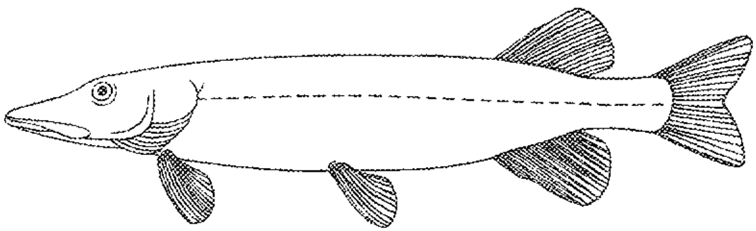
First three left pelvic fin rays. Annuli are difficult to see on the fin rays of old fish as the outer edge of the ray becomes opaque.

Secondary Structure:

Fish judged to be three years of age or younger can be accurately aged using scales for comparison. Opercular bones and vertebrae (Applegate and Smith 1951) may also show clear annuli (Plate 12).

Time of Annulus formation:

late May - early June.



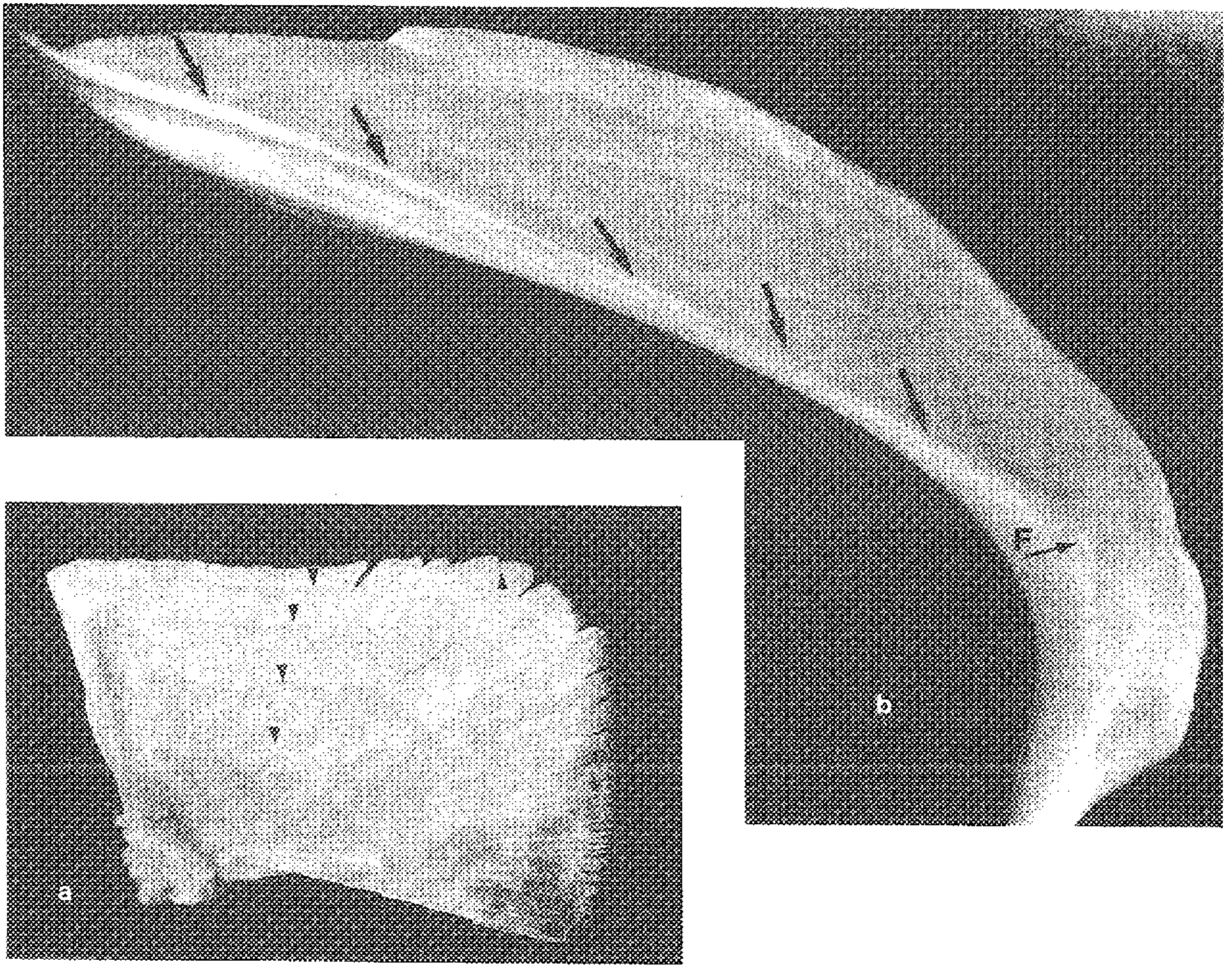


Plate 12. **Ageing structures for northern pike.**

a. cleithrum of a five year old northern pike from Lac Ste. Anne. Note location of focus.

b. opercular bone of a five year old northern pike from Clear Lake.

References:

Applegate, J., and L.L. Smith. 1951. The determination of age and rate of growth from vertebrae of the channel catfish, *Ictalurus lacustris punctatus*. Trans. Am. Fish. Soc. 80: 119-139.

Astanin, L.D. 1947. On the determination of the ages of fishes. Zoological J. 26: 287-288.

Casselman, J.M. 1974. Analysis of hard tissue of pike *Esox lucius* L. with special reference to age and growth. p. 13-27 IN: T.B. Bagenal (ed.). Ageing of fish. Proceedings of an International Symposium - Reading, England, 19-20 July, 1973. Unwin Brothers Ltd., Gresham Press, Surrey, England. 234 p.

Casselman, J.M. 1975. Cleithral method of determining age and growth of northern pike and other esocids. Proc. 37th Midwest Fish and Wildl. Conf., Dec. 7-10, 1975, Toronto, Ont.

Franklin, D.R., and C. Smith, Jr. 1960. Note on development of scale patterns in the northern pike, *Esox lucius* L. Trans. Am. Fish. Soc. 89 (1): 83.

Frost, W.E., and C. Kipling. 1959. The determination of the age and growth of pike (*Esox lucius* L.) from scales and opercular bones. J. Cons. Int. Explor. Mer. 24: 314-341.

__________. 1961. Some observations on the growth of pike, *Esox lucius*, in Windermere. International Assocation of Theoretical and Applied Limnology Proceedings 14: 776-781.

Harrison, E.J., and W.F. Hadley. 1979. A comparison of the use of cleithra to scales for age and growth studies. Trans. Am. Fish. Soc. 108: 452-456.

Healy, A. 1956. Fishes of Lough Rea, Co. Galway, Ireland. Pike and rudd with general conclusions. Salm. Trout Mag. 148: 246-249.

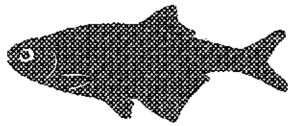
Johnson, L.D. 1971. Growth of known age muskellunge in Wisconsin. Wisc. Dep. of Nat. Res., Madison. Tech. Bull. # 49.

Makowecki, R. 1973. The trophy pike, *Esox lucius*, of Seibert Lake. M.Sc. Thesis, Univ. of Alta. 239 p.

Munro, W.R. 1957. The pike of Loch Choin. Freshwat. Salm. Fish. Res. (16): 16 p.

Williams, J.E. 1955. Determinations of age from the scales of northern pike (*Esox lucius* L.). Doctoral Dissertation Series, Pub. No. 12 868, Univ. Microfilms, Ann Arbor, Michigan.

GOLDEYE and MOONEYE



Goldeye: *Hiodon alosoides*
Mooneye: *Hiodon tergisus*

Key Contributors: Dave Fernet and Kevin Smiley

Preferred Structure:

Operculum (lethal) (Plate 13). Opercular bones can be quite thick and may require considerable time to dry and clear.

Secondary Structure:

First three pectoral fin rays (non-lethal).

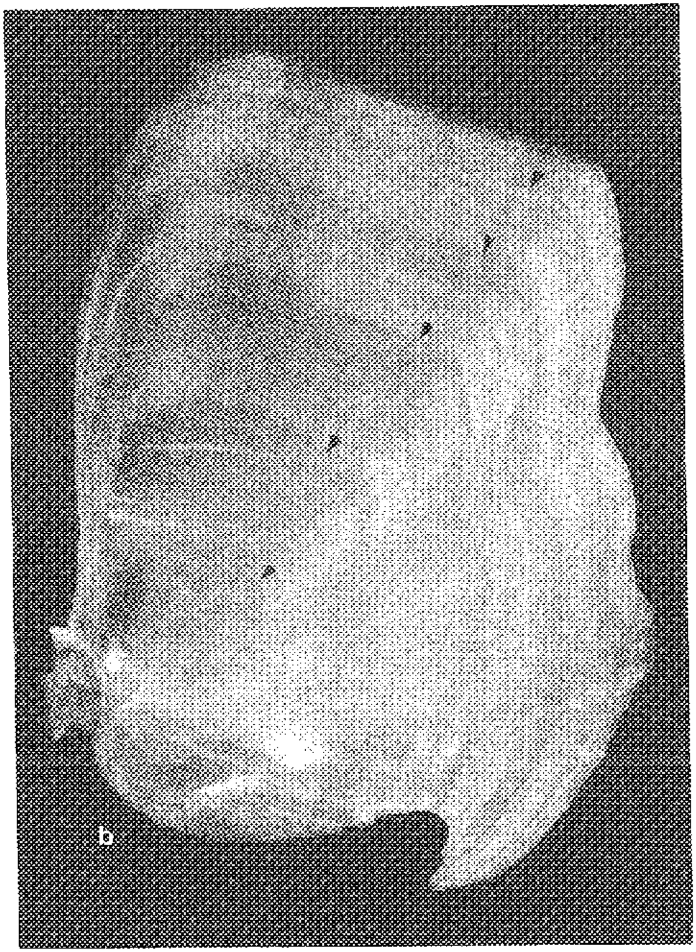
Scales (non-lethal) taken from below the dorsal fin and above the lateral line are suitable for fish less than five years of age. These ages should be validated with operculum ages (Plate 13).

