| |
|---|
| NPAFC<br>Doc. 63<br>Rev. ______ |

# Use of Historical Scale Characters to Apportion Chinook Salmon from Stocks of Alaska, British Columbia, and Washington

by

Nancy D. Davis

Fisheries Research Institute
School of Fisheries, WH-10
University of Washington
Seattle, Washington, U.S.A. 98195

submitted to the

**NORTH PACIFIC ANADROMOUS FISH COMMISSION**

by

The United States of America

September 1994

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:
Davis, N. D. 1994. Use of historical scale characters to apportion chinook salmon from stocks of Alaska, British Columbia, and Washington. (NPAFC Doc. 63.) FRI-UW-9414. Fisheries Research Institute, School of Fisheries, WH-10, University of Washington, Seattle. 22 pp.

# Use of Historical Scale Characters to Apportion Chinook Salmon from Stocks of Alaska, British Columbia, and Washington

## Abstract

Chinook salmon (*Oncorhynchus tshawytscha*) scale characters used in previous stock-identification analyses of high seas-caught salmon were re-examined to determine their usefulness for determining origins of chinook salmon taken in fisheries operating off the coast of Alaska. Standards were developed for the following nine stock-groupings: Yukon River, Kuskokwim River, Bristol Bay, Cook Inlet, Copper River, southeast Alaska-northern British Columbia (Alsek, Taku, and Stikine rivers), central British Columbia (Unuk, Chickamin, and Skeena rivers), Fraser River, and Columbia River. Stability of scale patterns was evaluated by pooling three brood-years and using the pooled brood-year standard to apportion a fourth brood-year. Results of these brood-year tests showed differences among groups were generally stable through time for the Yukon River (mean correct allocation 78%), Bristol Bay (69%), Cook Inlet (72%), southeast Alaska/northern British Columbia (70%), central British Columbia (82%), and the Columbia River (92%). Low accuracies for the Kuskokwim (mean correct allocation 17%) and Copper river groups (52%) indicate there was more annual variation in the scale patterns of these groups. The full pooled brood year-standard (1980-1983) was very accurate (92% correct) in regional apportionment of independent scales from known western Alaska stocks (including Canadian Yukon). Historical scale characters were less accurate when applied to a sub-regional analysis: Bristol Bay (mean correct allocation 69%), Yukon River (56%), and the Kuskokwim River (21%). Increased number and quality of samples from the Kuskokwim River, additional scale characters computed from existing measurements, and new measurements of the freshwater portion of the scale may increase the accuracy of separation among these western Alaskan groups.

## Introduction

I compiled a database of chinook scale characters to determine the stock origins of chinook salmon (*Oncorhynchus tshawytscha*) caught in the offshore waters of the North Pacific Ocean and Bering Sea (Davis 1990, 1991). The scale characters were selected to emphasize the similarities in scale patterns of chinook salmon collected from large geographical regions bordering the North Pacific Ocean. However, recent concern over the origin of incidentally caught chinook salmon in fisheries off Alaska prompted me to re-examine these scale data to determine their applicability to future analyses. Trawl fisheries operating in 1993 (through September) in the Bering Sea/Aleutian Islands and Gulf of Alaska areas incidentally caught an estimated 194,827 salmon, 25% (48,361) of which were chinook salmon (Low and Berger 1993). This bycatch of 48,361 chinook salmon may not represent a significant portion of salmon runs, if the fish originated from a broad spectrum of stocks, however, if the number of contributing stocks is small, this bycatch could be a significant portion of those stocks. To put the 1993 level of bycatch in perspective, 48,361 is 70% of the 1992 commercial chinook catch in Bristol Bay, Alaska, where the commercial catch was far below average in every district for the seventh consecutive year, and this bycatch approximates the Kuskokwim River commercial catch of 46,900 chinook salmon in 1992 (Geiger and Savikko 1993).

Western Alaskan stocks (including Canadian Yukon) are the major contributors to the chinook salmon population in the Bering Sea, as shown by the results of tagging experiments

(Myers et al. 1990) and scale pattern analyses (Major et al. 1975, 1977a,b; Ito et al. 1985; Myers et al. 1987; Myers and Rogers 1988; Davis 1990). Although there are few coastal recoveries (n=14) of high-seas tags from fish tagged in the Bering Sea, all of them were recovered in western Alaska (Yukon River, Kuskokwim River, and Bristol Bay). From these few tag recoveries, it is impossible to estimate the relative contributions of the Yukon River, the Kuskokwim River, and Bristol Bay chinook salmon to fisheries in the Bering Sea. However, estimates of the contributions of chinook salmon from western Alaskan sub-regions estimated from scale patterns have been calculated for chinook caught in the Japanese mothership salmon fishery in the central and western Bering Sea (Myers et al. 1987) and chinook incidentally caught in the groundfish fisheries in the eastern Bering Sea (Myers and Rogers 1988). Analysis of samples from the Bering Sea west of 175°W collected in the summer indicated that western Alaskan stocks predominated, and the Yukon River was the most common stock (48%), followed by the Kuskokwim River (21%) and Bristol Bay stocks (14%; Myers et al. 1987). In the bycatch of eastern Bering Sea trawl fisheries operating in the winter, spring and fall, western Alaskan stocks predominated, and Bristol Bay was the most common stock (29%), followed by the Kuskokwim River (24%) and the Yukon River stocks (17%; Myers and Rogers 1988). Apparently the impact on Yukon, Kuskokwim, and Bristol Bay stocks will vary with the location of the fishery and, possibly, with the time of the year.

Coded-wire tagged chinook salmon from Alaska, British Columbia, Washington, Oregon, Idaho, and California have been recaptured in trawl fisheries in the Gulf of Alaska (n=446; Myers et al. 1990). Most of the chinook salmon recovered in the Gulf of Alaska from coded-wire tagged fish originating from Alaska are freshwater age 1. (90%, n=70). Coded-wire tagged chinook salmon originating from British Columbia (91%, n=187), Washington (91%, n=72), and California (100%, n=1) are predominantly freshwater age 0., but slightly more than half of the recoveries from Oregon (52%, n=43) and Idaho (100%, n=1) have been freshwater age 1. fish. The far-northerly migrating freshwater age 1. stocks of Washington, Oregon, and Idaho include fish from the Columbia River, particularly Willamette River spring chinook, and coastal Washington and Oregon stocks (Table 1).

Forty-nine coded-wire tagged chinook salmon from Alaska, Yukon Territories, British Columbia, Washington, and Oregon have been recovered from fisheries operating in the Bering Sea (Myers et al. 1990; Dahlberg et al. 1994; M. L. Dahlberg, National Marine Fisheries Service, Auke Bay Laboratory, pers. comm.). Most Alaskan coded-wire tag recoveries have been from freshwater age 0. fish released in southeast Alaska (66%, n=6). Similarly, most recovered fish from British Columbia, Washington and Oregon have been freshwater age 0. (94%, n=30; 100%, n=1; and 80%, n=4; respectively). Far-northerly migrating stocks of freshwater age 1. stocks caught in the Bering Sea include fish from the Fraser River system of British Columbia and the Willamette River spring chinook (Table 2).

Recent scale pattern analyses of high-seas caught chinook salmon used brood-year analyses of freshwater age 1. fish (Ito et al. 1985; Myers et al. 1987; Myers and Rogers 1988; Davis 1990). A brood-year analysis requires that the scales in the standards (scales of known origin) be measured from the same brood-year and of the same freshwater age as the fish of unknown origin. This is disadvantageous if, due to the expense of collecting samples, a resource agency does not collect scale samples every year. In addition, if the unknown samples are collected from immature chinook salmon one to three years, or more, must pass before the brood matures and returns to the natal river where scales can be sampled for the standards. Although brood-year analyses may be preferable, the annual variation in scale patterns within stocks or regions may be relatively small compared to that between groups. Anas and Murai (1969) used a pooled brood-year standard (1956-1962) to classify mature sockeye salmon caught at sea in 1962. The pooled model was slightly more accurate when tested with scales of known origin than standards calculated from individual years. Mean misclassification for Bristol Bay was reduced from 19.6% to 19.1% and misclassification for Asia was reduced from 28.55% to 26.7% when the pooled brood-year model was used (Anas and Murai 1962). Davis (1991) investigated a pooled standard to determine stock origins of chinook salmon in the Japanese landbased salmon fishery because no standard samples had been measured for the same brood year as the fishery samples. The pooled standard was highly accurate when tested with scales of known origin (85.6% to 100% correct). Pooled brood-year models have been less successful for analysis of high-seas caught coho salmon. Walker's (1992) pooled models (mean overall accuracy 70%) did not perform as well as the single models (83%), so he reported the range of estimated mixing proportions of coho salmon caught in Asian high-seas squid driftnet fisheries based on three single-year models.

In this study, I re-analyzed North American stocks of the scale character database to assess the use of historical scale characters to separate the major stocks within the western Alaska region, i.e., Yukon, Kuskokwim, and Bristol Bay; and stocks from Alaska, British Columbia, and Washington. The practicality of pooling samples of brood years was examined by character stability testing in which scales of a brood year of the database were allocated using standards comprised of other brood years.

