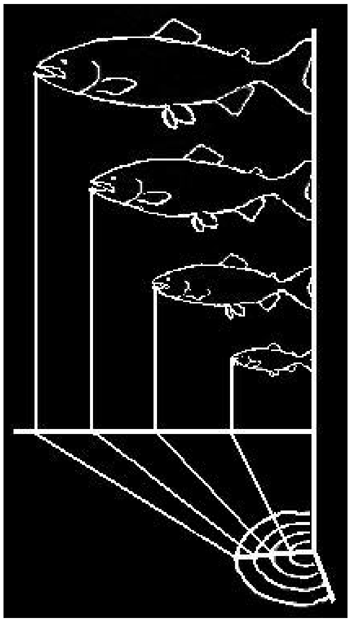
# FISH LIFE HISTORY ANALYSIS PROJECT:

# METHODS FOR SCALE ANALYSIS

## Information Report 2014-10

**September 2014**



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## MANUAL OUTLINE

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## PURPOSE

The purpose of this manual is to: 1) provide guidelines for scale analyses for new, supporting and collaborating staff, and 2) form a repository for historical and accumulated knowledge of methods used by the Oregon Department of Fish and Wildlife's Fish Life History Analysis Project (FLHAP). These methods include: 1) nomenclature and scale anatomy; 2) the use of reference samples and means for age validation; 3) age notation; 4) estimates of size-at-age; and 5) species- and region-specific biological characteristics. Background information on the FLHAP can be found in Clemens et al. 2013a. Information on standard operating procedures for scale collection and preparation and data management can be found in Clemens et al. 2013b. Terms are defined in the text and Glossary, the latter often highlighted in **bold** within the text. Species accounts and their unique, age-specific characteristics follow at the end of this manual, in appendices.

## INTRODUCTION

Why analyze fish scales? Fish scales are relatively easy to collect, store, and with training and practice, read. Fish scales provide a relatively inexpensive means of estimating life history characteristics of fishes — age, origin, growth; size-at-age; and repeat spawning. These characteristics can serve as a proxy for the health of fish stocks, yielding information on age structure; proportion of hatchery spawners; growth trajectories, and life history diversity (Figure 1).

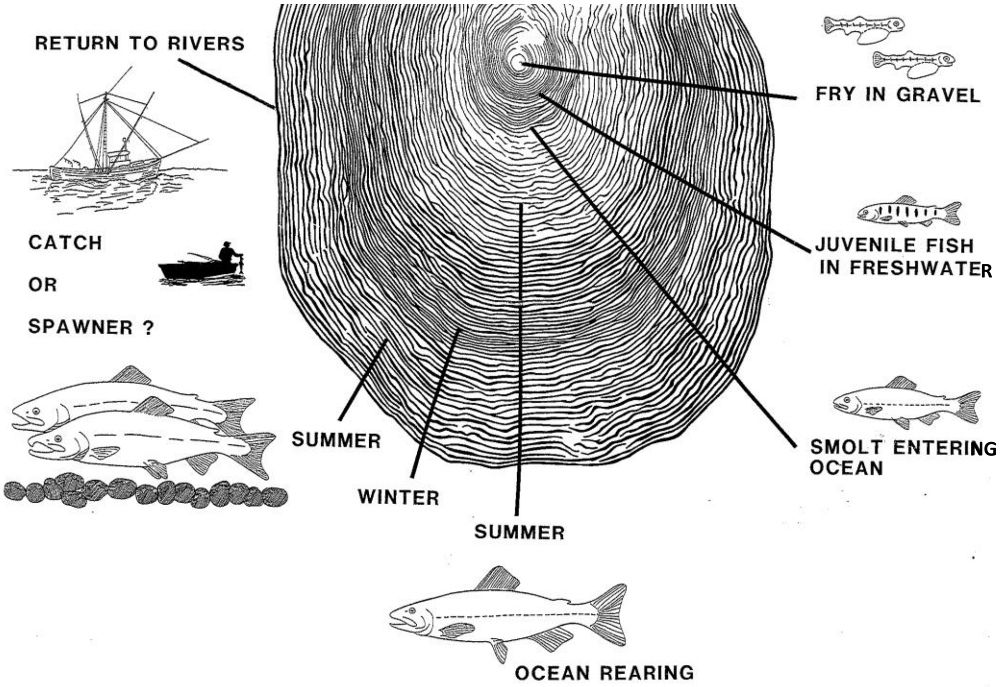

**Figure 1.** Schematic showing the life cycle of a salmonid in relation to its scales, growth, and age (Image: S. Torvik).

<u>Advantages of using scales to age fish</u>:

- Do not have to kill the fish
- Can be sampled at multiple times during life
- Easy and inexpensive to collect
- Based on foregoing points, easy to obtain sufficient sample sizes
- Easy to process
- In populations with coded wire tags (CWTs), age of those fish can be validated

<u>Disadvantages of using scales to age fish</u>:

- In general, using scales to estimate ages or other life history parameters are appropriate only for fish that have a maximum age of < 8-10 years old and spawn one to a few times. Salmonids and centrarchids are usually within this age range. In general, otoliths or other bony structures can be more useful for accurate and precise ageing of fishes that are older than about 10 years.
- Scale annuli may be difficult to recognize because they require interpretation of the patterns of multiple circuli.
- Scales can be lost and regenerated. A scale regenerated later in life cannot be read.
- Scales can be resorbed prior to spawning and information can be lost.

- Some fish do not have scales (e.g., lamprey, catfish, sturgeon). Aging scales is only possible for species with cycloid and ctenoid scales.

## SCALE ANATOMY

Scale anatomy is shown in Figure 2. As the fish grows the scale grows another, larger layer. A **circulus** is the edge of a layer and is visible as a ring on the scale. **Circuli** (more than one circulus) spacing and number can be a rough proxy for growth rate and time. During the summer when a fish is growing quickly, the circuli are thicker and more widely spaced than during the winter, when the fish grows slowly. Over a short period of time of high growth commensurate with an early life stage and optimal growth conditions, a circulus can be most easily associated with time.

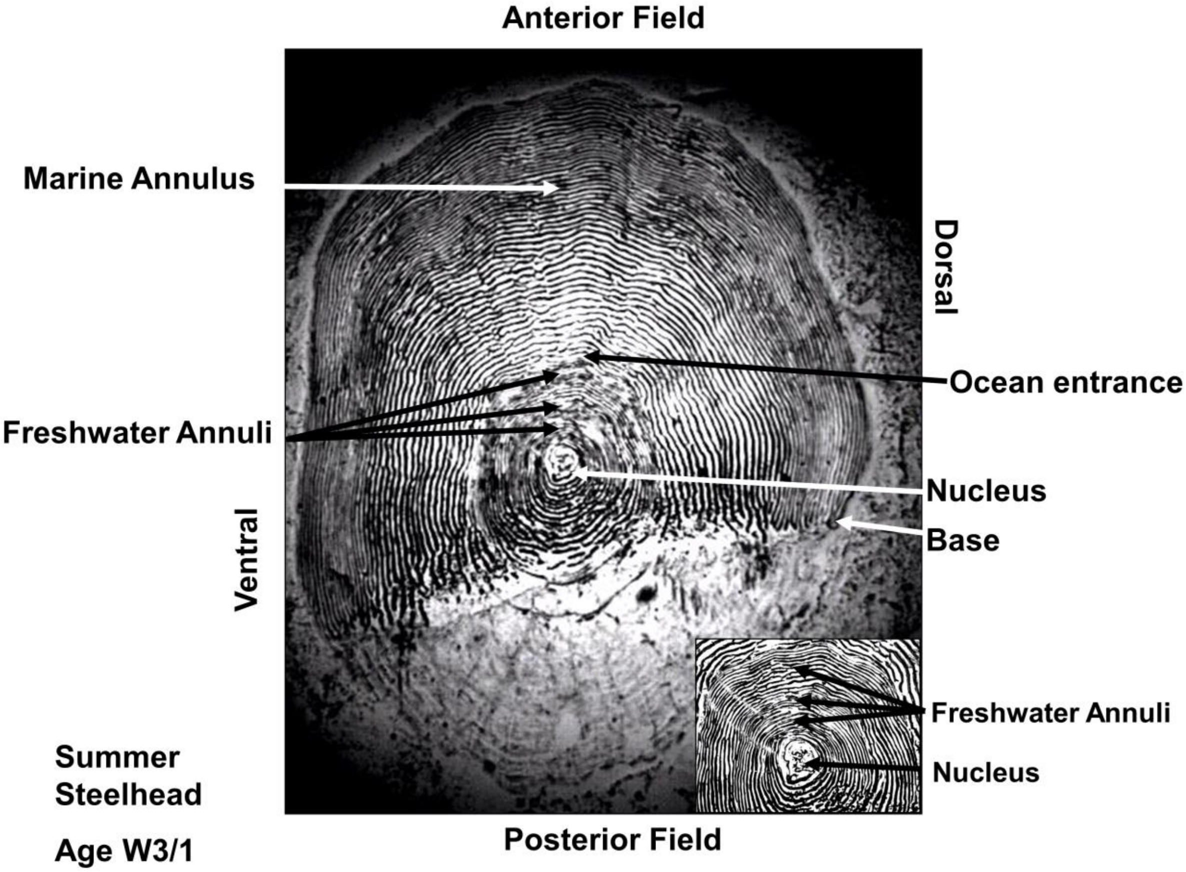

**Figure 2.** Scale anatomy. Inset shows the freshwater zone. The example shown here is for steelhead. Age notations will differ based upon species (see text). Definitions of the terms provided in this figure (e.g., **base**, etc.) can be found in the Glossary.

An **annulus** is a band of thin, narrowly-spaced circuli formed during a winter, slow-growth period (see Glossary for full definition). During the juvenile, freshwater phase, successive annuli are spaced relatively far apart. As fish get older, successive annuli are usually closer together.

The anterior field is the portion of the scale that, *in situ*, lies closest to the head of the fish and is within the pocket of skin and not visible. The anterior portion of the scale contains the circuli that are easiest to view. The posterior field, the portion of the scale that, *in situ*, lies closest to the tail of the fish, is covered with pigmented cells and comprises the visible portion of the scale. When you grasp a scale with forceps to remove it from the fish, it is the posterior field that is grasped. Salmonid scales from the “key area” of the fish are not symmetrical. The circuli extend further into the posterior field on the ventral side than on the dorsal side.

