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Evaluation of Coho Salmon Aging Methods and Scale Growth Patterns Using Known Age Specimens

by

Kent F Crabtree



Month Year

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

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**Weights and measures (metric)**

centimeter cm

deciliter dL

gram g

hectare ha

kilogram kg

kilometer km

liter L

meter m

milliliter mL

millimeter mm

**Weights and measures (English)**

cubic feet per second ft3/s

foot ft

gallon gal

inch in

mile mi

nautical mile nmi

ounce oz

pound lb

quart qt

yard yd

**Time and temperature**

day d

degrees Celsius °C

degrees Fahrenheit °F

degrees kelvin K

hour h

minute min

second s

**Physics and chemistry**

all atomic symbols

alternating current AC

ampere A

calorie cal

direct current DC

hertz Hz

horsepower hp

hydrogen ion activity pH

(negative log of)

parts per million ppm

parts per thousand ppt,

‰

volts V

watts W

**General**

Alaska Administrative

Code AAC

all commonly accepted

abbreviations e.g., Mr., Mrs., AM, PM, etc.

all commonly accepted

professional titles e.g., Dr., Ph.D.,

R.N., etc.

at @

compass directions:

east E

north N

south S

west W

copyright ©

corporate suffixes:

Company Co.

Corporation Corp.

Incorporated Inc.

Limited Ltd.

District of Columbia D.C.

et alii (and others) et al.

et cetera (and so forth) etc.

exempli gratia

(for example) e.g.

Federal Information

Code FIC

id est (that is) i.e.

latitude or longitude lat. or long.

monetary symbols

(U.S.) $, ¢

months (tables and

figures): first three

letters Jan,...,Dec

registered trademark ®

trademark ™

United States

(adjective) U.S.

United States of

America (noun) USA

U.S.C. United States Code

U.S. state use two-letter abbreviations (e.g., AK, WA)

**Mathematics, statistics**

*all standard mathematical*

*signs, symbols and*

*abbreviations*

alternate hypothesis HA

base of natural logarithm *e*

catch per unit effort CPUE

coefficient of variation CV

common test statistics (F, t, χ2, etc.)

confidence interval CI

correlation coefficient

(multiple) R

correlation coefficient

(simple) r

covariance cov

degree (angular ) °

degrees of freedom df

expected value *E*

greater than >

greater than or equal to ≥

harvest per unit effort HPUE

less than <

less than or equal to ≤

logarithm (natural) ln

logarithm (base 10) log

logarithm (specify base) log2, etc.

minute (angular) '

not significant NS

null hypothesis HO

percent %

probability P

probability of a type I error

(rejection of the null

hypothesis when true) α

probability of a type II error

(acceptance of the null

hypothesis when false) β

second (angular) "

standard deviation SD

standard error SE

variance

population Var

sample var

fishery manuscript series no. YY-XX

Evaluation of coho salmon aging methods and scale growth patterns using known age specimens

By

Kent F. Crabtree

Alaska Department of Fish and Game, Division of Commercial Fisheries, Douglas

Alaska Department of Fish and Game  
Division of Sport Fish, Research and Technical Services  
333 Raspberry Road, Anchorage, Alaska, 99518-1565

Month Year

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Kent F. Crabtree,

Alaska Department of Fish and Game, Division of Commercial Fisheries,

802 Third Street, Douglas, Alaska 99824, USA

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# abstract

Accurate age determination is essential to the development and refinement of stock-recruitment relationships and the derivation of appropriate escapement goals (Beamish and McFarlane 1983). Coho salmon are commonly aged by interpretation of the growth pattern observed on the scale. In order to investigate the growth pattern and the ageability of coho salmon scales and their growth characteristics, known-age groups have been created and allowed to rear in natural native environments.

This study affirms that the accuracy of coho salmon age determination has been imperfect. It is evident that coho salmon scale patterns are often highly variable from system to system and from year to year as these patterns are influenced by the habitat types and the environmental conditions during the particular years from which they originate. This quality makes it very difficult to define rigid criteria for identification of legitimate winter annuli that may be applied to all coho salmon. A collection of known age smolt scale samples from different locations and over several years provides the ability to evaluate the variability of scale patterns between locations and between years, and provides an aging standard for the years of the study. The collection also provides an important training tool for those wanting to improve their ability to interpret coho salmon scale patterns.

A collection of scale pattern images of known age was produced by this study. It is an extremely valuable training tool for those seeking to improve their ability to interpret coho salmon scale patterns. In some situations, such as attempting to age coho from mixed stock fisheries where the nature of the habitat of origin is unknown, it may be concluded that coho scale patterns are variable to such a degree that a high level of accuracy is unobtainable. For particular stocks, reared in certain habitat types, under certain environmental conditions (that vary from year to year) perhaps the only means of acquiring highly accurate age determination is to produce a known-age group as an aging standard for every system and every year.