I excluded scale pattern data from Asian stocks of chinook salmon from analysis of this database. Similarity in scale patterns between the Yukon River and Kamchatka River samples was sufficient in one brood-year (1982) to require the two groups be combined into one (Davis 1990). As discussed above, western Alaskan stocks (including Canadian Yukon) are the major contributor of chinook salmon in the Bering Sea, so I narrowed this analysis to include the North American groups in order to examine the capability of the database to separate western Alaskan stocks. However, analysis of a mixed fishery sample in which Asian stocks are present must include Asian stocks in the standards, otherwise the Asian samples will be incorrectly apportioned to North American groups and result in biased mixing proportion estimates.

## Methods

Scale data were collected using the Optical Pattern Recognition System (OPRS; Biosonics, Seattle, USA) as previously described in Davis (1990, 1991). Scale measurement methodology and scale data from Alaskan and British Columbian stock-groups were previously reported (Table 3; Davis 1990, 1991).

Scale samples were available from each of four brood-years (1980-1983) except for the Fraser River (two brood years) and the Columbia River (three brood years), but scale samples from the Fraser River for brood-year 1980 were so few that I combined these samples with those of brood-year 1981 (brood-year 1980, n=9; Table 4). Additional scales were measured from freshwater age 1. chinook salmon of the Columbia River, Puget Sound, and the Washington Coast (Fig. 1). The Columbia River group comprised spring chinook salmon caught in the lower river in the Corbett and Woody Island test fisheries in April, and spring chinook taken in lower river commercial fisheries from February to June. Many of these fish are Willamette River spring chinook salmon. A small sample (N=18) of Columbia River freshwater age 1. fall chinook salmon from commercial catch samples in September and October was treated as an unknown group. Freshwater age 1. fish from stocks in Puget Sound (Skagit, Stillaguamish, Snohomish, and Green rivers) and along the Washington coast (Quillayute River and Willapa Bay) were combined into the two groups because of similarity in scale patterns and small individual sample sizes.

Nine groups of stocks were defined. I separated the western Alaskan stocks to determine how well the scale characters used in this study characterize those three groups (Yukon River, Kuskokwim River, and Bristol Bay). I grouped the remaining stocks from central and southeastern Alaska, British Columbia, and Columbia River into six groups on the basis of similarities in their scale characters (Davis 1990, 1991). Linear discriminant software (PMDP7M; Dixon 1988) plotted the group means of the first and second canonical variables, and the Euclidean distance between each pair of stocks provided a measure of the similarity between groups (Walker 1990; as an example see Appendix Figure 1). Distinct groupings existed for Cook Inlet (north and central commercial fishery districts and the Susitna River sport fishery), the Copper River, southeast Alaska and northern British Columbia (SENBC; composed of the Alsek, Taku, and Stikine rivers), central British Columbia (CBC; composed of the Chickamin, Unuk, and Skeena rivers), the Fraser River, and the Columbia River.

First, pooled standards formed by combining samples of three of the four brood years (1980-1983) were used to apportion scales of stocks from the fourth brood-year as if they were of unknown origin. This character stability test was repeated so each combination of three brood-years could be pooled to form a standard by which to classify the brood-year left out. Then, I pooled the four brood-years (1980-1983) to form a standard for classifying omitted stocks of known origin from Alaska and the Columbia River. A multipurpose analysis-bootstrap-simulation software was used to calculate the maximum likelihood estimates of group proportions (Millar 1988, 1990) . The nine groups were sampled with replacement such that each brood year was equally weighted. For example, the relative contribution of each brood-year to the group was equal to 25% when I had data from four brood-years, equal to 33% when I had data from three years (Columbia River), and 100% when the data were from one brood-year (Fraser River). The mean proportion from 100 bootstrap estimates was used as the point estimate, and the 95% confidence interval (equal tails) comprised 95% of the 100 estimates.

## Results

In character stability tests the western Alaskan "unknowns" were predominantly apportioned to the western Alaskan region (mean correct allocation 92%), indicating that the scale characters contain information that makes the western Alaskan stocks distinctive from the other standards. However, confusion among western Alaska stocks occurred. The Kuskokwim River in particular was not highly distinctive from the Yukon River and Bristol Bay groups (Tables 5-8). From 82% to 99% of the Yukon River samples were correctly apportioned for brood-years 1980, 1982, and 1983, but the accuracy was 47% for the brood-year 1981 sample (Table 6). From 72% to 97% of the Bristol Bay samples were correctly apportioned for brood-year 1981, 1982, and 1983, but accuracy was 17% for the brood-year 1980 sample (17%; Table 5). The percentage of the Kuskokwim group that was correctly apportioned was low in all cases, ranging from 5% to 37% correct (Tables 5-8).

Correct apportionment of the Cook Inlet group for three of the four brood-years ranged from 68% to 96% , but was lower for brood-year 1981 (43%; Tables 5-8). Correct apportionment of the Copper River group were 52% and 86% for the brood-year 1981 and 1982 samples, but accuracies in the other two brood-years were lower (34% ). Mean accuracy for components of the SENBC group was 78%, excluding the brood-year 1982 and 1983 Stikine River samples that had lower accuracies (42% and 31%). Correct apportionment of the components of the CBC group was high (82%; Tables 5-8). Scale patterns from the Columbia River samples were distinctive and estimates were accurate for that group (mean correct apportionment= 92%; Tables 6, 7, and 8). This completed the character stability testing among the brood years.

The full pooled standard (9 stock groups and four brood years 1980-1983) resulted in apportionment of the upper Yukon River samples and Norton Sound and Kuskokwim Bay commercial fisheries samples to western Alaskan groups (Table 9). Three of the four Unalakleet commercial fishery samples were apportioned mainly to the Yukon River (42%-88%), but the highest percentage from the brood-year 1981 sample was apportioned to Bristol Bay (45%). The lower Yukon River test fisheries, Middle Mouth and Big Eddy, were apportioned to the Yukon River group (45%-68%), and also to the Kuskokwim River group (16%-43%). High percentages of the lower Yukon River stocks, Andreafsky, Anvik, and Nulato rivers, were apportioned to the Kuskokwim River group (65%-76%). High percentages of the middle Yukon River stocks, Koyukuk and Chena, stocks were correctly apportioned to the Yukon group (53% to 65%), but high percentages of the Salcha stock were apportioned to the Bristol Bay and Cook Inlet groups (33% and 20%). The Kogrukluk weir sample from the Kuskokwim River (brood-year 1980) had zero apportionment to the Kuskokwim group and 50% to the Cook Inlet group, and the weir sample for brood-year 1981 sample apportioned to the Bristol Bay and Kuskokwim groups (51% and 42%). The Kanektok River commercial fishery sample from brood-year 1980 apportioned primarily to the Yukon River group (87%), brood-year 1981 and 1982 had high percentages apportioned to the Bristol Bay group (67%-78%), and brood-year 1983 apportioned approximately one-third each to the three western Alaskan groups. The Goodnews River commercial sample from brood-year 1981 and 1982 apportioned to the Bristol Bay group (52%-95%), brood-year 1980 was assigned predominately to the Yukon River (40% ), and the brood-year 1983 Goodnews sample had high proportions for the Kuskokwim River and the Yukon River groups (48%-42%). The Nelson Lagoon commercial samples were apportioned in large numbers to the Yukon River group (43%-99%), and high percentages of the Chignik samples were apportioned to the Bristol Bay and Yukon group (64% and 87%; Table 9). Large percentages of the Red River sample (Kodiak Island) was apportioned to the Cook Inlet and the SENBC groups (53% and 46%; Table 9).

The Columbia River commercial fall chinook salmon sample apportioned to the Columbia River with a high accuracy (92%). A high proportion of the Washington coast sample was apportioned to the Columbia River group (92%) with a small proportion to the Fraser River group (8%). The Puget Sound sample was apportioned primarily to the Columbia River group (50%) and secondarily to the CBC group (31%; Table 9).

## Discussion

Stocks from the Unalakleet River to the Goodnews River were correctly apportioned to western Alaska, but considerable confusion occurred among test stocks within the three sub-regions of western Alaska. For example, the Yukon Middle Mouth test fishery apportioned 43% to the Kuskokwim River, the Yukon Big Eddy test fishery apportioned 35% to Bristol Bay, and the Kogrukluk weir sample apportioned 51% to Bristol Bay (Table 9). The Yukon River standard group was composed of the Emmonak commercial fishery samples, a lower river commercial fishery, that takes a preponderance of fish originating in the middle and upper portions of the watershed (McBride and Marshall 1983; Wilcock and McBride 1983; Wilcock 1984, 1985, Merritt 1988; Merritt et al. 1988; Schneiderhan 1993). Apportionment of the test fisheries and the middle Yukon stocks (Koyukuk, Salcha, and Chena rivers) were predominantly to the Yukon group, but the lower Yukon River stocks (Andreafsky, Anvik, Nulato rivers) were predominantly apportioned to the Kuskokwim River stocks. If the unknown sample was composed of lower Yukon River stocks, then the proportion of the Yukon River could be underestimated and the contribution of the Kuskokwim River could be overestimated. Overall, the accuracy of the Yukon River group was low (mean correct allocation is 56% for Yukon test fisheries; Table 9) for a sub-regional study where the objective is to determine the Yukon River contribution to the unknown mixture.