## SCALE READING PROTOCOL

The FLHAP uses the following protocol:

a. **Accrue background information.** Knowledge of the biology, basin, and hatchery practices (releases, sizes, marks, etc.) for target fish stocks are gleaned from local biologists, district reports, ODFW hatchery plans, or other sources to inform the scale readers of what life histories the fish might exhibit.

b. **Examine reference collections.** These constitute scales from known-age fish (CWT-validated) and historical collections that were previously aged. Note that life history characteristics often differ within species (e.g., stocks, life history diversity, and basins), and so wherever possible, reference scale samples from specific origins, stocks, and basins are used. Similarly, reference samples from the same types of surveys should be used because particular survey methods (and timing of those surveys) may result in unique selection bias with regards to life history type, stock, sex, body size, and age (e.g., see Clutter and Whitesel 1956).

c. **Conduct two initial reads.** Two trained readers conduct reads on the fish scales, independent of each other. These reads are usually conducted “blind” in that each reader is unaware of the biological data (i.e., length, mark, date, etc.) associated with each scale sample. However, basin, date, species and stock information is considered by the reader. The estimated age of each fish will depend on date. For example, in Chinook salmon, a presumptive annulus on the edge of its scales may be interpreted as a “gonad check” in fall Chinook versus an actual annulus in spring Chinook.

d. **Conduct a consensus read.** The two readers conduct a final, consensus read together for scales in which they had disagreements. “Body length”, “sex”, and “stock of origin” are considered at this stage to help achieve a consensus.

e. **Identify possible outliers.** The body lengths of the fish are plotted against age estimates, and scales from the fish that are outliers are re-examined. Sometimes this will result in an adjusted age estimate, but often it simply results as a note of potential data discrepancy (possible mis-measurement of the fish’s length or other problem). The largest and smallest fish of each age can be re-examined as appropriate.

f. **Validate age estimates.** If the fish being aged possess CWTs, then these data are acquired and used to validate the age estimates from scale reads.

Occasionally a collection will be read by only one reader. While not the ideal situation, sometimes work load and staff expertise will necessitate reading a collection by only one reader. The single reader should still read the collection twice and the collection should contain some known age (CWT) samples to use to estimate reading accuracy.

Background information for each scale collection aids the scale readers in interpreting patterns in circulus formation; and distinguishing annuli from “checks”, accounting for hatchery vs. wild origin, life history diversity, scale resorption, etc. Nevertheless, biology, environmental factors, and hatchery rearing practices are dynamic and cryptic or subtle diversity of life history strategies can exist. The scale reader, therefore, should attempt to keep an open mind.

New scale readers are trained by experienced readers. First, a trainee and experienced reader interpret a set of samples together. Second, the trainee and the experienced reader will independently interpret another set of samples, and then discuss any discrepancies in assigned ages. The trainee will also read scales read by previous readers, and scales from known-age fish (e.g., those with CWTs).

The FLHAP scale reading protocols are specifically designed to maximize precision and accuracy for estimating ages and other life history information from fish scales. This high degree of rigor includes redundancy (more than one reader), use of ancillary biological data to find potential errors in scale reads; use of reference samples and other means of corroboration to improve the readers’ ability to recognize life history characteristics. The FLHAP carefully uses particular language such as “estimates”, “validation” (accuracy), and “corroboration” (precision) to clearly and accurately communicate age data (Figure 3).

## Validation and Corroboration

It is important to realize that estimates of fish age, origin or life history using scales are just that: estimates. These estimates can be viewed with more confidence if the dataset can be validated or corroborated. Age validation means to compare estimated ages with known (true) ages to indicate a degree of accuracy within the dataset. Age validation is an important requirement in age estimates of fishes (Beamish and McFarlane 1983). For example, the FLHAP most frequently uses coded wire tagged (CWT) fish as a method of validation. Brood year, and therefore known age, is queried from the interagency CWT database providing a 'true' measure of age. Of course the CWT database has errors in it, too, so it should be examined carefully to insure no egregious errors are swaying what is otherwise taken to be the true, valid age. Other methods of validation include utilizing natural marks (e.g., patterns caused by oceanic regime shifts), chemically- or temperature-induced marks on hard tissues of the fish, or brood year identified by genetic pedigree.

Corroboration is a measure of the consistency or repeatability of an age determination method and enables an estimate of precision. To corroborate means to use multiple age estimation methods to arrive at the same estimate. For example, age and origin of a fish can be estimated using both scales and a bony structure such as an otolith or from independent reads by scale readers from other laboratories.

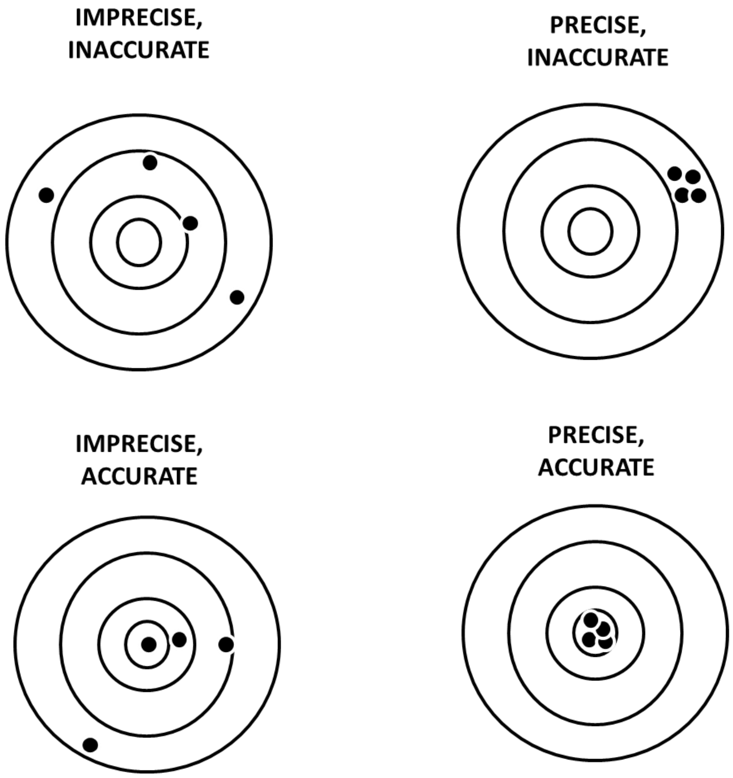

**Figure 3.** Arrow-to-target analogy for age estimates, showing combinations of precision (consistency), related to a true (accurate) age.

## AGE NOTATION

### Salmon (Chinook, Coho, Chum):

- Gilbert-Rich (Gilbert and Rich 1927) notation: $N_n$.
    - N = the total age of the fish.
    - n = the FW age; also the age at ocean entrance.

- For fall-spawning fishes like salmon, add “1” to the FW age (and therefore the total age). They experience their first winter as an egg or sac fry in the gravel before they grow scales. All fish turn 1 year older on January 1st. An example of an exception to this is would be bull trout, which are fall spawners and spring emergers. The scientific literature calls bull trout age-0 for their first year of life. Another example would be steelhead/rainbow trout, which are spring spawners and spring/summer emergers. These fish would also be age-0 for their first year of life.

- For spring-spawning fishes like steelhead, trout, and warmwater fishes, nothing is added to the annuli observed on the scales; the total annuli count for these fishes = the total age, each fish turning 1 year older on January 1st.

- Juveniles referred to as “zeroes” or “sub-yearlings” will have an “n” = 1; they are in their 1st year at migration (further details in Appendix 2 for Chinook salmon).

- Juveniles referred to as “yearlings” will have an “n” = 2; they are in their 2nd year at migration. Used for spring Chinook caught in the spring (further details in Appendix 2 for Chinook salmon).

- Capture year – N = Brood year.

- Outmigration year- n = Brood year.

### Steelhead:

For most coastal steelhead trout we follow the notation used by the old Coastal Steelhead Research Project in the 1980s – mid-1990s, with the exception of Rogue River. For Rogue steelhead a different notation is used which accommodates the “half-pounder” life history.

- Origin n/N and Origin n/N S.N S for repeat spawners
    - Origin= H for hatchery, W for wild.
    - n = number of annuli formed in freshwater before 1st ocean migration.
    - Slash “/” = 1st ocean migration.

  - N = number of “salt years” prior to first spawning. On winter steelhead, the final annulus may be barely showing on the edge so it is easier to count summer growth periods.
  - S = a spawning run and will follow a number representing the winter annulus that was resorbed or damaged during spawning. Most adult steelhead will be on their 1st spawning run so will not have an “S” in their age notation. Repeat spawners on their second spawning run will have one S, usually attached to their 2nd salt year, though they may have spawned as a “1-salt” or a “3-salt”. Fish on a third run will have two “S” in their notation. See Table 1 for examples.

- The freshwater zone of summer and winter steelhead is aged the same way for both races. However, for summer steelhead after initial ocean entrance (/) only visible saltwater annuli are counted, though a fish caught late in the summer or fall may resorb most of the previous annulus (which is to be counted). Summer steelhead experience another winter period in freshwater before spawning. Since the fish is not feeding and putting resources into gonad development instead of somatic growth, a normal annulus is not formed on the scale. If summer steelhead are aged at spawning (in the next calendar year from when they returned to freshwater), resorption on the scale edge caused by spawning efforts (the spawning check), is counted as the annulus for that winter.

- In past data sets, fish of hatchery origin may be denoted as just H/N without the number of freshwater annuli given. Because virtually all hatchery smolts were yearlings (released with one freshwater annulus) a reader can assume an “H” means the same as “H1”.

- The old Rogue River Research Project (1980s-1990s) used slightly different notation. Rogue steelhead may go on a non-spawning “half-pounder” run after their first summer in the ocean. They return to the river briefly during the winter and then migrate back out to the ocean. The fish are considered to weigh about a half pound (though they often weigh up to 2 lbs.) and they contribute to a popular fishery. The half pounder run causes an annulus that has some resorption but is occurring on a fish that is too small to be spawning. This is a well-documented life history. The half-pounder annulus was denoted by an “H” after the slash in the notation (Table 1). The half pounder life history occurs only in the Rogue, Klamath, and Eel rivers.

  - In 2020 the FLHAP modified the age notation for Rogue steelhead. The “H” after the slash that denotes a half-pounder check was replaced with “1h” (Table 1). The 1 makes it clear that a half-pounder check is in fact the first annulus after smolting. The lower case “h” differentiates the half-pounder notation from the upper case “H” used to notate hatchery origin before the slash.

**Trout**:

- Age = number of annuli.
- The FLHAP notes spawning runs in the comment column.

**Warmwater fishes**:

- Age = number of annuli.
- Age is often reported with Roman numerals.
- In the past, FLHAP has mostly worked with scales from largemouth bass, smallmouth bass, northern pikeminnow, and occasionally crappie and bluegill.

