CHINOOK SALMON

AGE DETERMINATION POLICIES AND PROCEDURES

OF THE

SCLEROCHRONOLOGY LAB PROGRAM

APPLIED TECHNOLOGY SECTION

MARINE ECOSYSTEM AND AQUACULTURE DIVISION

FISHERIES AND OCEANS CANADA

PACIFIC BIOLOGICAL STATION, NANAIMO, B.C.

by

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CONTENTS:

INTRODUCTION

This document describes policies and procedures employed by the Fisheries and Oceans Canada Sclerochronology Laboratory (SCL) program at the Pacific Biological Station in Nanaimo, B.C. for salmon age determination activities. It includes conventions applied to facilitate production of precise and accurate age data for stock assessment and focuses on chinook scale age determination.

The prime mandate of the SCL program is to provide good quality age data and advice regarding age determination activities to DFO in the Pacific region. This includes British Columbia and the Yukon. The SCL is a central depot for samples originating from commercial, sport and Aboriginal fisheries, hatcheries and scientific surveys. Age data contributes to the understanding of fish biology and the health of stocks. Salmon age data is primarily used for stock assessment and influences decisions on whether to open, close and extend fisheries. In the last 10 years the SCL provided age data for approximately 80,000 chinook, sockeye, coho and chum salmon annually. Fraser River sockeye and pink are excluded as these stocks are the mandate of the Pacific Salmon Commission. Table 1 lists the numbers of each salmon species aged by the SCL since 1990. Since 1990 the SCL has aged 1,724,758 salmon (7 species) of which 636,068 were chinook.

Species	# Fish
Chinook	636,068
Chum	281,001
Coho	229,786
Sockeye/Kokanee	568,165
Total	1,715,020

Table 1. Numbers of the 4 main species of salmon aged by the SCL since 1990.

QUALITY ASSURANCE SYSTEM

Most of the SCL's activities operate within a Quality Assurance (QC) system. It consists of planned, documented and systematic methods and procedures to demonstrate confidence in the age data quality and/or to confirm that the data conforms to specified requirements. Quality Control (QC) is part of the QA system and is the responsibility of everyone in the program. QC is a specific process to test results against set standards and the actions taken when there are discrepancies.

Although focused on production ageing, the SCL spends about 20% of its time working on projects to develop new methods or standards for age determination, quality control, method validation and data management. The program is age data centric working to build and maintain a deep and broad pool of expertise in the field of fisheries age determination. The SCL has no stake in the age data they create other than to produce the best quality possible. Campana (2001) provides a thorough review of the importance of accuracy, precision and quality control for age determination.

More often than not, data users and clients are only interested in the final ages without a concern for how the ages are derived. It is essential that age data production and subsequent use of the data be a collaborative effort between age readers and clients. The SCL documents age data issues to forward to data users. Clients are responsible for understanding the quality and limitations of the age data they use for stock assessments (Beamish and McFarlane 1983). In return, the SCL encourages feedback to help improve data quality.

Protocols and standards have evolved over time and have been established as part of the SCL's QA system and routine work culture. Establishing standard practices has promoted data continuity and precision (consistency) and has enhanced accuracy (closeness to true age) over the long term. This includes use of standard high quality equipment, ergonomics, reference materials, training systems, production ageing procedures and age determination methods with criteria.

1. Equipment and ergonomic standards

Standard, equivalent state-of-the-art-equipment with specialized ergonomic parts and best quality optics and lighting, are available to each SCL reader. If readers cannot "see" the same quality scale image they will not produce similar age estimates. Standard equipment facilitates consistent and accurate interpretation of growth patterns. Age determination involves long hours of repetitive work at a microscope which can lead to repetitive injuries. Ergonomic workstations ensure the physical health of readers who possess unique and difficult to learn skills and retains long-term employees.

a) Equipment

Figure 1 shows the equipment used by SCL staff to produce quality salmon scale impressions (Hudson and Crosby 2010) and to age and photograph scales. The majority of SCL salmon scale samples are aged using 4 Neopromar projectors that produce very large clear images of scale acetate impressions.

- Geo-Knight DK20SP scale press (Fig. 1a).
- Leitz Neopromar projectors (magnification 10-40X) produce a large clear image for salmon scale age determination (Fig.1b). These are the SCL's preferred scope for age determination of salmon scales.
- Leica MZ7.5 with transmitted light base with KL2500 LCD fibre optic light source (Fig. 1c). Lighted bases are used in conjunction with transmitted light to age some salmon scales with less complex patterns (ex. chum and coho stocks) when all Neopromars are in use.
- Leica DFC295 camera and M205C stereo-microscope system (Fig. 1d) or the Leica DM2000 compound microscope with DFC320 camera are 2 set ups used to photograph salmon scales. Both use the Leica Application Suite (LAS) version 3.1 or Image-Pro Plus 6.1 software to take digital images for documentation, demonstration and publication.

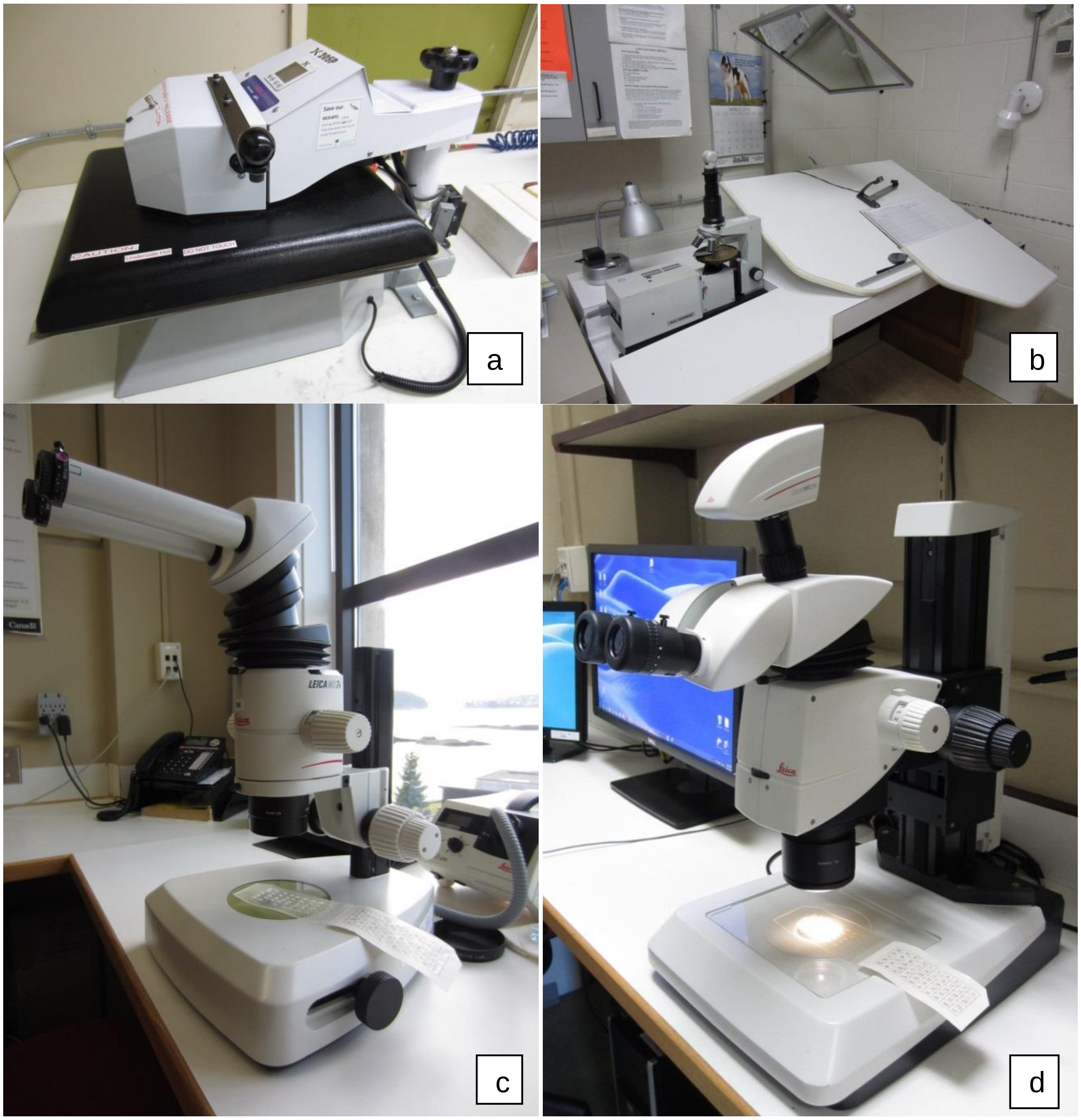


Fig. 1 Equipment used by SCL to age salmon scales. a) The Geo-Knight DK20SP scale press. b**)** Neopromar projector and ergonomic workstation. c) Leica MZ7.5 with transmitted light base with KL2500 LCD fibre optic light source. d) Leica DFC295 camera and M205C stereo-microscope system.

b) Ergonomics

Proper ergonomic workstations in the SCL have been a good investment in staff retention. The program strives to ensure that all equipment and workstations can safely be used by all staff without incurring repetitive injuries. Specialized equipment, ergonomic parts and setup have been researched to accommodate various “sized” people to work comfortably and safely, especially for shared workstations. If workstations are not adjustable injuries to the legs, back, neck, wrists and hands may occur over the long-term. This can compromise age data quality and lead to lost time and expertise impacting capacity.

SCL workstation ergonomics:
1. Adjustable eyepieces for focus and inter-pupilary distance to avoid eye strain.
2. Tilt-able scope heads to ensure straight ahead vision to prevent neck strain.
3. Scope height controls to adjust to different heights and promote good posture (sitting with a straight back and neck).
4. Coarse and fine focus knobs to avoid thumb and wrist problems.
5. Focus controls close to counter to avoid elbow pressure points and allow wrists to be kept straight as possible.
6. Rounded counter edges to avoid pressure ridges on arms.
7. High backed chairs with adjustable seat tilt and height, back tilt and adjustable arms to provide good support to back, shoulders and arms while promoting good posture.
8. Document holders to avoid neck strain.

2. Reference material

The SCL uses written materials, photographs and some physical samples as references. They facilitate training, help maintain age data quality, enhance demonstration, contribute to publications and help avoid reader drift. Reader drift usually occurs when readers unknowingly change how method criteria are applied. This can happen over a long period of time with one reader or quite suddenly when new readers come on board. Reader drift can have profound effects on stock assessment analysis. Documentation is a regular part of SCL activities and all staff are expected to participate.

a) Written documentation

Over time age determination methods and criteria used by the SCL have gone through purposeful updating or changes. These needed to be explained and discussed with data users and had to be thoroughly documented in writing. Written documentation is a strong tool that helps to avoid reader drift. After each salmon sample is aged the SCL first readers add to the cumulative information for each stock in a Word document that exists on a shared network drive (see below example). SCL salmon readers review this information each time before they age any chinook scale samples.

Example of Word documentation sequence written for chinook salmon scale samples aged over a period of years:

Atnarko Mark Recapture Program:

2009 fish were sampled Sept 9 – Oct 8. The majority were aged 0.3 along with some 0.2, 0.4, 0.5, and some 1.3 & 1.2. All scales were resorbed and a year was added when the + growth was 2 or more. *The resorbed scale criteria for Atnarko was changed this year (see below), this change was supported by CWT ages. **Scales with + growth of 1^2 or less remained the same age, those with 2^1 growth were given only a FW age and a year was added to scales with ≥2 + growth.*

09/12/23 DL/KC/DG

2010 Atnarko Mark Recapture samples were collected Sep 14-30. Scales were about 2/3rds OFWA and 1/3^{rd} 1FWA. There were many 0FWA with very strong Transition check (TC) that didn't look strong in the posterior and the circuli in the 1^{st} SW year were fairly regular and even in formation. Usually the FWA were quite distinct. The sample was overall fairly resorbed but was also very Wet with lots of regenerate and some upside down scales. I used the Resorption criteria from 2009 samples.

11/02/25 SEM

Precision results were fairly good at 87% agreement. However, comparison of scale age to CWT age in samples was 73% agreement. Most differences were due to assigning a FWA when the CWT indicated it would be a check (due to total CWT age) and the other difference would be that the scales were under-aged due to resorption. Looked at all CWT differences and took some photos to show the FW growth patterns that are occurring and how prominent the FW transition check can be vs. what a 1FW looks like in the Atnarko. Generally feel that the 1FW fish have very tight, closely spaced FW circuli (cutout) with breaking and pinching circuli and a larger 1^{st} SW year. With 0FW fish, the 1^{st} SW year tends to be smaller or about the same size as the 2^{nd} SW year and the circuli are more closely spaced than in the 2^{nd} SW year. In a OFW fish, the circuli after the focus can be wide with just a few closely spaced circuli near the end of FW with less pinching and breaking at the posterior margin (cap).

(11/03/03 DG)

..\..\..\..\Images\Salmon\Chinook\chin119.jpg ..\..\..\..\Images\Salmon\Chinook\chin120.jpg
..\..\..\..\Images\Salmon\Chinook\chin122.jpg ..\..\..\..\Images\Salmon\Chinook\chin123.jpg
..\..\..\..\Images\Salmon\Chinook\chin124.jpg ..\..\..\..\Images\Salmon\Chinook\chin125.jpg"

b) Image documentation

Photographic documentation is a very effective tool to ensure that methods and criteria remain consistent over time. Age determination is a visual pattern recognition skill where a picture truly is worth a thousand words. The SCL has standard protocols for capturing and annotating digital images. All readers are expected to contribute to the photographic archives. The readers in a team identify scales to be photographed as they age samples. Digital images are stored on the shared network drive for all staff to access. An Excel image log documents photos for each species (Fig. 2). In some cases images will be linked (see above) to the Word document that describes samples and ageing issues.

