



ORIGINS OF CHINOOK SALMON IN THE YUKON RIVER FISHERIES, 1986

By:

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April 1988

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ABSTRACT

Analysis of scale patterns and age composition of chinook salmon (*Oncorhynchus tshawytscha* Walbaum) from Yukon River escapements in Alaska and fish wheel catches in Canada were used to construct run and river of origin classification models for age-1.4 and - 1.3 fish. Samples from the Nulato, Jim and south fork Koyukuk Rivers, Alaska, were collected in 1986 and included in various models. Yukon River commercial and subsistence catch proportions by stock were estimated by run of origin models which yielded the greatest classification accuracy and allocation precision. Low classification accuracies of river of origin models precluded their use in estimating the stock composition of catches by river.

Total Yukon River harvest was 165,318 chinook salmon of which 67.9% was estimated to be upper Yukon, 26.6% lower Yukon and 5.5% middle Yukon run of origin. Similar to results obtained in years 1982-85, the fraction of the Districts 1 and 2 commercial catch composed of the lower Yukon run generally increased through time, while the fraction composed of the upper Yukon run generally declined. The contribution of the middle Yukon run to the total harvest was the lowest since 1982, when scale patterns analysis and age composition were first used to estimate the contributions of the various groups in Yukon River catches.

The effects of subjective interpretation of scale patterns by digitizer on scale measurements and classification accuracies was investigated with univariate and multivariate statistics. No significant difference was found between digitizers in their interpretation of the size of the freshwater growth zone. Interaction effects between digitizer and run of origin in the size of the freshwater plus growth zone confounded interpretation of the main effects due to run of origin and digitizer. A significant difference due to digitizer was detected in the first marine growth zone but the difference in size among runs of origin was not significant. Scale measurements by the two digitizers resulted in similar model accuracies and catch proportion estimates by stock. The small fraction of the 1986 Yukon River chinook salmon harvest composed of the middle Yukon run can not be directly attributed to a change in digitizer.

KEY WORDS: Chinook salmon, *Oncorhynchus tshawytscha*, stock separation, catch and run composition, linear discriminant analysis, Yukon River, Alaska

INTRODUCTION

Yukon River chinook salmon (*Oncorhynchus tshawytscha* Walbaum) are harvested in a wide range of fisheries in both marine and fresh waters. During their ocean residence, they are harvested in salmon gill net fisheries in the North Pacific Ocean and Bering Sea and as an incidental catch in trawl fisheries in the Bering Sea (Meyers and Rogers 1985). Within the Yukon River returning adults are harvested in commercial and subsistence fisheries in both Alaska and Canada (Figures 1 and 2).

The Yukon River commercial and subsistence chinook salmon fishery is one of the largest in Alaska, averaging 17% of statewide chinook salmon harvest annually (1980-84). In the first 20 years after statehood (1960-79), the combined Alaskan and Canadian Yukon River chinook salmon harvest averaged 122,971 fish annually. However, catches during the recent five years (1982-86) have increased substantially to a yearly average of 183,481 fish. While chinook salmon are harvested virtually throughout the entire length of the Yukon River, the majority of the catch has been taken in commercial gill net fisheries in Districts 1 and 2 (1982-86 average 65% of total drainage harvest). Subsistence harvests, including Canadian catches, account for another 25% (1982-86 average) of the total harvest. Most of the subsistence harvest is taken with fish wheels and gill nets in Districts 4, 5, and 6. In 1986 commercial and subsistence fishermen in Alaska and Canada harvested a total of 165,316 chinook salmon, of which 94,884 fish (57%) were taken by District 1 and 2 commercial fishermen.

Chinook salmon harvested in the Yukon River fisheries consist of a mixture of stocks destined for spawning areas throughout the Yukon River drainage. Although more than 100 spawning streams have been documented (Barton 1984), aerial surveys of chinook salmon escapements indicate that the largest concentrations of spawners occur in three distinct geographic regions: (1) tributary streams that drain the Andreafsky Hills and Kaltag Mountains between river miles 100 and 500; (2) Tanana River tributaries between river miles 800 and 1,100; and (3) tributary streams that drain the Pelly and Big Salmon Mountains between river miles 1,300 and 1,800. Chinook salmon stocks within these geographic regions were collectively termed runs by McBride and Marshall (1983) and are now referred to as the lower, middle, and upper Yukon runs.

A major controversy currently facing managers of Yukon River chinook salmon is apportionment of the harvest among competing user groups. Two such apportionment issues which have recently received considerable public attention are: (1) high seas interceptions of North American chinook salmon (including fish destined for the Yukon River) in the gill net and trawl fisheries in the North Pacific Ocean and Bering Sea; and (2) negotiations between the United States and Canada over inriver harvest of chinook salmon destined for the Canadian portion of the Yukon River drainage.

An increasingly important facet of Yukon River chinook salmon management is identification of the fisheries in which stocks are harvested and the relative harvest proportions. Harvest estimates of Western Alaskan/Canadian Yukon chinook salmon in the Japanese high seas gill net fisheries (Rogers et al. 1984, Meyers et al. 1984, Meyers and Rogers 1985), have become major

elements in the regulation of these ocean fisheries. Concurrent with offshore studies, stock composition of inriver fisheries has been studied to provide useful information for resource regulators making inriver allocation decisions and managers seeking to improve management precision through a better understanding of spatial and temporal migratory patterns of Yukon stocks. Stock composition estimates of the catch through time for Yukon River chinook salmon became available in 1980 and 1981 when the use of scale patterns analysis for District 1 was initially investigated (McBride and Marshall 1983). Since then, harvest proportions by geographic region of origin have been estimated annually for the entire drainage (Wilcock and McBride 1983, Wilcock 1984, Wilcock 1985, Wilcock 1986).

This report builds upon the catch, escapement, and age composition database compiled by Buklis (1987) for the 1986 return of salmon to the Yukon River. The objective was to classify the 1986 Yukon River chinook salmon commercial and subsistence harvest to river of origin and run of origin and compare their relative precision.

Also examined in this report is a change in people digitizing scale patterns (digitizer) and the effect on scale measurements and catch proportions by stock.

STOCK ORIGINS STUDY

Methods

Age Composition:

Scale samples provided age information for fish in the catch and escapement. Samples were collected from the left side of the fish approximately two rows above the lateral line along a diagonal line downward from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Clutter and Whitesel 1956). Scales were mounted on gummed cards and impressions made in cellulose acetate.

Catch. Scales were collected from commercial catches in Districts 1, 2, 4, 5, and 6, and in the Yukon Territory, Canada, and from subsistence catches in Districts 4, 5, and 6. District 3 was not sampled because few fish are harvested in that portion of the Yukon River and access is difficult. A small fraction of the District 2 catch can at times include District 3 catches delivered in District 2. Although subsistence catches were not sampled in Districts 1 and 2, subsistence fishing occurred concurrently with commercial effort and the age compositions for subsistence catches were assumed to be similar to the commercial catch. Samples were also collected from a test gill net fishery in District 1 and from a test fish wheel used to capture fish in a tagging project in the Yukon Territory. Sampling of Alaskan fisheries was conducted by the Alaska Department of Fish and Game (ADF&G), Division of Commercial Fisheries, while Canadian fishery and test fish wheel samples were collected by the Canadian Department of Fisheries and Oceans (DFO).

Escapement. Scale samples were collected during peak spawner die off from the Andreafsky, Anvik, Nulato, Jim, Chena, and Salcha Rivers in Alaska, and from the Big Salmon, Little Salmon, Nisutlin, Teslin, Tatchun, and mainstem Yukon Rivers in Canada (Figures 1 and 2). Virtually all samples were collected from carcasses. The age composition of lower, middle, and upper Yukon areas was estimated by weighting the age composition calculated for the individual spawning tributaries in each area by the escapement to each tributary as indexed by aerial surveys.

Catch Composition:

Linear discriminant function analysis (Fisher 1936) of scale patterns data and observed differences in age composition between escapements were used to classify 1986 Yukon River chinook salmon catches to river or run of origin.

Scale Patterns Analysis. Escapement samples in Alaska and DFO test fish wheel samples provided scales of known origin that were used to build linear discriminant functions (LDF). The Canadian standard was based on DFO fish wheel samples in 1986 unlike past years when this standard was developed from Canadian commercial fishery samples. Because the Canadian commercial fishery was terminated early in 1986 due to marketing problems, we felt that some spawning stocks might not be adequately represented in the commercial fishery sample. Canadian escapement samples could not be pooled to form a reasonable standard due to the lack of samples from several significant spawning populations.

Catch and test gill net samples provided scales of mixed stock composition which were classified using the discriminant functions. Proportions of river or run of origin fish aged 1.4 and 1.3 were estimated in District 1 and 2 catches by fishing period. It was assumed that the District 3 catch composition by stock was similar to that in District 2. District 4, 5 and 6 catches were classified for the entire season.

The U.S./Canada Joint Technical Committee (JTC) on Yukon River salmon recommended in April 1987 that chinook salmon catch contributions be estimated by river of origin where possible, and that these stock proportions then be summed to yield estimates of the lower, middle and upper Yukon runs (YRJTC 1987). It was believed that this approach could yield greater precision and similar accuracy as the method used previously: i.e., scales from different tributaries were pooled, weighted by aerial survey indices of abundance, to form run of origin standards. Both because of the recommendation by the JTC, and because more extensive escapement sampling was conducted in 1986 this new classification method was tested. Several different classification models were constructed for the 1986 data base, and that method which yielded the best classification accuracy and precision was selected for the final estimates of catch by river or run of origin.

Measurements of scale features were made as described by McBride and Marshall (1983). Scale images were projected at 100X magnification using equipment similar to that described by Ryan and Christie (1976) and

measurements were made and recorded by a microcomputer-controlled digitizing system. Measurements were taken along an axis approximately perpendicular to the sculptured field and the distance between each circulus in each of three scale growth zones (Figure 3) was recorded. The three zones were: (1) scale focus to the outside edge of the freshwater annulus (first freshwater annular zone), (2) outside edge of the freshwater annulus to the last circulus of freshwater growth (freshwater plus growth zone), and (3) the last circulus of the freshwater plus growth zone to the outer edge of the first ocean annulus (first marine annular zone). In addition, the total width of successive scale patterns zones was also measured for: (1) the last circulus of the first ocean annulus to the last circulus of the second ocean annulus (ages 1.4 and 1.3), and (2) the last circulus of the second ocean annulus to the last circulus of the third ocean annulus (age-1.4 only). Seventy-nine scale characters (Appendix Table 1) were calculated from the basic incremental distances and circuli counts. All available scale samples (standards) from six rivers in Alaska were used and 200 systematically-pooled samples from three DFO fish wheel sites comprised the primary river of origin model. Run of origin standards (pooled rivers) were weighted by aerial abundance estimates. River and run of origin models were constructed for the 1.4 and 1.3 age classes.

Linear discriminant functions (LDF) were calculated for each age class. Selection of scale characters for each analysis was by a forward stepping procedure using partial F statistics as the criteria for entry/deletion of variables (Enslein et al. 1977). A nearly unbiased estimate of classification accuracy for each LDF was determined using a leaving-one-out procedure (Lachenbruch 1967).

Contribution rates for age-1.4 and -1.3 fish in the District 1 and 2 catches were estimated for each fishing period. Contribution rates for the combined commercial and subsistence harvests in District 4 were estimated from samples collected from both fisheries (including both gill net and fish wheel gear types) during most of the season. Point estimates were adjusted for misclassification errors using the procedure of Cook and Lord (1978). The variance and 90% confidence intervals for these estimates were computed using the procedures of Pella and Robertson (1979).

When classified catch samples indicated an adjusted proportional estimate equal to or less than zero, the river or run indicating the most negative contribution was deleted from the model. Data were then resubmitted to the variable selection routines, and a new subset of variables chosen for the LDF. Catch was then reclassified. This process was continued until all adjusted proportional estimates in the catch were positive.

Results of the age-specific scale patterns analysis were summed to estimate total contribution by river or run of origin for age-1.4 and -1.3 chinook salmon to the District 1, 2, and 3 commercial and District 4 combined commercial and subsistence catches. For each district, the variance (V) around N_{ijt} (the catch of age class i and run j during period t) was computed for each period t as follows:

$$(1) \quad V[N_{ijt}] = N_t^2 \{ S_{ijt}^2 \cdot V[P_{it}] + P_{it}^2 \cdot V[S_{ijt}] - V[P_{it}] \cdot V[S_{ijt}] \}$$

where:

$$(2) \quad V[P_{it}] = P_{it}(1-P_{it})(n_t-1)^{-1}$$

and:

P is the proportion of age class i; S is the proportion of run j of age class i harvested during period t; and the variance, $V[S_{ijt}]$, is as derived by Pella and Robertson (1979). Variance around the district catch of ages 1.4 and 1.3 by run, N_j , was computed by summing variances across age classes and periods:

$$(3) \quad V[N_j] = \sum_t \sum_i^2 V[N_{ijt}] + 2 \sum_t \sum_i^2 \sum_{i>k}^2 N_t^2 \cdot \text{Cov}[P_{it}P_{kt}] \cdot S_{ijt} \cdot S_{kjt}$$

where:

$$(4) \quad \text{Cov}[P_{it}P_{kt}] = - P_{it}P_{kt}(n_t-2)^{-1}$$

and:

T is the total number of fishing periods sampled in each district and n_t is the sample size for the estimate of age composition in period t. Variance around the estimate of total harvest of age- 1.4 and -1.3 fish by river or run of origin from Districts 1, 2, 3, and 4 (estimated from scale patterns analysis) was calculated as the sum of the seasonal variances for combined ages across all districts. Total harvest estimates and associated variances by country of origin were calculated by assuming the sum of the Alaskan rivers or the lower and middle Yukon runs to be equal to the Alaskan contribution and the upper Yukon equal to the Canadian contribution. Variance around the estimate of Alaskan contribution, $N_{i(L+M)t}$, was computed by summing variances across runs:

S_{iLt} = estimated proportion of lower Yukon run present for age i at period t

S_{iMt} = estimated proportion of middle Yukon run present for age i at period t

$$(5) \quad V[N_{i(L+M)t}] = N_t^2 \{ (S_{iLt} + S_{iMt})^2 \cdot V[P_{it}] + P_{it}^2 \cdot V[S_{iLt} + S_{iMt}] - V[P_{it}] \cdot V[S_{iLt} + S_{iMt}] \}$$

where:

$$(6) \quad V[S_{iLt} + S_{iMt}] = V[S_{iLt}] + V[S_{iMt}] - 2\text{Cov}[S_{iLt}S_{iMt}]$$

Differential Age Composition Analysis. Classification of the remaining age classes in the District 1, 2, and 3 commercial catches and District 4 combined commercial and subsistence catches was based on differences in escapement age composition in each run of origin. An assumption implicit in this calculation is that harvest rates by stock and age are similar and differences in the escapement age composition reflect differing maturity schedules. This assumption may have been violated, but we believe any bias introduced was minor. Escapement age composition data, weighted by aerial survey estimates, was directly compared by computing ratios for each river or run whereby the proportion in the escapement of the age class in question was divided by the proportion in the escapement of an age class of known catch composition estimated by scale patterns analysis (either age-1.4 or -1.3):

E_{ci} = Proportion of fish of age class i in river or run c escapement samples where i was an age class of unknown river or run composition in the catch

E_{ca} = Proportion of fish of age class a in river or run c where a was an age class of known river or run composition in the catch (either age-1.4 or -1.3)

$$(7) R_{ci} = E_{ci}/E_{ca}$$

Because the relative contribution of age-1.2 fish in escapement samples collected in previous years has tended to decrease moving progressively upriver, this age class was compared to age-1.3 fish. All other age classes (2.3, 1.5, 2.4, and 2.5) were compared to age-1.4 fish since the relative contributions of each of these age classes have historically tended to increase in escapement samples moving progressively upriver. These ratios of proportional abundance were then multiplied by the apportioned catch of either age-1.4 or -1.3 fish. These computations were summed over all runs to calculate age-specific contribution rates. Multiplication by total catch by age class yielded age-specific run contribution estimates:

N_i = Total catch of age group i

N_{ca} = Catch of age group a (where a was either age-1.4 or -1.3) in run c

F_{ci} = Proportion of fish of run c in N_i

$$(8) F_{ci} = \frac{R_{ci} \cdot N_{ca}}{\sum_{j=1}^n R_{ji} \cdot N_{ja}} \quad \text{(where } j \text{ was run number and } n \text{ was 7 for river and 3 for run)}$$

The total harvest of run c for age group i was then:

$$(9) N_{ci} = F_{ci} \cdot N_i$$

Catch Composition by Fishery. Estimates of run composition from scale pattern analysis and differential age composition analysis of District 1,

2, and 3 commercial catches were used to classify the catches of subsistence fisheries in these districts. District 4 catches were divided into two components for purposes of estimating catch proportions by stock: mainstem catches and Koyukuk River subsistence catches. Mainstem catches were classified to the lower, middle, or upper run based on estimates of run composition from scale patterns analysis and differential age composition analysis of pooled samples from commercial and subsistence gill net and fish wheel catches. Subsistence catches from the Koyukuk River were taken primarily in the upper portions of the drainage beyond river mile 700 and were assumed to more closely resemble fish of middle Yukon origin. No attempt was made to classify the Koyukuk River catch composition by age class.