Key words: Coho salmon, *Oncorhynchus kisutch*, age, aging, scale pattern, growth, circuli, annulus, check, false-check, residual.

# introduction

Coho salmon (*Oncorhynchus kisutch*) rear in their natal freshwater habitats for one to three years. The marine life history is less variable. A large coho salmon spends approximately 16 months in the marine environment, which includes one winter, before returning to spawn. There is a smaller component of any given cohort that return as jacks. These are individuals that spend only about four months in the marine environment, thus a winter is not included in their marine life history. Determining the age of coho salmon is primarily a problem of determining the age at smolting; the freshwater age. The marine age is usually easily established by size of the fish, size of the scale, and by the presence or absence of a winter annulus on the scale pattern.

Coho salmon scale aging has been performed for many years as a component of stock recruit analysis and to further the understanding of the freshwater life history of juvenile coho salmon. Among those who age salmon scales coho salmon have developed a reputation for being among the more difficult. Our years of experience examining coho scale patterns has shown that the freshwater rearing portion is not very stable from year to year and that certain predictable characteristics are associated with different systems or rearing locations. In particular two of our study areas are the Berners River and Hugh Smith Lake from which we have collected smolt and adult scale data for over 30 years. This includes a seventeen year period of conducting an age validation study. The scale samples from these two locations predictably display distinctly differing traits from each other. The most obvious differences are in the concentration of circuli and the relative “strength” of the winter annulus. We have come to talk about “lake patterns” versus “river patterns” as a result of the observations made regarding the samples from these two systems and others as well. The lake pattern displays a higher concentration of circuli, the circuli being numerous and packed tightly together. Also the winter annuli are often weakly manifested and the circuli spacing tends to lack a high degree of seasonal graduations. The river pattern is characterized by fewer total circuli which are less tightly packed. The winter annuli are usually more strongly manifested and the circuli spacing is frequently well graduated becoming narrower as the winter annulus is approached.

[[Include comment regarding Auke Lake?]]

Common to both pattern types however, is the occurrence of “false checks”. These are episodes of constriction in the circuli spacing where the appearance is similar to that of a winter annulus. These “false checks” are a major source of aggravation and mis-aging especially when found among patterns bearing weak, but legitimate, winter annuli.

The extant literature concerning coho salmon aging offers nothing for the validation of ages or aging techniques applied to fish reared in the wild in their native habitats. The few studies done concerning scale growth and aging are relatively short-term investigations that include a single winter annulus at best and are always performed in artificial environments such as a laboratory or a hatchery. This literature is sparse and inconclusive in terms of offering knowledge on how to interpret a scale pattern from a wild specimen reared in their natural environment over the duration of their freshwater life history.

Due to the lack of adequate studies and our observations of these differing pattern types, and also the notable differences in the pattern characteristics from year to year for the same system it was necessary to undertake our own investigation. This study evaluates coho scale patterns in detail to improve our ability to understand the features and ultimately achieve improved aging accuracy.

This study of known age coho salmon smolt will provide information to improve scale pattern interpretation and the reliability of scale aging. The study will contribute new insight or methods for age determination, and will better define the level of accuracy that can be achieved.

# Methods

The fundamental concept of this study is to create a sub-population of rearing coho salmon that are marked as fry such that their age when recaptured and sampled at a later stage in life can be determined. The scale patterns from these samples can be examined to determine how they relate to the actual known age. Two systems are included in the study to compare two differing habitat types; Berners River as a “river type” habitat and Hugh Smith Lake as a “lake type” habitat.

This study is greatly facilitated by the fact that it is piggybacked upon ongoing coho research projects already occurring at these locations in the spring when newly hatched fry are available. Infrastructure already exists, crews are in place and logistical support is already provided for these remote field projects. These projects are in place to capture and coded-wire-tag outmigrating coho salmon smolt. Thus the equipment for coded-wire-tagging is already available and the activity of capturing coho salmon smolt is ongoing. The only procedures added to the field project to accomplish the goals of this study are the capture and tagging of newly emerged fry and the sampling of known age specimens that are recovered during the ongoing smolt trapping activities.

By looking at length frequency data for small coho salmon juveniles from these locations a size cut-off of 42 mm was selected for the first year of the study at Berners river. It was noted during the next fall that a few coho salmon fry were captured in November at Hugh Smith Lake from a tributary that were 31–36 mm. As a result the size cut-off was reduced to 38 mm. In order to tag such tiny fish, half-length coded wire tags were used. A tagging goal of 5000 was determined as a quantity that should provide a large enough known age sub-population to yield 100 to 300 potential samples.