The Kuskokwim River group had poor accuracies for each of the brood-years tested. Test apportionments of the Kuskokwim River showed that two brood years (1981 and 1982) were assigned to the Bristol Bay group and the other two brood years (1980 and 1983; Tables 5-8) were assigned to the Yukon River. These scale characters are not distinctive for the Kuskokwim River. The Kuskokwim River group was composed of the Bethel commercial samples. The Kogrukluk weir samples were not included in the Kuskokwim group because the weir samples were dirty and possibly included many non-preferred scales. Characterization of this group could be improved by increasing the geographic areas where scales are collected along the river and obtaining better quality scales at existing sampling sites. The Kanektok and Goodnews rivers, which drain into the southern end of Kuskokwim Bay, were not apportioned to the Kuskokwim River, but instead the highest percentages were assigned to Bristol Bay and secondarily to the Yukon River. Accuracies for the Kuskokwim River have been lower than for other western Alaskan stocks in previous analyses. In the sub-regional analysis of Myers et al. (1987) and Myers and Rogers (1988), the classification accuracies of the Kuskokwim standard were generally lower than the accuracies of either the Yukon River or Bristol Bay standards in a 6-group analysis that included standards from Asia, central Alaska, and southeast Alaska/British Columbia. In this study, the accuracies of the Kuskokwim River group were very poor for a sub-regional analysis of western Alaska (mean correct is 21% for Kogrukluk weir samples; Table 9).

Scale patterns from the Togiak, Nushagak, Alagnak, and Naknek rivers were similar, so I included all these stocks in the Bristol Bay standard. As a result, I did not have any samples from other Bristol Bay stocks in my database to test against the Bristol Bay group. However, test apportions of one brood-year with the other three pooled showed that correct assignments to Bristol Bay were higher than the Yukon River group. Scale characters from the Bristol Bay group may be sufficient for a regional study when the objective is to determine the contribution of Bristol Bay fish to an unknown mixture (mean correct allocation is 69% for brood-years 1980-1983; Tables 5-8).

Washington stocks including the fall chinook salmon, coastal, and Puget Sound samples were predominantly apportioned to the Columbia River group. Washington samples had a large freshwater zone and were distinctive from the more northerly groups (Appendix Table 1). Scale characters from lower Columbia River freshwater age 1. fish would be adequate for a study of the contribution of Columbia River fish in an unknown mixture with standards from more northerly areas (92% correct allocation; Table 9).

Results of these analyses suggest the ten scale characters (Table 3) can be used to analyze fishery samples at a regional level of stock grouping, i.e., western Alaska, central Alaska, southeast Alaska/British Columbia, the Fraser River, and the Columbia River (overall mean correct apportion for all these groups was 77%). Most of the scale characters used in this analysis were calculated from inter-circulus measurements of the fish's second year of scale growth. The first few circuli in this zone may contain freshwater circuli if the fish lingered in freshwater in the spring before entering the estuary or salt water (e.g., triplets 1 and 2; Table 3). The number and spacing of freshwater circuli, and the area on the scale depicting the fish's saltwater entry could be critical to the separation of western Alaskan groups because at this point the fish are leaving their river of origin, and they are not yet intermingling across wide areas of the Bering Sea and North Pacific Ocean. In the raw measurement data, measurements of freshwater circuli and differentiation between freshwater plus growth and growth in salt water was not measured and this may have contributed to the variability between brood years and confusion of the Kuskokwim River with the other groups in western Alaska. Additional scale characters computed from existing measurements, and new measurements of the freshwater portion of the scale would likely increase the separation among the western Alaskan groups.

## Recommendations

The chinook salmon scale characters used in this analysis are suitable for a pooled brood-year analysis to allocate unknown fishery samples to broad geographical regions of western Alaska, Cook Inlet/central Alaska, southeast Alaska/northern British Columbia, the Fraser River, and the Columbia River. Accuracy decreases for a sub-regional analysis of the western Alaskan stocks (Yukon River, Kuskokwim River, and Bristol Bay) with best success for Bristol Bay group and poorest for Kuskokwim River. In order to increase the accuracy of the Kuskokwim River group, an increased number and quality of samples from the Kuskokwim River might be helpful. To increase the separation among the western Alaskan groups, additional scale characters computed from existing measurements, and new measurements of the freshwater portion of the scale would likely increase the separation among the western Alaskan groups.

## Acknowledgments

Assistance was provided by biologists from the Alaska Department of Game, Department of Fisheries and Oceans Canada, and Washington Department of Fish and Wildlife, who provided chinook salmon scale samples and biological data. I thank Kate Myers for her guidance and insightful criticisms, and to her and to Drs. Mike Dahlberg, Jerry Pella, and Jim Olsen whose valuable comments greatly improved this report. I appreciate Trey Walker's assistance on various aspects of the computer analysis. Funding for this study was provided by the U. S. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory (NOAA Contract No. 50ABNF400001).

## References

Anas, R. E., and S. Murai. 1969. Use of scale characters and discriminant function for classifying sockeye salmon (*Oncorhynchus nerka*) by continent of origin. INPFC Bull. 26:157-192.

Dahlberg, M., S. Fowler, N. Maloney, and R. Heintz. 1994. Incidence of coded-wire tagged salmonids in commercial and research catches in the North Pacific Ocean and Bering Sea, 1993-1994. (NPAFC Doc.) Auke Bay Laboratory, Alaska Fisheries Science Center, NMFS, Juneau. 16 pp.

Davis, N. D. 1990. Origins of chinook salmon in the area of the Japanese mothership and landbased driftnet salmon fisheries in 1985 and 1986. (INPFC Doc.) FRI-UW-9015. Fish Res. Inst., Univ. Washington, Seattle. 34 pp.

Davis, N. D. 1991. Origins of chinook salmon in the Japanese traditional landbased driftnet salmon fishery in 1990 based on scale pattern analysis. (INPFC Doc.) FRI-UW-9114. Fish. Res. Inst., Univ. Washington, Seattle. 19 pp.

Dixon, W. J. (ed.) 1988. BMDP statistical software manual. Vol. 1. Univ. of California Press, Berkeley. 618 pp.

Geiger, H. J., and H. Savikko. 1993. Preliminary run forecasts and harvest projections for 1993 Alaska salmon fisheries and review of the 1992 season. Alaska Dept. of Fish and Game, Reg. Inform. Rep. 5J93-04. 79 pp.

Ito, J., Y. Ishida, and S. Ito. 1985. Stock identification of chinook salmon in offshore waters in 1974 based on scale pattern analysis. (INPFC Doc.) Fisheries Agency of Japan, Tokyo. 18 pp.

Johnson, J. K., and L. R. Longwill. 1988. Pacific salmonid coded wire tag releases through 1987. Regional Mark Processing Center, Pacific States Marine Fisheries Commission, Portland. 228 pp.

Johnson, J. K., and L. R. Longwill. 1991. Pacific salmonid coded wire tag releases through 1985-1991. Regional Mark Processing Center, Pacific States Marine Fisheries Commission, Portland. 230 pp.

Johnson, J. K., and L. R. Longwill. 1993. Pacific salmonid coded wire tag releases 1986-1992 (and preliminary 1993 releases). Regional Mark Processing Center, Pacific States Marine Fisheries Commission, Gladstone. 187 pp.

Low, L. L., and J. D. Berger. 1993. Incidental catch of salmon by U. S. groundfish fisheries in the Bering Sea/Aleutian Islands region, Gulf of Alaska, and the Pacific Coast, 1990-1993. (NPAFC Doc.) U. S. Dep. Commerce, NMFS, Alaska Fisheries Sci. Ctr., Seattle. 3 pp.

Major, R. L., S. Murai, and J. Lyons. 1975. Scale studies to identify Asian and Western Alaskan chinook salmon. INPFC Annu. Rep. 1973: 80-97.

Major, R. L., S. Murai, and J. Lyons. 1977a. Scale studies to identify Asian and Western Alaskan chinook salmon. INPFC Annu. Rep. 1974:78-81.

Major, R. L., S. Murai, and J. Lyons. 1977b. Scale studies to identify Asian and Western Alaskan chinook salmon. INPFC Annu. Rep. 1975:68-71.

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 Dept. Fish and Game, Info. Leaf. 208. 64 pp.

Merritt, M. F. 1988. Origins of chinook salmon in the Yukon River fisheries, 1987. Alaska Dept. Fish and Game, Tech. Fish. Rep. 88-14. 31 pp.

Merritt, M. F., J. A. Wilcock, and L. K. Brannian. 1988. Origins of chinook salmon in the Yukon river fisheries, 1986. Alaska Dept. Fish and Game, Tech. Data Rep. 223. 54 pp.

Millar, R. B. 1988. Statistical methodology for estimating composition of high seas salmonid mixtures using scale analysis. (INPFC Doc.) FRI-UW-8806. Fish. Res. Inst., Univ. Washington, Seattle. 57 pp.

Millar, R. B. 1990. Comparison of methods for estimating mixed stock fishery composition. Can. J. Fish. Aquat. Sci. 47:2235-2241.

Myers, K. W., C. K. Harris, C. M. Knudsen, R. V. Walker, N. D. Davis, and D. E. Rogers. 1987. Stock origins of chinook salmon in the area of the Japanese mothership salmon fishery. N. Am. J. Fish. Mgmt. 7:459-474.

Myers, K. W., and D. E. Rogers. 1988. Stock origins of chinook salmon in incidental catches by groundfish fisheries in the eastern Bering Sea. N. Am. J. Fish. Mgmt. 8:162-171.

Myers, K. W., R. V. Walker, S. Fowler, and M. L. Dahlberg. 1990. Known ocean ranges of stocks of Pacific salmon and steelhead as shown by tagging experiments, 1956-1989. (INPFC Doc.) Fish. Res. Inst., Univ. Washington, Seattle. 57 pp.