5	file name		BOOK/			CAUGHT	AREA/			IMAGE	IMAGE CAPTURE		IMAGE	ARCHIVE
6	.extensio	SAMPLE#	TRAY#	ID	AGE	YY/MM/D	LOCATION	ST	STRUCTU	DESCRIPTION	NOTES	COMMENTS	CREDIT/DA	CD#
40	chin23.tif	2005/0443	36747	1	0.2	05/10/18	Lower Shuswap		Scale	whole scale	1.25, Leica	RS scale; CWT 0.3 - our criteria 0.2	SJ-05/03/29	Pix2
41	chin23.jpg	2005/0443	36747	1	0.2	05/10/18	Lower Shuswap		Scale	whole scale	1.25, Leica	RS scale; CWT 0.3 - our criteria 0.2	SJ-05/03/29	Pix2
42	chin24.tif	2005/0443	60902	2	0.3	05/10/13	Lower Shuswap		Scale	whole scale	1.25, Leica	Int. age 0.3 CWT = 3; 2nd yr. check	SJ-05/03/29	Pix2
43	chin24.jpg	2005/0443	60902	2	0.3	05/10/13	Lower Shuswap		Scale	whole scale	1.25, Leica	Int. age 0.3 CWT = 3; 2nd yr. check	SJ-05/03/29	Pix2
44	chin25.tif	2005/0443	60902	4	0.3	05/10/13	Lower Shuswap		Scale	whole scale	1.25, Leica	Large 2nd, small 3rd; quite RS	SJ-05/03/29	Pix2
45	chin25.jpg	2005/0443	60902	4	0.3	05/10/13	Lower Shuswap		Scale	whole scale	1.25, Leica	Large 2nd, small 3rd; quite RS	SJ-05/03/29	Pix2
46	chin26.tif	2005/0443	60902	5	0.1	05/10/13	Lower Shuswap		Scale	whole scale	1.25, Leica	Jack, not very RS, very little edge growth	SJ-05/03/29	Pix2
47	chin26.jpg	2005/0443	60902	5	0.1	05/10/13	Lower Shuswap		Scale	whole scale	1.25, Leica	Jack, not very RS, very little edge growth	SJ-05/03/29	Pix2
48	chin27.tif	2005/0446	60604	2	0F	05/10/11	Lower Shuswap		Scale	whole scale	1.25, Leica	0F, due to criteria CWT = 3	SJ-05/03/30	Pix2
49	chin27.jpg	2005/0446	60604	2	0F	05/10/11	Lower Shuswap		Scale	whole scale	1.25, Leica	0F, due to criteria CWT = 3	SJ-05/03/30	Pix2
50	chin28.tif	2005/0446	60641	3	0.2	05/10/11	Lower Shuswap		Scale	whole scale	1.25, Leica	0.2 Int. Strong check in second marine yr.	SJ-05/03/30	Pix2
51	chin28.jpg	2005/0446	60641	3	0.2	05/10/11	Lower Shuswap		Scale	whole scale	1.25, Leica	0.2 Int. Strong check in second marine yr.	SJ-05/03/30	Pix2
52	chin29.tif	2005/0446	60632	5	0.3	05/10/12	Lower Shuswap		Scale	whole scale	1.25, Leica	0.3 - not v. RS so did not add a yr despite cri	SJ-05/03/30	Pix2
53	chin29.jpg	2005/0446	60632	5	0.3	05/10/12	Lower Shuswap		Scale	whole scale	1.25, Leica	0.3 - not v. RS so did not add a yr despite cri	SJ-05/03/30	Pix2
54	chin30.tif	2005/0446	60633	2	0.3	05/10/12	Lower Shuswap		Scale	whole scale	1.25, Leica	0.3 with normal size 3rd year.	SJ-05/03/3	Pix2
55	chin30.jpg	2005/0446	60633	2	0.3	05/10/12	Lower Shuswap		Scale	whole scale	1.25, Leica	0.3 with normal size 3rd year.	SJ-05/03/3	Pix2
56	chin31.tif	2005/0446	60633	4	0.3	05/10/18	Lower Shuswap		Scale	whole scale	1.25, Leica	0.3 with small 3rd year	SJ-05/03/30	Pix2
57	chin31.jpg	2005/0446	60633	4	0.3	05/10/18	Lower Shuswap		Scale	whole scale	1.25, Leica	0.3 with small 3rd year	SJ-05/03/30	Pix2
58	chin32.tif	2005/0445	60855	3	0.2	05/10/25	Lower Shuswap		Scale	whole scale	1.25, Leica	0.2 with second year check	SJ-05/03/30	Pix2
59	chin32.jpg	2005/0445	60855	3	0.2	05/10/25	Lower Shuswap		Scale	whole scale	1.25 Leica	0.2 with second year check	SJ-05/03/30	Pix2
60	chin33.tif	2002/0705	94452	1	1.3	02/08/21	Sloquet Creek		Scale	whole scale	1.25, Leica	New Creek	MH-05/06/20	
61	chin33.jpg	2002/0705	94452	1	1.3	02/08/21	Sloquet Creek		Scale	whole scale, labelled	1.25, Leica	New Creek	MH-05/06/20	Pix2
62	chin34.tif	2002/0705	94456	1	1.2	02/08/27	Sloquet Creek		Scale	whole scale	1.25, Leica	New Creek	MH-05/06/20	
63	chin34.jpg	2002/0705	94456	1	1.2	02/08/27	Sloquet Creek		Scale	whole scale, labelled	1.25, Leica	New Creek	MH-05/06/20	Pix2
64	chin35.tif	2002/0705	94456	2	1	02/08/27	Sloquet Creek		Scale	whole scale	1.25, Leica	New Creek	MH-05/06/20	
65	chin35.jpg	2002/0705	94456	2	1	02/08/27	Sloquet Creek		Scale	whole scale, labelled	1.25, Leica	New Creek	MH-05/06/20	Pix2
66	chin36.tif	2002/0705	94457	2	1.4	02/09/11	Sloquet Creek		Scale	whole scale	1.25, Leica	New Creek	MH-05/06/20	
67	chin36.jpg	2002/0705	94457	2	1.4	02/09/11	Sloquet Creek		Scale	whole scale, labelled	1.25, Leica	New Creek	MH-05/06/20	Pix2
68	chin 37.tif	2006/0135	46811	3	1.1	06/07/16	Area 3		Scale	freshwater zone	4x, leica	weak freshwater annulus	BC-07/02/02	
69	chin 37.jpg	2006/0135	46811	3	1.1	06/07/16	Area 3		Scale	freshwater zone	4x, leica	weak freshwater annulus	BC-07/02/02	
70	chin 38.tif	2006/0135	46811	7	0.1	06/07/16	Area 3		Scale	freshwater zone	4x, leica	strong freshwater check	BC-07/02/02	
71	chin 38.jpg	2006/0135	46811	7	0.1	06/07/16	Area 3		Scale	freshwater zone	4x, leica	strong freshwater check	BC-07/02/02	
72	chin 39.tif	2006/0135	46753	4	0.2	06/07/17	Area 3		Scale	whole scale	2.5, leica	fw checks, small 1st marine	BC-07/02/02	
73	chin 39.jpg	2006/0135	46753	4	0.2	06/07/17	Area 3		Scale	whole scale	2.5, leica	fw checks, small 1st marine	BC-07/02/02	
74	chin 40.tif	2006/0135	46753	8	0.1	06/07/17	Area 3		Scale	whole scale	4x, leica	fw checks	BC-07/02/02	
75	chin 40.jpg	2006/0135	46753	8	0.1	06/07/17	Area 3		Scale	whole scale	4x, leica	fw checks	BC-07/02/02	
76	chin 41.tif	2008/0029	74800	9	2.2	08/06/28	Area 4B		Scale	whole scale	4x, leica	2FWA annulli	MH-08/7/18	
77	chin41.jpg	2008/0029	74800	9	2.2	08/06/28	Area 4B		Scale	whole scale	4x, leica	2FWA annulli	MH-08/7/18	

Fig. 2 Excel file containing chinook image log.

c) Reference collections:

To avoid reader drift, some fisheries agencies prefer to assemble and maintain permanent or semi-permanent age sample reference collections for training and testing. These may or may not be known-age. Known-age samples are a QC tool utilized by the SCL to validate age data and methods whenever possible. These opportunities are generally rare for most species, however salmon are the exception.

Reference collections have their place, but they work best for labs with one to a few readers and or when numbers of species/stocks aged are small. The SCL employs 9-10 readers and production ages a large number of groundfish species (>40), two shellfish species, several herring stocks and four salmon species with 100's of stocks on an annual basis. Although the program assembled some reference collections years ago, it took an enormous amount of effort to do so and the labour to maintain them was significant, impacting production. Instead, the SCL relies more on published and unpublished documentation (manuals and reports with photos) and established QA/QC standards and procedures, including use of known-age (CWT) and documented past-aged samples as references to help ward off reader drift. Rather than maintaining specific formal reference collections, the SCL relies on demonstrative past/recently aged samples for training and testing.

3. Training and development system

The training and development policy of the SCL is intended to expand and preserve its expertise against loss through retirement and unforeseen events. The work culture of the program is unique, complex and dynamic. It takes several years for a newcomer to absorb it all. SCL readers eventually learn how to age all species using all methods employed by the program. To continue development, readers must demonstrate that they can maintain the designated level of expertise required to age the species they are already trained in over the long term. Depending on need and other duties, it generally takes 2-3 years for a novice SCL reader to be trained to age all chinook stocks and life history type samples sent to the program.

The SCL provides age data for hundreds of chinook stocks (Holtby and Kiruna 2007) from B.C. and Yukon waters. It takes a number of years and review of thousands of scales to accumulate both broad and deep coast wide expertise required to age all stocks. Acceptable deep expertise, in certain stocks, can be picked up in one to two seasons (years) by ageing in the range of hundreds to low thousands of fish. To gain broad expertise takes several seasons. The chinook reader needs to review many thousands of samples representing all stocks and life histories to achieve good broad experience in the SCL. A broad level of experience (coast wide) is needed before participating in age determination of mixed fishery samples (McNicol and MacLellan 2010). Although not the easiest salmon species to start with, chinook are often used to train novices as large numbers of samples are readily available throughout the year. Training begins with escapement samples with little scale resorption. There is an extensive learning curve regarding the consistent and accurate interpretation of freshwater growth.

Any skilled and experienced chinook reader in the SCL may be asked to train. They are chosen according to their demonstrated abilities, experience and in regards to their availability within the program's work schedule. Good coaching skills are important. The trainer is responsible for developing a written training plan with input from the student and is subject to the supervisor's approval. The trainer's task is to follow through with the process according to set policies and procedures and to objectively assess the student's progress and skill levels. A training plan (see end of this section) provides a step by step reference with clear goals and expectations for both the trainer and student. If progress does not go as expected it is up to the trainer to investigate and work with the student to overcome problems. It is equally important for the student to indicate when they need help to ensure that they achieve the expected goals.

The SCL assesses two key technical competencies, quality and quantity (productivity), to measure a student's age determination skills. The first is imperative while the second is necessary. Both are measured against standard target values. Quality is assessed by measuring precision and accuracy. Productivity is measured against established target rates (#fish/hour). Both competencies are important to develop and assess in stages by the trainer.

Comparative tests against self, experienced readers and CWT'd fish samples are used to assess a student's precision and accuracy to identify biases so that adjustments can be made with further coaching. Students learning to age chinook scales are expected to meet agreement targets of 80% and do so for both difficult as well as easy to age samples to be designated expert level. Progress and results are collated in an Excel training form (Fig. 3). Students must also learn to eventually meet productivity targets. The SCL is responsible for ageing >70-80,000 salmon a year plus herring, groundfish and shellfish. Students must learn to age swiftly with certainty. In order to become an expert reader a novice must develop good judgment and decisiveness so as not to spend too much time agonizing over the age assessment of a single fish. They need to know the limits of the methods and criteria they are employing.

Training requires a considerable effort. While teaching, the trainer's participation in production ageing and other regular duties are impacted, lowering SCL capacity. Training, especially novices, must be very carefully planned into the annual work schedule in order to ensure that all the region's priority age requests can be met on time. There is a limit to how much time and effort can be invested in training any one person. Not all people have the disposition and the skill set suited for this meticulous yet fast paced unique work. If a novice cannot establish technical competencies within the framework of the training plan they should be assessed incapable.

Novice chinook reader training plan:

Goal: To participate in production ageing of a wide variety of chinook stocks and life history types using the scale method.

Expectations:

- Must consistently demonstrate can meet a minimum precision target of 80% or better with themselves and expert readers to begin participating in routine production ageing as first reader.
- This is expected to occur after reviewing/ageing about 1,200-1,500 fish.
- Once participating in production ageing must work to quickly meet a precision target level of 80% or better with consistency.
- At this point can take on role of tester and will be a full participant in production ageing.
- After consistently meeting precision target work to meet productivity target of 40-80 fish/hr or an average of 60 fish/hour on samples with 5 scales/fish.
- Expert status is achieved when quality and quantity targets are met and maintained with difficult (ocean and stream type and resorbed scales) as well as easy samples.
- It is expected to maintain, broaden and deepen expertise in a wide range of B.C. stocks and life history types over the long term (over years) as required.

Stage 1:

- Review scales from 200-500 chinook to become "comfortable" and familiar with the scope of growth pattern characteristics and their variations. For example, Nass River (North coast) and Vancouver Island (South coast) stocks where usually only one life history type (stream type or ocean type but not both) occur within a system and scale resorption is not an issue. The goal is to be able to produce ages "similar" to those of an experienced reader and be consistent with themselves by looking at previously aged samples while having access to age data. Similar means generating the same age types for 60-70% of samples for samples previously aged by experienced readers.

- Once confident with recognising and interpreting these patterns, student will age approximately 500 additional, previously aged chinook scales from 2-3 stocks without the benefit of age data. After each sample, precision results will be calculated and any differences in age designation will be reviewed and discussed with the trainer. If precision results for samples reach 80% and trainee and student both feel the student is prepared, they are ready for the next stage.

Stage 2:

- Examine scales from 500-1000 chinook. Samples will be more challenging to interpret with: less defined annuli, prominent checks, stocks with both life history types (stream and ocean type present, e.g. Fraser River Albion Test Fishery) and moderate to severe scale resorption. The student will begin by examining previously aged samples with accompanying age data to enforce criteria interpretation until they feel confident, then go on to independently age about 500 fish. The precision goal is a minimum of 80% agreement with an experienced chinook age reader and any differences will be studied and discussed with the trainer.
- At this stage the student will be given un-aged samples that are easy to age as well as those that require more challenging interpretation. These samples, initially, will all be second read by an experienced chinook reader and if the student consistently exceeds the 80% agreement threshold, regular precision tests of 20% of the sample will be done rather than re-ageing the whole sample. If any sample falls below an 80% agreement precision result, it will be second read by an experienced chinook reader.
- The goal is to meet minimum precision target levels of 80% and better when possible. Historically, SCL chinook readers have produced agreement of 90% or better against self and other experienced readers. Students are expected to aspire to best precision possible.

Stage 3:

- It may take another 500-1000 fish before the student can participate fully in production ageing by testing other readers.
- Goal 3 is to meet production goals of 40-70 fish/hour (on samples of 5 scales per fish).
- By the end of this stage the student is expected to meet both quality (minimum 80% agreement) and quantity (40-70 fish/hr on 5 scale/fish samples) targets consistently for both easy as well as complex samples (complex life histories including resorbed scales)from a wide variety of stocks and regions. Samples may also be difficult and have varying degrees of resorption that must be interpreted consistently

Chinook Training: Student: X Trainer: Z											
Date started	Species	Sample #	Project Description	# Fish	Original % Agreement	Original Agers initials	% Agreement X	Preiscion (n)	Time (hrs.)	Date completed	Comments
STAGE 1	Chinook	2008/0282	Big Qualicum River Project	250	98%	M>K	Training with Z				
	Chinook	2006/0110	Nass R. Co-mgmt Program (Nisga'a)	33	100%	S>D	Training with Z				ocean type stock
	Chinook	2008/0042	Nass R. Co-mgmt Program (Nisga'a)	390	97%	K>M	86	first 200 read		12-09-27	stream-type stock
	Chinook	2007/0285	Big Qualicum River Project - unmarked jacks	100	100%	J>D	92	100		12-09-25	jacks
	Chinook	2007/0284	Big Qualicum River Project - unmarked males	140	96%	J>D	83	140		12-10-02	
	Chinook	2012/0025	Lower Stikine Commercial Sampling	450	97%	J>D	90	430	8	12-10-10	Variety of 1 & 2 FWA & age classes
Self Precision:	Chinook	2008/0042	Nass R. Co-mgmt Program (Nisga'a)	390		X>X	92	first 200 read	5	12-10-16	Stage 1
	Chinook	2012/0173	Lower Stikine Commercial Sampling	275	84%	X>Z		2nd read (275)	6	12-10-25	1st production sample
STAGE 2											
2012-10-25	Chinook	2010/0137	Albion Chinook Test Fishery	250	92%	K>D	78%	250		12-11-15	April- June sample variety of ages 1 & 0 FW. A few CWT's
2012-11-12	Chinook	2010/0139	Albion Chinook Test Fishery	360	93%	Z>D	87%	CCvs DG/DL - do 1st 300		12-11-23	July-Aug. sample; mix of ages
Note: X went on to do 1st readings on 2012 Albion Chinook Test Fishery samples: 2012/0360-363 with precision results of 87-89%. Samples were 2nd read by Z.											
X ready for production ageing on Harrison R. Chinook Enumeration 2012/0454-457, with Z as precision tester/spot checked.											
STAGE 3	More stocks, resorption on many; precision testing other readers' samples										
13/01/07	Chinook	2012/0454	Harrison River Chinook Eneumeration	231		X>Z	89	46	13.00	13/01/11	
13/01/14	Chinook	2012/0455	Harrison River Chinook Eneumeration	333		X>Z	93	67	11.00	13/01/18	
13/01/25	Chinook	2012/0261	Johnstone Strait Creel Survey	32		X>Z	80	10	1.50	13/02/06	
13/01/28	Chinook	2012/0258	Johnstone Strait Creel Survey	233		X>Z	88	47	6.00	13/02/07	
13/02/22	Chinook	2012/0431	Thompson Aggregate Chinook Bio-Sampling	101		M>X	95	20	3.50	13/02/22	
13/12/12	Chinook	2013/0274	W.C.V.I. Chinook Escapement	326		X>Z	94	65	9.25	13/12/16	
14/01/03	Chinook	2013/0404	Harrison River Chinook Enum. - Keystream	353		A>X	93	71	7.75	14/01/15	
14/01/09	Chinook	2013/0405	Harrison River Chinook Enum. - Keystream	384		A>X	84	77	8.00	14/01/16	

Fig. 3 Training plan form for student learning to age chinook scales.