The capture methods used at the two systems differ for both fry capture and smolt capture. At Hugh Smith Lake the fry are captured by using a fyke net installed in a tributary of the lake, Cobb Creek. This captures newly hatched fry as they drift with the current towards the lake. The mouth of the fyke net is about 1 m tall × 2 m wide. It has a holding box at the downstream terminus where the fry collect and find refuge from the current. The smolt are captured at the outlet of Hugh Smith Lake using a smolt weir installation with an inclined plane trap.

At Berners River the fry drift downriver from the spawning areas after emerging from the stream substrate and congregate in eddies and small sloughs out of the main river flow. They are found in good numbers in quiet waters where spills from beaver ponds occur. Presumably they wait in these locations for high water events; the opportunity to swim into the beaver pond areas since these seem to be preferred rearing habitat. The fry are captured simply by stalking these holding areas and scooping them up with a dip net. Often only 200 to 400 fry are tagged per day, this number can be captured in 10 to 15 minutes of dip netting effort. Smolt capture is achieved by using “spill traps”. These are a passive trap that requires a few inches of head or drop in water level to function. They are installed in the perimeter of beaver ponds where there is effluent flow. A dewatering trough is installed to receive the effluent, it terminates with a 4 inch pipe that directs the remaining flow into a floating holding box. As migrating smolt follow the flow out of the beaver pond they pass through the trough and the connecting pipe and are captured in the holding box. The box has a large perforated panel on one side that allows flow. Four or five of these traps are installed at different locations. They are checked once or twice a day depending on the run timing and intensity of smolt movements.

As the smolt catch is processed for tagging, those that are missing the adipose fin are put aside as potential known age specimens. When the day’s tagging is completed the adipose clipped smolt that have been discovered are run through the coded wire tag detector to determine which specimens contain tags. Those with tags are carefully examined at the adipose excision to determine if it is a fresh cut or if the cut is healed over. Only those that are healed are collected as known age samples. A few samples turn out to be fish that were tagged as presumed smolt the previous spring but which remained in freshwater another year. This error occurs almost exclusively with smolt captured in the slough versus the beaver pond since those areas are semi isolated from one another and tagged fish as smolt are released into the slough. The smolt that are selected are sampled for scales and length. An individually numbered Floy tag is attached to the smolt and the entire fish is preserved in a bottle of ethyl alcohol.

## Methods Used in Auke Lake Study

### Study Site

The Alaska Department of Fish and Game in cooperation with the National Marine Fisheries Service, Auke Bay Laboratories operates the Auke Creek Research Station located on the outlet from Auke Lake. Auke Lake is a productive, moderately deep lake covering 92 ha with a heavily forested shoreline. The lake and its tributaries support indigenous populations of coho, sockeye, and pink salmon, cutthroat trout, and Dolly Varden char, as well as incidental numbers of chum salmon and steelhead trout. The outlet stream, Auke Creek, is less than 1 km long, of moderate gradient with few natural pools or spawning gravel except for a small number of man-made backwater pools filled with gravel for spawning. The main tributary to Auke Lake, Lake Creek, is a low gradient stream of pools and riffles with an abundance of gravel suitable for adult coho spawning. Auke Creek Research Station maintains a concrete and steel fish weir structure located on Auke Creek just above the highest high tide level. The weir is operated in a downstream trapping configuration from early March through June to intercept emigrating salmon smolt and trout, then changed to the upstream trapping configuration and operated through early November for migrating adult salmon. It is assumed 100% of migrating salmonids are captured in the weir trap.

### Fish Enumeration and Aging

As a routine part of monitoring the Auke Lake coho salmon population, all smolts and adults are counted as they pass the weir, and examined for presence or absence of a coded wire tag. Additionally, before release downstream of the weir all emigrating coho smolts were sorted into four size categories by fork length: small (<90 mm), medium (90–110 mm), large (111–125 mm), and extra-large (>125 mm).

Smolt scales are taken in a systematic fashion to include all size categories. Scales are taken from the preferred area (INPFC 1963), and mounted on glass slides. Age determinations were based on examinations of scale images at 70× on a microfiche viewing projector. Criteria used to assign ages were similar to those of Mosher (1968). Photographs of selected scales were taken on a Leitz Laborlux S (trademark) microscope mounted with a Wild Leitz MPS 46 Photoautomat (trademark) camera using 35 mm Kodak Kodalith (trademark) film.

