Estimates of the Bycatch of Yukon River Chinook Salmon in U.S. Groundfish Fisheries in the Eastern Bering Sea, 1997-1999

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March 2004

Final Report to the Yukon River Drainage Fisheries Association (YRDFA)
YRDFA Contract Number: 04-001; Financial Coding; #4 NRDA, Obj. 1

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Study History

This project is a continuation of FY 2002 and FY 2003 research on factors that may have caused a decline in marine survival of Yukon River salmon in the late 1990s. Previous work has focused on delineating ocean migration patterns of Yukon River chinook salmon, estimating stock composition of incidental catches of chinook salmon by U.S. groundfish fisheries in the eastern Bering Sea, and evaluating food habits and trophic interactions of salmon migrating in the Bering Sea. The information presented in this report addresses the question: How many Yukon River chinook salmon were caught by U.S. groundfish fisheries in the eastern Bering Sea during the period of low returns in the late 1990s? This report presents the final results of FY 2002 to FY 2004 research addressing this question.

Abstract

Record low runs of chinook salmon to the Yukon River in the late 1990s intensified concerns about salmon bycatch by U.S. groundfish fisheries in the eastern Bering Sea and Aleutian Islands (BSAI). We estimated the bycatch of Yukon River chinook salmon by the BSAI groundfish fisheries in 1997-1999, and evaluated the effect of the BSAI bycatch on Yukon River fisheries and resources. Estimated interceptions of Yukon River chinook salmon by the BSAI fisheries were 7,266 fish in 1997, 8,908 fish in 1998, and 3,074 fish in 1999. Adult equivalent (AEQ) bycatch estimates were 6,522 fish in 1997, 7,510 fish in 1998, and 2,721 fish in 1999. The AEQ bycatch was equal to 1-4% of the minimum run, 12-51% of the minimum (lower river) escapement, 10-38% of upper river (Canadian) escapement, 3-35% of the Alaska commercial catch, 6-9% of the Alaska subsistence catch, or 22-84% of the Canadian catch of chinook salmon in the Yukon River in 1997-2000. We conclude that in years when chinook salmon runs are low, even relatively low incidental catches of salmon by non-target marine fisheries may reduce local utilization of chinook salmon resources and impede management and conservation efforts in the Yukon River.

Key Words

Bering Sea, bycatch, chinook salmon, groundfish, interception, western Alaska, Yukon

Project Data

Description of the Data

The project data include scale age determinations and measurements for U.S. National Marine Fisheries Service (NMFS), North Pacific Groundfish Observer Program, samples from chinook salmon caught in U.S. groundfish fisheries in the eastern Bering Sea and Aleutian Islands (BSAI) area in 1997, 1998, and 1999, and four regional (Kamchatka, Western Alaska, Cook Inlet, and Southeast Alaska-British Columbia) and three western Alaska subregional (Yukon, Kuskokwim, Bristol Bay) scale pattern baselines for five brood year groups (BY 1991, BY 1992, BY 1993, BY 1994, BY 1995) of freshwater age-1. fish.

Formats

Data are stored in MS Excel spreadsheet formats, as well as in an MS Access database.

Archive and Custodian

Data are archived by the High Seas Salmon Research Program, Fisheries Research Institute, School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, Washington 98195, USA (contact: K.W. Myers, tel. no. 206.543.1101, kwmyers@u.washington.edu).

Access Limitations

There are no access limitations on the data, but costs associated with filling sample and data requests (staff salaries, data storage media, shipping costs) must be paid by the person(s) or agency requesting the data.

Citation

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Executive Summary

Our primary objective was to estimate the bycatch of Yukon River chinook salmon by the Bering Sea and Aleutian Islands (BSAI) groundfish fisheries during the period of low returns of chinook salmon to western Alaska rivers in the late 1990s. We used scale pattern analysis to estimate the age and stock composition of chinook salmon in the BSAI bycatch samples collected in 1997-1999, and compared our results to previously published studies. Our age and stock composition estimates were applied to National Marine Fisheries Service (NMFS) estimates of the BSAI bycatch to estimate interceptions of Yukon River chinook salmon by the BSAI fisheries in 1997-1999. To evaluate the potential effects of the BSAI bycatch on Yukon River chinook salmon resources, we estimated the adult equivalent (AEQ) bycatch, i.e., interception estimates adjusted to account for natural ocean mortality of immature fish in the bycatch. The AEQ bycatch estimates were apportioned to the year that fish would have returned to the Yukon River had they not been intercepted, and compared to Yukon River catch and escapement estimates in 1997-2000. The management and conservation implications of our results are discussed.

The principal results show that most of the BSAI bycatch in 1997-1999 occurred in the eastern portion of the fishery area (east of 170ºW). Fall bycatch samples were dominated by age 1.2 Bristol Bay and Cook Inlet chinook salmon. Winter bycatch samples were dominated by age 1.3 and 1.4 western Alaska chinook salmon. Western Alaska chinook salmon stocks were 48% of the total bycatch in 1997 and 1998, and 60% of the total in 1999. The estimated interceptions of Yukon River chinook salmon were 7,266 fish in 1997, 8,908 fish in 1998, and 3,074 fish in 1999. The AEQ bycatches of Yukon River chinook salmon were 6,522 fish in 1997, 7,510 fish in 1998, and 2,721 fish in 1999. The AEQ bycatch was equal to 1.4-4.5% of the minimum run, 11.5-50.8% of the minimum (lower river) escapement, 9.7-37.5% of upper river (Canadian) escapement, 3.1-35.2% of the Alaska commercial catch, 6.2-9.0% of the Alaska subsistence catch, or 22.1-83.6% of the Canadian catch of chinook salmon in the Yukon River in 1997-2000.

We conclude that in the eastern Bering Sea in winter, immature (age 1.2 and 1.3) chinook salmon are more abundant along the outer shelf break (west of 170ºW), and maturing (age 1.3-1.5) chinook salmon are more abundant along the inner shelf break (east of 170ºW). Other factors that may influence the age composition of chinook salmon in the BSAI bycatch include year class strength, seasonal- and age-specific changes in the vertical distribution of chinook salmon, and long-term decreases in body size and increases in age at maturity of western Alaska chinook salmon. Despite the decline in abundance of western Alaska chinook salmon in the late 1990s, western Alaska was the dominant regional stock (average 56%) in BSAI bycatch samples in 1997-1999. As in the results of a previous study of chinook salmon bycatch by foreign and joint venture (JV) groundfish fisheries in the BSAI in the late 1970s and early 1980s, we found that: (1) the proportions of the three western Alaskan subregional stocks (Yukon, Kuskokwim, and Bristol Bay) in the BSAI area vary considerably with such factors as brood year, time, and area; (2) Yukon River chinook salmon are often the dominant stock in the BSAI in winter, particularly among age 1.2 fish in the western BSAI (west of 170ºW) and age 1.4 fish in the eastern BSAI (east of 170ºW); (3) Bristol Bay and Cook Inlet are the

dominant stocks of age 1.2 chinook salmon in the eastern BSAI in fall; and (4) age 1.1 chinook salmon in the eastern BSAI in fall are largely Gulf of Alaska stocks (Cook Inlet, southeast Alaska-British Columbia). The results of previous scale pattern analyses and tagging studies suggest that in summer immature Yukon River chinook salmon are distributed farther to the west in the Bering Sea than other North American stocks, which may explain their relatively low percentages in fall 1997-1999 bycatch samples from the eastern BSAI.

Our estimates of interceptions of Yukon River chinook salmon by U.S. groundfish fisheries in the BSAI in 1997-1999 were higher than estimated interceptions by the foreign and JV trawl fisheries in the BSAI after 1980. The accuracies of our interception estimates, however, depend on the accuracy of the NMFS estimates of chinook salmon bycatch. The high levels of uncertainty associated with the NMFS salmon bycatch estimates should be a major consideration, if our results are used to develop fishery management or conservation measures for Yukon River chinook salmon.

Our estimates of the AEQ bycatch of Yukon River chinook salmon by the domestic groundfish fisheries in the BSAI in 1977-1999 are not large enough to explain the low returns to the Yukon River in the late 1990s. The 1997-1999 BSAI bycatch apparently had the largest effect on local utilization and escapement of Yukon River chinook salmon in 1998 and 2000. The estimated AEQ bycatch of Yukon River chinook salmon represents a loss of fishing opportunity for commercial and subsistence fishermen, as well as a substantial loss of escapement to spawning grounds in 1998-2000. We conclude that in years when salmon returns to the Yukon River are low, even relatively low incidental catches of salmon by non-target marine fisheries may reduce local utilization of chinook salmon resources and impede management and conservation efforts in western Alaska.

Regulations implemented in 1999, which spread fishing effort over time to protect Steller sea lions (*Eumetopias jubatus*), apparently increased the portion of the chinook salmon bycatch taken in winter, as well as the estimated percentages of Yukon River chinook salmon in the bycatch. Future management efforts to conserve Yukon River chinook salmon should emphasize methods that will reduce the winter (January-June) bycatch of maturing (age 1.3, 1.4, and 1.5) chinook salmon in eastern BSAI (east of 170ºW). For example, accounting towards bycatch limits could begin on September 1, with the amount carried over to the next winter season.

In addition, the BSAI chinook salmon bycatch samples and data could be used more effectively to manage and conserve Yukon River chinook salmon. For example, NMFS Observer Program chinook salmon samples and data could be used to calculate annual estimates of the maturity, age, and stock composition of the chinook salmon in the bycatch samples. A new scale sampling scheme could be designed by NMFS to improve time and area coverage of the fishery and to estimate the variance of age composition estimates. Samples for DNA analysis (fin clips) could be collected by observers from the same fish that are sampled for scales. Information from the BSAI chinook salmon bycatch samples and data could be used by salmon fishery managers to improve both preseason and inseason stock assessments of Yukon River chinook salmon. Once comprehensive baselines are established, genetic (DNA) stock identification may prove to be an efficient tool for inseason estimates of the stock composition of chinook salmon in the BSAI bycatch.

Introduction

The effect of Bering Sea groundfish trawl fisheries on returns of chinook salmon to the Yukon River has been a major concern since 1977, when the U.S. National Marine Fisheries Service (NMFS) began to provide estimates of salmon bycatch by groundfish vessels operating in the U.S. Exclusive Economic Zone (EEZ; French et al. 1982; Fig. 1). Myers and Rogers (1988) used scale pattern analysis to estimate the age, regional stock composition, and interceptions of western Alaska chinook salmon in incidental catches by foreign and joint-venture (JV) groundfish fisheries operating in the Bering Sea and Aleutian Islands (BSAI) area of the U.S. EEZ in 1979-1982. This was a period of high abundance of western Alaska chinook salmon, and Myers and Rogers (1988) concluded that the BSAI groundfish fisheries had a negligible effect (<6% reduction) on western Alaska commercial chinook salmon catches. In the late 1990s, however, chinook salmon returns to western Alaska rivers declined to record lows (e.g., Kruse 1998; Fig. 2), and the effect of salmon bycatch by domestic groundfish fisheries in the BSAI on Yukon River chinook salmon was unknown.

Witherell et al. (2002) reviewed available information on salmon bycatch in domestic groundfish fisheries in the BSAI from 1990-2001, and used the age and stock composition estimates of Myers and Rogers (1988) to estimate interceptions of western Alaska salmon by these fisheries. Witherell et al. estimated that an annual bycatch of 30,000 immature chinook salmon in the BSAI groundfish fisheries equates to an adult equivalent (AEQ) bycatch of 14,581 western Alaska chinook salmon or a 2.7% reduction in western Alaska chinook salmon runs (catch and escapement). Witherell et al. discussed problems with their methods, including their use of outdated estimates of chinook salmon stock composition, and recommended that a high priority be given to salmon stock composition research.

We used scale pattern analysis methods similar to those of Myers and Rogers (1988) to estimate the age and regional stock composition of chinook salmon in BSAI bycatch samples collected in 1997-1999. Methods similar to Witherell et al. (2002) were used to estimate the AEQ bycatch of Yukon River chinook salmon by the 1997-1999 BSAI groundfish fisheries. These estimates are compared to Yukon River catch and escapement estimates to evaluate the potential effects of groundfish fishery bycatch on Yukon River chinook salmon resources. Similar estimates were calculated for chinook salmon returns to the Kuskokwim and Bristol Bay subregions of western Alaska.

The principal results show that most of the chinook salmon bycatch in 1997-1999 occurred in the eastern portion of the BSAI area (east of 170ºW). Fall (July-December) bycatch samples were dominated by age 1.2 and 1.3 Bristol Bay and Cook Inlet chinook salmon. Winter (January-June) bycatch samples were dominated by age 1.3 and 1.4 western Alaska chinook salmon. Western Alaska chinook salmon stocks were 48% of the total bycatch in 1997 and 1998, and 60% of the total in 1999. The estimated interceptions of Yukon River chinook salmon were 7,266 fish in 1997, 8,908 fish in 1998, and 3,074 fish in 1999. The AEQ bycatches of Yukon River chinook salmon were 6,522 fish in 1997, 7,510 fish in 1998, and 2,721 fish in 1999. The AEQ bycatch was equal to 1.4-4.5% of the minimum run, 11.5-50.8% of the minimum (lower river) escapement, 9.7-37.5% of upper river (Canadian) escapement, 3.1-35.2% of the Alaska commercial catch, 6.2-9.0% of the Alaska subsistence catch, or 22.1-83.6% of the Canadian catch of chinook salmon in the Yukon River in 1997-2000.

Objectives

1. Estimate the proportions of regional (Kamchatka, Western Alaska, Cook Inlet, and Southeast Alaska/British Columbia) and western Alaska sub-regional (Yukon, Kuskokwim, and Bristol Bay) stocks of chinook salmon in the salmon bycatch of the 1997-1999 BSAI groundfish fishery.
2. Estimate the bycatch (number of fish) of western Alaska sub-regional stocks (Yukon, Kuskokwim, and Bristol Bay) by the 1997-1999 BSAI groundfish fishery.
3. Compare the results to previously published studies.
4. Evaluate the effect of salmon bycatch by the BSAI groundfish fishery on Yukon River salmon runs (catch and escapement) in 1997-2000.
5. Discuss fishery management and conservation implications of the results.

Methods

Study Area

Witherell et al. (2002) reviewed information on the location and timing of incidental chinook salmon catches by U.S. groundfish fisheries in the BSAI region (Fig. 3). Briefly, most (>99%) of the chinook salmon bycatch is taken by trawl fisheries for walleye pollock (*Theragra chalcogramma*) operating in areas with bottom depths of 100 m to 200 m, and high bycatch rates can occur in any location throughout the BSAI region. During the period of our study, the largest bycatches were taken during fall (September and October) and winter (January and February) in the area east of 170°W (areas with numbers <520), particularly in NMFS statistical areas 517 and 509 (Fig. 3).

Observer Sampling

The methods used to sample salmon in the groundfish fishery bycatch are described by the North Pacific Groundfish Observer Program (Alaska Fisheries Science Center 2003). Scales are collected primarily for later verification of species identification, and are usually collected from no more than 20 chinook salmon per cruise number. Observers are instructed to collect at least 5-10 scales per fish, from the optimal "A" zone if possible, then from the "B" zone if there are none in "A", and if necessary the "C" zone. Scales from individual fish are put into paper envelopes. Accompanying biological and catch data (species, specimen number, haul number, date, length, sex, weight, missing fins, scale zone, cruise/vessel code) are recorded on the scale envelopes, and later transferred to standard data forms.

Scale Pattern Analysis

We prepared, aged, and measured scales using the general laboratory procedures described by Davis et al. (1990). To estimate the stock composition of chinook salmon in the bycatch samples, we followed the scale pattern analysis methods used by Myers and Rogers (1988) as closely as possible so that we could compare our results to this earlier study. The statistical methods used for scale pattern analysis were updated according to procedures used by Patton et al. (1998).

Acetate impressions of scales were made from a total of 5,386 chinook salmon samples collected by observers from the BSAI groundfish fishery bycatches in 1997 (2,007 fish), 1998 (1,994 fish), and 1999 (1,385 fish). The ages of chinook salmon in the observer samples were determined by counting the number of freshwater and ocean annuli on magnified scale impressions. Annuli are annual marks of closely-spaced circuli. Age was designated by the European formula (Koo 1962), i.e., the number of freshwater annuli and the number of ocean annuli separated by a dot; for example an age-1.3 fish has one freshwater annulus and three ocean annuli. Scales that were too regenerated to determine a freshwater or an ocean age or otherwise unusable (13% of the total sample) were removed from the data set. Thus, age composition estimates were calculated from a total of 4,687 fish (1,683 fish from 1997, 1,774 fish from 1998, and 1,230 from 1999; Table 1). Data on the maturity of chinook salmon in the observer samples were not available. Therefore, samples stratified by age group may contain both immature and maturing fish.