Schneiderhan, D. J. 1993. Origins of chinook salmon in the Yukon River fisheries, 1990. Alaska Dept. Fish and Game, Tech. Fish. Rep. 92-11. 34 pp.

Walker, R. V. 1990. Origins of coho salmon in the area of the Japanese landbased driftnet fishery in 1986 and 1987. (INPFC Doc.) FRI-UW-9012. Fish. Res. Inst., Univ. Washington, Seattle. 34 pp.

Walker, R. V. 1992. Estimates of origin of coho salmon caught in Asian high seas squid driftnet fisheries in 1991 and in an illegal Taiwanese salmon driftnet catch in 1989. (INPFC Doc.) FRI-UW-9208. Fish Res. Inst., Univ. Washington, Seattle. 18 pp.

Wilcock, J. A. 1984. Origins of chinook salmon (*Oncorhynchus tshawytscha* Walbaum) in the Yukon River fisheries, 1983. Alaska Dept. Fish and Game, Info. Leaf. 243. 30 pp.

Wilcock, J. A. 1985. Origins of chinook salmon (*Oncorhynchus tshawytscha* Walbaum) in the Yukon River fisheries, 1984. Alaska Dept. Fish and Game Technical Data Report No. 157. 29 pp.

Wilcock, J. A., and D. N. McBride. 1983. Origins of chinook salmon (*Oncorhynchus tshawytscha* Walbaum) in the Yukon River fisheries, 1982. Alaska Dept. Fish and Game, Info. Leaf. 226. 36 pp.

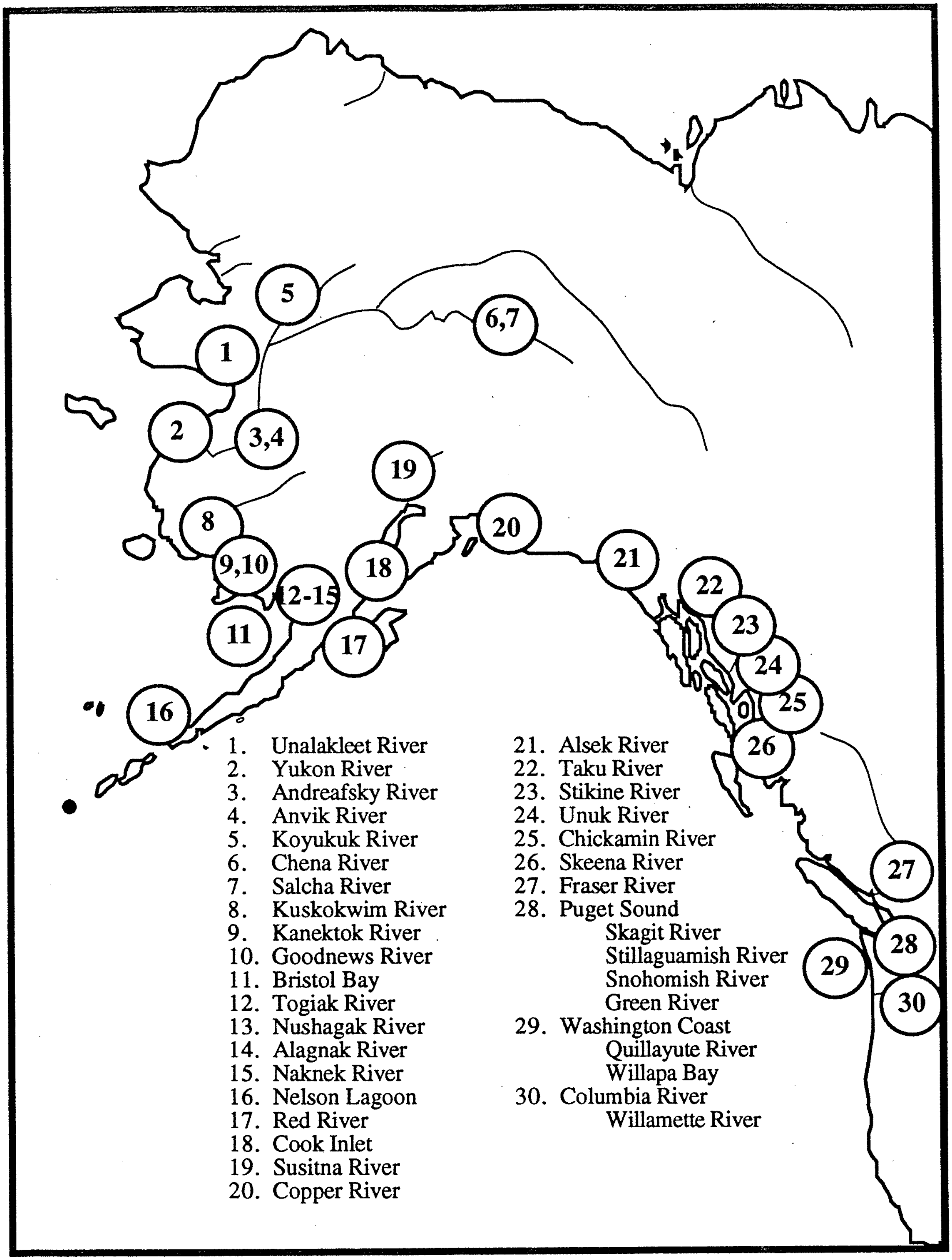



Figure 1. Location of stocks used to construct and test the pooled brood-year standard.

Table 1. Stocks of coded-wire tagged, freshwater age-1 chinook salmon that originated in Idaho (ID), Washington (WA), and Oregon (OR) and were recovered from trawl fisheries operating in the Gulf of Alaska in 1981-1993. The region of the Oregon coast has been divided into the north coast (Newport and north) and south coast (south of Newport). M.=middle, Fk.=fork, Lr.=lower, Cr.=creek

| Stock | Region | State | Recovery Area[1] | Number of Fish |
|---|---|---|---|---|
| Salmon | Snake | ID | W5058 | 1 |
| Similkameen | Up. Columbia | WA | W5556 | 1 |
| Wenatchee | Up. Columbia | WA | W5556 | 1 |
| Cowlitz | Lr. Columbia | WA | W5556 | 1 |
| Snake X Priest | Snake | WA | W5556 | 1 |
| Lewis | Lr. Columbia | WA | W5556 | 1 |
| Klickitat | Mid. Columbia | WA | W5556 | 1 |
| Cook Cr/Quinalt | Coastal | WA | W5556 | 1 |
| Umatilla | Mid Columbia | OR | W5056 | 1 |
| Willamette M Fk | Lr Columbia | OR | W5058 | 1 |
| Willamette M Fk | Lr. Columbia | OR | W5556 | 25 |
| Trask | North Coast | OR | W5556 | 3 |
| Cedar/Nestucca | North Coast | OR | W5556 | 1 |
| Willamette M Fk | Lr. Columbia | OR | W5558 | 2 |
| Willamette M.Fk | Lr. Columbia | OR | W6054 | 1 |
| Willamette | Lr. Columbia | OR | W6056 | 4 |
| Trask | North Coast | OR | W6056 | 1 |
| Willamette | Lr. Columbia | OR | W6554 | 1 |
| Total | | | | 48 |

[1] A standardized coding system used by the International North Pacific Fisheries Commission (INPFC) to identify 2°-latitutde by 5°-longitude areas. For example, area W5058 is the 2° of latitude by 5° of longitude statistical block with 150°W-longitude and 58°N-latitude intersecting at its lower lefthand corner.

Data Sources: Myers et al. 1990 and M. L. Dahlberg (National Marine Fisheries Service, Auke Bay Laboratory) pers. comm.

Table 2. Stocks of coded-wire tagged, freshwater age 1. chinook salmon that were recovered from trawl fisheries operating in the Bering Sea in 1981-1994. Ages are calculated from brood year and freshwater release dates provided for coded-wire tag codes in Johnson and Longwill (1988, 1991, 1993). AK=Alaska, OR=Oregon, BC=British Columbia, YT=Yukon Territories, M.=middle, FK=fork.

| Stock | Region | State or Province | Age | Recovery Area[1] | Number of Fish |
|---|---|---|---|---|---|
| Little Port Walter | southeast AK | AK | 1.3 | W7054 | 1 |
| Stikine River | southeast AK | AK | 1.3 | W7054 | 1 |
| Crystal Creek | southeast AK | AK | 1.3 | W7054 | 1 |
| Mitchie Creek | Canadian Yukon | YT | 1.2 | W7556 | 1 |
| Wolf Creek | Canadian Yukon | YT | 1.2 | W8060 | 1 |
| Quesnel River | Fraser | BC | 1.3 | W7054 | 1 |
| Nicola River | Fraser | BC | 1.1 | W7058 | 1 |
| Willamette M. Fk. | Lower Columbia | OR | 1.2 | W7054 | 1 |

[1] A standardized coding system used by the International North Pacific Fisheries Commission (INPFC) to identify 2°-latitutde by 5°-longitude areas. For example, area W7054 is the 2° of latitude by 5° of longitude statistical block with 170°W-longitude and 54°N-latitude intersecting at its lower lefthand corner.

Data Sources: Myers et al. 1990, Dahlberg et al. 1994, and M. L. Dahlberg (National Marine Fisheries Service, Auke Bay Laboratory) pers. comm.