### Marking and tagging

In October 1992, 13 adult female cohos and 11 adult male cohos migrating to Auke Lake were captured at the weir and held for several weeks. They were artificially spawned in November, which is timing similar to natural coho spawning in the Auke Lake system. The fertilized eggs were incubated in Heath (trademark) trays at the Auke Creek Research Station. Water for incubation came from Auke Creek, matching water temperature regimes expected for naturally spawned coho eggs. A total of 10,411 of the resulting coho fry were marked with a fin clip and planted as unfed fry into the Auke Lake watershed 25–28 May 1993. The plantings were made into two different habitat types: into shallow, weedy waters on the lake margin, considered prime juvenile coho rearing habitat; and into pools in Lake Creek where coho fry are frequently seen in spring.

Recoveries of marked smolts were made at the weir during daily sorts from April through June, 1994 and 1995. Not all marked fish were sampled. In 1994, only marked fish up to 110 mm fork length were sacrificed for samples, 125 out of 488 mark recoveries. In 1995, all mark recoveries, 61 fish in total, were sacrificed for samples.

In spring 1995, nomadic, young-of-the-year wild coho fry were captured in the downstream trap of the weir. Additional fry were caught with dip nets upstream of the weir to supplement weir numbers. Fry were marked with a fin clip and tagged with half-length coded wire in groups according to three release sites, Lake Creek, Auke Lake, and Auke Creek. Each group was sampled for fork length and absence of scales, and then released on 2 June, 19 June, and 19 June 1995, respectively. Pre-release tag retention ran 100%, 100%, and 99.5%, respectively. In summer and fall 1995, baited minnow traps were used in Auke Lake to catch tagged juvenile cohos. The few marked fish captured were checked for presence of a coded wire tag using a field detector, sampled for fork length and scales, and then released back into the lake. Recoveries of marked and tagged smolts were made at the weir during daily sorts in April through June 1996 and 1997. All were sacrificed for tag removal.

## Data Production

These samples are later turned in to the ADF&G CWT lab where they are dissected to recover the tag and the tag code is used to determine the year that the specimen was tagged as a fry, thus the age of the smolt is established.

In preparation for technical analysis a scale from each sample is selected and a digital image is created. The scale images are then processed by an image analysis software program using Optimate. This process produces a set of incremental measurements from the center of the scale to the outer margin circuli by circuli. An operator designates the measurements as different zones corresponding to the year of growth. From the focus to the end of the first annulus all measurements are designated as zone 1, continuing from there to the end of the second annulus all measurements are designated as zone 2. Growth that is beyond the outermost annulus is referred to as “plus growth”. For an age-1 smolt, plus growth is designated as zone 2. For an age-2 smolt, plus growth is designated as zone 3.

The resulting data are then entered into a database format that is organized to have one row per circulus measurement. Using this database, descriptive statistics are derived that characterize various features of the scale patterns according to age.

## Discriminant Analysis to Classify Coho Smolt

### Data and Method

Coho salmon smolt (age-1 or -2) were sampled from three stocks (AL, BR, and HS). AL stock were sampled in 1994–1998 and 2000; both BR and HS stocks were sampled in 1998–2005. Scales were collected for the scale pattern analysis (SPA). We were able to obtain up to 50 quantitative variables for each individual fish from SPA (Table 1). Among these 50 variables, some of them may not be retrieved from the age-1 smolt due to their younger age or slow growth. We excluded those variables from our analysis. The rest of variables (bold in Table 1) were applied on repeated iterations of STEPDISC (SAS, Inc.) to select the subset of variables that best differentiated the ages. This selection process was applied separately for each stock and selected subset of variables may differ in stocks. The subset of variables was applied to the discriminant analysis for each stock.

Discriminant analysis is used to classify an individual fish into either of two known age groups on the basis of a set of quantitative variables from SPA. The analysis first develops a discriminant criterion to classify each individual fish into one of the two age groups. The data set used to derive the discriminant criterion is called the training or calibration data set. The derived discriminant criterion can be applied to a second data set (test data set) to assign individual fish into age groups. We assume that the distribution within each age group is multivariate normal so that a parametric method can be used to develop a discriminant function. The performance of a discriminant function can be evaluated by estimating error rates (probabilities of misclassification). Error count estimates and posterior probability error rate estimates can be evaluated in the analysis.

We developed discriminant criterions separately for each of three stocks. We used the 1994–1998 data set as training data to develop a discriminant function for AL stock; 1998–2004 for BR and HS stocks. Then we applied the criterions to the latest year data set (test data set): 2000 data set for AL stock; 2005 data set for BR and HS stocks. We also pooled the three stocks and used pooled 1994–2004 data set as training data to develop a discriminant function for all the stocks and the used 2005 pooled data as test data set for its evaluation.