For young fish, scales are the preferred method due to ease of handling and easy reading.

Otoliths are relatively small and have not been used for ageing. There has been very little work comparing ageing structures of these species.

Time of Annulus Formation:

Young (age 1) individuals exhibit annulus formation by mid-July. Annulus formation is complete in older individuals in early August.



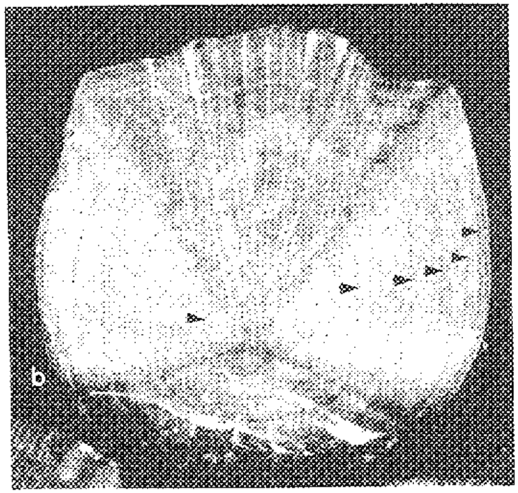


Plate 13. Goldeye from North Saskatchewan River (October 7, 1982).
a. operculum of five year old fish.
b. scale of a six year old fish.

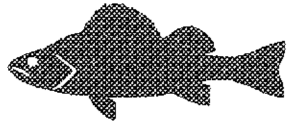
References:

Claflin, T.O. 1963. Age and rate of growth of the goldeye, *Hiodon alosoides* (Rafinesque) in the Missouri River. MA Thesis, Univ. S.D. 26 p.

Kennedy, W.A., and W.M. Sprules. 1967. Goldeye in Canada. Fish. Res. Board Canada Bull. No. 161. 45 p.

Miller, G.L., and W.R. Nelson. 1974. Goldeye, *Hiodon alosoides*, in Lake Oahe: abundance, age, growth, maturity, food and the fishery, 1963-1969. USDI Fish and Wildl. Serv., Tech. Paper No. 79.

YELLOW PERCH



(Perca flavescens)

Key Contributors: Bill Mackay and Hugh Norris

Preferred Structure:

The pelvic spine and first two fin rays (non-lethal) or the two anal spines. The anal spines are easier to read; however, removal of the pelvic spine is less harmful to fish being released. For back-calculation, the anal spine radius (X) to fork length (Y) for perch from Pine Lake was found to be $Y = 177.37 X + 46.18$ ($n = 153$, $r = 0.96$) and from Clear Lake was found to be $Y = 186.99 X + 46.49$ ($n = 40$, $r = 0.89$) (Norris 1984). Griffiths (1975) determined a pelvic spine radius (X) to total length (Y) relationship of $Y = 209.2 X + 76.86$ for perch in New Zealand.

The average fork lengths at the time of annulus formation for perch from Pine and Clear lakes was approximately 65 mm, 90 mm, and 122 mm for the first, second, and the third annulus, respectively (Norris 1984).

Secondary Structure:

Opercular bone (lethal). All annuli including the first should be visible in fish under three years of age. In fish over four years of age, the first annulus may be obscured by increased thickness of the operculum due to growth of the fish. Opercular bones from a good size range of fish still provide a valid ageing structure for perch populations, in the hands of an experienced fisheries worker.

Back-calculation of lengths using the opercular bone is feasible but it requires projection of the bone image onto a large flat surface. B. Mackay found an opercular bone to total length relationship of:
Total length (mm) $= 15 + 168X$ where $X =$ length of opercular bone.

Time of Annulus Formation:

Thin hyaline band first visible just after ice out. Complete annulus forms between mid-May and mid-June as the water warms and the fish begin to grow again. Annulus formation occurs slightly later in older fish.

References:

Bardach, J.E. 1955. The opercular bone of the yellow perch, *Perca flavescens*, as a tool for age and growth studies. Copeia 2: 107-109.

Deelder, C.L., and J.J. Willemse. 1973. Age determination in fresh-water teleosts, based on annular structures in fin rays. Aquaculture 1: 365-371.

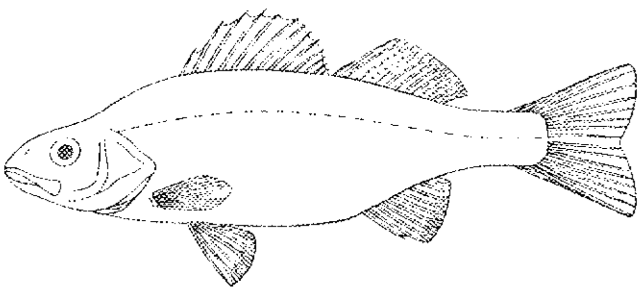
Griffiths, W.E. 1975. Age, growth, and feeding habits of European perch (*Perca fluviatilis* L.) in the Lake Ellesmere system. M.Sc. Thesis. Univ. of Canterbury, Christchurch, New Zealand.

Hile, R. 1970. Body-scale relation and calculation of growth in fishes. Trans. Am. Fish. Soc. 1970 (3): 468-474.

Joeris, L.S. 1956. Structure and growth of scales of yellow perch of Green Bay. Trans. Am. Fish. Soc. 86: 169-194.

Le Cren, E.D. 1947. The determination of the age and growth of the perch (*Perca fluviatilis*) from the opercular bone. J. Anim. Ecol. 16: 188-204.

Norris, H.J. 1984. A comparison of ageing techniques and growth of yellow perch (*Perca flavescens*) from selected Alberta lakes. M.Sc. Thesis. Univ. of Alta., Edmonton, Alberta. 173 p.



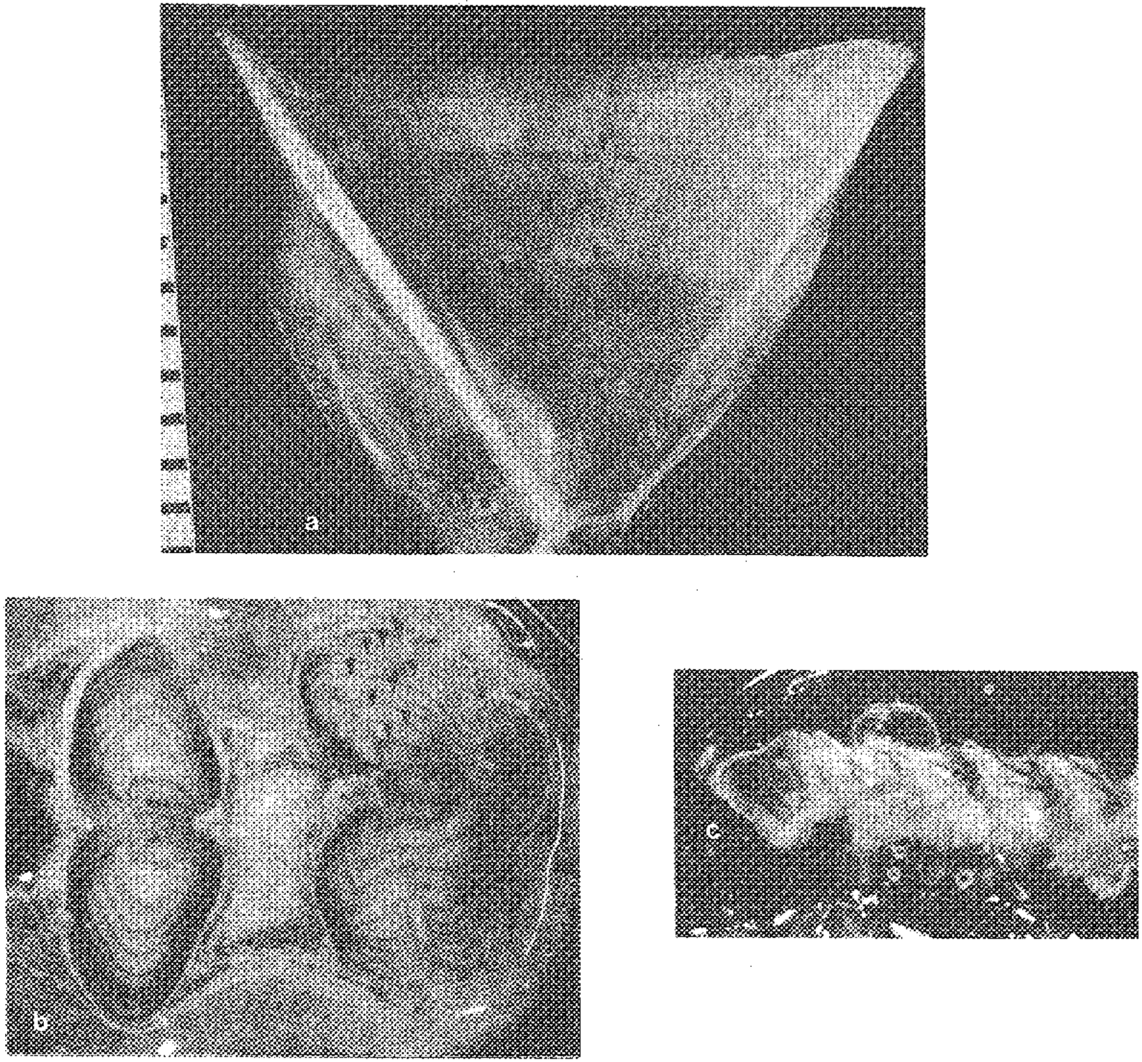


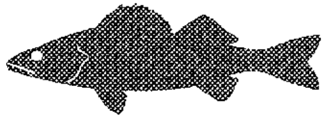
Plate 14. Ageing structures for yellow perch.

a. opercular bone of a four year old yellow perch from Pine Lake. First annulus which is normally not visible, is clear in this specimen. Fourth annulus is at margin. Fish collected in late May.

b. cross-section of first two anal spines from an 11 year old fish collected from Pine Lake in April. The eleventh annulus is not yet laid down.

c. pelvic spine of a three year old yellow perch from Pine Lake. Note - only a single annulus on small fin rays posterior to spine. Fish collected in April.