Table 3. The ten chinook salmon scale characters used in the scale pattern analysis.

| Scale Character Name | Description |
|---|---|
| FWYR | Size of the first year of growth on the scale measured from the center of the focus to the last circulus in the freshwater annulus. |
| OCYR | Size of the second year of growth on the scale measured from the last circulus in the freshwater annulus to the last circulus in the first ocean annulus. |
| OCYRCC | Number of circuli in the second year of growth on the scale (OCYR). |
| TR1 | Size of triplet 1 is the distance from the last circulus in the freshwater annulus to the third circulus in the second year of growth on the scale. |
| TR2 | Size of triplet 2 is the distance between the third and the sixth circulus in the second year of growth on the scale. |
| TR3 | Size of triplet 3 is the distance between the sixth and the ninth circulus in the second year of growth on the scale. |
| TR4 | Size of triplet 4 is the distance between the ninth and the twelfth circulus in the second year of growth on the scale. |
| TR5 | Size of triplet 5 is the distance between the twelfth and the fifteenth circulus in the second year of growth on the scale. |
| TR6 | Size of triplet 6 is the distance between the fifteenth and the eighteenth circulus in the second year of growth on the scale. |
| TR7 | Size of triplet 7 is the distance between the eighteenth and twenty-first circulus in the second year of growth on the scale. |

Table 4. Stock composition and sample size of the pooled brood-year standard (brood-years 1980-1983). Scale pattern data were used in a bootstrapping procedure with replacement such that each regional group and brood year were evenly weighted. For example, the four brood-years of Yukon River scales were each weighted 25% in the pooled standard. The three brood-years of Columbia River scales were each weighted 33% in the pooled standard. There were so few scales from the Fraser River brood-year 1980 sample that brood-year 1980 and 1981 were combined and considered as one sample.

| Stock or Fishery | Brood Year 1980 | | | Brood Year 1981 | | | Brood Year 1982 | | | Brood Year 1983 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Year of Return | Age at Return | N | Year of Return | Age at Return | N | Year of Return | Age at Return | N | Year of Return | Age at Return | N |
| **Yukon River** | | | | | | | | | | | | |
| Emmonak Commercial Fishery | 1986 | 1.4 | 127 | 1986, 1987 | 1.3, 1.4 | 241 | 1987, 1988 | 1.3, 1.4 | 228 | 1988 | 1.3 | 119 |
| **Kuskowim** | | | | | | | | | | | | |
| Bethel Comm. & Subst. Fishery | 1986 | 1.4 | 27 | 1986, 1987 | 1.3, 1.4 | 114 | 1987, 1988 | 1.3, 1.4 | 105 | 1988 | 1.3 | 59 |
| **Bristol Bay** | | | | | | | | | | | | |
| Nushagak Subsistence Fishery | 1986 | 1.4 | 65 | 1986, 1987 | 1.3, 1.4 | 135 | 1987, 1988 | 1.3, 1.4 | 121 | 1988 | 1.3 | 34 |
| Togiak Commercial Fishery | | | 0 | 1986, 1987 | 1.3, 1.4 | 124 | 1987, 1988 | 1.3, 1.4 | 120 | 1988 | 1.3 | 50 |
| Naknek Sport & Escapement | 1986 | 1.4 | 46 | 1986, 1987 | 1.3, 1.4 | 125 | 1987, 1988 | 1.3, 1.4 | 110 | 1988 | 1.3 | 61 |
| Alagnak Sport &Escapement | | | 0 | | | 0 | 1988 | 1.4 | 48 | 1988 | 1.3 | 83 |
| Sub-total | | | 111 | | | 384 | | | 399 | | | 228 |
| **Cook Inlet** | | | | | | | | | | | | |
| North District Comm. Fishery | 1986 | 1.4 | 99 | 1986, 1987 | 1.3,1.4 | 169 | 1987, 1988 | 1.3,1.4 | 169 | 1988 | 1.3 | 34 |
| Susitna Sport Fishery | | | 0 | | | 0 | 1988 | 1.4 | 68 | 1988 | 1.8 | 64 |
| Central District Comm. Fishery | 1986 | 1.4 | 173 | 1986, 1987 | 1.3,1.4 | 297 | 1987, 1988 | 1.3, 1.4 | 189 | 1988 | 1.3 | 77 |
| Sub-total | | | 272 | | | 466 | | | 426 | | | 175 |
| **Copper River** | 1986 | 1.4 | 198 | 1986, 1987 | 1.3,1.4 | 258 | 1987, 1988 | 1.3, 1.4 | 120 | 1988 | 1.3 | 59 |
| **Southeast Alaska-Northern British Columbia** | | | | | | | | | | | | |
| Alsek River | | | 0 | 1986, 1987 | 1.3,1.4 | 111 | 1987, 1988 | 1.3, 1.4 | 148 | 1988 | 1.3 | 76 |
| Taku River | 1986 | 1.4 | 103 | 1986, 1987 | 1.3,1.4 | 63 | 1987, 1988 | 1.3, 1.4 | 90 | 1988 | 1.3 | 55 |
| Stikine River | 1986 | 1.4 | 45 | 1986, 1977 | 1.3,1.4 | 86 | 1987, 1988 | 1.3, 1.4 | 120 | 1988 | 1.3 | 60 |
| Sub-total | | | 148 | | | 260 | | | 358 | | | 191 |
| **Central British Columbia** | | | | | | | | | | | | |
| Chickamin River | | | 0 | 1986, 1987 | 1.3, 1.4 | 71 | 1987, 1988 | 1.3, 1.4 | 83 | 1988 | 1.3 | 60 |
| Unuk River | 1986 | 1.4 | 127 | 1986, 1977 | 1.3,1.4 | 223 | 1987, 1988 | 1.3, 1.4 | 127 | 1988 | 1.3 | 60 |
| Skeena River | 1986 | 1.4 | 116 | 1986, 1977 | 1.3,1.4 | 120 | 1987, 1988 | 1.3, 1.4 | 120 | 1988 | 1.3 | 61 |
| Sub-total | | | 243 | | | 414 | | | 330 | | | 181 |
| **Fraser River** | 1986 | 1.4 | 9 | 1986 | 1.3 | 155 | | | 0 | | | 0 |
| **Columbia River** | | | 0 | 1986 | 1.3 | 101 | 1986, 1987 | 1.2, 1.3 | 180 | 1987 | 1.2 | 89 |
| Grand Total | | | 1136 | | | 2393 | | | 2146 | | | 1101 |

Table 5. Maximum likelihood estimates resulting from using a pooled standard (brood-years 1981, 1982, and 1983) and apportioning scales from known stocks (brood-year 1980) as if the origin of these stocks was unknown. Maximum likelihood proportion estimates are the mean estimate of 100 bootstrapped runs. The 95% confidence interval () comprises 95% (2-tailed) of the proportion estimates from the 100 bootstrapped runs. SENBC=southeast Alaska and northern British Columbia, CBC=central British Columbia.

| Unknowns | N | Yukon | Kuskokwim | Bristol Bay | Cook Inlet | Copper | SENBC | CBC | Fraser | Columbia |
|---|---|---|---|---|---|---|---|---|---|---|
| Yukon 80 | 127 | .819 (.722-.931) | .127 (.000-.245) | .021 (.000-.069) | .033 (.000-.091) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Kuskokwim 80 | 27 | .335 (.120-.580) | .052 (.000-.245) | .138 (.000-.303) | .412 (.155-.610) | .002 (.000-.002) | .000 (.000-.000) | .000 (.000-.000) | .059 (.000-.169) | .002 (.000-.002) |
| Bristol Bay 80 | 111 | .479 (.295-.604) | .159 (.000-.357) | .172 (.031-.350) | .178 (.070-.309) | .012 (.000-.047) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Cook Inlet 80 | 272 | .021 (.000-.073) | .007 (.000-.047) | .001 (.000-.004) | .963 (.894-.999) | .000 (.000-.000) | .008 (.000-.064) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Copper 80 | 198 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .008 (.000-.053) | .343 (.174-.480) | .649 (.462-.807) | .001 (.000-.003) | .000 (.000-.000) | .000 (.000-.000) |
| Taku 80 | 103 | .004 (.000-.025) | .000 (.000-.000) | .000 (.000-.000) | .317 (.095-.494) | .159 (.000-.396) | .509 (.242-.757) | .001 (.000-.001) | .010 (.000-.046) | .000 (.000-.000) |
| Stikine 80 | 45 | .007 (.000-.049) | .000 (.000-.000) | .000 (.000-.000) | .140 (.000-.348) | .019 (.000-.144) | .835 (.589-.999) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Unuk 80 | 127 | .000 (.000-.000) | .005 (.000-.035) | .000 (.000-.000) | .000 (.000-.000) | .002 (.000-.013) | .212 (.071-.366) | .779 (.615-.909) | .000 (.000-.000) | .003 (.000-.016) |
| Skeena 80 | 116 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000 | .247 (.040-.480) | .004 (.000-.031) | .464 (.212-.710) | .250 (.081-.418) | .036 (.000-.088) |
| Bella Coola 80 | 17 | .000 (.000-.000) | .000 (.000-.000) | .013 (.000-.091) | .000 (.000-.000) | .684 (.295-.974) | .000 (.000-.000) | .008 (.000-.010) | .295 (.000-.619) | .000 (.000-.000) |
| Fraser 80 | 9 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .017 (.000-.163) | .166 (.000-.520) | .000 (.000-.000) | .817 (.469-1.000) | .000 (.000-.000) |
| | means | correct apportion | | | | | | | | |