4. Production ageing system

The SCL's production ageing system is complex, designed to manage workload and includes a series of checks and balances to produce best quality age data efficiently to meet stock assessment deadlines. A sample tracking Excel file (Fig. 4) is kept to monitor sample progress and the roles of various staff are identified to ensure best quality age data through a series of QC steps and application of standards.

For the most part, two SCL readers are involved with processing a sample. Team members pair up to coordinate and complete samples keeping due dates in mind. They are designated as the first (primary) or the second reader (tester). The first reader ages the whole sample through while the tester ages a randomized independent subsample. Sometimes a third is called in to help out when agreement between the first two is elusive. Independent (blind) measurement of quality is carried out through precision tests and the use of available known-age techniques. Non-independent (access to first readings) data is generated during the resolution process after precision testing is concluded. This is a matter of expediency as continuing independent processes beyond the tester would significantly increase the effort required to complete samples and negatively impact SCL capacity.

Date			II. SALMON	#	# Structures			% Agreement			Prec.	Agers	Time (hrs.)			CWT %	Date	
tarted	Species	Sample #	Project Description	Fish	Scales	Otos	Fins	Scales	Otos	Fins	n	Initials	1st Read	QCt	QCn	CC agree.	Complete	Comments
/01/03	Chinook	2013/0333	Lower Shuswap Chinook Keystream	103	1030			90			21	KC>JM	4.00	0.75	29	100	14/01/21	CWT n = 11
/01/03	Chinook	2013/0404	Harrison River Chinook Enum. - Keystream	353	1765			93			71	AT>CC	7.75	1.75	77		14/01/15	
/01/03	Chinook	2013/0436	WCVI SEF (Tranquil Creek)	54	540			100			10	JG>KC	2.50	0.50	15		14/01/31	
/01/06	Chinook	2013/0414	Cowichan Adult Enumeration/Productivity Study	320	1600			91			62	JM>MH	4.50	1.00	71	88	14/01/15	CWT n= 41
/01/06	Chinook	2013/0347	WCVI Chinook Escapement - Leiner River	102	510			95			21	CC>DG	3.00	0.50	26		14/01/07	
/01/07	Chinook	2013/0348	WCVI Chinook Escapement - Gold River	71	490			100			14	CC>DG	2.00	0.50	16		14/01/09	sample had both 10A and 5A format
/01/08	Chinook	2013/0407	Chilliwack River Chinook	103	515			90			20	MH>JM	1.75	0.25	22		14/01/22	
/01/09	Chinook	2013/0339	Quinsam River Project	90	450			100			18	BC>JM	1.50	0.25	21		14/01/13	
/01/07	Chinook	2013/0233	Chilko River Adult Chinook (M/R)	209	2090			76			42	DG>KC	9.25	4.00	76		14/01/31	
/01/09	Chinook	2013/0394	Albion Chinook Test Fishery	290	1450			76			55	CC>AT	10.00	2.00	88		14/01/13	
/01/09	Chinook	2013/0405	Harrison River Chinook Enum. - Keystream	384	1920			84			77	AT>CC	8.00	2.00	80		14/01/16	
/01/08	Chinook	2013/0408	Chilliwack River Chinook	284	1420			91			56	MH>JM		1.00	64		14/01/15	
/01/09	Chinook	2013/0332	Lower Shuswap Chinook Keystream	143	1430			93			29	JM>KC	4.00	0.75	32	94	14/01/31	CWT n = 20
/09/09	Chinook	2013/0412	Chilliwack River Chinook	125	625			84				MH>JM	1.75	0.50	29		14/01/22	
/01/13	Chinook	2013/0395	Albion Chinook Test Fishery	277	1385			95			55	CC>AT	10.00	1.75	73		14/01/14	
/01/10	Chinook	2013/0335	Lower Shuswap Chinook Keystream	103	1030			81			21	JM>KC	2.50	0.50	26	94	14/01/15	CWT n = 19
/01/13	Chinook	2013/0328	Lower Shuswap Chinook Keystream	54	540			100			11	JM>KC	1.25	0.25	11	100	14/01/20	CWT n = 15
/01/14	Chinook	2013/0329	Lower Shuswap Chinook Keystream	120	1200			92			24	JM>KC	2.75	0.50	27	100	14/01/20	CWT n = 33
/01/15	Chinook	2013/0331	Lower Shuswap Chinook Keystream	218	2180			84			44	KC>DG	5.50	1.25	67	100	14/01/22	CWT n = 48
/01/15	Chinook	2013/0235	Chilko River Adult Chinook (M/R)	215	2150			88			43	DG>KC	8.00	2.00	51		14/01/31	
/01/15	Chinook	2013/0411	Chilliwack River Chinook	266	1330			91			53	JM>MH	3.00	1.00	61		14/01/16	
/01/15	Chinook	2013/0410	Chilliwack River Chinook	232	1160			97			46	JM>MH	2.75	0.75	50		14/01/17	
/01/16	Chinook	2013/0406	Harrison River Chinook Enum. - Keystream	403	2015			91			81	CC>AT	10.00	1.50	95		14/01/22	
/01/16	Chinook	2013/0334	Lower Shuswap Chinook Keystream	182	1820			97			36	JM>KC	3.75	0.50	38	91	14/01/20	CWT n = 34
/01/20	Chinook	2013/0330	Lower Shuswap Chinook Keystream	162	1620			88			32	KC>JM	3.75	0.75	48	93	14/01/24	CWT n = 32
/01/20	Chinook	2013/0343	Big Qualicum River Project	250	1250			88			50	BC>AT	3.25	1.50	66		14/01/27	
/01/20	Chinook	2013/0354	W.C.V.I Chinook Escapement - Tlupana R.	31	155			90			31	CC>DG	0.50	0.00	12		14/01/21	
/01/22	Chinook	2013/0336	Lower Shuswap Chinook Keystream	97	970			84			19	DG>JM	2.50	0.25	24	100	14/01/22	CWT n = 15
/01/20	Chinook	2013/0344	Big Qualicum River Project	250	1250			82			50	BC>AT	3.50	1.75	64		14/01/27	
/01/21	Chinook	2013/0409	Chilliwack River Chinook	247	1235			92			50	MH>JM	3.75	0.50	55		14/01/22	
/01/22	Chinook	2013/0355	W.C.V.I Chinook Escapement - Gold River	179	895			78			36	CC>DG	5.50	0.75	53		14/01/27	
/01/23	Chinook	2013/0476	Chilliwack River Recreational Fishery	53	265			100			10	MH>DG	1.00	0.25	12		14/01/27	
/01/23	Chinook	2013/0356	W.C.V.I Chinook Escapement - Burman River	286	1430			93			57	CC>DG	8.00	0.75	66		14/01/29	
/01/22	Chinook	2013/0337	Lower Shuswap Chinook Keystream	58	580			75			12	DG>JM	1.50	0.25	17	100	14/01/24	CWT n=6
/01/22	Chinook	2013/0353	Conuma River Hatchery	230	1150			87			46	JG>JM	4.00	1.25	61		14/01/29	
/01/27	Chinook	2013/0352	Conuma River Hatchery	206	1030			90			41	JG>JM	4.00	1.00	54		14/01/29	
/01/30	Chinook	2013/0413	Cowichan River CID	123	615			83			24	MH>JM	1.50	0.50	28		14/01/30	
/01/31	Chinook	2013/0383	Wannock (Owikeno) Co-Mgmt Program									KC>						
/01/03	Sockeye	2013/0311	Somass River Sockeye Escapement (GCL)	7	14			2nd read			0	JG>JM	0.00	0.00	7		14/01/06	
/01/03	Sockeye	2013/0312	Somass River Sockeye Escapement (Sproat R)	34	68			100			10	JG>JM	0.25	0.00	10		14/01/06	
/01/29	Kokanee	2013/0345	Alouette Lake Parental Analysis	168	336			97			36	DG>JM	3.00	0.75	50		14/01/30	
/01/07	Coho	2013/0226	Skeena River Test Fishery	207	1035			2nd read			0	MW>JM		2.00	207		14/01/13	
/01/10	Coho	2013/0227	Skeena River Test Fishery	169	845			91			34	MW>JM		2.75	62		14/01/16	

April13 | May13 | June13 | July13 | Aug13 | Sept13 | Oct13 | Nov13 | Dec13 | Jan14 | Feb14 | Mar14

Fig. 4 Excel Sample Tracking sheet for chinook.

a) Salmon age data sheet standards

Standard SCL hard-copy salmon age data (Fig. 5a) sheets have evolved over time. The sheets are geared towards the reader's needs to express age and record issues surrounding the age determination and resolution process. The salmon age data sheets were developed to record the ages for each reader and each scale collected from a fish (1, 2, 5 or 10) (MacLellan 2004) Each reader involved with a sample is responsible for filling out sheets according to set protocols (Appendix 1).

Salmon age data sheets have a header section for sample metadata. The header section includes information such as species, date of capture, sample location, number of fish in sample, precision results and processing times for the first and second readers and numbers of specimens involved in the QC process and general comments. The body of the sheet has a row for each fish with headings: fish ID, final age (type), "working columns" for age estimates for each scale (headed by: method employed, date aged and reader ID and finally reader comments. Readers make use of a number of codes to identify scale condition. Separate precision age data sheets (Fig. 5b) were developed for independent testing and require abbreviated header information. Appendix 1 describes in detail protocols to record salmon age data sheets.

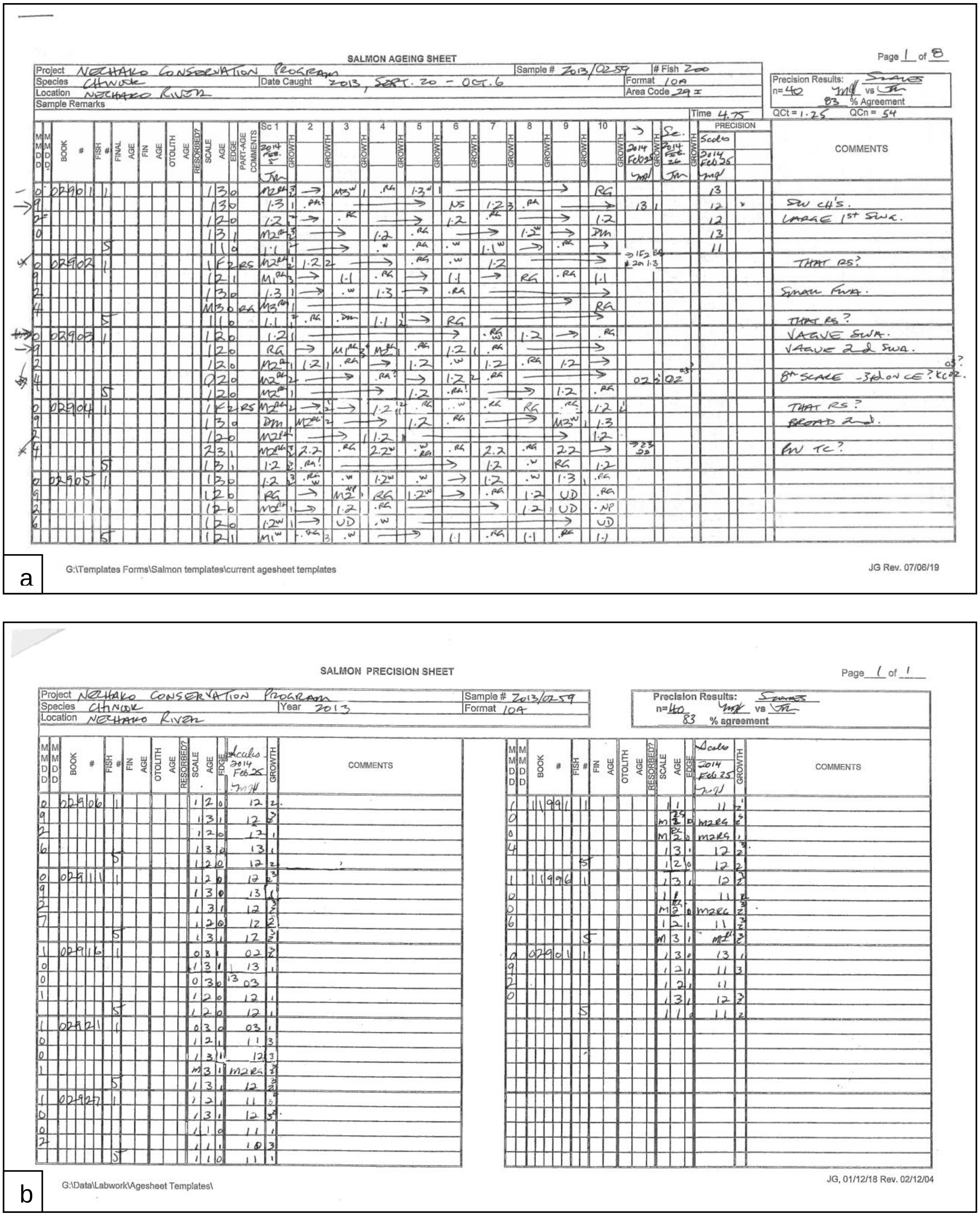


Fig. 5 Salmon a) age data (10 scales per fish example) and b) precision sheets

Expressing age uncertainty – No age and part ages

Age readers often are faced with a dilemma when unable to confidently assign one defined age to a fish. For example, "Is it 1.2 or 0.2?" Ambiguous scale patterns may make it difficult to apply criteria with certainty or perhaps the sample suffers from collection errors or poor preparation. There is pressure to deliver one age per fish that can easily be keypunched into databases. Reader biases arise from various circumstances such as: knowledge of dominant age types or preference to age older rather than younger. Hence a production age system should have some options built into it to allow readers to express uncertainty. These kinds of expressions alert other readers to issues and alert the client to the quality limitations of the age data they use.

SCL readers, however, are generally encouraged to make a decision on a single age for each chinook whenever possible. QC procedures are in place to provide additional checks by other readers to encourage resolution. The SCL expresses uncertainty in the "working columns" of the age data sheet by recording multiple age type possibilities per scale. When readers cannot resolve either the FW or SW age for all scales for the fish a part age (e.g. 1F or M2) is recorded in the final scale age column of the age data sheet. If both the FW and SW age can't be resolved, no age (NA) is recorded. It is not uncommon for significant numbers of part-age fish to result from chinook escapement samples due to regenerate and/or resorbed scales. FW age is not assessed if a regenerate scale is missing one or more circuli in the centre and SW age is not assessed if the number of SWA can't be estimated with certainty on resorbed scales.

b) Salmon age designation system

Designating age for salmonids is complex because of their anadromous life histories. Clients want to know the number of years spent in fresh and saltwater to help understand life histories, delineate stocks and make predictions. SCL readers can work with both the European (E) and Gilbert-Rich (GR) age designation systems (Koo 1962). But, E is the standard recorded on SCL age data sheets. The E age is input to the Pacific Age Database System (PADS) where it is converted to GR. The age data report sent to clients lists ages in both designations Table 2. The SCL uses the E system because it expresses age or age class while the GR system denotes "year of life". GR has historically been used by DFO Pacific region managers for assessments and is the reason why the SCL provides ages in both designations. Managers favour GR because it is easy to calculate brood year by subtracting the first number from the year caught.

The E system consists of two numbers separated by a decimal. The first number represents the number of years (winters) the salmon spent in freshwater and the second years spent in the ocean. The two numbers added together provide total age or age class, e.g. 1.3 = 1 year over-winter in freshwater and 3 in the ocean. The total age is 4 years old. The GR system also consists of 2 numbers of which the second is a subscript. A 1.3 E age translates to a 5_2 GR format and is spoken as "five sub two". The GR expression indicates that the fish was caught in its 5th year of life and went to sea during its 2nd year of life. The fish would be referred to as a "five year fish" by managers. By SCL standards this fish is 4 years old and would not be 5 until it reached the next January 1st birth date. The SCL works with and communicates using the E method as it designates age class and is less confusing than the GR method.

