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FINAL REPORT

DETERMINATION OF STOCK ORIGINS OF CHINOOK SALMON  
INCIDENTALLY CAUGHT IN FOREIGN TRAWLS IN THE ALASKA FCZ

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## EXECUTIVE SUMMARY

This is the final report for contract 81-5: Determination of Stock Origins of Chinook Salmon Incidentally Caught in Foreign Trawls in the Alaska FCZ.

Chinook salmon (Oncorhynchus tshawytscha) are the least abundant species of Pacific salmon in Alaska, but they often account for over 90% of the incidental catch of salmon by the foreign groundfish fishery in the Alaska FCZ. Incidental catches of chinook by the foreign groundfish fishery as high as those in 1979 and 1980 (>100,000 chinook) may significantly impact U.S. commercial, subsistence, and sport chinook fisheries, and escapement, yet stock origins of chinook caught by the groundfish fishery are not well known. We used models constructed from the scale patterns of major Asian and North American chinook stocks to classify the scales of chinook caught by the foreign groundfish fishery in the Alaska FCZ in 1978, 1979, and 1981 to region (Asia vs. Western Alaska vs. Central Alaska vs. Southeast Alaska/British Columbia vs. Washington/Oregon/California) and western Alaskan 'river' (Yukon, Kuskokwim, and Bristol Bay) of origin.

The highest incidental catches of chinook salmon by the foreign groundfish fishery in the Alaska FCZ usually occur along the continental slope (200 m contour) in the Bering Sea in INPFC statistical areas 1 and 2 during the first, third, and fourth quarters of the year, and most of the scale samples collected by U.S. observers were from these time-area strata. Chinook in the 1979 and 1981 groundfish fishery catches in the

eastern Bering Sea were predominantly ages 1.2 and 1.3. Mixing proportion estimates calculated for Bering Sea samples in 1979 and 1981 indicate that western Alaska was often the predominant regional stock. However, significant estimates for non-western Alaskan stocks indicate the presence of Asian, central Alaskan, and southeast Alaskan and British Columbian chinook, and these stocks predominated in some time-area strata. Age 1. chinook of Washington, Oregon, and California origin were not present in the 1979 and 1981 groundfish fishery samples from the eastern Bering Sea. Yukon was the predominant western Alaskan stock in 1979 catches of age 1.2 and 1.3 chinook and Bristol Bay was predominant in 1981 catches of age 1.2 chinook. Kuskokwim chinook did not appear to be present in the 1979 and 1981 trawl fishery catches. The quality and quantity of samples collected by U.S. observers on groundfish vessels in the Bering Sea in 1978 and the Gulf of Alaska for all years were not adequate for determination of stock origins.

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DETERMINATION OF STOCK ORIGINS OF CHINOOK SALMON  
INCIDENTALLY CAUGHT IN FOREIGN TRAWLS IN THE ALASKA FCZ

Final Report, September 30, 1983

INTRODUCTION

This is the final report on a two-year project to determine stock origins of incidental catches of chinook salmon (Oncorhynchus tshawytscha) in foreign groundfish fisheries of the U. S. Fishery Conservation Zone (FCZ) of Alaska. Scale pattern recognition techniques were used to determine region- or river-of-origin of chinook in samples collected by U. S. foreign fisheries observers in 1978, 1979, and 1981.

Chinook salmon is the least abundant species of Pacific salmon in Alaska (Major et al. 1978). However, chinook often account for over 90% of the incidental salmon catch in the Alaska FCZ foreign groundfish fishery (Table 1). Estimated incidental catches of over 100,000 chinook salmon in the Bering Sea/Aleutian Islands region in 1979 and 1980 (Table 1) amounted to more than 1/3 the average annual commercial harvest of 261,000 chinook salmon in western Alaska since 1963 (Meacham 1980). Incidental catches of this magnitude are likely to have a significant impact on commercial, subsistence, and sport chinook fisheries, and escapement of mature chinook to the spawning grounds.

Stock origins of chinook in foreign groundfish fishery catches in

the eastern Bering Sea and Gulf of Alaska are not well known. Tagging, scale, maturity, and distribution studies summarized by Major et al. (1978) indicate that the probable area of origin of chinook salmon stocks in the eastern Bering Sea is western Alaska, and over 90% of the chinook salmon produced in western Alaska probably originate in the Yukon, Kuskokwim, and Nushagak rivers (Meacham 1980). Chinook stocks in the Gulf of Alaska may originate from rivers along the North American coast from California to central Alaska (Major et al. 1978).

During the first year of this project, we determined that freshwater and marine growth patterns on the scales of selected major coastal chinook stocks allow region- or river-of-origin separation, and that scale samples collected by U.S. observers were adequate for a provisional classification of chinook stocks caught by foreign groundfish fisheries in the Alaska FCZ (Myers and Rogers 1982). This year, our primary objective was to classify chinook scale samples collected by U.S. observers in 1978, 1979, and 1981 to probable region- or western Alaskan river-of-origin.