# Observations of Scale Characteristics

As seen from these charts generally the lake system habitats, Hugh Smith Lake and Auke Lake, produce greater numbers of circuli in the first year of growth (Z1) than does the habitat of Berners River which consists of smaller volume and shallower water bodies such as stream channels, sloughs and beaver ponds. Auke Lake is much smaller than Hugh Smith Lake and it is located at a more northerly latitude and the Z1 growth is smaller.

[[ Figures ]]

* For Auke Lake the Z1 and Z2 for age 2.0 fish is roughly equivalent.
* Only two examples of age 3.0 fish have been obtained, both from Berners River. Surprisingly the circuli numbers for Z3 increase. Perhaps the fish at this age have reached a threshold size that allows them to feed more successfully or more competitively than the younger/smaller juveniles.
* The difference between circuli counts for Z1 of age 1.0 and age 2.0 is present for the Berners River samples but is less significant than it is for the lake systems because there is overall a lower number of circuli presumably due to a shorter favorable season of growth.
* For the majority of individuals Z1 has a greater number of circuli than does Z2 for both the Berners River and the Hugh Smith Lake Systems. Growth at Hugh Smith Lake is consistently greater than at Berners River as demonstrated by both circuli number and scale size.
* Lake habitat maintains a more stable growth environment, particular regarding temperature, and provides a longer growth season.

# Occurrence of a Coho Residual

During escapement sampling in October of 2010 a curious fish specimen was discovered and collected. The fish was dead on the stream bottom on the margin of a pool where coho adults aggregate in large numbers as they make their way upstream to spawning areas. The fish was coho jack size (260 mm fork length) but it had unusual coloration and spotting. It lacked the silvery appearance characteristic of fish returning from the marine environment and looked more trout-like, it was darker and greenish and its spotting was larger than is typical for coho and the spotting also occurred on the head and cheeks (opercles). Another irregularity was the size of the scales, they were smaller than would be expected from a jack. Though we thought it was most like a coho we investigated it further to learn more about its identity and life-history.

Samples submitted for DNA analysis identified the fish as a coho, not a hybrid of any kind. Growth patterns on the scale samples indicate that the fish never underwent growth in marine waters. The circuli numbers and spacing are consistent with freshwater growth. Also there are five annuli making this the oldest coho specimen that we have document, residual or otherwise. This came from brood year 2005 and is age 6.0, 260 mm. The gonads were examined and were very underdeveloped but appeared to be testes.

The scale pattern is quite normal from the focus through the second annulus. Twelve circuli per year and nicely graduated circuli spacing indicative of seasonal changes effecting growth. After the second annulus, typically marine growth would begin, were this a common two years of freshwater rearing coho. Between the second and third annulus however, the circuli are narrower and more consistently spaced possibly indicating a reduced growth rate and less variable environmental conditions. The pattern in this area is more similar to a “lake pattern” than to a typical Berners river pattern. This warrants speculating that the fish found its way to a different type of habitat during this period. There is a small lake (Berners Lake) that attaches to the Berners River system; it is located about 3 km downstream of where the carcass was recovered. Perhaps the fish was located there or perhaps some other water body where seasonal temperature variations are mitigated.

Beyond the third annulus the circuli spacing becomes more typical again with the exception that the fourth annulus is understated, it appears as a weak check. The circuli numbers continue to make sense at 10 or 11 for each year of growth before and after the fourth annulus with spacing typical of freshwater growth at Berners River.

The carcass was recovered upriver of the majority of the rearing habitat and was in fact in a holding pool full of adult cohos preparing to spawn. This inspires speculation that perhaps this residual was responding instinctually to an urge to undergo a spawning process which compelled to it to swim upriver to the spawning grounds. The gonads were underdeveloped which does not help to support this scenario. However, it appears that this particular coho suffered an atypical life history that might be characterized as deviant and unfit; thus an urge towards spawning behavior while still being sexually underdeveloped may be plausible. Perhaps this urge was the cause of death indirectly by compelling the fish to depart prime rearing habitat of the lower river and head for the leaner habitat of the spawning areas. Perhaps it also suffered the loss of the urge to feed as spawners typically do, and without the fat reserves that would have been acquired by marine feeding it may have starved. The fish does not look robust in the photographs.

There is no reason to suspect a population of residual cohos inhabits the area. Several holding pools in the upper river are beach seined each fall during spawning season. The nets used select for fish larger than 25 to 30 cm depending on their circumference so residuals could escape the net if they are smaller than this threshold. However, there have been no sightings during the foot surveys or during beach seining activities. Visibility is often very good and this fish could easily be distinguished from the Dolly Varden that are common in the area. In the springtime the lower river is trapped using baited minnow traps (which are size selective for fish above approximately 150mm) and also using spill traps that catch fish of any size coming out of beaver ponds. There is also a small amount of sport fishing. No other occurrence of a coho residual has ever been reported at Berners River therefore without additional evidence, this specimen must be considered an anomaly.