**Table 1.** Comparison of age notations for coastal and Rogue River steelhead. Number to the left of the "/" indicate freshwater age; numbers to the right of it indicate saltwater age. *The FLHAP uses the notation typical of coastal steelhead, with an "H" to the left of the "/" to indicate hatchery origin*. An "H" to the right indicates the ½ pounder life history. W = wild. S = spawning event.

| Common Age For 2 yr. Old Smolt | Coastal Steelhead | Rogue River Steelhead | Rogue River Steelhead w/2020 modification | Total Age at Time Scale Collected |
|---|---|---|---|---|
| 1-salt | W2/1 | W2/1 | W2/1 | 3 |
| Half pounder | -- | W2/H | W2/1h | 3 |
| 2 salt with half pounder | -- | W2/H2 | W2/1h.2 | 4 |
| 2-salt | W2/2 | W2/2 | W2/2 | 4 |
| Repeat spawner-2nd run | W2/2S.3 | W2/2S.3 | W2/2S.3 | 5 |
| Repeat spawner-3rd run | W2/2S.3S.4 | W2/2S.3S.4 | W2/2S.3S.4 | 6 |

## ORIGIN IDENTIFICATION

The FLHAP is often asked to identify hatchery fish from wild fish as a control for intentionally unclipped or otherwise mis-clipped hatchery fish. Accordingly, project staff often estimate origin with various levels of confidence, considering species, scale condition, basin geography, and hatchery rearing practices (release dates and sizes). Significant differences between the scale patterns are essential for distinguishing hatchery and wild fish. For many groups of fish, it is not possible to identify origin by their scale patterns.

The following general description is FLHAP procedure for identifying hatchery fish and wild fish, and there are exceptions to the generalization we describe. Scale readers should obtain scales from several fish of *known* origin from the species and basin of interest, and then familiarize themselves with those scale patterns.

The premise for identifying hatchery fish from wild fish is that the former are reared in a relatively constant environment often with near-optimum conditions (temperature and feed) for growth. Relative to the scales of wild fish, hatchery conditions *typically* result in scales with large freshwater zones, uniform circuli spacing, and thick circuli. By contrast, wild fish may experience highly variable rearing conditions seasonally that allow periods of slower and faster growth. The difference in spacing and thickness of circuli formed during winter versus spring by a wild fish can be striking and help identify the fish as wild In the past, the FLHAP has used statistical tools like discriminant function analysis to discern between hatchery and wild coho. However the ability to confidently discern origin is dependent upon representative “training” scale collections to accurately and precisely guide this analysis.

## SIZE-AT-AGE ESTIMATES

Occasionally the FLHAP is asked to estimate the size of the fish at a previous age or event using back calculation methods (Figure 5). Most often this type of analysis occurs with trout but an example for salmon would be estimating the size of the fish at ocean entrance. The scientific literature agrees that proportional methods are more appropriate than linear regression. However, the method most often used by the FLHAP in the past was linear regression because the proportional methods all require a measurement of the total scale radius. In past analyses involving estimation of size at ocean entrance, FLHAP personnel worked with adult salmon scales sampled from spawned-out carcasses. The scales were in poor condition with resorbed edges, so an accurate measurement of the total scale radius was impossible. Linear regressions should be developed from fish of similar size of the fish at the point of the back calculation (e.g., use smolts to develop the linear regression that will estimate size at ocean entrance measured on scales of returning adults).

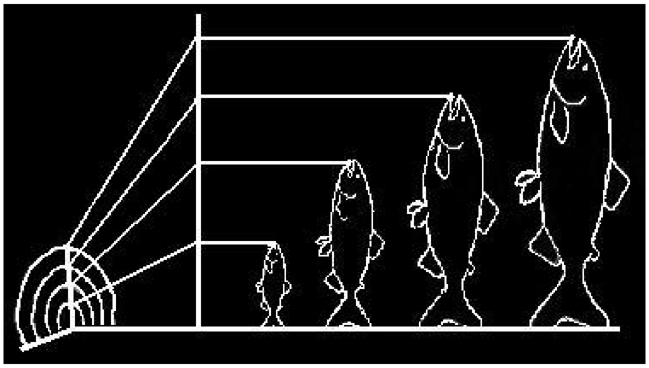

**Figure 5.** Schematic showing fish size by age estimated by scale reads. (Image: Trish Nickelson)

The FLHAP uses the Fraser-Lee method for regression of fish length (y-axis) against scale radius (x-axis) (Fraser 1916; Lee 1920). When the length of the fish does NOT originate at the y-intercept a correction factor adjusts the y-intercept.

- $L_i = [(L_c - a) * S_c^{-1}] * S_i + a$
  - $L_i$ =body length at time of interest
  - $L_c$ = body length of fish at capture (y-axis).
  - $S_i$= scale radius at point of interest
  - $S_c$ = total scale radius at capture (x-axis).
  - **a** = y-intercept correction factor for an even distribution of numbers of fish across a broad range of body sizes for a particular species and a particular population. Also known as the "intercept parameter" and the length that a particular fish species, for a particular population exhibits onset of scale formation (the fish is growing prior to forming scales).

- $[(L_c - a) * S_c^{-1}]$ = slope of regression line of L regressed against S.

- The regression averages out the slope of the line created by the plotting of data points of each fish, where the coordinate of the first point of each fish is ($S_c$, $L_c$), and the second point is (0, a).

Table 2. Values of 'a' for various salmon species

| Species | 'a' (cm) | source |
|---|---|---|
| Chinook | 3.0-3.5 | Project regressions |
| Coho | ~3.0 | Project regressions |
| Sockeye | 4.0 | Koo 1955 |

## SCALE MEASUREMENTS

The FLHAP uses a microscope connected to a computer and ImagePro software to conduct measurements of scale radius and circuli count. When conducting circuli counts (cc), the FLHAP counts the circuli along the 20° ventral angle, and if measuring the scale radius, the FLHAP also measures along this same angle (Figure 6). All measurements are conducted on the largest mounted scale. When FLHAP staff conduct comparisons of scale size, as measured by a ruler on the microfiche projection, those measurements were standardized with the magnification of the projected image by each microfiche (prior to 2012, all microfiche measures were conducted at 88X magnification). During 2012 and onward, the magnification has changed slightly from 88X for each microfiche. The FLHAP uses Image-Pro software (Media Cybernetics[a]) to conduct standardized measurements of fish scales.

[a] *Use of this software does not constitute endorsement.*

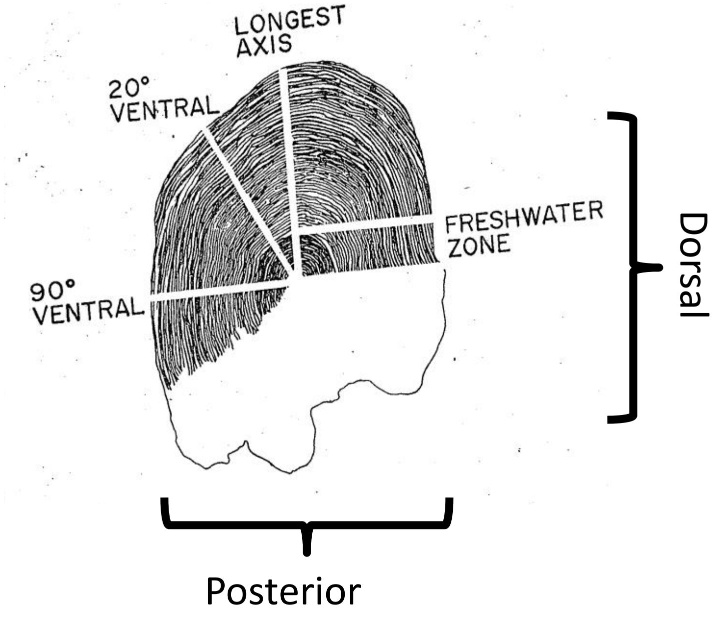

**Figure 6.** Scale axis and angles.

## PROBLEMS EXPERIENCED WITH SCALES

When one considers the fish from which scales are sampled and read to estimate life history information, it is clear that *scale reads are an estimate (of age) of an estimate (of the population)*. So the overall error presented by a particular collection of scales from a species, basin, and survey type could conceivably be accumulative or compounded.

For example, a recent experience in which the FLHAP received scale samples from 430 fish in the Willamette Basin. The first assumption is that these 430 fish are representative of the population at large, which may or may not be true. The second assumption is that the vast majority of these scales will yield "readable" scales, an assumption that is compromised by the fact that 33% of all samples were incorrectly mounted by another agency, independent of the FLHAP, yielding a sample size of 283 fish. Scale samples from 119 of these fish were either missing or unreadable because of scale damage, bringing the sample size down to 164 fish (283 – 119 = 164). Many of the remaining samples had only 1 readable scale, which raised further concerns by the FLHAP (see bullet #1, below). The estimated error rate for the FLHAP for assigning ages to adult Chinook salmon in the Willamette Basin, based on CWT validations from hatchery fish was 5 – 9%; when combined with the above example of a severely reduced sample size, it seems clear that the age data are likely not accurate. This example demonstrates the importance of minimizing error in every way possible to insure the highest degree of accuracy in age estimates. Age data from scale reads are often used for escapement estimates, run forecasts, and general age structure trends. This consideration makes it all the more clear why it is important to strive for both high accuracy and precision in scale reads. Failure to do so may result in a grossly-biased estimate of the overall population and management of that population.

The following problems are often experienced and if not appropriately addressed may affect the quality of life history estimates based on scale analysis:

1) **Too few scales**. The FLHAP uses 3 or more scales for estimates because often a particular scale will reveal more information than other scales from the same fish (FLHAP personnel observations). From experience, the FLHAP has found that although 3 scales or more are preferred, 2 will usually suffice, whereas a single scale leads to concerns about bias. Those scales are selected for reading from 8 – 10 scales collected from fish at sampling (see Clemens et al. 2013b).

2) **Regenerated scales**. Occurs when a fish experiences an injury that results in the loss of scales. Newly formed (regenerated) scales that form in place of lost scales will have a center devoid of circuli corresponding to the time period prior to scale loss. See Clemens et al. 2013b for an example.

3) **Resorbed scales**. (Also refer to the definition in the Glossary). Maturing, migrating, spawning and otherwise stressed fish will leach calcium from their scales. As the calcium is leached from the scales, the remaining material, especially on the edge will erode. The scales will be smaller than they would be otherwise, and the edges will be wavy, ragged, and indented, with circuli and annuli missing. See Clemens et al. 2013b for an example.

