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VARIATION IN SALMON SCALE CHARACTERS DUE TO BODY AREA SAMPLED

by

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INTRODUCTION

It has been known since at least the early 1900's that a great deal of variation exists between the scales of individual salmonids in terms of size and circuli number within various life history zones (Hutton 1910; Esdaile 1912; Huntsman 1918; Kelez 1932; LaLanne 1961; Scarnecchia 1979). An extensive analysis of the variation in the number of freshwater circuli occurring on scales over the body of juvenile and adult Fraser River sockeye salmon was undertaken by Clutter and Whitesel (1956). They showed that the scales of adult sockeye having the greatest number of freshwater circuli occurred between the dorsal and adipose fins and just above and below the lateral line. This area of the body coincides with the body area of juvenile sockeye where scales first begin to develop; therefore, these scales should have the longest record of an individual fish's life history (Clutter and Whitesel 1956; Koo 1962).

Stock separation analysis using scale pattern recognition assumes that differences in each stock's scale measurements, such as the size and number of circuli in life history zones, are the result of stock specific growth patterns, due to differences in each stock's genetic, geographic and environmental influences. When the variation in body areas sampled is great, the variation in scale measurements becomes large and the results of scale pattern analyses can be affected. The result could be increased variation in measurements that can decrease stock separability, or introduction of bias that can obscure stock differences in scale measurements or suggest differences that do not actually exist.

Recognizing this problem, the International North Pacific Fisheries Commission (INPFC) recommended that scales for stock separation analyses be collected from a restricted area 1-4 scale rows above the lateral line, between the posterior insertion of the dorsal fin and a line drawn mid-way between the posterior insertion of the dorsal fin and the anterior insertion of the adipose fin (INPFC 1958; Fig. 1). Soviet scientists, as a whole, have not adopted the INPFC recommendations for scale sampling. Soviet literature indicates that there are at least two different body areas from which scales are collected from salmon. Krogius (1958) performed a stock separation analysis of Kamchatkan sockeye stocks and collected scales from an area just above the lateral line and anterior to the dorsal fin. Pravdin (1966) recommended that scales be collected from under the dorsal fin over a rather wide area both above and below the lateral line (Fig. 2). A number of recent Soviet articles on scale pattern analysis have cited Pravdin's methodology (Bugayev 1978, 1981, 1984; Kovtun 1981), and on a recent joint U.S.-U.S.S.R. high seas salmon tagging cruise Soviet biologists took scrape samples of scales from this general area above the lateral line (Harris 1983).

This paper addresses the effect of body location on chinook, chum and sockeye salmon scale characters and morphology, and consists of three separate analyses. The first investigates the variation in chinook salmon scale characters due to body area sampled and whether differences due to body area are consistent across stocks, and also explores the effects of body area differences on stock separation studies. The second analysis compares Fisheries Research Institute (FRI) personnel's identification of non-preferred chinook scales collected by Japan Fisheries Agency (JFA) scientists with the actual body area codes recorded at the time of scale collection to determine how accurately non-preferred scales were identified using a set of visual criteria developed at FRI. The final analysis compares scale character means of chum and sockeye salmon scales collected by Soviet and U.S. biologists during a joint U.S.-U.S.S.R. research cruise to determine whether significant differences in scale measurements occurred between scales collected from the same fish by the two agencies.

CHINOOK SCALE CHARACTER VARIATION ACROSS BODY ZONES

This section is a summary of a more detailed report by Knudsen (1985), and for the sake of brevity the results of that report are often simply stated here without the accompanying tables or figures.

Juvenile Body Zone Differences

Scales were collected from five body zones (Fig. 3) of 41 juvenile fall chinook salmon ranging from 36-60 mm fork length. Fish were sampled from the University of Washington (UW) hatchery in early March 1984 (Fig. 4). Body Zone 1 corresponds to the area sampled by Krogius (1958), while Body Zone 2 corresponds to the lower portion of the upper body area described in Pravdin (1966). Body Zones 1, 2, 3 and 5 are located 1-3 scale rows above the lateral line. Body Zone 3 is located in the center of the INPFC preferred area, about 2-4 scale rows anterior to the INPFC preferred scale. Body Zone 4 is directly dorsal to Body Zone 3, 9-11 scale rows above the lateral line. Body Zone 5 is directly ventral to the anterior insertion of the adipose fin.

Measurements of total scale size and circuli number were made on each non-regenerated scale using a 10-mm disc micrometer mounted in the eyepiece of a binocular dissecting scope at 30X. Measurements were made to the nearest 0.1 mm, defined as an ocular unit, and circuli were counted along the measurement axis (Fig. 5). Scale size was measured from the inner edge of the first circulus to the outer edge of the scale.

The null hypothesis that there is no difference between body zone means of scale size and circuli counts was tested with two 1-way fixed-effects analyses of variance (ANOVA; Zar 1984). If a significant body zone effect was found ($\alpha = 0.05$), I used a Tukey multiple-comparisons test to determine which body zones were significantly different (Zar 1984).

The mean scale size and total number of circuli by body zone are given in Table 1, along with the results of the 1-way ANOVAs and Tukey tests. Both 1-way ANOVAs indicated significant body zone effects ($P < 0.01$). Body Zone 4 had the lowest mean scale size and circuli number and was significantly different from Body Zones 2, 3 and 5 in both Tukey tests. Body Zone 1 had the fourth highest average scale size and number of circuli and was significantly different from Body Zones 2, 3 and 5 for total circuli number. Body Zones 2, 3 and 5 were not significantly different from each other for either scale charcter and Body Zone 3 had the highest mean scale size and total circuli number.

If the assumption is true that once scales appear, they develop at about the same rate over the five body zones in fry less than 61 mm fork length, then some conclusions about initial scale development can be made. Since Body Zones 2, 3 and 5 have the highest mean scale size and circuli counts, they are the first body zones to develop scales. Body Zone 3 is the area where initial scale development begins since it has the highest mean size and total circuli count. Scale development then begins in Body Zones 2 and 5, perhaps almost simultaneously. Body Zone 1 follows, and Body Zone 4 is the last of the five body zones to develop scales. This pattern of initial scale development is in complete agreement with that described by Clutter and Whitesel (1956) and Koo (1962) for young sockeye. The ranking of the five body zones by their mean scale size and circulus counts is in agreement with the results of Bilton (1984) for similar body zones on yearling sockeye, as well. Therefore, it appears that initial scale development in chinook fry follows the same general pattern as in sockeye, beginning first between the dorsal and adipose fins along the lateral line and proceeding radially over the body from there. Initial scale development is most rapid along the lateral line and proceeds less rapidly in a dorsal and ventral direction (Clutter and Whitesel 1956; Bilton 1984).

Adult Body Zone Differences

Fall chinook scale samples were collected from carcasses of mature fish at the UW, Samish and Cowlitz hatcheries in October 1982 (Fig. 4). Scales were collected from 100 fish each at the Samish and Cowlitz facilities and from 106 fish at the UW hatchery. Spring chinook scales were collected from 66 adult carcasses at the Cowlitz hatchery in June and July 1983. Scales were removed from each of five body zones (Fig. 3) and mounted on numbered gummed cards. Scales were checked for regeneration as they were collected using a binocular dissecting scope. Acetate plastic impressions were made following the procedures of Koo (1962). Since many scales exhibited heavy resorbtion, the ocean ages of many fish could not be determined with the high degree of accuracy felt necessary to include ocean age as a factor in the statistical analyses below. Therefore, samples within stocks have been pooled over ocean ages even though it is known that brood year differences in scale measurements can be significant in chinook (Myers et al. 1984). Samples were pooled over sex, as well, but this was not felt to be a significant problem (Myers et al. 1984).

All non-regenerated scales were measured using a micro-computer based back-projected digitizing system specially designed for scale analysis. Scales were magnified at 104X and circulus counts and distance measurements, to the nearest 0.001 inch, were made along a set measurement axis, perpendicular to the line bisecting the posterior and anterior fields of the scale and running through the center of the focus (Fig. 6).

Scale measurements were made on each fall chinook scale of the distance between individual circuli (following the criteria of Tanaka et al. 1969) and the number of circuli in each of three life history zones (Fig. 6), defined as follows:

Zone 1 - Freshwater Zone (from the center of the focus to the outer edge of the last circulus in the outmigration check),

Zone 2 - First Ocean Zone (from the end of Zone 1 to the outer edge of the last circulus in the first annulus), and

Zone 3 - Second Ocean Zone (from the end of Zone 2 to the outer edge of the last circulus in the second annulus).

The outmigration check at the end of Zone 1 was defined as the last check associated with the relatively closely spaced circuli of freshwater growth. Twenty-five non-ratio and 21 homologous ratio scale characters were calculated from the raw scale measurement data (Table 2).

Cowlitz spring chinook scale samples were measured with the same equipment and following the same procedures used in processing the fall chinook samples, except that the life history zones were redefined. Two life history zones were measured on each scale (Fig. 7) and are defined as follows:

Zone 1 - Freshwater Zone (from the center of the focus to the outer edge of the last circulus in the first annulus) and

Zone 2 - First Ocean Zone (from the end of Zone 1 to the outer edge of the last circulus in the second annulus).

Zone 2 was made up primarily of ocean growth, but some freshwater plus growth did occur on some scales. A total of 39 scale characters was constructed from the raw data (Table 3).

Scale characters of both the fall and spring chinook stocks are grouped into 10 categories of similar types of scale characters to facilitate discussion of trends in body zones across and within stocks (Table 4).

Only those fish having a non-regenerated scale in each of the five body zones were used in the ANOVAs below. There were 47 UW, 11 Samish and 22 Cowlitz fall chinook and 28 Cowlitz spring chinook possessing a measurable scale in all five body zones, giving a grand total of 400 fall chinook scales and 140 spring chinook scales used in the ANOVAs.

The Kolmogorov-Smirnov goodness-of-fit test was used to compare the distribution of each Body Zone 3 scale character from each of the four stocks to a normal distribution having the same mean and standard deviation. Out of 177 stock/character combinations tested only 12 (7%) were distributed significantly different than normal ($\alpha = 0.05$), indicating that the assumption of normality is reasonable and the use of ANOVA is justified.

<u>2-way ANOVA Results</u>

A 2-way fixed-effects ANOVA (3 stocks X 5 body zones) with proportional replication in rows was performed on each of the 46 fall chinook scale characters (Zar 1984). Scale characters C1-C25 and C32-C46 showed significant body zone effects and the null hypothesis of equal means across body zones was rejected ($\alpha = 0.10$). Ratio scale characters C26-C31, homologous to C1, C2, C4 and C6-C8, respectively, were the only characters showing no significant body zone effects. In 41 of the 46 scale characters stock effects were significant. In no case was a scale character found to have a significant stock/body zone interaction effect and in over 3/4 of the characters the F-probabilities for interaction effects were equal to or greater than 0.80.

1-way ANOVAs and Tukey Tests

For each fall chinook scale character producing a significant body zone effect in the 2-way ANOVA, a 1-way fixed-effects ANOVA (body zones) was performed for each combination of stock and scale character. The same 1-way ANOVA was performed on all 39 spring chinook scale characters, as well. The within stock variances of the five body zones for each scale character were tested for equality of variances using Bartlett's test. Out of 177 Bartlett's tests only 8 (5%) resulted in significant differences ($\alpha = 0.05$), indicating that the assumption of homoscedasticity across body zones is justified.

The 1-way ANOVAs for fall chinook resulted in significant body zone effects ($\alpha = 0.05$) across all three stocks in 15 scale characters: C3, C9, C10, C13, C14, C16, C17, C21, C24, C32, C33, and C35-C38. These 15 scale characters are the most consistently sensitive to body zone effects across stocks. In addition, scale characters C5, C6, C8, C12, C41, C42 and C46 had significant body zone effects at the $\alpha = 0.10$ level across all three stocks indicating consistent, though less sensitive, body zone effects across stocks.

Results of the 1-way ANOVAs (body zones) for the Cowlitz spring chinook showed that scale characters C1-C14, C17, C21, C25-C31, C33, and C35-C39 had significant body zone effects at the $\alpha = 0.05$ level.

Appendix A gives the results of the 82 Tukey multiple-comparisons tests of fall chinook scale character means within stocks. Appendix A also gives the scale character means for each body zone ranked from lowest to highest. In cases where the 1-way ANOVA for a character was not significant, a Tukey test was not performed, although the body zone means for the character are listed and ranked. Also, the means for characters C26-C31 are listed and ranked for comparison even though no 1-way ANOVA or Tukey tests were performed.

When the results of the fall chinook Tukey pairwise comparisons of the five body zones are summed over all three stocks (Table 5), it is clear that Body Zones 3 and 2 and Body Zones 3 and 5 are the most similar; only one comparison employing these pairs resulted in a significant difference. The next most similar pair is Body Zones 1 and 2 followed by Body Zones 2 and 5, and 3 and 4. The most dissimilar pair was Body Zones 1 and 5, with 52 significant differences between them. There is a direct relationship between the distance separating a pair of body zones on the fish's body and the degree of similarity between the pair's scale character means. Generally, as the distance between a pair of body zones increases, the number of significant differences detected between the pair's scale character means also increases.

The results of the pairwise comparisons of fall chinook body zones by scale character categories (see Table 4 for category definitions) are also given in Table 5. Scale character categories LDF and CCR, ratios of the size and circulus number in life history zones, were the only categories in which no significant differences were found. For categories MT and MTR, 8 and 9%, respectively, of the pairwise comparisons of body zones resulted in significant differences. The most sensitive scale character category to body zone differences was ACSR, in which 32% of the body zone comparisons were significant.