# Discussion

# Recommendations

# Acknowledgements

# References Cited

Tables and Figures

Table 1.–Scale measurement and count characters calculated from intercirculus distances. (Note: variables in bold were selected for discriminant analysis.)

|  |  |  |
| --- | --- | --- |
| **Variable** |  | **Total Freshwater Annular Zone** |
| **Z1** | v1 | Number of circuli in FW Annular Zone (NCFAZ) |
| **Z2** | v2 | Width of FW Annular Zone (SFAZ) |
| **Z3** | z2/z1 | Average interval between circuli (SFAZ/NCFAZ) |
| **Z4** | v3 | Number of circuli in Plus Growth Zone (NCPGZ) |
| **Z5** | v4 | Width of Plus Growth Zone (SPGZ) |
| **Z6** | z4/z3 | Average interval between circuli (SPGZ/NCPGZ) |
| **Z7** | v5 | Distance from scale focus (C0) to circulus 1 (C1) |
| **Z8** | v6 | Distance from scale focus to circulus 2 (C0 - C2) |
| **Z9** | v7 | Distance from scale focus to circulus 3 (C0 - C3) |
| **Z10** | v8 | Distance from scale focus to circulus 4 (C0 - C4) |
| **Z11** | v9 | Distance from scale focus to circulus 6 (C0 - C6) |
| Z12 | v10 | Distance from scale focus to circulus 7 (C0 - C7) |
| Z13 | v11 | Distance from scale focus to circulus 8 (C0 - C8) |
| Z14 | v12 | Distance from scale focus to circulus 9 (C0 - C9) |
| Z15 | v13 | Distance from scale focus to circulus 12 (C0 - C12) |
| Z16 | v14 | Distance from scale focus to circulus 15 (C0 - C15) |
| Z17 | v15 | Distance from scale focus to circulus 21 (C0 - C21) |
| **Z18** | v8-v6 | Distance from circulus 2 to circulus 4 (C2 - C4) |
| **Z19** | v9-v6 | Distance from circulus 2 to circulus 6 (C2 - C6) |
| Z20 | v11-v6 | Distance from circulus 2 to circulus 8 (C2 - C8) |
| **Z21** | v9-v8 | Distance from circulus 4 to circulus 6 (C4 - C6) |
| Z22 | v11-v8 | Distance from circulus 4 to circulus 8 (C4 - C8) |
| **Z23** | v9-v7 | Distance from circulus 3 to circulus 6 (C3 - C6) |
| Z24 | v12-v7 | Distance from circulus 3 to circulus 9 (C3 - C9) |
| Z25 | v13-v7 | Distance from circulus 3 to circulus 12 (C3 - C12) |
| Z26 | v14-v7 | Distance from circulus 3 to circulus 15 (C3 - C15) |
| Z27 | v12-v9 | Distance from circulus 6 to circulus 9 (C6 - C9) |
| Z28 | v13-v9 | Distance from circulus 6 to circulus 12 (C6 - C12) |
| Z29 | v14-v9 | Distance from circulus 6 to circulus 15 (C6 - C15) |
| Z30 | v14-v12 | Distance from circulus 9 to circulus 15 (C9 - C15) |
| Z31 | v15-v12 | Distance from circulus 9 to circulus 21 (C9 - C21) |
| Z32 | v14-v13 | Distance from circulus 12 to circulus 15 (C12 - C15) |
| Z33 | v15-v13 | Distance from circulus 12 to circulus 21 (C12 - C21) |
| Z34 | v15-v14 | Distance from circulus 15 to circulus 215 (C15 - C21) |
| Z35 | v16 | Distance from sixth-to-last circulus to end of zone, C(NCFAZ-6) - EOZ |
| Z36 | v17 | Distance from third-to-last circulus to end of zone, C(NCFAZ-3) - EOZ |
| **Z37** | v2-v7 | Distance from circulus 3 to end of zone (C3 - EOZ) |

–continued–

Table 1.–Page 2 of 2.