Scales included in the baseline samples were chosen from major chinook-producing areas with stocks likely to be found in the Bering Sea. Because the analyses are based on measurements in the first year of marine growth, which is largely environmentally determined, stocks entering a common marine environment can represent smaller, neighboring stocks. Scales were requested from regional agencies for 1997-2000, the primary years of return for the predominant age groups in the observer samples (Table 1). Observer samples of fish that migrated to the ocean in their first year (age-0.) or after two winters in freshwater (age-2.) were substantially less than our target minimum sample size of 100 fish per year and age group strata. Therefore, we limited our analysis to chinook salmon that had spent one winter in freshwater (age-1.), which is the freshwater age of most (>99%) western Alaska chinook salmon.

Baseline samples of at least 400 scales from each year, distributed throughout the duration of the runs, were requested, to provide adequate numbers of the main age groups. For Asia, the only major Bering Sea population of chinook salmon is from the Kamchatka River, Russia (supplemental scales were also requested for 2001, to ensure adequate age class samples for the brood year 1995 analysis). From western Alaska, scales were used from the Yukon River (Big Eddy test fishery), Kuskokwim (Bethel and Quinhagak fisheries), and Bristol Bay (Nushagak and Togiak fisheries). South central Alaska was represented by scales from Cook Inlet (Palmer fishery, Kenai River survey, Homer fishery (1997 only), and Deep Creek (1997 only)) and the Copper River fishery. Southeastern Alaska was represented by northern and southern inside and outside commercial fisheries (ADF&G statistical areas 171-174). British Columbia scales came from Nass and Skeena River fisheries, northern stocks with large percentages of freshwater age-1. fish. Stocks from southern B.C., Washington, Oregon, Idaho, and California are composed predominantly of freshwater age-0. fish.

Independent baselines used to identify region of origin of chinook salmon were established for each of the five major brood-year groups in the 1997-1999 observer samples, i.e., brood years 1991-1995 (Table 2). A brood year is the year of spawning of the parental generation, e.g., an age-1.4 chinook salmon caught in 1997 is a brood year 1991 (BY91) fish. Target sample sizes for each brood-year specific baseline region (Kamchatka, western Alaska, central Alaska, and southeast Alaska-British Columbia) and western Alaska subregion (Yukon, Kuskokwim, and Bristol Bay) were 150-200 scales.

We measured only non-regenerated scales collected from the preferred body area of the fish (Major et al. 1972; Davis et al. 1990). Observers did not always record the body area of scale collection or sometimes recorded the wrong body area. We corroborated observer body-area designations (zones A, B, and C; AFSC 2003) by visual examination of scale size and shape. Scales with very large or misshapen foci, which indicates regeneration soon after scale formation, or scales with holes or other damage along the measurement axis were not measured. For BY91-BY95 chinook salmon, 74% (n = 3,257) of the observer scales used to estimate age composition were suitable for measuring (1,178 fish in 1997, 1,288 fish in 1998, and 851 fish in 1999).

The acetate impressions of baseline and observer scales were measured with a video-digitizing system (Optical Pattern Recognition System, model OPR-512, manufactured by BioSonics, Inc., Seattle). Scale measurements were made along the longest axis of the scale (Fig. 4). Incremental distances from the center of the focus to the end of the freshwater growth and to the outer edge of each ocean circulus to the end of the first ocean annulus were recorded. Circuli patterns in this portion of the scale form prior to broad mixing of regional salmon populations on the high seas.

Fourteen scale variables were calculated from the raw scale measurement data (Fig. 4). These variables included the size of the freshwater zone, the size of the first ocean zone, the average circulus spacing in the first ocean zone, the number of circuli in the first ocean zone, five circuli triplets, i.e., sizes of consecutive groups of three circulus increments from ocean circulus 1 through 15, and 5 reverse triplets, i.e., last circulus increment in the first ocean zone (annulus) to the 15^{th} circulus increment inward from the outer edge of the annulus.

All scale data sets were screened for measurement errors. Scales with errors were remeasured if sample sizes were small or dropped from the analysis if sample sizes were adequate. Descriptive statistics (means and standard deviations) were calculated for the 14 scale variables for each brood year and stock. Baseline scales that were extreme outliers (deviated more than +/-3.5 standard deviations from the stock means for 1 variable or 3 standard deviations for 2 or more variables) were dropped from the baseline. Observer scale data were also examined for extreme outliers. Scale variable values that fell outside the range of minimum and maximum values calculated for the baseline data set were deleted. Removal of records with measurement errors and extreme outliers amounted to a small (<3%) reduction in the total number of baseline and observer scales available for analysis.

For each brood-year baseline we evaluated whether or not there were sufficient scales (150-200 scales minimum) within each sample for a particular stock or regional group. If there were too few scales that stock was relegated to a "test" data subset that was not included in the final analyses for that brood year. These test data subsets were later used to evaluate the accuracy of the final statistical models. If baseline stock groups were not equal in size, random sampling with replacement was used to achieve a balanced number of scales per stock group by brood year.

Principal components analysis (S-Plus 2000, MathSoft, Inc.) was used to create a reduced set of uncorrelated variables for each of the 5 brood-year baseline and observer data sets. For all 5 brood years, the first 10 principal components explained 95% or more of the variation in the original 14 scale variables, and these 10 components were used as variables in all subsequent analyses.

For each brood year we developed a 4-region (Kamchatka, western Alaska, Cook Inlet, and southeast Alaska-British Columbia) maximum likelihood estimation model to evaluate the accuracies of our baselines in allocating simulated mixture samples to the correct region of origin (Millar 1987, 1990). The western Alaska baseline was composed of a subset of the Yukon, Kuskokwim, and Bristol Bay baseline data. The estimation procedure included 1000 iterations of randomly sampled scales in the model (with replacement) for specified cases of equal representation of all groups or 100% representation by one group in the simulated mixture. Confidence intervals on the estimates (95% CI) were derived from the 1000 simulation runs. For cases of equal (25%) representation the simulated maximum likelihood estimates (MLE) ranged from 24.2% to 25.2% for Kamchatka, 23.6-25.2% for western Alaska, 24.3-29.0% for Cook Inlet, and 22.6-26.9% for southeast Alaska-British Columbia (Table 2). For cases of 100% representation by one group the simulated estimates ranged from 94.6-96.5% for Kamchatka, 90.0-99.8% for western Alaska, 96.1-99.8% for Cook Inlet, and 93.3-99.8% for southeast Alaska-British Columbia (Table 3).

The 4-region MLE models were also evaluated by using test mixture samples of baseline scales that were not included in the 4-group models (Table 4). Only one test sample was available for Kamchatka, and the MLE was 95.6% Kamchatka (BY92 model). The MLEs ranged from 73.7% to 93.0% western Alaska fish for Yukon tests, 89.8-100% western Alaska fish for Kuskokwim tests, and 95.6-100% western Alaska fish for Bristol Bay tests. The MLEs for two Cook Inlet tests were 85.0% (BY91) and 95.9% (BY92) Cook Inlet fish. The MLEs for southeast Alaska and British Columbia tests ranged from 67.0% to 96.9% southeast Alaska-British Columbia. The Copper River, a stock not included in any of the models, was estimated to be predominately from neighboring regions (Cook Inlet or Southeast Alaska-British Columbia or both).

Our computer simulations and tests indicated that the accuracies of the brood-year specific MLE models were adequate for estimating the region and western Alaska subregion of origin of chinook salmon in the observer samples. Both regional (Kamchatka, Western Alaska, Cook Inlet, and southeast Alaska-British Columbia) and western Alaska sub-regional (Kamchatka, Yukon, Kuskokwim, Bristol Bay, Cook Inlet, and southeast Alaska-British Columbia) MLE models were used to estimate the percentages of western Alaska chinook salmon in the 1997-1999 observer samples. The MLEs were calculated only for strata with 100 or more fish in the observer samples. Confidence intervals on the estimates (95% CI) were derived from 1000 bootstrap runs (random sampling with replacement). In order to compare the results with the previous analysis (Myers and Rogers 1988), MLEs were calculated for samples stratified by year, age group, fishery area (east and west of 170°E), and fishery season (winter = January-June, fall = July-December). These stratified MLEs were also used to estimate the bycatch of Yukon River chinook salmon.

Interception and Adult Equivalent Bycatch Estimates

Estimates of the interceptions of Yukon River chinook salmon by the 1997-1999 BSAI groundfish fisheries were based on salmon bycatch estimates calculated by NMFS, Alaska Region, Sustainable Fisheries Division, Juneau. The NMFS estimates include bycatch by the open access fishery and, if available, by the Western Alaska Community Development Quota (CDQ) Program, which allocates a percentage of all BSAI quotas for groundfish, prohibited species, halibut, and crab to eligible communities. The NMFS bycatch estimates were stratified by fishery area (east and west of 170°W) and fishery season (winter = January-June, fall = July-December) by summing NMFS estimates stratified by month and BSAI statistical area (Fig. 3).

We assumed that the subset of age groups and brood years of chinook salmon for which we had stock proportion estimates were representative of the entire bycatch in the study years (1997-1999). We calculated interception estimates (number of fish) stratified by year, fishery area, fishery season, and age group by applying our annual age composition estimates for the subset of freshwater age-1. fish (adjusted to equal 1.0) to the stratified NMFS bycatch estimates. We estimated the interceptions of western Alaska chinook salmon by multiplying the stratified NMFS bycatch estimates by our stratified regional MLEs. The estimated proportions of the western Alaska sub-regional stocks were adjusted to equal 1.0, and multiplied by the stratified western Alaska interception estimates to calculate stratified estimates of the interceptions of Yukon, Kuskokwim, and Bristol Bay chinook salmon.

The adult equivalent (AEQ) bycatch of Yukon, Kuskokwim, and Bristol Bay chinook salmon was calculated using methods similar to Witherell et al. (2002). The stratified interception estimates for the western Alaska sub-regional stocks were adjusted to account for natural ocean mortality associated with the age of immature fish in the bycatch (adult equivalent bycatch). For these calculations we used the general assumptions and rough approximations of Witherell et al. (2002) with respect to age composition of adult returns and ocean survival, as follows: (1) all western Alaska chinook salmon return as age-1.3 or age-1.4 fish, (2) Yukon River returns are 30% age

1.3 and 70% age 1.4 fish, and Bristol Bay returns are 43% age 1.3 and 57% age 1.4 fish, and (3) ocean survival for immature chinook salmon is 80% between ages 1.2 and 1.3 and 90% between ages 1.3 and 1.4. Witherell et al. did not include Kuskokwim River returns in their analysis. We assumed that the age composition of Kuskokwim returns was the same as Yukon River returns. We also assumed that ocean survivals of immature chinook salmon are 60% between ages 1.0 and 1.1, 70% between ages 1.1 and 1.2, and 100% between ages 1.4 and 1.5.

To evaluate the effect of the BSAI groundfish fishery bycatch on chinook salmon returns to western Alaska, we calculated the total AEQ bycatch by return year and compared these interceptions to run size estimates and utilization (commercial, subsistence, sport, and personal use catch) in the Yukon, Kuskokwim, and Bristol Bay regions in 1997-2000. The run size estimates were provided by the Alaska Department of Fish and Game (ADFG, D. Eggers, pers. comm.), and are minimum estimates because escapements are not estimated for some major chinook salmon producing rivers and tributaries in western Alaska. These run size estimates are the best available, and the Yukon and Bristol Bay estimates are the same as those used by Witherall et al. (2002). There are no minimum escapement estimates available for the Kuskokwim River.

Results

Age Composition Estimates

There were 14 different age groups of chinook salmon in the 1997-1999 NMFS Observer Program scale samples from the BSAI (Table 1). Age-1. was the dominant freshwater age group (96.4%, n = 4,687 fish). A high percentage (89.4%) of the total sample was from the eastern BSAI (east of 170°W). In the eastern BSAI, old fish (ages 1.3 and 1.4) dominated chinook salmon scale samples collected in winter, and young fish (primarily age 1.2) dominated samples collected in fall (Fig. 5). The percentage of age 1.4 chinook salmon in winter 1997 samples was high (48.7%) compared to other years (Table 1), and the fall 1998 samples contained a high percentage of age 1.1 fish (29.9%). In the western BSAI (west of 170°W) there were few winter samples, and percentages of age 1.3 fish in these samples were high (Fig. 5). Fall samples from the western BSAI were composed largely of ages 1.2 and 1.3 fish. Monthly mean fork lengths and body weights by sex and ocean age group of freshwater age-1. chinook salmon in 1997-1999 NMFS Observer Program scale samples are shown in Appendix Table 1.

Stock Composition Estimates

Stock composition estimates for the five brood-year strata (1991-1995) averaged 56% Western Alaska, 31% Cook Inlet, 8% Southeast Alaska-British Columbia, and 5% Kamchatka chinook salmon (Table 5a). Western Alaska was the dominant regional stock of chinook salmon in all samples stratified by fishery year and age group except for relatively small samples (<150 fish) of age 1.1 fish in 1998 and age 1.4 fish in 1999 (Table 5b). When stratified by fishery area (east and west of 170°W) and season (winter = January-June; fall=July-December), sample sizes were insufficient (<100 fish) to calculate any stock composition estimates for the western BSAI, as well as for older age groups (ages 1.3 and 1.4) in fall and younger age groups (ages 1.1 and 1.2) in winter

(Table 5c). The estimates for western Alaska fish in the area- and season-stratified analysis (Table 5c) were similar to those in the year- and age-stratified analysis (Table 5b), except for a decrease in the estimate for age-1.2 chinook salmon in 1997. Percentages of Cook Inlet chinook salmon in most strata were relatively high, and Cook Inlet fish dominated the only sample of age 1.1 fish (fall 1998), as well as samples of age-1.2 fish from the eastern BSAI area in fall 1997 (Table 5b,c).

Within the Western Alaska estimates, the proportion of the sub-regional stock composition estimates for the five brood-year strata (1991-1995) averaged 40% Yukon, 34% Bristol Bay, and 26% Kuskokwim chinook salmon (Table 6a). In the eastern BSAI, Yukon or Kuskokwim or both were the dominant stocks of age-1.4 fish in winter, and Bristol Bay was the dominant western Alaska sub-regional stock of age-1.2 fish in fall (Table 6b). The mixture of western Alaska subregional stocks in winter samples of age-1.3 chinook salmon was varied, with roughly equivalent percentages of Yukon and Bristol Bay fish in 1997 and 1999, and all three subregional stocks in 1998.

Interception and AEQ Bycatch Estimates

Stratified NMFS bycatch estimates indicated that most of the chinook salmon in 1997 (50,530 fish), 1998 (60,557 fish), and 1999 (14,558 fish) were caught in the eastern BSAI (east of 170°W; 82.3% of the total bycatch in 1997, 94.8% in 1998, and 84.1% in 1999; Table 7; Fig. 6). The largest NMFS estimated bycatches of chinook salmon in 1997-1999 were in the eastern BSAI in fall 1997 (27,616 fish) and fall 1998 (39,630 fish) (Table 7; Fig. 7). In 1999, the largest NMFS estimated bycatches of chinook salmon were in the eastern BSAI in winter (7,884 fish).

In the eastern BSAI, the estimated bycatches of young (ages 1.0, 1.1, and 1.2) chinook salmon were largest in fall 1997 (24,772 fish) and fall 1998 (33,566 fish); estimated bycatches of age 1.3 chinook salmon were largest in winter 1998 (11,254 fish); and estimated bycatches of ages 1.4 and 1.5 chinook salmon were largest in winter 1997 (7,528 fish) (Table 8). The estimated interception of western Alaska chinook salmon in the BSAI was 47.5% of the total NMFS estimated bycatch in 1997, 47.9% in 1998, and 59.8% in 1999 (Table 9). The estimated percentages of Yukon River and Arctic-Yukon-Kuskokwim (AYK) fish were 14.4% Yukon (29.4% AYK) of the total bycatch in 1997, 14.7% (25.1%) in 1998, and 21.1% (31.9%) in 1999. The total estimated interception of Yukon River chinook salmon in the BSAI was 7,266 fish in 1997, 8,908 fish in 1998, and 3,074 fish in 1999 (Table 10).

Estimates of the AEQ bycatches of Yukon River chinook salmon by the BSAI groundfish fishery were 6,522 fish in 1997, 7,510 fish in 1998, and 2,721 fish in 1999 (Table 11). The majority of the western Alaska salmon in the 1997-1999 AEQ bycatch in the BSAI area would have returned to their natal rivers in 1997-2000 (Table 12). The estimated Yukon AEQ bycatch by year of adult return was equivalent to from 1.4 to 4.5% of the estimated minimum run (catch + minimum escapement estimate), from 11.5 to 50.8% of the minimum (lower river) escapement estimate, from 9.7 to 37.5% of upper river (Canadian) escapement, from 3.1 to 35.2% of the Alaska commercial catch, from

6.2 to 9.0% of the Alaska subsistence catch, or from 22.1 to 83.6% of the Canadian catch of chinook salmon in the Yukon River in 1997-2000 (Table 13).