From Table 5 it can be seen that Body Zones 1 and 3 are significantly different in a number of scale character categories, however, categories LD, ACS, FWT, MT, LDR and CCR exhibited no significant difference between this body zone pair. Thus, if it were known that scales had been collected from Body Zones 1 and 3 in a sample to be classified to region of origin using Body Zone 3 scales as standards, one would avoid using scale characters from categories CC, ACSR, FWTR and MTR in order to prevent the introduction of serious bias due to body area differences. Any pair of body zones can be examined in this way to determine which categories of scale characters are likely to introduce serious bias problems.

The Cowlitz spring chinook Tukey test results are given in Appendix B and summarized in Table 6. Body Zones 2 and 3 were the only pair having no significant differences. Body Zones 1 and 2 were the next most similar followed by Body Zones 2 and 4 and 3 and 5. Again, as in the fall chinook, Body Zones 1 and 5 were the most dissimilar pair. These results are very similar to the fall chinook results, the major difference being the greater number of significant differences detected between Body Zones 3 and 5 in the spring chinook. These differences occurred in characters dealing with freshwater triplets primarily (7 out of 8 cases). As in the fall chinook, the incidence of significant differences between character means generally increased with distance between body zones. Body Zone 4 was consistently different than the other four zones located along the lateral line, but was most similar to Body Zone 3, immediately ventral to it.

Once again, categories LDR and CCR were the only ones in which no significant differences were detected between body zones (Table 6). Spring chinook categories MT and MTR had 1 and 9%, respectively, of the total possible body zone comparisons result in significant differences. For the other six categories, 30 to 58% of the body zone comparisons resulted in significant differences.

Across-Stock Trends in Body Zone Rankings

Large Distance Characters (LD)

Body Zones 1 and 4 had the lowest means in both the fall and spring chinook for these characters. Body Zone 4 was most often lowest. Body Zone 3 had the highest mean for characters describing pre-smoltification growth and Body Zone 5 had the highest mean for post-smolt life history zones and total scale size and circuli number in all four stocks.

Circulus Count Characters (CC)

In general, for Body Zones 1, 2, 3 and 5, there was an anterior-to-posterior increase in circuli number across all four stocks. Body Zone 4 means were generally ranked fourth or third highest.

Average Circulus Spacing Characters (ACS)

Body Zone 4 had the lowest mean in all but one case in all four stocks. Body Zone 5 was often ranked fourth highest or nearly equal to the fourth highest mean across all stocks. Body Zones 1, 2 and 3 were ranked highest, Body Zones 1 and 2 most often being the highest.

Freshwater Triplet Characters (FWT)

Body Zones 4 and 5 generally had the lowest means while Body Zones 1 and 2 had the highest across all four stocks. The overall trend was an anterior-to-posterior decrease in the means of body zones located along the lateral line.

Marine Triplet Characters (MT)

The most distinct trend for these characters was that Body Zone 4 scales had the lowest mean in almost all cases. The other four body zones were very similar and no clear across stock pattern emerged in their ranking.

Large Distance Ratios (LDR)

The means of the five body zones for these characters are essentially equal in value varying by less than 3% within any of the four stocks. This was one of only two categories showing no significant body zone effects in the ANOVAs. The only consistent trend was in the characters describing pre-smolt growth (C26 for falls and C23 for springs), in which Body Zones 4 and 5 ranked fourth and fifth highest, respectively, across stocks.

Circulus Count Ratios (CCR)

There was virtually no difference between the mean values of the five body zones within each stock for these characters and each zone was as likely to be ranked highest as lowest. This group of scale characters exhibited no significant body zone effects in any of the ANOVAs.

Average Circulus Spacing Ratios (ACSR)

The pattern of body zone ranking was the same across all four stocks. Body Zones 5, 3 and 1 were always ranked fifth, fourth and first, respectively, and Body Zones 5 and 3 were often equal. Body Zones 2 and 4 ranked second and third and were often equal. Body zones located just above the lateral line demonstrated a very clear anterior-to-posterior decrease in mean value.

Freshwater Triplet Ratios (FWTR)

There was a pattern of decreasing mean value the farther posterior the body zone was located for Body Zones 1, 2, 3 and 5. Body Zone 4 often varied relative to the other body zones, ranking anywhere from fourth to second highest.

Marine Triplet Ratios (MTR)

In general, there was an anterior-to-posterior decrease in mean value for Body Zones 1, 2, 3 and 5. Body Zone 4 means ranged from the lowest to highest in the fall stocks and did not follow any clear pattern, but ranked second highest in seven of eight spring chinook characters.

It is clear from the results above that the relative rankings of the five body zones are very similar across all four stocks for the 10 scale character categories. This is also reflected in the lack of any significant stock/body zone interaction effects in the 2-way ANOVAs. The scales from these five body zones are developing in a very similar and consistent manner across the four stocks during comparable life history phases. This is likely to be the result of similar across-stock body form changes that occur during these life history stages.

Linear Discriminant Function Analysis of Fall Chinook Stocks

One standard for each fall chinook stock was constructed from Body Zone 3 (INPFC Area A) scales of fish that were excluded from the previous ANOVAs due to regenerated or missing scales in one or more of the other four body zones. The samples to be classified (unknowns) were made up of the scales used in the ANOVAs above arranged into 15 stock/body-zone groups. Individual scales from the 15 groups were classified to one of the three standard stocks using the BMDP7M linear discriminant function (LDF) program (Brown et al. 1983).

The LDF technique was chosen to conform to current and past chinook salmon scale pattern analyses at FRI (Knudsen et al. 1983; Myers et al. 1984; Myers and Rogers 1985). A forward stepping technique was used to enter variables and a jackknife procedure was used to determine the most nearly unbiased estimate of the classification accuracies for the standards. Classification accuracies for the standards were computed for each set of characters entered into an LDF, and the LDF having the highest overall classification accuracy was chosen to classify the 15 stock/body-zone groups.

Three separate classifications were performed using the same set of standards and "unknowns" but different sets of scale characters. The first classification selected from the 25 non-ratio characters (C1-C25), the second selected from the 21 homologous ratio scale characters (C26-C46), and the third selected from the "best scale characters", that is, those which demonstrated no significant body zone effects (C26-C31). Differences between the results of the three analyses are due primarily to the different character sets used and from these results it can be determined which set of characters selected is most accurate in separating the standards and/or gives the highest classification accuracies for the "unknowns." The classification accuracy and direction of misclassifications for each stock/body-zone group provided an indication of how that stock would have classified had it been represented by scales from only that body zone.

Non-ratio Scale Character LDF

The classification matrix for the non-ratio LDF is given in Table 7 along with the results of classifying the 15 stock/body-zone groups and the scale characters used in the LDF. Overall classification accuracy for the standards was 88%. In the unknown groups Body Zone 4 showed the lowest overall accuracy and Body Zone 2 the highest, averaging 82% and 91%, respectively.

Misclassifications of the UW body zone groups occurred to both the Samish and Cowlitz and were similar across body zones. Misclassi-ficiations of Samish scales occurred for Body Zones 3, 4 and 5 (1 scale each) toward the Cowlitz stock. The Cowlitz body zone groups misclassified to both the UW and Samish, although individual body zones misclassified in different directions. Cowlitz Body Zones 1 and 4 misclassified exclusively to the Samish, while Body Zones 2, 3 and 5 misclassified exclusively to the UW.

Ratio Scale Character LDF

Classification accuracies for the standards and unknowns in the ratio LDF are given in Table 8 along with the scale characters entered. Overall classification accuracy for the standards was 90%, just 2% higher than the non-ratio LDF. Overall classification accuracy was highest in the unknowns for Body Zone 5 (91%) and lowest for Body Zone 4 (84%). Body Zones 1 and 4 had the lowest classification accuracies in the UW and Cowlitz. Misclassifications in the UW unknown groups were similar to those from the non-ratio LDF. Just a single scale misclassified in all of the five Samish body zone groups. Cowlitz body zone groups misclassified in much the same manner as in the non-ratio LDF. Body Zones 1 and 4 misclassified primarily to the Samish, while Body Zones 3 and 5 misclassified exclusively to the UW. Body Zone 2 scales were evenly divided between the Samish and UW.

"Best Scale Characters" LDF

The best scale character (BSC) LDF classification matrix and the scale characters chosen, in order of selection, are given in Table 9. Overall classification accuracy for the standards dropped 6-8% from the previous LDFs to 82%. However, classification accuracies for the 15 stock/body-zone groups were equal to or greater than those obtained in the non-ratio and ratio LDFs in 25 out of 30 comparisons. Body Zone 5 had the highest overall classification accuracy (94%), while Body Zone 1 had the lowest (87%).

Scales in the UW unknowns misclassified primarily to the Samish, much as in the ratio LDF. The Samish unknowns had only one misclassification from Body Zone 1 to the UW, unlike the ratio and non-ratio LDFs where a single scale from either Body Zone 3, 4 or 5 had misclassified to the Cowlitz. Cowlitz Body Zone 4 scales did not misclassify to the Samish, as in the previous two LDFs. However, scales from Body Zone 1 still misclassified to the Samish, unlike Body Zones 2, 3, 4 and 5.

The ratio and non-ratio LDFs were equally effective at separating the standard samples, differing by only 2% in overall classification accuracy. Despite the inclusion of characters C27, C28 and C29 in the ratio LDF there were still misclassifications related to body zones similar to those found in the non-ratio LDF. This appears to be related to the inclusion of C34 and C36 in the ratio LDF and C1, C4 and C6 in the non-ratio LDF. Body Zones 1 and 4 were always ranked together for C1, C4, C6, C34 and C36, and were generally the most dissimilar to Body Zone 3. Since the standards were made up of Body Zone 3 scales, this resulted in Body Zones 1 and 4 having the lowest classification accuracies and dissimilar direction of misclassification relative to Body Zones 2, 3 and 5. This was most evident in the UW and Cowlitz samples. Due to the smaller standard deviations in the Samish samples for characters C1, C4, C6, C27, C28 and C29, the dispersion of the Samish samples in multivariate space was reduced relative to the other groups in all three LDFs, resulting in much less overlap with the other two groups' dispersions. This in turn resulted in few misclassifications of Samish scales in the standards and unknowns.

The BSC LDF resulted in lower overall classification accuracies in the standards, but generally higher classification accuracies in the unknown groups. In addition, the direction of misclassification for Cowlitz Body Zone 4 scales was reversed and resembled the results for Body Zones 2, 3 and 5 more closely than in the ratio and non-ratio LDFs. However, Body Zone 1 scales from all three stocks still appeared to be effected by body zone differences to some extent.

JFA-FRI BODY ZONE CODE COMPARISONS

In 1985 JFA provided codes of the areas of the fish's body from which chinook salmon scales were collected aboard Japanese high seas research and mothership vessels during 1980. The original 1980 scale samples had been provided to FRI for use as unknowns in a racial analysis by Myers et al. (1984) and were classified to region of origin. During the course of Myers' et al. analysis certain high seas scale samples were eliminated. The rejected scales were suspected of having been collected from non-preferred body areas due to their unusual morphology and circulus patterns and therefore were not considered to be representative samples. Using the 1980 body-area codes provided by JFA it was possible to compare the codes assigned by both agencies and calculate the percent agreement.

JFA used the INPFC body-area codes when collecting scales (Fig. 1). However, it should be noted that JFA expressed some doubt about the accuracy or consistency of the codes recorded on various vessels. FRI personnel developed visual criteria based on chinook scales taken from known body areas relatively far from the INPFC preferred area in order to identify obviously non-preferred scales. Non-preferred scales were characterized by being smaller than preferred scales, laterally compressed or oddly shaped, with non-circular foci often surrounded by greater than 12 complete unbroken circuli, and having numerous circuli extending into the posterior field, particularly at the outer edge of the scale.

FRI personnel coded scales having some or all of these characters as non-preferred type scales. Scales having none of these characteristics were coded as preferred scales. During the course of examining scales taken from INPFC Areas A and B it was found that there were no visual criteria with which one could distinguish between them, and so JFA codes A and B were combined into a single "preferred" type scale category. Since there are no significant differences when comparing scales from INPFC area A to area B in terms of scale size and circuli counts (see Chinook Scale Character Variation Across Body Zones section above) this procedure was considered acceptable. Comparisons were then possible between JFA and FRI preferred/non-preferred scale types.

The scales collected from two mothership and two research vessels in 1980 were selected for use in this analysis due to their relatively large sample sizes and variety of scale codes used. The body-area codes made by each agency for each individual fish were compared and the number of scales in which there was agreement and disagreement was calculated for each vessel and for all four vessels combined (Table 10). Overall agreement in scale code determinations ranged from 84 to 92% and averaged 89% across vessels.

A chi-square test was used to determine whether scale code determinations of JFA and FRI pooled over vessels were independent (Table 11). The resulting chi-square statistic was highly significant ($P \ll 0.001$) due to the much higher number of observed agreements and lower number of observed disagreements than would be expected if the two agencies' determinations were independent. The greatest number of disagreements occurred in cases where JFA coded a scale as preferred and FRI coded the same scale as non-preferred (100 out of 119 total disagreements). Some of these disagreements could be due to errors in coding by JFA.

The visual criteria used by FRI personnel were effective in identifying non-preferred (INPFC Area C) type scales as indicated by the high degree of agreement between the two agencies' codes. For this reason we conclude that bias due to scale quality in the chinook high seas samples used in estimating mixing proportions in Myers et al. (1984) is not a serious problem.