4) **Disintegrating scales**. Possibly related to microbial decay, scales can become highly degraded and brittle and easily damaged when preparing and mounting. We have found this condition in scales from both spawning ground carcasses and fresh, ocean-caught fish.

5) **Lateral line scales and other non-key scales**. These scales are compressed and mis-shapen, and do not contain the most complete life history information from the fish (Clutter and Whitesel 1956) (see Clemens et al. 2013b).

6) **Dirty scales**. Periphyton, dirt, sand, and scale debris that are not sufficiently cleaned during the mounting process (Clemens et al. 2013b), obscure scale features. Scales sandwiched between sticky notes or other non-waterproof paper may stick to the paper and make them more difficult to clean, process, and read. Some waterproof papers (e.g., glossy) are also particularly problematic, as they become tightly glued to the scale.

7) **Poor data quality control**. Examples of poor data quality control include: mis-alignment of ancillary biological data; disagreements between sex, date, or body length on the scale envelope and the electronic data; and use of spreadsheet formulae that can become corrupted and then lead to mis-numbering of samples. Everyone makes mistakes and some errors are to be expected. Therefore good quality assurance/quality control procedures should be implemented. Excessive and persistent errors are particularly troublesome as they take a significant amount of time to check and remedy, and they raise concerns over broader, more insidious problems that may exist with the data or the samples collected.

## SPECIES INDENTIFICATION

Most samples will have the correct species labeled on the envelope or card. Occasionally, a fish carcass will be in such poor shape that the FLHAP may be asked to identify the species, based on scale characteristics. Occasionally, a sampler either mis-identifies a fish or records the wrong species on the envelope. In this event FLHAP staff will need to recognize an incorrect species within a collection. Table 3 and Figure 7 compare scale features that help identify the correct species. Details are from Mosher (1969) and FLHAP personnel observations.

**Table 3.** Comparison of scale features used in species identification of salmonids.

| Scale feature | Coho | Chinook | Chum | Steelhead |
|---|---|---|---|---|
| Common # FW annuli | 1 | 0 coastal<br>0, 1 Willamette<br>1 inland | 0 | 1-4 |
| Common # SW annuli | 0, 1 | 1-6 | 1-4 | 1-4 |
| Globular reticulation | Rare | Some | Extensive | Common |
| Circuli appearance | Coarse | Fine, regular | Coarse | Coarse, broken |
| Scale shape | Oval, long anterior-posterior axis | Round | Oval, long ventral-dorsal axis | Rectangular |
| Margin of circuli and posterior field | Uneven, with “danglers” | Very straight | Covered by globular reticulation | Uneven |
| Complete circuli around nucleus | >6 | 6-8 | <7 | >12 |
| Most distinguishing feature(s) | FW annulus, coarse circuli | Multiple SW annuli, fine circuli | Globular reticulation, “flat” shape | Scale shape, multiple FW annuli |

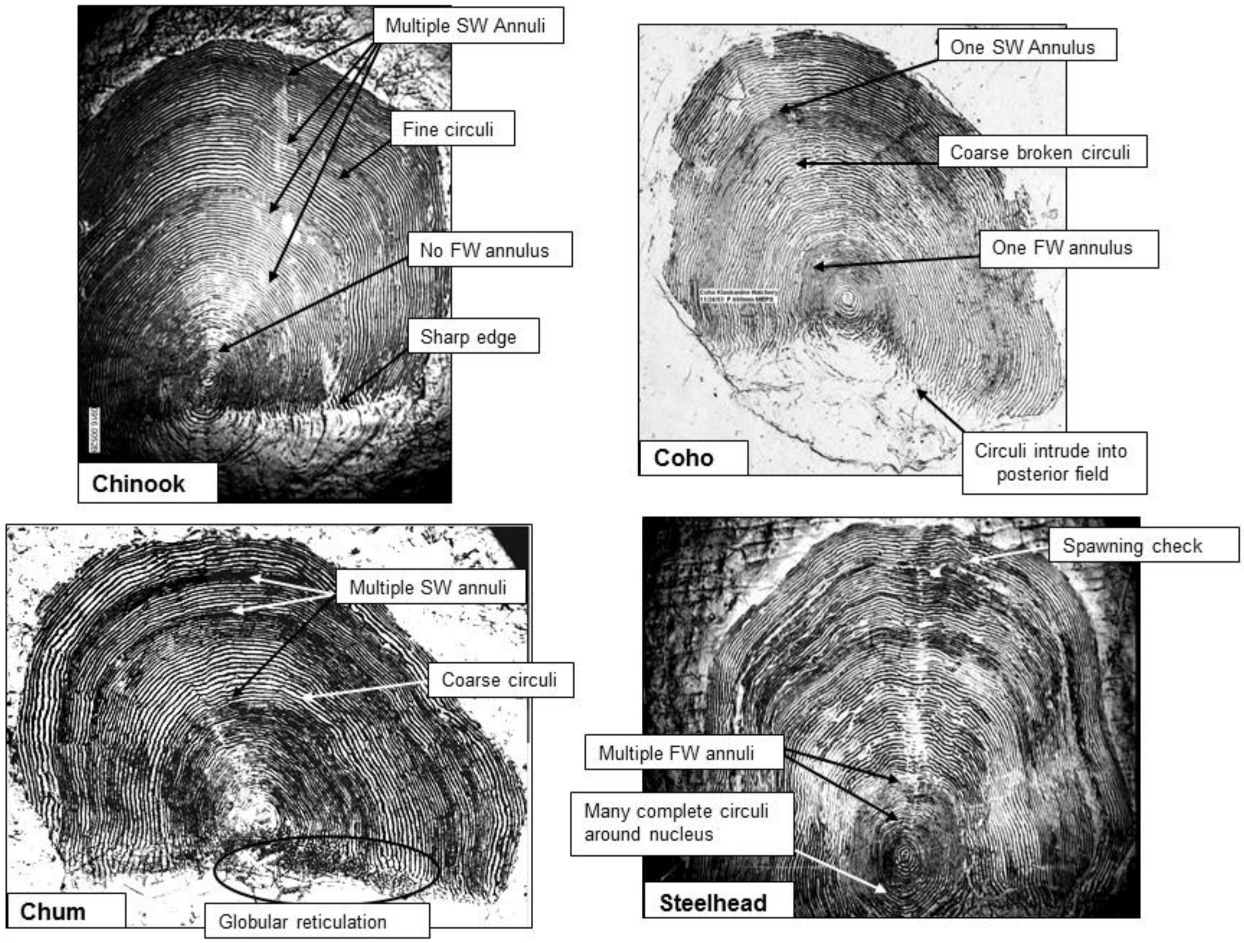

**Figure 7.** Identifying scale features of Chinook, coho, and chum salmon; and steelhead trout.

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## GLOSSARY

**Accuracy –** The process of achieving an age estimate (or other measure) that equates with the actual age (or other measure). A true measure.

**Annuli –** Plural for annulus.

**Annulus –** Singular for annuli. Band of thin, narrowly-spaced circuli, laid down during a winter, slow-growth period. Indication of one year of life.

**Anterior field –** Portion of a fish scale growing closest to the head of the fish; shows circuli and annuli. In live fish, this part is covered up by other scales.

**Axis (of scale) –** Plane of view or measurement from the posterior field of the scale to the anterior field of the scale, to its tip.

**Base (of scale) –** Nexus of the posterior and anterior fields.

**Check –** Pseudo-annulus caused by conditions that are stressful to the fish and reflected by decreased growth; represented on the scale as several circuli spaced closer together than surrounding circuli. See **mid-summer check** and **spawning check** for examples.

**Circuli –** Plural for circulus.

**Circulus –** Singular for growth increment. Concentric growth increments radiating out from the nucleus of the scales that form over the course of weeks.

**Concordance –** Agreement rate on an age estimate between two different types of methods (e.g., scale reads and genetic pedigree analyses). Note that each method is not infallible, hence the usage of this term, as compared with **validation** or **accuracy**. Nevertheless, concordance can be considered as being more scientifically sound than **corroboration**.

**Corroboration –** Back-up evidence supporting a particular age estimate or other scientific measure that is NOT irrefutable, and therefore does not replace **validation**.

**Ctenoid –** Scale type particular to warmwater fishes (basses, sunfishes, etc.). Similar to cycloid scales with some anatomical differences, most notably having a spiny posterior margin.

**Cycloid –** Scale type particular to coolwater fishes (trout, salmon, whitefish, etc.). Similar to ctenoid scales with some anatomical differences, most notably having a smooth posterior margin.

**Dorsal field –** That part of the scale that, *in situ*, lies closest to the top of the fish (the fish's back).

**Estimate –** Best approximation of the true value of something (e.g., age), given the available data (the fish scales, background information, reference samples, observations, etc.).

**Estuary type –** Life history strategy used by some Chinook salmon of rearing relatively low in a particular basin, specifically in the estuary, before emigrating to the ocean and subsequently returning freshwater. For example, some coastal CHF enter an estuary early in the summer and wait until fall to enter the ocean as a large smolt. Compare and contrast with **ocean type** and **stream type**.

**Fall Chinook salmon –** Chinook that enter freshwater during the fall to spawn. Because they are in freshwater for the least amount of time relative to spring and summer Chinook, their scales are usually in the best condition. Their scales record a **pseudo-annulus** or **gonad check** on the scale edge that should NOT be counted in age estimates.

**Freshwater zone –** The center of the scale comprising the nucleus and other circuli that radiate out from the nucleus and are a biological record of the fish's age and relative growth rate in fresh water.

**Gilbert-Rich notation –** Form of age notation (Gilbert and Rich 1927) used by ODFW in ageing salmonid scales: $N_n$, wherein N = the total age of the fish and n = age at which the fish enters the ocean.

**Globular reticulation –** "Bumps" or "nodules" on a scale. Often observed at the scale **base** of chum salmon and steelhead scales, at the scale base. Characteristic useful in species identification via scales.

**Gonad check –** Psuedo-annulus or narrowing between circuli on the outside edge of fall Chinook scales at return to freshwater. Indicative of slower growth during gonad development. See **Check**.

**Gonad development –** The physiological process of sexual maturation: spermatogenesis for males and oogenesis for females. During this period fish put more resources into development of eggs and sperm and less into somatic growth.

**Hatchery fish –** Fish spawned and reared in a hatchery environment. Hatchery origin fish often experience even and significant growth prior to release (freshwater phase) due to consistent and ideal environmental conditions in the hatchery. Contrast with wild fish, which have uneven and usually less growth during the fresh water rearing phase, but which undergo compensatory growth rapidly upon entering salt water. See also **Hatchery residual**.