WALLEYE and SAUGER



Walleye: *Stizostedion vitreum vitreum*
Sauger: *S. canadense*

Key Contributors: Martin Brilling and Jim O'Neil

Preferred Structure:

Pelvic spine and first two pelvic fin rays (non-lethal).

Secondary Structure:

Dorsal spines, otoliths or opercular bones can also be used. Opercular bones are easy to read and the first annulus is not obscured. This is a good technique to teach the public if they are interested in walleye.

Use of scales is not recommended as they are difficult to read and often result in under-ageing of old fish.

Time of Annulus Formation:

May - June.

Distinguishing Characteristics and Alberta Distribution:

Sauger are not known to be a commonly caught fish in Alberta. Their distribution is limited to the cool-water fish habitat sections of the North Saskatchewan, Red Deer, Bow, Oldman and Milk rivers. The absence of reports of these fish may be due in part to confusion of this species with walleye. Walleye inhabit these waters except the Milk River. They are also found in lakes with suitable habitat throughout Alberta except for the mountain and foothill areas.

These species are distinguished by:

Sauger
- membrane of the spiny dorsal fin with definite spots but no dark blotch at the posterior base of this fin.
- no white tip on the lower lobe of the caudal fin

Walleye
- no definite spots on the spiny dorsal fin except for a large dark blotch at the posterior base.
- a white tip present on the lower lob of the caudal fin.

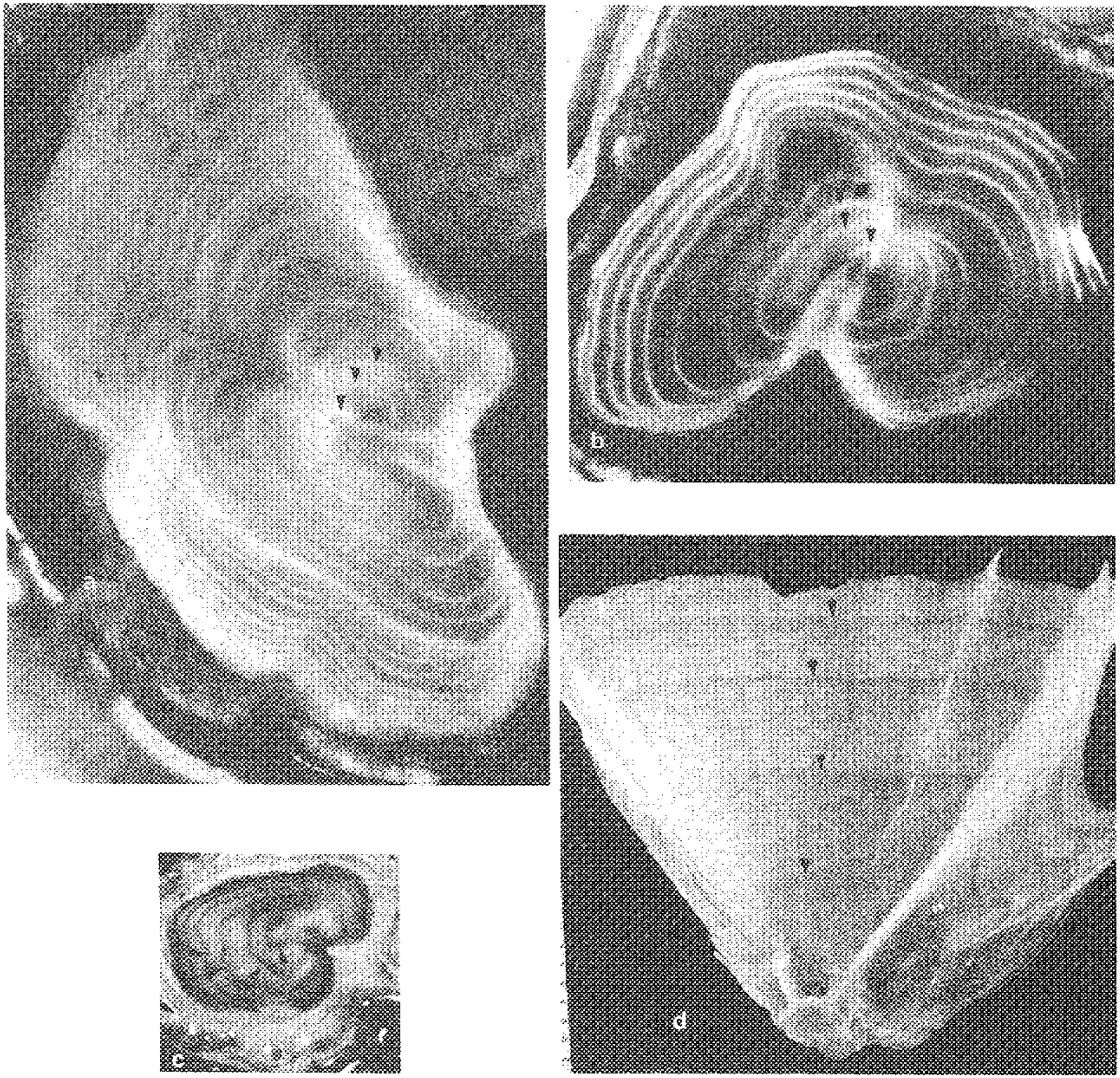


Plate 15. Cross sections of pelvic spines from walleye from Fawcett Lake.

a. 19 year old fish from Fawcett Lake.
b. 9 year old fish from Fawcett Lake.
c. 6 year old fish from Pine Lake.
d. opercular bone of 4 year old walleye from Pine Lake. Note that the first annulus on walleye opercular bones is usually apparent.

'a' and 'b' are viewed with transmitted light, 'c' is viewed under reflected light.

References:

Babaluk, J.A., and J.S. Campbell. 1987. Preliminary results of tetracycline labelling for validating annual growth increments in opercula of walleyes. N. Am. J. Fish. Manage. 7(1): 138-141.

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BURBOT

(*Lota lota*)

Key Contributor: Jim O'Neil

Photo Contributor: Tom Boag

Preferred Structure:

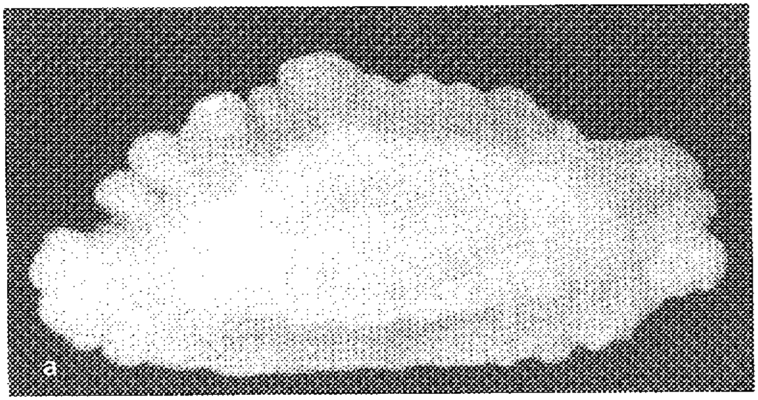
Sagittal otolith (Plate 16). For younger fish with smaller otoliths, it may be possible to read annuli without further preparation (i.e., lateral view). For older fish with larger otoliths, proceed with sectioning and burning approach (i.e., splitting through focus and heat over flame or on hot plate). The nucleus, the adjacent hyaline band, and the first opaque band are considered to represent the first years growth.

Secondary Structure:

Burbot possess small cycloid scales imbedded in the skin which lack identifiable annuli. Opercular bones, cleithra, and pectoral fin rays have been used with limited success. Based on present information otoliths appear to be the only ageing structure in general use. Agreement with length-frequency distribution is therefore the easiest method of age validation.

Time of Annulus Formation:

Annuli likely are formed in spring, although investigation is needed to pinpoint the time.



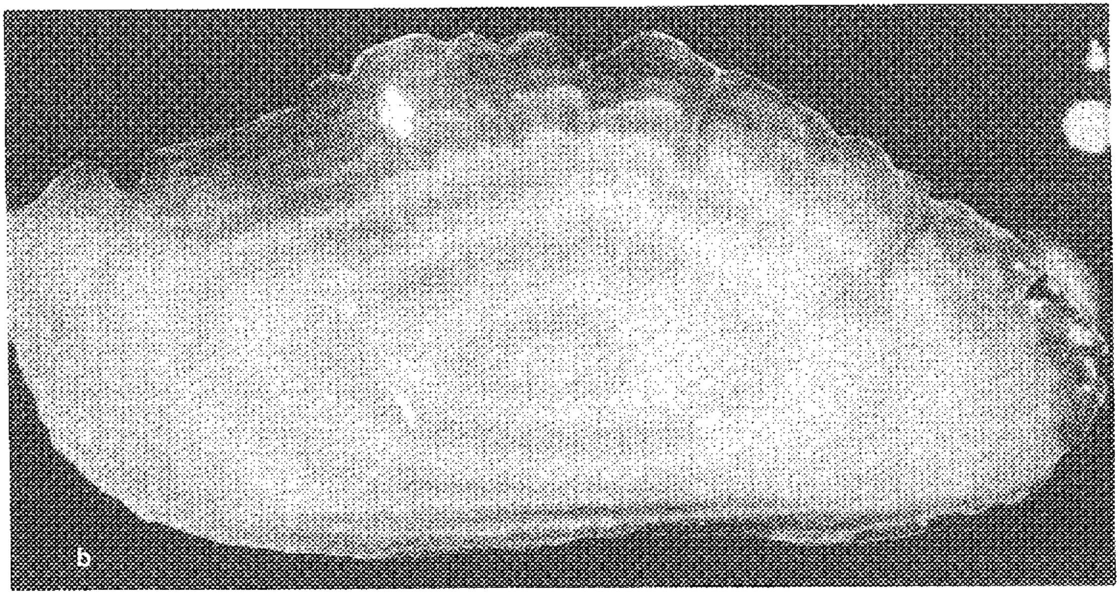


Plate 16. Otoliths of burbot from Lac Ste. Anne.

a. whole otolith from a one year old burbot.

b. whole otolith from a nine year old burbot caught in February.