Catch Composition Based on Geography. Catches in Districts 5, 6, and the Yukon Territory were classified to run based on geography. The entire District 5 harvest was classified as upper Yukon run because most of the District 5 catch occurred above the confluence of the Tanana River, and there are few documented chinook salmon spawning concentrations between the Tanana River confluence and the Yukon Territory fishery centered in Dawson. The entire District 6 harvest was determined to be the middle Yukon run, since neither lower nor upper runs are present in the Tanana River. The Yukon Territory harvest was classified as the upper run since neither lower nor middle runs are present in the Yukon Territory.

Results and Discussion

Age Composition:

Age-1.3 and -1.5 fish comprised a greater proportion of samples from all Alaskan rivers and in most Canadian rivers than was found in previous years for each of these rivers (Table 1). The weaker age-1.4 contribution to escapements as compared with samples from earlier years indicates relatively poor productivity and/or survival from the 1980 brood year. Increasing proportions of older-age fish in escapements progressing upriver were similar to trends observed in prior years. Age-1.5 fish generally increased in relative abundance from 5.8% and 10.6% in the Andreafsky and Anvik Rivers, respectively, to an average of 20.0% for Canadian rivers combined. Conversely, the proportion of age-1.3 fish declined from 69.8% and 50.0% in the Andreafsky and Anvik Rivers, respectively, to an average of 13.9% for Canadian rivers combined.

The greatest proportion of freshwater-age-2 fish was found in the Nisutlin River sample, comprising 33.9%. In past years, freshwater-age-2 fish were primarily found in upper river samples. However, samples from the Jim River in 1986 showed a relatively high proportion of age-2.2, -2.3 and -2.4 fish (9.0% combined) compared to other samples collected in interior Alaska.

Classification Accuracies of Run and River of Origin Models:

Age 1.4. A 3-way run of origin model using the same pooled-river standards as in previous years (lower: Andreafsky and Anvik Rivers; middle: Chena and Salcha Rivers; upper: Canada mainstem commercial fishery) gave a mean classification accuracy of 69.6% (Table 2A), 2.1 times greater than random

chance. Model classification accuracy of age-1.4 fish in 1986 was slightly less than in 1985 (71.1%). The only difference in the model presented in Table 2A from models used in previous years was the use of DFO fish wheel samples as the standard and not Canadian commercial fishery samples. Similar to past years, the lower river standard showed the greatest classification accuracy (86.4%). Middle and upper river standards showed the least classification accuracy (62.6% and 59.8%, respectively), misclassifying primarily to each other. High misclassification between middle and upper river standards has been observed every year since initiation of the Yukon River chinook salmon stock identification study in 1980.

A second 3-way model was constructed which differed in that it included samples from the Nulato River in the lower river standard (Table 2B). The Nulato River was included into the lower river standard because univariate analysis of variance F- tests of scale feature measurements indicated no significant difference ($\alpha = 0.05$, $df=2,102$) in the majority (59.5%) of mean freshwater annular, freshwater plus growth and combined marine annular zone scale variables among the Nulato, Andreafsky and Anvik Rivers. These three rivers are located in the same lower Yukon geographic area. Mean classification accuracy of this model was 66.7%, 2.0 times greater than random chance. Again, the lower river standard had the greatest classification accuracy (78.5%) and the upper river standard had the least (56.0%). Misclassification trends were similar to those of the model in Table 2A.

A 2-way model was constructed which differed from the above 3-way model in that the middle river standard was excluded (Table 2C). This model was necessary to identify runs of origin in age-1.4 samples from commercial fishing periods in which middle river stocks did not contribute to the harvest. This occurred when a 3-way model resulted in large negative proportions of middle run fish estimated in the catch. Mean classification accuracy of this model was 79.1%, 1.6 times greater than random chance.

A 4-way model was constructed with the Nulato River included in the lower river standard and the Jim and South Fork Koyukuk River escapements as a fourth standard (Table 2D). Middle and upper river standards were the same as in the preceding 3-way models. Jim and South Fork Koyukuk Rivers formed a fourth standard because in analysis of variance tests using run of origin data for age-1.4 fish, scale variables in samples from the Jim and South Fork Koyukuk Rivers suggested distinction from other Alaskan escapement samples. Geographically, the confluence of the Koyukuk River with the Yukon River is located between the lower and middle river regions. However, chinook salmon spawning populations in the upper Koyukuk River drainage are about as far from the mouth of the Yukon River as is the Canadian border, and were the northern most samples collected in this study. Mean classification accuracy for this 4-way model was 50.3%, 2.0 times greater than random chance. The lower and middle river standards showed the greatest classification accuracy (57.4% each), while the Jim and South Fork Koyukuk Rivers showed the least (39.1%). Jim and South Fork Koyukuk River samples misclassified primarily to lower and middle river fish in this age-1.4 model.

Mean classification accuracy of a 7-way river of origin model (six Alaskan escapements and pooled DFO fish wheel sample) was 38.4%, or 2.7 times greater than random chance (Table 3). The Chena River showed the greatest classification accuracy (54.6%) while the Anvik River showed the least (19.2%). Andreafsky, Anvik and Nulato Rivers misclassified primarily among themselves as a group (75.7%, 57.6%, and 82.5%, respectively) supporting the pooling of these rivers into a lower river standard. Samples from the Jim and South Fork Koyukuk Rivers misclassified in equal proportions (30.4%) to escapements downriver and upriver from the confluence of the Koyukuk with the Yukon River. These results indicate that sampling of the Koyukuk River drainage should be expanded, and scale patterns more fully examined. Chena and Salcha Rivers misclassified primarily to each other as a group (73.2% and 61.0%, respectively) which supports pooling of these rivers into a middle river standard. Misclassification of age-1.4 DFO fish wheel samples to Alaskan rivers was 69.2%. The average age-1.4 Alaskan escapement sample misclassified 10.0% to Canada.

Age 1.3. A 3-way run of origin model using the same pooled-river standards as in previous years gave a mean classification accuracy of 83.4% (Table 4A), which is 2.5 times greater than random chance. Model classification accuracy of age-1.3 fish in 1986 was the highest on record. Similiar to past years, the lower river standard showed the greatest classification accuracy (96.5%). Middle and upper river standards showed the least accuracy (75.8% and 77.9%, respectively), misclassifying primarily to each other.

A second 3-way model was constructed which differed in that it included samples from the Nulato River in the lower river standard (Table 4B). The Nulato River was included in the lower river standard, because similiar to age-1.4 fish, analysis of variance F-tests indicated no significant difference ($\alpha = 0.05$, $df=2,234$) in the majority (66.7%) of mean freshwater annular, freshwater plus growth and combined marine annular zone scale variables among the Nulato, Andreafsky and Anvik Rivers. Mean classification accuracy was 80.7%, 2.4 times greater than random chance. Again, the lower river standard had the greatest classification accuracy (95.3%) and the middle river standard had the least (70.5%). Misclassification trends were similiar to those in the model in Table 4A.

A 2-way model was constructed which differed from the above 3-way model in that the middle river standard was excluded (Table 4C). This model was necessary to identify runs of origin in age-1.3 samples from commercial fishing periods in which middle river stocks did not contribute to the harvest. This occurred when a 3-way model resulted in large negative proportions of middle run fish estimated in the catch. Mean classification accuracy of this model was 96.6%, 1.9 times greater than random chance.

A 4-way model was constructed which included the Nulato River in the lower river standard and the Jim and South Fork Koyukuk River escapements as a fourth standard (Table 4D). Middle and upper river standards were the same as in the preceeding 3-way models. In analysis of variance tests using run of origin scale variable data from age-1.3 fish, Jim and South Fork Koyukuk River scale variables were significantly different from lower river standards, although not as distinctive from middle river standards. Mean classification accuracy for this 4-way model was 65.2%, 2.6 times

greater than random chance. Similiar to age-1.4 fish, the lower and middle river standards showed the greatest classification accuracies (94.3% and 67.4%, respectively). However, in contrast to the age-1.4 model, Canadian samples showed the poorest classification accuracy (48.2%), and age-1.3 Jim and South Fork Koyukuk River samples misclassified primarily to Canada.

Mean classification accuracy of a 7-way river of origin model was 43.5%, or 3.0 times greater than random chance (Table 5). The Salcha River showed the greatest classification accuracy (68.8%), while the Anvik River showed the least (19.6%). Andreafsky, Anvik, and Nulato Rivers classified primarily among themselves as a group (94.8%, 89.2% and 93.3%, respectively) supporting pooling of these rivers into a lower river standard. Samples from the Jim and South Fork Koyukuk Rivers misclassified primarily to Canada. Chena and Salcha Rivers classified primarily to each other as a group (67.8% and 84.4%, respectively) supporting pooling of these rivers into a middle river standard. The misclassification pooling rate of age-1.3 DFO fish wheel samples to Alaskan rivers was 55.8%. The average age-1.3 Alaskan escapement sample misclassified 9.2% to Canada.

Catch Composition:

Model Selection. Relative precision of the 3-way, 4-way, and 7-way models was defined by comparing the width of 90% confidence intervals around adjusted run proportion estimates for commercial catches by period in Districts 1, 2, and 4. The greatest levels of precision in estimating the catch proportions by stock for both age-1.4 and -1.3 fish were obtained using 3-way run of origin models which included samples from the Nulato River in the lower river standards. These models were chosen to classify the 1986 Yukon River chinook salmon harvest to geographic region of origin. Hereafter, any references to a run of origin model will be the 3-way which included samples from the Nulato River.

Catch proportions by stock for age-1.4 and -1.3 fish using 4-way models with Koyukuk River as the fourth standard apportioned only small percentages of the total harvest to middle run stocks. Primary problems with the 4-way models were misclassification of Jim and South Fork Koyukuk River stocks with lower and upper run of origin stocks, and low precision of adjusted run proportion estimates.

Catch proportions by stock for age-1.4 and -1.3 fish using 7-way river of origin models produced wide 90% confidence intervals around adjusted mean estimates. Increased precision in discerning river of origin stocks is required before these models can supplant geographic region of origin models.

Scale Patterns Analysis. Scale character measurements which were most powerful in distinguishing between the three runs of origin for age-1.4 fish were: (1) width of freshwater annular zone relative to size of total freshwater growth zone, (2) distance between the sixth and twelfth circulus relative to the total width of the first marine annular zone, (3) distance between the last two circuli of the freshwater annular zone relative to the width of the zone, and (4) the number of circuli in the freshwater plus growth zone (variables 67, 100, 26, and 61, respectively, in Appendix

Table 2). For age-1.3 fish, the most distinguishing scale measurements were: (1) width of freshwater annular zone relative to size of total freshwater growth zone, (2) width of the freshwater plus growth zone, (3) average distance between circuli in the freshwater zone, and (4) number of circuli in freshwater plus growth (variables 67, 62, 27, and 61, respectively). Secondarily selected variables were derived from the first marine and first freshwater annular zones.

Group means and their standard errors for the number of circuli and width of the first freshwater, plus growth, and marine annular zones are shown in Appendix Table 3. The number of circuli and width of zones by year for lower, middle and upper runs of origin are shown in Appendix Figures 1-3. Digitized scales of age-1.4 and -1.3 middle run fish in 1986 demonstrated the least freshwater growth of the last five years (1982-86). For age-1.3 fish, lower run stocks were characterized with the least plus growth and upper run stocks with the greatest first marine zone growth of the last 5 years.

Proportion of Catch. Lower and upper runs of origin comprised the greatest proportion of the catch in Districts 1 and 2 for age-1.4 and -1.3 fish (Tables 6 and 7) in 1986. This contrasts with results for previous years, in which middle run of origin stocks contributed significantly to the commercial catch. Possibilities for the apparent low harvest of middle run fish were investigated, including bias in digitizing. Results from multivariate tests between data from different people who digitized scales did not indicate that bias in digitizing caused middle run fish to drop out of catch contributions by stock. Lack of significant middle run contribution to the 1986 Yukon River chinook salmon harvest may be attributed to either a less than average return of middle run fish and/or the timing of the lower river fishery relative to the entry timing of middle run stocks. In either case the escapement objectives were achieved for the Chena and Salcha Rivers.

Similar to previous years, proportions of lower and upper run fish varied in Districts 1 and 2 catches through time (Figures 4- 7). In District 1 the contribution of the lower run increased and the upper run decreased as the fishing season progressed. Run of origin contribution rates by fishing period demonstrated an irregular linear trend in District 1 and a sigmoidal trend in District 2 for both age-1.4 and -1.3 lower and upper run fish. Differences in run of origin contribution rates by fishing period are likely due to differential run timing of the contributing stocks and differential harvest pressures.

We estimate that the total District 1 age-1.4 catch was composed of 7,999 (35.1%) lower, 1,109 (4.9%) middle, and 13,696 (60.0%) upper Yukon fish (Table 8). In District 2, the age-1.4 catch was estimated to be composed of 7,116 (40.2%) lower, 104 (0.6%) middle, and 10,466 (59.2%) upper Yukon fish, (Table 9).

The age-1.3 catch in District 1 was estimated to be composed of 7,278 (44.1%) lower, 15 (0.1%) middle, and 9,202 (55.8%) upper run of origin fish (Table 8). In District 2 the age-1.3 catch was composed of 4,910 (36.5%) lower, 120 (0.6%) middle, and 8,417 (59.5%) upper run of origin fish (Table 9).

Scale patterns analysis was applied to the age-1.4 and -1.3 commercial catches from Districts 1 and 2 and commercial and subsistence catches from District 4 to classify 64.8% (72,942 fish) of the total Yukon River age-1.4 and -1.3 harvest (112,626 fish) to their run of origin. Of those fish classified, a total of 31,263 (42.9%) were estimated to be of Alaskan origin (Table 10). Precision of this estimate was high (coefficient of variation 5.9%). Harvest of Canadian origin fish was estimated at 41,679 (57.1%).

An additional 11,891 fish (7.2% of total harvest) from estimated age-1.4 and -1.3 subsistence catches in Districts 1, 2, and 3 were classified to their run of origin by applying proportions estimated from scale patterns analysis of commercial catches in these same districts.

Differential Age Composition Analysis. The remaining six age classes contributed 52,691 fish (31.5%) to the total drainage harvest. They were classified to run of origin using differences in escapement age composition in each run (Table 11). The majority of age-1.5 harvests (54%-63%) in Districts 1-4 were classified to the upper run of origin, as were the majority of age-1.2 harvests (75%-79%). Virtually all fish with 2 years of freshwater growth (age-2.3, -2.4 and -2.5) were classified to the upper run of origin.

In districts of mixed runs (Districts 1-4) middle run fish of all ages combined were least abundant in Districts 1 (1,988 fish or 3.4%) and 2 (355 fish or 0.7%) and most abundant in District 4 (1,172 or 21.8%) commercial and subsistence catches. Lower Yukon fish comprised a greater percentage of commercial and subsistence catches in District 1 (21,214 fish or 36.4%) and 2 (17,894 fish or 37.0%) than in District 4 (2,609 fish or 25.9%). Upper Yukon fish were also more abundant in District 1 (35,107 fish or 60.2%) and 2 (30,084 fish or 62.2%) than in District 4 (5,364 fish or 53.2%) commercial and subsistence catches.

Geographic Analysis. A total of 44,377 fish (26.8% of total drainage harvest) was classified to run of origin based on geography. District 5 and Yukon Territory commercial and subsistence catches (38,785 fish or 23.5% of total drainage harvest) were assumed to be of upper Yukon River origin. Commercial and subsistence catches in District 6 and subsistence catches from the Koyukuk River in District 4 were classified entirely to the middle Yukon run and totaled 5,592 fish (3.4% of total drainage harvest).

Total Harvest. The commercial and subsistence harvest of chinook salmon from the entire Yukon River drainage was classified to run of origin (Table 11) based on: (1) the findings of the scale patterns analysis of age-1.4 and -1.3 fish, (2) the age composition analysis of the remaining age classes, (3) the assumptions concerning unsampled fisheries, and (4) stock origins based on geography. Upper Yukon River fish comprised the largest run component and contributed 112,189 fish or 67.9% of the total drainage harvest. Lower Yukon fish were next in abundance at 43,928 fish (26.6%). The contribution of 9,201 fish from the middle Yukon run comprised only 5.6% of the total harvest.

COMPARISON OF SCALE PATTERN MEASUREMENTS AMONG DIGITIZERS

Methods

The senior author became project leader for the Yukon River chinook salmon stock biology project in November 1986, and was responsible for aging scales, measuring scale features (digitizing), constructing run of origin models, and classifying catches by stock. The second author had digitized Yukon River chinook salmon scales collected from 1982-85 and had been responsible for model construction and catch classification by stock (Wilcock and McBride 1983; Wilcock 1984; 1985; 1986). Merritt was trained by Wilcock to read and digitize scales to minimize differences that could arise due to the subjective nature of interpreting scale features.