Discussion

Comparison of Age Composition Estimates to Previous Studies

Extensive research in the Bering Sea and North Pacific Ocean has shown that immature age 1.2 fish and, to a lesser extent, age 1.3 fish are the dominant age-maturity groups of chinook salmon in offshore waters spring, summer, and fall (e.g., Major et al. 1978; Myers et al. 1993). In winter, the highest concentrations of immature age 1.2 chinook salmon may be in the central and northwestern Bering Sea (Radchenko and Glebov 1998). In our study, there was a strong seasonal difference in the age composition of chinook salmon in the BSAI bycatch samples, with age 1.2 fish dominating fall samples and ages 1.3 and 1.4 fish dominating winter samples (Table 1, Figs. 6 and 7). In contrast, Myers and Rogers (1988) found that young (age 1.2) fish were the dominant age group in winter bycatch samples from the BSAI in 1979–1982. The differences in the age composition of chinook salmon between the two studies is likely the result of changes in the area where most of the winter fishing occurred. The majority of winter samples analyzed by Myers and Rogers (1988) were from fish caught in waters northwest of 56ºN, 175ºW (Areas 523 and 550, Fig. 3). In our study, there were few samples from the region west of 170ºW in winter, and these were primarily from fish caught in the Aleutian Islands area southeast of 53ºN, 177ºW (Area 541, Fig. 3). In the eastern Bering Sea in winter, therefore, immature (age 1.2 and 1.3) chinook salmon may be more abundant along the outer shelf break (west of 170ºW), whereas maturing (age 1.3-1.5) chinook salmon may be more abundant along the inner shelf break (east of 170ºW).

The differences in age composition estimates between our study and Myers and Rogers (1988) could also be related to differences in year-class strength of western Alaska salmon populations. For example, high percentages of age 1.4 chinook salmon in the winter 1997 BSAI samples (Table 1) were followed by high escapements of age 1.4 chinook salmon in the Yukon River in 1997 (e.g., ADFG 2003, DFO 2003). Similarly, the high bycatch of western Alaska chinook salmon (predominantly age 1.2 fish) in the winter 1979 BSAI bycatch was followed by large returns of chinook salmon to western Alaska in 1981 (Myers and Rogers 1988; Figs. 1 and 2).

Seasonal- and age-specific differences in the vertical distribution of chinook salmon may also influence the age composition of the BSAI salmon bycatch. For example, in the western Bering Sea in winter immature age-.1 chinook salmon are distributed mainly in pelagic (near surface) waters, whereas older, larger fish (primarily ocean age-.2) tend to be distributed at or near the bottom (180 m and above) along the outer continental shelf (Radchenko and Glebov 1998). The bycatch of chinook salmon (primarily age 1.2 and 1.3 fish) by foreign and JV groundfish fisheries in the eastern Bering Sea late 1970s and early 1980s was usually highest in demersal (4-6 m above the bottom) trawl fisheries operating along the 200-m contour west of 170ºW during late fall, winter, and early spring (Myers and Rogers 1988). An increase in the use of pelagic (mid-water trawls) after 1981 was associated with a decline in chinook salmon bycatch (Fig. 1; Nelson et al. 1981). Sonic tracking of a few chinook salmon (probably immature, age 1.2 and 1.3 fish) in the central Bering Sea indicates that in summer they swim in or below the thermocline, about 20-40 m deep in most areas, with occasional vertical movements toward the surface or deeper layers (Ogura and Ishida 1995). Data from commercial trawl operations off the U.S. west coast (1985-1990) also indicated a seasonal shift in abundance and depth distribution of chinook salmon, that is, catches were higher in winter and were dispersed throughout a greater range of depths (100-482 m) than in summer, when catches were smaller and occurred at shallower depths (less than 220 m, Erickson and Pikitch 1994). In addition, trawls may be more effective at catching older, larger chinook salmon in winter, when fish are less active.

The relatively high percentages of old (age 1.3-1.5) chinook salmon in our samples may also reflect long-term trends in size and age at maturity of Pacific Rim salmon populations (e.g., Ricker 1980; Ishida et al. 1993; Helle and Hoffman 1995). Bigler et al. (1996) found a long-term decline from 1975 to 1993 in average body weights of chinook salmon from the Yukon and Kuskokwim rivers; in addition, they found that the mean age at return of Kuskokwim River chinook salmon decreased, age at return of Yukon River chinook salmon was unchanged, and age at return of Cook Inlet chinook salmon increased over the same period. All age groups of Yukon and Cook Inlet chinook salmon tested by Bigler et al. decreased by approximately 3-5% of body length from 1975 to 1993. The long-term decrease in size at age may affect the ocean distribution, migration, feeding, and maturation of chinook salmon, making them more or less susceptible to capture by trawls. For example, in winter small age 1.2 chinook salmon might remain in near surface waters, where they would be less likely to be caught in midwater or bottom trawls. Maturation of small age 1.3 and 1.4 fish could be delayed, causing them to remain for longer periods in midwater and near-bottom continental shelf-break areas, where they would be more likely to be caught by trawls. In addition, small age 1.3 and 1.4 chinook salmon might not be able to sustain the swimming speeds that enable larger fish of the same age to escape trawls. A comprehensive time series of size at age data are not presently available for the BSAI chinook salmon bycatch samples, but could be developed from historical scale collections and body size data archived by the North Pacific Groundfish Observer Program.

Comparison of Stock Composition Estimates to Previous Studies

Scale pattern analyses have provided the only previous quantitative estimates of the stock composition of chinook salmon in the Bering Sea (Major et al. 1975, 1977a, 1977b; Myers et al. 1984, 1987; Myers and Rogers 1988). In the 1960s and early 1970s, an increase in the catches of chinook salmon by the Japanese mothership driftnet fleet in the Bering Sea – from annual averages of 47,000 fish before 1964 to 237,000 in 1964-70 – coincided with poor runs in western Alaska (Major et al. 1975). Analyses of 1966-1970 high seas samples indicated that percentages of western Alaska chinook salmon increased from west to east across the Bering Sea, and that roughly 50-100% of chinook salmon in the region from 175ºE to 175ºW, where the highest Japanese catches occurred, were western Alaska stocks (Major et al. 1975, 1977a,b, 1978). Estimates of the stock composition of immature (age-1.2) chinook salmon in the Japanese mothership fishery area in the Bering Sea (165ºE-175ºW) in summer 1975-1981 averaged 70% Western Alaska, 18% Kamchatka, 10% central Alaska (Cook Inlet), and 2% southeast Alaska-British Columbia (Myers et al. 1987). In time-area strata where western Alaska stocks dominated, estimated proportions of the western Alaska subregional stocks averaged 48% Yukon, 21% Kuskokwim, and 14% Bristol Bay (Myers et al. 1987). In July, percentages of Yukon chinook salmon were higher in the area between 175ºE-180° than in the area east of 180° (Myers et al. 1987). These results suggest that in summer immature Yukon River chinook salmon are distributed farther to the west than other North American stocks, which may explain their relatively low percentages in our samples from the eastern BSAI in fall (Table 6b).

Healey (1991) used high seas disk tag recovery data (1956-1984; C. Harris, Fisheries Research Institute, University of Washington, pers. comm.), coded wire tag recovery data (1980-1986; Dahlberg 1982; Wertheimer and Dahlberg 1983, 1984; Dahlberg and Fowler 1985; Dahlberg et al. 1986), and the results of scale pattern analyses (Major et al. 1978; Myers et al. 1984, 1987; Ito et al. 1985, 1986; and Myers 1986) to describe the distribution and relative abundance of regional stock groups of chinook salmon in the western and central Bering Sea (between 165ºE-175ºW) in summer. Healey concluded that in this region western Alaskan chinook salmon (including Canadian Yukon fish) are the most abundant stock group, Kamchatka and central Alaska stocks are about half as abundant as western Alaska stocks, and that the abundance of the southeast Alaska and British Columbia stocks is low.

The late 1970s-early 1980s was a period of high abundance of western Alaska chinook salmon (Fig. 2), and western Alaska stocks were estimated to account for a relatively high average percentage (60%) of the chinook salmon in the BSAI area in 1979, 1981, and 1982 (Myers and Rogers 1988). Because of the decline in abundance of western Alaska chinook salmon in the late 1990s (Fig. 2), Witherell et al. (2002) speculated that their application of the estimates of Myers and Rogers (1988) probably overestimated the contribution of western Alaska stocks to the BSAI trawl fishery bycatch in 1990-2000.

Our results provide the first direct estimates of the stock composition of chinook salmon in the bycatch of U.S. groundfish fisheries operating in the BSAI area. Despite the decline in abundance of western Alaska chinook salmon in the late 1990s, western Alaska was the dominant regional stock (average 56%) in BSAI bycatch samples in 1997-1999 (Table 5a). Similar to the results of Myers and Rogers (1988), our results show that: (1) the proportions of the three western Alaskan subregional stocks (Yukon, Kuskokwim, and Bristol Bay) in the BSAI area vary considerably with such factors as brood year, time, and area; (2) Yukon River chinook salmon are often the dominant stock in the BSAI in winter, particularly among age 1.2 fish in the western BSAI and age 1.4 fish in the eastern BSAI; (3) Bristol Bay and Cook Inlet are the dominant stocks of age 1.2 chinook salmon in the eastern BSAI in fall; and (4) age 1.1 chinook salmon in the eastern BSAI in fall are largely Gulf of Alaska stocks (Cook Inlet, southeast Alaska-British Columbia) (Tables 5 and 6; Myers and Rogers 1988).

Limited data from high seas tagging studies corroborate our scale pattern analyses results. The few (14 fish) recoveries of chinook salmon tagged and released in the Bering Sea during high seas salmon investigations by Japan, Russia, and the United States (1955-present) were all from fish that returned to western Alaska and the Canadian Yukon (Fig. 8). All but one of these tagged fish was released west of 179°W in June and July. These data show that immature Yukon, Kuskokwim, and Bristol Bay chinook salmon mix in offshore waters of the Bering Sea in summer, and indicate that Yukon River chinook salmon are the dominant stock of western Alaskan salmon in the central and northwestern Bering Sea in summer. There are also a few (15 fish) ocean recoveries of coded-wire tagged (CWT) hatchery fish from the Canadian Yukon (Whitehorse Hatchery; Fig. 9). All of these recoveries were in the eastern Bering Sea.. Recoveries in October in the vicinity of Norton Sound were juvenile (ocean age-.0) chinook salmon caught in a pelagic (surface) research trawl. One June recovery was probably a maturing fish, approaching the mouth of the Yukon River from the south. The other recoveries were from fish caught in winter (December-March) groundfish trawl fisheries along the eastern Bering Sea shelf break (200-m depth contour), northwestward from Unimak Pass to the international boundary. The overall pattern of recoveries of tagged Yukon chinook salmon suggests seasonal movements of between summer feeding grounds in the central and northwestern Bering Sea and wintering areas in the southeastern Bering Sea.

Myers et al. (2001) provided a detailed review of high seas CWT recovery data for Cook Inlet, southeastern Alaska, British Columbia, Washington, Oregon, and California chinook salmon in the Bering Sea and Gulf of Alaska. The number of recoveries reflects the regional pattern of releases of CWT hatchery fish and trawl fishing effort rather than the relative abundance of the regional stocks of chinook salmon. The recoveries of CWT chinook salmon from all release locations except Cook Inlet, however, were substantially higher in the Gulf of Alaska or off the coasts of Washington, Oregon, and California than in the Bering Sea. The Bering Sea recoveries of CWT Gulf of Alaska region stocks (Cook Inlet, Southeast Alaska, British Columbia) are most numerous along the continental shelf-break in the "horseshoe" area just north of Unimak Pass, an area where trawl fishing effort is high (Figs. 10-12). Bering Sea recoveries of CWT Cook Inlet chinook salmon are distributed both east and west of 170ºW in fall, whereas recoveries of CWT southeast Alaska and British Columbia fish are distributed primarily in the area east of 170ºW. These general trends are in agreement with our scale pattern analysis results.

Comparison of BSAI Interception Estimates to Previous Studies

Previous studies have focused on estimating interceptions of Yukon River salmon by foreign fisheries in the Bering Sea. Yukon River (age 1.2 fish) was estimated to be the major stock contributing to chinook salmon catches by the Japanese mothership fishery in the Bering Sea, averaging 36% of the total catch during 1975-1977 and 42% during 1978-1981 (Rogers 1987). An exceptionally large catch of 864,000 chinook salmon by the Japanese mothership and landbased driftnet salmon fisheries in the Bering Sea and North Pacific Ocean in 1980 included an estimated 229,000 Yukon, 196,000 Kuskokwim, 13,000 Bristol Bay, 275,000 Cook Inlet, 55,000 southeast Alaska-British Columbia, and 96,000 Kamchatka chinook salmon (Rogers 1987).

Compared to interceptions by the former Japanese high seas salmon driftnet fisheries, the estimated interceptions of Yukon River chinook salmon by foreign and JV trawl fisheries in the BSAI region in 1977-1985 were relatively low (6,300 fish in 1977, 5,600 fish in 1978, 32,600 fish in 1979, 16,600 fish in 1980, 2,500 fish in 1981, 600 fish in 1982, 1,500 fish in 1983, 1,600 fish in 1984, 1,400 fish in 1985, and 800 fish in 1986; Myers and Rogers 1988). Our estimates of interceptions of Yukon River chinook salmon by U.S. trawl fisheries in the BSAI in 1997-1999 (Table 10), as well as the estimate of Witherell et. al. (2002; 6,652 fish), are higher than estimated interceptions by the foreign and JV trawl fisheries after 1980 (Myers and Rogers 1988).

The accuracies of our estimates of the interceptions of Yukon River chinook salmon by the U.S. groundfish fisheries in the BSAI depend on the accuracy of the NMFS estimates of chinook salmon bycatch. To estimate chinook salmon bycatch by the BSAI groundfish fishery, NMFS uses "*ad hoc* procedures for stratification, expansion, and blending of observer data with industry retained catch reports" (Turnock and Karp 1997). Although NMFS does not calculate the variances of their salmon bycatch estimates, these variances are expected to be high (Turnock and Karp 1997). The high levels of uncertainty associated with the NMFS salmon bycatch estimates should be a major consideration, if our results are used to develop fishery management or conservation measures for Yukon River chinook salmon.

Effect of BSAI Bycatch on Yukon River Salmon Runs (Catch and Escapement) in 1997-2000

The United States has been concerned about the impact of high seas catches of chinook salmon on the food supply and economy of western Alaska since the since the early 1950s (Major et al. 1975; Jackson and Royce 1986). High seas catches of chinook salmon by the former Japanese mothership and landbased driftnet salmon fisheries operating in the Bering Sea and North Pacific Ocean (west of 175ºW, 1952-1991) often equaled or exceeded western Alaska commercial catches of chinook salmon. Major (1984) estimated that the 1980 mothership fishery reduced the aggregate weight of 1980-1983 chinook salmon runs to western Alaska (catch plus escapement) by 5,712 t (range 1,986-13,288 t). Rogers (1987) estimated that the approximate exploitation rates (average interceptions in 1975-1981, divided by average coastal runs in 1976-1983) by the Japanese high seas fisheries in the Bering Sea and North Pacific Ocean were 26% for Yukon, 18% for Kuskokwim, and 4% for Bristol Bay chinook salmon. In contrast, the total estimated interceptions of western Alaska chinook salmon by foreign and JV trawl fisheries in the BSAI in 1977-1986 were less than 6% of the total commercial harvest in western Alaska in 1977-1986 (Myers and Rogers 1988). Witherell et al. (2002) estimated that interceptions of western Alaska chinook salmon by U.S. trawl fisheries in the BSAI are about 2.7% of the average minimum run (1990-2000) in western Alaska (540,000 chinook salmon).

The Yukon River chinook salmon resource, which may be the world's largest wild run of chinook salmon, is utilized primarily by commercial (over 800 permits fished annually) and subsistence (over 1,400 households, primarily for human consumption) fishermen in Alaska (ADFG 1998). In Alaska, subsistence fishing has statutory priority over all other uses, and is under joint management authority of the ADFG and the U.S. Fish and Wildlife Service. The Alaska Board of Fisheries (BOF) establishes policies and regulations for salmon management by ADFG. In Canada, the Canadian Department of Fisheries and Oceans conducts management activities. Guidelines for Canadian harvests (commercial, aboriginal, domestic, and sport) and escapements are set by bilateral treaty agreements (Pacific Salmon Treaty, U.S./Canada Joint Technical Committee of the Yukon River Panel). Escapements of age 1.4 chinook salmon in the Yukon River in 1997 were some of the largest on record (ADFG 2003). Runs of chinook salmon to the Yukon River in 1998-2000, however, were the lowest on record (Fig. 2; Table 13). Inriver management restrictions on commercial harvest and problems in achieving subsistence harvest goals resulted in "significant economic hardship" for Yukon River fishermen and communities in Alaska (ADFG 1998). In 2000, the Alaska BOF determined that the Yukon River chinook salmon were a "stock of concern". In Canada, there were restrictions and closures of commercial, domestic, and sport fisheries in the Yukon mainstem to conserve spawning escapement, and catches in 1998 and 2000 were the lowest on record.