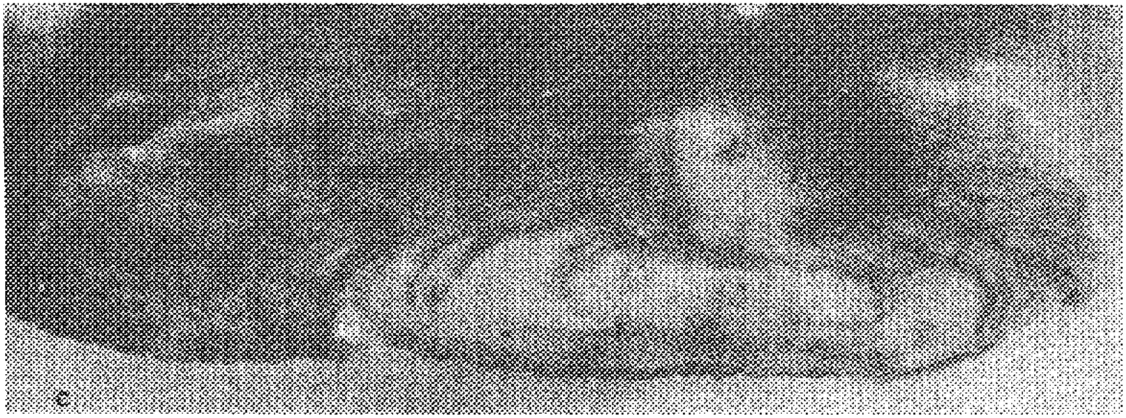


Plate 16. Continued.
c. broken, polished and toasted otolith from an 11 year old burbot caught in February.

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SUCKERS

(Family Catostomidae)

Key Contributor: Jim O'Neil

This method was developed for white suckers but it works on longnose suckers and presumably would work on other species of suckers as well.

Preferred Structure:

Pectoral fin rays (proximal end). Focus is considered as first annulus. Fin rays are distinctly superior to scales for back-calculation. Fin ray sections can be preserved after viewing by wrapping in parafilm and returning to envelope. Pelvic fin rays have also been used, but the first annulus is often close to the centre of the ray, and difficult to identify.

Secondary Structure:

Scales are acceptable to about age 5 or 6. Remove scales from left side below anterior insertion of dorsal fin and above lateral line. Use scales for small fish (less than 100 mm fork length).

Time of Annulus Formation:

Completed in spring.

Plates not available. See fin ray plates from walleye but note that the annuli are not as distinct in suckers.

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TROUT-PERCH

(*Percopsis omiscomaycus*)

Key Contributor: Dave Berry

Trout-perch can be aged by otoliths. Otoliths should be removed from fresh samples, or from specimens which have been preserved for a very short time (a day or two). Validate age determination using length-frequency analysis.

SCULPINS

(Family Cottidae)

Key Contributor: Dave Berry

The short life span (early sexual maturity and high mortality) of these fish makes length-frequency analysis a reliable means of ageing samples. Age from otoliths can be used to validate length-frequency analysis.

Time of Annulus Formation:

Late June - early July.

References:

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CYPRINIDS

(Family Cyprinidae)

Key Contributor: Dave Berry

All species except flathead chub and possibly lake chub have short life spans. Generally they grow fast, mature early, and have a high post-spawning mortality. The maximum age of most cyprinids in Alberta is three years, although three year old fish are seldom found except in early spring prior to spawning. Scales and otoliths can be used; however, the chemical preserving of fish samples makes these structures difficult to use in ageing cyprinids. Length-frequency data can be used to assign ages.

Pectoral fin ray sections appear to be the best structure for ageing flathead chub although scales and otoliths can be used. Ageing structures should be removed from fresh rather than preserved specimens. Age should be determined quickly after removal of the structure. Length-frequency analysis can be used to validate ageing.

STICKLEBACKS

(Family Gasterosteidae)

Key Contributor: Dave Berry

The short life of these fish makes age determination by length-frequency analysis and validation by otoliths the most appropriate ageing technique.

CHAPTER 7

TECHNIQUES FOR PREPARATION OF STRUCTURES USED FOR AGEING FISH

INTRODUCTION

Since the same structure is often used to age several different species, we have included in this section a general discussion of each of the structures used for ageing fish. On the following pages we describe general methods for removal, storage, preparation, and counting annuli on the structures recommended for ageing fish in Alberta. Throughout this section we include specific comments relating to single species or groups of species. Fishery workers should carefully read the entire section dealing with the structure they will use to age fish **before** they go into the field to collect fish. They should also decide, before going into the field to collect fish, what method will be used to validate the ageing technique they have chosen.

If readers need more information on the technique used for a particular species, refer to that species in Chapter 6 and contact the contributors listed.

SAGITTAL OTOLITH

Removal

Otoliths can be removed using scissors and fine point forceps. For larger fish, side-cutter pliers, tin snips or pruning shears should be used instead of scissors.

Hold the fish upside down and then cut through all the gill arches and isthmus (Plate 17a) exposing the roof of the mouth (Plate 17b). Cut ¾ of the way through the roof of the mouth (parasphenoid bone) where the first gill arch joins the roof of the mouth (Plate 17c). Hold the head of the fish and "break" the backbone downward where the cut was made in the roof of the mouth. This exposes the otoliths in the roof of the mouth (Plate 17d) and they can easily be removed with forceps (Plate 17e). Retain both otoliths, since one is usually easier to read than the other.

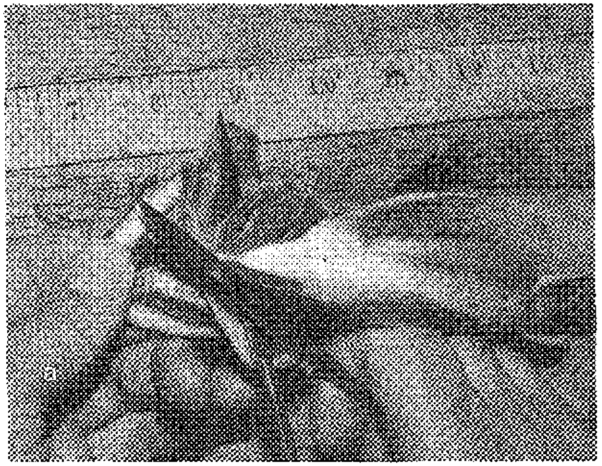
This technique requires minimal practice, takes less than one minute to complete and rarely requires a search for the otoliths. It has been used successfully on all of the trout species, lake whitefish, mountain whitefish, white suckers, northern pike, and yellow perch. This technique is easily learned and is much quicker than other techniques reported in the literature. Karl Dietz may have been the first to use this technique in Alberta. The description above was written by S.J. Herman. A similar technique has recently been described in the scientific literature by Schneidervin and Hubert (1986).

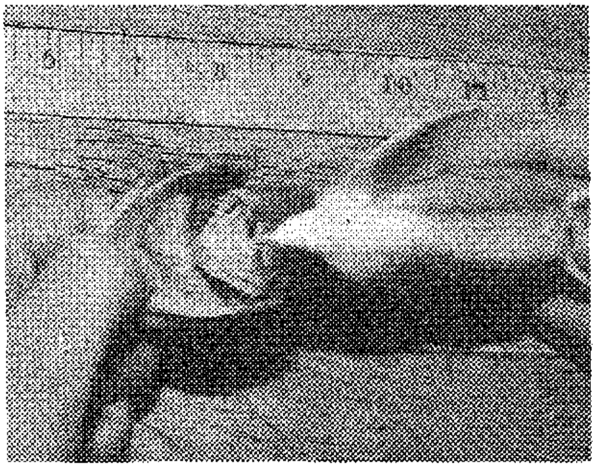
Storage

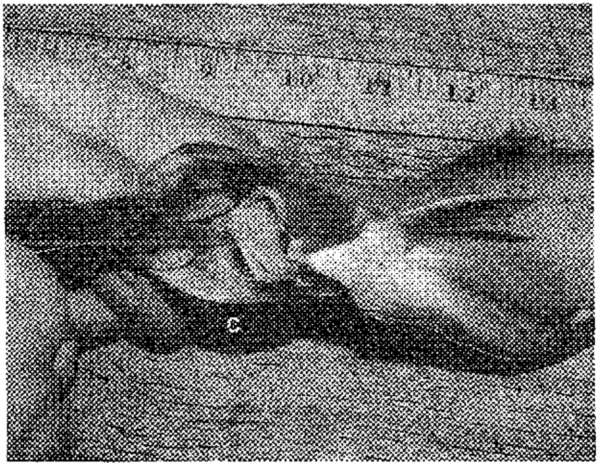
Collection of otoliths should be from fresh or frozen specimens rather than from fish preserved in formalin. Preservation in unbuffered formalin renders otoliths chalky, opaque and fragile (McMahon and Tash 1979).