Table 2. European and Gilbert-Rich salmon age designation systems.

Conversion table for salmon age data: European to Gilbert-Rich Designation								
European system				Gilbert-Rich system				
Age designation	No. FW annuli	No. SW annuli	Total age	Age designation	Yr of life caught	Yr of life went to sea	Yr caught	Brood yr
0.0	0	0	0	1_1	1	1	2002	2001
0.1	0	1	1	2_1	2	1	2002	2000
0.2	0	2	2	3_1	3	1	2002	1999
0.3	0	3	3	4_1	4	1	2002	1998
0.4	0	4	4	5_1	5	1	2002	1997
0.5	0	5	5	6_1	6	1	2002	1996
0.6	0	6	6	7_1	7	1	2002	1995
1.0	1	0	1	2_2	2	2	2002	2000
1.1	1	1	2	3_2	3	2	2002	1999
1.2	1	2	3	4_2	4	2	2002	1998
1.3	1	3	4	5_2	5	2	2002	1997
1.4	1	4	5	6_2	6	2	2002	1996
1.5	1	5	6	7_2	7	2	2002	1995
1.6	1	6	7	8_2	8	2	2002	1994
2.0	2	0	2	3_3	3	3	2002	1999
2.1	2	1	3	4_3	4	3	2002	1998
2.2	2	2	4	5_3	5	3	2002	1997
2.3	2	3	5	6_3	6	3	2002	1996
2.4	2	4	6	7_3	7	3	2002	1995
3.0	3	0	3	4_4	4	4	2002	1998
3.1	3	1	4	5_4	5	4	2002	1997
3.2	3	2	5	6_4	6	4	2002	1996
3.3	3	3	6	7_4	7	4	2002	1995
3.4	3	4	7	8_4	8	4	2002	1994
4.0	4	0	4	5_5	5	5	2002	1997
4.1	4	1	5	6_5	6	5	2002	1996
4.2	4	2	6	7_5	7	5	2002	1995
4.3	4	3	7	8_5	8	5	2002	1994

c) Productivity standards

Good quality data is the first, but not the only issue of concern for production ageing. High volumes must also be produced and in some cases, especially for salmon, the SCL works with turnaround times as short as 24 hours. Productivity is important.

The SCL keeps records of the time it takes readers to age samples once through (first read) to the nearest quarter hour. This data has been analyzed to build production reader target rates (number fish aged/hour). Average rate and rate range targets were calculated (Table 3) for salmon species processed from 1999 to 2004. At least 6-8 experienced readers were involved having aged thousands of fish. The targets reveal that chinook are the most challenging salmon species to age having the lowest average rate of 60 fish/hr.

Table 3. Reading rate (productivity) targets for salmon aged by the SCL.

Species	Ageing Method	Sample size (99/00-04/05)	Average reading avg. rate targets (#/hour)	Reading rate ranges (#/hour)
Chinook	scales	186682	60	40-80
Chum	scales	86816	98	60-125
Coho	scales	82096	81	60-120
Sockeye	scales	176834	80	50-90

An experienced chinook reader is expected to meet established speed targets most of the time. The target rate ranges are delineated by 25% and 75% quartiles. Ranges were produced because not all samples and readers are the same. Rate can be affected by: species, stock, sample, complexity of life history, scale pattern clarity, number of scales per fish, severity of scale resorption and/or age composition. Generally, experienced SCL chinook scale readers spend about 1 minute determining the age of a single fish.

d) Data quality standards

i) Precision

Precision testing is a key QC tool used by the SCL to assess quality. All chinook scale samples are tested. Test results are viewed as an opportunity to learn and advance expertise (ensure similar application of criteria) while monitoring and improving the quality of age data that goes out to clients. Recognizing the importance of quality data, SCL readers feel a level of assurance knowing that their work is checked to ensure that best quality age data will be passed on to clients. It`s a team effort. The minimum precision target set for most chinook stocks is 80% agreement, with results of 90% or better often attained.

The SCL currently assesses precision via percent agreement. More advisable stringent statistical tests such as Average Percent Error and Co-efficient of Variation (Beamish and Fournier 1981, Chang 1982, Kimura and Lyons 1991, Campana et al. 1995) are not used by the program yet because only the final age is input to the salmon age database. All precision tests are conducted independently (blind). The tester does not have access to the first reader's ages. The 80% agreement precision target for chinook is based on analysis of many different reader's results for thousands of fish and multiple stocks over two decades of samples.

20% of each salmon sample is independently aged. The first reader has no knowledge which will be tested while ageing. Rather than choosing individual fish, whole scale books are identified for testing by rolling dice after the first reading is completed. Thereafter, every 5th book is tested to evenly distribute monitoring throughout the sample. All fish in a book are tested unless the last book chosen contains more fish than are required for the test.

Books to be tested are identified by the first reader with a "dash" beside the book number on the original age data sheet. They prepare a separate precision test sheet (sample header information and scale book ID numbers) for the tester. The tester retrieves the sample and test sheet and independently re-ages the subsample. Upon completion, the tester will recover the primary reader's ageing sheets, transfer the test ages to them and calculate percent agreement. The tester then begins the process to resolve any differences or biases showing up from the precision test and also will 2nd read any fish that have been flagged by the 1st reader in the sample. If the 80% precision target is not met then a portion or all of a sample is re-aged. If biases can be identified, only those affected ages, aside from the precision test, will be re-aged by the tester. If there appears to be no biases, a problematic situation, then a "random" number of fish or perhaps all will be re-aged to see if more differences can be identified. Once the sample has been looked at by the precision tester, the sample will be given back to the first reader to go over any unresolved fish until both readers agree on the final age assignments.

ii) Accuracy

The SCL uses CWT information whenever available to independently validate the accuracy of scale ages for hatchery chinook. Release information provides total and FW age confirmation. The reader is not allowed access to CWT information when originally ageing a sample. CWT ages are checked after the fact. If there is a discrepancy between the two ages an SCL reader does not automatically change the age on the data sheet to agree with the CWT age. A change must make sense given the scale pattern when reviewed again with CWT information. The change is only done if the reader expressed uncertainties on the age data sheet and/or recorded an alternative age(s) that match the CWT age.

The SCL also uses genetic information to help improve the accuracy of ageing some chinook stocks when available. DNA analysis, done by various salmon programs, identifies the probability that fish belong to certain stocks within a mixed fishery. If these stocks are known to be predominantly stream or ocean-type, this assists in the verification of the FW age of scales. As per CWT's, DNA information is checked after the fact and ages are only changed if it makes sense considering the scale pattern.

5. Scale age determination method – criteria, standards & procedures

a) Terminology standards

The main tasks of a salmon scale reader are to consistently and accurately count annual growth zones and identify what environment they were formed in. This often means interacting with other readers. Therefore, clear communication becomes important to ensure that readers are talking about the same thing. The SCL employs standard terminology (Chilton and Beamish 1982, MacLellan 1997) to ensure consistent exchange of information. The Glossary at the end of this document provides definitions of terms used in this document.

b) Standards to generate age data

During production ageing of chinook scales, SCL readers estimate age based on growth pattern characteristics, not biological factors such as specimen length, weight, maturity and/or sex of individual fish. It should be noted, however, that these factors may have had a role during the development phase for the method when they would be converted into pattern recognition criteria such as location, shape and size of annual growth zones. Biological data are not available to SCL readers during age determination as it is considered to be biasing. These data may be taken into consideration, but not until after the fact, and is strictly left up to data users to employ. The expectation is that clients will provide feedback to the SCL if they find that age data is in conflict with biological data. Criteria may be modified, based on this kind of feedback, especially if it would make a difference for a significant proportion of a species or stock.

To generate salmon age data the SCL reader must have access to 3 pieces of sample data; species, location and date caught, and apply a standard birthdate of January 1st. Although usually discernable once the scales are examined, species ID provides general growth pattern expectations. Likewise, location, especially for escapement samples, helps when stock specific pattern criteria needs to be applied. Finally, the date caught is critical when making sure that year of death is attributed to the correct calendar year.

i) Date of capture information

The SCL will not age a sample unless the date of capture is provided. To assess age accurately, the date of capture is necessary and must be available to the reader. The year is not important, but the month is essential. The day is also very useful in terms of placement within a month; early, mid or late. This can be critical to the age decision making process, especially in spring and fall when scale growth zone deposition is changing from fast or slow growth conditions. The month and day provide expectations for the type, size and completion of the last growth zone (summer/winter) on the scale margin. The date requirement ensures that the last annual growth zone visible on the scale edge, complete or not, is assigned to the correct calendar year of formation, either the previous or the catch year. Without accurate catch date information a fish can be miss-aged by one year.

ii) January 1st birthdate standard

Age or age type is determined for salmon using a January 1st birthdate (INPFC 1958) with reference to the catch date or the date the fish died. Employment of a January 1st rather than a biological birthdate ensures that all fish born in the same calendar year are grouped together for analysis. Figure 6 illustrates how the SCL assesses age as scale growth progresses throughout the calendar year. A salmon is not designated a year older until January 1st. Use of different birthdates can lead to a discrepancy of one year during certain catch times of the year causing difficulties when exchanging data with other agencies/groups that share data. The SCL makes an “adjustment” for deadpitch samples (scales collected from dead fish) after January 1st. These samples are considered to have died in the previous calendar year ahead of scale collection. In this case, date of death is noted for determining age.

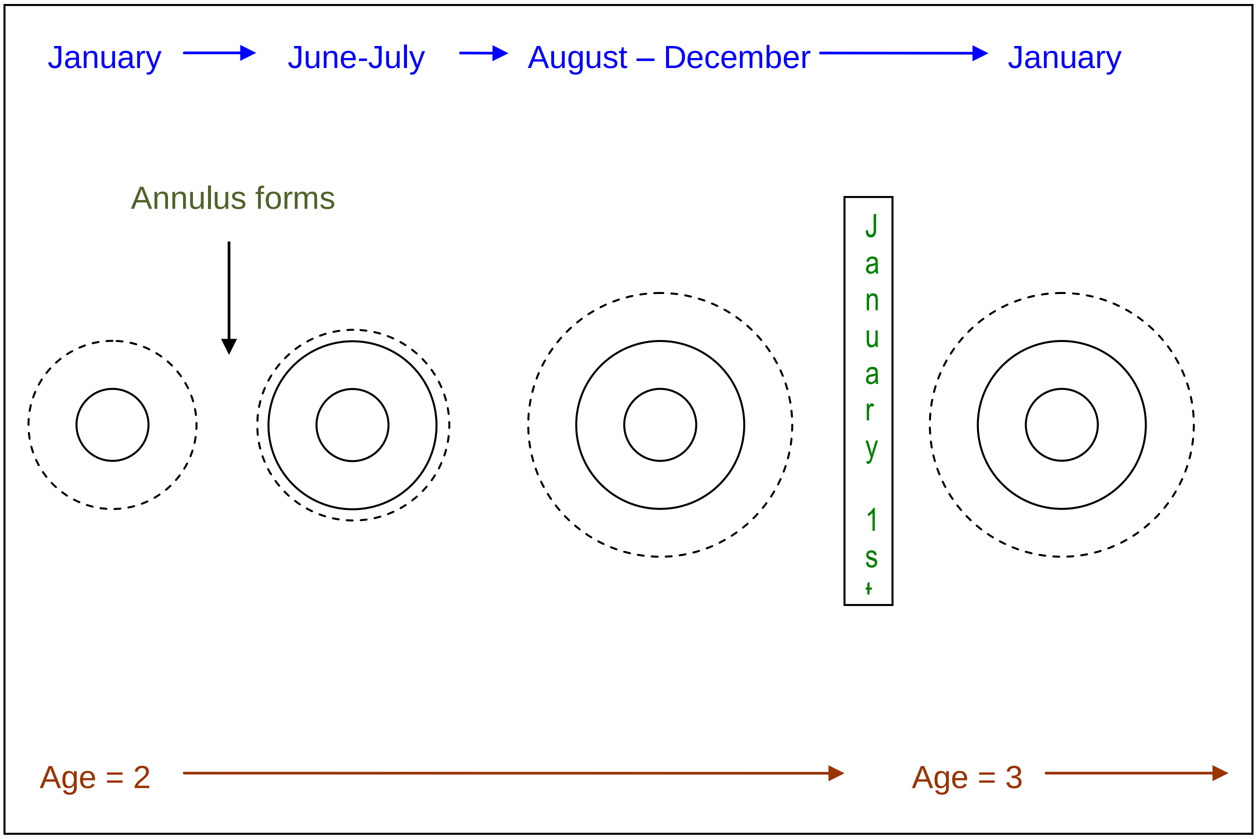


Fig. 6 Illustration demonstrating how the Jan 1st birthdate is applied to salmon scales. The annulus (solid line) cannot be identified until new summer growth (wide white zone) begins to form. The annulus (last circulus of winter zone) appears sometime in the late winter – early spring. This is followed by new year's growth that forms from June through till the end of winter past the January 1st date. The marginal growth zone (dashed line) that gradually becomes larger and fuller in the fall is not counted as another year until after Jan. 1st.

iii) Location information

Chinook stocks from B.C. and the Yukon experience myriad complex life histories described as stream or ocean type producing a range of age types. Stream types spend one or more winters in freshwater while ocean type fish go to sea during their first year of life. Fish that spend 2 winters in freshwater are quite rare from Canadian stocks. Generally, those stocks found in southern B.C. tend to be ocean type and those from northern B.C. and the Yukon are stream type. Ocean type stocks tend to give way to stream type chinook around B.C.'s central coastal. There are exceptions to the north-south trend. For example, Fraser River chinook stocks that spawn in its far reaches are stream type while those closer to the mouth are ocean type. There are a number of systems that have both age types. The SCL also age mixed fishery samples that include stocks from Washington and Oregon, so must keep records of age types and life histories and any unique scale patterns associated with them.

The SCL prefers to know the location samples were collected. Minor nuanced, unique age criteria exist for some chinook stocks. Location is very helpful when ageing escapement samples in order to anticipate stream or ocean type scale patterns and to apply resorption criteria. Mixed stock fisheries samples present their own challenges obliging the SCL to fall back to most basic growth pattern criteria. This document does not cover criteria unique to specific B.C. and Yukon stocks rather focuses on the basic criteria used to age any chinook scale.

c) Basic scale ageing criteria

The basic criteria for ageing chinook scales are similar to that of all salmon species. Age is determined by interpreting circuli growth patterns in terms of numbers of freshwater (FWA) and saltwater annuli (SWA) present. Circuli are growth ridges that form concentrically on the anterior portion of the scale exterior. The area that is bound by the first circulus is called the focus. The focus and several subsequent circuli will form fully in all quadrants of the chinook scale, in both the anterior and posterior.

The first circuli that form in the spring, whether in freshwater (FW) or saltwater (SW), are thicker and wider-spaced than those that form later in the fall and winter. FW circuli usually appear more delicate (thinner) and closer-spaced than SW circuli which are more robust in appearance and wider-spaced. FW annual zones are significantly smaller than SW zones. An SCL reader will always look at the overall growth pattern to get a first impression of age type before focusing in on individual annual zones. Marine annual zones on chinook scales generally become proportionately smaller with each year. The first is usually the largest or at least as large as the second marine zone depending on stock and sometimes whether the fish has a stream or ocean-type.

The reader must learn to discriminate three scale growth zones (Fig. 7):

1. <u>Winter zones</u> and associated <u>annuli</u>
   - form during the fall, winter and early spring months
   - represents slower growth
   - consist of progressively closer-spaced and thinner circuli and the last close-spaced circulus of the zone is the annulus
   - annuli by definition form only once a year
2. <u>Summer zones</u>
   - form during the late spring, summer and early fall months
   - represent a time of faster growth
   - consist of thick wide-spaced circuli
3. <u>Checks</u>
   - form within the normally fast-growing summer zone
   - represent a slowing of growth due to some kind of stress
   - usually consists of only a few circuli

One <u>annual zone</u> consists of a summer zone followed by a winter zone with annulus.