Our estimates of the AEQ bycatch of Yukon River chinook salmon by the domestic groundfish fisheries in the BSAI in 1997-1999 are not large enough to explain the low returns to the Yukon River in the late 1990s (Table 12). Although we did not have estimates of total annual runs of chinook salmon to the Yukon River, the 1997-1999 BSAI bycatch apparently had the largest effect on local utilization of Yukon River chinook salmon in 1998 and 2000 (Table 13). If the Yukon River chinook salmon intercepted by the BSAI groundfish fisheries had returned to the river, they would have amounted to a substantial improvement in escapement to spawning grounds in 1998-2000 (Table 13), as well as greater fishing opportunity for commercial and subsistence fishermen.

Fishery Management and Conservation Implications

In 1976, the Manguson-Stevens Fishery Conservation and Management Act (MSFCMA) established U.S. management authority over fisheries in the U.S. Exclusive Economic Zone (EEZ). Fishery management regulations under the MSFCMA are enacted by the North Pacific Fishery Management Council (NPFMC) and NMFS. Witherell and Pautzke (1997) and Witherell et al. (2002) reviewed management measures designed to reduce the bycatch of salmon by groundfish fisheries in the eastern Bering Sea. In response to large bycatches of chinook salmon by foreign groundfish fleets in 1979 and 1980 (>100,000 fish; Fig. 1), an annual bycatch limit of 55,250 chinook salmon was established in 1982. Following another large bycatch by the foreign fleets in 1984 (>80,000 chinook salmon), a 5-yr plan for a 75% reduction in Pacific salmon bycatch was implemented. In 1987 bycatch limits for JV fisheries were established, and through 1990, when a domestic observer program was implemented, the estimated bycatch of chinook salmon in the BSAI groundfish fisheries remained at relatively low levels (approximately ≤20,000 fish; Fig. 1). After 1990, the estimated annual bycatch by the domestic fleet has remained relatively high (~ 40,000-60,000 chinook salmon), except for a few low bycatch years (1995, 1999, 2000). In 1996, a chinook salmon bycatch limit (48,000 fish) and savings areas, closed to all trawling if the limit was reached before

April 15, were implemented. In 1997 the NPFMC began analysis of a proposal by YRDFA to include chinook salmon taken after April 15 as part of the 48,000 fish limit, which if reached would trigger a closure for the remainder of a year, or to reduce the overall bycatch limit to 36,000 salmon. In 1998, the analysis was extended to include additional options and issues, e.g., hotspot area closures at the start of the fishing year, closures only to the pollock fishery, gear interactions resulting from a hotspot closure, 100% observer coverage on vessels over 60 ft in the hotspot area, use of vessel monitoring systems on pollock trawlers, accuracy of basket sampling for salmon, measures to ensure accurate counts of catch, and subdivision of the bycatch limits among pollock fisheries (shoreside, mothership, and offshore) and non-pollock fisheries.

In 1999, the NPFMC implemented measures to protect Steller sea lions (*Eumetopias jubatus*), which eliminated directed fishing for pollock within 10 nm of sea lion rookeries and haulouts, reduced catch of pollock within critical sea lion habitat areas, prohibited pollock fishing in the Aleutian Islands (AI) area, and created four pollock fishing seasons in the Bering Sea area to spread effort over time. Closure of the AI area to pollock fishing also resulted in closure of the western section of the chinook salmon savings areas. The regulations implemented to protect Steller sea lions may have reduced the bycatch of chinook salmon in the BSAI area in 1999. Our results indicate, however, that the proportion of Yukon River chinook salmon in the bycatch increased (from 15% of the total in 1998 to 21% of the total in 1999) because the portion of the bycatch taken in winter increased.

In 2000 new regulations to incrementally reduce the chinook salmon bycatch cap for pollock trawl fisheries (48,000 salmon in 1999, 41,000 in 2000, 37,000 in 2001, 33,000 in 2002, and 29,000 in 2003) were implemented. The new regulations also included annual (January 1-December 31) accounting of chinook salmon bycatch by the pollock fishery, revised boundaries of the chinook salmon savings areas, and more restrictive closure dates (Witherell et al. 2002). The NPFMC also recommended development of a sampling scheme that would accurately estimate bycatch of chinook salmon, and requested an analysis to apportion the chinook salmon bycatch limit by sector or individual fishery co-operatives. The low bycatch of chinook salmon in the BSAI in 2000, however, resulted primarily from a U.S. District Court order that closed all Steller sea lion critical habitat and offshore foraging areas to trawl fishing from August 8 to December 14 (Witherell et al. 2002). In 2001-2003 the BSAI chinook salmon bycatch increased to levels similar to those in the early 1990s (approximately 40,000 fish; Fig. 1).

The NPFMC and NMFS are developing an ecosystem-based approach for management of Bering Sea groundfish fisheries (Witherell et al. 2000). Without adequate information on the age, maturity, and stock composition of chinook salmon in the BSAI bycatch, however, the effects of removals of chinook salmon by BSAI groundfish fisheries on Bering Sea and freshwater ecosystems are uncertain. Fishery managers need a better understanding of how changes in the times and areas of operation of the BSAI groundfish fishery may affect returns of chinook salmon to the Yukon River. In 1997-1999, the largest interceptions of Yukon River chinook salmon occurred in the eastern BSAI in winter. Although we do not have data on the maturity of the chinook salmon in the BSAI bycatch, many, if not most, of the age 1.3 and 1.4 fish caught in winter were probably maturing fish that would have returned to the Yukon river in late May and June. Future management efforts to conserve Yukon River chinook salmon, therefore, should emphasize methods that will reduce the winter (January-June) bycatch in the BSAI. For example, accounting towards bycatch limits could begin on September 1, with the amount carried over to the next winter season. This approach seems reasonable in terms of the life history of the fish, as well as local utilization of the salmon resource. Measures designed to minimize the mortality of chinook salmon bycatch, such as separation devices attached to pollock trawls (Rose 2004), should be tested for seasonal-, age-, and size-specific differences in their effectiveness.

In addition, the BSAI chinook salmon bycatch samples and data could be used more effectively to manage and conserve Yukon River chinook salmon. For example, NMFS Observer Program chinook salmon samples and data could be used to calculate annual estimates of the maturity, age, and stock composition of the chinook salmon in the bycatch samples. A new scale sampling scheme could be designed to improve time and area coverage of the fishery and to estimate the variance of age composition estimates. Samples for DNA analysis (fin clips) could be collected by observers from the same fish that are sampled for scales. Information from the BSAI chinook salmon bycatch samples and data could be used by fishery managers to improve both preseason and inseason stock assessments of Yukon River chinook salmon.

Although our analysis provided useful retrospective information on the stock composition of chinook salmon in the BSAI bycatch in 1997-1999, scale pattern analysis requires brood-year and age-specific baseline data from the scales of adult salmon that have already returned to their natal streams. Retrospective analyses that use both genetic and scale pattern data may be more accurate at identifying individual stocks than analyses that use of only one type of data. Once comprehensive baselines have been established, genetic (DNA) stock identification may provide an efficient tool for inseason estimates of salmon stock composition. Because of genetic similarities among AYK and Cook Inlet chinook salmon populations (Utter and Allendorf 2003), mixed stock analyses of chinook salmon in the eastern Bering Sea may continue to prove challenging.

Summary and Conclusions

1. Our study provides the first estimates of the age and stock composition of chinook salmon in the bycatch of U.S. groundfish fisheries in the eastern Bering Sea. There was a strong seasonal difference in the age composition of chinook salmon in the 1997-1999 BSAI bycatch samples, with young (age 1.2) fish dominating fall samples and old (age 1.3 and 1.4) fish dominating winter samples. In the Bering Sea in winter, immature (age 1.2 and 1.3) chinook salmon seem to be more abundant along the outer shelf break (west of 170ºW), and maturing (age 1.3-1.5) chinook salmon may be more abundant along the inner shelf break (east of 170ºW). Other factors that may influence the age composition of chinook salmon in the BSAI bycatch include year class strength, seasonal- and age-specific changes in the vertical distribution of chinook salmon, and long-term decreases in body size and increases in age at maturity of western Alaska chinook salmon.

2. Despite the decline in abundance of western Alaska chinook salmon in the late 1990s, western Alaska was the dominant regional stock (average 56%) in BSAI bycatch samples in 1997-1999. Similar to the results of Myers and Rogers (1988), our results show that: (1) the proportions of the three western Alaskan subregional stocks (Yukon, Kuskokwim, and Bristol Bay) in the BSAI area vary considerably with such factors as brood year, time, and area; (2) Yukon River chinook salmon are often the dominant stock in the BSAI in winter, particularly among age 1.2 fish in the western BSAI (west of 170ºW) and age 1.4 fish in the eastern BSAI (east of 170ºW); (3) Bristol Bay and Cook Inlet are the dominant stocks of age 1.2 chinook salmon in the eastern BSAI in fall; and (4) age 1.1 chinook salmon in the eastern BSAI in fall are largely Gulf of Alaska stocks (Cook Inlet, southeast Alaska-British Columbia). The results of previous scale pattern analyses and tagging studies suggest that in summer immature Yukon River chinook salmon are distributed farther to the west in the Bering Sea than other North American stocks, which may explain their relatively low percentages in fall 1997-1999 bycatch samples from the eastern BSAI.

3. Our estimates of interceptions of Yukon River chinook salmon by domestic groundfish fisheries in the BSAI in 1997-1999, were higher than estimated interceptions by the foreign and JV trawl fisheries after 1980. The accuracies of our interception estimates, however, depend on the accuracy of the NMFS estimates of chinook salmon bycatch. The high levels of uncertainty associated with the NMFS salmon bycatch estimates should be a major consideration, if our results are used to develop fishery management or conservation measures for Yukon River chinook salmon.

4. Our estimates of the AEQ bycatch of Yukon River chinook salmon by the domestic groundfish fisheries in the BSAI in 1977-1999 are not large enough to explain the low returns to the Yukon River in the late 1990s. The 1997-1999 BSAI bycatch apparently had the largest effect on local utilization and escapement of Yukon River chinook salmon in 1998 and 2000. The estimated AEQ bycatch of Yukon River chinook salmon represents a substantial loss of escapement to spawning grounds in 1998-2000, as well as a loss of fishing opportunity for commercial and subsistence fishermen. In years when salmon returns to rivers are low, even relatively low incidental catches of salmon by non-target marine fisheries may reduce local utilization of chinook salmon resources and impede management and conservation efforts to achieve spawning escapement goals in the Yukon River.

5. Regulations implemented in 1999, which spread fishing effort over time, apparently increased the portion of the chinook salmon bycatch taken in winter, and estimated percentages of Yukon River chinook salmon in the bycatch also increased. Future management efforts to conserve Yukon River chinook salmon should emphasize methods that will reduce the winter (January-June) bycatch of maturing (age 1.3, 1.4, and 1.5) chinook salmon in the eastern BSAI (east of 170ºW). For example, accounting towards bycatch limits could begin on September 1, with the amount carried over to the next winter season.

6. The BSAI chinook salmon bycatch samples and data could be used more effectively to manage and conserve Yukon River chinook salmon. For example, NMFS Observer Program chinook salmon samples and data could be used to calculate annual estimates of the maturity, age, and stock composition of the chinook salmon in the bycatch samples. A new scale sampling scheme could be designed to improve time and area coverage of the fishery and to estimate the variance of age composition estimates. Samples for DNA analysis (fin clips) could be collected by observers from the same fish that are sampled for scales. Information from the BSAI chinook salmon bycatch samples and data could be used by fishery managers to improve both preseason and inseason stock assessments of Yukon River chinook salmon. Once comprehensive baselines are established, genetic (DNA) stock identification may provide an efficient tool for inseason estimates of salmon stock composition in the BSAI bycatch.

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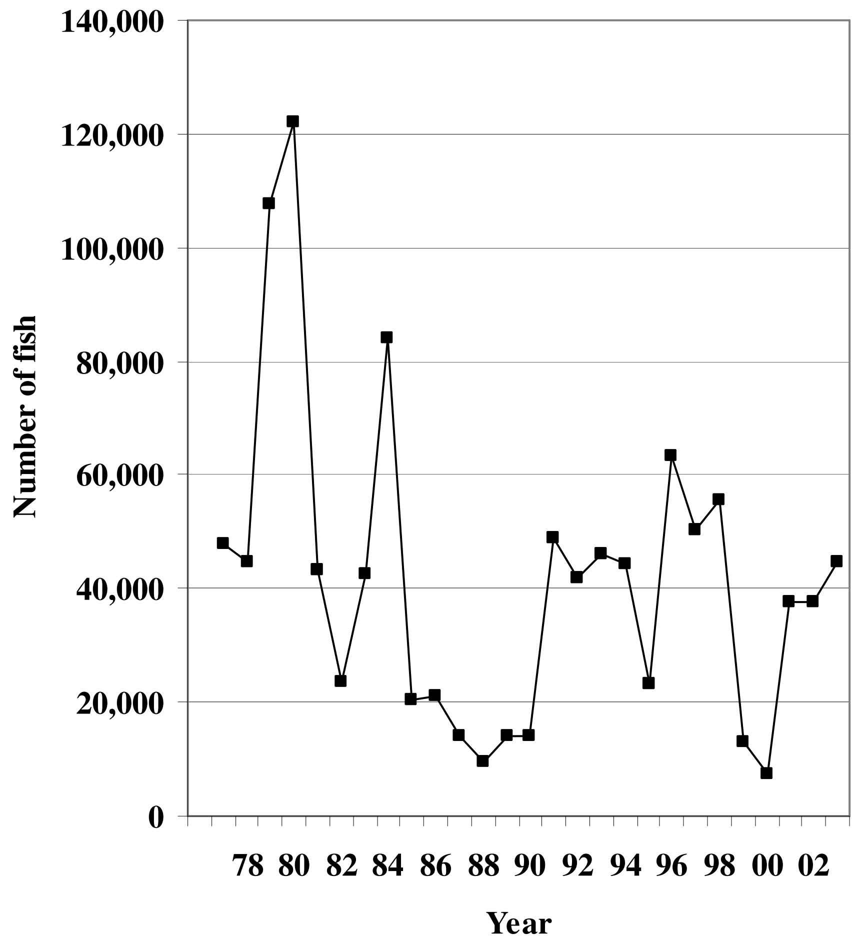

Fig. 1. Trends in the estimated bycatch of chinook salmon by foreign, joint-venture, and domestic groundfish fisheries in the Bering Sea and Aleutian Islands (BSAI) area of the U.S. Exclusive Economic Zone, 1977-2003 (Berger 2003; preliminary 2003 estimate is from NMFS, Alaska Region, Sustainable Fisheries Catch Accounting Report through 13 December 2003; estimates of Community Development Quota salmon bycatch are not included).

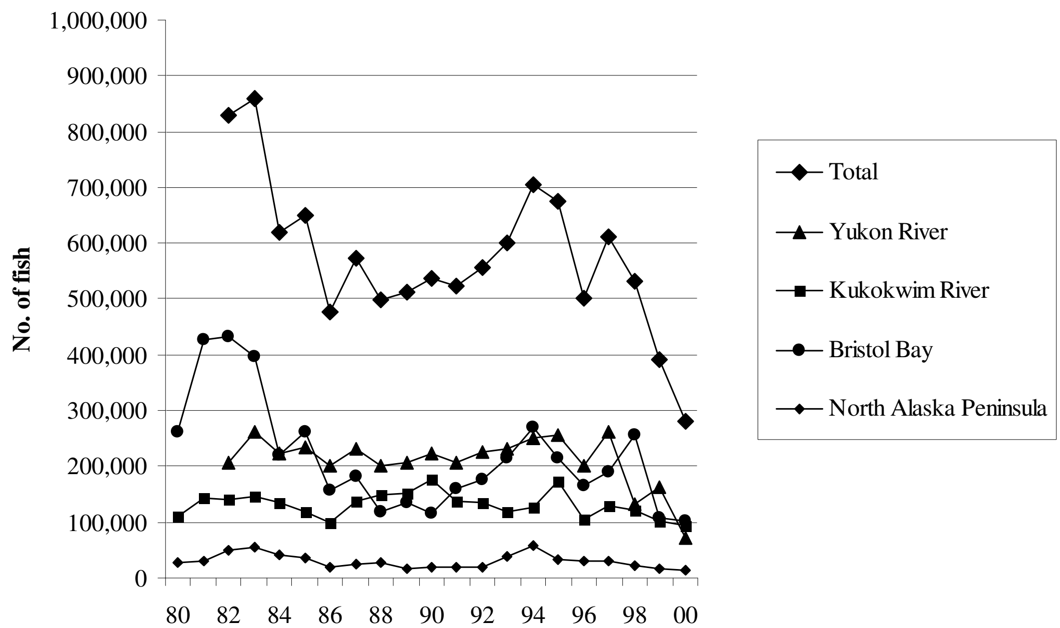

Fig. 2. Trends in western Alaska chinook salmon runs, 1980-2000. Data source: D. Eggers, Alaska Department of Fish and Game.