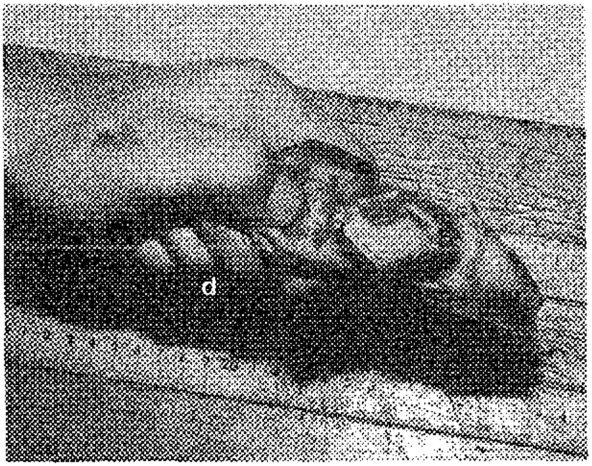
For cisco, lake trout, bull trout, brook trout, brown trout, rainbow trout, cutthroat trout, golden trout, and burbot: remove the membranous sac from around the otolith. For small otoliths this will be easiest with fine forceps and pointed probes. Large otoliths can sometimes be cleaned by rinsing in water while rubbing them between thumb and forefinger. Once the sacs have been removed, the otoliths should be stored in a solution of 10% glycerol and 90% alcohol. Alternatively the otoliths may be stored dry in scale envelopes; however, if treated roughly they are prone to breaking.

Lawler and McRae (1961) found that glycerol preserved otoliths of burbot often became opaque and difficult to age, but they became readable when heated in glycerin for 10 minutes at 190°C, or for longer times at lower temperatures.









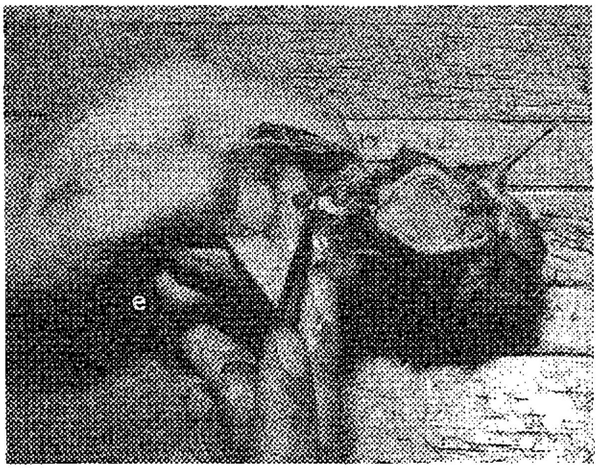


Plate 17. Removal of sagittal otoliths from a brook trout.

a. cutting gill arches and isthmus.
b. roof of mouth.
c. cutting parasphenoid bone.
d. exposed otoliths lying in place in brain case.
e. otolith being removed with forceps.

Grinding

Larger otoliths may be difficult to read due to their thickness near the centre. Grinding may be done on a fine oil/whetstone or with carborundum powder on a glass plate, or on fine emery cloth. Grinding of the distal surface is most common. The proximal (grooved) surface may also be ground if it makes ageing easier. Your finger tip or a small cork may be used to move the otolith during the grinding procedure. Pressure must be gentle or the otolith may shatter. Care must be taken not to damage the thin outer edges of the otolith or annuli may be destroyed accidentally.

Cisco - the distal edge of otoliths from large, old fish may have to be ground to make annuli easier to read.

Lake trout - otoliths are prepared for ageing by gently grinding both sides to reduce the thickness of the central portion.

Cutthroat and golden trout - both lateral surfaces of the otolith should be polished to facilitate ageing of old fish.

Trout-perch - larger otoliths can be ground to improve annuli clarity.

Clearing

For thicker otoliths, it may be necessary to clear the otolith to permit light to pass through.

Lake trout - leaving the otolith in a KOH solution for a couple of hours completely cleared the otolith, making it unusable.

Cutthroat and golden trout - if otoliths are not stored in an alcohol-glycerin solution, they may be placed in that solution for ½ to 1 hour prior to reading.

Trout-perch - the otolith can be cleared in a 3:1 mixture of benzyl benzoate and methyl salicylate.

Sectioning

a) Break and Burn - if annuli are very crowded near the edge of the otolith, then the otolith should be split through the focus using a knife. Shattering during splitting can be reduced if the otolith is placed grooved side down on a folded paper towel when it is being split. The otolith halves are then 'toasted' (to medium to dark brown color) on a hot plate (500-700°C). They may also be toasted over an alcohol burner or candle. Be careful not to char by overheating, or cause them to become soot covered by holding them too low over the flame.

b) Thin section using a Buehler Isomet saw, etc. Fill a plastic drinking straw (split in half), with 24 hour epoxy and embed the otolith, properly oriented, in the epoxy. Section after epoxy dries.[1]

Mounting and Viewing

a) Unmounted ground or unground whole otoliths

Otoliths that have been stored for a long period may be quickly dipped in a weak solution of HCl (20%) just prior to reading. This treatment is not critical for fresh otoliths. Otoliths should be completely immersed in a 50-70% solution of alcohol and water, or alcohol and glycerol, when annuli are being counted. View against a black or light blue background using reflected light. Dark plasticine works well as a background and makes it easy to orient and anchor the otolith in the best position. Annuli should be counted on the distal side from the focus (nucleus) to the edge of the dorsal tip.

For determination of back-calculated length at annulus formation, use an eyepiece with crosshair and graticule to measure the distance from the focus to the outer edge of the annulus.

For younger trout read otoliths by viewing laterally.

[1]See also Chilton, D.E., and R.J. Beamish. 1982. Age determination methods for fishes studied by the groundfish program of the Pacific Biological station. Canadian Special Publ. of Fisheries and Aquatic Sciences No. 60.

b) Permanent mounts of whole or thin sectioned otoliths -

Mount the whole otolith, groundside down, on a glass or acetate slide using permanent mounting solution (e.g., Diatex). This will clear the otolith in a manner similar to the glycerol-alcohol storage solution. Some flexibility is lost in that you can't rotate the otolith while reading it; however, this method provides an easily retrieved reference collection. The slide can be immersed in water during reading.

c) Broken and toasted otoliths

Mount the sections (with cross-section facing upwards) on a plasticine base in a Petri dish filled with water or a clearing medium (glycerol or a 3:1 solution of benzyl benzoate and methyl salicylate). View using reflected light and a dissecting microscope (25-40X). Tilt and/or rotate the otolith to obtain the best contrast between hyaline (winter growth) and opaque (summer growth) zones.

Interpretation

Determine the location of the embryonic otolith to ensure that the check which forms at the edge of the embryonic otolith is not incorrectly counted as an annulus. The central kernel of dense matter (i.e., embryonic otolith) is surrounded by a thin transparent ring and then by a thin opaque ring before the first annulus. There is more growth between the check and the first annulus in fall spawning fish than there is in spring spawners. Chugunova (1963) has described this feature of fish otoliths.

Cisco - checks (false annuli) are most common in the first three or four years of growth (prior to sexual maturity) but can usually be distinguished from annuli by their relative position and prominence. Checks in the first three years are generally more apparent and hence more of a problem on split otoliths than on laterally viewed otoliths; therefore, determine the location of the first three annuli on the unbroken otolith and compare them to the location of annuli on the split otolith. Note the age at which the growth rate is drastically reduced and the position of the first few annuli in relation to the dorsal and ventral edges of the otolith.

Cutthroat trout, golden trout, and rainbow trout from the east slopes - At the time of emergence the fry have a small otolith which forms the nucleus of the otolith in adult fish. When the fry begins to take food and grow, the otolith also begins to enlarge and form the first opaque zone. The point on the otolith where this growth begins leaves a check. In two to three months (early September to late October depending on the climate), summer growth stops and winter growth (maintenance) begins (this forms the first hyaline or transparent zone). This zone will persist until the beginning growth of the following summer (first true annulus).

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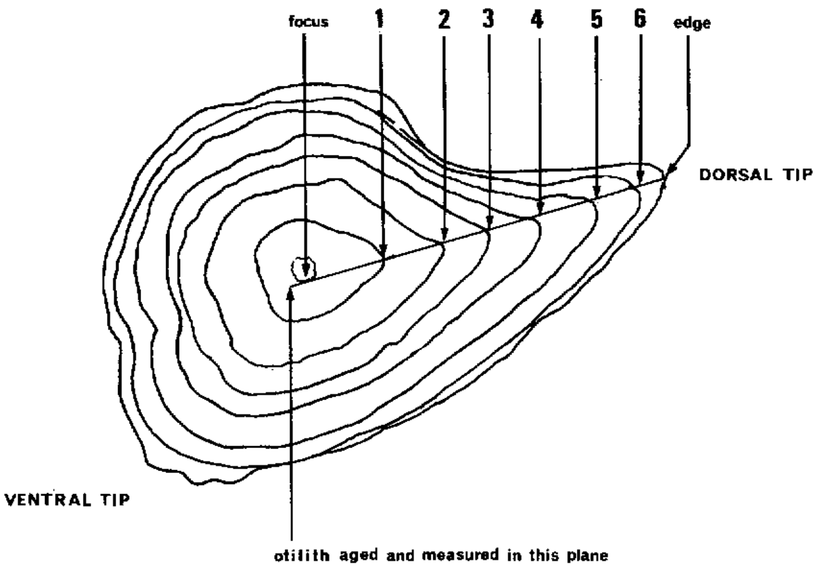

OPERCULUM

Preparation

Remove gill cover by cutting along the anterior border and separate the joint from skull at the top of the gill cover. Store frozen until the time of lab preparation if possible. Remove soft tissue from the operculum by placing it in hot but not boiling water. Do not boil or the operculum may become totally opaque. After about one minute in the hot water remove the operculum and wipe it clean with a cloth or paper towel. If the tissue sticks, place the operculum in the water longer or increase the water temperature. Let the operculum air dry. Opercular bones can be quite thick and may require a few days to dry and clear.