We hypothesized that the change in project leaders would not adversely affect the comparability of current stock composition estimates with historical data. Two approaches were taken to investigate the effect a change in digitizer might have on scale measurements, model construction, and estimates of catch proportions by stock. First, to test for a significant effect on scale measurements due to digitizer, a two-way multivariate analysis of variance (MANOVA) was conducted. A full factorial two-way MANOVA design (Morrison 1976) was used to determine the resulting source of variation due to the interaction of digitizer and stock: i.e., a significant interaction effect would indicate that the main effect or difference in scale measurements between stocks would be confounded with a digitizer effect. A second approach was to compare the accuracy of linear discriminant functions and the resulting catch apportionments based on models built with scale measurements made by Wilcock and Merritt from the same group of scales. Even if there was a significant effect due to digitizer, or interaction between digitizer and stock, of ultimate interest were the effects on model accuracy and catch apportionment.

Variability due to experimental error was controlled directly by randomly selecting 25 Yukon River chinook salmon age-1.4 scales from each of the three runs of origin. Scales were digitized by the two readers using standard procedures and the same hardware and software. A fixed effect model was assumed and the Pilai trace was used as a test statistic. It is the most robust statistic against violation of the assumptions of multivariate normality and homogeneity of covariance matrices of those statistics commonly reported by computer based statistical packages (Harris 1985). All variables screened for LDF analysis (Appendix Table 1) were functions of the number of circuli or size of each of five scale growth zones, resulting in 10 key variables. The size and count variables for each scale zone were highly correlated. MANOVA assumes a p-dimensional multinormal random variable, and use of a set of pairwise-correlated measurements was believed to be in violation of this assumption. A decision to use only size or count variables, but not both, was made. Only variables which were a function of the size of the first three zones entered the LDF model in 1986. Accordingly, only the size of the first three scale zones (freshwater annular, freshwater plus growth, and first marine annular) were included as dependent variables. Run of origin (upper, lower, and middle)

and digitizer (Merritt and Wilcock) were the independent variables. Separate analysis using circuli count data was also conducted.

Each scale reader digitized all age-1.4 scale samples from the lower run, a subsample of 100 scales each from the middle and upper Yukon runs, and all available catch samples from the four largest periods in the 1986 lower Yukon River commercial fishery. Stock standards were composed of samples in proportion to abundance as indexed by aerial surveys from the Andreefsky, Anvik and Nulato Rivers for the lower Yukon run, and the Chena and Salcha Rivers for the middle run. The upper run was represented by scales sampled from fish wheel catches of a mark and recapture study conducted by DFO in the mainstem Yukon River just upstream from the US/Canada border. Linear discriminant functions were calculated for each reader using standard procedures. Classification results were used to estimate the stock composition of catches from fishing periods 2 and 3 in District 1, and fishing periods 3 and 5 in District 2. Run composition estimates were intended only for comparison between readers, therefore no attempt was made to estimate catch composition by stock, and constrained models with fewer than three stocks were not generated when estimated proportions were less than zero.

Results

There were differences in the mean size of the first three scale growth zones as measured by Merritt and Wilcock (Table 12). In addition there appears to be a departure from parallelism (Figure 8) in all cases, though it is most striking in the freshwater plus growth zone. The approximate 50% difference in size of the freshwater plus growth zone (20 units) between digitizers for the upper run of origin represents a difference of 1.7 circuli (Figure 8). This departure indicates a possible interaction between the effect due to the run of origin and the change in digitizer. Results from a series of ANOVAs support the conclusions drawn from inspection of the data. Tests for homogeneity of variance showed no significant difference among treatment cell variances for the freshwater annular and freshwater plus growth zones only. Attempts to fulfill the assumption of homogeneity of variances by transformations of the raw data for the size of the first marine annular zone were unsuccessful, and a non-parametric test was used. Residuals from the ANOVAs are presented in Figure 9 and are thought not to deviate too greatly from a normal distribution to invalidate this rather robust technique.

An additive model could be assumed (non-significant interaction term) for freshwater annular growth (Table 13). The difference between readers was not significant ($p=.23$) and the difference due to run of origin was highly significant ($p<.001$). A significant interaction between digitizer and run of origin in the size of the freshwater plus growth zone confounded any discussion of the main effect or differences due to digitizer or run of origin. Two non-parametric tests using size of first marine annular zone as the independent variable were conducted. A significant difference due to digitizer was detected but the difference in size among runs of origin was not significant ($p=0.32$). A run of origin effect could exist but was not detected above the within group variation, which in this case contains the

significant effect due to digitizer. A non-parametric test designed to test interaction was not found.

Results of the MANOVA (Table 14) indicate a significant interaction effect. Again this confounds any discussion of the main effects of run of origin or digitizer. A similar analysis was conducted using circuli count data for the three scale zones with similar results.

Linear discriminant models were developed for age-1.4 chinook salmon from measurements made by Merritt and Wilcock using the same scale samples (Table 15). Scale character Variable 67, the size of the first freshwater annular zone relative to the size of the total freshwater growth zone, was selected first for discriminant models for both scale readers (Table 15). The second variable selected differed between readers (Variable 66 for Wilcock and Variable 62 for Merritt), but were related as both were a function of the size of the freshwater plus growth zone. The third variable selected for each reader was based on incremental distances between circuli in the first marine annular zone relative to the total size of the zone.

Mean classification accuracies for both scale readers were similar (70% for Wilcock and 66% for Merritt). The greatest difference observed between readers was in the percentage of lower Yukon scales correctly classified (83.1% for Wilcock and 69.2% for Merritt). Lower Yukon scales digitized by Merritt were more frequently misclassified as upper Yukon (23.1%) than scales digitized by Wilcock (9.3%). The difference between readers for all other correct classifications and misclassifications was less than 5%.

Run composition estimates of catch from four commercial fishing periods compared well between models built by both scale digitizers (Table 16, Figure 10). Differences in run composition estimates between readers were largest for lower Yukon fish from period 5 of District 2 (28.1% difference) and period 3 of District 1 (19.9% difference). The average difference between run proportion estimates for the two readers was less than 12% and confidence intervals for all estimates overlapped considerably.

Variability in repetitive scale patterns measurements of District 1 catch samples was tested for Merritt with an ANOVA. No significant differences ($\alpha=0.05$, $df=1,38$) were detected in the size or number of circuli in the first 3 scale growth zones (Variables 1, 2, 61, 62, 70 and 71). Within-reader variability in scale patterns measurements for Wilcock was not examined.

Discussion

An evaluation of the difference between readers in their interpretation of scale features was prompted by the 1986 catch apportionment results. In no year since catch apportionments were initiated in 1982 has the middle run contributed so few fish to total catch. This could have been due to a very weak return of middle run fish in 1986, differential exploitation of runs due to the timing and execution of the fishery, or an underallocation due to the change in digitizer. Escapement data refuted the assertion of a very weak return of middle run chinook salmon (Barton 1987, ADF&G 1987). The

evaluation of the difference between readers did not indicate any bias limited to middle run scales. No significant difference was found between digitizers in either their interpretation of the size of the freshwater annular growth zone (Table 13) or in the simple effect of digitizer for middle run chinook salmon freshwater plus growth zone measurements (a post hoc comparison of a 2-way ANOVA using a Bonferroni critical value for setwise error of $\alpha = .05$). There was a significant difference between digitizers for the first marine annular zone and overall a significant interaction effect from the MANOVA. Figure 8 best illustrates the difference in mean size of the three scale growth zones by run of origin and digitizer. The relationship between digitizers was fairly constant for the lower and middle runs. Additional calibration of the new digitizer for the upper run freshwater plus growth zone, and the first marine growth zone for all runs, could increase comparability with historical data. The middle run proportions are all within 5% between the two digitizers (Table 15), and it is the classification of lower run fish that shows the greatest difference, with misclassification to the upper run. Yet overall the two digitizers classified the catch quite similarly (Figure 10) and trend well together.

In conclusion, the small apportionment of the 1986 catch to middle run chinook salmon can not directly be attributed to a change in digitizer. Results are compatible with previous years, although additional calibration is recommended for upper run freshwater plus growth zone measurements and the first marine growth zone for all three runs.

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LITERATURE CITED

- ADF&G (Alaska Department of Fish and Game). 1987. Annual management report 1986 Yukon area. Alaska Department of Fish and Game, Division of Commercial Fisheries, Region III Report, Anchorage.
- Barton, L.H. 1987. Population estimate of chinook salmon escapement in the Chena River in 1986 based upon mark and recapture techniques. Alaska Department of Fish and Game, Division of Commercial Fisheries, Region III: Yukon Salmon Escapement Report 31, Anchorage, Alaska.
- Barton, L.H. 1984. A catalog of Yukon River salmon spawning surveys. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 121, Juneau.
- Buklis, L.S. 1987. Age, sex, and size of Yukon River salmon catch and escapement, 1986. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 221, Juneau.
- Clutter, R.I. and L.E. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. Bulletin of the International Pacific Salmon Fisheries Commission 9, Vancouver, British Columbia.
- Cook, R. and G. Lord. 1978. Identification of stocks of Bristol Bay sockeye by evaluating scale patterns with a polynomial discriminant method. U.S. Fish and Wildlife Service Fisheries Bulletin 76 (2):415-423.
- Enslein, K., A. Ralston, and H.S. Wilf, Editors. 1977. Statistical methods for digital computers. John Wiley & Sons, Inc., New York.
- Fisher, R.A. 1936. The use of multiple measurements in taxonomic problems. Annual Eugenics 7:179-188.
- Harris, R.J. 1985. A primer of multivariate statistics, 2nd edition. Academic Press, Inc., New York.
- Hollander M. and D.A. Wolfe. 1973. Nonparametric statistical methods. John Wiley & Sons, New York.
- Lachenbruch, P.A. 1967. An almost unbiased method of obtaining confidence intervals for the probability of misclassification in discriminant analysis. Biometrics 23(4):639-645.
- McBride, D.N. and S.L. Marshall. 1983. Feasibility of scale pattern analysis to identify the origins of chinook salmon (*Oncorhynchus tshawytscha* Walbaum) in the lower Yukon River commercial gillnet fishery, 1980-1981. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 208, Juneau.

LITERATURE CITED (Continued)

- Meyers, K.W. and five coauthors. 1984. Origins of chinook salmon in the area of the Japanese mothership and landbased driftnet salmon fisheries in 1975-1981. (Report submitted to annual meeting of the International North Pacific Fisheries Commission, Vancouver, Canada, November 1984). Fisheries Research Institute, University of Washington, Seattle.
- Pella, J. and T. Robertson. 1979. Assessment of composition of stock mixtures. Fishery Bulletin 77 (2):387-398.
- Rogers, D.E., K.W. Meyers, C.K. Harris, C.M. Knudsen, R.V. Walker, and N.D. Davis. 1984. Origins of chinook salmon in the area of the Japanese mothership salmon fishery. Final Report, July 1983-Sept. 1984. Contract No. 84-0152. Fisheries Research Institute. University of Washington. Seattle.
- Ryan, P. and M. Christie. 1976. Scale reading equipment. Fisheries and Marine Service, Canada. Technical Report PAC/T-75-8.
- Sokal, R.R. and F.J. Rohlf. 1969. Biometry. W.H. Freeman and Co., San Francisco, California.
- Wilcock, J.A. and D.N. McBride. 1983. Origins of chinook salmon (*Oncorhynchus tshawytscha* Walbaum) in the Yukon River fisheries, 1983. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 243, Juneau.
- Wilcock, J.A. 1985. Origins of chinook salmon (*Oncorhynchus tshawytscha* Walbaum) in the Yukon River fisheries, 1984. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 157, Juneau.
- Wilcock, J.A. 1986. Origins of chinook salmon (*Oncorhynchus tshawytscha* Walbaum) in the Yukon River fisheries, 1985. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Report 178, Juneau.
- YRJTC (Yukon River Joint Technical Committee). 1987. Yukon River Technical Report, 1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage.

TABLES AND FIGURES

Table 1. Age composition summary of Yukon River chinook salmon escapements, 1986.

River	Aerial Survey Est.	Sample Size	Brood Year and Age Group								
			1983 1.1	1982 1.2	1981 1.3	1980 2.2	1980 1.4	1980 2.3	1979 1.5	1979 2.4	1978 2.5
Andreafsky	5,112	275 ^a	0.0	2.2	69.8	0.0	21.5	0.4	5.8	0.4	0.0
Anvik	1,118	142 ^b	0.0	0.7	50.0	0.0	38.0	0.0	10.6	0.7	0.0
Nulato	2,974	189	0.0	1.6	50.3	0.5	31.2	0.0	15.3	1.1	0.0
Jim	238 ^c	166	0.0	3.0	48.2	1.2	25.3	4.8	12.0	3.0	2.4
Chena	2,288 ^d	729	0.1	9.3	51.2	0.0	28.5	1.4	9.2	0.1	0.1
Salcha	3,368	586	0.2	11.8	43.7	0.0	28.5	1.0	14.8	0.0	0.0
Big Salmon	745 ^e	233	0.0	1.7	21.9	0.9	41.2	5.6	19.7	6.0	3.0
Little Salmon	54 ^f	58	0.0	0.0	20.7	0.0	39.7	10.3	20.7	5.2	3.4
Nisutlin	703	177	0.0	0.0	2.8	0.0	40.7	2.8	11.9	31.1	10.7
Tatchun	155 ^g	2	0.0	50.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0
Teslin	-	34	0.0	5.9	8.8	0.0	41.2	0.0	38.2	2.9	2.9
Mainstem Yukon	-	30	0.0	0.0	10.0	0.0	30.0	0.0	46.7	0.0	13.3

- a Includes 17 East Fork beach seine samples, 81 East Fork carcass samples, and 177 West Fork carcass samples.
- b Includes 3 beach seine samples.
- c Includes South Fork Koyukuk
- d Includes carcasses removed by tag recovery crew before date of aerial survey.
- e ADF&G aerial survey above Souch Cr.
- f Incomplete or poor survey conditions resulting in a minimal count.
- g Foot survey, DFO, Canada.

Table 2. Classification accuracies of linear discriminant run of origin models for age-1.4 Yukon River chinook salmon, 1986.

A. Three-way with pooled standards equivalent to historical data
 (1) lower: Andreafsky, Anvik (2) middle: Chena, Salcha (3)
 upper: DFO fish wheel^a

Region of Origin	Sample Size	Classified Region of Origin		
		Lower	Middle	Upper
Lower	44	<u>0.864</u>	0.023	0.114
Middle	187	0.102	<u>0.626</u>	0.273
Upper	199	0.181	0.221	<u>0.598</u>

Mean Classification Accuracy: 0.696

a Variables in the Analysis: 67, 62, 102, 26, 85, 61

C. Two-way^a
 (1) lower: Andreafsky, Anvik, Nulato (2) upper: DFO fish wheel

Region of Origin	Sample Size	Classified Region of Origin	
		Lower	Upper
Lower	61	0.787	0.213
Upper	185	0.205	0.795

Mean Classification Accuracy: 0.791

a Variables in the Analysis: 101, 62, 70

B. Three-way^a
 (1) lower: Andreafsky, Anvik, Nulato (2) middle: Chena, Salcha
 (3) upper: DFO fish wheel

Region of Origin	Sample Size	Classified Region of Origin		
		Lower	Middle	Upper
Lower	65	<u>0.785</u>	0.077	0.138
Middle	184	0.082	<u>0.658</u>	0.261
Upper	200	0.192	0.250	<u>0.560</u>

Mean Classification Accuracy: 0.667

a Variables in the Analysis: 67, 100, 26, 61, 70, 89, 8, 2

D. Four-way^a
 (1) lower: Andreafsky, Anvik, Nulato (2) Koyukuk: Jim, South Fork
 (3) middle: Chena, Salcha (4) upper: DFO fish wheel

Region of Origin	Sample Size	Classified Region of Origin			
		Lower	Koyukuk	Middle	Upper
Lower	61	<u>0.574</u>	0.262	0.049	0.115
Koyukuk	23	0.261	<u>0.391</u>	0.217	0.130
Middle	136	0.037	0.184	<u>0.574</u>	0.206
Upper	186	0.194	0.124	0.210	<u>0.473</u>

Mean Classification Accuracy: 0.503

a Variables in the Analysis: 67, 26, 61, 100, 85

Table 3. Classification accuracy of a seven-way linear discriminant river of origin model for age-1.4 Yukon River chinook salmon, 1986.^a

River of Origin	Sample Size	Classified River of Origin						
		Andreafsky	Anvik	Nulato	Jim	Chena	Salcha	DFO f. w.
Andreafsky	33	<u>0.424</u>	0.030	0.303	0.152	0.000	0.030	0.061
Anvik	26	0.192	<u>0.192</u>	0.192	0.154	0.077	0.038	0.154
Nulato	40	0.225	0.150	<u>0.450</u>	0.075	0.075	0.000	0.025
Jim-Koyukuk	23	0.174	0.087	0.043	<u>0.391</u>	0.000	0.174	0.130
Chena	97	0.010	0.062	0.052	0.062	<u>0.546</u>	0.186	0.082
Salcha	82	0.024	0.012	0.024	0.183	0.232	<u>0.378</u>	0.146
DFO f. w.	185	0.092	0.168	0.065	0.065	0.200	0.103	<u>0.308</u>

Mean Classification Accuracy: 0.384

^a Variables in the Analysis: 67, 8, 102, 61, 30, 85, 26, 70, 106

Table 4. Classification accuracies of linear discriminant run of origin models for age-1.3 Yukon River chinook salmon, 1986.