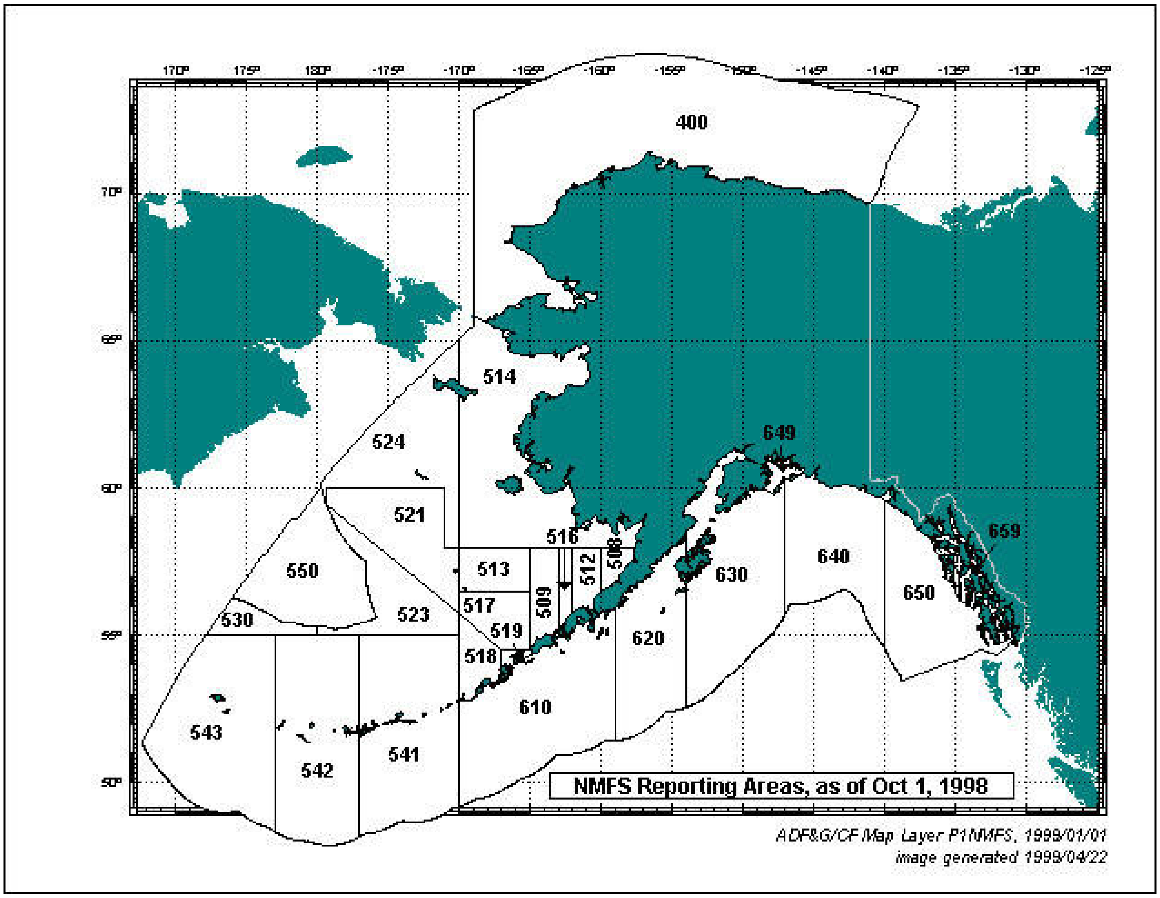

Fig. 3. Map showing National Marine Fisheries Service (NMFS) reporting areas in the Bering Sea and Aleutian Islands (BSAI; areas numbers in the 500s) and Gulf of Alaska (areas numbers in the 600s).

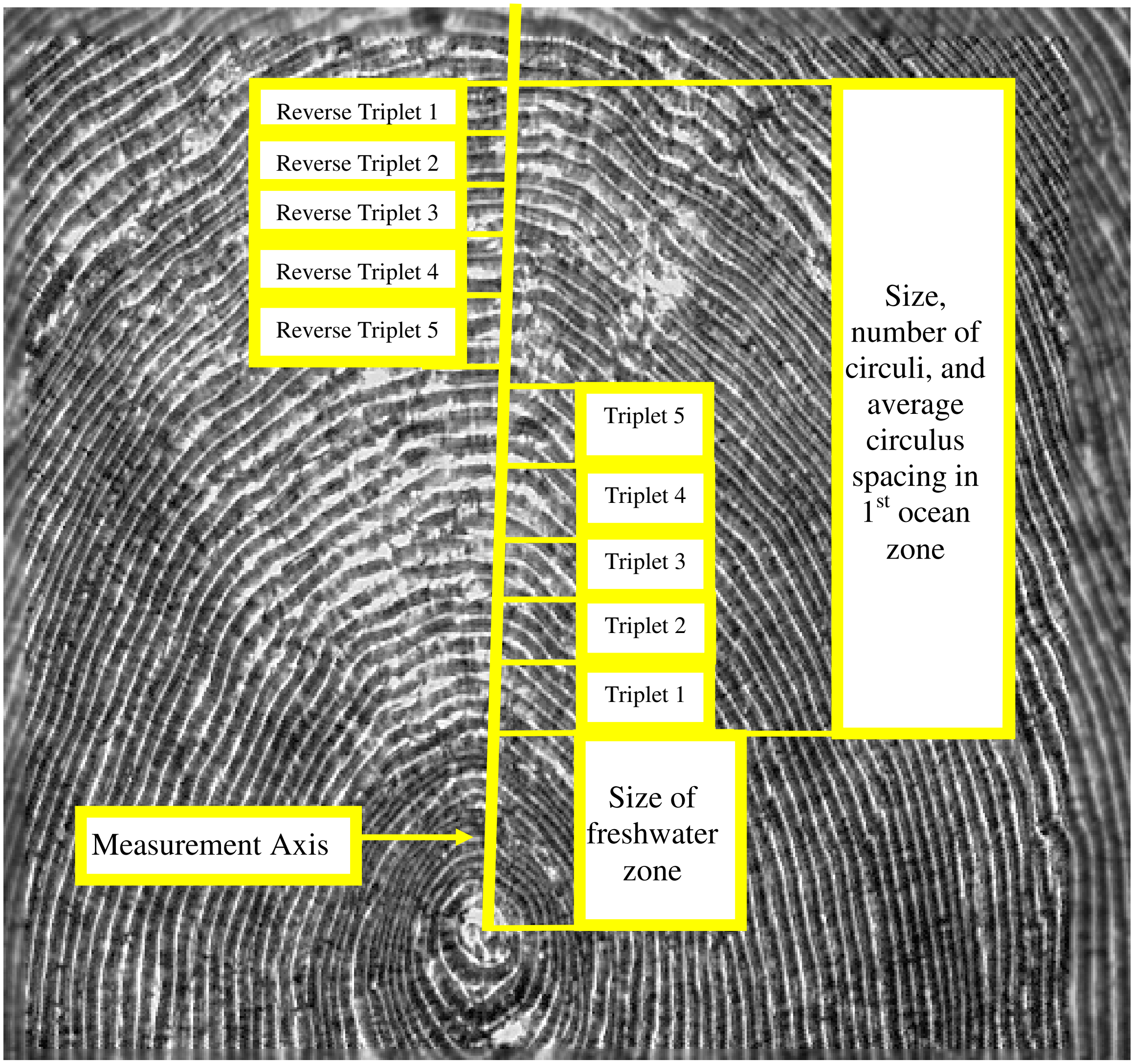

Fig. 4. Chinook salmon scale showing scale measurement axis and 14 scale pattern measurement variables used in the analysis.

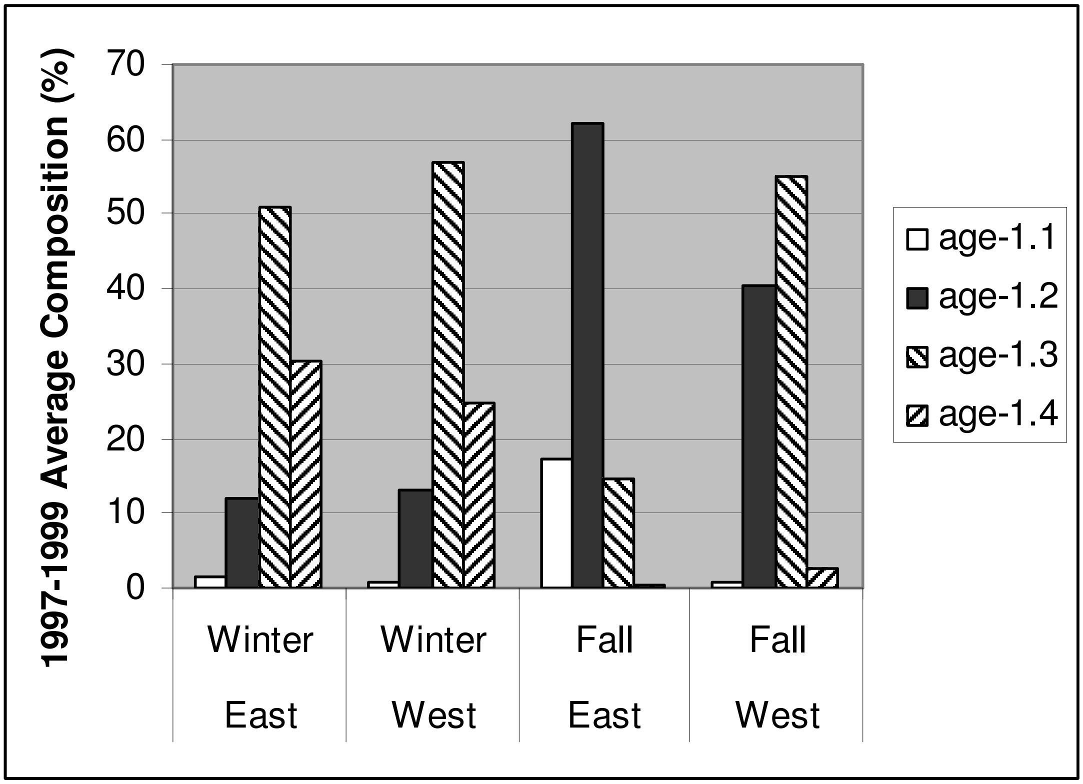

Fig. 5. Average annual age composition of major age groups of chinook salmon in 1997-1999 scale samples from bycatch of U.S. groundfish fisheries in eastern Bering Sea by fishing season (winter and fall) and area (east and west of 170°W). See Table 1 for values of age composition estimates.

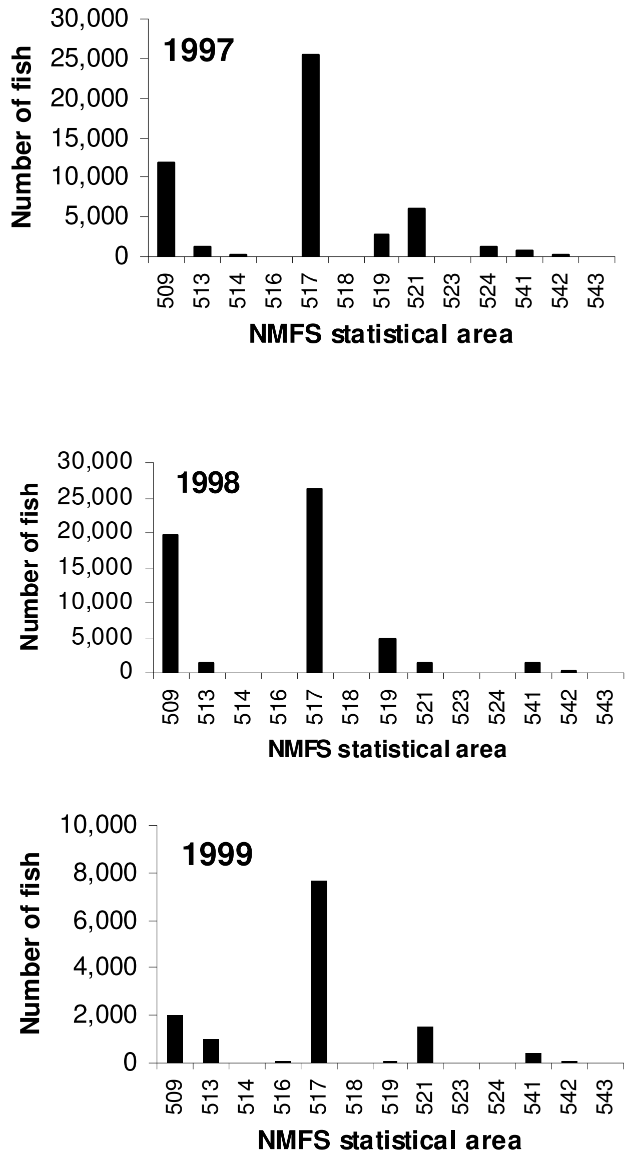

Fig. 6. Bycatch of chinook salmon in the open access U.S. groundfish fisheries in the Bering Sea and Aleutian Islands by NMFS statistical area, 1997-1999. Statistical areas with numbers ≤ 519 are located east of 170°W and areas with numbers ≥521 are located west of 170°W (see Fig. 3).

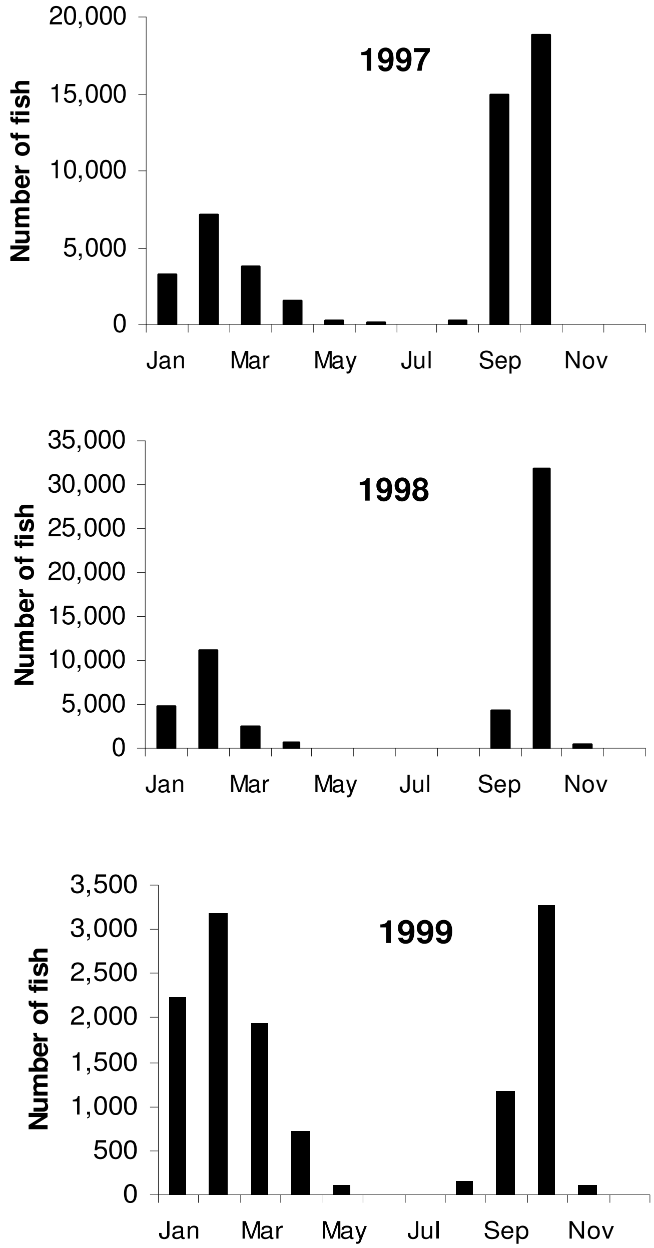

Fig. 7. Bycatch of chinook salmon by the open access U.S. groundfish fisheries in the Bering Sea and Aleutian Islands area by month, 1997-1999.