**Hatchery residual –** Hatchery steelhead that has 2 clear annuli in the fresh water zone. While released as an age-1 juvenile, it spent an additional year rearing in freshwater before ocean entrance. Observed as a clear hatchery pattern with even circuli spacing, extremely large freshwater zone.

**Iteroparity / Iteroparous –** Life history strategy of repeat spawning (occurs in trout).

**Jack –** Precocious male with a total age of 2 for coho and **fall Chinook salmon**, and a total age of 3 for a **spring Chinook salmon** with a yearling or **sub-2** juvenile life history. A mini-jack is a fish that is smolt-sized but did not go to the ocean and is sexually mature. See also **jill**.

**Jill –** Precocious female of the same age as a jack.

**Key scales / Key area –** The preferred sampling area for scales of salmonids. Used by ODFW. This area is located at the intersection of an imaginary line connecting the posterior insertion point of the dorsal fin and the anterior insertion point of the anal fin, and just above the lateral line. These scales are the preferred (key) scales to use because studies have shown on sockeye salmon that these are the first scales to form and therefore record the most complete age and growth trajectories of salmonids, therefore leading to a higher chance of scale reading personnel generating non-biased age estimates.

**Lateral line scales –** Non-key area scales collected from the lateral line. Identified by obvious lateral line pores along the scale axis.

**Mid-summer check – Psuedo-annulus** representing a period of reduced growth in the ocean during the warm summer period. When present, exists between the first and second annuli. Usually obvious by its few circuli and spacing relative to the first and second annuli. When present, it can sometimes, but not always, be strong. Can be found on coho and Chinook salmon and steelhead.

**Non-key scales –** Those scale sampled outside of the key sampling area on the fish.

**Nucleus –**The focal or center *point* of the fish scale surrounded by the first circulus, in the middle of the fresh water zone. Discrete location at which the FLHAP has historically originated a line for measuring scale radius (see Figure 6). From a broader perspective, the scale nucleus is the center *area* of the scale, surrounded by the first complete circulus.

**Ocean entrance –** The portion of the scale following the fresh water zone. Delineated by the transition from the (usually) relatively slow growth of the fresh water zone to the rapidly increasing growth of the ocean environment. Represented by dramatic increase in spacing of circuli.

**Ocean maturing –** Coho, chum, and **fall Chinook salmon** and **winter steelhead** all develop near-mature eggs and sperm in the ocean. They spawn very soon after returning to freshwater.

**Ocean type –** Life history strategy used by some Chinook salmon of rearing relatively low in a particular basin, for a short period of time (see **sub-yearling**) before emigrating to the ocean. Most of the first summer is spent in the ocean.

**Plus growth –** Sometimes referred to just as "growth" by the FLHAP. Indication of growth following an annulus on the edge. Depending on the situation (species, life history, basin), this observation can be used to justify counting the annulus preceding this growth in the age estimation, and in some cases, in adding another, not visible annulus into the age estimation (**resorbed**). Guidance for doing this has been provided by reference samples, including those from lower in basins with more complete scales and information from hatchery fish that were CWT, and therefore validate age estimates generated by FLHAP personnel.

**Posterior field –** Portion of the scale showing on a live fish and does NOT record circuli or annuli. Usually the first part on the scale to resorb, followed by the anterior field. This knowledge is useful in determining the status of a scale and estimating whether crucial age information (annuli) are missing.

**Precision –** The repeatability of a given measure or age estimate.

**Psuedo-annulus –** Check or false annulus formed by a biological or environmental stressor to the fish causing a slow-down in its growth. Observed as a congregation of a few circuli that is often less substantial than an actual annulus.

**Rainbow trout –** Non-anadromous *Oncorhynchus mykiss* identified by the lack of saltwater annuli.

**Reference samples –** Scales taken from a known location and time, sometimes with age estimates attached to them, sometimes with age validation by CWT information or other; sometimes with a more complete scales collected from fish lower in a particular basin. Used by scale readers as a means to "calibrate" subsequent reads by a scale reader from other, newer scales from the same species of fish and the same basin, with the express goal of attaining a high level of accuracy and precision.

**Regenerated –** "Blank" area of a scale caused by a previous injury to the fish that resulted in its losing that scale. The fish quickly grows a blank scale. When the blank scale reaches the size of adjacent, non-damaged scales, it will again form circuli.

**Resident** – Fish that are not anadromous, but their cohorts may be. Examples include kokanee (sockeye); **rainbow trout** (steelhead); and other species that can residualize such as Chinook and coho salmon. Resident fish are identified as such by the lack of saltwater annuli and may be smaller compared to the same age anadromous fish.

**Residual –** See **hatchery residual.**

**Resorbed –** Scales that have gone through resorption, during which the fish used its somatic energy reserves to fuel gonadal maturation, migration, and spawning, leading to a loss of somatic tissue (like scale edges). If the fish continues to grow after the event that caused the resorption, the scale will have a "blank" band without circuli. "Resor*p*tion" = noun; "resor*b*" = verb.

**Saltwater zone –** The location including ocean entrance outward towards the edges of the scale, exemplified by good growth — relative to the freshwater zone.

**Scale base –** See **base**.

**Semelparity / Semelparous –** Life history strategy of single spawning followed by death (salmon; some steelhead).

**Somatic –** Any bodily tissue other than gonadal.

**Spawning check –** Pseudo-annulus resulting from a spawning event, present on scales of iteroparous fishes. Usually appears as a band of resorbed scale material. The spawning check may resorb over the most recent annulus of a winter steelhead and forms instead of the most recent annulus of a summer steelhead.

**Spring Chinook salmon –** Chinook that enter fresh water in the spring and spawn the following fall.

**Stream maturing –** Summer steelhead and spring Chinook salmon enter freshwater with immature gonads. They spend months in freshwater prior to spawning and during this time the eggs and sperm mature.

**Stream type** – Life history strategy used by some Chinook salmon of rearing higher up in a particular basin, for a longer period of time (see "Yearling") before emigrating to the ocean. The first summer and winter occur in freshwater.

**Sub-yearling –** Chinook life history strategy of emigrating to the ocean prior to reaching its first year of life post-hatch. The same as a sub-1. Typically discerned through estimating ages of adult scales.

**Sub-1 –** Chinook life history strategy of emigrating to the ocean prior to reaching its second year of life post-hatch. Also called a sub-yearling. "Sub" refers to the subscript value of the Gilbert-Rich notation – a sub-1 is in its first year at ocean entrance.

**Sub-2 –** Chinook life history strategy of emigrating to the ocean after its second year of life post-hatch. Also called a yearling. "Sub" refers to the subscript value of the Gilbert-Rich notation – a sub-2 is in its second year at ocean entrance.

**Summer Chinook salmon –** Chinook that enter freshwater during the summer (intermediate timing relative to spring and fall Chinook) to spawn in the fall.

**Summer steelhead –** Steelhead that enter freshwater during the summer to spawn the following spring. The salt water zone on the scales from these fish is aged by counting the winter periods (annuli).

**Validation –** Practice of using irrefutable proof to backup or ground truth the estimated ages of fish from scales. An example is the use of CWTs to ground truth age estimates by scale readers. However, it should be noted that CWT data, being collected by humans, and can sometimes have errors associated with it.

**Ventral field –** That part of the scale that, in situ, lies closest to the bottom of the fish (the fish's "abdomen"). Compared with the dorsal field, the ventral field is somewhat tapered.

**Winter steelhead –** Steelhead that enter freshwater late (during the winter) to spawn the following spring. The salt water zone on the scales from these fish is aged by counting the summers (growth periods between annuli).

**Yearling –** Chinook life history strategy of emigrating to the ocean after reaching its second year of life post-hatch. Typically discerned through estimating ages of adult scales. Also called a **sub-2**.

## **APPENDIX 1:** ACRONYMS

cc: Circuli count.

CCRMP: Coastal Chinook Research and Monitoring Program.

CWT: Coded-wire tags.

FLHAP: Fish Life History Analysis Project.

MEPS: Mid-eye to posterior scale.

ODFW: Oregon Department of Fish and Wildlife

## **APPENDIX 2.** CHINOOK SALMON

The Fish Life History Analysis Project (FLHAP) analyzes scales of more Chinook salmon than any other species. Whereas FLHAP personnel have read Chinook scales from all parts of Oregon, our focus is on coastal, Willamette, Sandy, and Hood River stocks. The Oregon Department of Fish and Wildlife (ODFW) research group in LaGrande reads Chinook and steelhead scales from the NE region, although in the past FLHAP staff have assisted in training their staff and lent support as needed. The Deschutes River Research projects read their own scales with occasional support from FLHAP. Scales collected during Columbia River management activities are usually read by ODFW staff in Clackamas.

Juvenile life histories of Chinook salmon have been characterized by Rich (1920) as **ocean type** and **stream type**. “Ocean type” juveniles migrate to the ocean as sub-yearlings, usually early enough in the year that part of their first summer is spent in the ocean. “Stream type” juveniles stay in freshwater through their entire first year and migrate during their second spring. In Oregon, most coastal Chinook fall somewhere between these two life histories, representing an **estuary type**. Estuary type fish emigrate out of freshwater similar to an ocean type juvenile, and then spend the summer in the estuary with ocean entrance occurring in the fall.

Oregon has both spring and fall Chinook salmon. Both stocks/life history types occur in coastal rivers and tributaries of the Columbia River (inland stocks). Generally, coastal fall Chinook migrate to the ocean as estuary-type sub-yearlings and mature at ages 2-7. Coastal spring Chinook migrate to the ocean as estuary-type sub-yearlings and mature at ages 2-6. Inland fall Chinook migrate to the ocean as ocean-type sub-yearlings and mature at ages 2-6. Inland spring Chinook tend to migrate to the ocean as yearling or stream type juveniles and mature at ages 3-5.

There are 63 coastal rivers in Oregon, 16 of which support large populations of Chinook salmon and another 10-15 that support relatively small populations. The Columbia and Willamette Rivers are two of the most complex river basins in Oregon in terms of geomorphic complexity, hatchery releases and other management actions, and life history diversity in stocks of Chinook salmon. Whereas the FLHAP has not read scales from Chinook salmon in the Columbia in recent years, a growing number of projects within ODFW’s Willamette Biological Opinion group have required scale reads from Chinook salmon from the Willamette.

Most coastal Chinook will exhibit an estuary-type, sub-yearling life history at ocean entrance, yet the FLHAP has found fish that exhibit a yearling life history in these populations.

## COASTAL CHINOOK SALMON

### Background Information

**Life History:** A brief summary of life histories observed in coastal stocks of Chinook salmon is given in Table A2.1. A discussion of how information in the columns affects scale interpretation follows the table. A more detailed discussion of this information is given by Nicholas and Hankin (1988).