Essentially the reader's job boils down to the ability to differentiate annuli from checks and vice versa. If counted over-ageing occurs. Checks (Fig. 7) can look very similar to annuli. They may exhibit some or many of the characteristics attributed to annuli but usually are less prominent. They can form both in the FW or SW zones of chinook scales. The SCL does not count an annual zone until the annulus can be identified. This means that at least one thicker wider-spaced summer zone circulus must be visible beyond the annulus on the scale margin.

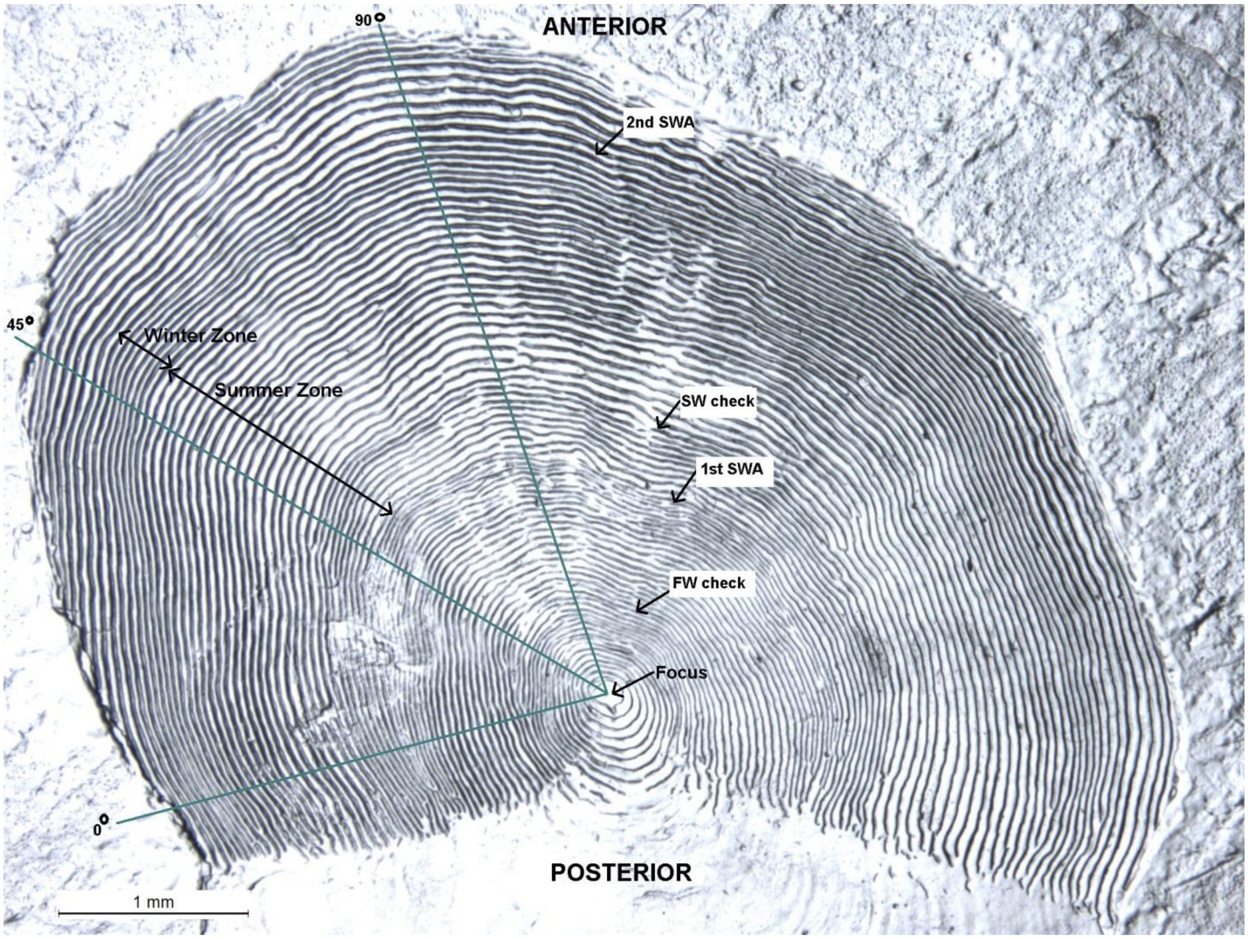


Fig. 7 Typical ocean type chinook scale showing summer and winter zones, annuli and some checks. The focus, posterior and anterior quadrants as well as standard axes (90° and 45°) used for measurements are labelled.

Determination of life history type and number of annuli are the basic tasks when estimating the age of a chinook scale. Figure 8 demonstrates typical rather straight forward scale growth patterns for stream (1FWA) and ocean (0 FWA) type scales.

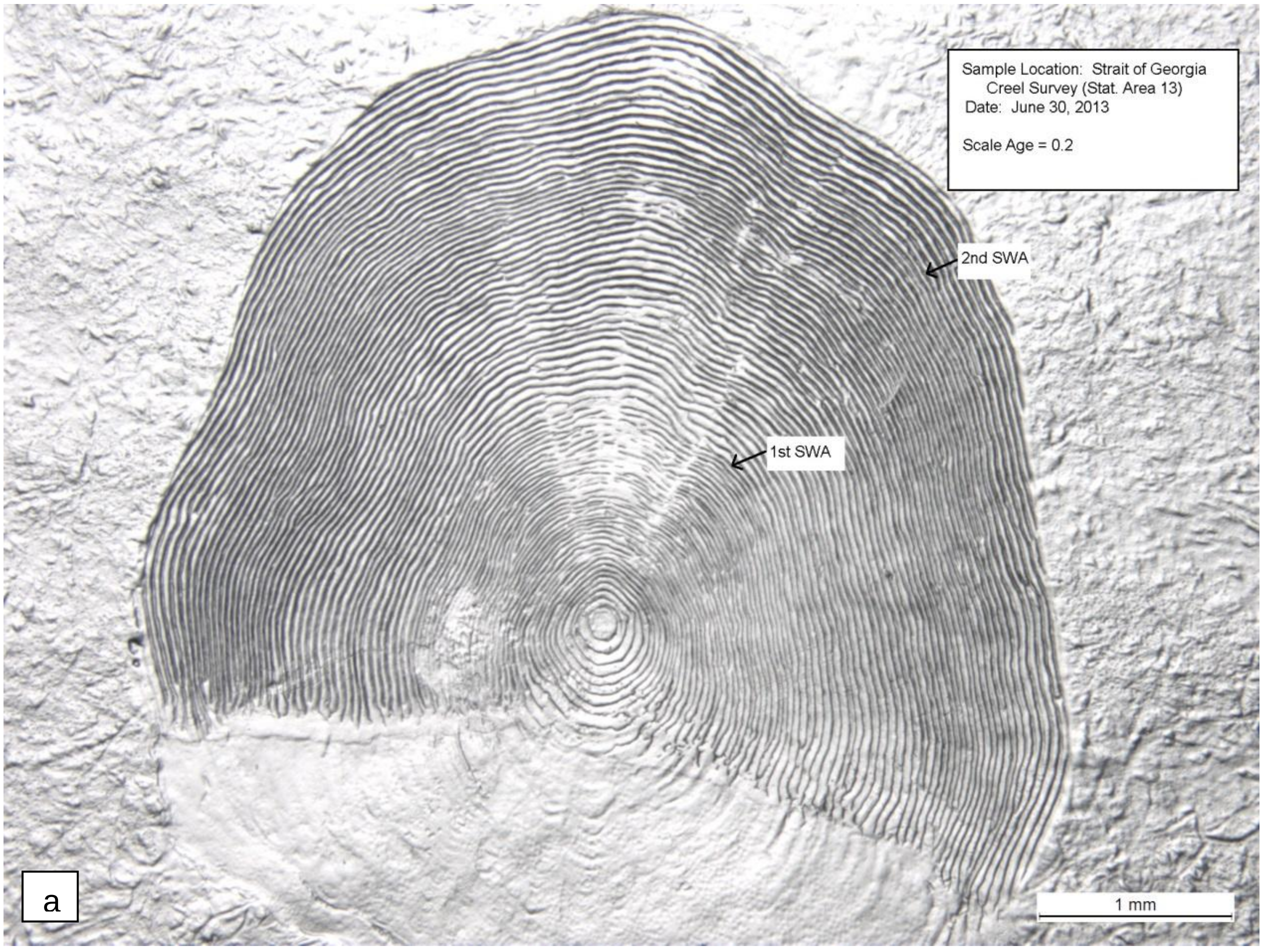
General criteria used to identify both FW and SW annuli on salmon scales:

1. Annulus is preceded by a band of successively closer-spaced and thinner circuli.
2. Circuli "cross-over", are broken or merge around the outer circumference of the winter zone

3. Circuli “pinch” and bend in towards the focus along the posterior axis of the scale.
4. Annulus is followed by relatively wider spaced and thicker circuli, formed in either FW or SW
5. Circuli following annuli tend to turn outwards, away from the focus, along the posterior scale line.

Additional criteria used to identify FWA, in descending order of reliability:

1. Presence of FW spring plus growth beyond a FWA. Spring growth consists of a band of a few to several slightly thicker wider-spaced and relatively parallel FW circuli that surround the FWA. There is no pinching or bending in towards the focus at its outer limits along the posterior scale axis. This zone represents a short period of time spent in freshwater in the spring after the annulus has been deposited and before migrating to sea.
2. Presence of many FW circuli that appear densely packed together and are concentric around the entire focus area, known as a “cut out” (Yole 1989).
3. FWA is followed by significantly thicker and wider-spaced marine circuli. This represents a clear and distinct change from FW to SW.
4. A FW annual zone usually consists of at least 8-10 circuli.
5. Distance from the focus to the 1st SWA is larger than distance from the 1st SWA to the 2nd SWA.
6. Circuli spacing in the 1st marine summer zone is very similar to the circuli spacing in the 2nd marine summer zone.
7. Presence of a prominent striation that extends into the posterior part of the scale, mirroring the annulus.


Sample Location: Strait of Georgia
Creel Survey (Stat. Area 13)
Date: June 30, 2013
Scale Age = 0.2
2nd SWA
1st SWA
a
1 mm

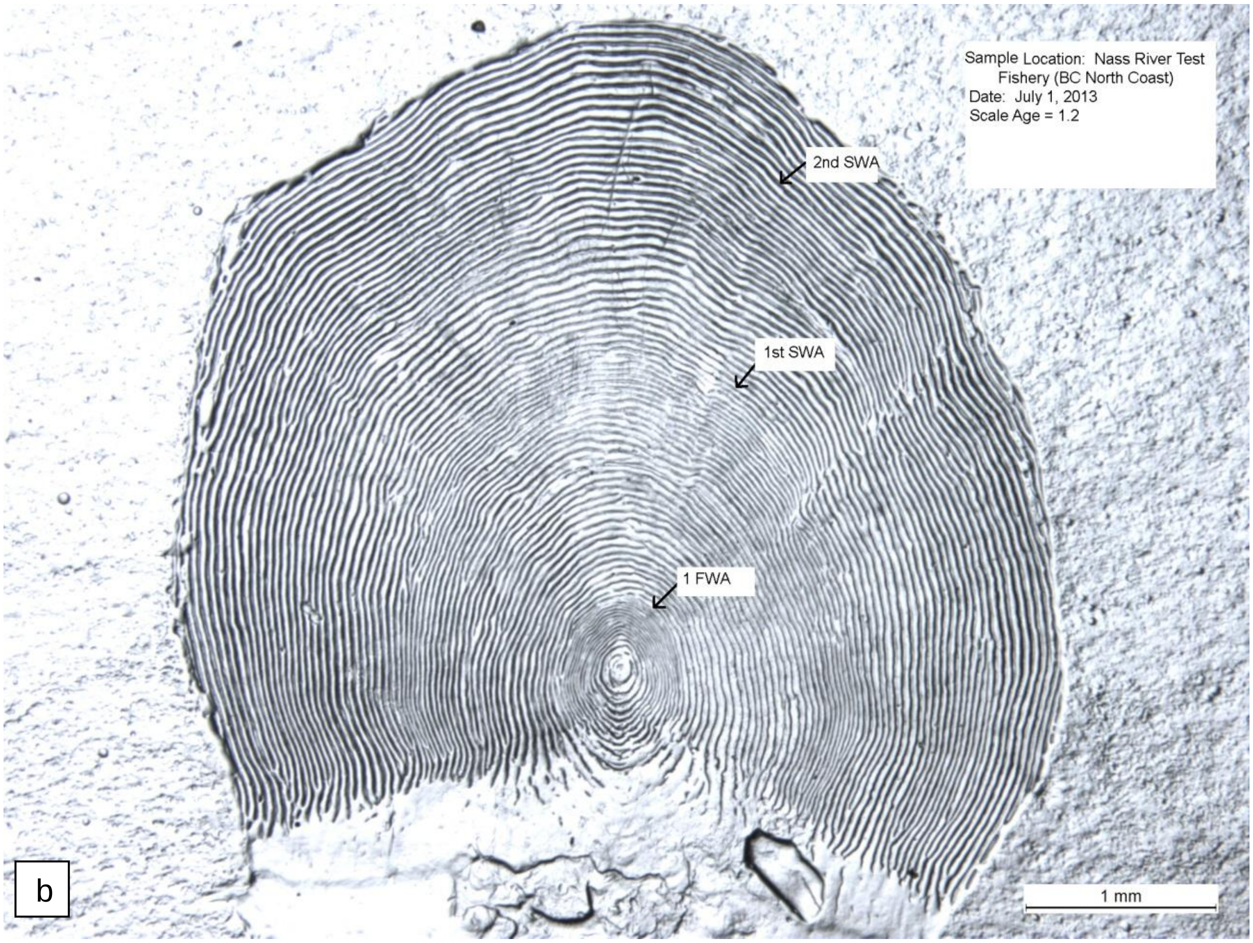


Fig. 8 Images of typical and clear 0FWA a) and 1FWA b) chinook scales with annuli pointed out.

d) Challenges for chinook scale age determination

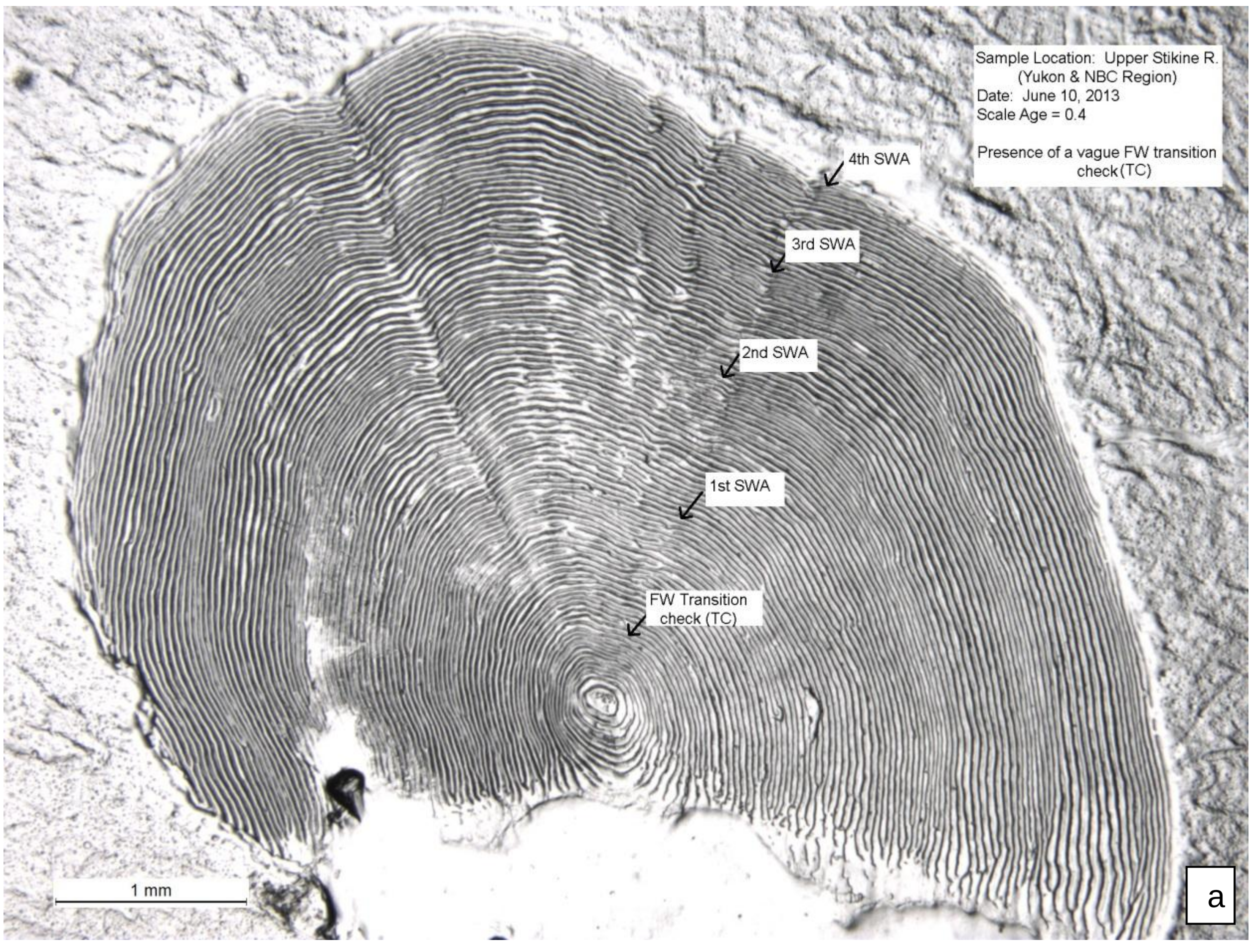
The main challenges to accurately ageing chinook scales are:

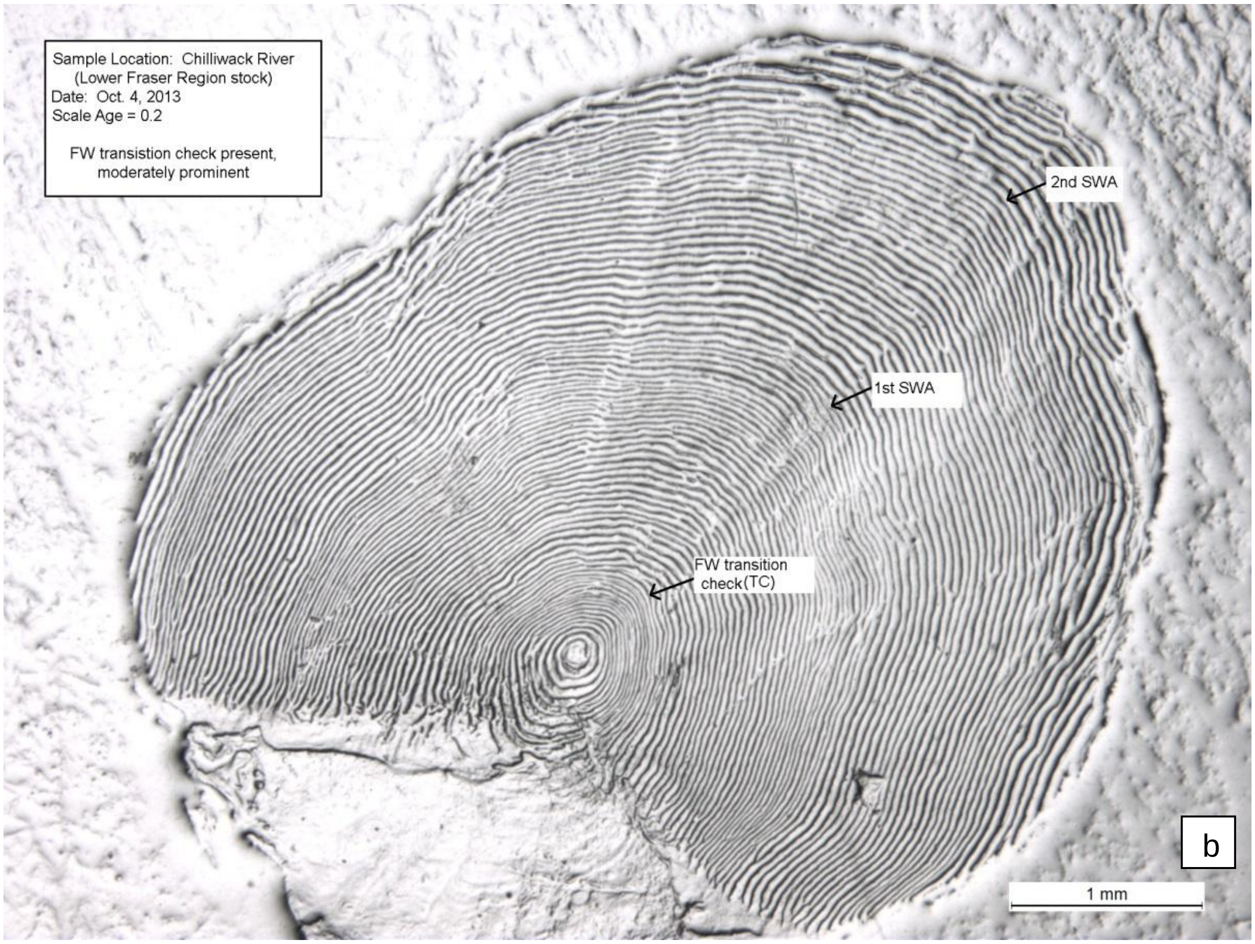
1. Presence of prominent FW checks
2. Presence of prominent SW checks
3. Indistinct SWA
4. Determining if resorption is affecting age

i) Freshwater checks

Probably the biggest challenge the SCL faces when ageing chinook scales is determining the presence or absence of a FWA as opposed to checks. Ambiguity results when basic annulus and additional FWA criteria appears inconsistently reliable. In particular, the SCL finds that not all "additional" FWA criteria pertain to all chinook stocks and/or fish in the same sample. These kinds of samples usually come from mixed fisheries, large river systems with a number of minor stocks or contain both hatchery and wild fish.

A prominent freshwater transition check (TC) may form at the end of FW growth in the first year (Fig. 9). The check is attributed to smolting stresses that slow growth. Sometimes the TC satisfies one or more criteria for an annulus and can appear as/more prominent. Knowing the stock origin can have a strong influence of whether to discount a check even when it is prominent. The SCL has learned that when faced with conflicting evidence for the presence of a freshwater annulus, it is more likely to be a check. This is based on information from coded wire tagged (CWT) hatchery chinook that are known-aged. The SCL finds that scales from hatchery reared chinook are more likely to have a prominent TC.




Sample Location: Chilliwack River
(Lower Fraser Region stock)
Date: Oct. 4, 2013
Scale Age = 0.2
FW transistion check present, moderately prominent
2nd SWA
1st SWA
FW transition check(TC)
b
1 mm

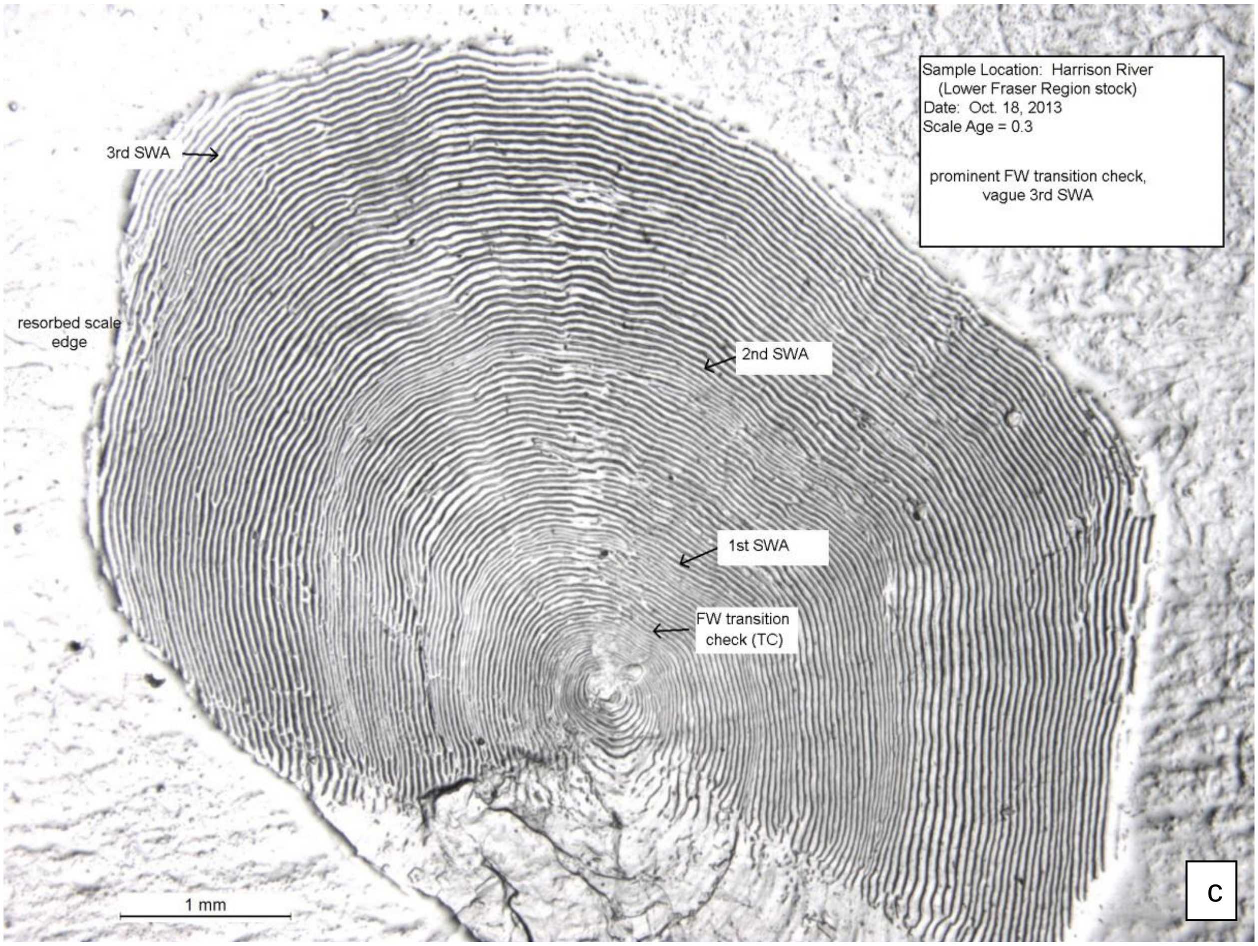
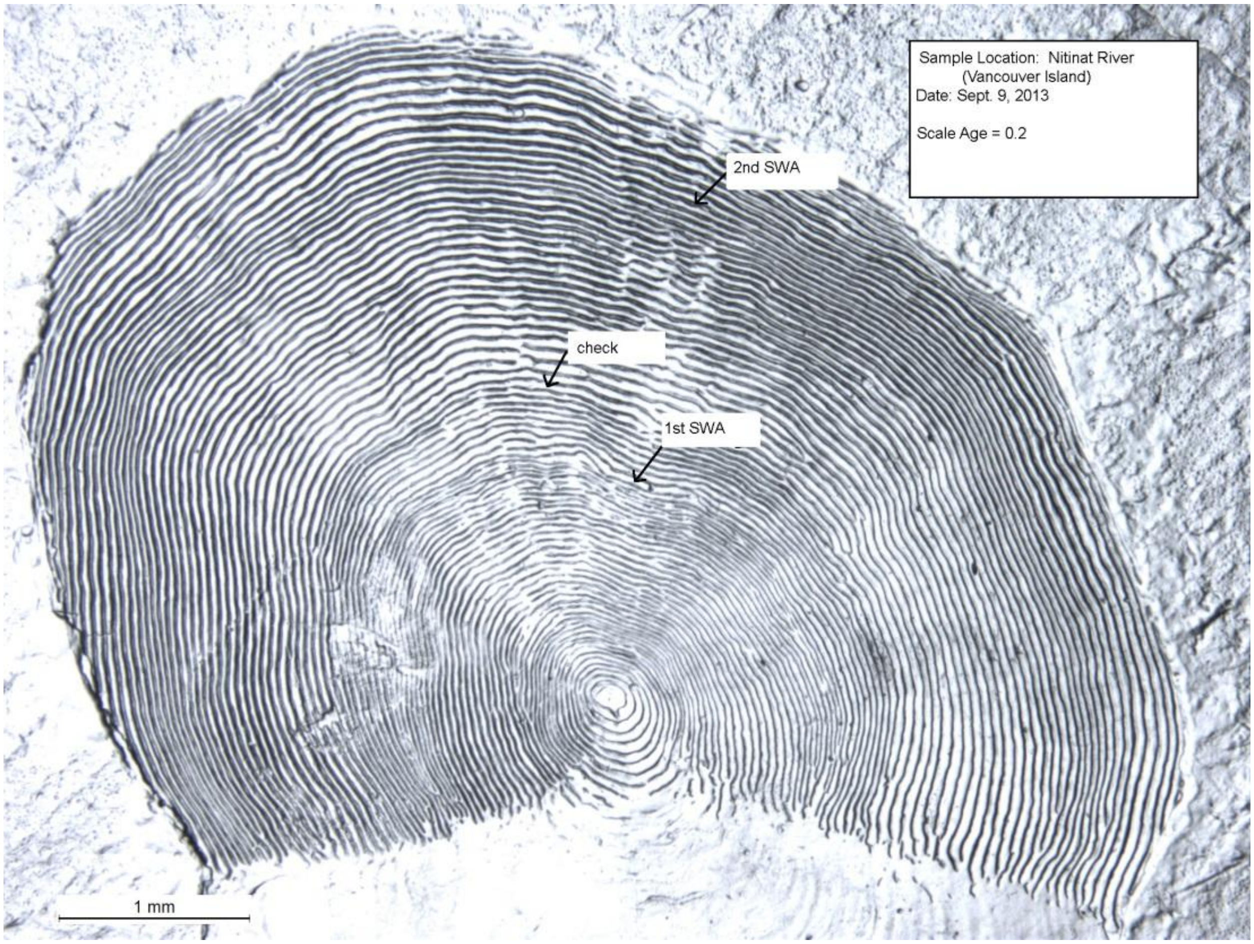


Fig. 9 Chinook scales showing transition checks that range in prominence, a) not very, b) moderate, c) very.

ii) Saltwater checks

Checks in marine summer zones are generally easy to identify because only a few circuli are involved (~2-3). A SW check is preceded and followed by wide spaced circuli. The check can be difficult to identify if it seems to be located where an annulus is expected to be. The general expectation is that marine annual zones on chinook scales start off with the first or the first and second being the largest followed by consecutively smaller years. A check will disrupt this pattern (Fig. 10) and cause later marine zones to appear unexpectedly small or large. There are some stocks that don`t follow the general rule, e.g. when a late forming marine zone is larger than the previous one or all zones are very similar in size.