## METHODS

Stock separation of salmon by scale pattern analysis is based on the assumption that fish from a particular region or stock grow in a characteristic manner. This characteristic growth is reflected in the number and spacing of circuli (concentric bony ridges) on the scales, and these patterns can be used to identify fish in a mixed stock

population. Training samples or "standards" constructed from the scale patterns of inshore samples of chinook of known origin were used to classify the scales of chinook of unknown origin in the groundfish fishery samples.

#### Inshore Scale Samples

A valid scale pattern analysis requires the inclusion of all stocks likely to be present in the mixed stock population. Because of the lack of information and distribution of chinook stocks in the eastern Bering Sea and Gulf of Alaska, we decided to include all major hatchery and wild chinook stocks from California to the Yukon River and Asia for which scale samples were available. We used inshore scale samples collected by the Asian and North American fisheries agencies involved in managing these stocks and gathered by personnel on a Fisheries Research Institute (FRI) project funded by the Alaska Department of Fish and Game (ADF&G). The samples gathered by this project are listed in Rogers et al. (1983), and include 1975-82 scales of North American stocks from the Sacramento River in California to the Yukon River in western Alaska, and 1975-76 and 1978-81 scales of Asian chinook from the Kamchatka and Bolshaya rivers. The only notable gap in this scale collection in terms of our analysis was the lack of samples from the Kamchatka and Bolshaya in 1982.

#### Stock Composition of Standards and Abundance Estimates

The inshore scale samples were grouped into five regional standards (Asia, Western Alaska, Central Alaska, Southeast Alaska and British

Columbia, and Washington, Oregon, and California) and three western Alaska river standards (Yukon, Kuskokwim, and Bristol Bay). The major stocks included in these standards and their geographic locations are shown in Figure 1, and estimates of their abundance are presented in Tables 2-6. These abundance estimates were used to weight the proportions of the stocks included in the standards.

The Asian standards include the only two stocks (Kamchatka and Bolshaya) for which Asian chinook scale samples are available. Abundance estimates for Asian stocks are limited to commercial catch statistics for east and west Kamchatka (Table 2). These were used to weight the proportions of Kamchatka River (east Kamchatka) and Bolshaya River (west Kamchatka) scales in the Asian standards. The catch estimates for 1980-81 were unofficial, and no estimates were available for 1982.

The Western Alaska standards were composed of six stocks (Yukon, Kuskokwim, Kanektok, Goodnews, Nushagak, and Togiak), and these same stocks were used to construct the three western Alaskan river standards. Both Alaskan and Canadian fish were included in the Yukon scale samples and abundance estimates. The total run size estimates for the Yukon, Kuskokwim, Kanektok, and Goodnews (Table 3) were prepared for us by ADF&G (pers. comm., R. I. Regnart, 1982).

The Central Alaska standards included Cook Inlet and Copper River (Cordova Management Area) stocks. Because reliable estimates of escapement were not available for some central Alaskan stocks, proportions of Cook Inlet and Copper River chinook in the standards were weighted by catch (Table 4).

Seven major chinook stocks (Alsek, Taku, Stikine, Nass, Skeena, Bella Coola, and Fraser) were included in the Southeast Alaska and British Columbia standards. The estimates for these stocks (Table 5) represent the best abundance data available. However, as survey and estimation techniques may vary among stocks and years, Canadian Department of Fisheries and Oceans (DFO) biologists caution that these estimates are unreliable (P. J. Starr, pers. comm., 1983).

Washington, Oregon, and California chinook were grouped into six major "stocks": Washington Inland Waters, Washington Coastal, Columbia River, Oregon Coastal, and California). Component stocks of these six major groups are listed in Figure 1. Abundance estimates for these stocks included terminal and inriver commercial (treaty and non-treaty) and sport catch and escapement estimates (Table 6).

#### Age Determination

The inshore scale samples for all major chinook stocks from North America (1979-1982) and Asia (1978-1981) were re-aged by FRI scale analysts to insure consistency in age interpretation and age composition data. We did not age regenerated scales (identified by their large, irregularly shaped nucleus), as scales with missing circuli are invalid for use in scale pattern analyses.

Age was designated by the European method, where the number before the decimal point is the number of freshwater annuli and the number after the decimal point is the number of ocean annuli. For example, a scale designated as a "0.2" has no freshwater annulus and two ocean

annuli.