Coastal Chinook in northern Oregon return to freshwater before those in southern Oregon. In many years, north migrators have more obvious annuli compared to south migrators, depending on ocean conditions. Appearance of ocean annuli are somewhat consistent between all populations that go to the same area in the ocean.

**Table A2.1.** Life history characteristic of coastal Chinook salmon stocks. Blank cells = information unavailable. Basins are listed from north to south.

| Basin | Life history | Juv. life history | Estuary rearing | Long FW rearing | Ocean entrance | Ocean migration | Misc. |
|---|---|---|---|---|---|---|---|
| **Nehalem** | Fall | Sub-yearling | Yes | Some | Late summer/ Fall | North | Spring or summer run exists |
| **Wilson** | Fall | Sub-yearling | Yes | Yes | Late summer/ Fall | North | |
| **Trask** | Fall | Sub-yearling | Yes | Yes | | North | |
| | Spring | Sub - yearling | Yes | | | North | Spring run juveniles mix with CHF |
| **Nestucca** | Fall | Sub-yearling | Yes | Yes | Late summer/ Fall | North | |
| | Spring | Sub-yearling | Yes | | | North | |
| **Salmon** | Fall | Sub-yearling | Yes | | Summer/ Fall | North | |
| **Siletz** | Fall | Sub-yearling | Yes | Yes | Late summer/ Fall | North | |
| | Spring | Sub-yearling | Yes | | | North | Spring run juveniles mix with CHF |
| **Yaquina** | Fall | Sub-yearling | Yes | | Late summer/ Fall | North | |

| Basin | Life history | Juv. life history | Estuary rearing | Long FW rearing | Ocean entrance | Ocean migration | Misc. |
|---|---|---|---|---|---|---|---|
| **Alsea** | Fall | Sub-yearling | Yes | Some | Late summer/ Fall | North | |
| | Spring | Sub-yearling | Yes | | | North | |
| **Siuslaw** | Fall | Sub-yearling | Yes | | Late summer/ Fall | North | Very large smolts |
| **Umpqua** | Fall | Sub-yearling | Yes | | | North | Degraded scales |
| | Spring | Yearling, sub-yearling | Yes | Yes | Spring and fall | North and South | Degraded scales |
| **Coos** | Fall | Sub-yearling | Yes | | Late summer/ Fall | North | Degraded scales |
| **Coquille** | Fall | Sub-yearling | Yes | | Late summer/ Fall | North | Degraded scales |
| **Sixes** | Fall | Sub-yearling | Yes | | Late summer/ Fall | North | |
| **Elk** | Fall | Sub-yearling | Slight | Some | Summer | North, some south | Adult run extremely late fall |
| **Rogue** | Fall | Sub-yearling | Slight | Yes | Summer | South | |
| | Spring | Sub-yearling | Slight | Yes | Summer | South | Some yearlings |
| **Chetco** | Fall | Sub-yearling | slight | Yes | Late summer | South | |

Four pieces of information are essential to FLHAP personnel when ageing scales from Chinook salmon. These include knowledge of:

1) life history diversity;
2) the timing of ocean entrance;
3) the basin of origin, including geomorphology, water temperatures, and migration distance to the ocean; and
4) management practices, including hatchery release timing and release sizes.

All of these pieces of information inform how FLHAP personnel interpret the scales. Knowledge of life history diversity and the timing of ocean entrance are discussed in further detail below.

Knowledge of life history/histories of a particular stock of Chinook salmon and their basin of origin is necessary for FLHAP personnel to interpret the scale edges. Another essential piece of information used by FLHAP personnel is the time of ocean entrance, to be able to predict the space between the ocean entrance check and the first annulus.

*Life Histories:*

*Spring Chinook salmon:* The spring migrating, yearling life history of spring Chinook salmon (sometimes referred to as the **stream type**) may occur in any coastal basin of Oregon, but they are more common in the Umpqua River Basin. Note that spring Chinook can exhibit **yearling** and **sub-yearling** life histories. Spring Chinook salmon also tend to be more prevalent farther inland, in interior Oregon. These fish are best identified by a relatively small or "tight" FW zone with annulus. Yearling Chinook salmon tend to have significant ocean growth during the first summer, and a well formed saltwater (SW) annulus that is relatively far from the nucleus of the scale. Because spring Chinook return to freshwater (FW) in the spring, an annulus and sometimes a few circuli of **plus growth** can be present on the scale edge. As these fish hold in FW until spawn time in late summer-fall, they do not grow, and will resorb their scale edges to the point where spring growth and sometimes the last annulus are lost. "Summer" growth on the edge of a ragged scale from a spring Chinook usually means an annulus has been resorbed (and should be added to the annuli count).

*Fall Chinook salmon:* The fall migrating, sub-yearling life history of fall Chinook (sometimes referred to as the **ocean type**) occur predominately in drainages near the ocean, and strong fall Chinook salmon runs also occur in the Columbia River Basin. Note that whereas fall Chinook is largely synonymous with a **sub-yearling** life history, this life history may also produce yearlings. Fall Chinook enter FW in the fall and will have grown during their last summer. By late summer these fish put more energy into maturation of their gonads. These fish are best identified by having a "diffuse" FW zone with *no* annulus. Sub-yearling Chinook salmon tend to have a vague band of "medium" spaced circuli following ocean entrance. The edge of their scales will have a band of wide-spaced circuli (summer growth), ending with a band of narrow circuli, that form a **gonad check** (not an annulus). Summer growth on the edge of a ragged scale from a fall Chinook means the gonad check has been resorbed. The earliest, ocean type fish may have so much summer growth between ocean entrance and the first marine that it may be as far out on the scale as a second annulus on a late sub-yearling or a yearling. Late summer to fall migrants may not have any summer growth between ocean entrance and the first annulus. Without the change in spacing of circuli, the beginning of the annulus is not obvious. The annulus may be a vague band that is difficult to define.

*River and Estuary Rearing*: The extent of river or estuary rearing facilitates FLHAP personnel in understanding FW patterns on Chinook scales. Coastal Chinook salmon that rear in a river where habitat conditions are limiting early in the summer (e.g., Yaquina or Siuslaw Rivers), then pass into the estuary may have a scale pattern that looks like the FW pattern of a yearling Chinook from Northeast Oregon. This particular scale pattern exhibits a band of tight FW circuli, followed by much wider circuli, similar to a FW annulus followed by "spring" growth. Field data on these Chinook from Nicholas and Hankin (1988) indicates that this pattern is a combination of river and estuary growth, and not an annulus.  Coastal Chinook salmon that rear for extended periods of time in-river can seem relatively small at ocean entrance, and lack improved estuary growth.

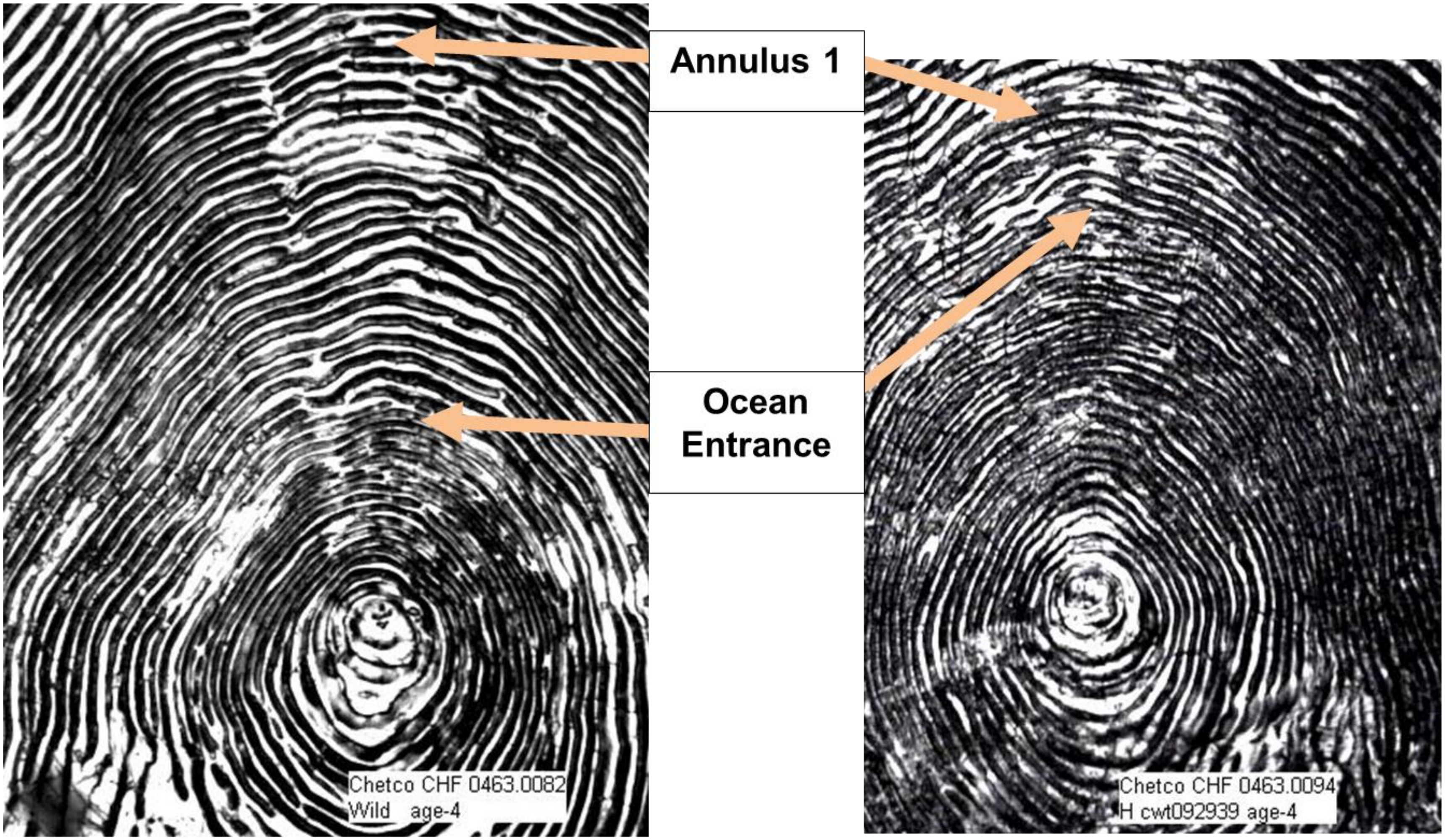
**Size-at-age trends**:  Chinook have a good correlation between body length  and age, yet these trends can be offset by life history.  For example, spring Chinook exhibiting yearling life histories without the last summer of ocean growth tend towards smaller body sizes than fall Chinook of the same age.  Also, substantial overlap in body sizes can occur across age classes.  Table A2.2 provides some size-by-age associations that should be viewed as rough approximations.