A. Three-way with pooled standards equivalent to historical data
 (1) lower: Andreafsky, Anvik (2) middle: Chena, Salcha (3)
 upper: DFO fish wheel^a

Region of Origin	Sample Size	Classified Region of Origin		
		Lower	Middle	Upper
Lower	143	<u>0.965</u>	0.000	0.035
Middle	132	0.023	<u>0.758</u>	0.220
Upper	199	0.030	0.191	<u>0.779</u>

Mean Classification Accuracy: 0.834

a Variables in the Analysis: 67, 1, 83, 61, 26, 103, 72, 21, 71, 18

C. Two-way^a
 (1) lower: Andreafsky, Anvik, Nulato (2) DFO fish wheel

Region of Origin	Sample Size	Classified Region of Origin	
		Lower	Upper
Lower	211	<u>0.962</u>	0.038
Upper	199	0.030	<u>0.970</u>

Mean Classification Accuracy: 0.966

a Variables in the Analysis: 67, 83, 61, 62, 2, 14

B. Three-way^a
 (1) lower: Andreafsky, Anvik, Nulato (2) middle: Chena, Salcha
 (3) upper: DFO fish wheel

Region of Origin	Sample Size	Classified Region of Origin		
		Lower	Middle	Upper
Lower	211	<u>0.953</u>	0.014	0.033
Middle	132	0.053	<u>0.705</u>	0.242
Upper	199	0.025	0.211	<u>0.764</u>

Mean Classification Accuracy: 0.807

a Variables in the Analysis: 67, 62, 27, 61, 83, 14, 106, 8, 1, 16

D. Four-way^a
 (1) lower: Andreafsky, Anvik, Nulato (2) Koyukuk: Jim, South Fork
 (3) middle: Chena, Salcha (4) upper: DFO fish wheel

Region of Origin	Sample Size	Classified Region of Origin			
		Lower	Koyukuk	Middle	Upper
Lower	211	<u>0.943</u>	0.033	0.009	0.014
Koyukuk	55	0.109	<u>0.509</u>	0.145	0.236
Middle	132	0.061	0.076	<u>0.674</u>	0.189
Upper	199	0.015	0.286	0.216	<u>0.482</u>

Mean Classification Accuracy: 0.652

a Variables in the Analysis: 67, 62, 27, 61, 83, 72

Table 5. Classification accuracy of a seven-way linear discriminant river of origin model for age-1.3 Yukon River chinook salmon, 1986.^a

River of Origin	Sample Size	Classified River of Origin						DFO f. w.
		Andreafsky	Anvik	Nulato	Jim	Chena	Salcha	
Andreafsky	117	0.427	0.256	0.265	0.026	0.017	0.000	0.009
Anvik	46	0.326	0.196	0.370	0.087	0.000	0.000	0.022
Nulato	74	0.311	0.176	0.446	0.041	0.027	0.000	0.000
Jim-Koyukuk	55	0.036	0.073	0.000	0.436	0.109	0.073	0.273
Chena	118	0.000	0.000	0.042	0.102	0.407	0.271	0.178
Salcha	77	0.013	0.000	0.026	0.026	0.156	0.688	0.091
DFO f. w.	199	0.005	0.010	0.000	0.261	0.141	0.141	0.442

Mean Classification Accuracy: 0.435

a Variables in the Analysis: 67, 62, 1, 65, 80, 106

Table 6. Run composition estimates for age-1.4 chinook salmon from sampled commercial catches in Yukon River Districts 1, 2, and 4, 1986.

District	Commercial Fishing Period	Dates	Sample Size	Region of Origin	Prop. of Catch	90 Percent Confidence Interval	
						Lower Bound	Upper Bound
1	Preseason	6/06-6/13	104	Lower	0.082	-0.069	0.233
				Upper	0.918	0.767	1.069
	1 ^a	6/14-6/14	71	Lower	0.062	-0.111	0.236
				Upper	0.938	0.764	1.111
	2 ^b	6/19-6/20	98	Lower	0.309	0.146	0.471
				Upper	0.691	0.529	0.854
	3 ^b	6/23-6/24	120	Lower	0.244	0.065	0.423
				Middle	0.252	-0.035	0.539
				Upper	0.504	0.157	0.850
	4 ^a	6/25-6/26	64	Lower	0.360	0.165	0.555
				Upper	0.640	0.445	0.835
	5 ^b	6/29-6/30	132	Lower	0.416	0.268	0.565
				Upper	0.584	0.435	0.732
	6 ^a	7/02-7/02	25	Lower	0.364	0.068	0.661
Upper				0.636	0.339	0.932	
7 ^b	7/03-7/04	105	Lower	0.711	0.539	0.884	
			Upper	0.289	0.116	0.461	
8 ^a	7/07-7/08	25	Lower	0.434	0.135	0.733	
			Upper	0.566	0.267	0.865	
2	1 ^a	6/15-6/15	34	Lower	0.160	-0.084	0.404
				Upper	0.840	0.596	1.084
	2 ^a	6/21-6/21	29	Upper	1.000	0.853	1.279
				Lower	0.112	-0.031	0.255
	3 ^b	6/22-6/23	125	Upper	0.888	0.745	1.031
				Lower	0.112	-0.031	0.255
5 ^b	6/26-6/27	119	Lower	0.580	0.419	0.740	
			Upper	0.420	0.260	0.581	
6 ^b	7/01-7/02	125	Lower	0.799	0.630	0.967	
			Upper	0.201	0.033	0.370	
4	1-16 ^c	6/22-8/29	268	Lower	0.268	0.154	0.382
				Middle	0.208	0.049	0.367
				Upper	0.524	0.319	0.729
				Lower	0.268	0.154	0.382

a Six in (15.2 cm) maximum mesh size.

b Unrestricted mesh size.

c Fish taken by set gill net and fish wheel.

Table 7. Run composition estimates for age-1.3 chinook salmon from sampled commercial catches in Yukon River Districts 1, 2, and 4, 1986.

District	Commercial Fishing Period	Dates	Sample Size	Region of Origin	Prop. of Catch	90 Percent Confidence Interval	
						Lower Bound	Upper Bound
1	Preseason	6/06-6/13	133	Lower	0.279	0.186	0.372
				Middle	0.050	-0.111	0.210
				Upper	0.671	0.493	0.849
	1 ^a	6/14-6/14	106	Lower	0.288	0.183	0.392
				Middle	0.012	-0.158	0.183
				Upper	0.700	0.506	0.894
	2 ^b	6/19-6/20	82	Lower	0.452	0.354	0.550
				Upper	0.548	0.450	0.646
	3 ^b	6/23-6/24	84	Lower	0.249	0.162	0.335
				Upper	0.751	0.665	0.838
	4 ^a	6/25-6/26	104	Lower	0.432	0.345	0.519
				Upper	0.568	0.481	0.655
	5 ^b	6/29-6/30	82	Lower	0.648	0.553	0.744
				Upper	0.352	0.256	0.447
	6 ^a	7/02-7/02	52	Lower	0.463	0.340	0.586
Upper				0.537	0.414	0.660	
7 ^b	7/03-7/04	55	Lower	0.592	0.474	0.711	
			Upper	0.408	0.289	0.526	
8 ^a	7/07-7/08	35	Lower	0.642	0.497	0.787	
			Upper	0.358	0.213	0.503	
2	1 ^a	6/15-6/15	60	Lower	0.129	0.045	0.212
				Upper	0.871	0.788	0.955
	2 ^a	6/21-6/21	84	Lower	0.121	0.051	0.191
				Upper	0.879	0.809	0.949
	3 ^b	6/22-6/23	83	Lower	0.304	0.213	0.395
				Upper	0.696	0.605	0.787
	5 ^b	6/26-6/27	103	Lower	0.453	0.338	0.569
				Middle	0.029	-0.122	0.180
Upper				0.518	0.336	0.699	
6 ^b	7/01-7/02	83	Lower	0.524	0.426	0.622	
			Upper	0.476	0.378	0.574	
8 ^b	7/06-7/07	44	Lower	0.358	0.229	0.487	
			Upper	0.642	0.513	0.771	
4	1-16 ^c	6/22-8/29	268	Lower	0.428	0.353	0.503
				Middle	0.016	-0.079	0.111
				Upper	0.555	0.439	0.671

a Six in (15.2 cm) maximum mesh size.
b Unrestricted mesh size.
c Fish taken by set gill net and fish wheel.

Table 8. Classification of age-1.4 and -1.3 chinook salmon catches by run and fishing period for the commercial fishery in Yukon River District 1, 1986.

Region of Origin	Commercial Fishing Period	Dates	Age Group		Region of Origin	Commercial Fishing Period	Dates	Age Group	
			1.3	1.4				1.3	1.4
Lower	1 ^a	6/14-6/14	362	61	Lower	5	6/29-6/30	1,039	1,103
Middle			15	0	Middle			0	0
Alaska	^b		377	61	Alaska			1,039	1,103
Upper	^c		880	922	Upper			565	1,548
Total			1,257	983	Total			1,604	2,651
Lower	2	6/19-6/20	2,448	3,040	Lower	6 ^a	7/02-7/02	386	182
Middle			0	0	Middle			0	0
Alaska			2,448	3,040	Alaska			386	182
Upper			2,969	6,798	Upper			448	319
Total			5,417	9,838	Total			834	501
Lower	3	6/23-6/24	750	1,074	Lower	7	7/03-7/04	823	1,837
Middle			0	1,109	Middle			0	0
Alaska			750	2,183	Alaska			823	1,837
Upper			2,264	2,219	Upper			567	747
Total			3,014	4,402	Total			1,390	2,584
Lower	4 ^a	6/25-6/26	909	483	Lower	8-16 ^a	7/07-8/22	561	219
Middle			0	0	Middle			0	0
Alaska			909	483	Alaska			561	219
Upper			1,196	858	Upper			313	285
Total			2,105	1,341	Total			874	504
TOTAL					Lower	1-16	6/14-8/22	7,278	7,999
					Middle			15	1,109
					Alaska			7,293	9,108
					Upper			9,202	13,696
					Total ^d			16,495	22,804

a Chum salmon season, 6 in (15.2 cm) maximum mesh size.

b Lower and middle runs comprise the Alaskan contribution.

c Upper runs comprise the Canadian contribution.

d Restricted mesh periods 9-16 were not sampled, but catch composition was assumed to be the same as in period 8.

Table 9. Classification of age-1.4 and -1.3 chinook salmon catches by run and fishing period for the commercial fishery in Yukon River District 2, 1986.

Region of Origin	Commercial Fishing Period Dates		Age Group		Region of Origin	Commercial Fishing Period Dates		Age Group	
	Period	Dates	1.3	1.4		Period	Dates	1.3	1.4
Lower	1 ^a	6/15-6/15	51	33	Lower	5	6/26-6/27	1,875	3,181
Middle			0	0	Middle			120	0
Alaska ^b			51	33	Alaska			1,995	3,181
Upper ^c			345	174	Upper			2,143	2,304
Total			396	207	Total			4,138	5,485
Lower	2 ^a	6/21-6/21	108	0	Lower	6	7/01-7/02	1,056	2,538
Middle			0	0	Middle			0	0
Alaska			108	0	Alaska			1,056	2,538
Upper			783	465	Upper			960	638
Total			891	465	Total			2,016	3,176
Lower	3	6/22-6/24	1,291	716	Lower	7 ^a	7/03-7/04	53	34
Middle			0	0	Middle			0	0
Alaska			1,291	716	Alaska			53	34
Upper			2,955	5,675	Upper			360	182
Total			4,246	6,391	Total			413	216
Lower	4 ^a	6/24-6/24	68	44	Lower	8	7/07-7/15	149	469
Middle			0	0	Middle			0	104
Alaska			68	44	Alaska			149	573
Upper			460	231	Upper			266	665
Total			528	275	Total			415	1,238
					Lower 9-16 ^a		7/09-8/24	259	101
					Middle			0	0
					Alaska			259	101
					Upper			145	132
					Total			404	233
TOTAL					Lower 1-16		6/15-8/24	4,910	7,116
					Middle			120	104
					Alaska			5,030	7,220
					Upper			8,417	10,466
					Total ^d			13,447	17,686

a Chum salmon season, 6 in (15.2 cm) maximum mesh size.

b Lower and middle runs comprise the Alaskan contribution.

c Upper runs comprise the Canadian contribution.

d Restricted mesh periods 4, 7, and 9-16 were not sampled. Catch composition of periods 4 and 7 was estimated from period 1. Catch composition of periods 9-16 was estimated to be the same as in periods 8-16, District 1.

Table 10. Total harvest of age-1.4 and -1.3 chinook salmon by nation of origin estimated from scale patterns analysis for Yukon River Districts 1, 2 and 4, 1986.^a

Region of Origin	Number of Fish	%	Approximate 90 Percent Confidence Interval		SE	Coefficient of Variation ^b
			Lower Bound	Upper Bound		
Alaska	31,263	(42.9)	28,228	34,297	1,845	5.9%
Canada	41,679	(57.1)	38,593	44,764	1,876	4.5%
Total ^c	72,942	(100.0)				

a For illustration purposes the estimated number of fish is assumed to follow a normal distribution.

b Coefficient expressed as a percentage.

c Includes District 1 commercial catch in periods 1-8, District 2 commercial catch in periods 1-3, 5, 6, and 8, and District 4 commercial and subsistence season total catch minus 941 from the Koyukuk River.

Table 11. Run composition by age class and region of origin of chinook salmon from Yukon River Alaskan Districts 1, 2, 3, 4, 5, 6 and Yukon Territory commercial and subsistence catches, 1986.

		Brood Year and Age Group													
District	Fishery	Commercial Fishing Dates	Region of Origin	1983		1982		1981		1980		1979		1978	Total
				1.1	1.2	1.3	2.2	1.4	2.3	1.5	2.4	2.5			
1	Commercial Gillnet	6/14-8/22	Lower	0	159	7,278	0	7,999	21	3,813	26	0	19,296		
			Middle	0	3	15	0	1,109	8	672	0	0	1,807		
			Alaska	0	162	7,293	0	9,108	29	4,485	26	0	21,103		
			Upper	0	538	9,202	0	13,696	241	7,666	496	92	31,931		
			Total	0	700	16,495	0	22,804	270	12,151	522	92	53,034		
	Subsistence Gillnet ^a	Lower	0	16	723	0	795	2	379	3	0	1,918			
		Middle	0	0	2	0	111	1	67	0	0	181			
		Alaska	0	16	725	0	906	3	446	3	0	2,099			
		Upper	0	54	915	0	1,362	24	763	49	9	3,176			
		Total	0	70	1,640	0	2,268	27	1,209	52	9	5,275			
2	Commercial Gillnet	6/15-8/24	Lower	0	93	4,908	0	7,057	32	3,385	20	0	15,495		
			Middle	0	19	120	0	104	1	63	0	0	307		
			Alaska	0	112	5,028	0	7,161	33	3,448	20	0	15,802		
			Upper	0	429	8,424	7	10,508	323	5,916	331	110	26,048		
			Total	0	541	13,452	7	17,669	356	9,364	351	110	41,850		
	Subsistence Gillnet ^b	Lower	0	14	760	0	1,093	5	524	3	0	2,399			
		Middle	0	3	19	0	16	0	10	0	0	48			
		Alaska	0	17	779	0	1,109	5	534	3	0	2,447			
		Upper	0	67	1,305	1	1,628	50	917	51	17	4,036			
		Total	0	84	2,084	1	2,737	55	1,451	54	17	6,483			
3	Commercial Gillnet	6/26-8/24	Lower	0	2	119	0	178	1	86	1	0	387		
			Middle	0	0	2	0	8	0	5	0	0	15		
			Alaska	0	2	121	0	186	1	91	1	0	402		
			Upper	0	9	169	0	194	7	110	7	2	498		
			Total	0	12	290	0	380	8	201	8	2	901		
	Subsistence Gillnet ^c	Lower	0	11	559	0	840	4	407	3	0	1,824			
		Middle	0	2	11	0	40	1	25	0	0	79			
		Alaska	0	13	570	0	880	5	432	3	0	1,903			
		Upper	0	42	797	1	915	31	520	33	11	2,350			
		Total	0	55	1,367	1	1,795	36	951	36	11	4,252			
4 ^d		6/22-8/29	Lower	0	98	1,213	0	860	29	398	11	0	2,609		
			Middle	0	5	45	0	668	61	393	0	0	1,172		
			Alaska	0	103	1,258	0	1,528	90	791	11	0	3,781		
			Upper	0	340	1,573	0	1,682	388	915	227	239	5,364		
Total	0	443	2,831	0	3,210	478	1,706	238	239	10,086 ^{e, f}					
5 ^d		6/27-8/31	Upper	20	764	5,349	18	6,410	933	3,851	962	415	18,721 ^g		
6 ^d		7/04-9/13	Middle	0	206	2,135	0	1,645	95	570	0	0	4,651		
Yukon Territory	Commercial Gill net	7/02-10/9	Upper	0	0	1,661	0	4,865	119	4,034	59	59	10,797		
			Subsistence Gill net ^h	Upper	0	0	1,426	0	4,175	102	3,462	51	51	9,267	
Total Harvest			Lower	0	393	15,560	0	18,822	94	8,992	67	0	43,928		
			Middle	0	238	2,349	0	3,701	167	1,805	0	0	8,260 ^e		
			Alaska	0	631	17,909	0	22,523	261	10,797	67	0	52,188 ^e		
			Upper	20	2,243	30,821	27	45,435	2,218	28,154	2,266	1,005	112,189 ^e		
			Total	20	2,875	48,730	27	67,958	2,479	38,950	2,333	1,005	165,318 ^e		

a apportionment based on season total District 1 commercial catch samples
b apportionment based on season total District 2 commercial catch samples
c apportionment based on District 3 commercial catch samples
d combined commercial and subsistence, fish wheel and gill net
e includes Koyukuk River subsistence catch (941 fish) not apportioned by age class
f commercial catch = 502; subsistence catch = 9,583
g commercial catch = 2,733; subsistence catch = 15,988
h age apportionment based on Yukon Territory commercial catch samples

Table 12. Mean size and standard deviation for the size of scale zones of age-1.4 fish used in the linear discrimination of Yukon River chinook salmon runs, 1986. Each standard deviation was calculated from 25 observations. ^a

Run of Origin	Mean (top) and STD (bottom) for Size of Scale Zone					
	Freshwater		Freshwater Plus Growth		First Marine	
	Wilcock	Merritt	Wilcock	Merritt	Wilcock	Merritt
Lower	129.4	122.8	29.0	30.8	413.6	458.5
	15.9	15.6	14.1	14.6	62.5	67.1
Middle	111.3	105.1	56.8	59.7	435.2	465.1
	18.4	20.7	13.2	13.5	50.6	42.0
Upper	119.6	121.7	64.7	45.1	426.6	452.5
	18.5	19.3	22.4	19.8	86.0	51.6

^a Only the treatment cells of the first marine zone had significantly different variances ($\alpha = .05$ with F_{\max} -test, Sokal and Rohlf 1969).