Table 6. Maximum likelihood estimates resulting from using a pooled standard (brood-years 1980, 1982, and 1983) and apportioning scales from known stocks (brood-year 1981) as if the origin of these stocks was unknown. Maximum likelihood proportion estimates are the mean estimate of 100 bootstrapped runs. The 95% confidence interval () comprises 95% (2-tailed) of the proportion estimates from the 100 bootstrapped runs. SENBC=southeast Alaska and northern British Columbia, CBC=central British Columbia.

| Unknowns | N | Yukon | Kuskokwim | Bristol Bay | Cook Inlet | Copper | SENBC | CBC | Columbia |
|---|---|---|---|---|---|---|---|---|---|
| Yukon 81 | 241 | .466 (.338-.584) | .175 (.000-.453) | .359 (.191-.492) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Kuskokwim 81 | 114 | .002 (.000-.017) | .159 (.000-.397) | .683 (.453-.907) | .125 (.000-.266) | .021 (.000-.074) | .010 (.000-.097) | .001 (.000-.022) | .000 (.000-.000) |
| Bristol Bay 81 | 384 | .020 (.000-.053) | .001 (.000-.011) | .967 (.935-.998) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .013 (.000-.031) | .000 (.000-.000) |
| Cook Inlet 81 | 466 | .000 (.000-.000) | .011 (.000-.057) | .082 (.015-.156) | .431 (.261-.601) | .014 (.000-.078) | .432 (.270-.593) | .030 (.000-.074) | .000 (.000-.000) |
| Copper 81 | 258 | .000 (.000-.000) | .000 (.000-.001) | .004 (.000-.017) | .000 (.000-.000) | .516 (.361-.685) | .000 (.000-.000) | .474 (.307-.606) | .006 (.000-.033) |
| Alsek 81 | 111 | .000 (.000-.000) | .000 (.000-.000) | .006 (.000-.040) | .000 (.000-.002) | .103 (.000-.359) | .787 (.536-.969) | .103 (.000-.247) | .000 (.000-.000) |
| Taku 81 | 63 | .000 (.000-.000) | .000 (.000-.011) | .004 (.000-.027) | .021 (.000-.186) | .006 (.000-.065) | .808 (.570-.966) | .130 (.000-.298) | .032 (.000-.090) |
| Stikine 81 | 86 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .032 (.000-.154) | .073 (.000-.291) | .748 (.360-.976) | .147 (.000-.311) | .000 (.000-.000) |
| Unuk 81 | 223 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .001 (.000-.006) | .000 (.000-.000) | .999 (.993-.999) | .000 (.000-.000) |
| Chickamin 81 | 71 | .000 (.000-.000) | .000 (.000-.012) | .000 (.000-.007) | .001 (.000-.008) | .019 (.000-.092) | .000 (.000-.003) | .979 (.902-.999) | .000 (.000-.000) |
| Skeena 81 | 120 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .073 (.000-.213) | .000 (.000-.000) | .910 (.774-.999) | .017 (.000-.060) |
| Bella Coola 81 | 60 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .220 (.062-.458) | .001 (.000-.003) | .779 (.540-.937) | .000 (.000-.000) |
| Fraser 81 | 155 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .164 (.004-.319) | .000 (.000-.000) | .799 (.604-.959) | .037 (.000-.078) |
| Columbia 81 | 101 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .041 (.000-.090) | .000 (.000-.000) | .017 (.000-.061) | .942 (.880-.986) |
| Skagit 81 | 20 | .000 (.000-.000) | .000 (.000-.000) | .023 (.000-.087) | .000 (.000-.000) | .002 (.000-.004) | .000 (.000-.000) | .605 (.367-.776) | .370 (.164-.569) |
| | | | | | | | | | |
| | means | correct apportion | | | | | | | |

Table 7. Maximum likelihood estimates resulting from using a pooled standard (brood-years 1980, 1981, and 1983) and apportioning scales from known stocks (brood-year 1982) as if the origin of these stocks was unknown. Maximum likelihood proportion estimates are the mean estimate of 100 bootstrapped runs. The 95% confidence interval () comprises 95% (2-tailed) of the proportion estimates from the 100 bootstrapped runs. SENBC=southeast Alaska and northern British Columbia, CBC=central British Columbia.

| Unknowns | N | Yukon | Kuskokwim | Bristol Bay | Cook Inlet | Copper | SENBC | CBC | Fraser | Columbia |
|---|---|---|---|---|---|---|---|---|---|---|
| Yukon 82 | 228 | .994 (.973-.999) | .000 (.000-.000) | .006 (.000-.025) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Kuskokwim 82 | 105 | .000 (.000-.000) | .373 (.000-.830) | .451 (.003-.791) | .007 (.000-.062) | .094 (.000-.250) | .069 (.000-.198) | .005 (.000-.044) | .000(.000-.000) | .001 (.000-.009) |
| Bristol Bay 82 | 399 | .000 (.000-.000) | .000 (.000-.000) | .886 (.819-.946) | .002 (.000-.014) | .080 (.000-.147) | .023 (.000-.068) | .009 (.000-.039) | .001 (.000-.006) | .000 (.000-.003) |
| Cook Inlet 82 | 426 | .000 (.000-.000) | .000 (.000-.000) | .081 (.025-.135) | .676 (.506-.797) | .207 (.098-.313) | .035 (.000-.146) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Copper 82 | 120 | .000 (.000-.000) | .000 (.000-.000) | .001 (.000-.003) | .000 (.000-.000) | .864 (.697-.999) | .000 (.000-.000) | .106 (.000-.270) | .030 (.000-.125) | .000 (.000-.000) |
| Alsek 82 | 148 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .251 (.000-.551) | .699 (.347-.949) | .039 (.000-.142) | .011 (.000-.039) | .000 (.000-.000) |
| Taku 82 | 90 | .000 (.000-.000) | .000 (.000-.000) | .001 (.000-.011) | .000 (.000-.000) | .022 (.000-.133) | .964 (.811-.999) | .013 (.000-.091) | .000 (.000-.000) | .000 (.000-.000) |
| Stikine 82 | 120 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .264 (.010-.532) | .417 (.158-.626) | .292 (.125-.455) | .027 (.000-.074) | .000 (.000-.000) |
| Unuk 82 . | 127 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .971 (.900-.999) | .028 (.000-.096) | .000 (.000-.000) |
| Chickamin 82 | 83 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .999 (.999-1.00) | .000 (.000-.000) | .000 (.000-.000) |
| Skeena 82 | 120 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .058 (.000-.162) | .000 (.000-.000) | .645 (.478-.817) | .297 (.175-.459) | .000 (.000-.000) |
| Columbia 82 | 180 | .000 (.000-.000) | .000 (.000-.000) | .006 (.000-.020) | .000 (.000-.000) | .013 (.000-.046) | .000 (.000-.000) | .007 (.000-.035) | .050 (.002-.102) | .923 (.871-.975) |
| Puget Sound 82 | 13 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .299 (.000-.555) | .004 (.000-.004) | .697 (.437-.938) |
| Washington Coast 82 | 11 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .093 (.000-.266) | .907 (.728-1.00) |
| | means | correct apportion | | | | | | | | |

Table 8. Maximum likelihood estimates resulting from using a pooled standard (brood-years 1980, 1981, and 1982) and apportioning scales from known stocks (brood-year 1983) as if the origin of these stocks was unknown. Maximum likelihood proportion estimates are the mean estimate of 100 bootstrapped runs. The 95% confidence interval () comprises 95% (2-tailed) of the proportion estimates from the 100 bootstrapped runs. SENBC=southeast Alaska and northern British Columbia, CBC=central British Columbia.