Viewing and Interpretation

Goldeye/mooneye - The annulus is recognized as an optically less dense zone extending completely across the operculum in transmitted light.

Yellow perch - View through a dissecting microscope against a flat black background using reflected light. Annuli will appear as narrow hyaline bands. The first annulus is about 4 mm from the origin in a fish which is 65 mm (fork length) at the time of formation of the first annulus. The first annulus is usually obscured by thickening of the bone as the fish grows.

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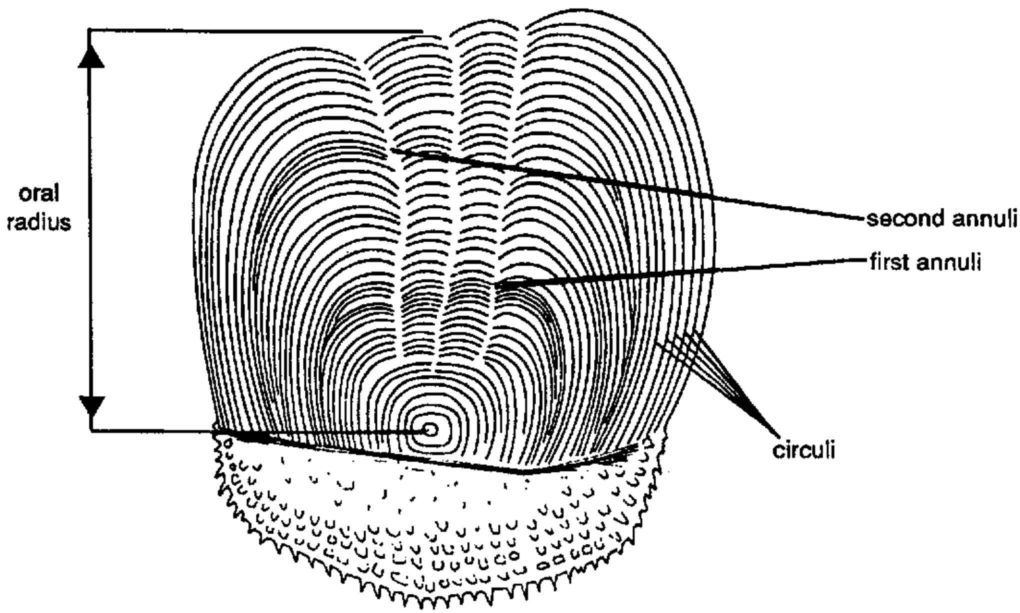

CLEITHRUM

Removal

Expose the cleithrum by lifting the gill cover. Push the thumb between the posterior edge of the cleithrum and the muscle and connective tissue. Separate the inner surface of the cleithrum from the underlying soft tissue. Move the thumb along the inner surface of the cleithrum dorsally toward the posterior end of the cleithrum to loosen the bone. Push the thumb or index finger through the connective tissues at the anterior end of the cleithrum. Pull the cleithrum away from its dorsal joining point. When the dorsal tip of the cleithrum has been released, grasp it between the thumb and index finger. Pull the cleithrum out from the body towards the front. The anterior tip will now be exposed. It is important during this procedure to pull the cleithrum strongly away from the body to avoid tearing or breaking the tip and growing edge. Push the cleithrum over the index finger of the same hand, or over the thumb or index finger of the other hand. This peels away the muscle and connective tissue from the outer surface of the cleithrum.

Preparation

Freeze samples until analysis (maximum storage time two months). Clean by simmering in 60-70°C water for five minutes to remove the flesh and oils. Air dry. Read within two weeks by viewing against a black background using reflected light.

Interpretation

Annuli are continuous hyaline lines along the blade of the cleithra onto the 'elbow-shaped' ventral posterior curve. Look for decreasing distances between annuli toward the outside edge. The first annulus at the origin is often obscured due to thickening of the cleithrum in older fish. Growth checks are common. False annuli are usually characterized by faint or incomplete annuli or two or more annuli very close together. Do not confuse false annuli with true annuli that are close together in old fish because little growth has occurred.

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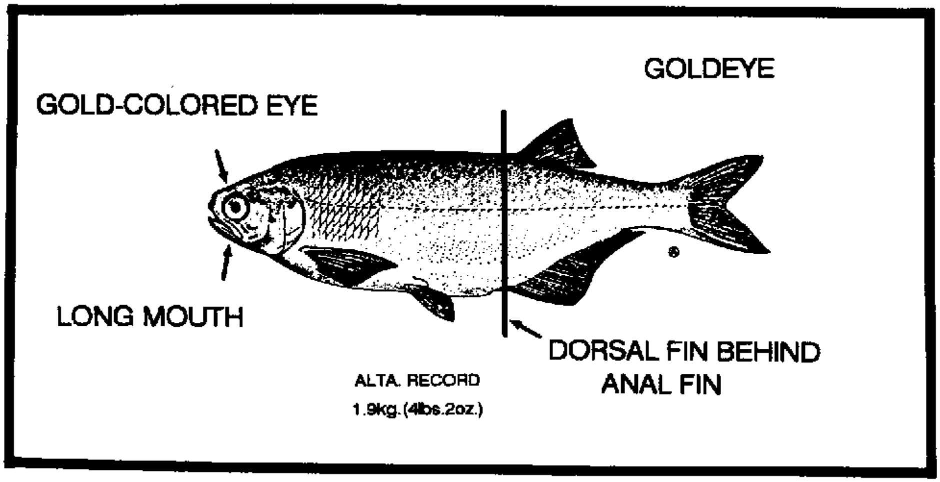

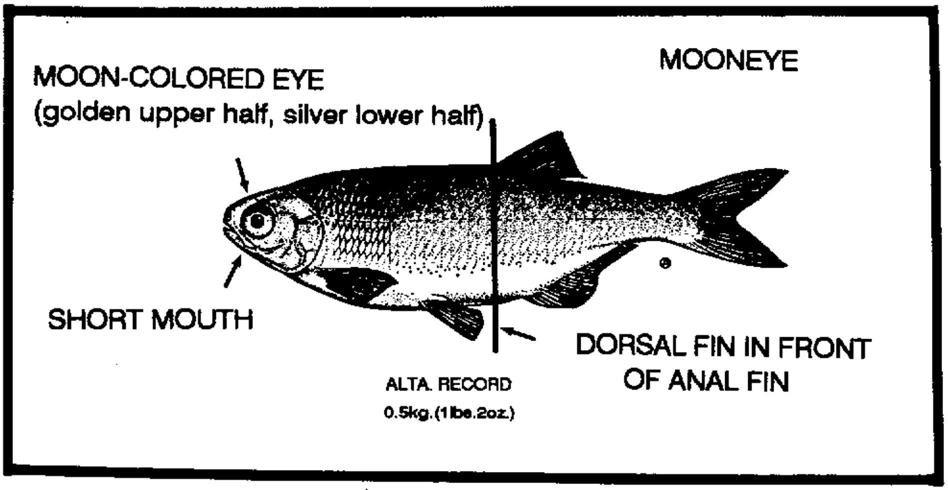

FIN RAYS AND SPINES

The rays or spines of pelvic, anal, and pectoral fins are commonly used for age determination. The method used for preparing rays or spines from all three fins is the same. If fish are to be released after sampling you must consider the effect of the sampling procedure on swimming ability (Churchill 1963; Coble 1967) and choose the fin which will have the least adverse effect on the fish. Whichever fin is chosen, take only the first few rays or spines so that damage to the fin is minimal. When dead fish are sampled take the largest fin ray or spine since its greater size will ensure that annuli are more widely spaced, making them easier to observe. Musker (1985) noted that lake trout pectoral fin rays are not as good as pelvic fin rays since the rays of the pectoral fin are very small and the annuli are very crowded.

Removal

Fin rays should be removed from fish using a sharp, clean pair of side-cutter pliers. The pliers should be cleaned and sterilized frequently to prevent infection and transmission of fish diseases. Sterilization can be accomplished by dipping them frequently in surgical disinfectant or in alcohol. The fin should be removed as close to the body as possible and cut perpendicular to the fin ray. It is important to cut close to the body because only the basal section of the ray shows the first annulus. In addition, cutting the ray perpendicular to its long axis eliminates the need to square off the ray during the preparation phase, thereby saving time and equipment (i.e. saw blades).

For most fish species in Alberta, only the first three fin rays need to be removed, as those are the only rays large enough for sectioning and ageing. Removing the entire fin results in an increased wound area (i.e., increasing the possibility of infection) and may reduce fish maneuverability.

After the fin rays have been collected, excess mucus should be removed with tissue paper, paper towel, or a cloth and they should be placed in an adequately labelled coin envelope. Fin rays may be stored frozen or allowed to air dry depending on the length of time between collection and sectioning.

Lake sturgeon - Take the first fin ray with a heavy cutting implement (i.e., large side-cutter pliers); store in envelope and let dry for approximately two months prior to sectioning. Drying is necessary to obtain translucence and strength in these sections.

Lake trout, yellow perch, walleye - Fins should be kept frozen until lab preparation. Prior to sectioning, allow to thaw and dry for a few days to remove excess moisture. The stage of dryness has a considerable effect on the readability of lake trout fin rays. Do not allow them to over-dry.

White sucker - Take the first three pectoral fin rays with a heavy cutting implement. If possible, air dry before storing in envelope.