Table 13. Analysis of variance and non-parametric test statistics for the univariate analysis of differences in size of scale zone due to digitizer or run of origin for Yukon River chinook salmon, 1986.

Source	df	Sum of Squares		Size of Zone				First Marine	
		Freshwater	Freshwater Plus	Freshwater		Freshwater Plus		T.S. ^b	P-value
				F	P-value	F	P-value		
Digitizer (D)	1	482	938	1.46	0.23	3.38	0.07 ^a	18,533	0.001
Run (R)	2	8,447	23,953	12.81	0.00	43.22	0.00	2.27	0.32
D x R	2	603	4,027	0.91	0.40	7.27	0.001		
Error	144	4,782	39,905						

^a Due to the significance of the interaction term the main effect due to digitizer and run of origin are confounded.

^b Non-parametric test statistic (T.S.) for one-way layout testing for effect of digitizer was the Mann-Whitney U, and for the effect of run of origin the Kruskal-Wallis statistic. (Hollander and Wolfe 1973). Because a two-way design was not used interaction effect could not be tested.

Table 14. Multiway analysis of variance statistics for the multivariate analysis of differences in size of scale zone due to digitizer or run of origin for Yukon River chinook salmon, 1986. ^a

Source	df	Pillai Trace	F-Statistic	P-value
Digitizer (D)	3, 142	0.127	6.874	0.00
Run (R)	2, 286	0.455	14.043	0.00
D x R	6, 286	0.096	2.440	0.03

^a Due to the significance ($p < .05$) of the interaction term the effect of digitizer and run are confounded.

Table 15. Classification accuracies of linear discriminant models for age-1.4 Yukon River chinook salmon digitized by two scale readers, 1986.

Wilcock

Actual Run of Origin	Sample Size	Classified Run of Origin		
		Lower	Middle	Upper
Lower	65	0.831	0.077	0.092
Middle	100	0.120	0.670	0.210
Upper	100	0.190	0.210	0.600

Mean Classification Accuracy = 0.700

Variables in the analysis: 67, 66, 100.

Merritt

Actual Run of Origin	Sample Size	Classified Run of Origin		
		Lower	Middle	Upper
Lower	65	0.692	0.077	0.231
Middle	100	0.101	0.717	0.182
Upper	100	0.210	0.220	0.570

Mean Classification Accuracy = 0.660

Variables in the analysis: 67, 62, 102, 26, 70.

Table 16. Run composition estimates for age-1.4 chinook salmon from commercial catches in Yukon River Districts 1 and 2 using linear discriminant function analysis of samples digitized by two scale readers.

District	Commercial Fishing Period	Sample Size	Run of Origin	Wilcock			Merritt		
				Prop. of Catch	90% C.I.		Prop. of Catch	90% C.I.	
					Lower Bound	Upper Bound		Lower Bound	Upper Bound
1	2	108	Lower	0.371	0.175	0.567	0.309	0.048	0.571
			Middle	-0.108	-0.312	0.097	-0.018	-0.226	0.190
			Upper	0.737	0.443	1.031	0.709	0.341	1.077
	3	119	Lower	0.092	-0.070	0.253	0.245	0.025	0.466
			Middle	0.191	-0.046	0.428	0.237	0.028	0.446
			Upper	0.717	0.427	1.008	0.518	0.199	0.837
2	3	131	Lower	0.147	-0.015	0.309	0.128	-0.109	0.365
			Middle	0.134	-0.089	0.357	0.039	-0.182	0.261
			Upper	0.720	0.440	0.999	0.833	0.475	1.191
	5	124	Lower	0.478	0.303	0.653	0.759	0.471	1.046
			Middle	0.067	-0.118	0.253	-0.046	-0.208	0.116
			Upper	0.454	0.212	0.696	0.287	-0.075	0.650

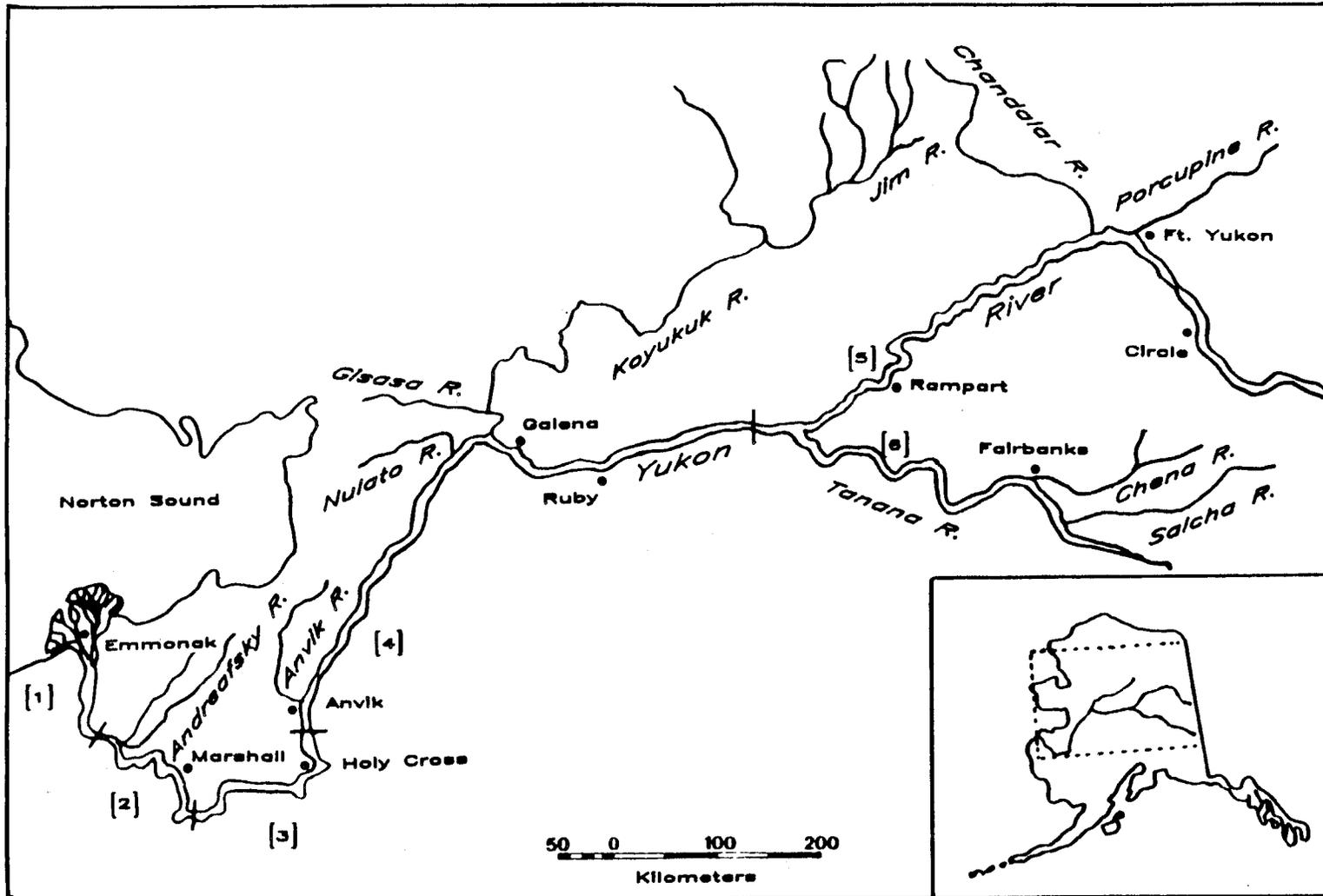


Figure 1. Alaskan portion of the Yukon River showing the six regulatory districts.

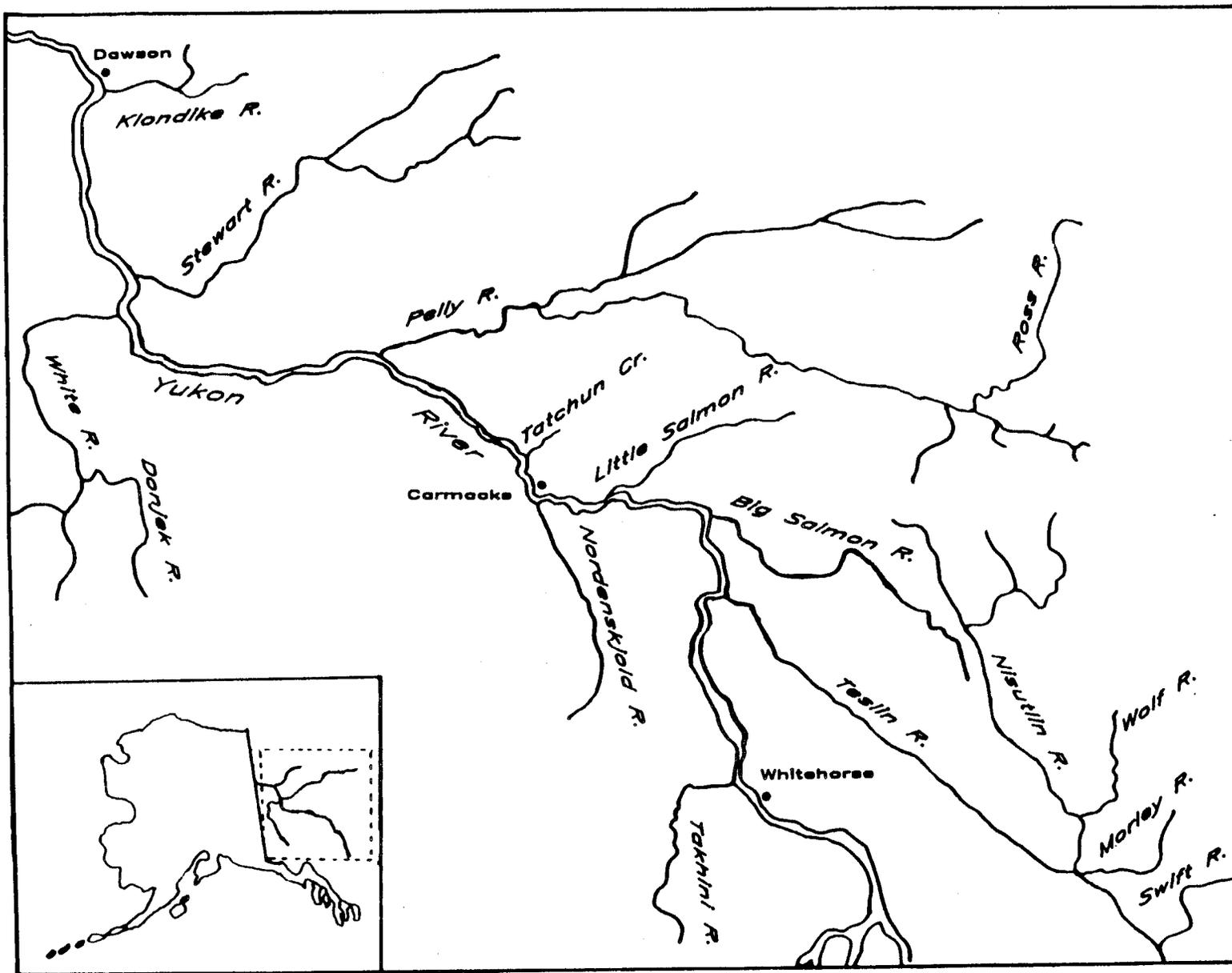


Figure 2. Canadian portion of the Yukon River.

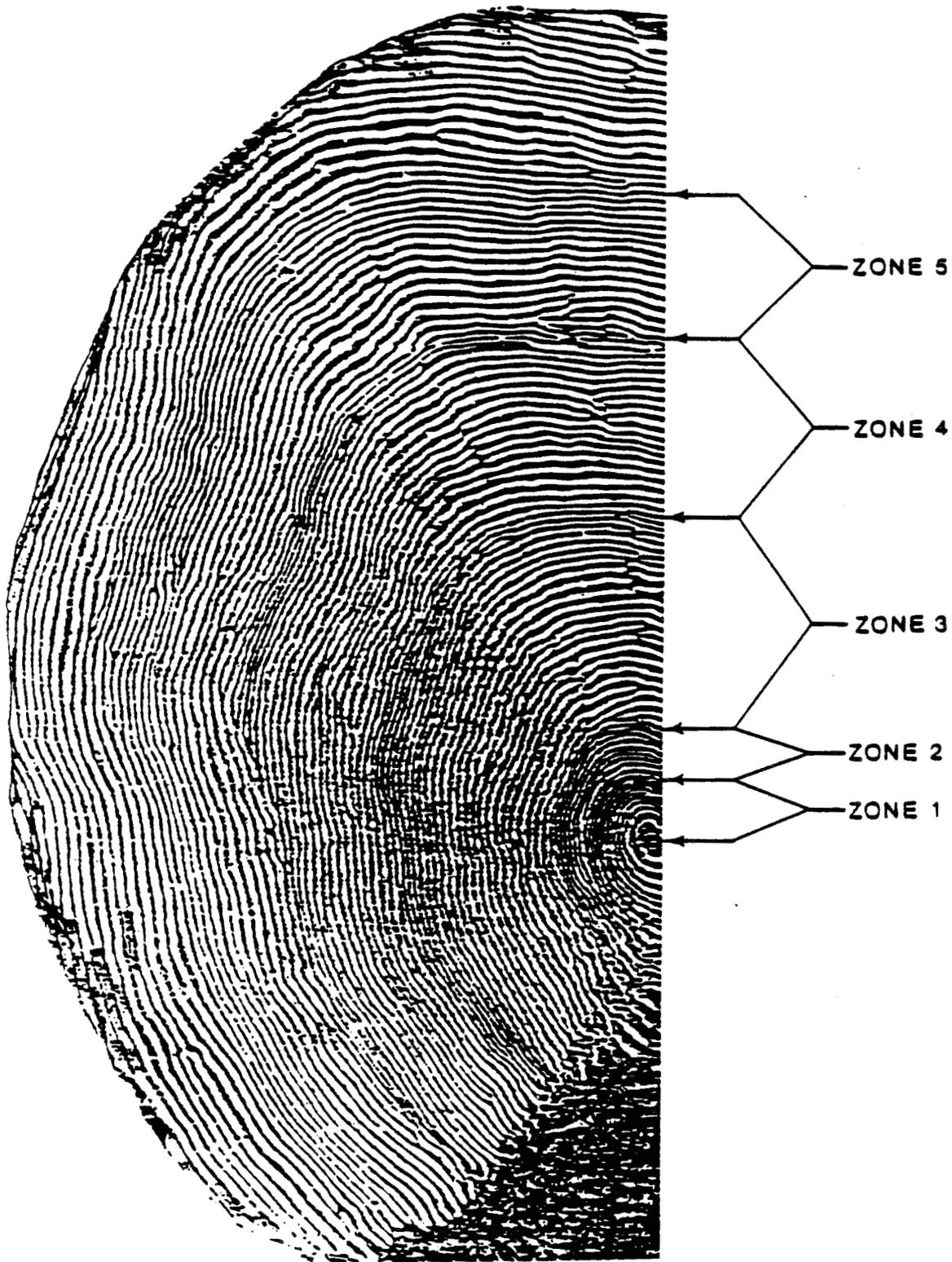


Figure 3. Age-1.4 chinook salmon scale showing zones measured for linear discriminant analysis.