|  |  |  |
| --- | --- | --- |
| **Variable** |  | **Total Freshwater Annular Zone** |
| Z38 | v2-v12 | Distance from circulus 9 to end of zone (C9 - EOZ) |
| Z39 | v2-v14 | Distance from circulus 15 to end of zone (C15 - EOZ) |
| Z40 | z25/z2 | Relative width, (variable 25)/SFAZ |
| Z41 | z26/z2 | Relative width, (variable 26)/SFAZ |
| Z42 | z27/z2 | Relative width, (variable 27)/SFAZ |
| Z43 | z28/z2 | Relative width, (variable 28)/SFAZ |
| Z44 | z29/z2 | Relative width, (variable 29)/SFAZ |
| Z45 | z30/z2 | Relative width, (variable 30)/SFAZ |
| Z46 | z32/z2 | Relative width, (variable 32)/SFAZ |
| Z47 | z34/z2 | Relative width, (variable 34)/SFAZ |
| **Z48** | v18 | Number of circuli in first 1/2 of zone |
| **Z49** | v19 | Number of circuli in first 3/4 of zone |
| **Z50** | v20 | Maximum distance between two consecutive circuli |

|  |  |
| --- | --- |
|  | [ insert another photo here?? ] |

Figure 1.–

|  |
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|  |
|  |
|  |

Figure 2.–

Appendix

Appendix A.–SAS code [description needed].

Code-1:

/\* Convert the data format from the scale lab to the one for the discriminant analysis using SAS and collect the variables from the scale pattern\*/

%let fileid=AL\_BR\_HS; /\* Filename of input file \*/

%let filext=csv; /\* file extension \*/

libname x 'H:\SAS Splus Consulting\Juvenile coho SPA for Leon';

/\* -------------------------------------------- \*/

/\*Get import data, transpose from 1 row/fish to 1 row/cirulus\*/

**data** a;

length sampleID $ **20** tagcode $ **12** sublocation $ **16** comment $ **50**;

infile "&fileid..&filext" firstobs=**2** delimiter=',' lrecl=**1000**;

count+**1**;

input sampleID $ location $ year date $ floyno tagcode $ age length sublocation $

comment $ npairs @;

do i=**1** to npairs;/\*loop thru each data pair,output to a,1 row/circ.\*/

input zone dist @;

output;

end;

drop i count;

**run**;

**data** c; /\* change zone zone coding for age 2 so that 1fw+2fw=faz (freshwater annular zone) \*/

set a;

if age=**3** then delete;

if age=**2** then do;

if zone=**2** then zone=**1**;

if zone=**3** then zone=**2**;

end;

**run**;

**proc** **summary** data=c; /\* count up circuli and sum width by id-zone \*/

by sampleID zone;

var dist;

output out=outsum2 n=ncirc sum=totwidth;/\* output sumout=1 row/zone\*/

**run**;

**data** fazone; /\* output b = 1 row/circulus \*/

merge c outsum2(drop=\_TYPE\_ \_FREQ\_);

by sampleID zone;

**run**;

/\* Calculate basic recombinant variables: \*/

**data** cnvrt3;

set fazone;

by sampleID zone;

array v{\*} ncfaz sfaz ncpg spgz fc0\_c1 fc0\_c2 fc0\_c3 fc0\_c4 fc0\_c6

fc0\_c7 fc0\_c8 fc0\_c9 fc0\_c12 fc0\_c15 fc0\_c21

efaz\_6 efaz\_3 ncfaz1\_2 ncfaz3\_4 maxfaz;

retain v;

if first.sampleID then do i=**1** to dim(v);

v{i}=**0**;

end;

if first.zone then do;

count=**0**; sumdist=**0**;

end;

count+**1**;

sumdist+dist;

if zone=**1** then do;

if count>**1** and dist>maxfaz then maxfaz=dist;

if count=**1** then fc0\_c1=sumdist;

else if count=**2** then fc0\_c2=sumdist;

else if count=**3** then fc0\_c3=sumdist;

else if count=**4** then fc0\_c4=sumdist;

else if count=**6** then fc0\_c6=sumdist;

else if count=**7** then fc0\_c7=sumdist;

else if count=**8** then fc0\_c8=sumdist;

else if count=**9** then fc0\_c9=sumdist;

else if count=**12** then fc0\_c12=sumdist;

else if count=**15** then fc0\_c15=sumdist;

else if count=**21** then fc0\_c21=sumdist;

if ncirc-count=**6** then efaz\_6=totwidth-sumdist;

else if ncirc-count=**3** then efaz\_3=totwidth-sumdist;

if sumdist le **.5**\*totwidth then ncfaz1\_2=count;

else if sumdist le **.75**\*totwidth then ncfaz3\_4=count;

if last.zone then do;

ncfaz=ncirc; sfaz=totwidth;

end;

end;

else if zone=**2** then do;

ncpg=ncirc; spgz=totwidth;

end;

if last.sampleID then output;