**Table A2.2.**  General size-by-age associations for Chinook.

| Total age | MEPS length (mm) | FL (mm) |
|---|---|---|
| 2 | < 500 | *Add ~8 to MEPS (bigger fish, bigger diff.) |
| 3 | 500 – ~700 | *Add ~10 to MEPS (bigger fish, bigger diff.) |
| 4 | >700 – low 800s | *Add ~12 to MEPS (bigger fish, bigger diff.) |
| 5 | Lots of overlap with 4s | *Add ~15 to MEPS (bigger fish, bigger diff.) |
| 5 and 6 | No discernible difference | *Add ~15 to MEPS (bigger fish, bigger diff.) |

**Origin**:  The FLHAP can estimate hatchery vs. wild origin in Chinook salmon with some confidence only in the Chetco, Winchuck, and Elk Rivers because these basins have relatively small estuaries, so FW growth mostly occurs within the river.  The wild juveniles tend to emigrate from these rivers into the ocean during mid-summer.  The Elk River Hatchery releases juvenile Chinook salmon into the Chetco, Winchuk, and Elk Rivers during the fall at relatively large body sizes.  Thus these smolts have scale patterns that differ  from the local, wild juvenile Chinook salmon (Figure A2.1).

The scale patterns of wild and hatchery Chinook in other coastal basins are too similar to enable FLHAP personnel to identify origin. The hatchery Chinook salmon are released at the same time the wild juveniles are emigrating to the ocean and the estuaries in the coastal basins allow wild juveniles to be of comparable size to the hatchery juveniles at ocean entrance.



**Wild**

**Elk River Hatchery, Chetco Stock**

**Figure A2.1**. Scale patterns from wild and hatchery (coded-wire tagged) Chinook from the Chetco River.

**Basin specific observations:**

- Miller et al. (2012), working with OSU colleagues, report on evidence of a genetic difference between the early-run (fall) and late-run (spring or summer) Chinook in Nehalem.
- The following are considered important basins for monitoring for the Pacific Salmon Treaty:
    - North Oregon Coast (NOC) aggregate
        - Nehalem (Escapement Indicator)
        - Siletz (Escapement Indicator)
        - Siuslaw (Escapement Indicator)
        - Salmon River (Exploitation Rate Indicator)
    - Mid Oregon Coast (MOC) aggregate
        - Coquille (Proposed Escapement Indicator)
        - South Umpqua (Proposed Escapement Indicator)
        - Elk River (Proposed Exploitation Rate Stock)
- Siuslaw: Has some of the biggest smolts found on the coast (tremendous growth resulting in very large freshwater zones). The fish are relatively large at the 1st marine annulus.
- Umpqua, Coos, and Coquille basins tend to have some of the most degraded fall Chinook scales, including the final annulus missing on some of the fish scales.

**Validation, age**: Whenever possible, the FLHAP seeks to obtain scales from CWT-fish as a means to validate age estimates from scales. Typical agreement rates between ages determined from CWT information and age estimates from scales for the FLHAP are >91 – 97%, and typically 95 – 97%. With two exceptions, all fish with CWTs and thus known ages have been hatchery fish. In 2002, wild fish were captured and tagged in the Siuslaw River; scale ages agreed with CWT ages at the rate of 98%. In 2012, the CCRMP began implanting CWTs in wild fish in the Salmon River. The earliest returns of these fish will be in 2014. CWT fall Chinook are released from Salmon River and Elk River hatcheries as well as various STEP programs. CWT spring Chinook are released from Trask, Cedar Creek, Rock Creek, and Cole Rivers Hatcheries.

**Validation, origin**: To date, validation of fish origin by scales has largely only been with hatchery fish, due to the recovery of CWTs. In the Elk and Chetco Rivers, where there are releases of “100%” fin-clipped hatchery fish from Elk River Hatchery, the FLHAP cannot assume that all unmarked fish are wild for validation purposes. A small percentage of hatchery fish are poorly clipped or regenerate their adipose fins.

**Reference scales**: The FLHAP has multi-year scale collections of CWT hatchery fish from Salmon River and Elk River hatcheries that were sampled from sport fisheries, from carcasses on spawning grounds, and hatchery returns. The FLHAP also has scales from miscellaneous STEP activities that have reared juveniles to smolt stage and implanted them with CWTs before release. Because the FLHAP has documented the juvenile life histories in most coastal basins of Oregon to be predominately sub-yearlings, the same life history as hatchery fish in these areas, the FLHAP uses hatchery Chinook salmon from the same return year as a reference for ocean ages of wild Chinook salmon.

## WILLAMETTE RIVER BASIN CHINOOK

### Background Information

In his work on Chinook in the Willamette River, Mattson (1962) reported the first data on age estimates, growth and outmigration timing from 1947 – 1951. This data is considered the closest approximation to a "baseline" for populations of Willamette Chinook. However, when considering the potential for a baseline comparison of Mattson's data to contemporary dates, some considerations are necessary:

- Some river impoundment within the Willamette Basin had already occurred at the time of Mattson's studies.
- Only two sampling stations were used, including:
  - In the Molalla River (for "residents"); and
  - In the lower, mainstem Willamette (for ocean migrants).
- Mattson (1962) sampled scales from *outside* of the **key area** (see Glossary definition).
- The angle of measurement for circuli differs from the 20° angle typically used for scale analyses (this manual).

Pertinent observations from Mattson (1962 and 1963).: Three periods of emigration to the ocean:

  - Late winter-spring (1st spring or summer = "Fingerlings"; 8-10 months old [FL = 37 – 100 mm]), ≤ 55% of a year class;
  - Fall-early winter (≥ 1 year old; October – December [FL = 100 – 150 mm]), ≤ 50% of a year class; and
  - 2nd spring migration (15 – 19 months; February – first of May [FL = 100 – 140 mm]), ≤ 33% of a year class.

- These three distinct migratory periods may equate with **ocean type** (**sub-yearling**), **estuary type** (**yearling**), and **stream type** migrants (**yearling** plus)
- Freshwater annuli occur between 10th and 20th circuli
- Freshwater annuli formed by 4 – 6 circuli
- Distinguishing between yearlings and sub-yearlings:
  - Fingerling: Mean number of FW circuli at time of emigration = 9 – 11
  - **Sub-yearling**: Mean number of FW circuli at time of emigration = 20 – 35
  - **Yearlings**: Mean number of FW circuli at time of emigration = 19 – 25
- "Depending upon their size at time of movement, some migrants exhibited accelerated scale growth, comparable to brackish or marine growth found on adult scales; this has been termed 'superior freshwater growth'. Comparisons were made of migrant and adult scale growth patterns to show similarities, which were striking in many cases."
- "Rich (1920) observed an accelerated type of freshwater growth on scales of young salmon from the lower reaches of the Columbia which he called 'intermediate'. These intermediate rings represent a period of growth more rapid than normal growth in freshwater and yet not as vigorous as true ocean growth."
- "Age and weight data were obtained from sport-caught salmon because later in the summer the scales are absorbed, aging becomes impossible, and weight is lost."
  - Age-3 mean FL = 25.0" (635 mm)….~50% yearlings, 50% sub-yearlings
  - Age-4 mean FL = 30.6" (777 mm)….~70% yearlings, 30% sub-yearlings
  - Age-5 mean FL = 33.9" (861 mm)….92% yearlings, 8% sub-yearlings
  - Age-6 mean FL = 37.3" (947 mm)….MOST were yearlings
- "In eight marking experiments using Willamette River stocks and involving 421 recoveries, Rich and Holmes (1929) found that 5 year old adults predominated, 6 year olds returned in larger numbers than 4 year olds, and only a few 3 year olds were recovered."

The juvenile life histories described by Mattson may still exist in the Willamette River Basin. Currently, there is not a viable population in the Molalla River where Mattson sampled, but the Clackamas, North Santiam, South Santiam, McKenzie, and the Upper Willamette subbasins support populations with fingerling, sub-yearling, and yearling life histories. Slight changes in current methods relative to Mattson's methods (key area collection, different angle of scale measurement) will yield different circuli counts between FLHAP and Mattson.

In 1997, using analyses of fish scales, the FLHAP originally reported on life history diversity of Willamette River Chinook, including a life history pattern that appears to be remarkably similar to what ODFW personnel have more recently been identifying as "reservoir-reared juveniles": "The most common pattern…indicated a large size at ocean entrance with the freshwater annulus and ocean entrance superimposed as if the fish had migrated in the winter" (Lindsay et al. 1997). A high proportion of these potential "reservoir-reared juveniles" were age-4 adults returning to the McKenzie River. They concluded that the prevalence of this life history type could not be fully attributed to hatchery releases or strays (Lindsay et al. 1997). More recent work on otolith microchemistry (Caudill et al. 2011; Bourret 2013) and other data (Keefer et al. 2012) have confirmed that some juveniles do rear in reservoirs. A recent comparison of scale morphology and otolith microchemistry indicates a high concordance, suggesting that scale analyses can be used to effectively identify life history types of juveniles (Caudill et al. 2011; Bourret 2013).

Further insight into life history diversity has come from comparisons of age estimates from scale reads with genetic pedigree analyses; collections of scales from juveniles in reservoirs, screw traps at the base of dams; and scales from late fall juveniles from Leaburg Dam (McKenzie River) corresponding with reservoir draw-down.

The FLHAP has identified a scale pattern from adult Chinook salmon in the Willamette Basin, where a large FW zone is evident with a superimposed FW annulus and an ocean entrance check, related to rearing in a reservoir. The FLHAP came to name this scale pattern "X", as questions arose at the beginning as to whether an annulus existed in this pattern and from what kind of juvenile rearing conditions were needed for this type of scale pattern to occur. The FLHAP has realized that this pattern is associated with reservoir-rearing for one year. Therefore, pattern "XX" = reservoir rearing for two years; and pattern "SX" = rearing in cooler streams in the upper watershed(**s**tream) for one year, plus subsequent rearing in the reservoir during a second year (Figure A2.2).

### *Areas needing validation*

Based on Chinook from the McKenzie River Basin, the FLHAP has found that yearlings generally have $\geq$ 50 circuli between the scale nucleus and the last circulus on the first marine annulus. Therefore, if one counts ~50 circuli (± ~5 circuli) to the end of the first marine annulus, then there *should* be a FW annulus prior to this marine annulus. This is only a generality , and FLHAP personnel have found exceptions to it. Nevertheless, FLHAP personnel have also found agreement between this relationship of circuli count, 1st marine annulus, and the presence of a FW annulus among stocks of Willamette and coastal Chinook.