Preparation

In the lab, fin rays should be allowed to air dry prior to sectioning. The flesh and skin around the rays and connecting the rays should be dry and hard enough to provide a matrix to hold the fins in position during sectioning. Caution should be used not to dry the rays too much or they may become brittle and fracture. Very dry, brittle rays or those from small specimens should be lightly coated with 5-minute epoxy and allowed to dry thoroughly (i.e., approximately 12 hours) before sectioning.

For cutting, place the fin ray in a small vise with the anterior (largest) ray facing up. Using a jewellers saw equipped with a fine toothed (e.g., No. 5) jewellers saw blade, cut three to five sections of approximately 0.5 mm thickness. Sections should be examined periodically under a dissecting microscope to ensure that they are suitable for ageing (i.e., thin enough to allow adequate light transmission for identification of annuli, yet thick enough to prevent sections from becoming too translucent). Sections removed from the ray should be placed on a labelled glass microscope or acetate slide in the order they were removed from the fin ray (i.e., place the basal section closest to the label and each successive section adjacent to the previous one). The sections can be permanently affixed to the slide by applying a small drop of mounting medium (e.g., Diatex, Flotex) on each section. The mounting medium should be allowed to dry thoroughly before the slides are returned to the scale envelopes for storage to prevent the surface of the medium from distorting or adhering to the envelope.

Lake sturgeon - Sunde (1961) placed sturgeon fin ray sections in absolute alcohol for temporary viewing.

White suckers - It may be necessary to embed fins of smaller suckers in epoxy to prevent shattering when they are sectioned. Fin ray sections can be preserved after viewing by wrapping them in parafilm and returning them to their envelope.

Yellow perch - Thaw and let fin air dry for a few days before sectioning. Very small fins should be embedded in epoxy to prevent them from shattering.

Interpretation

View prepared fin ray sections under a dissecting microscope using 20 to 50X magnification. The microscope should be equipped with an adjustable mirror situated below the slide base to allow viewing using transmitted light (light directed through the structure from below). Adjusting the mirror to increase or decrease the amount of transmitted light often improves the image and provides better definition of the annuli. Using transmitted light, the hyaline annuli appear as narrow, light, concentric rings.

The use of transmitted light on fin ray sections with very closely spaced annuli may make it very difficult to distinguish individual annuli. These are often easier to see if viewed using reflected light (light shone directly on the viewing surface from above) and a flat black viewing background. In reflected light, the hyaline annuli will appear as dark narrow bands.

Lake sturgeon - View with a dissecting microscope using transmitted light. Identification of annuli can be facilitated using a blue filter. The innermost visible growth check is considered as the first annulus. Some fin rays (particularly from older females) are difficult to read because of crowded annuli. Haugen (1969) found that annuli could be more easily distinguished at their greatest curvature on the ventral-radial axis of the arrow-shaped sections. Ages were assigned to these individuals by taking the mean of readings from two persons from four pectoral ray cross-sections.

Lake trout - View using reflected lighting.

Goldeye/mooneye - View under transmitted light.

White sucker - View at 50X using transmitted or reflected light. The focus is considered to be the first annulus.

Yellow perch - View against a flat black background using reflected light. If the first annulus is missed there will be a triangular, diffuse, lighter shape in the centre of the structure.

Walleye - View at 40X, using transmitted or reflected light. Annuli appear as complete lines around the focus (small hazy area in centre). The first annulus is relatively close to the focus. Often in older fish the annuli are crowded and somewhat obscure near the outside edge of the section. False annuli usually appear as faint, incomplete lines or shady areas in close proximity to true annuli.

Plate 18. Cross sections of anal fin rays from yellow perch.

a. second section from near base of anal spine showing first annulus.
b. fourth section from base showing loss of first annulus on first spine.

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SCALES

Removal

Scrape mucus and epithelial cells from sample area prior to taking scales. Deposit scales in envelope for drying. Bind envelopes together with an elastic band to prevent scales from curling in the envelopes.

Rainbow trout - Scales from juvenile fish can be collected and stored as smears on thin, flexible acetate slides covered with "Stretch and Seal" or another plastic film (Power 1964). Larger scales are best collected in envelopes.

Preparation[1]

For hard to read scales, place scales in a pepsin solution (5 mL powdered pepsin in 250 mL warm water[2]). Remove them after one to two minutes, rinse them in fresh water, and then rub the scales with a paper towel to remove foreign material. Scales should then be dried for three to five minutes before ageing. Scales can be placed directly between the glass plates of a microfiche reader or placed between glass slides (taped together) or between acetate slides held together with a few drops of acetone.

After mounting the scales on the slides, slides can be immersed in a pepsin bath or a pepsin solution can be injected between the slides to clean the scales to facilitate reading.

An alternate method of cleaning the scales that works for rainbow trout involves soaking scales mounted on slides for five hours in 2% KOH solution, followed by an overnight soaking in de-ionized water. It may be necessary to soak the scales in a wetting agent (e.g., 0.25% Brij solution) before cleaning to ensure penetration of the KOH

[1]Note: Some of the suggested methods include cleaning and clearing scales with enzyme solutions (pepsin or trypsin). Jim Allen reports a loss of small thin scales presumably by continued enzyme action. To prevent this he dips the scales into an ammonia solution ("household ammonia seems to work well") to denature the enzyme and help to prevent long term deterioration of the scale.

[2]Note: Pepsin may break down quickly in solution. Prepare a fresh solution each day.

solution, and to hold slides in a press to prevent curling. Samples should be viewed under polarized, transmitted light to count annuli.

The scales can then be read with the microfiche reader (such as Bell and Howel Model ABR 917 microfiche reader equipped with a 17 mm and a 22 mm lens) or with a scale projector.

Scales from large lake whitefish and cisco are often dark making annuli identification difficult. These scales should be imprinted onto acetate slides using a scale press and then the impressions can be aged with a microfiche reader.

Interpretation

Many fish populations exhibit excellent growth for their first three or four years. The first annulus is usually quite obvious.

The lateral and posterior fields of the scale are both used for ageing. The lateral field normally shows the the annuli clearly up to the age of maturation, but after this, the posterior field usually must be used to identify annuli.

An annulus can be identified using the following criteria:

- when seasonal growth stops, one or two or a series of partial or broken circuli crowded together may be produced between two complete ones.
- circuli are often seen ending at different places along the lateral margin at the time the annulus is formed. Sometimes there is a 'crossing or cutting' over when growth resumes as a new circulus is laid down which cuts off the unfinished ends of the previous circuli.
- the relative distance between the circuli is another criteria used in ageing. Circuli tend to be farther apart during the period of fast growth (spring and summer) and closer together during the period of slow growth (fall and winter). Annuli are characterized by a crowding or narrowing of the circuli that can usually be followed around the anterior and lateral portion of the scale.
- after the fish mature, their growth slows substantially and becomes fairly uniform from year to year with a similar number of circuli being laid down. This can be used to a certain extent to identify annuli.

Cisco - most populations exhibit excellent growth for their first three or four years, often with 30-40 circuli being laid down each year. The first annulus is very obvious. The lateral portion of the scale show annuli very clearly up to the age of sexual maturity. After sexual maturity the posterior portion of the scale must be used.

Brown trout - Annuli are characterized by crowding of circuli, usually around at least half of the circumference, followed by widely-spaced circuli. 'Crossing-over' of circuli also occurs in some samples.

Rainbow trout - Scales from fish older than the age of maturity may under-estimate age, especially where growth is slow. In all cases, this method should be carefully validated.

Goldeye/mooneye - Circuli and annuli are generally quite clear and distinct. Cutting over is the best criterion for identifying the annulus; true annuli are generally apparent through the distal portion (posterior field) of the scale.

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CHAPTER 8

ADDITIONAL SELECTED REFERENCES ON FISH AGEING

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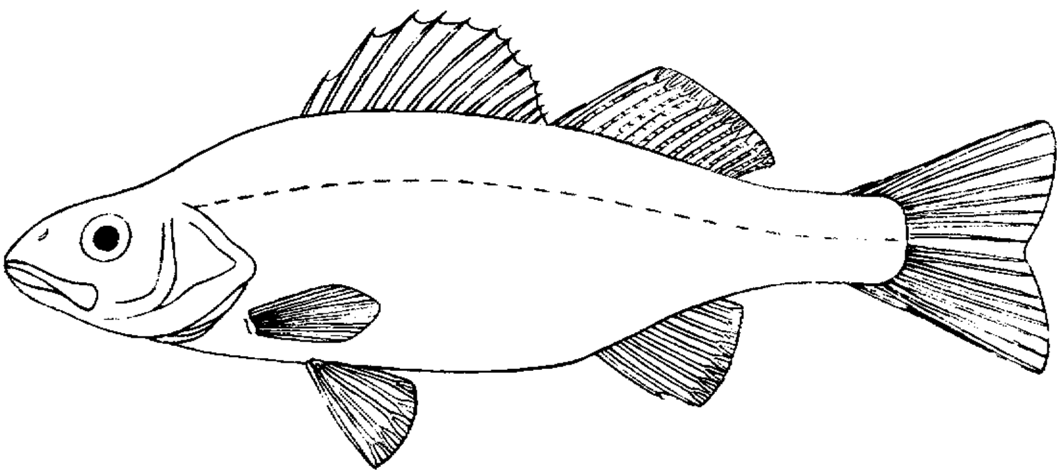

APPENDIX A

ANALYSIS OF COVARIANCE FOR COMPARING LENGTH-WEIGHT REGRESSION EQUATIONS

The preferred method of comparing the condition of fish populations is through comparison of the length-weight regression equations using analysis of covariance.

The following is an explanation of some of the terms whose values should be recorded during the calculation of the length-weight regression. These values are necessary for the comparison of two or more regression equations. In this discussion, the $\log_{10}$ length values are represented as X, and the $\log_{10}$ weight values are represented by Y.