Annuli were identified by a decrease in spacing and thickness of circuli, and by breakage and interbraiding of circuli. Thickness and spacing of freshwater circuli was less than thickness and spacing of ocean circuli. Because age 0. chinook, particularly fish of hatchery origin, often have checks or zones of closely spaced circuli in the first year of growth that may resemble freshwater annuli, several other criteria in addition to presence or absence of a freshwater annulus were used to separate 0.'s from 1.'s. These criteria often involved a comparison of zone sizes and spacing and thickness of circuli. Scales in which the size of the first ocean zone was smaller than the size of the second ocean zone, spacing between circuli in the first ocean zone was closer than spacing in the second ocean zone, and width of circuli in the first ocean zone was less than width in the second ocean zone were aged as 0.'s. Scales with a series of three or more checks through the first year of growth and an indistinct first ocean annulus were also aged as 0.'s. Although we were as consistent as possible in our use of these criteria for age determination, an examination of scale patterns of coded wire tagged chinook of known age showed that no one character or set of characters always provided accurate freshwater age determinations. A consistent bias in all our age determinations was that in cases where the reader was not sure of the freshwater age, the scales were assigned freshwater age of one.

### Age Compositions of Inshore scale Samples

Age compositions of the inshore scale samples were used to determine the proportions of each stock to be included in the standards. These data are presented by region, stock, and year in Tables 7-11. Although these represent the best estimates of age composition that we were able to calculate for this analysis, we caution that they are based on samples collected by techniques that often vary considerably within and between stocks and years.

### Trawl Scale Samples

The trawl scale samples, collected by U. S. observers aboard foreign groundfish vessels in the Alaska FCZ in 1978, 1979, and 1981, were provided by the National Marine Fisheries Service (NMFS, Northwest and Alaska Fisheries Center). A complete description of these samples is included in Myers and Rogers (1982). Only non-regenerated scales collected from the preferred and adjacent areas (A and B, Fig. 2) on the body of the fish were considered to be adequate for further analysis, and only samples of 25 fish or more for a particular age class, International North Pacific Fisheries Commission (INPFC) statistical area, month, and year were used.

### Construction of Brood Year Standards

Because the age at maturity of chinook in the trawl samples was unknown, we decided to classify them with inshore scale samples of fish of the same brood year. All age classes that a fish in the trawl

samples might have matured as were included in a particular brood year standard. For example, a fish caught by the groundfish fishery in February 1979 at age 1.2 (brood year 1975) was classified with inshore scale samples of fish that matured at ages 1.2 in 1979, 1.3 in 1980, 1.4 in 1981, and 1.5 in 1982. However, no fish that returned after 1982 were included, as we did not have any 1983 inshore scale samples at the time of this analysis.

Up to ten different brood year standards (Table 12) were required for each region- or river-of-origin for a complete scale pattern analysis of area-significant ( $\geq 25$  fish) samples of age 1. chinook. No samples of age 0. chinook were area-significant (Myers and Rogers, 1982).

The brood year standards were constructed in the following manner. The total "run size" (catch and/or escapement) for each stock in each year (Tables 2-6) was weighted by the age composition of the respective inshore scale sample (Tables 7-11) to determine a "total return" for each age class in each year. The total return for each age class and stock to be included in a particular brood year standard was then summed to obtain a total "brood year return." Then, the proportion of the total brood year return represented by each age class and stock was computed. This proportion was multiplied by the total sample size of each brood year standard (200 scales) to determine the number of scales needed for each age class and stock.

The number of scales needed for each stock and age class and final sample sizes are presented by brood year in Tables 13-22. Final sample

sizes were often less than 200 scales because of a shortage of scale samples for particular stock, return year, and age class combinations. However, no attempt was made to readjust the number of scales needed for each stock on the basis of the number of scales available. Therefore, the final sample size for each stock, return year, and age class is equal either to the total sample size needed (as calculated on the basis of run size and age composition) or the total number of useable scales available for a particular combination.

Several departures from our usual sample construction techniques were required in the case of the Asian standards to obtain sufficient sample sizes. The brood year 1973 Asian standard was composed of all useable scales of ages 1.4 and 1.5 chinook returning to the Kamchatka and Bolshaya rivers in 1979 and 1980 (Table 13). We were not able to obtain any 1982 Asian chinook scale samples. Therefore, the brood year 1975 Asian standards did not include any age 1.5 fish (Tables 15-17) and the brood year 1976 Asian standards did not include any age 1.4 fish (Tables 18-19). The brood year 1977 Asian standards were constructed by taking a stratified random sample of the required age classes from the entire collection of 1978-1981 Asian samples (Tables 20-21); and the brood year 1978 standard was constructed from all usable age 1.2 chinook scales from the Kamchatka and Bolshaya rivers from 1975-76 and 1978-81 (Table 22).

Washington, Oregon, and California standards were not constructed for brood years 1973 and 1975c (Tables 13 and 17) because of a lack of age 1.4 and 1.5 chinook from this region (Table 11).

With the exception of brood year 1973, river standards were constructed for all brood years where Western Alaska was the predominant stock for at least one time-area strata in the classification of the trawl samples to region-of-origin. We did not have enough scales from the Kuskokwim to construct river standards for brood year 1973.