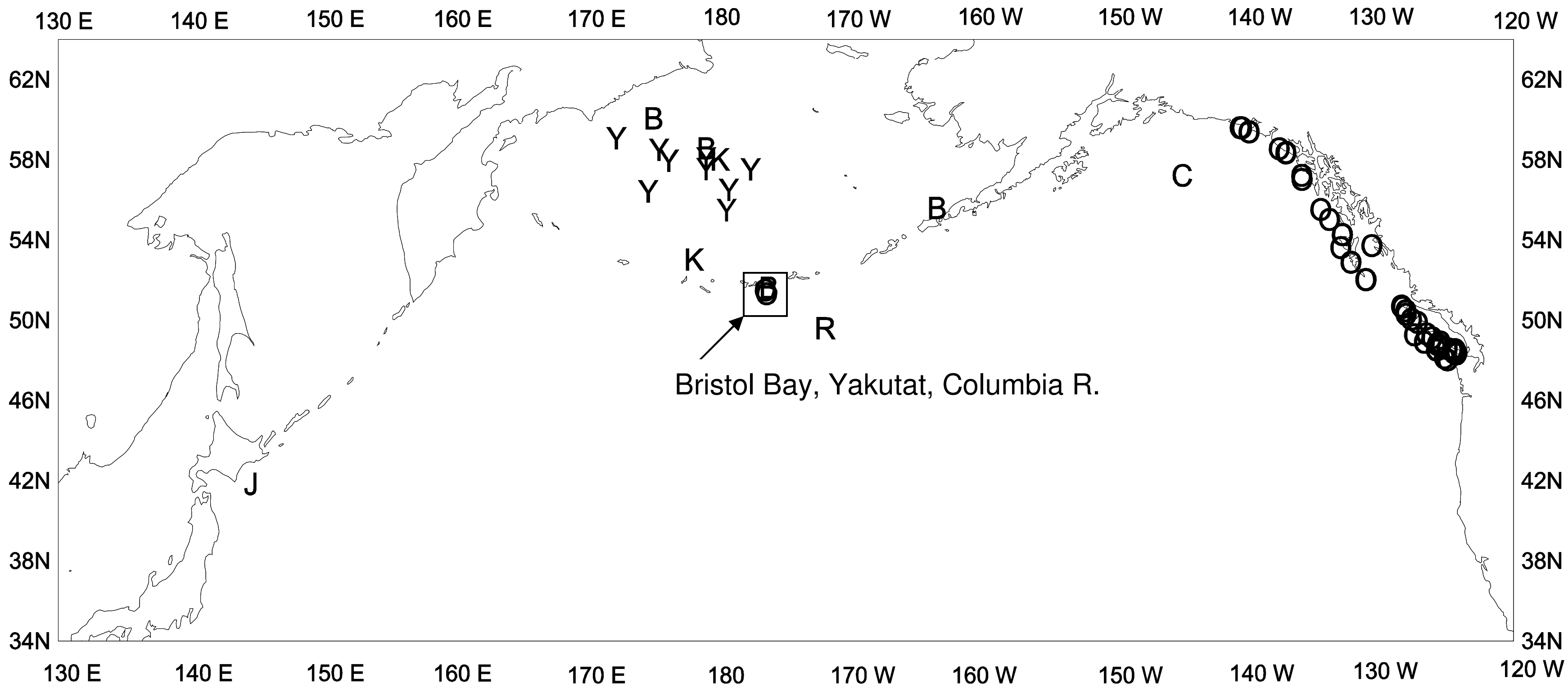

Fig. 8. Ocean release locations of tagged chinook salmon recovered in Japan (J, n=1), Russia (R, n=1), Yukon River (Y, n=9), Kuskokwim River (K, n=2), Bristol Bay (B, n=4), Cook Inlet (C, n=1), and other North American areas (O), including Yakutat (n=1), southeastern Alaska (n=7), British Columbia (n=57), Washington (n=24), Columbia River/Snake R. (n=15), and Oregon (n=2).

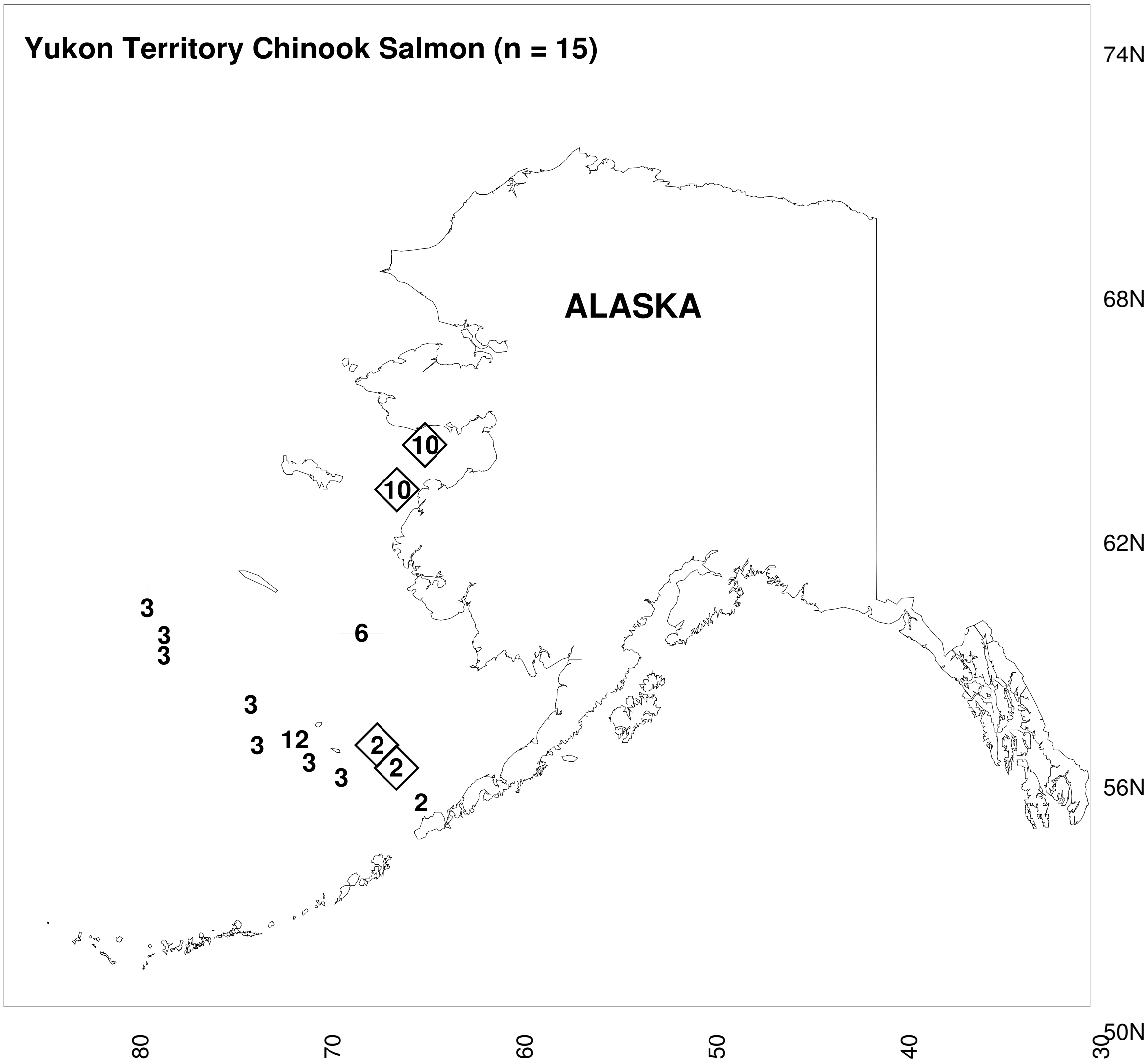

Fig. 9. Recovery locations of coded-wire tagged (CWT) Yukon River (Yukon Territory) hatchery chinook salmon caught by U.S. research and groundfish (trawl) fishery vessels in the eastern Bering Sea, 1992-2003. The numbers at each location indicate the month of recovery (adapted from Myers et al. 2001). Five new recoveries reported by Myers et al. (2003) are indicated by open diamonds (two overlap at the northernmost location). Three new recoveries of coded-wire tagged juvenile (ocean age-.0) fish during a U.S. NMFS survey in October 2002 at 64°06′N, 164°31′W (2 recoveries) and at 63°00′N, 165°58′W are northern extensions of the known ocean range of Yukon River chinook salmon. Two new recoveries in February show the overwintering location of Yukon River salmon during their first winter at sea.

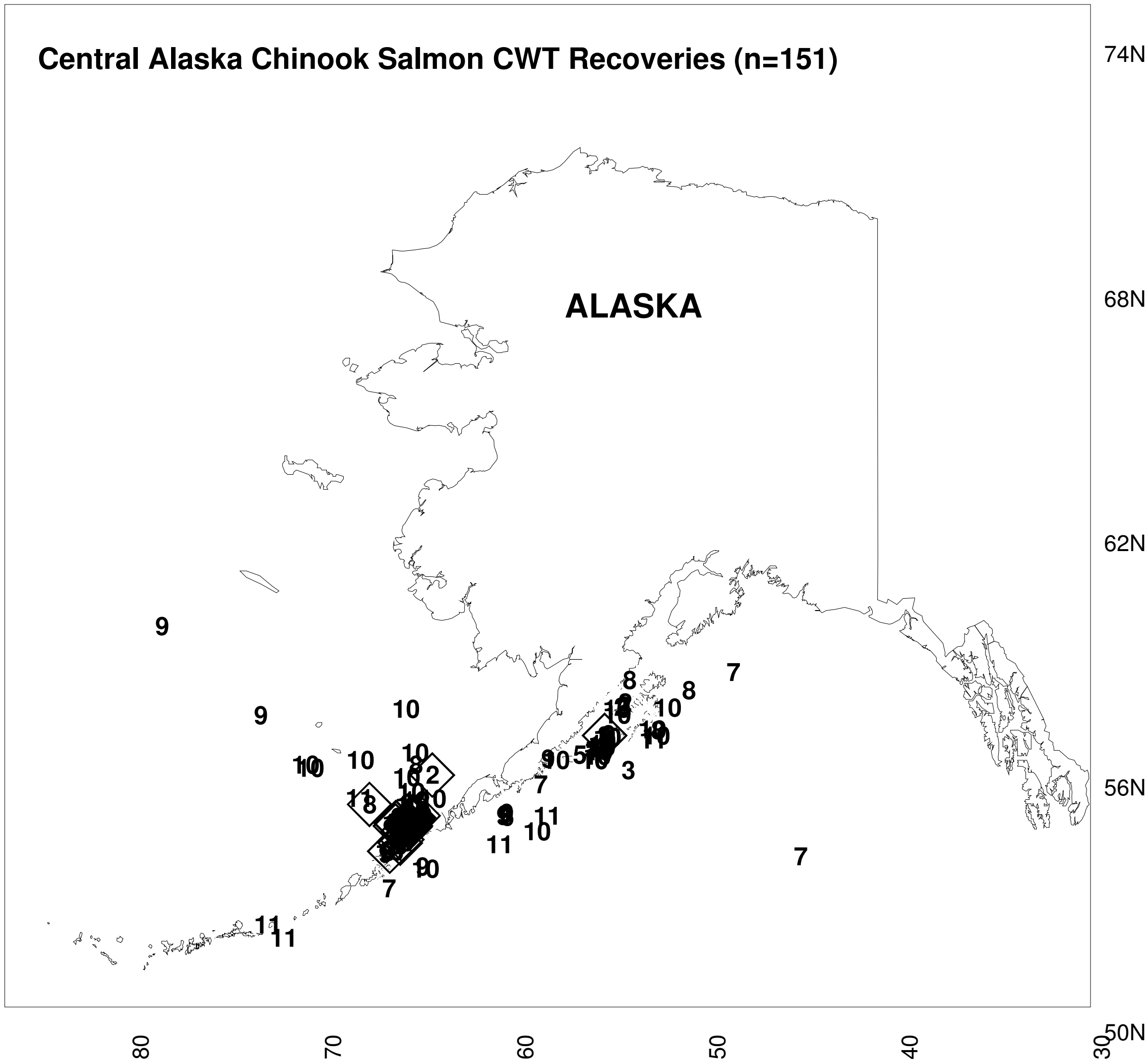

Fig. 10. Recovery locations of coded-wire tagged (CWT) central Alaska (Cook Inlet) chinook salmon caught by U.S. and foreign research vessels and by U.S. and joint-venture groundfish (trawl) fishery vessels in the eastern Bering Sea and Gulf of Alaska, 1981-2002 (adapted from Myers et al. 2001). The numbers at each location indicate the month of recovery. Twenty-one new recoveries reported by Myers et al. (2003) are indicated by open diamonds.

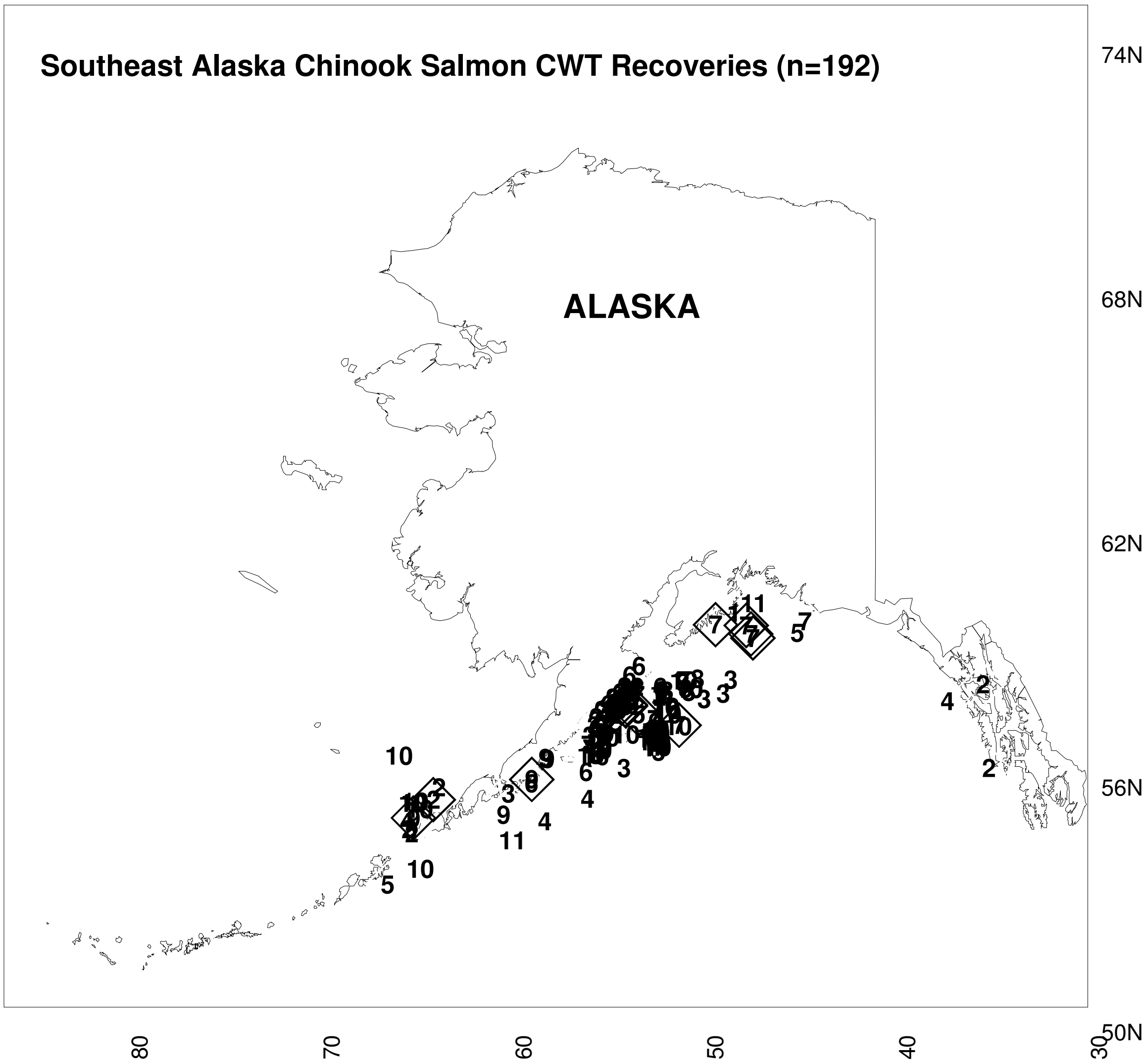

Fig. 11. Recovery locations of coded-wire tagged (CWT) southeast Alaska chinook salmon caught by U.S. research vessels and by U.S. and joint-venture groundfish (trawl) fishery vessels in the eastern Bering Sea and Gulf of Alaska, 1983-2003 (adapted from Myers et al. 2001). The numbers at each location indicate the month of recovery. Thirteen new recoveries reported by Myers et al. (2003) are indicated by open diamonds.