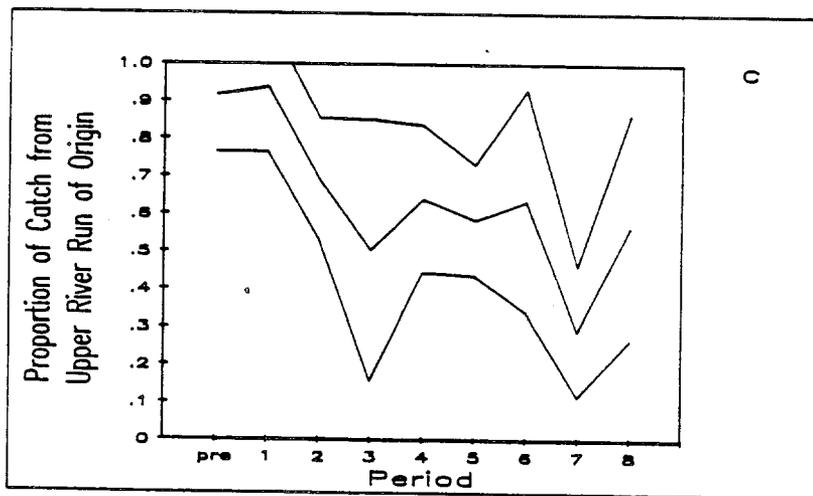
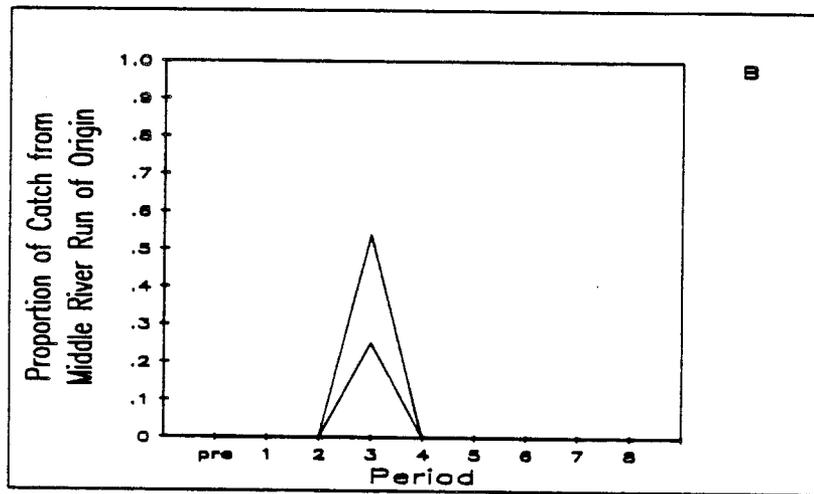
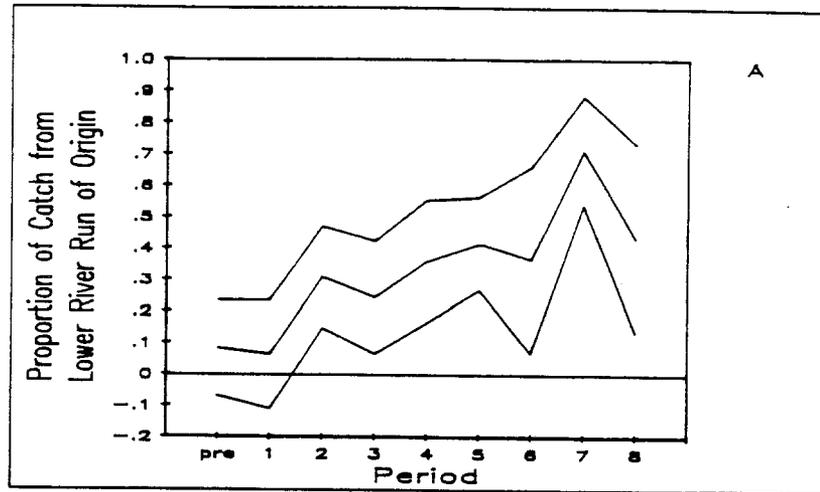


Figure 4. Run composition estimates and 90% confidence intervals from scale patterns analysis of age-1.4 chinook salmon, Yukon River District 1, 1986.

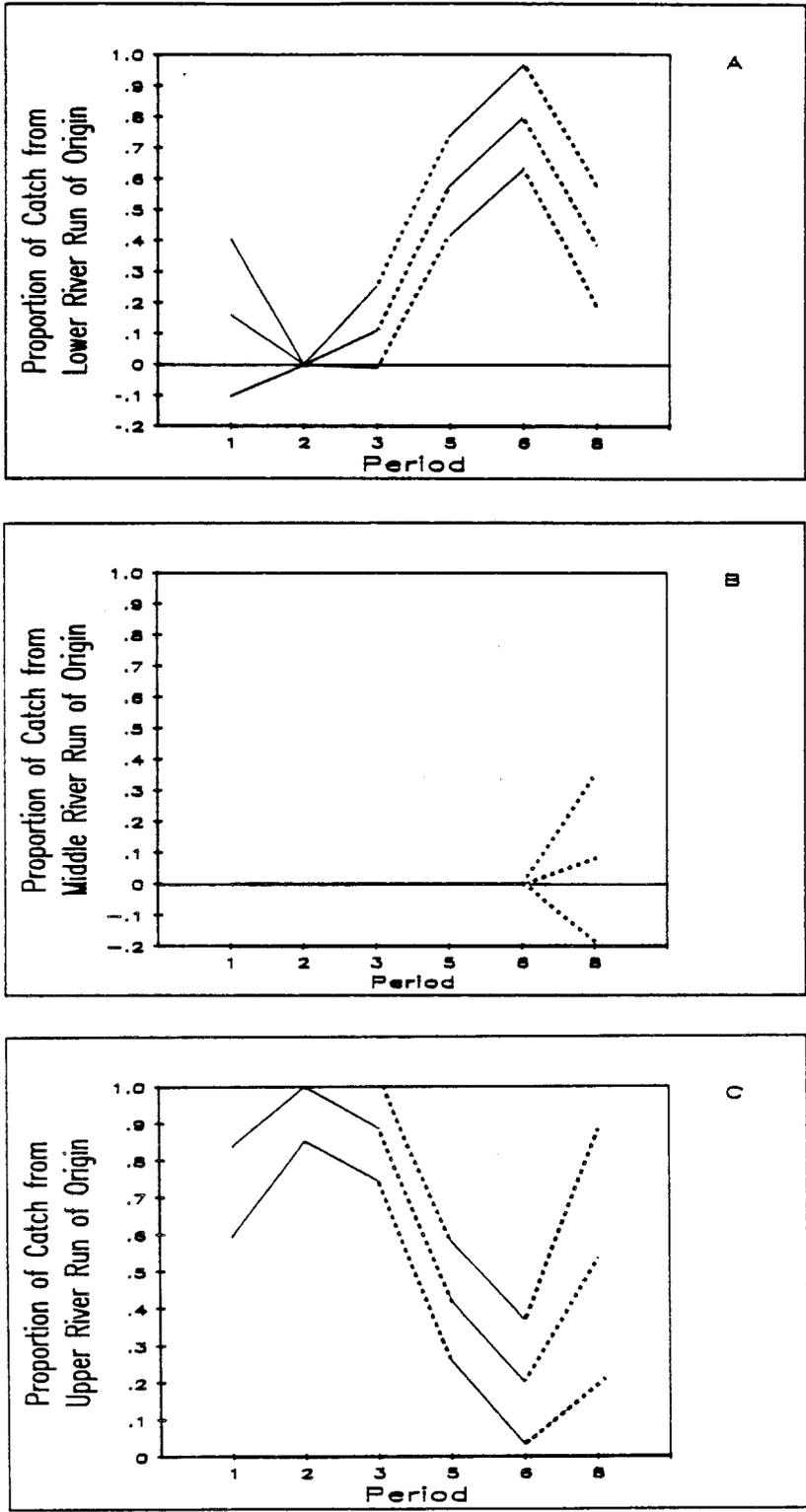


Figure 5. Run composition estimates and 90% confidence intervals from scale patterns analysis of age-1.4 chinook salmon, Yukon River District 2, 1986.

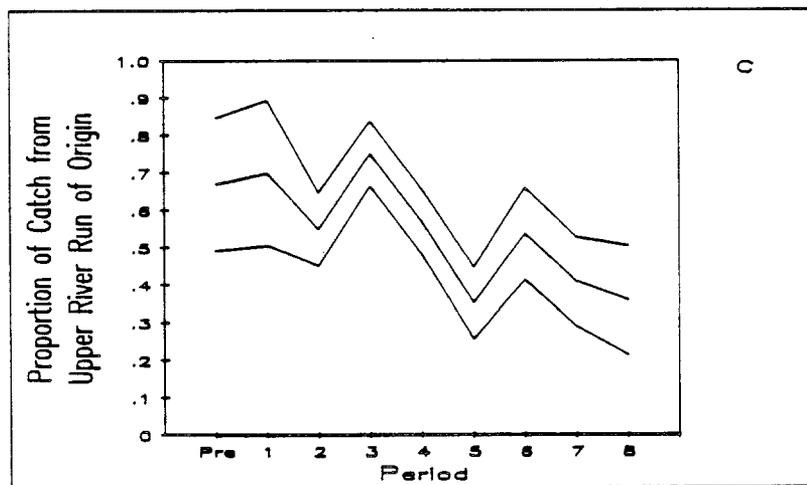
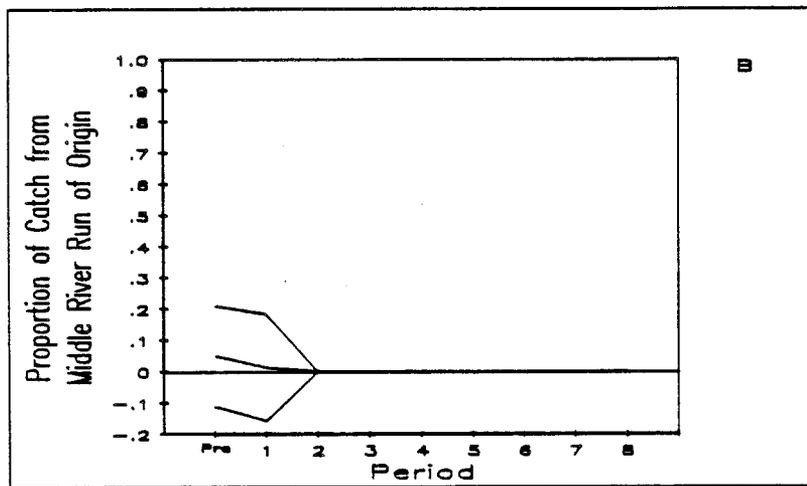
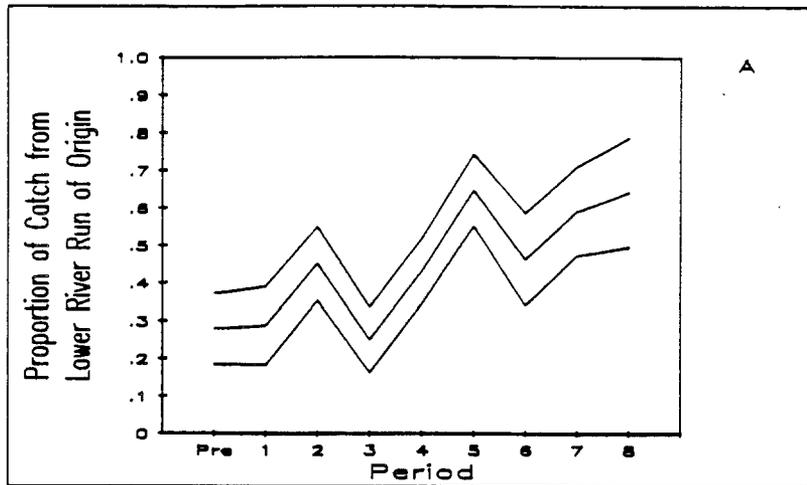


Figure 6. Run composition estimates and 90% confidence intervals from scale patterns analysis of age-1.3 chinook salmon, Yukon River District 1, 1986.

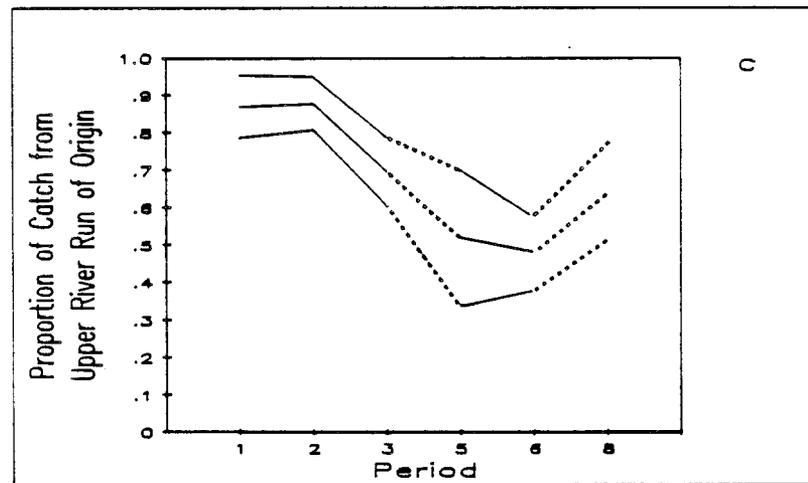
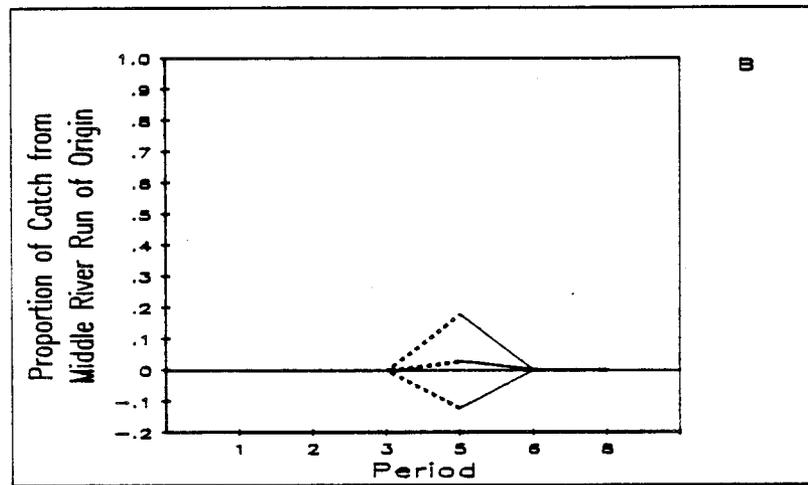
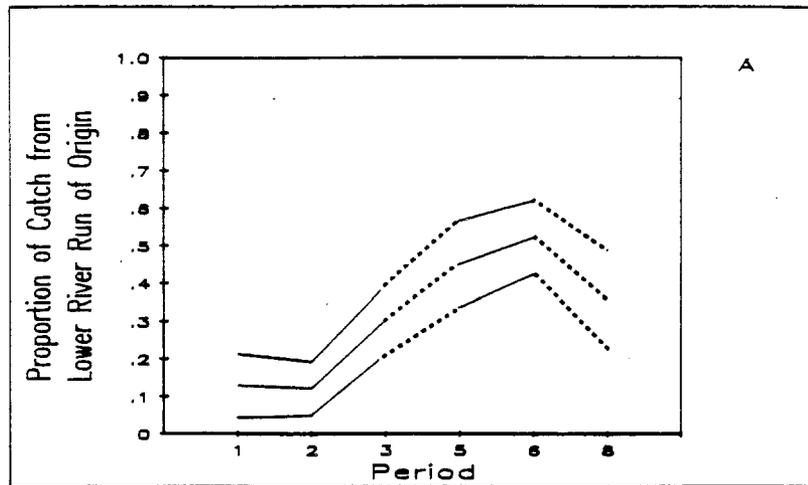


Figure 7. Run composition estimates and 90% confidence intervals from scale patterns analysis of age-1.3 chinook salmon, Yukon River District 2, 1986.