#### Measurement of Scale Samples

Scales in the standards and trawl unknowns were measured using a micro-computer based digitizing system developed by FRI in 1979 for INPFC-related research (Harris et al. 1980). Acetate impressions of the scales were rear-projected onto the digitizing surface at 100 power. The measurement axis and the three life history zones measured on the scales are illustrated in Figure 3. For each scale, starting at the center of the focus and measuring to the outer edge of each successive circulus, the distance between each circulus in each of the three life history zones was measured and recorded.

#### Character Selection

Sixty scale characters were generated from the raw scale data (Table 23). A subset of six characters was chosen for each analysis using the method of Cook and Lord (1978). Briefly, a Kruskal-Wallis H-statistic (Kruskal and Wallis 1952) and the difference between the average sum of the ranks for each pairwise class combination were calculated. Characters having the largest H-statistic and the greatest pairwise differences were chosen.

Classification and Point Variance Estimation Procedures

A nonparametric scale pattern recognition technique (Cook 1982) was used as the classification scheme to assign scales of individual fish in the trawl samples to their probable region- or river-of-origin. Briefly, the classification technique was Specht's (1966) polynomial discriminant function adapted to the leaving-one-out approach (Lachenbruch 1967). The smoothing parameter was estimated using the maximum likelihood method of Habbema et al. (1974).

The patterns of selected scale characters were used to devise a separate regional or river classification model for each age class and brood year combination to be classified in the unknowns (Table 12). Overall classificatory accuracies of these models were calculated as the unweighted means of the accuracies on the diagonals of the decision arrays.

Point and variance estimation procedures used in this analysis are described by Cook (1983). Nearly unbiased estimates of the mixing proportions of component stocks in the trawl fishery samples were determined by the classification matrix correction procedure (Cook and Lord 1978). When negative values were obtained for the mixing proportion estimates, we imposed Cook's (1983) constraint instead of devising a new classification model. Application of the constraint corrects estimates less than zero or greater than one to values of zero or one, respectively. The resulting estimates were used with Pella and Robertson's (1979) variance formulae to obtain 90% confidence intervals.

Region-of-origin (Asia vs. Western Alaska vs. Central Alaska vs. Southeast Alaska and British Columbia vs. Washington, Oregon and California) mixing proportion estimates were calculated for all trawl fishery samples greater than or equal to 25 scales when stratified by 10-day period or month for the following areas:

- 1) Region (Bering Sea or Gulf of Alaska);
- 2) INPFC (Bering 1, Bering 2, Shumagin, and Chirikof) statistical areas (Fig. 4);
- 3)  $2^{\circ} \times 5^{\circ}$  (INPFC  $2^{\circ}$  - latitude by  $5^{\circ}$  - longitude) areas (Fig. 4);
- 4)  $1^{\circ} \times 1^{\circ}$  ( $1^{\circ}$  - latitude by  $1^{\circ}$  - longitude) areas; and
- 5)  $1^{\circ} \times 1/2^{\circ}$  ( $1^{\circ}$  - longitude by  $1/2^{\circ}$  - latitude) areas.

For each time-area strata, if Western Alaska was the predominant stock and estimates of zero were obtained for at least two other regional stocks, the regional stocks with estimates of zero were dropped from the analysis, and river-of-origin estimates were calculated for the remaining regional stocks and the three western Alaska stocks (Yukon, Kuskokwim, and Bristol Bay).

We did not know what effect inclusion of adjacent-to-preferred-area (B, Fig. 2) scales from the trawl fishery samples would have on the mixing proportion estimates. Therefore, we performed two separate analyses: the first, in which only samples coded as preferred-area scales (A, Fig. 2) by U. S. observers were included, and the second, in which scales coded as either A or B were included.

The term "positive estimate" refers to any mixing proportion esti-

mate greater than zero. The term "negative estimate" refers to a point estimate less than or equal to zero. The term "significant estimate" refers to a point estimate whose 90% confidence interval does not include zero. The term "predominant stock" refers to the stock for which the largest significant mixing proportion estimate was obtained. The INPFC statistical areas referred to are illustrated in Figure 4.

## RESULTS

### Scale Characters and Classification Models

Twenty-two different classification models were required for a complete analysis of the trawl unknowns. The scale characters used as variables and the decision arrays calculated for those models are presented by brood year in Tables 24-33. Overall classificatory accuracies ranged from 66.1% to 81.9% for the eight 5-way regional models and were 71.8% and 71.5% for the two 4-way regional models. For individual regions, accuracies were usually lowest for Central Alaska (48.8 - 78.9%) with the largest number of misclassifications usually to Southeast Alaska/British Columbia or Asia. Classification accuracies were consistently highest for the Washington/Oregon/California standards (75.0 - 90.1%). Overall classificatory accuracies were lower for the river analyses, and ranged from 58.6% to 76.4% for the seven 5-way models and from 59.3% to 66.4% for the five 4-way models. In the 5-way models accuracies were always lowest for the Kuskokwim standards (47.4 - 63.9%).