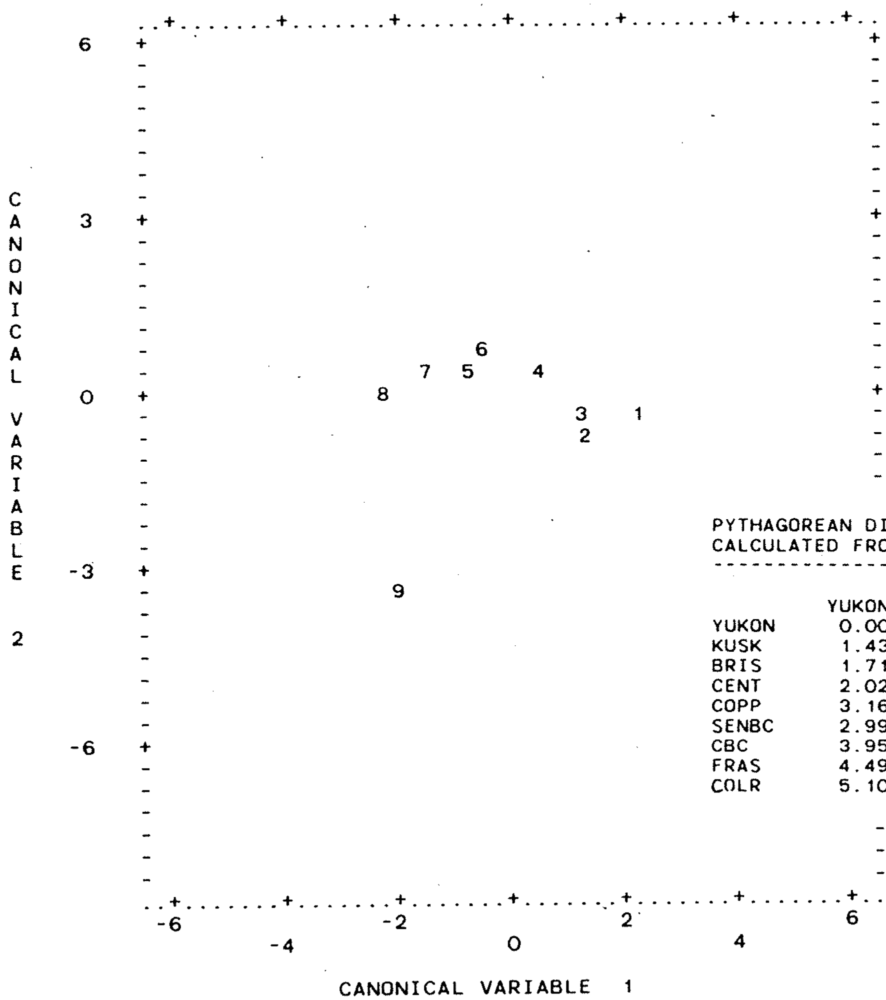
| Unknowns | N | Yukon | Kuskokwim | Bristol Bay | Cook Inlet | Copper | SENBC | CBC | Fraser | Columbia |
|---|---|---|---|---|---|---|---|---|---|---|
| Yukon 83 | 119 | .847 (.682-.970) | .000 (.000-.000) | .153 (.030-.302) | .000 (.000-.000) | .000 (.000-.000). | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Kuskokwim 83 | 59 | .903 (.667-.999) | .087 (.000-.322) | .010 (.000-.119) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Bristol Bay 83 | 228 | .093 (.023-.177) | .019 (.000-.110) | .723 (.597-.844) | .145 (.041-.232) | .010 (.000-.053) | .002 (.000-.008) | .009 (.000-.034) | .000 (.000-.000) | .000 (.000-.000) |
| Cook Inlet 83 | 175 | .044 (.000-.111) | .143 (.000-.274) | .000 (.000-.000) | .813 (.690-.923) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Copper 83 | 59 | .000 (.000-.000) | .002 (.000-.027) | .000 (.000-.000) | .551 (.079-.863) | .339 (.046-.610) | .108 (.000-.545) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Alsek 83 | 76 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .194 (.000-.458) | .000 (.000-.000) | .806 (.413-.999) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Taku 83 | 55 | .032 (.000-.097) | .021 (.000-.101) | .000 (.000-.000) | .106 (.000-.418) | .001 (.000-.000) | .830 (.532-.995) | .001 (.000-.001) | .009 (.000-.050) | .000 (.000-.000) |
| Stikine 83 | 60 | .000 (.000-.000) | .001 (.000-.001) | .000 (.000-.000) | .670 (.353-.988) | .006 (.000-.055) | .306 (.000-.647) | .002 (.000-.006) | .000 (.000-.000) | .015 (.000-.050) |
| Unuk 83 | 60 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .245 (.004-.412) | .755 (.545-.979) | .000 (.000-.000) | .000 (.000-.000) |
| Chickamin 83 | 60 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .201 (.002-.434) | .782 (.549-.982) | .000 (.000-.000) | .017 (.000-.052) |
| Skeena 83 | 61 | .000 (.000-.000) | .015 (.000-.074) | .002 (.000-.004) | .026 (.000-.105) | .234 (.000-.519) | .000 (.000-.000) | .715 (.433-.956) | .009 (.000-.055) | .000 (.000-.000) |
| Columbia 83 | 89 | .000 (.000-.000) | .001 (.000-.008) | .000 (.000-.007) | .000 (.000-.000) | .021 (.000-.088) | .000 (.000-.000) | .003 (.000-.033) | .079 (.000-.156) | .896 (.828-.965) |
| | means | correct apportion | | | | | | | | |

Table 9. Maximum likelihood estimates resulting from using a full pooled standard (brood-years 1980-1983) and apportioning scales from known stocks (brood-years 1980-1983) as if the origin of these stocks was unknown. None of the scales tested were included in the standards used to apportion them. Maximum likelihood estimates are the mean estimate of 100 bootstrapped runs. The 95% confidence interval () comprises 95% (2-tailed) of the proportion estimates from the 100 bootstrapped runs. SENBC=southeast Alaska and northern British Columbia, CBC=central British Columbia.

| Unknowns | N | Yukon | Kuskokwim | Bristol Bay | Cook Inlet | Copper | SENBC | CBC | Fraser | Columbia |
|---|---|---|---|---|---|---|---|---|---|---|
| Unalakleet 80 | 123 | .416 (.253-.568) | .276 (.013-.509) | .242 (.000-.427) | .000 (.000-.000) | .005 (.000-.041) | .000 (.000-.000) | .001 (.000-.003) | .044 (.008-.098) | .016 (.000-.060) |
| Unalakleet 81 | 133 | .192 (.042-.330) | .356 (.024-.665) | .452 (.193-.666) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Unalakleet 82 | 60 | .884 (.710-.999) | .005 (.000-.050) | .107 (.000-.273) | .004 (.000-.012) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Unalakleet 83 | 54 | .509 (.255-.745) | .105 (.000-.390) | .386 (.049-.685) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Yukon-Middle Mouth 80 | 76 | .678 (.491-.856) | .157 (.000-.378) | .010 (.000-.073) | .118 (.000-.276) | .001 (.000-.006) | .000 (.000-.000) | .023 (.000-.058) | .000 (.000-.000) | .013 (.000-.040) |
| Yukon-Middle Mouth 81 | 80 | .490 (.230-.708) | .430 (.048-.707) | .080 (.000-.264) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Yukon-Big Eddy 80 | 65 | .634 (.381-.922) | .348 (.057-.598) | .018 (.000-.085) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Yukon-Big Eddy 81 | 111 | .448 (.304-.585) | .206 (.000-.453) | .347 (.112-.544) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Yukon-Andreafsky 81 | 101 | .240 (.082-.384) | .663 (.338-.885) | .096 (.000-.289) | .000 (.000-.000) | .000 (.000-.000) | .001 (.000-.013) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Yukon-Anvik 81 | 38 | .135 (.000-.365) | .761 (.318-.999) | .066 (.000-.290) | .038 (.000-.244) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Yukon-Nulato 81 | 60 | .063 (.000-.177) | .646 (.196-.996) | .286 (.000-.612) | .004 (.000-.040) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Yukon-Koyokuk 81 | 55 | .651 (.426-.823) | .280 (.000-.549) | .037 (.000-.163) | .031 (.000-.145) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Yukon-Salcha 81 | 59 | .289 (.014-.537) | .173 (.000-.799) | .329 (.000-.624) | .201 (.000-.388) | .000 (.000-.000) | .007 (.000-.066) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Yukon-Chena 81 | 60 | .527 (.299-.739) | .065 (.000-.340) | .374 (.151-.591) | .022 (.000-.106) | .000 (.000-.000) | .012 (.000-.059) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Kuskokwim-Kogrukluk Weir 80 | 89 | .349 (.218-.472) | .000 (.000-.000) | .069 (.000-.145) | .500 (.352-.637) | .028 (.000-.151) | .000 (.000-.000) | .008 (.000-.043) | .046 (.000-.096) | .000 (.000-.003) |
| Kuskokwim-Kogrukluk Weir 81 | 60 | .000 (.000-.000) | .415 (.013-.762) | .512 (.185-.839) | .036 (.000-.196) | .000 (.000-.000) | .033 (.000-.128) | .005 (.000-.044) | .000 (.000-.000) | .000 (.000-.000) |
| Kanektok 80 | 60 | .869 (.741-.957) | .016 (.000-.113) | .005 (.000-.043) | .033 (.000-.115) | .000 (.000-.000) | .003 (.000-.025) | .019 (.000-.078) | .039 (.000-.120) | .017 (.000-.051) |
| Kanektok 81 | 120 | .026 (.000-.096) | .249 (.000-.552) | .666 (.396-.893) | .015 (.000-.105) | .031 (.000-.103) | .010 (.000-.057) | .004 (.000-.029) | .000 (.000-.000) | .000 (.000-.000) |
| Kanektok 82 | 112 | .000 (.000-.000) | .077 (.000-.323) | .782 (.514-.916) | .017 (.000-.100) | .085 (.000-.182) | .000 (.000-.000) | .026 (.000-.099) | .000 (.000-.000) | .014 (.000-.038) |
| Kanektok 83 | 60 | .349 (.103-.606) | .316 (.000-.673) | .336 (.029-.601) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Goodnews 80 | 31 | .395 (.049-.685) | .141 (.000-.568) | .162 (.000-.443) | .277 (.000-.434) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .025 (.000-.097) |
| Goodnews 81 | 119 | .003 (.000-.023) | .455 (.184-.688) | .518 (.272-.760) | .008 (.000-.051) | .001 (.000-.002) | .000 (.000-.000) | .014 (.000-.042) | .000 (.000-.000) | .000 (.000-.000) |
| Goodnews 82 | 101 | .000 (.000-.000) | .019 (.000-.101) | .952 (.839-.999) | .000 (.000-.000) | .024 (.000-.083) | .000 (.000-.000) | .003 (.000-.024) | .002 (.000-.022) | .000 (.000-.000) |
| Goodnews 83 | 60 | .418 (.163-.686) | .479 (.155-.741) | .050 (.000-.158) | .034 (.000-.194) | .007 (.000-.048) | .010 (.000-.052) | .000 (.000-.000) | .002 (.000-.007) | .000 (.000-.000) |
| | means | correct apportion | | | | | | | | |