PAIRED U.S.-U.S.S.R. CHUM AND SOCKEYE SCALE CHARACTER COMPARISONS

Soviet and FRI biologists collected sockeye and chum scale samples from the same individual fish on a joint U.S.-U.S.S.R. high seas salmon cruise in 1983 (Harris 1983). The FRI biologist collected scale samples from about one to six scale rows above or rarely below the lateral line and within the anterior and posterior limits of INPFC Area A on the right and/or left side of each fish. When no scales were available from this area no scale sample was taken. Soviet biologists collected scrape scale samples from a relatively large area of the fish's body, between the anterior and posterior insertions of the dorsal fin and from the lateral line to up to 2/3 of the way from the lateral line to the dorsal fin. After the cruise Soviet personnel randomly subsampled 1-3 scales from each scrape sample. These subsamples made up the U.S.S.R. scale samples in the analyses below. Paired scale samples were available from a total of 49 age 2.1 and 2.2 sockeye, 15 age 1.1 and 1.2 sockeye, and 79 age 0.2 and 0.3 chum salmon .

An individual scale was measured from each agency's sample at 50X using a microcomputer based digitizer. Figure 8 shows the measurement axis and life history zones measured on chum salmon scales. Definitions of the chum scale characters are given in Table 12. Figure 9 shows the life history zones measured on freshwater age 1. and 2. sockeye scales, and Table 13 gives definitions of these scale characters. Scale growth occurring at the outer edge of the scale after the last annulus was called "summer growth".

Both the chum and sockeye samples contained various freshwater and ocean age classes. Chum, freshwater age 1. sockeye and freshwater age 2. sockeye were each analyzed separately. Within each of these three groups scale measurements were pooled over ocean ages when all subjects possessed common life history zones. Otherwise each age class within a group was analyzed separately. A two-tailed paired sample t-test ($\alpha = 0.05$) was made on each species/age/scale character combination to determine if the difference between the U.S. and U.S.S.R. paired samples was significantly different than zero (Zar 1984).

Chum Scale Character Comparisons

In 94% of the paired sample t-tests U.S. samples were greater in value on average than U.S.S.R. samples, and in 76% of those tests the difference was significant (Table 14). The U.S.S.R. samples were greater in value on average than the U.S. samples for scale character C03 in age 0.3 chum, but the difference was not significant. Summer growth (C03 and S03 in age 0.2 chum and C04 and S04 in age 0.3 chum) was much greater in the U.S. samples, and accounted for 86% and 38% of the difference in total circuli number and 57% and 22% of the difference in total scale size in age 0.2 and 0.3 chum, respectively. The U.S. samples averaged 1.1 to 1.4 more total circuli and were 0.22 to 0.29 inches (at 50X) larger in total scale size than the U.S.S.R. samples.

Age 1. Sockeye

In all but two tests the U.S. samples were greater in value than the U.S.S.R. samples on average, and in 29% of these tests the difference was significant (Table 15). Summer growth was a major contributor to the difference in total scale size and circuli number. Summer growth in age 1.1 sockeye (C02 and S02) accounted for 75% of the total circuli difference and 58% of the total scale size difference, and in age 1.2 sockeye (C03 and S03) accounted for 30% of the total circuli difference and 16% of the total scale size difference. U.S. samples averaged 2.0 more total circuli and were 0.32 to 0.33 inches (at 50X) larger in total scale size than paired U.S.S.R. samples.

Age 2. Sockeye

The U.S. samples were significantly greater in value than the U.S.S.R. samples in 82% of the tests (Table 16). Only scale character CFW2 was significantly higher in the U.S.S.R. samples, averaging 0.5 more circuli than the U.S. samples. Once again summer growth contributed a large proportion of the difference in total scale size and circuli number. In the age 2.1 sockeye, summer growth (C02 and S02) accounted for 46% of the total circuli difference and 50% of the total scale size difference, while in age 2.2 sockeye summer growth (C03 and S03) accounted for 50% of the total circuli difference and 39% of the total scale size difference. U.S. samples were 0.23 to 0.27 inches (at 50X) larger in total scale size on average and had 2.0 to 2.2 more total circuli than the U.S.S.R. samples.

The overall trend in both the chum and sockeye scale characters was that the Soviet samples were smaller in total scale size and size of individual life history zones and had fewer circuli than U.S. samples, and this difference in scale character values was often statistically significant. However, the magnitude of the differences across species and ages was never greater than 2.2 circuli and 0.33 inches (at 50X) in total circuli number and scale size.

DISCUSSION

Results from the chinook scale character analysis above indicate that sampling from non-preferred body areas can create bias in many scale characters which in turn can affect the results of stock separation analyses using the LDF technique. The degree to which the results for a particular LDF are affected is determined by such factors as the particular characters entered into the LDF, the discrimination power each biased scale character contributes to the function, the direction of bias for each scale character (either increasing or decreasing the mean), the magnitude of the bias relative to the magnitude of the distances separating the standards, the size of each standard's multivariate dispersion, the ranking of each standard's mean for the biased scale characters, and finally, the particular body area from which the scales were selected.

The chinook LDF portion of the above analysis explored in part the scenario where samples from the unknowns, to be classified to region of origin, had been collected from four non-preferred body areas. However, from our analysis of JFA and FRI chinook body zone codes, it does not appear that this problem was significant in previous chinook stock separation studies at FRI, such as Myers et al. (1984). A more likely problem is that scale samples collected by Soviet biologists making up our Asian standards were collected from non-preferred body areas.

If the difference between Soviet and U.S. paired sockeye and chum scale characters analyzed above are representative of the general differences due to the two agencies' scale collection methodologies, and if the results can be extrapolated to chinook salmon scale characters, then there probably is a consistent bias tending to lower the mean scale size and circulus number in the Asian chinook samples. However, the magnitude of the difference in means is about equal to that occurring between scales collected from Body Zones 2 and 3. Previous studies of differences in freshwater scale characters due to body-area effects in sockeye salmon indicate that if Soviet scales had been collected from under the dorsal fin and no lower than 1/2 - 2/3 of the way up from the lateral line, there should be a difference of 4-6 circuli between the U.S. and Soviet first freshwater zone circuli means (Clutter and Whitesel 1956; Bilton 1984). However, differences in the mean number of circuli in the first freshwater zone between the two agencies equaled about one circulus. This difference in circuli number and the difference in mean size of the first freshwater zone are on the order of what one would expect had the Soviets collected scales from Body Zone 2 and the U.S. from Body Zone 3 (Clutter and Whitesel 1956; Bilton 1984). These two body zones were the only pair between which there were no significant differences for any scale character in the chinook scale character analysis above. It is not known, however, how representative the body area sampled by the Soviet biologists during the 1983 U.S.-U.S.S.R. cruise was relative to previous Soviet mainland scale sampling methodology and, according to one Soviet biologist, scale sampling methodology is determined by individual biologists and is not standardized across the Far Eastern U.S.S.R. (Harris, pers. comm.).

Until the actual body area or areas sampled by Soviet biologists is known, the direction, magnitude, and effect of possible biases in scale characters cannot be determined. If the body area of collection of Kamchatkan standard scale samples used by Myers et al. (1984) can be determined, then more analyses could be done to elucidate directions and magnitudes of possible biases due to the body-area problem.

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FIGURES AND TABLES

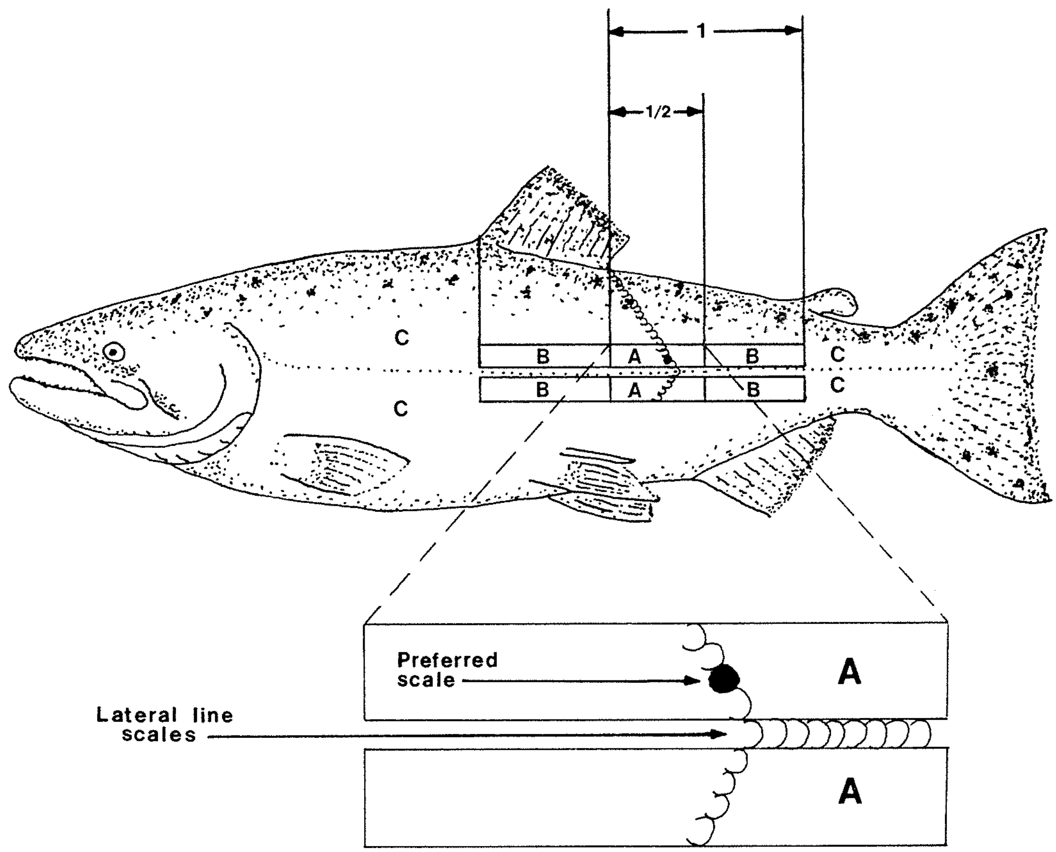

Figure 1. The area of a salmonid's body designated as the preferred area for scale collection (Area A) by the International North Pacific Fisheries Commission. Note the location of the "preferred scale" along the diagonal scale row running from the posterior insertion of the dorsal fin to the second scale row above the lateral line.

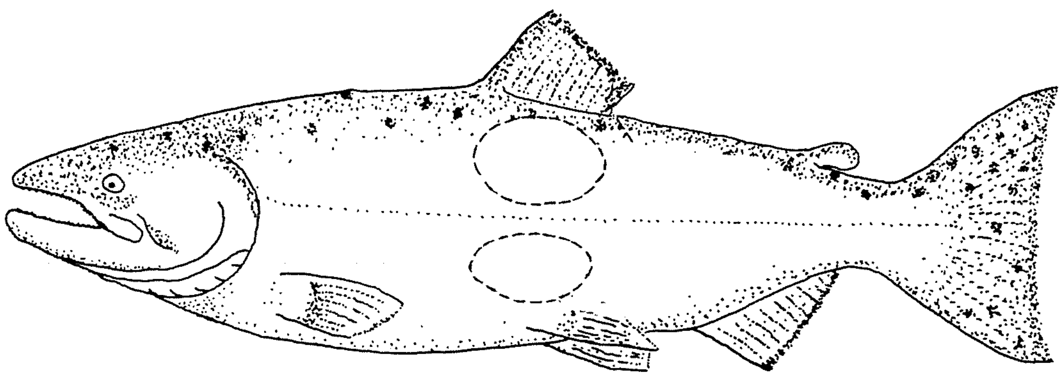

Figure 2. The area of the fish's body designated by Pravdin (1966) for scale collection enclosed by dashed circles.

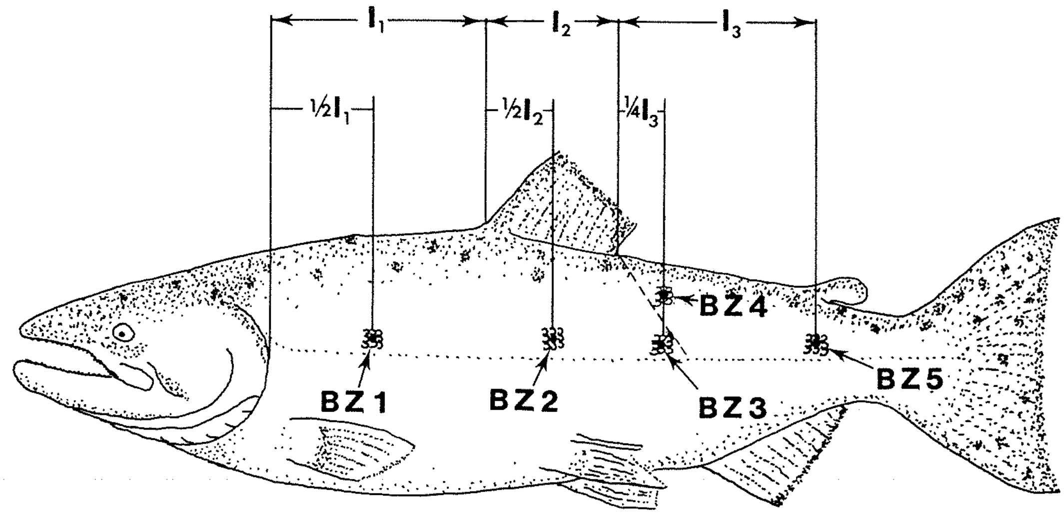

Figure 3. Location of the five body zones from which scales were collected on juvenile and adult chinook salmon. Body Zones 1, 2, 3 and 5 are 1-3 scale rows above the lateral line and Body Zone 4 is 9-11 scale rows above the lateral line. The dashed line from the posterior insertion of the dorsal fin represents the approximate position of the diagonal scale row used to locate the INPFC preffered scale.