A general rule-of-thumb is that overall accuracies of classification models should be approximately halfway between random chance and 100% for the models to be acceptable for use in classifying unknowns (pers. comm., R. C. Cook). By this criterion, we decided that all of our models were adequate for analysis of the trawl samples.

#### Mixing Proportion Estimates for Preferred-Area Scales

The mixing proportion estimates and 90% confidence intervals obtained by classifying area-significant samples of preferred-area (A, Fig. 2) scales of chinook caught by foreign groundfish fisheries in the Bering Sea and Gulf of Alaska in 1979 and 1981 are presented by brood year in Tables 34-39. Estimates for a particular sample may be repeated several times in the same table if the sample is inclusive of several different time-area strata. If estimates for a particular time-area stratum were non-significant for all regional stocks, these data were not included in the tables. None of the samples collected by U. S. observers in 1978 and none of the samples of age 1.1 chinook in 1979 or age 1.4 chinook in 1981 were area-significant for preferred-area scales.

#### Brood Year 1973 - Age 1.4, 1979

The only area-significant sample for age 1.4 chinook in 1979 was a small samples ( $n = 29$ ) from Bering 2 (Fig. 4) in February (Table 34). Western Alaska was the predominant stock (63.2%), and a significant estimate (26.9%) was also obtained for Southeast Alaska/British Columbia.

Brood Year 1974 - Age 1.3, 1979

All area-significant samples for age 1.3 chinook in 1979 were from Bering 2 in January and February (Table 35). Western Alaska was the predominant stock in all time-area strata. Significant estimates were also obtained for Asia and Southeast Alaska/British Columbia in February samples from Bering 2 (W8058). No significant estimates were obtained for Central Alaska, and all estimates for Washington/Oregon/California were negative. Yukon was the predominant western Alaskan stock in samples from Bering 2 (W8058) in early February, and significant estimates were also obtained for Bristol Bay. No significant estimates were calculated for Kuskokwim.

Brood Year 1975 - Age 1.2, 1979

Area-significant samples for age 1.2 chinook in 1979 were from Bering 2 in January, February, November, and December and Bering 1 in September and October (Table 36). Significant estimates were obtained for both Western Alaska and Central Alaska in those samples. Western Alaska was the predominant stock in samples from Bering 1 (W7054) in September and Bering 2 (W8058) in January and December. Western Alaska was also the predominant stock in early October samples from Bering 1 (W7054), but central Alaska was the predominant stock in estimates for the entire month of October from this area. Central Alaska was the predominant stock in samples from Bering 2 (W7556) in November. Early and mid-February samples from Bering 2 (W8058) were predominantly Western Alaska, while a late February sample from Bering 2 (W7556)

contained roughly equivalent proportions of western and central Alaskan chinook. The predominant stock in samples from adjacent  $1^{\circ}$  x  $1^{\circ}$  and  $1^{\circ}$  x  $1/2^{\circ}$  areas in Bering 2 in February varied between Central Alaska and Western Alaska. No significant estimates were obtained for any other stocks in the regional analysis, and all but one estimate for Washington/Oregon/California was negative.

Significant estimates were obtained for both Yukon and Bristol Bay in the river analyses, although Yukon was usually the predominant western Alaskan stock. The major western Alaskan stock in samples taken at adjacent  $1^{\circ}$  x  $1/2^{\circ}$  areas in early February ( $175^{\circ}\text{W}$  x  $58^{\circ}\text{N(A)}$  and  $175^{\circ}\text{W}$  x  $58^{\circ}\text{N(B)}$ ) varied between Yukon and Bristol Bay. All estimates calculated for Kuskokwim were negative.

Brood Year 1976 - Age 1.3, 1981

Area-significant samples for age 1.3 chinook in 1981 were from Bering 2 in January and April (Table 37). Asia was the predominant stock in January samples and Western Alaska was the predominant stock in April samples. Positive but non-significant estimates were obtained for Central Alaska in both months and Southeast Alaska/British Columbia in April. All estimates calculated for Washington/Oregon/California were negative.

Brood Year 1977 - Age 1.2, 1981

Area-significant samples for age 1.2 chinook in 1981 were from Bering 2 in January, February, March, April, and December, Bering 1 in

October and November, and Chirikof in October (Table 38). Western Alaska was the predominant stock in all cases except for a small sample from the eastern Gulf of Alaska (Chirikof, W6054) in October. Asia classified as the predominant stock in this area. Significant estimates were also obtained for Asia in late January samples from Bering 2 and samples from Bering 1 ( $166^{\circ}\text{W} \times 54^{\circ}\text{N}$ ) in November. Significant estimates were calculated for Southeast Alaska/British Columbia in April samples from Bering 2 (W7556,  $172^{\circ}\text{W} \times 56^{\circ}\text{N}$ ) and October (W7054) and November samples from Bering 1. All other estimates for Asia and Southeast Alaska/British Columbia were positive but non-significant. No significant estimates were obtained for Central Alaska, but approximately half of the estimates were positive. Positive (non-significant) estimates were obtained for Washington/Oregon/California in October and early November (W7054) samples from Bering 1 and October samples from Chirikof (W7054, W6054). However, the majority of estimates for Washington/Oregon/California were negative.