Sample Location: Nitinat River
(Vancouver Island)
Date: Sept. 9, 2013
Scale Age = 0.2
2nd SWA
check
1st SWA
1 mm

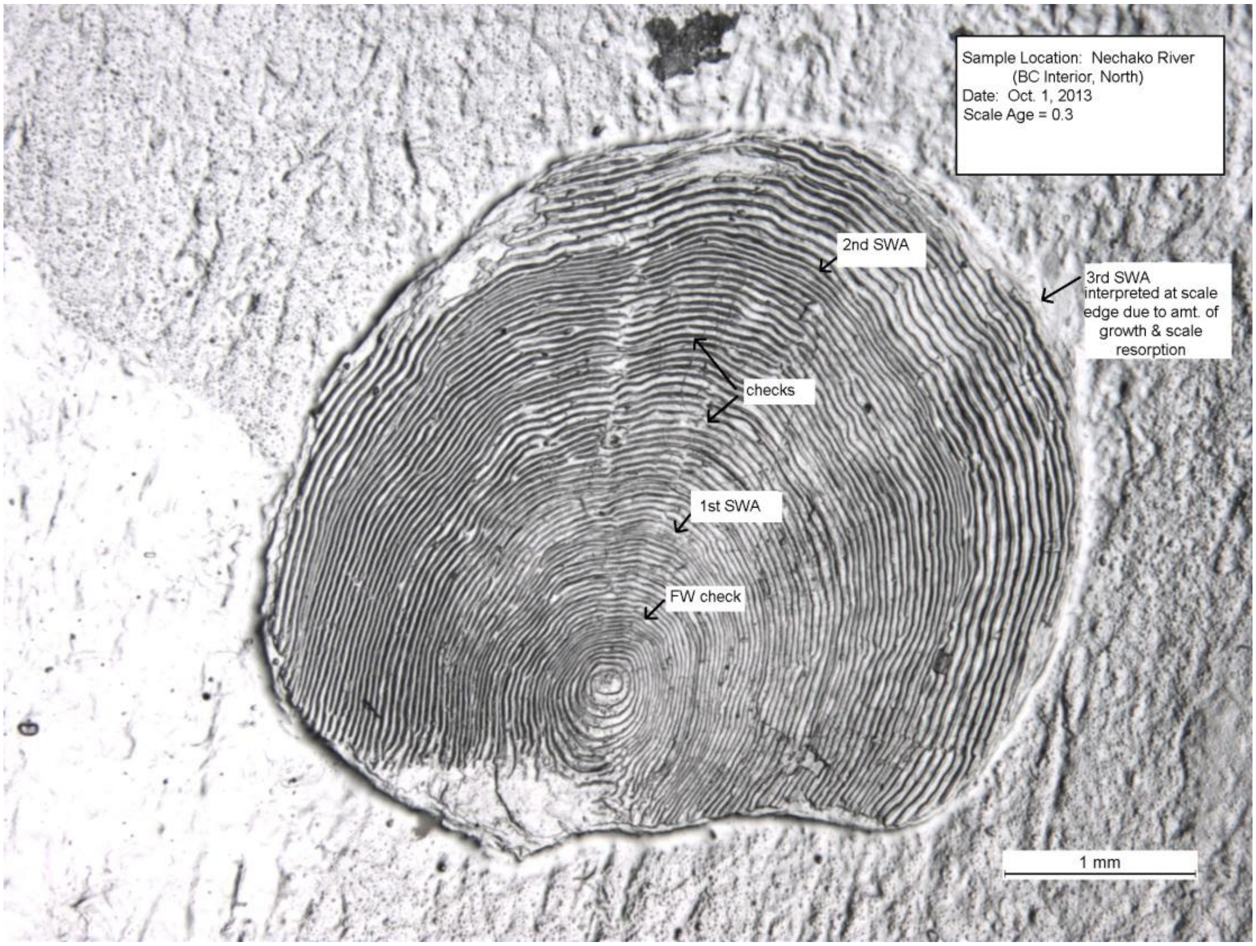


Fig. 10 Chinook scales with a prominent check(s) in the marine annual zones.

iii) **Indistinct marine annuli**

Vague SW annuli are a challenge that may cause under-ageing of chinook scales. The SCL attributes this kind of pattern to fish that do not experience much slowing of growth during the winter months. These annuli usually are not preceded by an obvious or a typical winter zone with narrowing and closely packed circuli. There is often little evidence of merging and pinching of circuli. The SCL reader will look for a vague annulus if there appears to be an annulus missing from an expected location and the annual zone appears larger than usual. A good area to look for indistinct annuli is along an angle from the vertical scale axis and for subtly and slightly more close-spaced circuli (Fig. 11). The first circulus of the next summer zone may be only slightly thicker and wider-spaced than the vague annulus.

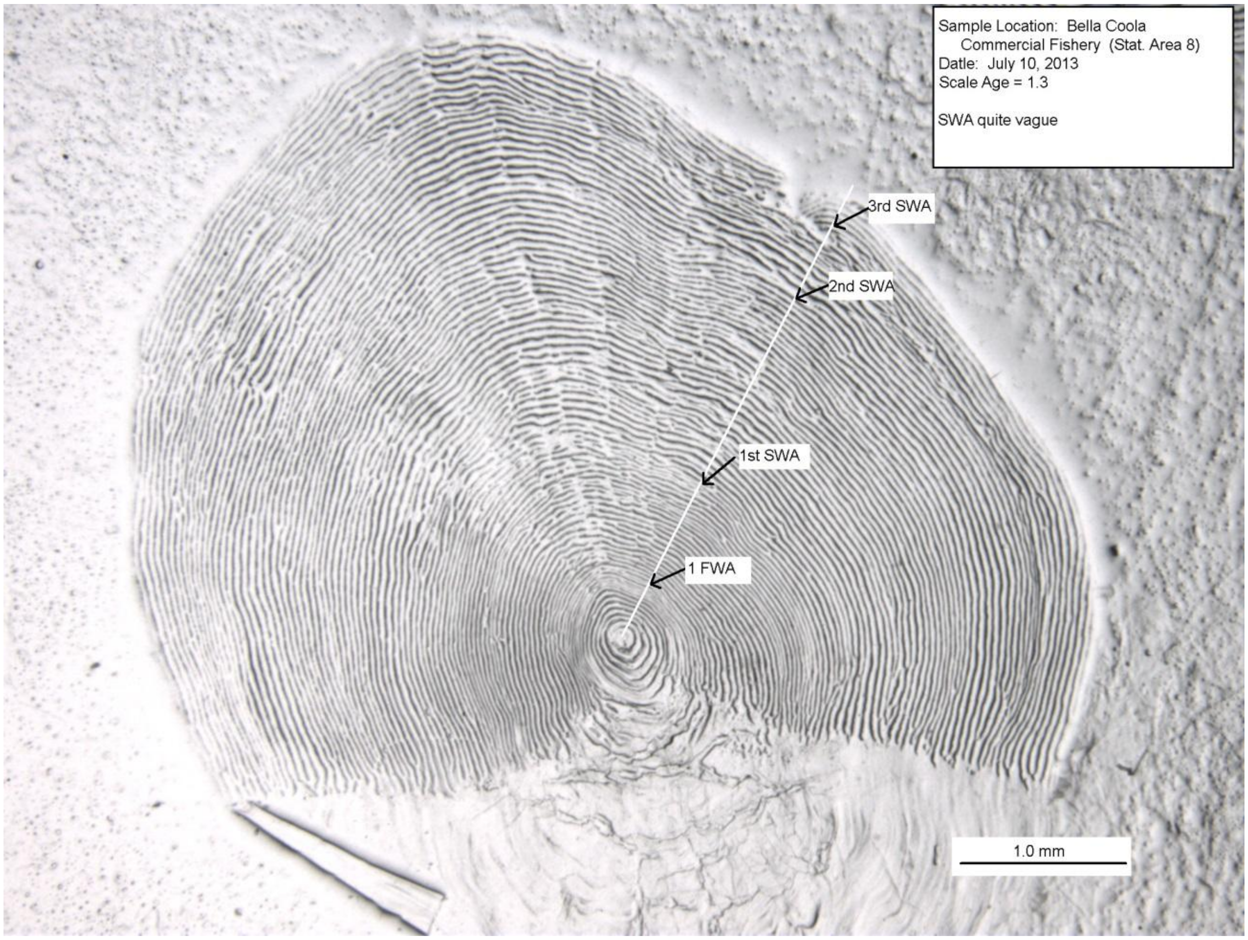


Fig. 11 Chinook scale with vague SWA identified.

iv) Resorption

The fourth biggest challenge to accurate ageing of chinook scales is when resorption is a factor. Resorption occurs on the scales of mature chinook. It may begin while the fish is still in the ocean, but is usually associated with returning to freshwater. Resorption takes place on the scale margin and in extreme cases on the inner surfaces of chinook scales. Resorbed scales have some unknown amount of missing growth on the margin.

The SCL is asked to age a large number of escapement samples with resorbed scales. To provide the most accurate ages the SCL developed some objective criteria to estimate whether or not an annulus is missing and if a year should be added to the marine age. Generally, this resorbed scale criteria is most often applied to samples from relatively long river systems or samples from the upper Fraser system to central and northern B.C. and the Yukon. It is known from CWT samples that southern B.C. stocks, including west coast Vancouver Island, rarely resorb back past the last formed marine annulus. It is not often required to use resorbed criteria when ageing these stocks.

Resorbed scale criteria:

Resorbed criteria compares the size (width) of the last visible growth zone on the scale margin to the previous annual zone. A growth code (see below) is assigned to describe relative size of the margin growth for each scale. Growth is measured (Fig. 12) by eye and using a pen to assess relative size of the last 2 annual zones visible on the scale. Measurement occurs wherever the maximum amount of growth is present on the scale as the rate of resorption is not consistent between scales or around the circumference of the scale (Fig. 13). Each scale collected from a fish is coded. The final age decision is made using the scale with the most growth beyond the last visible annulus.

<u>Codes describing relative size of last annual zone on scale margin:</u>

- 1= less than ¼ previous year (1-2 circuli)
- 1^2 = about ¼ previous year
- 2^1 = just short of ½ of previous year
- 2 = about half the width of previous year
- 2^3 = a little more than ½ of previous year
- 3^2 = just short of previous year
- 3 = same as previous year
- 3^+ = more than previous year

Fig. 12 Photo demonstrating how SCL salmon readers use a pen to “measure” the size of annual growth zones on the scale image.

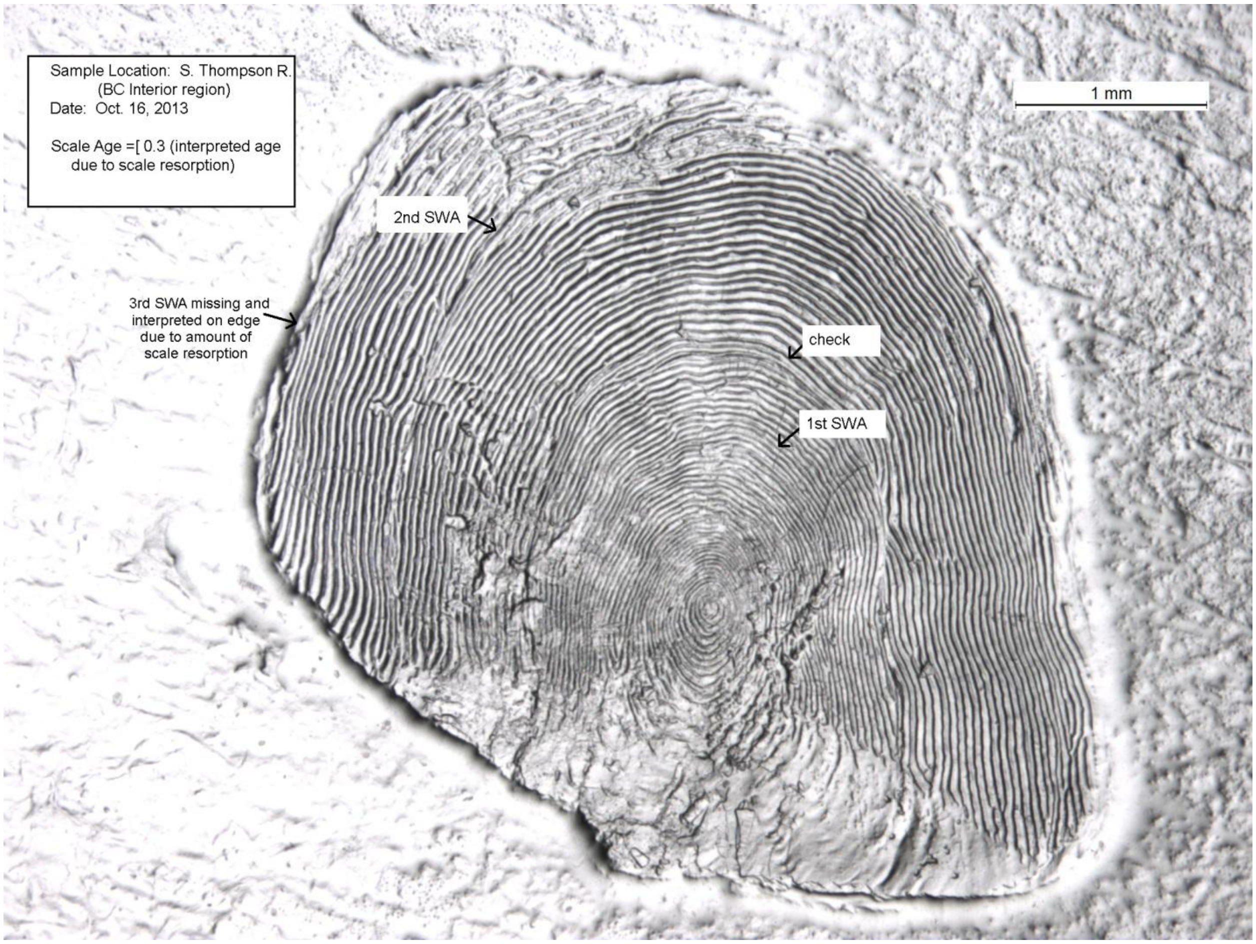


Fig. 13 Photo of a chinook scale demonstrating varying amounts of RS around the margin.

The SCL applies the above criteria to make determinations as to whether no, one or some unknown number of annual zone(s) is missing. A total age is assessed in the first two cases, but for the third only a FW age will be supplied. A year is added to the SW age in the case where one annual zone is determined to be missing and none to the case where no annual zone is missing.. On the age data sheet this is identified as a resorbed age (RS) and the final age on the age data sheet will also be given an edge code (see below) to indicate how the reader assessed resorption. See Appendix 1 for more detail.

<u>Edge codes for scales:</u>

- blank = no resorption
- 0 = resorption present, but not affecting age
- 1 = resorption has eroded past the last annulus and it is assessed that one year should be added to the "visible" age of the scale
- 2 = the scale is resorbed to an extent such that it cannot be determined if any number of annuli are missing from the scale margin
- 3 = one year added to visible age due to date fish was caught (e.g. January – June)

- 4 = one year added to visible age due to date fish was caught and the scale is slightly resorbed, but not affecting age

The SCL has documented that different aged chinook and stocks experience different rates of scale resorption. For instance, jack scales can be challenging when trying to apply resorption criteria because they often put on more growth in their only marine zone and appear to resorb scales at a different rate than older counterparts. Overall relative scale size is sometimes used to help identify jack scales. The decision making process whether to add a year can therefore differ slightly between stocks as well as for different ages within stocks. Figure 14 reproduces the information and resorption criteria for different age types of Kitsumkalum chinook scales. Other stocks will have different decision making criteria. The SCL makes use of CWT information to corroborate the nuances of applying resorption criteria. If it works most of the time (~80%) the criteria is deemed valid.

2007 Kitsumkalum River Chinook Enumeration Keystream project (2007/177-180) CWT results were 59% agreement. Of 55 CWT's only 37 could be compared due to part/non-ages. Agreement was improved with some review of and update to criteria. Also, many of the books were fairly wet and were slightly under-pressed which led to incorrect identification of 1FWA's that were 0FWA. The adjustment in criteria is directed at jacks for which we have not had RS criteria before, and can be seen in updated RS Index table below. CWT's indicate that 2^3 index can be 1.1, but this can be difficult to determine especially when scale size is ambiguous. Therefore, these should be given a part-age. The other change is that if we have books this wet in future, especially in combination with a light press, we should be more cautious about assigning a FW age and assign more part ages. Once we had gone over the ages and changed our minds on a few, our agreement with the CWT's was 76%.

Age	Growth Index	Interpreted Age
1.1	≤2	1.1
1.1	2^3	1F
1.1	$≥3^2$	1.2
1.2	1-2	1.2
1.2	2-3	1.3
1.3	1	1.3
1.3	2-3	1.4
1.4	1	1.4
1.4	2-3	1.5

(07/11/29 SEM)

Fig. 14 Excerpt from the SCL's Word document that records criteria for each stock's samples over time. Criteria (Growth indices) are used to provide an interpreted age for Kitsumkalum chinook scales that are resorbed and are of different visible ages (Age). The first column is the visible age on the resorbed scale. The Growth Index is the measured size of the last growth zone relative to the previous year's growth. The interpreted age indicates if no or one year is added to the visible age or if some unknown amount of marine growth is missing, in which case a part age (FW age only) is given, e.g. 1F.