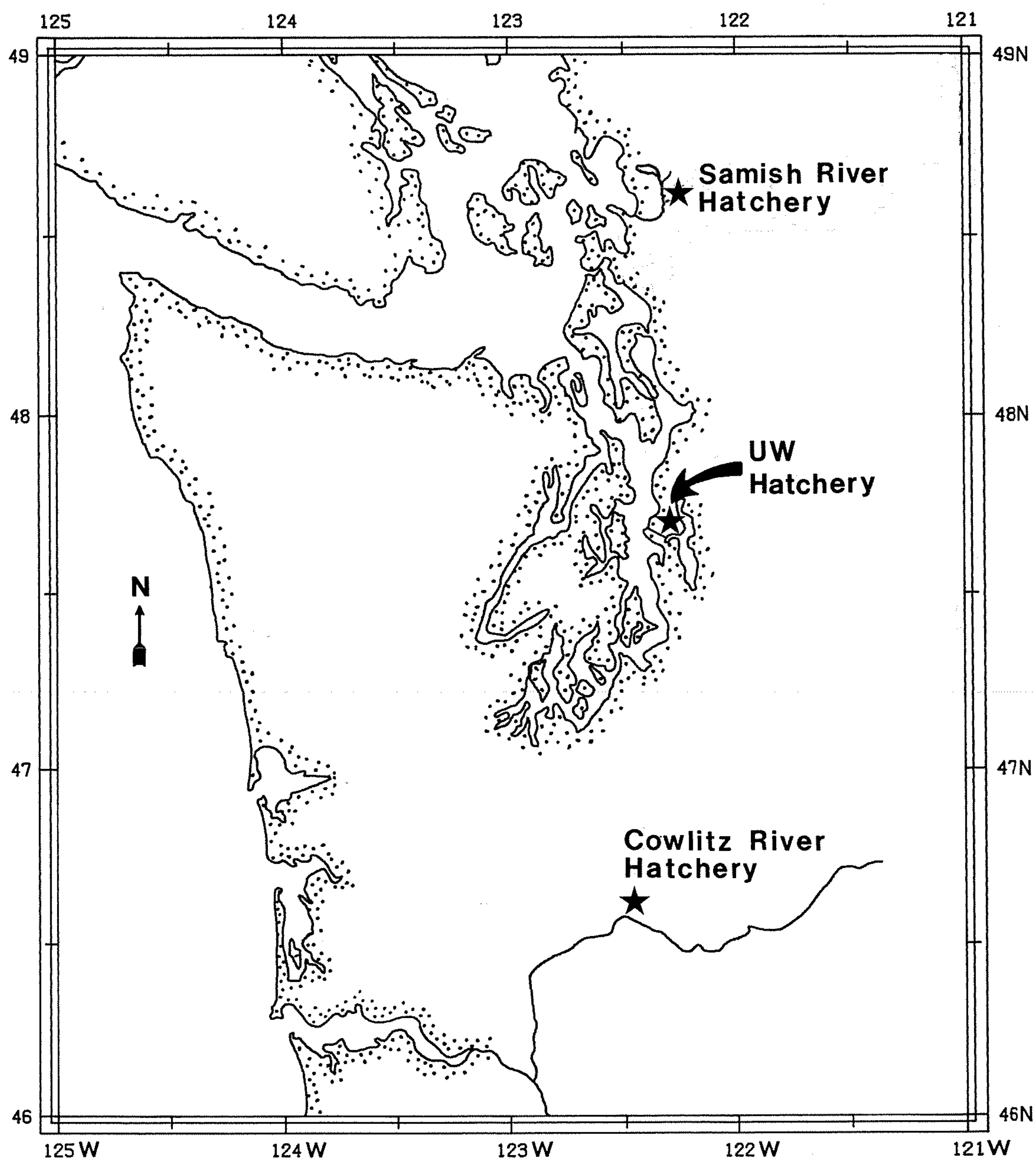

Figure 4. Map of western Washington state showing the location of the Samish River, University of Washington (UW), and Cowlitz River chinook salmon hatcheries.

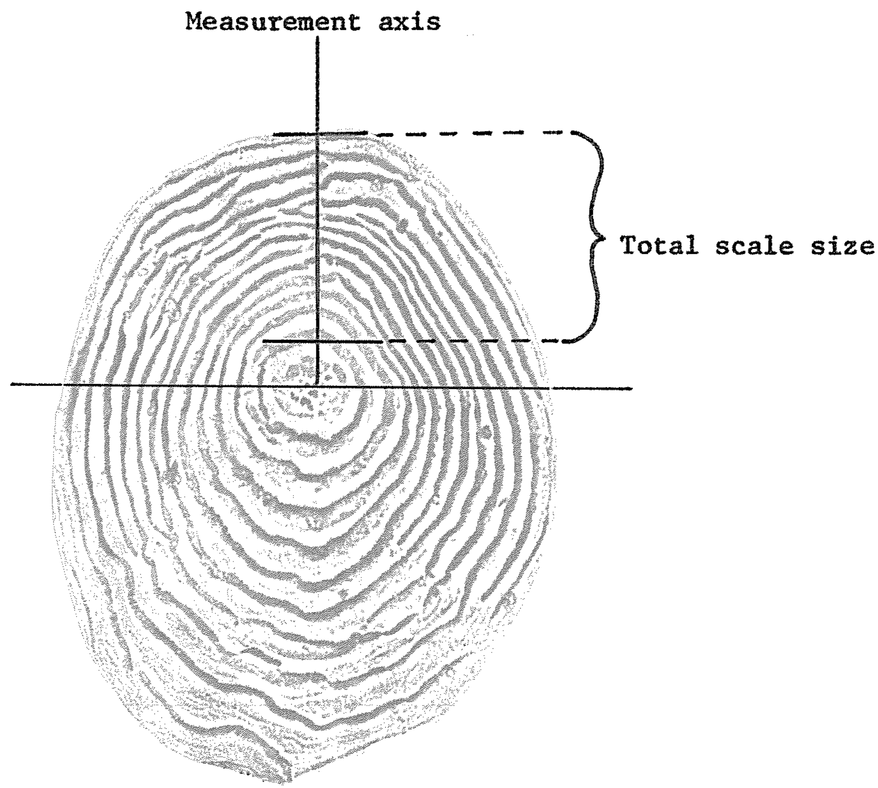

Figure 5. Juvenile UW fall chinook scale taken from an 82mm fish showing the measurement axis and the total scale size measured.

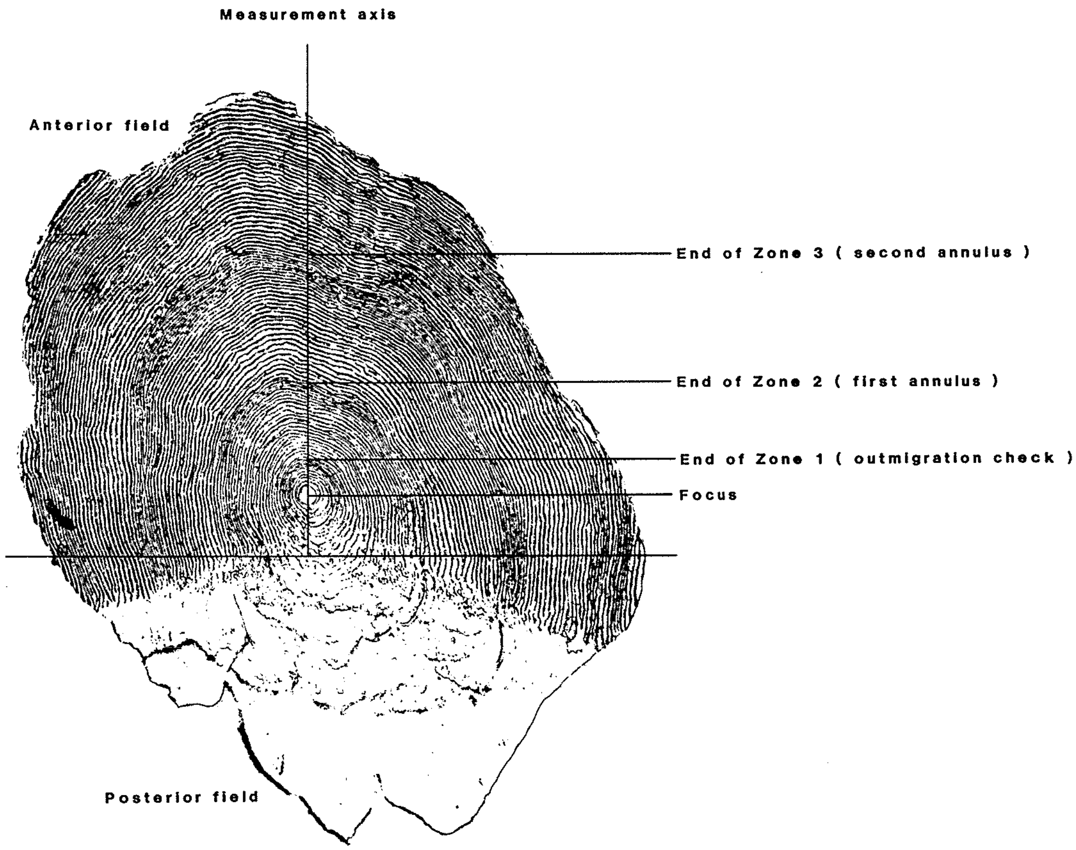

Figure 6. Adult fall chinook scale from the Samish stock showing the measurement axis and the three life history zones measured per scale.

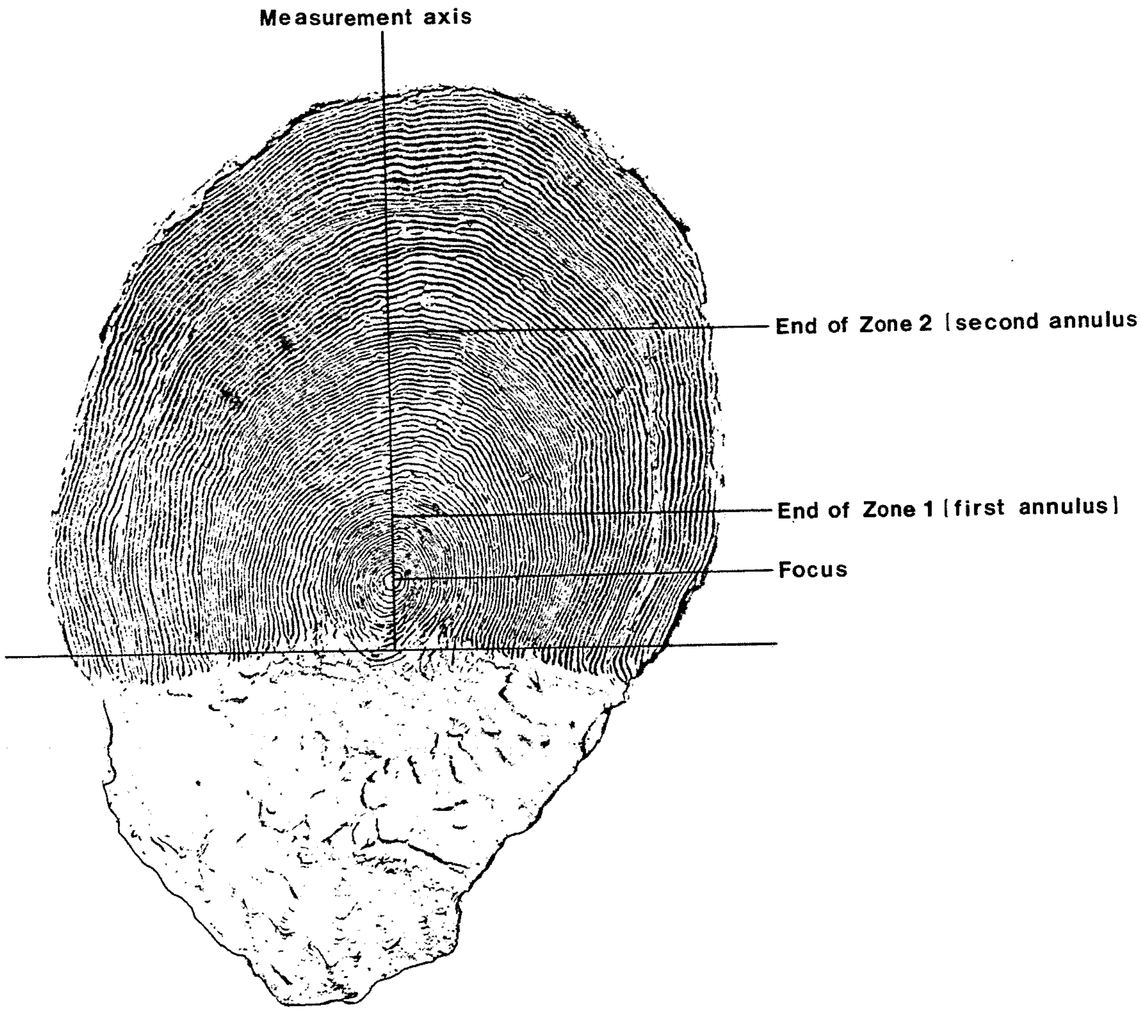

Figure 7. Spring chinook scale from the Cowlitz stock showing the measurement axis and the two life history zones measured per scale.