Table 9. Continued.

| Unknowns | N | Yukon | Kuskokwim | Bristol Bay | Cook Inlet | Copper | SENBC | CBC | Fraser | Columbia |
|---|---|---|---|---|---|---|---|---|---|---|
| Nelson Lagoon 80 | 135 | .936 (.822-.999) | .007 (.000-.056) | .004 (.000-.028) | .053 (.000-.144) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Nelson Lagoon 81 | 183 | .554 (.408-.688) | .000 (.000-.000) | .220 (.026-.381) | .225 (.091-.358) | .001 (.000-.008) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Nelson Lagoon 82 | 121 | .426 (.257-.582) | .000 (.000-.000) | .405 (.169-.573) | .167 (.025-.308) | .003 (.000-.030) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Nelson Lagoon 83 | 59 | .989 (.940-1.000) | .000 (.000-.000) | .009 (.000-.045) | .002 (.000-.009) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Chignik 81 | 34 | .182 (.000-.401) | .034 (.000-.328) | .636 (.255-.913) | .029 (.000-.190) | .120 (.000-.359) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Chignik 82 | 42 | .871 (.649-.999) | .114 (.000-.332) | .008 (.000-.101) | .004 (.000-.034) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .002 (.000-.027) |
| Red River 81 | 53 | .000 (.000-.000) | .000 (.000-.000) | .008 (.000-.045) | .531 (.230-.870) | .003 (.000-.003) | .457 (.100-.761) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) |
| Columbia River Fall 80-83 | 18 | .000 (.000-.000) | .014 (.000-.101) | .018 (.000-.083) | .000 (.000-.000) | .003 (.000-.003) | .023 (.000-.153) | .000 (.000-.000) | .027 (.000-.124) | .916 (.770-1.000) |
| Washington Coast 82 | 11 | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .081 (.000-.256) | .919 (.738-1.000) |
| Puget Sound 81-82 | 33 | .000 (.000-.000) | .000 (.000-.000) | .016 (.000-.077) | .000 (.000-.000) | .000 (.000-.000) | .000 (.000-.000) | .307 (.056-.501) | .176 (.000-.422) | .502 (.349-.684) |
| | means | correct apportion | | | | | | | | |




| GROUP | MEAN COORDINATES | | SYMBOL FOR MEAN |
|---|---|---|---|
| YUKON | 2.18 | -0.32 | 1 |
| KUSK | 1.25 | -0.42 | 2 |
| BRIS | 1.23 | -0.39 | 3 |
| CENT | 0.41 | 0.34 | 4 |
| COPP | -0.79 | 0.33 | 5 |
| SENBC | -0.45 | 0.86 | 6 |
| CBC | -1.58 | 0.43 | 7 |
| FRAS | -2.24 | 0.04 | 8 |
| COLR | -1.96 | -3.22 | 9 |

PYTHAGOREAN DISTANCES BETWEEN STOCKS
CALCULATED FROM BMDP OUTPUT OF CANONICAL VARIABLES EVALUATED AT GROUP MEANS

| | YUKON | KUSK | BRIS | CENT | COPP | SENBC | CBC | FRAS | COLR |
|---|---|---|---|---|---|---|---|---|---|
| YUKON | 0.0000 | | | | | | | | |
| KUSK | 1.4319 | 0.0000 | | | | | | | |
| BRIS | 1.7158 | 0.8514 | 0.0000 | | | | | | |
| CENT | 2.0291 | 1.3478 | 1.5522 | 0.0000 | | | | | |
| COPP | 3.1624 | 2.3982 | 2.3510 | 1.3147 | 0.0000 | | | | |
| SENBC | 2.9912 | 2.1967 | 2.3141 | 1.0326 | 0.9286 | 0.0000 | | | |
| CBC | 3.9500 | 3.0346 | 2.9840 | 2.1871 | 1.2259 | 1.4440 | 0.0000 | | |
| FRAS | 4.4944 | 3.7717 | 3.8946 | 2.8515 | 1.8336 | 2.2613 | 1.5853 | 0.0000 | |
| COLR | 5.1072 | 4.3216 | 4.4018 | 4.2826 | 3.7881 | 4.3540 | 3.7669 | 3.4276 | 0.0000 |

Appendix Figure 1. Plot of stock centroids evaluated at the first and second canonical variable and the euclidean distances calculated from the centroid for nine stock-groups from Alaska, British Columbia, and Washington (pooled brood-year 1980-1983). YUKON=Yukon River, KUSK=Kuskokwim River, BRIS=Bristol Bay, CENT=Cook Inlet, COPP=Copper River, SENBC=southeast Alaska and northern British Columbia, CBC=central British Columbia, FRAS=Fraser River, and COLR=Columbia River.

Appendix Table 1. Descriptive statistics for scale data from the pooled brood year standard 1980-1983. The southeast Alaska/northern British Columbia (SENBC) group is composed of the Alsek, Taku, and Stikine rivers. The central British Columbia (CBC) group is composed of the Unuk, Chickamin, and Skeena rivers.

| | Yukon River | Kuskokwim River | Bristol Bay | Cook Inlet | Copper River | SENBC | CBC | Fraser River | Columbia River |
|---|---|---|---|---|---|---|---|---|---|
| **Freshwater Zone Size** | | | | | | | | | |
| mean | 310.68 | 307.62 | 307.02 | 293.33 | 300.60 | 277.18 | 301.96 | 326.46 | 466.96 |
| std. dev. | 47.29 | 47.41 | 46.07 | 50.94 | 48.59 | 50.79 | 48.66 | 52.68 | 92.02 |
| | | | | | | | | | |
| **Ocean Circuli Count** | | | | | | | | | |
| mean | 32.29 | 34.03 | 35.04 | 33.18 | 35.30 | 33.73 | 36.55 | 36.88 | 37.95 |
| std. dev. | 2.84 | 3.80 | 3.85 | 3.66 | 3.08 | 3.44 | 3.66 | 3.85 | 4.05 |
| | | | | | | | | | |
| **Ocean Zone Size** | | | | | | | | | |
| mean | 1429.46 | 1398.04 | 1476.57 | 1310.25 | 1330.64 | 1256.69 | 1328.45 | 1283.71 | 1432.51 |
| std. dev. | 133.06 | 161.84 | 174.04 | 163.78 | 136.03 | 142.67 | 149.37 | 152.65 | 158.86 |
| | | | | | | | | | |
| **Triplet 1** | | | | | | | | | |
| mean | 80.71 | 74.22 | 80.00 | 80.53 | 85.76 | 81.41 | 85.92 | 80.71 | 77.62 |
| std. dev. | 13.67 | 12.47 | 13.29 | 13.54 | 13.99 | 13.12 | 14.46 | 12.63 | 14.11 |
| | | | | | | | | | |
| **Triplet 2** | | | | | | | | | |
| mean | 93.36 | 87.92 | 92.92 | 91.91 | 94.55 | 93.64 | 100.46 | 99.52 | 93.61 |
| std. dev. | 18.45 | 19.16 | 18.30 | 17.81 | 17.23 | 18.51 | 19.26 | 18.77 | 21.56 |
| | | | | | | | | | |
| **Triplet 3** | | | | | | | | | |
| mean | 144.96 | 106.10 | 106.26 | 109.90 | 107.63 | 110.58 | 112.12 | 111.65 | 112.75 |
| std. dev. | 20.02 | 18.24 | 19.77 | 20.86 | 18.64 | 19.72 | 17.60 | 17.16 | 24.65 |
| | | | | | | | | | |
| **Triplet 4** | | | | | | | | | |
| mean | 130.25 | 118.86 | 121.16 | 124.24 | 122.53 | 117.85 | 112.99 | 118.99 | 122.04 |
| std. dev. | 20.84 | 18.95 | 19.16 | 19.27 | 18.93 | 18.81 | 16.76 | 18.41 | 20.65 |
| | | | | | | | | | |
| **Triplet 5** | | | | | | | | | |
| mean | 148.85 | 130.37 | 131.45 | 131.87 | 127.49 | 122.25 | 111.71 | 124.15 | 126.00 |
| std. dev. | 25.38 | 22.00 | 21.51 | 19.17 | 17.36 | 18.28 | 16.58 | 17.21 | 17.50 |
| | | | | | | | | | |
| **Triplet 6** | | | | | | | | | |
| mean | 165.77 | 142.85 | 143.03 | 136.68 | 125.10 | 123.52 | 112.52 | 115.64 | 126.12 |
| std. dev. | 26.18 | 23.15 | 22.24 | 19.85 | 15.86 | 18.43 | 17.13 | 18.52 | 17.09 |
| | | | | | | | | | |
| **Triplet 7** | | | | | | | | | |
| mean | 169.43 | 153.01 | 149.70 | 136.17 | 120.34 | 122.35 | 115.43 | 109.90 | 124.43 |
| std. dev. | 22.62 | 24.37 | 21.46 | 20.03 | 15.97 | 17.62 | 17.64 | 18.58 | 17.59 |
| | | | | | | | | | |
| **Sample Size** | 715 | 305 | 1122 | 1339 | 635 | 957 | 1168 | 164 | 370 |