**run**;

**data** x.&fileid.\_FAZ;

set cnvrt3;

array v{\*} ncfaz sfaz ncpg spgz fc0\_c1 fc0\_c2 fc0\_c3 fc0\_c4 fc0\_c6

fc0\_c7 fc0\_c8 fc0\_c9 fc0\_c12 fc0\_c15 fc0\_c21

efaz\_6 efaz\_3 ncfaz1\_2 ncfaz3\_4 maxfaz;

z1=v{**1**}; z2=v{**2**}; z3=z2/z1; z4=v{**3**};

z5=v{**4**}; z6=z4/z3; z7=v{**5**}; z8=v{**6**};

z9=v{**7**}; z10=v{**8**}; z11=v{**9**}; z12=v{**10**};

z13=v{**11**}; z14=v{**12**}; z15=v{**13**}; z16=v{**14**};

z17=v{**15**}; z18=v{**8**}-v{**6**}; z19=v{**9**}-v{**6**}; z20=v{**11**}-v{**6**};

z21=v{**9**}-v{**8**}; z22=v{**11**}-v{**8**}; z23=v{**9**}-v{**7**}; z24=v{**12**}-v{**7**};

z25=v{**13**}-v{**7**}; z26=v{**14**}-v{**7**}; z27=v{**12**}-v{**9**}; z28=v{**13**}-v{**9**};

z29=v{**14**}-v{**9**}; z30=v{**14**}-v{**12**};z31=v{**15**}-v{**12**}; z32=v{**14**}-v{**13**};

z33=v{**15**}-v{**13**};z34=v{**15**}-v{**14**}; z35=v{**16**}; z36=v{**17**};

z37=v{**2**}-v{**7**}; z38=v{**2**}-v{**12**}; z39=v{**2**}-v{**14**}; z40=z25/z2;

z41=z26/z2; z42=z27/z2; z43=z28/z2; z44=z29/z2;

z45=z30/z2; z46=z32/z2; z47=z34/z2; z48=z18;

z49=z19; z50=z20;

keep sampleID location year date floyno tagcode age length sublocation comment z1-z50;

**run**;

Code-2

%let loc = BR; /\*location of fry; loc can be AL, BR, or HS\*/

**data** d1; /\*get rid of useless variables.\*/

set x.Al\_br\_hs\_faz (drop = tagcode sublocation comment date floyno length z12-z17 z20 z22 z24-z36 z38-z47);

**data** x.&loc; /\*analyze Hugh Smith Lake data\*/

set d1;

if location = "&loc";

**data** x.knowns; /\*generate subdata set, leave year 2005 data for test\*/

set x.&loc;

if year = **2005** then delete;

**data** x.unknowns; /\*2005 data to be classfied\*/

set x.&loc;

if year = **2005**;

**run**;

Code-3

/\*stepwise discriminant to select variables that are used for discriminant analysis \*/

**proc** **stepdisc** data=x.knowns;

class age;

var z1-z11 z18 z19 z21 z23 z37 z48-z50;

**run**;

Code-4

/\*use this calibration information to classify observations in testdata\*/

**proc** **discrim** data=x.knowns testdata=x.unknowns testlist;

class age;

var z3 z6 z8 z21 z23 z37 z50;

title 'linear discriminant analysis';

**run**;

Appendix B. Tables of results provided by Xinxian Zhang.

**AL: 1994-1998 for 2000**

Number of Observations and Percent Classified into age

From age 1 2 Total

2 13 31 44

29.55 70.45 100.00

Total 13 31 44

29.55 70.45 100.00

Error Count Estimates for age

2 Total

Rate 0.2955 0.2955

Priors 0.5000 0.5000

**BR: 1998-2004 for 2005**

Number of Observations and Percent Classified into age

From age 1 2 Total

1 188 11 199

94.47 5.53 100.00

2 4 106 110

3.64 96.36 100.00

Total 192 117 309

62.14 37.86 100.00

**HS: 1998-2004 for 2005**

Error Count Estimates for age

1 2 Total

Rate 0.0553 0.0364 0.0458

Priors 0.5000 0.5000

Number of Observations and Percent Classified into age

From age 1 2 Total

1 57 2 59

96.61 3.39 100.00

2 4 8 12

33.33 66.67 100.00

Total 61 10 71

85.92 14.08 100.00

Error Count Estimates for age

1 2 Total

Rate 0.0339 0.3333 0.1836

Priors 0.5000 0.5000

**All data: 1994-2004 for 2005**

Number of Observations and Percent Classified into age

From age 1 2 Total

1 224 34 258

86.82 13.18 100.00

2 19 103 122

15.57 84.43 100.00

Total 243 137 380

63.95 36.05 100.00

Error Count Estimates for age

1 2 Total

Rate 0.1318 0.1557 0.1438

Priors 0.5000 0.5000