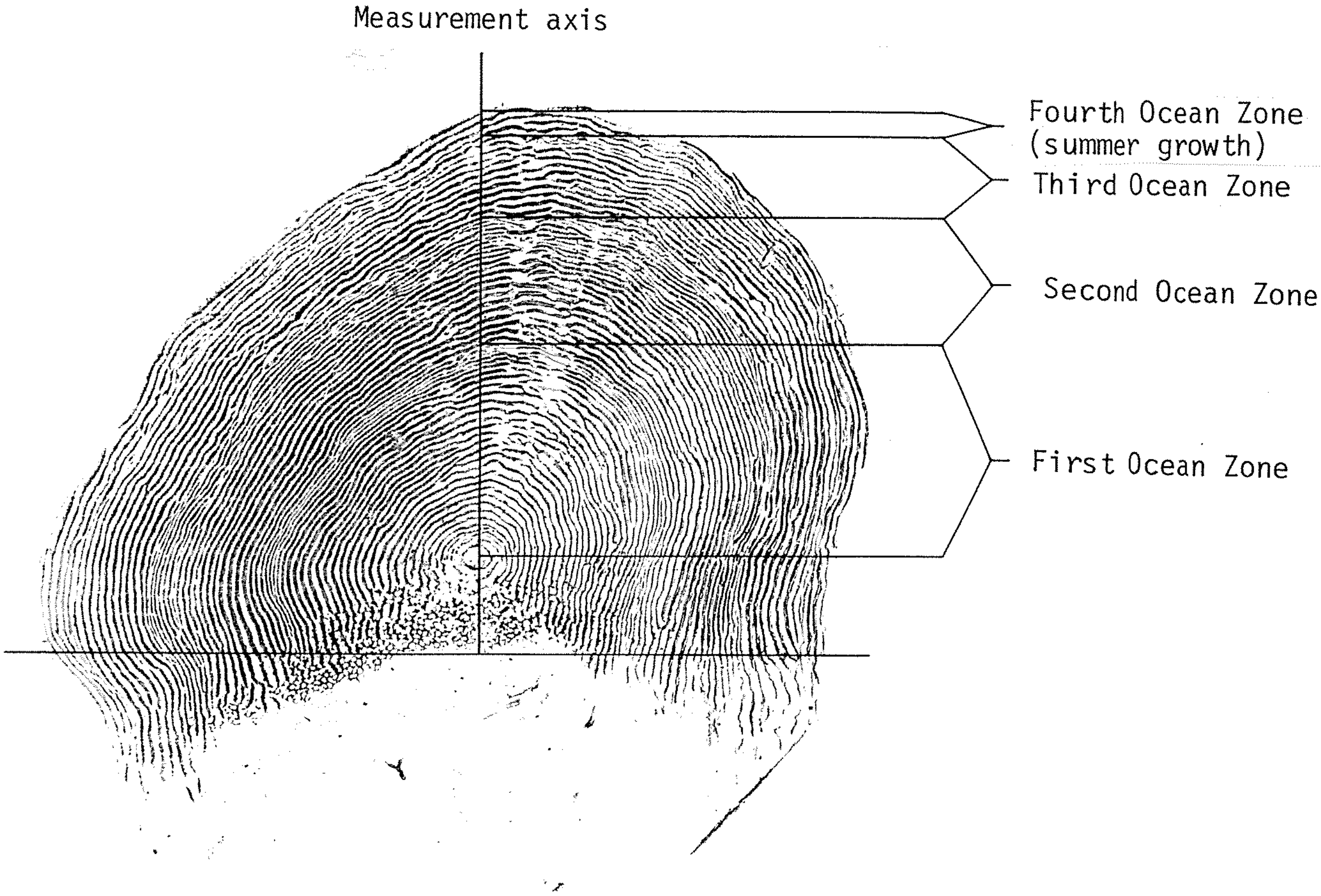

Figure 8. Age 0.3 chum salmon scale showing the life history zones measured.

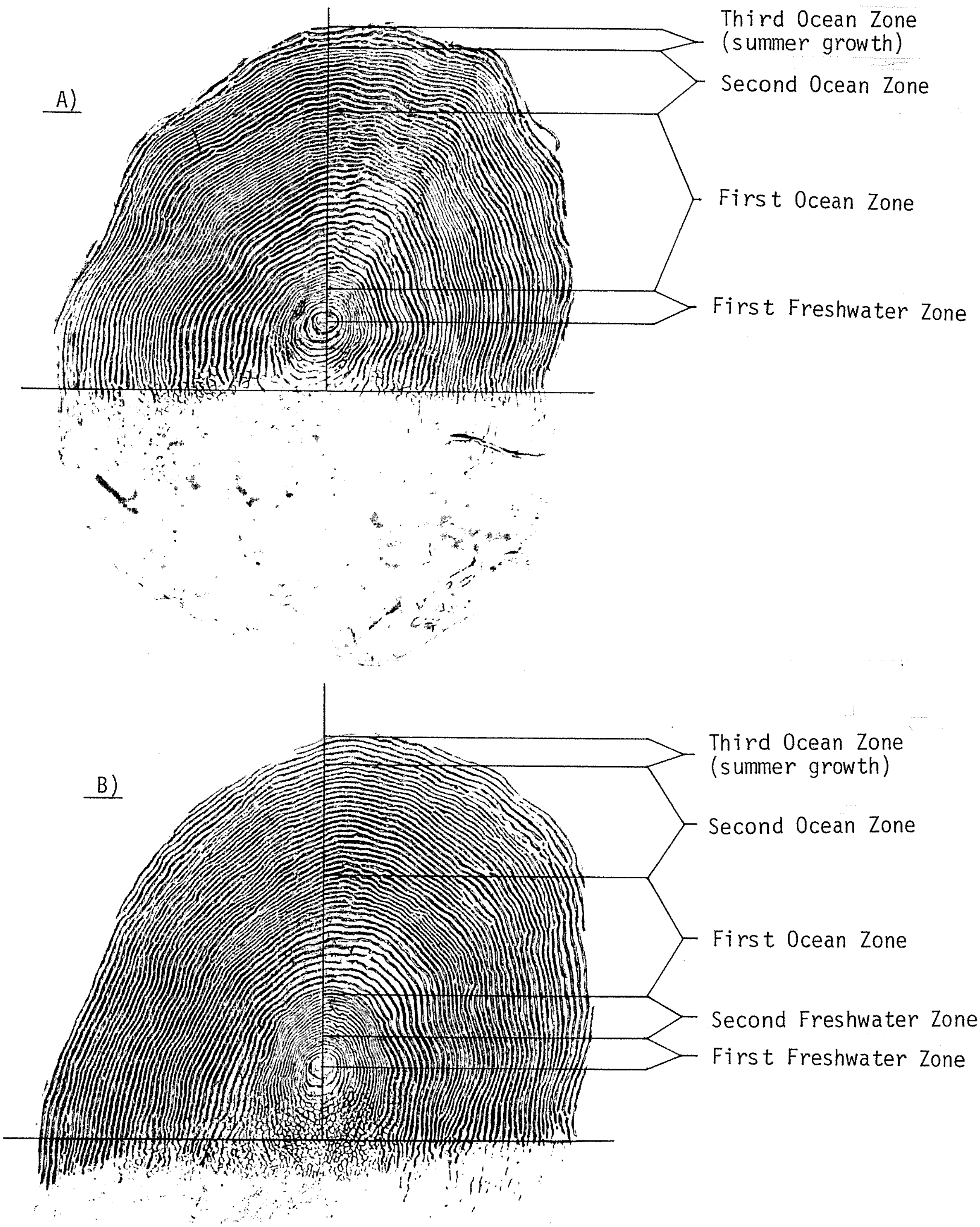

Figure 9. A) Age 1.2 sockeye salmon showing the life history zones measured. B) Age 2.2 sockeye salmon showing the life history zones measured.

Table 1. Results of the Tukey multiple comparisons tests on 41 UW chinook fry comparing means of scale size (in ocular units) and total circuli number from five body zones (BZ1-BZ5) per fish. Body zones are ranked from lowest to highest and means are located below the respective body zone.

Scale character	1-way ANOVA result	Tukey multiple-comparisons test results				
Scale size	P < .005	BZ4 5.7	BZ1 6.2	BZ5 7.1	BZ2 7.3	BZ3 7.4
Total number circuli	P < .01	BZ4 4.5	BZ1 4.7	BZ2 5.6	BZ5 5.7	BZ3 5.9

Table 2. A) Definitions of the 46 scale characters derived from measurements of fall chinook salmon scales collected at the UW, Samish, and Cowlitz hatcheries. B) Homologous pairs of non-ratio and ratio scale characters.

A)

Character number	Character category[1]	Character definition
C1	LD	Size of Zone 1 (freshwater zone)
C2	LD	Size of Zone 2 (first ocean zone)
C3	LD	Size of Zone 3 (second ocean zone)
C4	LD	Size of Zones 1+2 (first years growth)
C5	LD	Size of Zones 1+2+3 (total growth first two years)
C6	CC	No. circuli Zone 1
C7	CC	No. circuli Zone 2
C8	CC	No. circuli Zone 3
C9	CC	No. circuli Zones 1+2+3
C10	ACS	Size Zone 1/No. circuli Zone 1
C11	ACS	Size Zone 2/No. circuli Zone 2
C12	ACS	Size Zone 3/No. circuli Zone 3
C13	ACS	Size Zones 1+2/No. circuli Zones 1+2
C14	ACS	Size Zones 1+2+3/No. circuli Zones 1+2+3
C15	FWT	Distance circulus 1 - circulus 3 in Zone 1
C16	FWT	" " 4 - " 6 " " "
C17	FWT	" " 1 - " 6 " " "
C18	FWT	" " 1 - " 9 " " "
C19	MT	" " 1 - " 3 " " 3
C20	MT	" " 4 - " 6 " " "
C21	MT	" " 7 - " 9 " " "
C22	MT	" " 10 - " 12 " " "
C23	MT	" " 1 - " 6 " " "
C24	MT	" " 7 - " 12 " " "
C25	MT	" " 1 - " 9 " " "
C26	LDR	Size Zone 1/Size Zones 1+2+3
C27	LDR	Size Zone 2/Size Zones 1+2+3
C28	LDR	Size Zones 1+2/Size Zones 1+2+3
C29	CCR	No. circuli Zone 1/No. circuli Zones 1+2+3
C30	CCR	" " " 2/ " " " "
C31	CCR	" " " 3/ " " " "
C32	ACSR	(Size Zone 1/No. cir. Zone 1)/Size Zones 1+2+3
C33	ACSR	(" " 2/ " " " 2)/ " " "
C34	ACSR	(" " 3/ " " " 3)/ " " "
C35	ACSR	(Size Zones 1+2/No. cir. Zones 1+2)/Size Zones 1+2+3
C36	FWTR	(Distance cir. 1-3 Zone 1)/Size Zones 1+2+3
C37	FWTR	(" " 4-6 " 1)/ " " "
C38	FWTR	(" " 1-6 " 1)/ " " "
C39	FWTR	(" " 1-9 " 1)/ " " "
C40	MTR	(" " 1-3 " 3)/ " " "

Table 2. A) Definitions of the 46 scale characters derived from measurements of fall chinook salmon scales collected at the UW, Samish, and Cowlitz hatcheries. B) Homologous pairs of non-ratio and ratio scale characters - cont'd.

A)

Character number	Character category[1]	Character definition								
C41	MTR	(	"	"	4-6	"	3)/	"	"	"
C42	MTR	(	"	"	7-9	"	3)/	"	"	"
C43	MTR	(	"	"	10-12	"	3)/	"	"	"
C44	MTR	(	"	"	1-6	"	3)/	"	"	"
C45	MTR	(	"	"	7-12	"	3)/	"	"	"
C46	MTR	(	"	"	4-9	"	3)/	"	"	"

[1]See Table 4 for definitions of character categories.

B)

Non-ratio scale characters	Ratio scale characters
C1	C26
C2	C27
C3	--
C4	C28
C5	--
C6	C29
C7	C30
C8	C31
C9	--
C10	C32
C11	C33
C12	C34
C13	C35
C14	--
C15	C36
C16	C37
C17	C38
C18	C39
C19	C40
C20	C41
C21	C42
C22	C43
C23	C44
C24	C45
C25	C46

Table 3. A) Definitions of the 39 scale characters derived from measurements of Cowlitz spring chinook. B) Homologous pairs of non-ratio and ratio scale characters.

A

Character number	Character[1] category	Character definition
C 1	LD	Size Zone 1 (freshwater zone)
C 2	LD	Size Zone 2 (first ocean zone)
C 3	LD	Size Zones 1 + 2
C 4	CC	Number of circuli Zone 1
C 5	CC	Number of circuli Zone 2
C 6	CC	Number of circuli Zones 1 + 2
C 7	ACS	Size Zone 1/Number circuli Zone 1
C 8	ACS	Size Zone 2/Number circuli Zone 2
C 9	ACS	Size Zones 1 + 2/Number circuli Zones 1 + 2
C10	FWT	Distance circulus 1-3 in Zone 1
C11	FWT	" " 4-6 " " "
C12	FWT	" " 7-9 " " "
C13	FWT	" " 1-6 " " "
C14	FWT	" " 1-9 " " "
C15	MT	" " 1-3 " " 2
C16	MT	" " 4-6 " " "
C17	MT	" " 7-9 " " "
C18	MT	" " 10-12 " " "
C19	MT	" " 13-15 " " "
C20	MT	" " 1-6 " " "
C21	MT	" " 7-12 " " "
C22	MT	" " 1-9 " " "
C23	LDR	Size Zone 1/Size Zones 1 + 2
C24	CCR	No. circuli Zone 1/No. circuli Zones 1 + 2
C25	ACSR	(Size Zone 1/No. circuli Zone 1)/Size Zones 1+2
C26	ACSR	(" " 2 " " " 2 " " "
C27	FWTR	Distance circulus 1-3 Zone 1/Size Zones 1 + 2
C28	FWTR	" " 4-6 " " " " "
C29	FWTR	" " 7-9 " " " " "
C30	FWTR	" " 1-6 " " " " "
C31	FWTR	" " 1-9 " " " " "
C32	MTR	" " 1-3 " 2 " " "
C33	MTR	" " 4-6 " " " " "
C34	MTR	" " 7-9 " " " " "
C35	MTR	" " 10-12 " " " " "
C36	MTR	" " 13-15 " " " " "
C37	MTR	" " 1-6 " " " " "
C38	MTR	" " 7-12 " " " " "
C39	MTR	" " 1-9 " " " " "

[1]See Table 4 for definition of character categories.