Bristol Bay was the predominant western Alaskan stock for all time-area strata. Except for one negative estimate ( $166^{\circ}\text{W} \times 54^{\circ}\text{N}$ (B), November), all estimates for Yukon were positive, but non-significant. Positive (non-significant) estimates were obtained for Kuskokwim in March and April (Bering 2) samples from the Bering Sea and November samples from Bering 1 (W7054,  $166^{\circ}\text{W} \times 54^{\circ}\text{N}$ ,  $165^{\circ}\text{W} \times 54^{\circ}\text{N}$  (B)). However, over half of the estimates for Kuskokwim were negative.

Brood Year 1978 - Age 1.1, 1981

Area-significant samples for age 1.1 chinook in 1981 were from the eastern Gulf of Alaska in October and November (Chirikof, W6054) and from Bering 1 (W7054) in November (Table 39). Southeast Alaska/British Columbia was the predominant regional stock in all time-area strata. No significant estimates were obtained for any other stocks. Positive (non-significant estimates) were obtained in all cases for Asia and Central Alaska. All estimates for Western Alaska and Washington/Oregon/California were negative.

Mixing Proportion Estimates for Preferred andAdjacent-to-Preferred-Area Scales

The mixing proportion estimates and 90% confidence intervals obtained by classifying area-significant samples of preferred- and adjacent-to-preferred-area (A and B, Fig. 2) scales are presented in Appendix Tables 1-9. The addition of adjacent-to-preferred-area scales to the unknown samples often significantly altered mixing proportion estimates for particular time-area strata. When compared to estimates derived from preferred-area scales only, the usual effect was to lower estimates for Western Alaska and increase estimates for Asia and/or Central Alaska. Therefore, we concluded that the use of scales collected by U.S. observers from body areas adjacent to the preferred-area is not valid for stock separation analyses.

## DISCUSSION

Mixing proportion estimates calculated from samples that included adjacent-to-preferred-area scales (B, Fig. 2) of trawl-caught chinook were determined to be invalid. Therefore, the following discussion pertains only to the results of an analysis of preferred-area (A, Fig. 2) scale samples. The discussion is limited to samples collected by observers in 1979 and 1981. The few samples collected in 1980 were for purposes of species identification only, and no samples collected in 1978 were area-significant ( $n \geq 25$ ) for preferred-area scales. This was due, largely, to the fact that many observers in 1978 did not record the body zone from which scale samples were collected (Myers and Rogers 1982).

### Stock Origins of Trawl-Caught Chinook in the Bering Sea

The estimated incidental catch of chinook by the foreign groundfish fishery in the Bering Sea/Aleutian Islands region in 1979 was 100,382 (Table 1). Eighty-one percent of the total incidental catch of salmon was taken in INPFC statistical Area 2 (Fig. 4) and 18% in Area 1, and the incidence of salmon was highest in Area 2 during the first and fourth quarters of the year (Nelson et al. 1980). Age compositions calculated by month and INPFC statistical area from the scale samples that we aged in 1982 (Myers and Rogers 1982) indicate that the majority of chinook caught by the groundfish fishery in Bering Sea areas 1 and 2 were age 1.2 (Table 40).

Mixing proportion estimates indicate that age 1.2 chinook in Areas 1 and 2 in 1979 were of both western and central Alaska origin, and that the predominant western Alaskan stock was Yukon (Table 36). The distribution of western and central Alaskan stocks over the various time-area strata was patchy, and this was most evident in February samples from Area 2. The predominant regional stock in samples from adjacent or nearby  $1^{\circ}$ -long. by  $1^{\circ}$ -lat. and  $1^{\circ}$ -long. by  $1/2^{\circ}$ -lat. areas stratified by 10-day period and month often varied between western and central Alaska (Table 36).

Age 1.3 chinook were the second most abundant age class in the Bering Sea samples in 1979 (Table 40). Our results suggest that age 1.3 chinook were primarily of western Alaskan origin, although Asia and Southeast Alaska/British Columbia chinook were also present in February samples from W8058 (Table 35). In contrast to the mixing proportion estimates calculated for age 1.2 chinook in 1979, no significant estimates were obtained for Central Alaska for age 1.3 chinook in 1979. However, Yukon was also the predominant western Alaskan stock for age 1.3 chinook. Significant estimates were also obtained for Bristol Bay for both age classes, and estimates for both age classes suggest that Kuskokwim stocks were not present (Table 35-36).