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GLOSSARY:

Accurate/accuracy measures the closeness to the true or actual age.

Age class refers to fish that were all born in the same calendar year.

Age designation systems denote how age is to be recorded for various species.

Age type refers to ocean or stream type age designations for salmonids that indicate the number of years spent in freshwater and saltwater.

An **annual growth zone** forms once a year. It is composed of a fast-growing summer zone followed by a slow growing winter zone.

A scale **annulus (plural annuli)** is the last close-space circulus of the winter zone that forms during the “winter” months (fall/winter/early spring) representing a slowing of growth. By definition it forms only once a year.

Biases describe systematic differences in how readers apply ageing criteria and assign age to fish.

The **biological birthdate** is the actual time of the year that a fish hatches.

Blind ageing - see independent ageing.

A reader is considered to have **broad experience** when they have aged a wide variety of salmon species or stocks.

Capacity refers to the volume of work that the SCL can generate over time, e.g. a year, based on resources (trained staff) and effort required to age different species.

Checks may form within the summer zone and look very much like annuli. More than one may form per year and if prominent enough can be mistaken for annuli. They also represent a slowing of growth due to some kind of stress (usually unknown). Mistaking checks for annuli will lead to over-ageing.

Circuli are growth ridges that form on the exterior side of the dorsal part of a salmon scale.

Coded wire tags (CWT) are tiny metal tags injected into the noses of salmon smolts that contain codes identifying hatchery, brood year and date of release.

Compound microscopes are high powered scopes (40X-1,000X) used to view small, two dimensional specimens with transmitted light.

Continuity in age determination refers to long term consistency in how age is assessed for a species. This is usually achieved through documentation, training, standards, QA/QC systems, ergonomic practices and maintaining readers over the long term.

Age **criteria** are the rules developed, documented and employed to interpret annual growth patterns on scales in order to estimate age.

Cut out is term used to describe very densely packed dark appearing freshwater annual zone.

Dissecting microscopes are low powered scopes (1X-50X magnification) normally used to view relatively large three dimensional opaque specimens and may use either reflected or transmitted light.

A reader is considered to have **deep experience** if they have aged a significant number of salmon for a single species or stock over many years.

Edge growth forms on the margin of scales.

Expert status is granted to a reader that has demonstrated the ability to consistently meet precision and speed targets for both easy and difficult samples and maintains this status over the long term.

Ergonomic workstations and equipment physically ensure the health and longevity of readers.

Escapement samples are collected from mature fish found on freshwater spawning grounds.

The **final age** is the age generated by the SCL for a fish. This age is keypunched into databases and is used for analysis.

The **first (primary) reader** is the first reader to age a sample.

SCL readers **flag** specimens on their age data sheets that need a second non-independent opinion from another reader to resolve the age.

The first circulus to form in the centre of a scale is called the **focus**.

Independent (blind) ageing occurs when an additional reading of a fish is done without access to the first reading.

A **jack** is a precociously mature male chinook salmon that over-winters only one year in the ocean and then returns to spawn.

The **January 1st birthdate** is the accepted standard birthdate used to assign age class rather than biological birthdate to fish in the northern hemisphere. All fish become one year older as of January 1st. This keeps fish born in the same calendar year grouped together for assessment and management purposes.

Known-age/part known-age refers to fish where the total or part of the actual or true age is known because of some process that has established the annual regularity of growth zone deposition and/or the calendar year of birth.

The **margin/edge** refers to the outer circumference of a scale where new growth forms.

Non-independent ages are generated when readers have access to other readings during age determination.

Ocean type life history chinook go to sea during their first year of life.

Pacific Age Database System (**PADS**) is a central Oracle database used by the SCL that replaced the former Ingres database used to record salmon age data in 2002.

Part known-age (see known-age).

Percent agreement calculates agreement of age data between 2 readers, within a reader or reader against known-age samples.

Precision measures repeatability or consistency. Age estimates for the same fish can be compared within/without readers or agencies.

Precision tests are a quality control tool where independent (blind) tests are carried out to assess the repeatability of readings (ages).

Primary reader – see first reader.

Production ageing refers to the long term routine age determination of large numbers of samples for stock assessment purposes.

Productivity refers to the number of fish per hour a reader can age.

A **Quality Assurance (QA) system** consists of planned, documented and systematic procedures developed to demonstrate confidence in the age data quality and/or to confirm that the data conforms to specified requirements.

Quality Control (QC) is part of the QA system and is the responsibility of everyone in the program. QC is a specific process to test results against set standards and the actions taken when there are discrepancies.

Reader biases exist when a reader is prone to choosing certain ages/age types over others when faced with indecision, e.g. older or younger, stream or ocean type.

Reader drift occurs when a reader changes how they apply age criteria resulting in discontinuity of age data over time.

SCL **reader rates** represent the number of fish that a reader can age in an hour.

Reference collections are specifically chosen samples that are set aside and maintained to test and train readers over time to prevent reader drift.

Reflected light is directed down onto a specimen that is placed under a microscope objective.

Regenerate scales are missing circuli from the focal area caused by loss of scales at some point. The result is a blank space in the scale pattern representing missing growth information and affecting the reader's ability to provide an accurate age.

The **resolution process** occurs when a reader works to decide amongst differing multiple ages generated for one specimen, narrowing it down to a single age. This process usually involves at least 2 readers or readings.

Resorbed scale (see resorption).

Scale **resorption** occurs during the migration of spawning salmon. Physiological processes break down the edges/margins of scales resulting in the loss of growth zones.

Scale books are used to collect SCL salmon scale samples in the field. They consist of a gummed card with a grid of 50 squares to mount the scales.

SCL is the acronym for the Sclerochronology Lab program.

When a sample is **second read** the second reader will read the whole sample through having access to the first reader's ages, i.e. is not an independent reading.

The **second reader (tester)** is the next reader to age a subsample of the first reader's sample via a precision test.

Self precision measures agreement of independent multiple readings by the same reader.

Spring plus growth is a band of freshwater circuli that forms in the new year, after a freshwater annulus, and represents a short time spent in freshwater before smolting.

Summer zone is the growth zone on scales that forms during the fast-growing seasons of late spring, summer and early fall. Only one summer zone forms per year, but it may be broken up by the presence of one or more checks.

Sclerochronology is the study of how time is recorded on the hard tissues of organisms. This includes tissues from fish such as otoliths, fins, vertebrae and scales.

Stream type life history chinook spend at least one winter in freshwater.

Technical competencies such as accuracy, precision and productivity are measured by the SCL to assess a reader's skill.

Tester – see second reader.

Transmitted light is directed upwards through a specimen that is placed on a microscope stage.

Validation of an ageing method occurs through the use of known-age specimens via a variety of techniques such CWT's. CWT's verify the accuracy of the salmon scale ageing method.

The **winter zone** on scales is the growth zone that forms during the slow-growing seasons of late fall, winter and early spring. Only one winter zone forms per year. It consists of thinner and consecutively more narrow-spaced circuli with the annulus being the last close-spaced circulus of the zone.

Working columns are found on SCL age data sheets. Readers record age estimates for each scale for a fish in these columns. A series of working columns are available to record the results of multiple readings including precision test results and other readings needed to resolve differences.

A **year class** indicates the calendar year of birth. Strong year class information can be useful yet biasing when estimating age of fish samples.

The **year of life** refers to the year a salmon migrates to sea or back to freshwater. It is not the same as age or age class. For example, a fish in its 3rd year of life is not 3 years old. It is 2 years old and will not be 3 until it lives past its 3rd January 1st birthday.

APPENDICES:

Appendix 1

Salmon Age Data Sheet Recording Conventions

The conventions for the salmon age data sheets are very complicated because of the complex life histories of various salmon species and because multiple structures are used to produce age for one fish. This usually means multiple scales or perhaps fins or otoliths in addition to scales. One or more bundles of scale books/cards, with header cards, bearing all the same information are considered a sample. They often span more than one day but are from the same location. Individual samples are identified by a project name and by a database (PADS) generated number. The number format denotes calendar year and a sample number starting from one each year, e.g. 2010/001, 2010/002.

Much of the salmon age data sheet format is set up for the scale method. The SCL works with and records salmonid ages in the European age designation system (Table 2). The standard January 1st birthday is used to assign age with respect to date caught and the amount and type of growth on the scale margin. As of Jan. 1st all fish become one year older. There is one exception, deadpitch samples may not be sampled until after Jan. 1st but are assumed to have died in the previous year. This convention is necessary to keep a spawning cohort together for analysis. Precision test results are transferred to the original age data sheet, after the fact, for quality assessment and resolution.

Header information:

Project – project name assigned to samples from specific regional salmon programs (see header card)
Sample # - calendar year and database sample number assigned by PADS (e.g. 2010/51)
# of Fish – number of fish in the sample
Species – salmon species common name
Format – format used to mount scales onto the scale card grid (e.g. 2a=2 across, 5d=5 down, 5a=5 across, 10a=10 across)
Date caught – date(s) the fish were caught/died, format yyyy mon dd (e.g. 2010 Nov 08), may be a range (e.g. 2010 Sep 23 – Oct 01)
Location – place the sample was collected (e.g. Nass River, Albion Ferry)
Area code – BC statistical area code indicating where the sample was collected (e.g. 29C, 23)
Sample remarks - summarize significant sample issues or observations
Time – 1st reader record the time it took to age the sample through once to nearest 15 minutes
QCt – tester record the time it took to complete the precision test and age any additional fish that were flagged or precision results indicated should be read a 2nd time

QCn – tester add together and record the number of fish aged in the precision test plus any additional fish aged a 2nd time aside from the precision test

Precision results:
Precision results - record which structures were tested (e.g. scales, fins, otoliths).
n – number of fish in precision test
vs - record the reader ID's involved in precision test, tester vs 1st reader (e.g. PK vs RD)
% Agreement - record percent agreement between tester and 1st reader

Fish information (far left of working columns):

- MMDD - Month and day sampled , fill in both columns for a date ranges
- Book # - scale book number (for scale samples only)
- Fish # - individual fish numbers within each book (e.g. 1-5, 1-10, 1-25 or 1-50)

Resolved age columns (left of working columns):

- Final age – input age type resolved ages from multiple methods (e.g. otoliths and scales)
- Fin age – input final resolved fin age
- Otolith age – input final resolved otolith age
- Resorbed?* – record a check to indicate that resorption is occurring on otoliths
- Scale age – input final resolved scale age type
- Edge** – record code indicating whether scale resorption has affected age
- Part-age comments*** - record codes to indicate cause for scale part-age, e.g. RG, Wet, etc.

* ** *** See Codes section below

Working columns:

Each working column "group" includes a header and columns for age and edge growth. Label working column headers in order of: method (e.g. scale 1, scale 2, otolith surface, fin xs), date the sample was aged (yyyy mon dd) and reader ID initials (e.g. RJ, TM).
The ages in these columns reflect only the number of annuli present/visible on the structure. Age class is interpreted later based on edge growth amount, presence of resorption, time of year caught and the January 1st birthdate from all structures aged for each fish and then recorded in the otolith, fin, scale and/or final resolved age columns.

Age is recorded using the European age designation system (e.g. 1.2, 0.3). Multiple scales are usually collected for each salmon. The general rule is that a reader should review and record the age of at least two scales/fish to assess age class accurately. It may be necessary to review more than two or all scales if resorption or ambiguous fresh/saltwater growth zones are issues. Different scales may present slightly different information. Each age data cell in the working columns may contain multiple pieces of information besides age, e.g. scale condition codes. When either fresh or saltwater age cannot be assessed a part age should be recorded in the working column cell, e.g. M2=2 marine annuli, no freshwater age or 1F=1 freshwater annuli, no marine age. Part ages can be of some use to clients. A number of codes have been developed to provide information about scale pattern or sampler problems and must be included in the same cell with the age, e.g. M2 W or M3 RG. The part age codes will be transferred to accompany the age class. The most common codes used for part age describe scales that are damaged (DM), wet (W), taken from the lateral line (LL), are non-preferred (NP), poorly pressed (PP), regenerate (RG) or resorbed (RS). If no age can be estimated due to scale condition record a code(s) to explain the lack of an age, e.g. W, RG, NS. This information can provide valuable feedback to clients to help improve sample quality issues.

Each working column group includes a growth column. This column records an edge growth code for each age. The amount of edge growth influences the age class interpretation. In the case of scales, resorption affects the reader's ability to make that assessment. Scale growth codes**** express how much scale margin growth was present after the last annulus and indicate if resorption and/or time of year caught affected the assignment of the age class in the resolved age column. The codes represent an objective relative measurement that describes how "complete" the last annual growth zone is relative to the previous year's growth. Rough measurements are done by eye.

To speed up recording information for multiple scales per fish a short hand was developed to record information in the working columns:

- Arrow - indicates same age/circumstance as previous cell(s)
- Dot– means the scale was examined but provided no new information from any of the previous cells
- Blank cell - reader decided it was unnecessary to look at all scales

Codes:

<u>* Scale condition codes:</u>

- 2F = 2 freshwater annuli with unknown number of saltwater annuli (usually due to resorption)
- CE = clean edge (little to no resorption evident on the scale margin, a smooth edge)
- DM = damaged (scale is ripped or missing parts)
- DSA = distinct 2nd saltwater annulus
- DS = double scales in one scale book cell
- FWA = freshwater annulus
- LL = lateral line scale (scale has a hole and distorted growth in the centre)
- M2 = unknown number of freshwater annuli (usually regenerate or wet) with 2 saltwater annuli
- MF = mixed fish (scales taken from 2 different fish)

- NA = no age (readers/readings from different structures could not agree on either FW or SW age)
- NS = no structure (missing scales, otoliths or fins)
- NP = non-preferred scale (scale pattern may be miss-shaped, distorted or missing growth because it was taken from a non-preferred location on the body)
- PC = prominent check
- PP = poor pressing (pressing too "light" to discern pattern clearly)
- RG = regenerate scale (scale centre is missing, therefore blank)
- RS = resorbed scale (growth from scale margin is missing from scale surface)
- SWA = saltwater annulus
- W = wet scale (scales were mounted onto gummed card with too much water, glue has filled in scale ridges resulting in blank featureless areas on the scale impression)
- TC – transition check (growth stress indicating a movement from fresh to saltwater)
- UD = upside-down (scale has been mounted with smooth side up)
- UF = irresolvable number of freshwater annuli (readers cannot decide on freshwater age)
- UM = irresolvable number of marine annuli (readers cannot decide on a marine age)
- VSA = vague 2nd SWA

** Edge codes for scales:

- blank = no resorption
- 0 = resorption present, but not affecting age
- 1 = resorption has eroded past the last annulus and it is assessed that one year should be added to the "visible" age of the scale
- 2 = the scale is resorbed to an extent such that it cannot be determined if any number of annuli are missing from the scale margin
- 3 = one year added to visible age due to date fish was caught (e.g. January – June)
- 4 = one year added to visible age due to date fish was caught and the scale is slightly resorbed, but not affecting age

***Codes describing relative size of last annual zone on scale margin:

- 1= less than ¼ previous year (1-2 circuli)
- 1^2 = about ¼ previous year
- 2^1 = just short of ½ of previous year
- 2 = about half the width of previous year
- 2^3 = a little more than ½ of previous year
- 3^2 = just short of previous year
- 3 = same as previous year
- 3^+ = more than previous year

Precision columns:

There are two columns for precision test results in case more than one structure is used to age the sample. As for the working columns, record method, date aged & reader ID in column headers. Transfer the age class from the precision sheets to the precision columns for comparison against the age class recorded in the final/otolith/fin/scale resolved age columns. Do not transfer edge growth codes from the precision sheets; rather use the cell beside the age class to mark an X to flag disagreement with the first reader's age class.

Comments column:

The comments column contains remarks regarding the quality of the structures, problems generating an age or perhaps other possible ages. Comments can include codes listed above, otherwise words must be written out in full.