Table 3. A) Definitions of the 39 scale characters derived from measurements of Cowlitz spring chinook. B) Homologous pairs of non-ratio and ratio scale characters - continued.

B)

Non-ratio scale characters	Ratio scale characters
C 1	C23
C 2	--
C 3	--
C 4	C24
C 5	--
C 6	--
C 7	C25
C 8	C26
C 9	--
C10	C27
C11	C28
C12	C29
C13	C30
C14	C31
C15	C32
C16	C33
C17	C34
C18	C35
C19	C36
C20	C37
C21	C38
C22	C39

Table 4. Scale character category definitions.

Scale character category	Category definition
Large distances (LD)	Absolute distance or size of a zone or combination of zones
Circulus counts (CC)	Number of circuli within a zone or combination of zones
Average circulus spacing (ACS)	The size of a zone or zones divided the number of circuli within the zone or zones
Freshwater triplets (FWT)	The distance between triplets of circuli in Zone 1
Marine triplets (MT)	The distance between triplets of circuli in Zone 3 for fall chinook and Zone 2 for spring chinook
Large distance ratios (LDR)	The size of a zone or zones divided by the total size of all zones combined
Circulus count ratios (CCR)	The number of circuli in a zone divided by the number of circuli in all zones combined
Average circulus spacing ratios (ACSR)	The average circulus spacing in a zone divided by the size of all zones combined, that is, the proportion of the total size represented by the average circulus spacing within a zone
Freshwater triplet ratios (FWTR)	The distance between triplets of circuli in Zone 1 divided by the size of all zones combined
Marine triplet ratios (MTR)	The distance between triplets of circuli in Zone 3 divided by the size of all zones combined

Table 5. Number of significant differences detected between pairs of body zones by scale character categories summed over fall chinook stocks.

Body zone comparisons	LD	CC	ACS	FWT	MT	LDR	CCR	ACSR	FWTR	MTR	Total
BZ1-BZ2	1	2	0	0	0	0	0	3	1	0	7
BZ1-BZ3	0	5	0	0	0	0	0	10	7	5	27
BZ1-BZ4	0	0	8	7	4	0	0	2	3	1	25
BZ1-BZ5	4	7	4	6	0	0	0	11	11	9	52
BZ2-BZ3	0	0	0	0	0	0	0	0	0	0	0
BZ2-BZ4	5	0	7	5	9	0	0	0	0	0	26
BZ2-BZ5	0	1	1	5	0	0	0	4	4	0	15
BZ3-BZ4	5	1	3	3	3	0	0	1	0	2	18
BZ3-BZ5	0	0	0	0	0	0	0	0	1	0	1
BZ4-BZ5	6	4	3	0	4	0	0	7	1	5	30
Total	21	20	26	26	20	0	0	38	28	22	
% of total possible comparisons that are significant[1]	14.0	16.7	17.3	21.7	8.3	0.0	0.0	31.7	23.3	9.2	

[1]The total number of possible pairwise comparisons made for a category, T, is a function of the number of scale characters in a category (n), the number of stocks (3), and the number of possible body zone comparisons per character (10). Therefore, T = (3)(10)(n). The percent of T which is significant is calculated by dividing the total number of significant differences found in a category by the appropriate T value.

Table 6. Number of significant differences detected between pairs of body zones by scale character categories for Cowlitz spring chinook.

Body zone comparisons	Scale character categories										
	LD	CC	ACS	FWT	MT	LDR	CCR	ACSR	FWTR	MTR	Total
BZ1-BZ2	0	0	0	1	0	0	0	0	3	0	4
BZ1-BZ3	1	2	0	0	0	0	0	2	5	3	13
BZ1-BZ4	0	0	2	5	1	0	0	1	3	0	12
BZ1-BZ5	2	3	1	5	0	0	0	2	5	4	22
BZ2-BZ3	0	0	0	0	0	0	0	0	0	0	0
BZ2-BZ4	1	0	3	4	0	0	0	0	0	0	8
BZ2-BZ5	0	1	1	5	0	0	0	1	5	0	13
BZ3-BZ4	3	1	3	3	0	0	0	0	0	0	10
BZ3-BZ5	0	0	1	4	0	0	0	0	3	0	8
BZ4-BZ5	3	2	2	0	0	0	0	2	5	0	14
Total	10	9	13	27	1	0	0	8	29	7	
Percent[1]	33.3	30.0	43.3	54.0	1.3	0.0	0.0	40.0	58.0	8.8	

[1]The percent of the total possible comparisons that resulted in significant differences.

Table 7. Classification matrix for the non-ratio scale character set. Results for the standards (used to classify the "unknowns") are given first. "Unknown" stock/body zone groups are ordered by stock (UW, SAM, COW) and body zone (1-5). Classifications are given in numbers of scales with percentages in parentheses. Scale characters used in the LDF were, in order of selection: C6, C4, C1 and C17.

Correct group	Number of scales classified into group (%)			Group sample size
	UW	Samish	Cowlitz fall	
Standards				
UW	28 (75.7)	7 (18.9)	2 (5.4)	37
Samish	0 (0.0)	45 (100.0)	0 (0.0)	45
Cowlitz	3 (8.8)	1 (2.9)	30 (88.2)	34
Unknowns				
UW1	34 (72.3)	7 (14.9)	6 (12.8)	47
UW2	37 (78.7)	6 (12.8)	4 (8.5)	47
UW3	35 (74.5)	7 (14.9)	5 (10.6)	47
UW4	32 (68.1)	8 (17.0)	7 (14.9)	47
UW5	36 (76.6)	6 (12.8)	5 (10.6)	47
SAM1	0 (0.0)	11 (100.0)	0 (0.0)	11
SAM2	0 (0.0)	11 (100.0)	0 (0.0)	11
SAM3	0 (0.0)	10 (90.9)	1 (9.1)	11
SAM4	0 (0.0)	10 (90.9)	1 (9.1)	11
SAM5	0 (0.0)	10 (90.9)	1 (9.1)	11
COW1	0 (0.0)	3 (13.6)	19 (86.4)	22
COW2	1 (4.5)	0 (0.0)	21 (95.5)	22
COW3	3 (13.6)	0 (0.0)	19 (86.4)	22
COW4	0 (0.0)	3 (13.6)	19 (86.4)	22
COW5	2 (9.1)	0 (0.0)	20 (90.9)	22

Table 8. Classification matrix for the ratio scale character set. Results for the standards (used to classify the "unknowns") are given first. "Unknown" stock/body zone groups are ordered by stock (UW, SAM, COW) and body zone (1-5). Classifications are given in numbers of scales with percentages in parentheses. Scale characters selected for use in the LDF were, in order of importance: C29, C28, C36, C27 and C34.

Correct group	Number of scales classified into group (%) UW	Samish	Cowlitz fall	Group sample size
Standards				
UW	30 (81.1)	5 (13.5)	2 (5.4)	37
Samish	0 (0.0)	44 (97.8)	1 (2.2)	45
Cowlitz	3 (8.8)	0 (0.0)	31 (91.2)	34
Unknowns				
UW1	36 (76.6)	8 (17.0)	3 (6.4)	47
UW2	37 (78.7)	6 (12.8)	4 (8.5)	47
UW3	41 (87.2)	4 (8.5)	2 (4.3)	47
UW4	35 (74.5)	7 (14.9)	5 (10.6)	47
UW5	41 (87.2)	5 (10.6)	1 (2.1)	47
SAM1	0 (0.0)	11 (100.0)	0 (0.0)	11
SAM2	0 (0.0)	11 (100.0)	0 (0.0)	11
SAM3	0 (0.0)	10 (90.9)	1 (9.1)	11
SAM4	0 (0.0)	11 (100.0)	0 (0.0)	11
SAM5	0 (0.0)	11 (100.0)	0 (0.0)	11
COW1	0 (0.0)	5 (22.7)	17 (77.3)	22
COW2	1 (4.5)	1 (4.5)	20 (90.9)	22
COW3	2 (9.1)	0 (0.0)	20 (90.9)	22
COW4	1 (4.5)	4 (18.2)	17 (77.3)	22
COW5	3 (13.6)	0 (0.0)	19 (86.4)	22

Table 9. Classification matrix for the BSC LDF. Results for the standards (used to classify the "unknowns") are given first. "Unknown" stock/body zone groups are ordered by stock (UW, SAM, COW) and body zone (1-5). Classifications are given in numbers of scales with percentages in parentheses. Scale characters used in the LDF were, in order of selection: C29, C28 and C27.

Correct group	Number of scales classified into group (%)			Group sample size
	UW	Samish	Cowlitz fall	
Standards				
UW	25 (67.6)	5 (13.5)	7 (18.9)	37
Samish	1 (2.2)	44 (97.8)	0 (0.0)	45
Cowlitz	5 (14.7)	2 (5.9)	27 (79.4)	34
Unknowns				
UW1	41 (87.2)	4 (8.5)	2 (4.3)	47
UW2	39 (83.0)	5 (10.6)	3 (6.4)	47
UW3	36 (76.6)	7 (14.9)	4 (8.5)	47
UW4	36 (76.6)	6 (12.8)	5 (10.6)	47
UW5	38 (80.9)	7 (14.9)	2 (4.3)	47
SAM1	1 (9.1)	10 (90.9)	0 (0.0)	11
SAM2	0 (0.0)	11(100.0)	0 (0.0)	11
SAM3	0 (0.0)	11(100.0)	0 (0.0)	11
SAM4	0 (0.0)	11(100.0)	0 (0.0)	11
SAM5	0 (0.0)	11(100.0)	0 (0.0)	11
COW1	1 (4.5)	3 (13.6)	18 (81.8)	22
COW2	1 (4.5)	0 (0.0)	21 (95.5)	22
COW3	2 (9.1)	0 (0.0)	20 (90.9)	22
COW4	3 (13.6)	0 (0.0)	19 (86.4)	22
COW5	0 (0.0)	0 (0.0)	22(100.0)	22

Table 10. Comparisons of preferred and non-preferred scale code determinations by JFA and FRI for individual age 1.2 and 1.3 immature chinook collected by Japanese mothership and research vessels in 1980.

Scale code comparisons by vessel, JFA:FRI	Frequency of determinations		Percent of total comparisons made	
Jinyo Maru				
Agreement				
preferred:preferred		301		88.8
non-preferred:non-preferred		9		2.7
Subtotal	310		91.5	
Disagreement				
preferred:non-preferred		21		6.2
non-preferred:preferred		8		2.4
Subtotal	29		8.6	
Total comparisons made		339		100.1
Meiyo Maru				
Agreement				
preferred:preferred		439		84.3
non-preferred:non-preferred		30		5.8
Subtotal	469		90.1	
Disagreement				
preferred:non-preferred		43		8.3
non-preferred:preferred		9		1.7
Subtotal	52		10.0	
Total comparisons made		521		100.1
Kumamoto Maru				
Agreement				
preferred:preferred		53		84.1
non-preferred:non-preferred		0		0.0
Subtotal	53		84.1	
Disagreement				
preferred:non-preferred		8		12.7
non-preferred:preferred		2		3.2
Subtotal	10		15.9	
Total comparisons made		63		100.0

Table 10. Comparisons of preferred and non-preferred scale code determinations by JFA and FRI for individual age 1.2 and 1.3 immature chinook collected by Japanese mothership and research vessels in 1980 - continued.

Scale code comparisons by vessel, JFA:FRI	Frequency of determinations		Percent of total comparisons made	
<u>Hoyo</u> <u>Maru</u>				
<u>Agreement</u>				
preferred:preferred		152		84.4
non-preferred:non-preferred		0		0.0
Subtotal	152		84.4	
<u>Disagreement</u>				
preferred:non-preferred		28		15.6
non-preferred:preferred		0		0.0
Subtotal	28		15.6	
Total comparisons made		180		100.0
All vessels combined				
<u>Agreement</u>				
preferred:preferred		945		85.7
non-preferred:non-preferred		39		3.5
Subtotal	984		89.2	
<u>Disagreement</u>				
preferred:non-preferred		100		9.1
non-preferred:preferred		19		1.7
Subtotal	119		10.8	
Total comparisons made		1103		100.0

Table 11. Chi-square test for independence of scale codings by JFA and FRI for age 1.2 and 1.3 immature chinook pooled over the four Japanese mothership and research vessels.

		FRI		
		Preferred	Non-preferred	Row totals
JFA	Preferred	observed: 945 expected: 913.31	observed: 100 expected: 131.69	1045
	Non-preferred	observed: 19 expected: 50.69	observed: 39 expected: 7.31	58
	Column totals	964	139	1103 Grand total

$$X^2 = 160.7 >> X^2_{0.001,1} = 10.8$$

Table 12. Definitions of the 14 chum scale characters. Scale size characters are in 0.001 inch at 104X.

Scale character	Character definition
C01	Number of circuli in first ocean zone
S01	Size of first ocean zone
C02	Number of circuli in second ocean zone
S02	Size of second ocean zone
C03	Number of circuli in third ocean zone (summer growth in age 0.2's)
S03	Size of third ocean age (summer growth in age 0.2's)
C04	Number of circuli in fourth ocean zone (summer growth in age 0.3's)
S04	Size of fourth ocean zone (summer growth in age 0.3's)
C01-02	Number of circuli in ocean zones 1 and 2
S01-02	Size of ocean zones 1 and 2
C01-03	Number of circuli in ocean zones 1 through 3
S01-03	Size of ocean zones 1 through 3
C01-04	Number of circuli in ocean zones 1 through 4
C01-04	Size of ocean zones 1 through 4

Table 13. Definitions of the 18 possible sockeye salmon scale characters. Scale size characters are in 0.001 inch at 104X.