The estimated incidental catch of 36,626 chinook by the foreign groundfish fishery in the Bering Sea/Aleutian Islands region in 1981 was considerably less than the 1979 catch (Table 1). Sixty percent of the total incidental catch of salmon was taken in Area 2 and 36% in Area 1, and the incidence of salmon was highest in Area 2 during the first

quarter of the year (61% of the total catch) (Nelson et al. 1982).

Similar to age compositions in 1979, the predominant age classes in Areas 1 and 2 in 1981 were age 1.2 and 1.3 (Table 40). Mixing proportion estimates indicate that Western Alaska was the predominant stock for both age classes and all time-area strata except for a small sample ( $n = 30$ ) of age 1.3 chinook from Area 2 in January that was predominantly Asian (Tables 37-38). A few significant estimates were also obtained for Asia and Southeast Alaska/British Columbia for age 1.2 chinook (Table 38). In contrast to the 1979 samples, no significant estimates were calculated for Central Alaska for age 1.2 chinook, and the predominant western Alaskan stock for age 1.2 chinook was Bristol Bay instead of Yukon. However, except for one zero estimate all estimates for Yukon were positive (Table 38). Cook et al. (1981) suggest that a dominance of positive valued nonsignificant estimates indicates the presence of a stock in low abundances. As with 1979 samples, no significant estimates were obtained for Kuskokwim for age 1.2 chinook in 1981, and over half of the estimates for Kuskokwim were zero (Table 38), indicating that this stock was not present in the trawl fishery samples.

No significant estimates were obtained for Washington/Oregon/California for any age 1. chinook in any of the time-area strata examined. In addition, very few positive (nonsignificant) estimates were calculated for this regional stock. These results indicate that age 1. chinook of Washington/Oregon/California origin were not present in foreign groundfish fishery catches in the Bering Sea in 1979 and 1981.

### Stock Origins of Trawl-Caught Chinook in the Gulf of Alaska

Our results provide very little information on origins of chinook caught by the foreign groundfish fishery in the Gulf of Alaska. The only samples large enough for scale pattern analysis were from the Chirikof and Shumagin areas (Fig. 4) in the western Gulf of Alaska in October and November, 1981. Southeast Alaska/British Columbia was the predominant stock in two small samples of age 1.1 chinook from Shumagin in mid-October (n = 26) and Chirikof (W6054) in November (n = 36) (Table 39). The only other significant estimate was for Asia in a small sample (n = 26) of 1.2's from Chirikof (W6054) in October (Table 38).

The estimated incidental catch of chinook by the foreign groundfish fishery in the Gulf of Alaska in 1981 was 28,576 (Table 1). Over 66% of the total incidental catch of salmon was taken in the Chirikof area, and most of the remainder (31%) was taken in the Shumagin area (Wall et al. 1982). However, the samples we analyzed do not correspond to the time-area strata described by Wall et al. (1982) as having the highest incidence rates for salmon in the Gulf of Alaska in 1981.

### CONCLUSIONS

1. Freshwater and marine growth patterns on the scales of selected major coastal chinook stocks allow region- or river-of-origin separation of chinook in samples of incidental catches by the foreign groundfish fishery in the Alaska FCZ.

2. The only notable gap in our inshore scale collection was the lack of Asian samples from 1982 returns. However, mixing proportion estimates for 1981 groundfish fishery samples are provisional, as standards used to classify these unknowns did not include scale samples of fish that matured after 1982.
3. Age compositions of inshore scale samples (Tables 7-11) used to weight the standards were the best estimates we could calculate for this analysis. However, these estimates may be somewhat biased toward age 1. chinook, and are based on samples collected by techniques that often vary considerably within and between stocks and years.
4. There is a need for more accurate catch and escapement data for almost every major Asian and North American chinook stock. Abundance estimates used to weight the standards (Tables 2-6) were the best estimates that we were able to obtain for our analysis, but these estimates are often unreliable, as survey and estimation techniques may vary within and between stocks and years.
5. Preferred-area (A, Fig. 2) scale samples collected by U.S. observers in 1979 and 1981 were adequate for a classification of trawl-caught chinook to region- or river-of-origin (Tables 34-39), but an analysis (Appendix Tables 1-9) using scales taken from body areas adjacent to the preferred area (B, Fig. 2) was not valid.
6. The analysis of preferred-area scales of trawl-caught chinook was limited to samples collected by U.S. observers in 1979 and 1981.

The few samples collected in 1980 were for purposes of species identification only, and no samples collected in 1978 were area-significant.