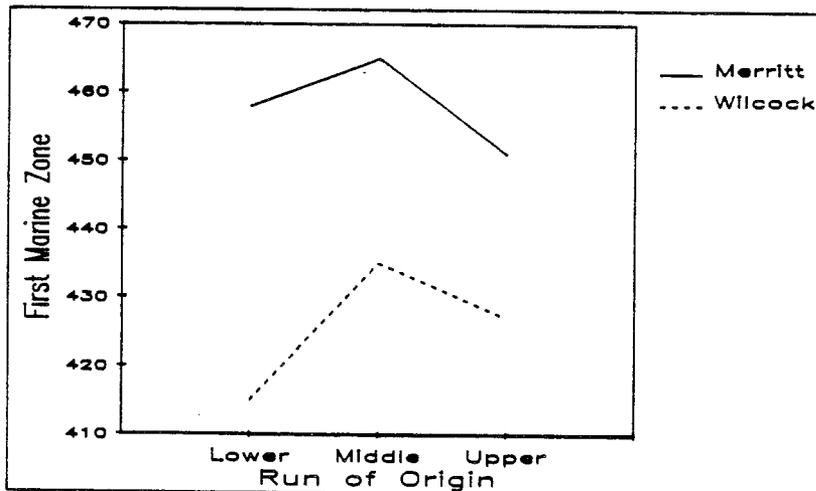
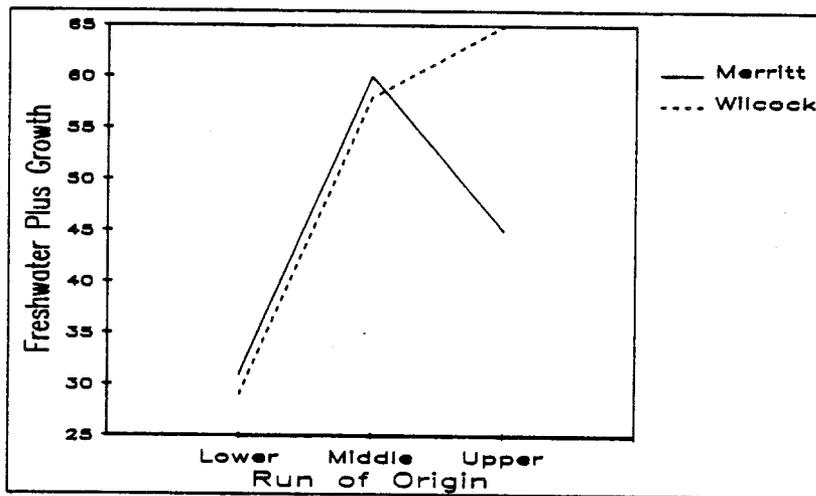
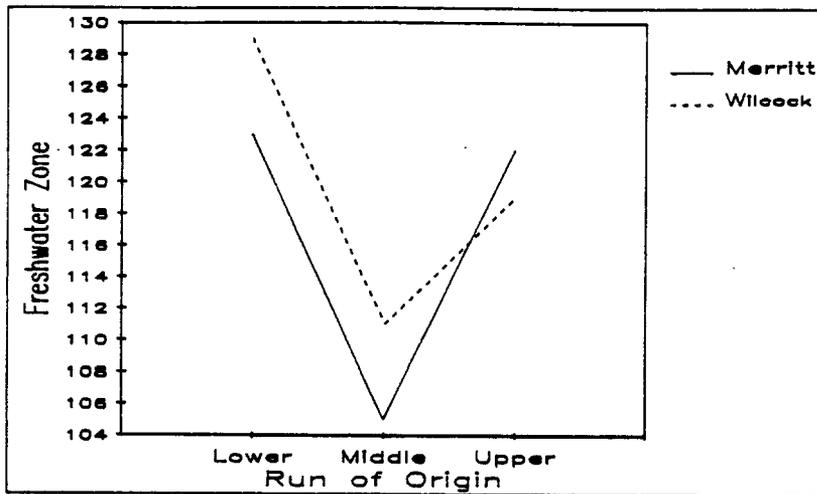


Figure 8. Mean size of the freshwater annular zone (top), freshwater -plus growth zone (middle) and first marine growth zone of Yukon River chinook salmon by digitizer and run of origin, 1986.

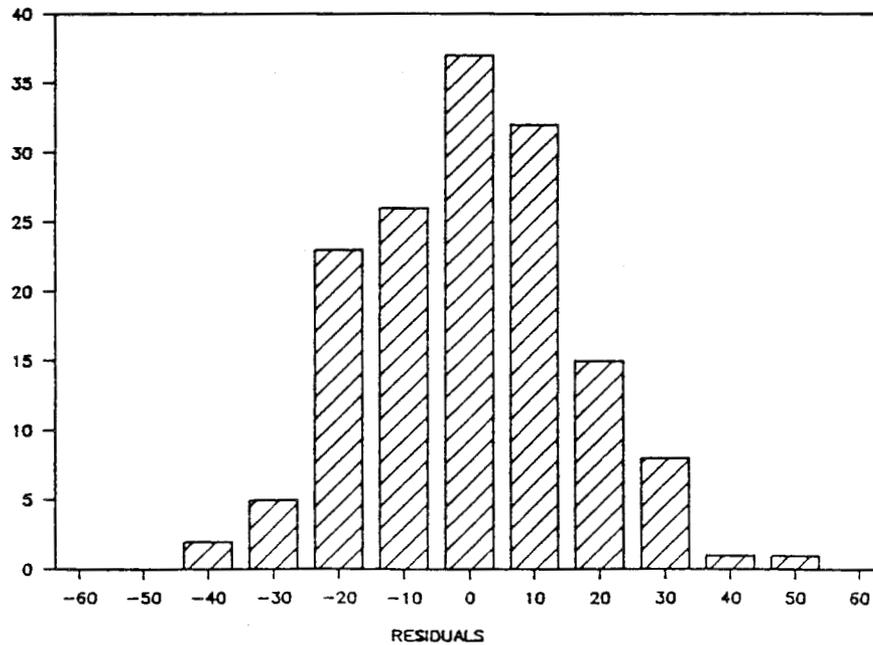
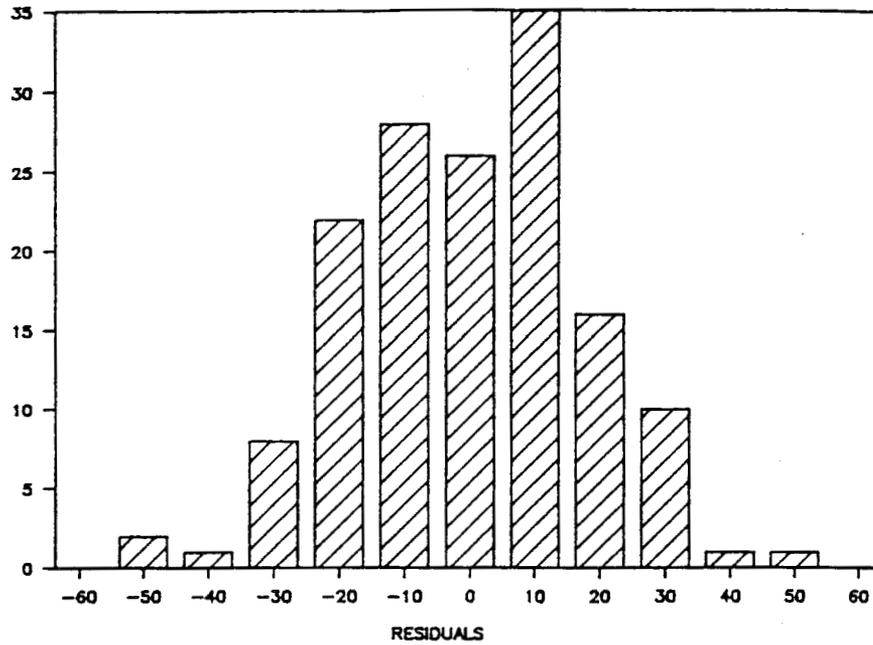


Figure 9. Residuals from 2-way analysis of variance with size of freshwater growth (top) and freshwater plus growth (bottom) of 1986 Yukon River chinook salmon scales as dependent variables and digitizer and run of origin as independent variables.

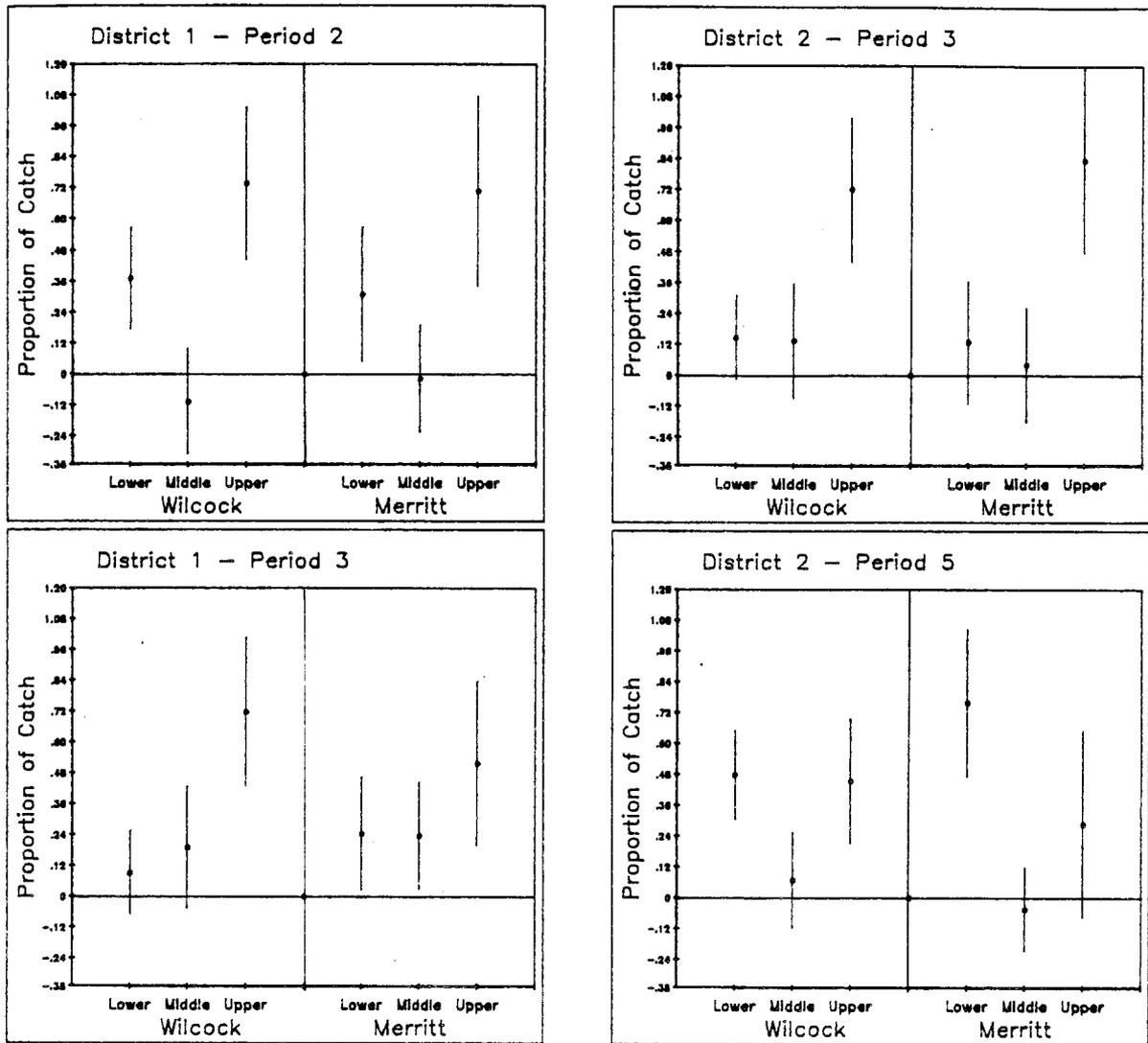


Figure 10. Run composition estimates and 90% confidence intervals for age-1.4 chinook salmon from commercial catches in Yukon River Districts 1 and 2 using linear discriminant function analysis of samples digitized by two scale readers.

APPENDICES

Appendix Table 1. Scale variables screened for linear discriminant function analysis of age-1.4 and -1.3 Yukon River chinook salmon.

Variable	1st Freshwater Annular Zone
1	Number of circuli (NC1FW) ^a
2	Width of zone (S1FW) ^b
3 (16)	Distance, scale focus (C0) to circulus 2 (C2)
4	Distance, C0-C4
5 (18)	Distance, C0-C6
6	Distance, C0-C8
7 (20)	Distance, C2-C4
8	Distance, C2-C6
9 (22)	Distance, C2-C8
10	Distance, C4-C6
11 (24)	Distance, C4-C8
12	Distance, C(NC1FW -4) to end of zone
13 (26)	Distance, C(NC1FW -2) to end of zone
14	Distance, C2 to end of zone
15	Distance, C4 to end of zone
16-26	Relative widths, (variables 3-13)/S1FW
27	Average interval between circuli, S1FW/NC1FW
28	Number of circuli in first 3/4 of zone
29	Maximum distance between 2 consecutive circuli
30	Relative width, (variable 29)/S1FW

Variable	Freshwater Plus Growth
61	Number of circuli (NCPG) ^c
62	Width of zone (SPGZ) ^d

Variable	All Freshwater Zones
65	Total number of freshwater circuli (NC1FW+NCPG)
66	Total width of freshwater zone (S1FW+SPGZ)
67	Relative width, S1FW/(S1FW+SPGZ)

-(Continued)-

Appendix Table 1. Scale variables screened for linear discriminant function analysis of age-1.4 and -1.3 Yukon River chinook salmon (continued).

Variable	1st Marine Annular Zone
70	Number of circuli (NC10Z) ^e
71	Width of zone (S10Z) ^f
72 (90)	Distance, end of freshwater growth (EFW) to C3
73	Distance, EFW-C6
74 (92)	Distance, EFW-C9
75	Distance, EFW-C12
76 (94)	Distance, EFW-C15
77	Distance, C3-C6
78 (96)	Distance, C3-C9
79	Distance, C3-C12
80 (98)	Distance, C3-C15
81	Distance, C6-C9
82 (100)	Distance, C6-C12
83	Distance, C6-C15
84 (102)	Distance, C(NC10Z -6) to end of zone
85	Distance, C(NC10Z -3) to end of zone
86 (104)	Distance, C3 to end of zone
87	Distance, C9 to end of zone
88	Distance, C15 to end of zone
90-104	Relative widths, (variables 73-86)/S10Z
105	Average interval between circuli, S10Z/NC10Z
106	Number of circuli in first 1/2 of zone
107	Maximum distance between 2 consecutive circuli
108	Relative width, (variable 107)/S10Z

Variable	All Marine Zones
109	Width of 2nd marine zone, (S20Z)
110	Width of 3rd marine zone, (S30Z)
111	Total width of marine zones (S10Z+S20Z+S30Z)
112	Relative width, S10Z/(S10Z+S20Z+S30Z)
113	Relative width, S20Z/(S10Z+S20Z+S30Z)

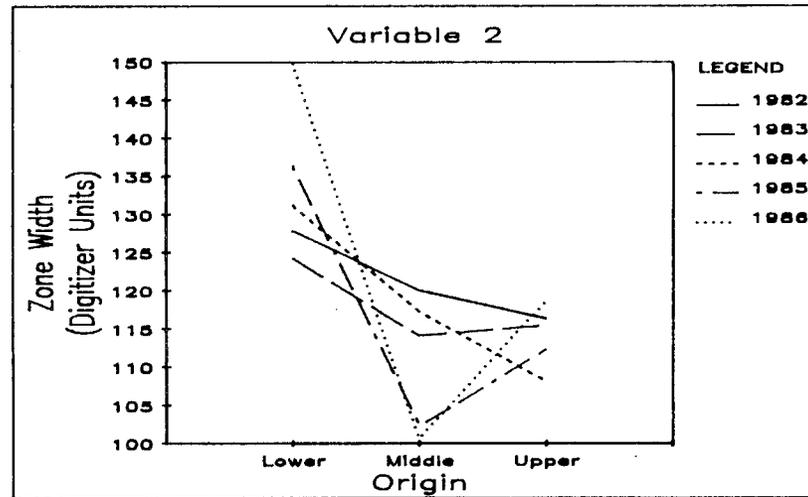
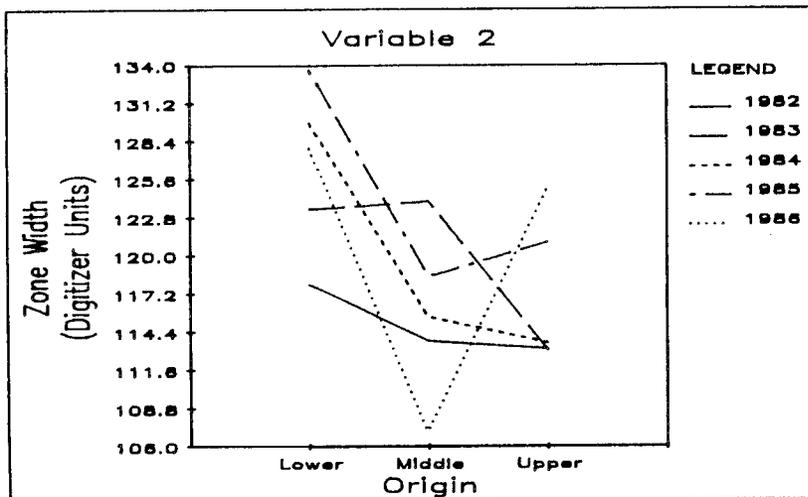
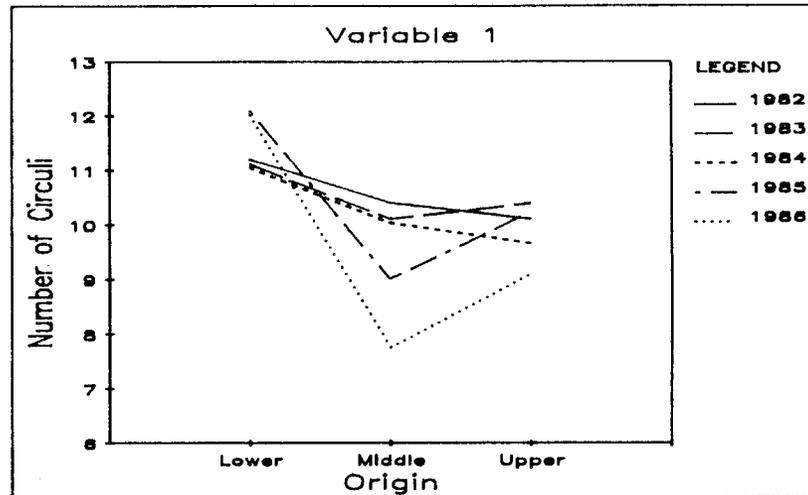
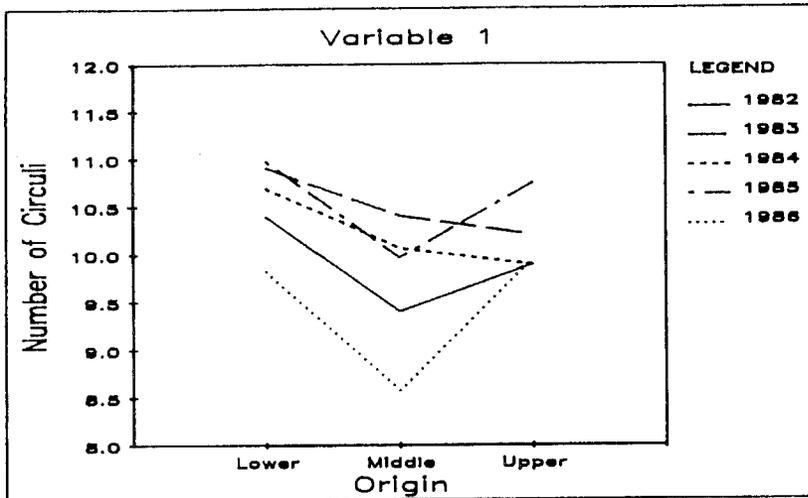
- a Number of circuli, 1st freshwater zone.
- b Size (width) 1st freshwater zone.
- c Number of circuli, plus growth zone.
- d Size (width) plus growth zone.
- e Number of circuli, 1st ocean zone.
- f Size (width) 1st ocean zone.