Scale character	Character definition
CFW1	Number of circuli in first freshwater zone
SFW1	Size of first freshwater zone
CFW2	Number of circuli in second freshwater zone (age 2.'s only)
SFW2	Size of second freshwater zone (age 2.'s only)
CO1	Number of circuli in first ocean zone
SO1	Size of first ocean zone
CO2	Number of circuli in second ocean zone (summer growth in ages 1.1 and 2.1)
SO2	Size of second ocean zone (summer growth in ages 1.1 and 2.1)
CO3	Number of circuli in third ocean zone (summer growth in ages 1.2 and 2.2)
SO3	Size of third ocean zone (summer growth in ages 1.2 and 2.2)
CFW1-FW2	Number of circuli in CFW1 + CFW2 (age 2.'s only)
SFW1-FW2	Size of SFW1 + SFW2 (age 2.'s only)
CFW1-O1	Number of circuli in CFW1 + CFW2 + CFO1 (age 2.'s) or CFW1 + CO1 (age 1.'s)
SFW1-O1	Size of SFW1 + SFW2 + SO1 (age 2.'s) or SFW1 + SO1 (age 1.'s)
CFW1-O2	Number of circuli in CFW1 + CFW2 + CO1 + CO2 (age 2.'s) or CFW1 + CO1 + CO2 (age 1.'s)
SFW1-O2	Size of SFW1 + SFW2 + SO1 + SO2 (age 2.'s) or SFW1 + SO1 + SO2 (age 1.'s)
CFW1-O3	Number of circuli in CFW1 + CFW2 + CO1 + CO2 + CO3 (age 2.'s) or CFW1 + CO1 + CO2 + CO3 (age 1.'s)
SFW1-O3	Size of SFW1 + SFW2 + SO1 + SO2 + SO3 (age 2.'s) or SFW1 + SO1 + SO2 + SO3 (age 1.'s)

Table 14. Mean difference (d) between paired US and USSR chum scale samples by scale character and age group. The t-probabilities (t-prob.) and sample sizes (n) from the paired-sample t-tests are given also. Definitions of the scale characters are given in Table 12. Values of d > 0 indicate U.S. samples are greater in value than U.S.S.R. samples on average.

Scale	Age 0.2			Age 0.3			Ages combined		
character	d	t-prob.	n	d	t-prob.	n	d	t-prob.	n
C01	-			-			0.8	.00	79
S01	-			-			179	.00	79
C02	-			-			0.3	.11	79
S02	-			-			16	.36	79
C03	1.2	.00	19	-0.4	.06	60	-		
S03	122	.00	19	-2	.88	60	-		
C04	-			0.6	.00	50	-		
S04	-			63	.00	50	-		
C01-02	-						1.1	.00	79
S01-02	-						194	.00	79
C01-03	1.4	.13	19	1.1	.02	60	-		
S01-03	215	.02	19	229	.00	60	-		
C01-04	-			1.6	.00	50	-		
S01-04	-			286	.00	50	-		

Table 15. Mean difference (d) between paired US and USSR age 1.1 and 1.2 sockeye salmon scale samples by scale character and age group. The t-probabilities (t-prob.) and sample sizes (n) from the paired-sample t-test are given also. Definitions of the scale characters are given in Table 13. Values of d > 0 indicate U.S. samples are greater in value than U.S.S.R. samples on average.

Scale	Age 1.1			Age 1.2			Age 1. combined		
character	d	t-prob.	n	d	t-prob.	n	d	t-prob.	n
CFW1	-			-			0.9	0.06	15
SFW1	-			-			65	0.01	15
CO1	-			-			0.0	1.00	15
SO1	-			-			152	0.01	15
CO2	1.5	0.18	4	-0.1	0.87	11	-		
SO2	158	0.11	4	73	0.09	11	-		
CO3	-			0.6	0.30	9	-		
SO3	-			52	0.26	9	-		
CFW1-O1	-			-			0.9	0.32	15
SFW1-O1	-			-			217	0.01	15
CFW1-O2	2.0	0.54	4	0.9	0.34	11	-		
SFW1-O2	316	0.21	4	312	0.00	11	-		
CFW1-O3	-			2.0	0.14	9	-		
SFW1-O3	-			330	0.01	9	-		

Table 16. Mean difference (d) between paired US and USSR age 2.1 and 2.2 sockeye salmon scale samples by scale character and age group. The t-probabilities (t-prob.) and sample sizes (n) from the paired-sample t-test are given also. Definitions of the scale characters are given in Table 13. Values of d > 0 indicate U.S. samples are greater in value than U.S.S.R. samples on average.

Scale	Age 2.1			Age 2.2			Age 2. combined		
character	d	t-prob.	n	d	t-prob.	n	d	t-prob.	n
CFW1	-			-			1.1	0.00	49
SFW1	-			-			59	0.00	49
CFW2	-			-			-0.5	0.03	49
SFW2	-			-			-11	0.41	49
CO1	-			-			0.9	0.01	49
SO1	-			-			133	0.00	49
CO2	1.0	0.02	12	-0.3	0.32	37	-		
SO2	113	0.00	12	-3	0.92	37	-		
CO3	-			1.0	0.00	32	-		
SO3	-			105	0.00	32	-		
CFW1-FW2	-			-			0.6	0.03	49
SFW1-FW2	-			-			47	0.02	49
CFW1-O1	-			-			1.5	0.00	49
SFW1-O1	-			-			181	0.00	49
CFW1-O2	2.2	0.01	12	1.2	0.01	37	-		
SFW1-O2	228	0.02	12	199	0.00	37	-		
CFW1-O3	-			2.0	0.00	32	-		
SFW1-O3	-			269	0.00	32	-		

APPENDICES

Appendices A and B give the results of the Tukey tests for the four fall and spring chinook stocks. Tukey tests are summarized by underscoring means that are not significantly different, eg., X Y Z. However, a test may yield ambiguous results, as shown above, with overlapping sets of similarities. In this case we can say that X and Z come from different populations, but the results for Y are not clear.

Appendix A. Means of the five body zones (BZ1-BZ5) are ranked from left to right in increasing value for each stock/scale character combination. Results of the Tukey tests are given for those stock/scale character combinations with significant body zone effects in the 1-way ANOVAs. Groups of body zone means between which no significant differences were found in the Tukey test are underscored.

Scale character	UW					Samish					Cowlitz				
C1	BZ4 2080	BZ1 2286	BZ5 2346	BZ2 2393	BZ3 2435	BZ4 1265	BZ1 1325	BZ5 1338	BZ2 1409	BZ3 1433	BZ4 1800	BZ1 1919	BZ5 2058	BZ3 2096	BZ2 2163
C2	BZ4 3540	BZ1 3917	BZ3 3995	BZ2 4073	BZ5 4388	BZ4 3452	BZ1 3619	BZ3 3623	BZ2 3799	BZ5 3824	BZ1 2068	BZ4 2150	BZ2 2282	BZ3 2452	BZ5 2528
C3	BZ4 4090	BZ1 4222	BZ2 4486	BZ3 4557	BZ5 4591	BZ1 4581	BZ4 4884	BZ3 5152	BZ2 5161	BZ5 5456	BZ4 5246	BZ1 5366	BZ3 5790	BZ2 5926	BZ5 6153
C4	BZ4 5621	BZ1 6203	BZ3 6430	BZ2 6466	BZ5 6734	BZ4 4717	BZ1 4944	BZ3 5057	BZ5 5162	BZ2 5208	BZ4 3949	BZ1 3986	BZ2 4445	BZ3 4548	BZ5 4586
C5	BZ4 9711	BZ1 10425	BZ2 10952	BZ3 10987	BZ5 11326	BZ1 9526	BZ4 9601	BZ3 10208	BZ2 10370	BZ5 10618	BZ4 9195	BZ1 9353	BZ3 10338	BZ2 10371	BZ5 10739
C6	BZ1 16.5	BZ4 17.3	BZ2 17.5	BZ3 18.3	BZ5 18.4	BZ1 10.1	BZ2 10.6	BZ4 10.6	BZ5 11.3	BZ3 11.9	BZ1 16.4	BZ4 17.1	BZ2 18.9	BZ3 19.1	BZ5 19.7
C7	BZ1 25.4	BZ4 25.9	BZ2 26.7	BZ3 27.4	BZ5 29.9	BZ1 26.0	BZ3 27.7	BZ4 27.7	BZ2 27.8	BZ5 29.9	BZ1 16.6	BZ2 18.1	BZ4 18.5	BZ3 19.8	BZ5 20.6
C8	BZ1 23.2	BZ4 24.4	BZ2 24.9	BZ3 26.0	BZ5 26.3	BZ1 25.7	BZ2 28.1	BZ4 29.1	BZ3 29.6	BZ5 30.5	BZ1 30.0	BZ4 31.5	BZ2 32.2	BZ3 32.6	BZ5 34.8
C9	BZ1 65.1	BZ4 67.6	BZ2 69.1	BZ3 71.7	BZ5 74.5	BZ1 61.8	BZ2 66.5	BZ4 67.5	BZ3 69.3	BZ5 71.6	BZ1 63.0	BZ4 67.1	BZ2 69.2	BZ3 71.5	BZ5 75.1
C10	BZ4 120	BZ5 127	BZ3 133	BZ2 136	BZ1 138	BZ4 119	BZ5 119	BZ3 121	BZ1 133	BZ2 133	BZ5 105	BZ4 106	BZ3 111	BZ2 115	BZ1 119

Appendix A. Means of the five body zones (BZ1-BZ5) are ranked from left to right in increasing value for each stock/scale character combination. Results of the Tukey tests are given for those stock/scale character combinations with significant body zone effects in the 1-way ANOVAs. Groups of body zone means between which no significant differences were found in the Tukey test are underscored - cont'd.

Scale character	UW					Samish					Cowlitz				
C11	BZ4	BZ3	BZ5	BZ2	BZ1	BZ4	BZ5	BZ3	BZ2	BZ1	BZ4	BZ5	BZ3	BZ1	BZ2
	136	145	147	152	153	124	127	130	136	138	113	120	120	121	123
C12	BZ4	BZ5	BZ3	BZ2	BZ1	BZ4	BZ3	BZ1	BZ5	BZ2	BZ4	BZ5	BZ3	BZ1	BZ2
	168	175	176	181	182	168	175	179	180	185	168	178	178	179	185
C13	BZ4	BZ5	BZ3	BZ2	BZ1	BZ4	BZ5	BZ3	BZ2	BZ1	BZ4	BZ5	BZ3	BZ2	BZ1
	130	139	140	146	147	123	125	127	135	137	110	113	116	119	120
C14	BZ4	BZ5	BZ3	BZ2	BZ1	BZ4	BZ3	BZ5	BZ1	BZ2	BZ4	BZ5	BZ3	BZ1	BZ2
	143	152	153	158	160	142	147	148	154	156	137	143	145	148	150
C15	BZ4	BZ5	BZ3	BZ2	BZ1	BZ3	BZ5	BZ4	BZ2	BZ1	BZ5	BZ4	BZ3	BZ2	BZ1
	351	372	384	394	405	389	391	396	431	438	333	355	369	386	405
C16	BZ4	BZ5	BZ3	BZ2	BZ1	BZ5	BZ4	BZ1	BZ3	BZ2	BZ4	BZ5	BZ3	BZ1	BZ2
	275	305	329	332	345	268	276	296	297	321	280	289	313	322	328
C17	BZ4	BZ5	BZ3	BZ2	BZ1	BZ5	BZ4	BZ3	BZ1	BZ2	BZ5	BZ4	BZ3	BZ2	BZ1
	626	674	713	726	750	659	672	686	734	752	622	635	682	713	727
C18	BZ4	BZ5	BZ3	BZ2	BZ1	BZ5	BZ4	BZ1	BZ3	BZ2	BZ4	BZ5	BZ3	BZ1	BZ2
	928	988	1046	1064	1118	872	876	879	942	986	899	906	988	1021	1027
C19	BZ5	BZ3	BZ4	BZ2	BZ1	BZ4	BZ5	BZ3	BZ1	BZ2	BZ4	BZ3	BZ5	BZ1	BZ2
	540	544	548	576	579	548	549	551	572	611	504	506	511	539	546
C20	BZ4	BZ3	BZ2	BZ1	BZ5	BZ5	BZ4	BZ3	BZ2	BZ1	BZ4	BZ5	BZ3	BZ1	BZ2
	559	600	613	613	615	548	562	592	596	612	512	549	551	568	570
C21	BZ4	BZ5	BZ1	BZ3	BZ2	BZ4	BZ3	BZ2	BZ1	BZ5	BZ4	BZ3	BZ1	BZ5	BZ2
	537	590	592	592	598	518	610	612	614	618	525	567	574	575	608

Appendix A. Means of the five body zones (BZ1–BZ5) are ranked from left to right in increasing value for each stock/scale character combination. Results of the Tukey tests are given for those stock/scale character combinations with significant body zone effects in the 1-way ANOVAs. Groups of body zone means between which no significant differences were found in the Tukey test are underscored – cont'd.