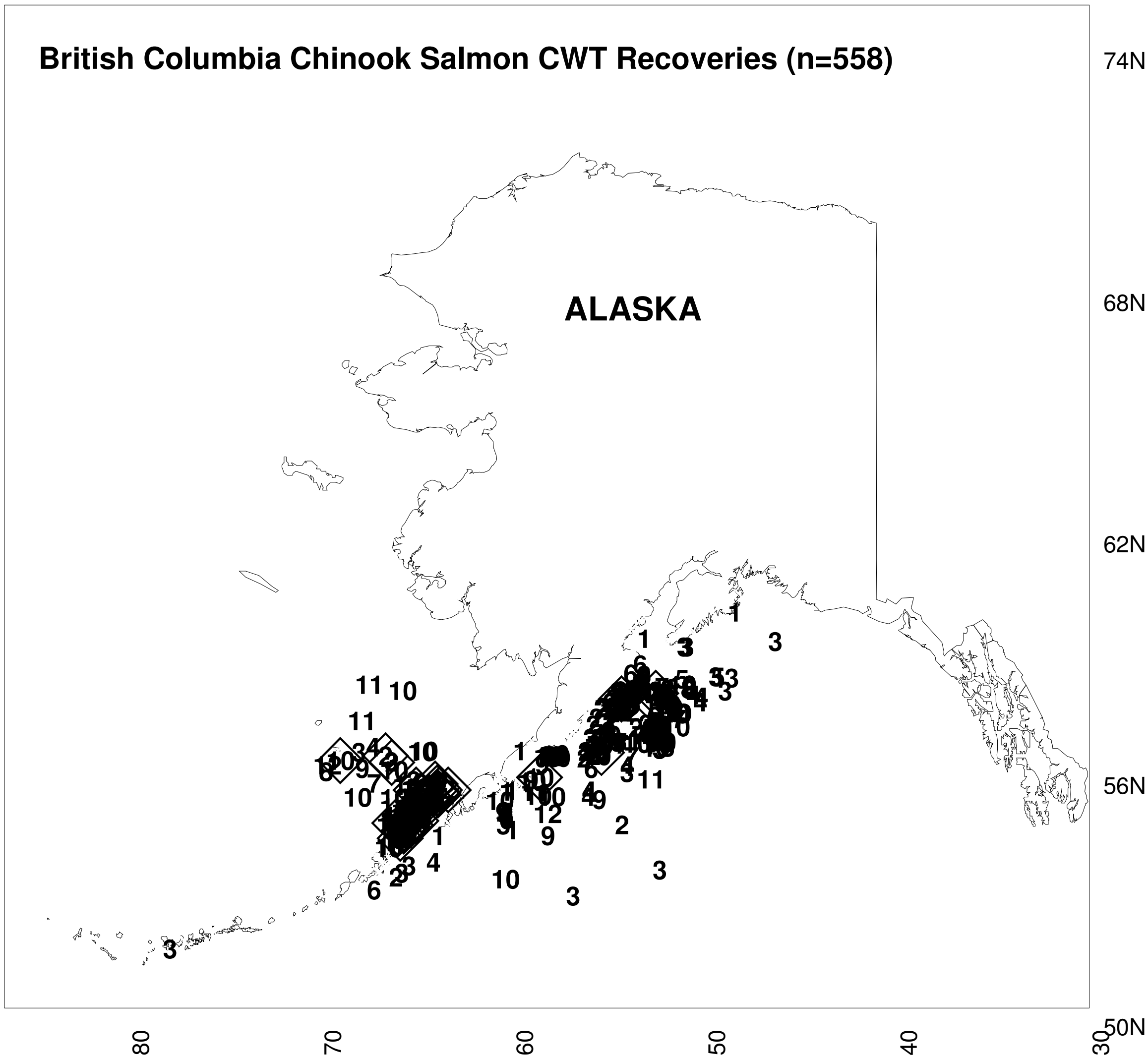

Fig. 12. Recovery locations of coded-wire tagged (CWT) British Columbia chinook salmon caught by U.S. and joint-venture groundfish (trawl) fishery vessels in the eastern Bering Sea and Gulf of Alaska (north of 50°N), 1982-2003 (adapted from Myers et al. 2001). The numbers at each location indicate the month of recovery. Twenty-three new recoveries reported by Myers et al. (2003) are indicated by open diamonds.

Table 1. Age composition (% of total sample size, n) of chinook salmon in incidental catches by U.S. commercial groundfish fisheries in the eastern Bering Sea in 1997, 1998, and 1999. Fishery area: East = east of 170°W longitude, West = west of 170°W longitude. Fishery season: winter = January-June, most samples from January (50.0%) and February (41.5%), n=2,432; fall = July-November, most samples from September (61.2%) and October (34.7%), n=2,255. Total n = total number of fish in the fishery observer samples with scales that could be assigned both freshwater and ocean ages.

Fishery	Fishery	Fishery	Age Group														
year	area	season	0.1	0.2	0.3	0.4	0.5	1.0	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	Total n
1997	East	Winter	0.0	0.1	1.5	0.9	0.1	0.0	0.1	9.6	35.0	48.7	3.8	0.1	0.1	0.0	822
		Fall	1.3	6.9	0.8	0.0	0.0	0.0	12.9	68.7	9.2	0.2	0.0	0.0	0.0	0.0	651
	East total		0.6	3.1	1.1	0.5	0.1	0.0	5.8	35.7	23.6	27.2	2.1	0.1	0.1	0.0	1,473
	West	Winter	0.0	0.0	0.0	2.0	0.0	0.0	0.0	19.2	53.8	23.1	1.9	0.0	0.0	0.0	52
		Fall	0.0	0.0	0.7	0.0	0.0	0.0	0.6	63.9	30.4	4.4	0.0	0.0	0.0	0.0	158
	West total		0.0	0.0	0.5	0.4	0.0	0.0	0.5	52.9	36.2	9.0	0.5	0.0	0.0	0.0	210
1997 Total			0.5	2.7	1.1	0.4	0.1	0.0	5.1	37.8	25.2	25.0	1.9	0.1	0.1	0.0	1,683
1998	East	Winter	0.0	0.3	1.6	0.8	0.1	0.0	1.0	9.5	61.1	19.8	5.0	0.1	0.6	0.1	885
		Fall	0.8	3.0	0.7	0.2	0.0	0.8	29.9	50.0	14.5	0.1	0.0	0.0	0.0	0.0	730
	East total		0.3	1.5	1.1	0.5	0.1	0.4	14.1	27.8	40.1	10.9	2.7	0.1	0.3	0.1	1,615
	West	Winter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.4	4.8	4.8	0.0	0.0	0.0	21
		Fall	0.0	0.0	0.7	0.0	0.0	0.0	0.0	16.7	81.2	1.4	0.0	0.0	0.0	0.0	138
	West total		0.0	0.0	0.6	0.0	0.0	0.0	0.0	14.5	82.4	1.9	0.6	0.0	0.0	0.0	159
1998 Total			0.3	1.4	1.1	0.4	0.1	0.3	12.8	26.6	43.9	10.1	2.5	0.1	0.3	0.1	1,774
1999	East	Winter	0.0	0.5	0.1	0.0	0.1	0.0	3.1	16.3	56.4	22.4	0.8	0.3	0.0	0.0	644
		Fall	0.0	2.0	0.2	0.2	0.0	0.0	9.2	67.5	20.0	0.9	0.0	0.0	0.0	0.0	456
	East total		0.0	1.0	0.2	0.1	0.1	0.0	5.6	37.5	41.3	13.5	0.5	0.2	0.0	0.0	1,100
	West	Winter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	50.0	25.0	0.0	0.0	0.0	0.0	8
		Fall	0.0	0.8	0.0	0.0	0.0	0.0	1.6	41.0	54.1	2.5	0.0	0.0	0.0	0.0	122
	West total		0.0	0.9	0.0	0.0	0.0	0.0	1.5	40.0	53.8	3.8	0.0	0.0	0.0	0.0	130
1999 Total			0.0	1.0	0.2	0.1	0.1	0.0	5.2	37.8	42.6	12.4	0.4	0.2	0.0	0.0	1,230
Grand Total			0.3	1.8	0.9	0.4	0.1	0.1	8.0	33.6	36.8	16.0	1.8	0.1	0.1	0.0	4,687

Table 2. Major brood year (BY) groups in the North Pacific Groundfish Observer Program scale samples from chinook salmon caught by U.S. groundfish fisheries in the eastern Bering Sea in 1997-1999. Bold font indicates brood year groups for which scale pattern baselines were established.

	Observer Program Sample Year		
Age group	1997	1998	1999
Age 1.0	**BY95**	BY96	BY97
Age 1.1	**BY94**	**BY95**	BY96
Age 1.2	**BY93**	**BY94**	**BY95**
Age 1.3	**BY92**	**BY93**	**BY94**
Age 1.4	**BY91**	**BY92**	**BY93**
Age 1.5	BY90	**BY91**	**BY92**

Table 3. Evaluation of the accuracies of the 4-group maximum likelihood estimate (MLE) models for brood year 1991-1995 chinook salmon, as indicated by computer simulations. Simulations are from 1000 iterations of randomly sampled scales in the model (with replacement), and include specified cases of equal representation of all groups or 100% representation by one group only. Numbers in parentheses are 95% confidence intervals (CI) derived from the 1000 simulations. Percentages represented by 0.0 are small numbers, less than 0.05 but greater than 0. N = number of scales in the simulated sample. Bold font indicates correct regional stock group for 100% simulations.

	Brood year and stock	Maximum likelihood estimates (MLE) of stock composition (%)								
Brood	composition of		Kamchatka		Western Alaska		Cook Inlet		SE Alaska/BC	
year	simulated mixture sample	N	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)
1991	Equal proportions (25%)	150	24.2	(19.1-30.1)	25.2	(20.4-30.1)	24.9	(18.2-31.1)	25.7	(20.3-31.4)
	100% Kamchatka	150	**96.2**	**(88.5-99.9)**	0.0	(0-0)	3.8	(0.0-11.5)	0.0	(0-0.0)
	100% Western Alaska	150	0.1	(0-0.7)	**99.8**	**(97.9-99.9)**	0.1	(0-1.4)	0.0	(0-0.8)
	100% Cook Inlet	150	0.0	(0-0.0)	0.5	(0-4.4)	**98.4**	**(92.0-99.9)**	1.1	(0-6.6)
	100% British Columbia	150	0.1	(0-1.6)	0.0	(0-0.0)	0.3	(0-3.8)	**99.6**	**(95.8-99.9)**
1992	Equal proportions (25%)	200	25.2	(16.8-33.3)	23.6	(16.1-32.5)	24.3	(15.0-34.7)	26.9	(18.9-35.3)
	100% Kamchatka	200	**95.8**	**(90.1-99.8)**	1.9	(0-5.3)	2.3	(0-7.3)	0	(0-0)
	100% Western Alaska	200	4.1	(0-11.2)	**95.5**	**(88.3-100)**	0.0	(0-0.0)	0.4	(0-2.7)
	100% Cook Inlet	200	0.8	(0-4.0)	1.6	(0-5.7)	**97.5**	**(92.5-100)**	0.1	(0-1.4)
	100% British Columbia	200	0	(0-0)	0.2	(0-1.2)	0	(0-0.0)	**99.8**	**(98.8-100)**
1993	Equal proportions (25%)	200	24.2	(16.3-32.1)	23.8	(14.3-34.3)	28.8	(16.8-41.1)	23.2	(15.3-31.5)
	100% Kamchatka	200	**94.9**	**(88.9-99.5)**	2.8	(0-7.8)	1.9	0-7.4)	0.4	(0-2.1)
	100% Western Alaska	200	0.9	(0-5.6)	**96.8**	**(88.5-99.9)**	2.1	(0-9.7)	0.2	(0-1.7)
	100% Cook Inlet	200	0.0	(0-0.0)	0.1	(0-1.1)	**99.8**	**(98.1-99.9)**	0.1	(0-1.0)
	100% SE Alaska	200	0.0	(0-0.3)	1.5	(0-5.4)	0.2	(0-2.4)	**98.3**	**(93.5-99.9)**

Table 3. Evaluation of the accuracies of the 4-group maximum likelihood estimate (MLE) models for brood year 1991-1995 chinook salmon, as indicated by computer simulations (continued).

Brood year	Brood year and stock composition of simulated mixture sample	N	Kamchatka MLE	Kamchatka (95% CI)	Western Alaska MLE	Western Alaska (95% CI)	Cook Inlet MLE	Cook Inlet (95% CI)	SE Alaska/BC MLE	SE Alaska/BC (95% CI)
1994	Equal proportions (25%)	200	24.4	(16.5-32.8)	24.0	(15.6-33.2)	29.0	(18.2-40.6)	22.6	(15.4-29.7)
	100% Kamchatka	200	**94.6**	**(87.9-100)**	0	(0-0.0)	4.9	(0.0-10.7)	0.5	(0-3.4)
	100% Western Alaska	200	0.0	(0-0.5)	**90.0**	**(81.0-98.5)**	10.0	(1.0-18.9)	0	(0-0)
	100% Cook Inlet	200	0.7	(0-4.7)	2.7	(0-9.9)	**96.1**	**(88.0-100)**	0.5	(0-2.7)
	100% SE Alaska	200	0.2	(0-2.0)	0.2	(0-1.6)	6.3	(0.3-12.9)	**93.3**	**(87.0-99.0)**
1995	Equal proportions (25%)	200	25.0	(16.4-34.6)	23.8	(14.3-33.8)	28.4	(17.2-40.4)	22.8	(14.8-31.4)
	100% Kamchatka	200	**96.5**	**(89.6-100.0)**	3.0	(0-9.7)	0.4	(0-4.0)	0.1	(0-0.9)
	100% Western Alaska	200	2.2	(0-9.4)	**97.0**	**(89.2-100.0)**	0.4	(0-4.2)	0.4	(0-2.5)
	100% Cook Inlet	200	0	(0-0)	1.2	(0-6.7)	**98.0**	**(91.4-100.0)**	0.8	(0-5.6)
	100% Southeast Alaska	200	0.5	(0-4.0)	0.6	(0-4.4)	3.3	(0-11.2)	**95.6**	**(88.1-100.0)**

Table 4. Evaluation of the accuracies of the 4-group stock identification models for brood year 1991-1995 chinook salmon, as indicated by maximum likelihood estimates (MLE) of the stock composition of test samples. Test samples are scales not included in the final 4-group models. Numbers in parentheses are 95% confidence intervals (CI) derived from 1000 bootstrap runs (random sampling with replacement). The results for the correct regional stocks are indicated in bold font. Percentages represented by 0.0 are small numbers, less than 0.05 but greater than 0. N = number of scales in test sample. The Copper River is located geographically between the Cook Inlet region and the Southeast Alaska-British Columbia region. Bold font indicates correct regional stock group.

			Maximum likelihood estimates (MLE) of stock composition (%)							
			Kamchatka		Western Alaska		Cook Inlet		SE Alaska/BC	
Brood year	Stock composition of test sample	N	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)
1991	Yukon (100%)	97	13.8	(4.0-27.0)	**86.2**	**(70.5-95.1)**	0	(0-3.1)	0.0	(0-7.2)
	Kuskokwim (100%)	103	0.0	(0-1.9)	**100**	**(97.2-100)**	0.0	(0-1.1)	0	(0-0)
	Bristol Bay (100%)	97	0	(0-0.0)	**99.4**	**(94.3-100)**	0.0	(0-2.5)	0.6	(0-5.4)
	Cook Inlet (100%)	49	0	(0-4.9)	6.3	(0-17.4)	**85.0**	**(61.5-98.1)**	8.7	(0-29.4)
	Copper River (100%)	84	0	(0-0)	33.4	(14.2-53.0)	9.4	(0.0-27.8)	57.2	(32.6-77.1)
1992	Kamchatka (100%)	26	**95.6**	**(73.7-100)**	4.0	(0-13.3)	0.4	(0-20.2)	0	(0-0)
	Yukon (100%)	65	18.0	(3.9-33.8)	**75.6**	**(59.1-89.8)**	6.4	(0-16.2)	0	(0-1.8)
	Kuskokwim (100%)	126	0	(0-4.6)	**100**	**(91.1-100)**	0	(0-7.6)	0	(0-0.0)
	Bristol Bay (100%)	117	0	(0-0)	**97.8**	**(93.2-100)**	0.2	(0-3.8)	2.0	(0-5.8)
	Cook Inlet (100%)	19	0	(0-0)	4.1	(0-33.4)	**95.9**	**(66.4-100)**	0	(0-0)
	Copper River (100%)	60	0	(0-0)	0	(0-7.0)	39.2	(10.9-70.5)	60.8	(29.5-87.3)
	SE Alaska (100%)	137	7.3	(0-17.3)	0.4	(0-4.2)	2.6	(0-18.5)	**89.7**	**(71.9-97.5)**
1993	Yukon (100%)	129	7.0	(0.0-18.9)	**93.0**	**(80.5-100)**	0	(0-0)	0	(0-0)
	Kuskokwim (100%)	126	0.1	(0-5.7)	**99.9**	**(87.9-100)**	0	(0-9.8)	0	(0-0)
	Bristol Bay (100%)	124	0	(0-0)	**100**	**(93.4-100)**	0	(0-3.4)	0	(0-0)
	Copper River (100%)	49	0	(0-0)	0	(0-0)	100	(78.0-100)	0	(0-0)
	British Columbia (100%)	135	0	(0-0)	0	(0-0)	3.1	(0-18.2)	**96.9**	**(82.0-100)**

Table 4. Evaluation of the accuracies of the 4-group stock identification models for brood year 1991-1995 chinook salmon, as indicated by maximum likelihood estimates (MLE) of the stock composition of test samples (continued).