Appendix Table 2. Group means, standard errors and one-way analysis of variance F-test for scale variables selected for use in linear discriminant models of age-1.4 and-1.3 Yukon River chinook salmon runs, 1986.

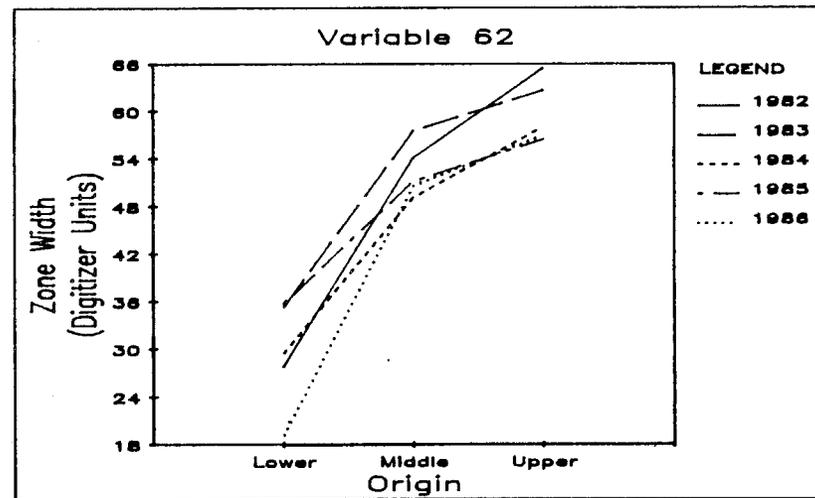
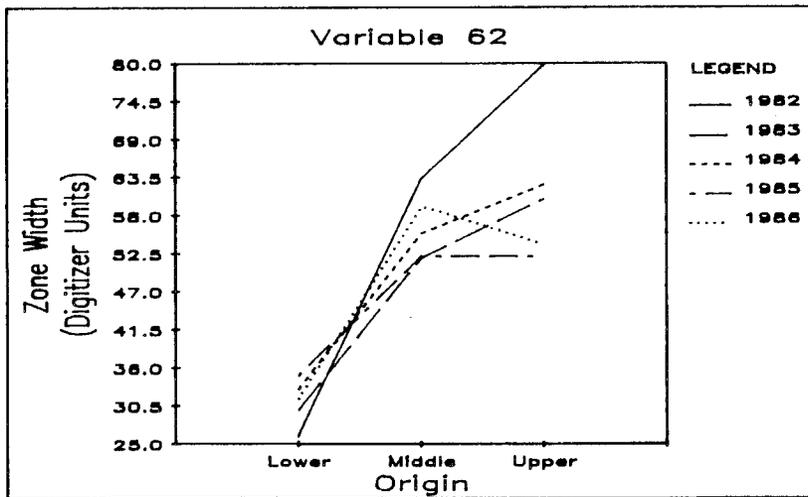
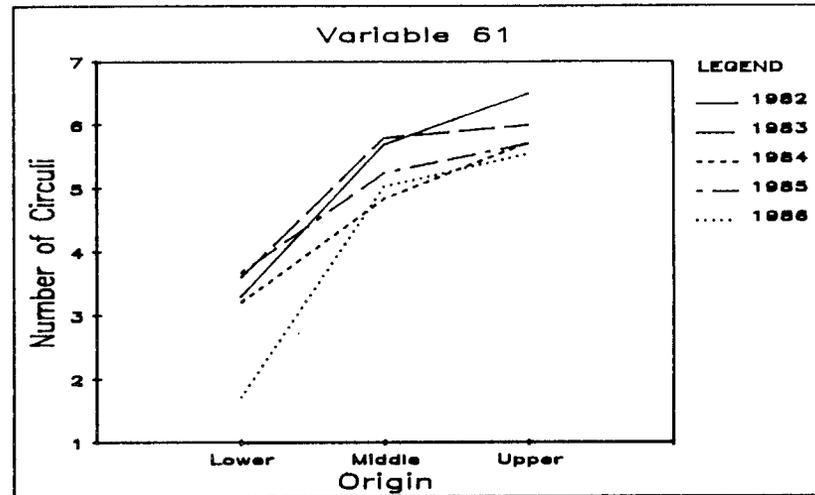
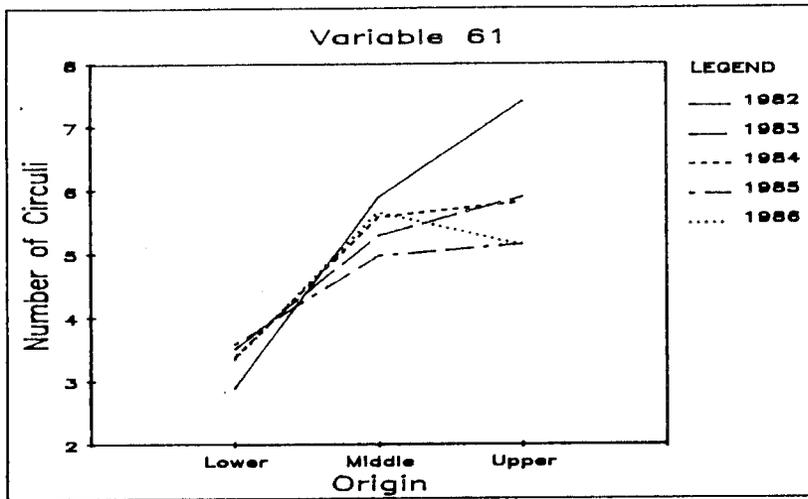
Age Growth Zone	Variable	Lower		Middle		Upper		F-value	
		Mean	SE	Mean	SE	Mean	SE		
1.4 1st FW Annular	2	127.92	1.99	107.14	1.29	125.09	1.43	55.61	
	8	45.19	0.88	36.59	0.50	42.03	0.48	50.01	
	26	0.12	0.01	0.15	0.01	0.12	0.01	43.33	
	FW Plus Growth	61	3.34	0.19	5.65	0.13	5.13	0.17	32.06
	Total FW Growth	67	0.81	0.01	0.65	0.01	0.71	0.01	63.02
	1st Ocean Ann.	70	26.00	0.34	25.14	0.22	24.09	0.23	11.36
		89	219.45	7.21	182.79	4.37	165.17	4.36	20.14
		100	0.23	0.01	0.26	0.01	0.28	0.01	26.77
	1.3 1st FW Annular	1	12.02	0.12	7.74	0.11	9.11	0.11	330.62
		8	45.44	0.46	35.57	0.58	41.10	0.51	84.18
14		95.14	1.26	48.39	1.23	63.93	1.00	395.60	
16		0.37	0.01	0.53	0.01	0.47	0.01	293.78	
27		12.57	0.09	13.08	0.14	13.26	0.14	10.17	
FW Plus Growth		61	1.71	0.06	5.04	0.12	5.54	0.10	558.36
		62	19.18	0.67	50.70	1.24	56.93	1.10	467.76
Total FW Growth		67	0.89	0.01	0.67	0.01	0.68	0.01	684.73
1st Ocean Ann.		83	168.74	1.35	171.26	1.84	186.18	1.42	42.50
		106	13.74	0.10	13.85	0.14	12.62	0.11	37.09

Appendix Table 3. Group means, standard errors, and one-way analysis of variance F-test for the number of circuli and incremental distance of salmon scale growth zone measurements from age-1.4 and-1.3 Yukon River chinook salmon runs, 1986.

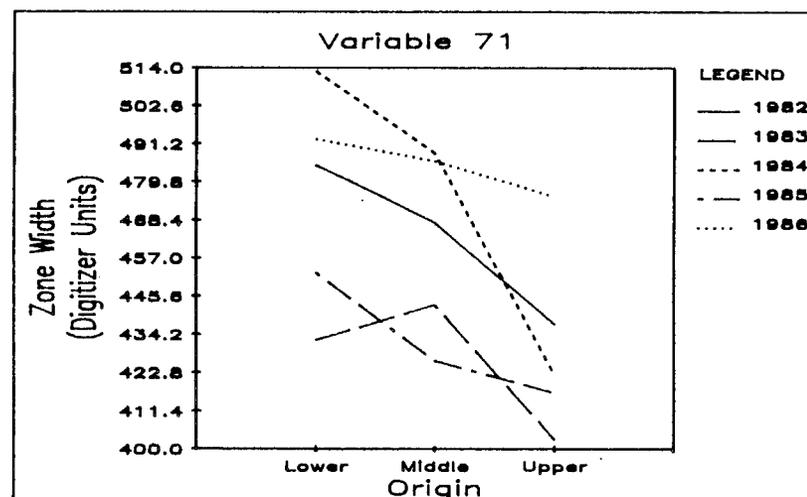
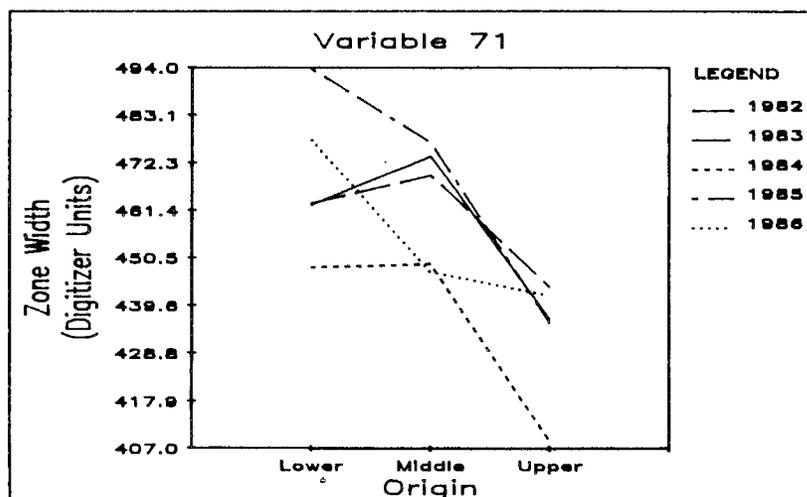
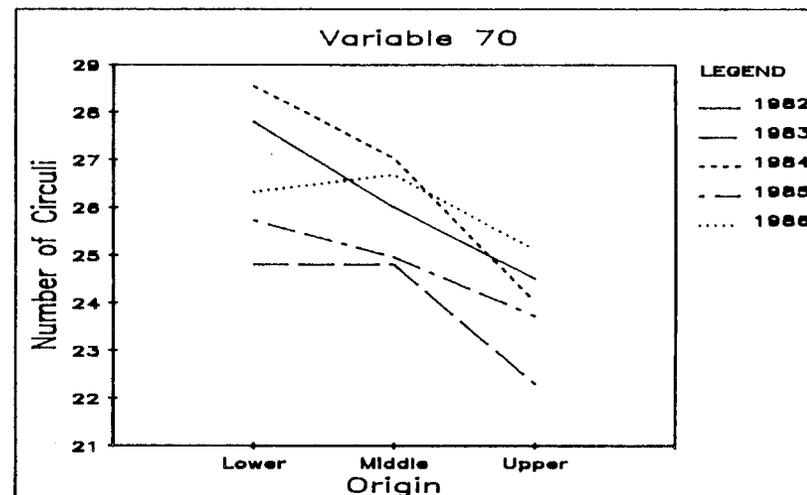
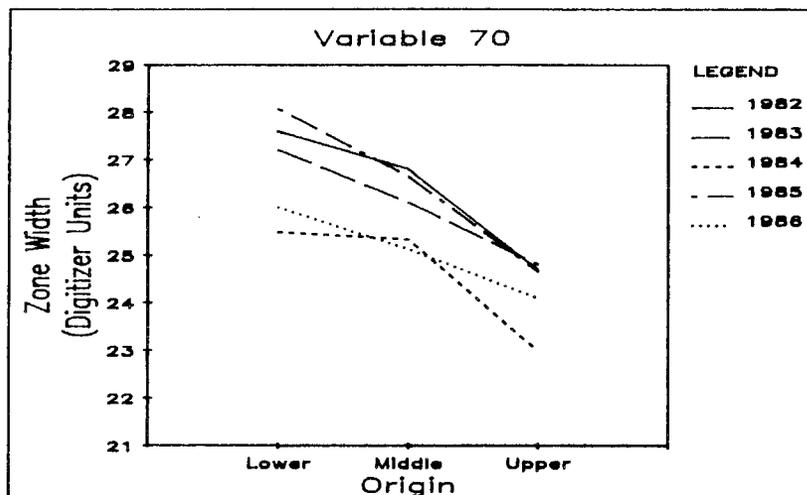
Age Growth Zone	Variable	Lower		Middle		Upper		F-Value
		Mean	SE	Mean	SE	Mean	SE	
1.4 1st FW Annular	No. Circ.	9.82	0.19	8.57	0.12	9.96	0.13	32.85
	Incr. Dist.	127.92	1.99	107.14	1.29	125.09	1.43	55.61
FW Plus Growth	No. Circ.	3.34	0.20	5.65	0.13	5.13	0.17	32.06
	Incr. Dist.	31.51	1.86	59.40	1.36	53.77	1.79	41.10
1st Ocean Annular	No. Circ.	26.00	0.34	25.14	0.21	24.09	0.23	11.36
	Incr. Dist.	477.51	7.02	447.20	4.22	441.77	4.00	9.80
2nd Ocean Annular	Incr. Dist.	402.57	9.31	383.63	5.56	385.52	5.24	1.62
3rd Ocean Annular	Incr. Dist.	411.57	7.62	403.36	4.29	407.58	3.78	0.57
1.3 1st FW Annular	No. Circ.	12.02	0.12	7.74	0.11	9.11	0.11	330.62
	Incr. Dist.	149.83	1.31	100.71	1.54	118.81	1.43	343.03
FW Plus Growth	No. Circ.	1.71	0.62	5.04	0.12	5.54	0.10	558.36
	Incr. Dist.	19.18	0.67	50.70	1.24	56.93	1.10	467.76
1st Ocean Annular	No. Circ.	26.33	0.17	26.70	0.22	25.11	0.18	19.79
	Incr. Dist.	492.54	3.68	485.90	4.66	475.08	3.68	5.61
2nd Ocean Annular	Incr. Dist.	472.95	4.98	439.27	6.10	427.21	4.96	22.57



Appendix Figure 1. Number of circuli (variable 1) and width (variable 2) of the freshwater annular zone in digitized scales by year for lower, middle, and upper Yukon runs of origin. Age-1.4 (left) and -1.3 (right) chinook salmon are shown.



Appendix Figure 2. Number of circuli (variable 61) and width (variable 62) of the freshwater plus growth zone in digitized scales by year for lower, middle, and upper Yukon runs of origin. Age-1.4 (left) and -1.3 (right) chinook salmon are shown.



Appendix Figure 3. Number of circuli (variable 70) and width (variable 71) of the first marine annular zone in digitized scales by year for lower, middle, and upper Yukon runs of origin. Age-1.4 (left) and -1.3 (right) chinook salmon are shown.

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