Scale character	UW					Samish					Cowlitz				
C22	BZ4	BZ1	BZ3	BZ5	BZ2	BZ4	BZ1	BZ5	BZ2	BZ3	BZ4	BZ1	BZ5	BZ3	BZ2
	536	564	566	570	571	543	581	593	598	611	554	593	595	605	627
C23	BZ4	BZ3	BZ5	BZ2	BZ1	BZ5	BZ4	BZ3	BZ1	BZ2	BZ4	BZ3	BZ5	BZ1	BZ2
	1108	1143	1155	1188	1191	1098	1110	1143	1185	1207	1016	1057	1059	1107	1116
C24	BZ4	BZ1	BZ3	BZ5	BZ2	BZ4	BZ1	BZ2	BZ5	BZ3	BZ4	BZ1	BZ5	BZ3	BZ2
	1073	1156	1158	1160	1169	1061	1195	1210	1210	1220	1078	1168	1169	1172	1235
C25	BZ4	BZ3	BZ5	BZ1	BZ2	BZ4	BZ5	BZ3	BZ1	BZ2	BZ4	BZ3	BZ5	BZ1	BZ2
	1645	1735	1744	1783	1786	1628	1715	1752	1799	1820	1541	1624	1634	1682	1724
C26	BZ5	BZ4	BZ2	BZ1	BZ3	BZ5	BZ4	BZ2	BZ1	BZ3	BZ5	BZ4	BZ3	BZ1	BZ2
	0.208	0.215	0.219	0.221	0.222	0.127	0.133	0.137	0.141	0.142	0.194	0.198	0.205	0.208	0.212
C27	BZ3	BZ4	BZ2	BZ1	BZ5	BZ3	BZ5	BZ4	BZ2	BZ1	BZ2	BZ1	BZ4	BZ5	BZ3
	0.362	0.364	0.370	0.374	0.385	0.353	0.357	0.358	0.366	0.378	0.214	0.215	0.228	0.231	0.231
C28	BZ4	BZ3	BZ2	BZ5	BZ1	BZ5	BZ4	BZ3	BZ2	BZ1	BZ1	BZ5	BZ4	BZ2	BZ3
	0.579	0.584	0.589	0.593	0.595	0.485	0.491	0.495	0.503	0.519	0.423	0.424	0.426	0.426	0.437
C29	BZ5	BZ2	BZ1	BZ3	BZ4	BZ5	BZ4	BZ2	BZ1	BZ3	BZ4	BZ1	BZ5	BZ3	BZ2
	0.247	0.253	0.255	0.256	0.257	0.158	0.158	0.161	0.164	0.172	0.257	0.261	0.264	0.269	0.275
C30	BZ3	BZ4	BZ2	BZ1	BZ5	BZ3	BZ4	BZ5	BZ2	BZ1	BZ2	BZ1	BZ5	BZ3	BZ4
	0.381	0.382	0.385	0.389	0.399	0.401	0.411	0.417	0.419	0.422	0.258	0.259	0.271	0.272	0.273
C31	BZ5	BZ1	BZ4	BZ2	BZ3	BZ1	BZ2	BZ5	BZ3	BZ4	BZ3	BZ5	BZ2	BZ4	BZ1
	0.354	0.357	0.361	0.362	0.364	0.415	0.421	0.425	0.427	0.431	0.459	0.466	0.468	0.470	0.480
C32	BZ5	BZ3	BZ4	BZ2	BZ1	BZ5	BZ3	BZ4	BZ2	BZ1	BZ5	BZ3	BZ2	BZ4	BZ1
	0.011	0.012	0.013	0.013	0.014	0.011	0.012	0.013	0.013	0.014	0.010	0.011	0.011	0.012	0.013
C33	BZ5	BZ3	BZ2	BZ4	BZ1	BZ5	BZ3	BZ4	BZ2	BZ1	BZ5	BZ3	BZ2	BZ4	BZ1
	0.013	0.013	0.014	0.014	0.015	0.012	0.013	0.013	0.013	0.015	0.011	0.012	0.012	0.012	0.013

Appendix A. Means of the five body zones (BZ1-BZ5) are ranked from left to right in increasing value for each stock/scale character combination. Results of the Tukey tests are given for those stock/scale character combinations with significant body zone effects in the 1-way ANOVAs. Groups of body zone means between which no significant differences were found in the Tukey test are underscored - cont'd.

Scale character	UW					Samish					Cowlitz				
C34	BZ5	BZ3	BZ2	BZ4	BZ1	BZ5	BZ3	BZ4	BZ2	BZ1	BZ5	BZ3	BZ2	BZ4	BZ1
	0.016	0.016	0.017	0.018	0.018	0.017	0.017	0.018	0.018	0.019	0.017	0.017	0.018	0.019	0.019
C35	BZ5	BZ3	BZ2	BZ4	BZ1	BZ5	BZ3	BZ4	BZ2	BZ1	BZ5	BZ3	BZ2	BZ4	BZ1
	0.012	0.013	0.014	0.014	0.014	0.012	0.013	0.013	0.013	0.014	0.011	0.011	0.012	0.012	0.013
C36	BZ5	BZ3	BZ2	BZ4	BZ1	BZ5	BZ3	BZ4	BZ2	BZ1	BZ5	BZ3	BZ2	BZ4	BZ1
	0.033	0.035	0.036	0.037	0.039	0.037	0.038	0.042	0.042	0.046	0.032	0.036	0.038	0.039	0.044
C37	BZ5	BZ4	BZ3	BZ2	BZ1	BZ5	BZ4	BZ3	BZ2	BZ1	BZ5	BZ3	BZ4	BZ2	BZ1
	0.027	0.029	0.030	0.031	0.034	0.026	0.029	0.029	0.031	0.031	0.027	0.031	0.031	0.032	0.035
C38	BZ5	BZ3	BZ4	BZ2	BZ1	BZ5	BZ3	BZ4	BZ2	BZ1	BZ5	BZ3	BZ4	BZ2	BZ1
	0.060	0.066	0.066	0.067	0.073	0.063	0.068	0.070	0.073	0.078	0.059	0.067	0.070	0.070	0.080
C39	BZ5	BZ3	BZ4	BZ2	BZ1	BZ5	BZ4	BZ3	BZ1	BZ2	BZ5	BZ3	BZ4	BZ2	BZ1
	0.088	0.096	0.097	0.098	0.109	0.083	0.091	0.093	0.093	0.096	0.086	0.097	0.099	0.101	0.111
C40	BZ5	BZ3	BZ2	BZ1	BZ4	BZ5	BZ3	BZ4	BZ2	BZ1	BZ5	BZ3	BZ2	BZ4	BZ1
	0.048	0.050	0.053	0.056	0.057	0.052	0.054	0.057	0.060	0.061	0.048	0.050	0.053	0.055	0.058
C41	BZ5	BZ3	BZ2	BZ4	BZ1	BZ5	BZ2	BZ3	BZ4	BZ1	BZ5	BZ3	BZ2	BZ4	BZ1
	0.055	0.055	0.057	0.059	0.060	0.052	0.058	0.058	0.059	0.065	0.052	0.054	0.056	0.056	0.062
C42	BZ5	BZ3	BZ2	BZ4	BZ1	BZ4	BZ5	BZ3	BZ2	BZ1	BZ5	BZ3	BZ4	BZ2	BZ1
	0.053	0.054	0.055	0.056	0.058	0.054	0.059	0.059	0.060	0.065	0.054	0.055	0.058	0.059	0.062
C43	BZ5	BZ3	BZ2	BZ1	BZ4	BZ5	BZ4	BZ2	BZ3	BZ1	BZ5	BZ3	BZ4	BZ2	BZ1
	0.051	0.052	0.053	0.055	0.056	0.056	0.057	0.058	0.060	0.062	0.056	0.059	0.061	0.061	0.064
C44	BZ5	BZ3	BZ2	BZ1	BZ4	BZ5	BZ3	BZ4	BZ2	BZ1	BZ5	BZ3	BZ2	BZ4	BZ1
	0.103	0.105	0.110	0.116	0.116	0.105	0.113	0.117	0.117	0.126	0.100	0.104	0.109	0.111	0.120

Appendix A. Means of the five body zones (BZ1-BZ5) are ranked from left to right in increasing value for each stock/scale character combination. Results of the Tukey tests are given for those stock/scale character combinations with significant body zone effects in the 1-way ANOVAs. Groups of body zone means between which no significant differences were found in the Tukey test are underscored - cont'd.

Scale character	UW					Samish					Cowlitz				
C45	**BZ5**	**BZ3**	**BZ2**	**BZ1**	**BZ4**	**BZ4**	**BZ5**	**BZ2**	**BZ3**	**BZ1**	**BZ5**	**BZ3**	**BZ4**	**BZ2**	**BZ1**
	0.103	0.106	0.108	0.112	0.112	0.112	0.115	0.118	0.120	0.127	0.110	0.115	0.118	0.121	0.126
C46	**BZ5**	**BZ3**	**BZ2**	**BZ4**	**BZ1**	**BZ5**	**BZ4**	**BZ3**	**BZ2**	**BZ1**	**BZ5**	**BZ3**	**BZ2**	**BZ4**	**BZ1**
	0.156	0.160	0.165	0.172	0.173	0.163	0.171	0.173	0.177	0.191	0.154	0.159	0.168	0.169	0.182

Appendix B. Results of the 1-way ANOVAs for body zone effects are given as F probabilities for the 39 Cowlitz spring chinook scale characters. Means of the five body zones (BZ1-BZ5) are ranked from left to right in increasing value. Results of the Tukey multiple-comparisons tests are given for those characters with significant body zone effects. Groups of body zone means between which no significant difference was found are underscored.

Scale character	F prob.	Tukey test results				
C1	.0000	BZ4	BZ1	BZ2	BZ5	BZ3
		2862	3151	3306	3347	3478
C2	.0009	BZ4	BZ1	BZ2	BZ3	BZ5
		5827	5971	6317	6805	7077
C3	.0000	BZ4	BZ1	BZ2	BZ3	BZ5
		8689	9122	9623	10283	10424
C4	.0001	BZ1	BZ4	BZ2	BZ3	BZ5
		24.1	25.5	26.0	27.7	28.4
C5	.0050	BZ1	BZ4	BZ2	BZ3	BZ5
		36.5	37.8	38.0	41.1	42.6
C6	.0000	BZ1	BZ4	BZ2	BZ3	BZ5
		60.6	63.3	64.0	68.8	70.9
C7	.0000	BZ4	BZ5	BZ3	BZ2	BZ1
		112	118	126	127	131
C8	.0016	BZ4	BZ1	BZ3	BZ2	BZ5
		154	163	165	166	167
C9	.0000	BZ4	BZ5	BZ3	BZ1	BZ2
		137	147	149	150	150

Appendix B - cont'd.

Scale character	F prob.	Tukey test results				
C10	.0000	BZ5	BZ4	BZ2	BZ3	BZ1
		341	346	383	383	404
C11	.0000	BZ5	BZ4	BZ2	BZ3	BZ1
		276	278	323	328	359
C12	.0000	BZ4	BZ5	BZ3	BZ2	BZ1
		304	307	331	341	357
C13	.0000	BZ5	BZ4	BZ2	BZ3	BZ1
		617	624	706	711	763
C14	.0000	BZ5	BZ4	BZ3	BZ2	BZ1
		924	928	1041	1047	1120
C15	.2807	BZ1	BZ4	BZ2	BZ3	BZ5
		348	351	374	375	388
C16	.1917	BZ5	BZ4	BZ3	BZ2	BZ1
		376	382	397	409	430
C17	.0491	BZ4	BZ2	BZ3	BZ5	BZ1
		436	464	484	491	495
C18	.1999	BZ4	BZ5	BZ3	BZ2	BZ1
		481	512	514	517	545
C19	.1720	BZ4	BZ5	BZ1	BZ3	BZ2
		484	522	523	525	532
C20	.7217	BZ4	BZ5	BZ3	BZ1	BZ2
		734	764	772	778	783

Appendix B - cont'd.

Scale character	F prob.	Tukey test results				
C21	.0536	BZ4 917	BZ2 981	BZ3 998	BZ5 1003	BZ1 1039
C22	.2379	BZ4 1170	BZ2 1247	BZ5 1255	BZ3 1256	BZ1 1273
C23	.3683	BZ5 .324	BZ4 .333	BZ3 .342	BZ2 .347	BZ1 .349
C24	.9897	BZ1 .401	BZ5 .403	BZ4 .405	BZ3 .406	BZ2 .409
C25	.0000	BZ5 .011	BZ3 .012	BZ4 .013	BZ2 .013	BZ1 .015
C26	.0016	BZ5 .016	BZ3 .016	BZ2 .018	BZ4 .018	BZ1 .018
C27	.0000	BZ5 .033	BZ3 .038	BZ2 .040	BZ4 .041	BZ1 .045
C28	.0000	BZ5 .027	BZ3 .032	BZ4 .033	BZ2 .034	BZ1 .040
C29	.0000	BZ5 .030	BZ3 .033	BZ4 .036	BZ2 .036	BZ1 .040
C30	.0000	BZ5 .060	BZ3 .070	BZ4 .073	BZ2 .074	BZ1 .085

Appendix B - cont'd.

Scale character	F prob.	Tukey test results				
C31	.0000	BZ5	BZ3	BZ4	BZ2	BZ1
		.090	.103	.109	.110	.125
C32	.4212	BZ3	BZ5	BZ1	BZ2	BZ4
		.037	.038	.039	.039	.041
C33	.0027	BZ5	BZ3	BZ2	BZ4	BZ1
		.037	.040	.043	.045	.048
C34	.1235	BZ5	BZ3	BZ2	BZ4	BZ1
		.048	.048	.049	.052	.055
C35	.0121	BZ5	BZ3	BZ2	BZ4	BZ1
		.050	.051	.055	.057	.061
C36	.0318	BZ5	BZ3	BZ2	BZ4	BZ1
		.051	.052	.056	.057	.059
C37	.0233	BZ5	BZ3	BZ2	BZ4	BZ1
		.074	.076	.082	.086	.087
C38	.0212	BZ5	BZ3	BZ2	BZ4	BZ1
		.098	.099	.104	.108	.117
C39	.0206	BZ5	BZ3	BZ2	BZ4	BZ1
		.122	.125	.132	.137	.142