The FLHAP is working with researchers to help validate the life history patterns noted above. Specifically, the FLHAP is working with researchers who are using otolith microchemistry to assess microchemistry signatures, through strontium profiles in the otoliths. The FLHAP is also working with colleagues to bolster scale information with tag-recapture data from juveniles in-river and with known reservoir-rearing fish. Finally, FLHAP personnel are exploring different scale measurements to identify diversity in freshwater rearing — both growth and age — through graphical comparisons of an invariant number. Preliminary examinations indicate that this approach shows promise in identifying diversity in freshwater rearing. The invariant number is calculated as:

(Fork length * scale radius to freshwater annulus $1^{-1}$) * Circuli count for annulus 1.

Finally, the FLHAP recently purchased equipment for processing and analyzing the morphology (thermal marks; ages) of salmonid otoliths. We will be exploring techniques to use otoliths to supplement and complement our age estimates and identification of putative life history types.

## Reference samples

Reference samples from the fishery in the Willamette below Willamette Falls are provided by Clackamas ODFW. These scales reveal an annulus near the edge of the scale. This seems to agree with Mattson's observation that, "Some of the scales from spent fish were approximately half their original size, and possibly 1 or even 2 annuli may have disappeared." (1963).

## Age validation

### *Coded Wire-Tagged Fish*

Validation between age determination by CWTs and age estimation by fish scales yields an agreement rate of ~91%; this is lower than for coastal Chinook, perhaps for three reasons: 1) the greater diversity of life history types in the Willamette (Figures A2.2); 2) a greater presence of hatchery fish, some of which are unclipped; and 3) the more degraded nature of scales from Chinook salmon in the Willamette River Basin, relative to those in coastal basins.

More recently personnel from ODFW's Upper Willamette River Research, Monitoring, and Evaluation project use otolith scores for all unclipped fish to verify their origin (hatchery fish in the Willamette will have thermal bands from temperature variation designed to create those bands for the purposes of origin identification). This is helpful in parsing out hatchery from wild fish so that the scale reads for putative life history types can be focused only on wild fish (the FLHAP has not had success in identifying hatchery fish from wild fish based on scales alone).

### *Genetic pedigrees*

Chinook salmon trapped at Cougar Dam on the SF McKenzie River are released above the dam in Cougar Reservoir. These fish are fin clipped for a genetic pedigree study. Given these are live fish, otolith scores are not available. The Genetic Pedigree study matched adult offspring to parents that had been placed above Cougar Reservoir to spawn. The adult offspring were trapped immediately downstream of Cougar Dam upon return from the ocean. Because the parents and offspring were sampled on known dates, geneticists can determine the brood year and age of the adult offspring to validate the scale ages. Validation rate for scale reads has been in the high 70 to high 80 percentiles for age-4 and age-5 fish for 2011 and 2012. Further comparisons and data QA and QC are underway, including examining potential sources of error for the pedigrees.

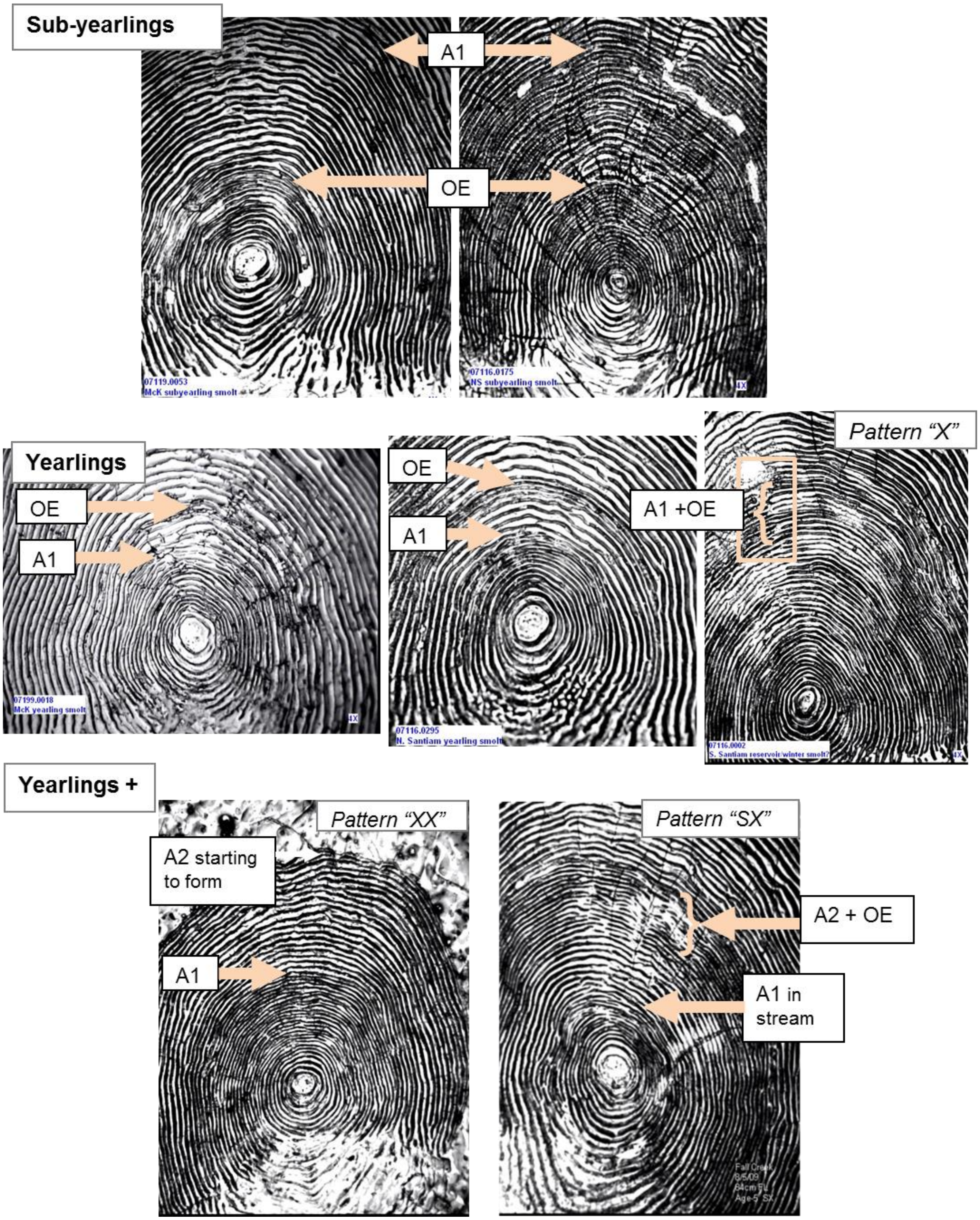


**Figure A2.2.** **F**reshwater (FW) life histories for wild Chinook salmon from the Willamette Basin. "Sub-yearlings" = FW age-1; "yearlings" = FW age-2; and "yearlings +" = FW age-3 (**Gilbert-Rich** notation). Patterns "X", "XX", and "SX" are FW life histories that are defined in the text. A1 = Annulus 1, A2 = Annulus 2, OE = ocean entrance. Note that the pattern "XX" scale is from a smolt.

## Hood River Chinook

Spring and fall life histories of Chinook salmon exist in Hood River. The fall Chinook population is considered extirpated though strays and a small amount of natural production still spawn each year. The juvenile life history of the spawners is a sub-yearling that appears to be an early summer emigrant (ocean type). FLHAP personnel were unable to discern hatchery patterns from wild patterns. The wild spring Chinook salmon migrate to the ocean as both sub-yearlings and yearlings. Hatchery fish are released as yearlings and are "100%" fin clipped. All hatchery fish carry an adipose fin clip as well as a maxillary clip or ventral clip specific to a single release year. The double clips, while not as exact as CWT, corroborate the scale age.

## John Day River

Criteria were developed by the FLHAP in 1987 for reading scales from John Day spring Chinook. Scales from spawned-out carcasses reveal a high degree of resorption. There are no hatchery fish released in the John Day River. What follows is a description of the protocol for estimating the ages of Chinook salmon from the John Day River.

## Criteria for when to add an annulus

SITUATION

1) <u>Add 1 to visible annulus count</u>. The last visible annulus is not on the scale edge. Several complete circuli of summer growth exist between the last visible annulus and the scale edge.
2) <u>Do not add to count of visible annuli</u>. The annulus or part of the annulus might be on the edge. The edge might have narrowing for annulus or "pre"-annulus. The last <u>full</u> annulus is far from the edge and what could be a full summer's growth zone exists between the last <u>full</u> annulus narrowing on edge. Part of the posterior field should still exist and radial striations may also show. Count the narrowing on the edge as the last annulus.

Many scales do not neatly match the above situations. Here are some guidelines to follow when it is not clear which situation you are dealing with.

a. If any summer circuli are complete around the entire scale edge, this is situation #1.
b. If there might be summer circuli beyond an annulus on the edge but it is not clear, FLHAP staff will consider this situation #2.
c. The edge of the scale is so broken that in some places the annulus is on the edge and in other places summer circuli are on the edge. If the posterior edge is

virtually gone and summer circuli show along ≥ 4 inches of the scale edge (at a magnification of 88X), consider this as situation #1 and add 1 to the annulus count.

d. If part of the posterior field is still present and summer circuli show along < 4 inches of the scale edge (at a magnification of 88X), consider this as situation #2, and do not add to the annulus count. Count the last visible annulus as the <u>last</u> annulus.

### When to throw out a scale

Since the vast majority of these **spring Chinook salmon** are **yearling** migrants, one can still age the scales if there is regeneration in the freshwater (FW) zone. Assume there is a FW annulus.

If the regeneration extends beyond the FW zone and the reader feels that they might be missing a SW annulus, do not attempt to age those particular scales.

If the scale is so <u>resorbed</u> that the posterior field is completely gone and the "bottoms" of the circuli are worn off, consider not ageing those particular scales. Two annuli may be missing. If the scale is in really bad shape and the fish length is too large for the estimated age, look carefully at the posterior field and bottoms of the circuli.

### Upper Columbia and Snake River Chinook

Spring and summer life histories exist. All juveniles appear to migrate as yearlings with a FW annulus followed by spring growth on their scales. In the past the FLHAP has identified hatchery or wild origin using discriminant analysis on samples collected for the Lower Snake Compensation Plan (Messmer et al. 1990) and for NOAA Fisheries' barging study (Borgerson and Bowden 1993).

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