7. Most of the area-significant scale samples were from INPFC statistical Areas 1 and 2 (Fig. 4) during the first, third, and fourth quarters of the year, and these were the same time-area strata where the highest incidental catches of chinook salmon by the foreign groundfish fishery in the Alaska FCZ occurred.
8. Chinook in the 1979 and 1981 groundfish fishery catches in the eastern Bering Sea were predominantly ages 1.2 and 1.3 (Table 40).
9. Mixing proportion estimates calculated for Bering Sea samples in 1979 and 1981 (Tables 34-39) indicate that western Alaska was often the predominant regional stock. However, significant estimates for non-western Alaskan stocks indicate the presence of Asian, central Alaskan, and Southeast Alaskan and British Columbian chinook, and these stocks predominated in some time-area strata.
10. Age 1. chinook of Washington, Oregon, and California origin were not present in the groundfish fishery samples from the Bering Sea in 1979 and 1981.
11. Yukon was the predominant western Alaskan stock in 1979 catches of age 1.2 and 1.3 chinook, and Bristol Bay was the predominant western Alaskan stock in 1981 catches of age 1.2 chinook. Kuskokwim chinook did not appear to be present in the 1979 and 1981 trawl

fishery catches.

12. Because of small samples sizes, our results provided very little information on origins of chinook caught by the foreign groundfish fishery in the Gulf of Alaska.

## RECOMMENDATIONS

In view of the results of this study, we recommend the following additional areas for research:

### 1. Interception estimates

Mixing proportion estimates and data on age composition of the fishery samples could be used in combination with catch data to provide estimates of the number of fish of each stock caught by the foreign groundfish fishery in the Alaska FCZ. These estimates would be directly applicable to the evaluation of the economic impact of the foreign trawl fishery on western Alaska and other regional stocks.

### 2. Classification of 1982 foreign trawl fishery samples

If quality and quantity of the samples are adequate, brood year 1976 (age 1.4), 1977 (age 1.3), 1978 (age 1.2), and 1979 (age 1.1) chinook scales collected by NMFS observers in 1982 could be classified to region or stock of origin using the same techniques that we have devised for our present study. This would provide needed additional information on the stock-of-origin of chinook caught by the foreign groundfish fishery and the distribution of chinook salmon stocks in the eastern Bering Sea and Gulf of Alaska.

### 3. Improvements in classification of 1981 trawl samples

We think that the mixing proportion estimates of brood years 1976 (age 1.3), 1977 (age 1.2), and 1978 (age 1.1) chinook in the 1981 trawl

samples would be improved by the addition of the 1983 inshore scale samples to the standards used for classification. The estimates obtained for 1981 NMFS observer samples during our present study should be considered as provisional since the scales of 1983 returns were not available in time to be included in our analyses. In addition, our present standards for brood years 1975-78 do not include any samples of 1982 Asian chinook returns. These samples have been requested (Rogers et al. 1983), and we hope to receive them within the next year.

#### 4. Effect of non-preferred scales on mixing proportion estimates

To our knowledge, no studies have been conducted on the effect of inclusion of non-preferred-area scales in standard or unknown samples in scale pattern recognition studies. FRI is currently collecting scale samples from different areas on the bodies of chinook salmon to examine variability in scale characters with body zone. These studies could be extended to determine the effect of inclusion of non-preferred-area scales on classification of high seas fishery unknowns. Perhaps, a set of scale characters that do not vary with body zone could be determined. These types of studies would be particularly relevant to the analysis of NMFS trawl samples, as they are collected from many different areas on the body of the fish (Myers and Rogers 1982). We found that when both preferred- and adjacent-to-preferred-area scales were included in the unknown samples, we often obtained larger mixing proportion estimates for Asian chinook than when preferred-area scales only were included in the analysis. We suspect that many of our Asian scale samples may have been collected from a different body area than our North American scale

standards. This is a problem which deserves more attention.

5. Analysis of freshwater age 0. chinook

A secondary objective of our study was to provide recommendations on the applicability of scale pattern recognition techniques to stock separation of chinook caught by the S.E. Alaska troll fishery. Although our success to date with separation of freshwater 1. age classes of chinook in the trawl fishery is encouraging, our study does not provide any information on classification accuracies of freshwater age 0. chinook salmon stocks. As this age class is more prevalent in S.E. Alaska fishery samples than in the Bering Sea and Gulf of Alaska trawl fishery samples, we think further analyses are needed to determine the applicability of scale pattern recognition techniques to S.E. Alaska troll fishery samples. Furthermore, a successful analysis of S.E. troll fishery samples may have to include an examination of hatchery and wild contribution. These are areas that need more research before direct applications can be made to stock separation of chinook in the S.E. Alaska troll fishery.

6. Statistical methods and scale characters for stock separation

Many different statistical techniques are used for stock separation analysis of scale pattern data. We used a direct density leaving-one-out approach (Cook 1982) for our analysis of the trawl fishery samples. Other methods presently in wide use include stepwise linear discriminant (Dixon and Brown 1979) and nearest neighbor (Clover and Hart 1967) techniques. Graduate student research at FRI, funded in part by this study,

is directed at examining the application of these techniques to different types of scale character sets and stock separation models. The use of new types and combinations of scale characters other than the traditional linear measurements, counts of circuli, and life history zones is also being examined. We think that additional research in these areas will provide more standardization of stock separation techniques among fisheries agencies and increase accuracies of separation of salmon stocks with scale pattern recognition techniques.

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