Coef. of Determination = r^2

Formula: $$r^2 = \left(\frac{n(\Sigma XY) - (\Sigma X)(\Sigma Y)}{\sqrt{(n\Sigma X^2 - (\Sigma X)^2)\,(n\Sigma Y^2 - (\Sigma Y)^2)}} \right)^2 \qquad (1)$$

$\log_{10}$ Length means $= \bar{X} = \frac{\Sigma X}{n}$ (2)

$\log_{10}$ Weight means $= \bar{Y} = \frac{\Sigma Y}{n}$ (3)

Sum of X squared $= \Sigma X^2$ (4)

Sum of x squared = corrected sum of X squares $= \Sigma x^2 =$

$$\Sigma X^2 - \left(\frac{(\Sigma X)^2}{n} \right) \qquad (5)$$

Sum of Y Squared $= \Sigma Y^2$ (6)

Sum of y squared = corrected sum of Y squares = Σy^2 =

$$\Sigma Y^2 - \left(\frac{(\Sigma Y)^2}{n}\right) \qquad (7)$$

$$\text{Sum of XY} = \Sigma (X \cdot Y) \qquad (8)$$

$$\text{Sum of } xy = \text{corrected XY} = \Sigma xy = \Sigma XY - \left(\frac{\Sigma X \cdot \Sigma Y}{n}\right) \qquad (9)$$

COMPARISON OF REGRESSION EQUATIONS:

Line 1: $Y_1 = a_1 + b_1 X_1$

Line 2: $Y_2 = a_2 + b_2 X_2$

(1) Test of Slopes $H_0 : b_1 = b_2$ (adapted from Sokal and Rohlf 1969, p. 455)

$$F_s = \frac{(b_1 - b_2)^2}{\left[\frac{\text{ERROR SUM SQ}_1 + \text{ERROR SUM SQ}_2}{n_1 + n_2 - 4}\right] \cdot \left[\frac{1}{\Sigma x_1^2} + \frac{1}{\Sigma x_2^2}\right]}$$

where: ERROR SUM SQ can usually be read directly from an analysis of variance table for each when a computer statistical package is used, or calculated as

$$\Sigma y^2 - \frac{(\Sigma xy)^2}{\Sigma x^2}$$

Σx^2, is the "Sum of x Squared" (equation 5) (i.e., corrected sum of squares); and n = sample size for each.

For rejection region, compare $F_S \geq F_{[(1, n_1 + n_2 - 4)]}$

or $T_s = \sqrt{F_s} \geq t_{(n_1 + n_2 - 4)}$

If testing $b_1 = b_2$, use 2-tailed test (i.e., $1 - \alpha/2$); if testing null hypothesis that $b_1 \leq b_2$ or else $b_1 \geq b_2$ in such a way that the probability of Type 1 error is P or less, then use a one-tailed test of significance (i.e., $1 - \alpha$)

(2) Test of Regression Intercepts $H_0 : a_1 = a_2$

(adapted from Kleinbaum and Kupper 1978, p. 103)

$$T = \frac{a_1 - a_2}{\sqrt{\dfrac{\text{ERROR SUM SQ}_1 + \text{ERROR SUM SQ}_2}{n_1 + n_2 - 4} \cdot \left[\dfrac{1}{n_1} + \dfrac{1}{n_2} + \dfrac{(\bar{X}_1)^2}{\Sigma x_1^2} + \dfrac{(\bar{X}_2)^2}{\Sigma x_2^2} \right]}}$$

where: ERROR SUM SQ can usually be read directly from an analysis of variance table for each when a computer statistical package is used, or calculated as

$$\Sigma y^2 - \frac{(\Sigma xy)^2}{\Sigma x^2}$$

$\bar{X} = \log_{10}$ Length Means from equation 2

Σx^2 is the "Sum of x squared" (equation 5) (i.e., corrected sum of squares); and

n = sample size for each.

For rejection region, compare $|T| \geq t_{(n_1 + n_2 - 4,\ 1 - \alpha/2)}$ for $H_0 : a_1 \neq a_2$

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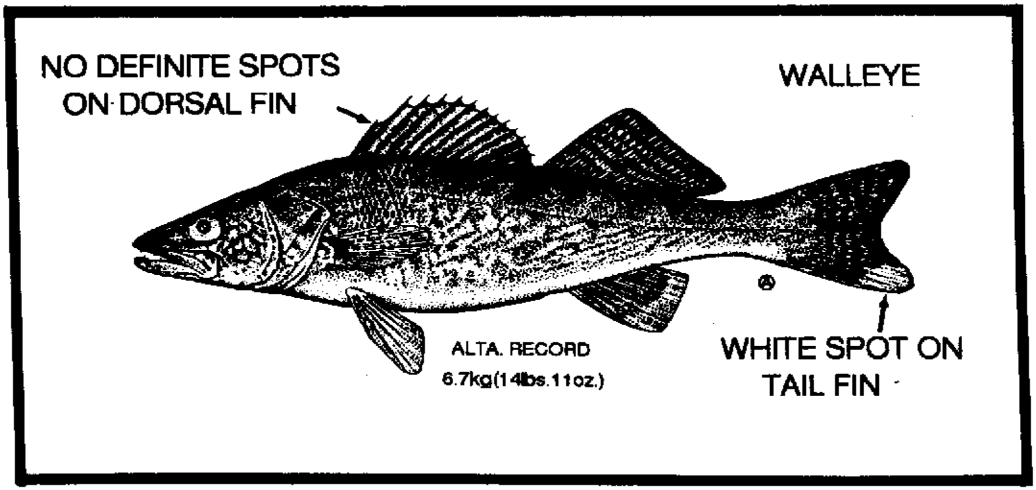

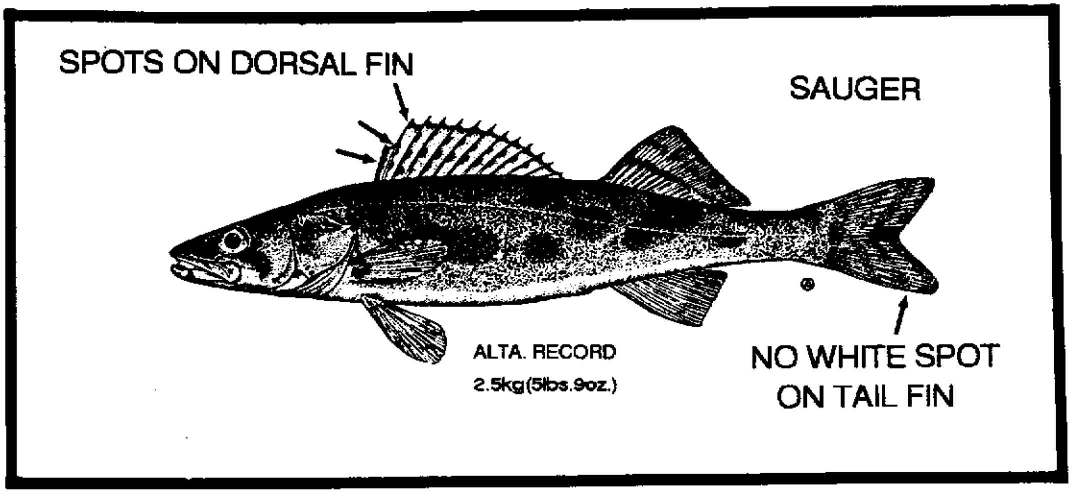

APPENDIX B

ABBREVIATIONS

The preferred abbreviations to be used in reporting fisheries data are those outlined in the Canadian Journal of Fisheries and Aquatic Science Guide to Authors (first issue each year). These are as follows:

becquerel	Bq
calorie	cal
centimetre	cm
centimetre, cubic	cm^3
centimetre, square	cm^2
centimeter per gram per second	$cm \cdot g^{-1} \cdot s^{-1}$
coulomb	C
day	d
decimetre	dm
degree Celsius	°C
degrees of freedom	df
gram	g
hectare	ha
hertz	Hz
hour	h
joule	J
kilometre	km
litre	L
lumen	lm
lux	lx
metre	m
metre, square	m^2
metre, cubic	m^3
micrometre	µm
milligram	mg
millilitre	mL
millimetre	mm
millimetre, square	mm^2
minute	min
molar mass	*M*

ABBREVIATIONS (Continued)

mole	mol
moles per litre	mol/L, *M*
month	mo
Pascal	Pa
second	s
standard deviation	SD
standard error	SE
tonne	t
volt	V
volume	vol
watt	W
week	wk
year	yr

SPELLING

Spelling of the following words is frequently inconsistent in fisheries reports. It is recommended that authors follow the style of the Canadian Journal of Fisheries and Aquatic Science which is presented below:

age-class (n.)
age-group (n.)
aquaculture (n.)
Arctic char (n.)
brackish water (n.)
brackish-water (adj.)
chi-square (n., adj.)
cold water (n.)
cold-water (adj.)
deep sea (n.)
deep-sea (adj.)
deep water (n.)
deepwater (adj.)
freshwater (n., adj.)
fresh water (n.)
groundwater (n., adj.)
hard water (n.)
hardwater (adj.)
headwater (n., adj.)
lake water (n., adj.)
meltwater (n., adj.)
open water (n.)
open-water (adj.)
percent (n.)
salt water (n.)
saltwater (adj.)
sea-run (adj.)
seawater (n., adj.)
shallow water (n.)
shallow-water (adj.)
short term (n.)
size-class (n.)
snowmelt (n.)
soft water (n.)
softwater (adj.)
tidewater (n., adj.)
t-test (n., adj.)
warm water (n.)
warmwater (adj.)
year-class (n.)
young-of-the-year (n., adj.)

ageing - the process of determining the age of a fish.
aging - the process of getting old.