			Maximum likelihood estimates (MLE) of stock composition (%)							
Brood	Stock composition of		Kamchatka		Western Alaska		Cook Inlet		SE Alaska/BC	
year	test sample	N	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)
1994	Yukon (100%)	128	3.7	(0-9.2)	**80.0**	**(64.0-91.8)**	16.3	(3.4-33.1)	0	(0-0)
	Kuskokwim (100%)	123	0	(0-0)	**89.8**	**(73.6-100)**	10.2	(0.0-26.4)	0	(0-0)
	Bristol Bay (100%)	128	0	(0-0)	**100**	**(100-100)**	0	(0-0.0)	0	(0-0)
	Copper River (100%)	49	0	(0-1.3)	0	(0-31.7)	100	(64.4-100)	0	(0-9.6)
	British Columbia (100%)	78	0	(0-0)	0	(0-0)	33.0	(6.5-67)	**67.0**	**(33-93.5)**
1995	Yukon (100%)	125	18.4	(0.0-42.0)	**73.7**	**(42.4-96.8)**	7.9	(0.0-25.7)	0	(0-0)
	Kuskokwim (100%)	131	0	(0-0)	**100**	**(97.9-100)**	0	(0-0.2)	0	(0-1.9)
	Nushagak (100%)	127	0	(0-0)	**98.0**	**(85.4-100)**	0.4	(0-11.2)	1.6	(0-9.5)
	Togiak (100%)	75	0	(0-0)	**95.6**	**(84.0-100)**	0	(0-0.0)	4.4	(0-16.1)
	Copper River (100%)	61	0	(0-0)	0	(0-0)	35.1	(11.2-66.6)	64.9	(33.4-88.8)
	British Columbia (100%)	58	0	(0-0)	0	(0-4.9)	31.4	(3.9-62.8)	**68.6**	**(37.2-95.3)**

Table 5. Maximum likelihood estimates (MLE) of the regional stock composition of chinook salmon in incidental catches by U.S. commercial groundfish fisheries in the eastern Bering Sea 1997-1999. The estimates are summarized by (a) brood year (BY) 1991-1995, (b) fishery year and age group, and (c) for the fishery area east of 170°W by fishery season, year, and age group. Fishery season: fall = July-December, winter = January-June. Numbers in parentheses are 95% confidence intervals (CI) derived from 1000 bootstrap runs (random sampling with replacement). An estimate of zero without a confidence interval indicates that the stock was not present. Percentages represented by 0.0 are small numbers, less than 0.05 but greater than zero.

			Kamchatka		Western Alaska		Cook Inlet		SE Alaska-British Columbia	
Sample Description	Age(s)	N	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)
(a) Summary by brood year:										
BY91, 1997-1998	1.4-1.5	373	9.5	(4.2-16.6)	59.5	(48.4-68.4)	31.0	(19.5-41.6)	0.0	(0-4.1)
BY92, 1997-1999	1.3-1.5	530	6.5	(3.3-10.9)	55.8	(47.6-63.0)	32.2	(23.5-40.5)	5.5	(2.4-9.2)
BY93, 1997-1999	1.2-1.4	1111	7.4	(3.5-12.3)	53.6	(44.9-62.2)	30.1	(21.9-39.0)	8.9	(5.9-11.8)
BY94, 1997-1999	1.1-1.3	762	0		65.3	(56.3-73.3)	25.7	(16.6-35.5)	9.0	(5.8-13.4)
BY95, 1998-1999	1.1-1.2	481	3.1	(0.0-8.6)	43.6	(33.6-52.1)	36.4	(24.3-48.5)	16.9	(9.6-24.5)
(b) Summary by fishery year and age group:										
1997	1.2	426	2.6	(0-7.0)	51.7	(42.6-60.4)	37.9	(28.1-47.0)	7.8	(3.8-13.1)
	1.3	345	3.8	(0.7-7.6)	56.8	(47.8-64.8)	31.2	(21.5-41.3)	8.2	(4.4-13.1)
	1.4	342	7.6	(2.6-14.6)	60.4	(50.2-70.3)	32.0	(19.5-42.4)	0.0	(0-5.2)
1998	1.1	141	0		14.6	(5.0-24.9)	52.5	(34.3-70.9)	32.9	(18.1-47.5)
	1.2	316	0		55.5	(44.8-66.3)	34.4	(21.4-46.9)	10.1	(4.3-18.0)
	1.3	559	8.9	(4.3-15.0)	59.0	(49-68.4)	20.8	(11.2-31.6)	11.3	(7.4-15.0)
	1.4	181	13.5	(6.3-22.4)	53.7	(41.2-64.9)	32.7	(19.7-43.5)	0.1	(0-4.3)
1999	1.2	340	5.4	(0.5-12.6)	57.6	(44.5-68.3)	25.7	(13.0-40.4)	11.3	(5.1-18.2)
	1.3	381	0		75.4	(65.8-82.8)	17.2	(9.4-26.7)	7.4	(4.2-11.1)
	1.4	126	27.8	(14.1-42.4)	31.4	(12.5-52.6)	37.3	(17.4-55.5)	3.5	(0-9.6)

Table 5. Maximum likelihood estimates (MLE) of the regional stock composition of chinook salmon in incidental catches by U.S. commercial groundfish fisheries in the eastern Bering Sea 1997-1999 (continued).

			Kamchatka		Western Alaska		Cook Inlet		SE Alaska-British Columbia	
Sample Description	Age(s)	N	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)
(c) Summary for the fishery area east of 170°W by fishery season, year, and age group:										
Fall 1998	1.1	134	0		11.2	(1.5-21.5)	53.1	(34.1-71.7)	35.7	(20.3-52.0)
Fall 1997	1.2	286	3.9	(0.0-9.2)	33.1	(23.7-43.5)	53.1	(40.4-63.9)	9.9	(4.9-16.3)
Fall 1998	1.2	249	0		54.3	(42.6-65.8)	35.6	(21.1-49.6)	10.1	(3.8-17.5)
Fall 1999	1.2	222	3.4	(0.0-10.5)	62.9	(47.0-74.9)	28.2	(14.8-42.2)	5.5	(0.6-11.7)
Winter 1997	1.3	240	6.0	(1.7-10.9)	59.5	(49.1-68.7)	26.8	(16.8-38.2)	7.7	(3.0-13.1)
Winter 1998	1.3	428	8.0	(3.0-14.2)	58.7	(45.9-68.9)	20.7	(11.3-33.1)	12.6	(8.2-17.1)
Winter 1999	1.3	279	0		72.8	(63.2-81.2)	17.5	(8.9-27.0)	9.7	(5.6-14.5)
Winter 1997	1.4	327	8.3	(2.7-15.5)	59.4	(49.0-68.6)	32.3	(19.5-43.4)	0.0	(0-5.6)
Winter 1998	1.4	178	12.7	(4.9-21.9)	54.3	(41.4-66.0)	32.9	(19.0-44.9)	0.1	(0-4.5)
Winter 1999	1.4	122	27.9	(13.5-43.5)	32.0	(15.5-53.6)	36.3	(14.9-55.6)	3.8	(0-10.5)

Table 6. Maximum likelihood estimates (MLE) of the western Alaska subregional (Yukon, Kuskokwim, and Bristol Bay) stock composition of chinook salmon in incidental catches by U.S. commercial groundfish fisheries in the eastern Bering Sea portion of the U.S. exclusive economic zone in 1997-1999. The estimates are summarized by (a) brood year (BY) 1991-1995 and (b) for the fishery area east of 170°W by fishery season, year, and age group. Fishery season: fall = July-December, winter = January-June. Numbers in parentheses are 95% confidence intervals (CI) derived from 1000 bootstrap runs (random sampling with replacement). An estimate of zero without a confidence interval indicates that the stock was not present and the data were re-analyzed without those baseline groups. Percentages represented by 0.0 are small numbers, less than 0.05 but greater than zero. Dashes indicate that no baseline data were available for that regional stock group. Bold font emphasizes results for western Alaska subregional stocks.

Sample			Kamchatka		**Yukon**		**Kuskokwim**		**Bristol Bay**		Cook Inlet		SE Alaska		British Columbia	
description	Age(s)	N	MLE	(95% CI)	**MLE**	**(95% CI)**	**MLE**	**(95% CI)**	**MLE**	**(95% CI)**	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)
(a) Summary by brood year:																
BY91	1.4-1.5	373	4.1	(0.0-10.0)	**37.2**	**(17.2-56.1)**	**27.0**	**(4.4-47.4)**	**4.2**	**(0.0-12.1)**	27.5	(18.3-37.5)	-	-	0	
BY92	1.3-1.5	530	6.0	(2.5-9.6)	**29.7**	**(16.6-39.9)**	**5.5**	**(0.0-22.1)**	**21.0**	**(12.4-29.2)**	33.4	(24.6-41.3)	-	-	4.4	(1.5-8.2)
BY93	1.2-1.4	1111	5.9	(3.0-9.5)	**12.7**	**(4.0-23.2)**	**24.5**	**(11.4-37.3)**	**17.9**	**(11.1-25.3)**	28.5	(21.8-34.1)	8.5	(5.7-11.2)	2.0	(0.0-4.1)
BY94	1.1-1.3	762	0		**20.2**	**(12.3-30.4)**	**0**		**41.7**	**(33.9-49.7)**	30.0	(20.5-37.5)	8.1	(5.1-11.8)	-	-
BY95	1.1-1.2	481	4.4	(0.1-10.2)	**12.2**	**(4.2-20.7)**	**15.8**	**(6.7-24.1)**	**10.6**	**(0.0-28.1)**	41.9	(28.4-52.4)	15.1	(9.2-22.0)	-	-
(b) Summary for the fishery area east of 170°W by fishery season, year, and age group:																
Fall 1998	1.1	134	0		**6.1**	**(0-15.0)**	**3.9**	**(0-9.4)**	**0**		57.7	(37.1-74.8)	32.3	(16.5-47.9)	-	-
Fall 1997	1.2	286	3.8	(0.0-8.7)	**0.0**	**(0-13)**	**16.1**	**(1.7-25.4)**	**17.6**	**(9.5-28.5)**	49.2	(37.1-58.5)	8.5	(3.7-14.5)	4.8	(0.2-10.5)
Fall 1998	1.2	249	0		**10.2**	**(2.5-21.4)**	**0**		**41.4**	**(29.8-51.6)**	38.7	(25.5-50.2)	9.7	(4.7-16.2)	-	-
Fall 1999	1.2	222	5.8	(0.0-12.9)	**13.0**	**(2.0-25.3)**	**18.3**	**(5.6-33.3)**	**27.2**	**(4.5-50.2)**	31.3	(16.3-44.7)	4.4	(0.0-9.8)	-	-
Winter 1997	1.3	240	5.7	(1.5-10.4)	**24.6**	**(10.2-38.3)**	**5.9**	**(0.0-27.6)**	**28.0**	**(14.5-39.5)**	30.0	(18.2-40.8)	-	-	5.8	(1.3-11.3)
Winter 1998	1.3	428	4.6	(0.8-9.7)	**23.1**	**(11.2-36.9)**	**22.8**	**(6.7-38.8)**	**17.3**	**(8.8-27.3)**	18.2	(9.9-26.4)	11.9	(7.5-16.3)	2.1	(0-6.3)
Winter 1999	1.3	279	0		**34.7**	**(23.0-47.4)**	**0**		**37.6**	**(27.4-47.8)**	18.5	(8.9-28.3)	9.2	(5.3-13.5)	-	-
Winter 1997	1.4	327	3.9	(0.0-9.7)	**34.6**	**(14.8-53.7)**	**28.4**	**(6.8-48.9)**	**4.7**	**(0.0-13.4)**	28.4	20.3-34.6)	-	-	0	
Winter 1998	1.4	178	10.9	(3.8-18.6)	**35.0**	**(17.4-49.9)**	**12.8**	**(0.0-34.9)**	**10.1**	**(0.0-21.0)**	31.2	(19.3-41.9)	-	-	0	
Winter 1999	1.4	122	22.0	(9.1-36.4)	**9.9**	**(0.0-31.2)**	**32.2**	**(8.6-50)**	**2.9**	**(0-13.5)**	28.2	(11.2-44.4)	4.8	(0-10.4)	0	

Table 7. Estimates of the bycatch of chinook salmon (No., number of fish) by U.S. open access and community development quota (CDQ) groundfish fisheries in the eastern Bering Sea in 1997-1999 stratified by fishery year, area, and season. Fishery season: winter = January through June, highest bycatches in January and February; fall = July through December, highest bycatches in September and October. The 1997-1999 salmon bycatch estimates were provided by, NMFS, Sustainable Fisheries Division, Alaska Groundfish Fisheries Management, Juneau, Alaska. No CDQ bycatch estimates were available for 1997. NMFS does not estimate the variance of their salmon bycatch estimates.

Fishery		Fishery	Open access bycatch		CDQ bycatch		Total bycatch
year	Fishery area	season	No.	% of total	No.	% of total	No. of fish
1997	East of 170°W	Winter	13,940	27.6			13,940
		Fall	27,616	54.7			27,616
	West of 170°W	Winter	2,592	5.1			2,592
		Fall	6,382	12.6			6,382
1997 Total			50,530				50,530
1998	East of 170°W	Winter	16,903	30.5	848	16.5	17,751
		Fall	35,482	64.0	4,148	80.9	39,630
	West of 170°W	Winter	2,030	3.7	90	1.8	2,120
		Fall	1,017	1.8	39	0.8	1,056
1998 Total			55,432		5,125		60,557
1999	East of 170°W	Winter	7,324	56.6	560	34.5	7,884
		Fall	3,589	27.7	771	47.5	4,360
	West of 170°W	Winter	880	6.8	5	0.3	885
		Fall	1,143	8.8	286	17.6	1,429
1999 Total			12,936		1,622		14,558

Table 8. Estimates of the bycatch (number of fish, No., bold font) of six ocean age groups of freshwater age-1. chinook salmon by U.S. commercial groundfish fisheries in the eastern Bering Sea in 1997-1999 stratified by fishery year, area, and season. The age compositon estimates (%) for the six groups (Table 1) were adjusted to equal 100% (excluding freshwater age-0. and age-2. groups, which averaged less than 4% of the bycatch). The time- and area-stratified salmon bycatch estimates (Table 7) were multiplied by these percentages to estimate the age-stratified bycatch. Dashes indicate that there were no fish of that age group in the stratified scale samples (Table 1).

Fishery year	Fishery area	Fishery season	Age-1.0 %	Age-1.0 No.	Age-1.1 %	Age-1.1 No.	Age-1.2 %	Age-1.2 No.	Age-1.3 %	Age-1.3 No.	Age-1.4 %	Age-1.4 No.	Age-1.5 %	Age-1.5 No.	Total No.
1997	East of 170°W	Winter		–	0.1	**14**	9.9	**1,380**	36.0	**5,018**	50.1	**6,984**	3.9	**544**	**13,940**
		Fall		–	14.2	**3,922**	75.5	**20,850**	10.1	**2,789**	0.2	**55**		–	**27,616**
	West of 170°W	Winter		–		**–**	19.6	**508**	54.9	**1,423**	23.6	**612**	1.9	**49**	**2,592**
		Fall		–	0.6	**38**	64.4	**4,110**	30.6	**1,953**	4.4	**281**		–	**6,382**
1997 Total						**3,974**		**26,848**		**11,183**		**7,932**		**593**	**50,530**
1998	East of 170°W	Winter		–	1.0	**178**	9.9	**1,757**	63.4	**11,254**	20.5	**3,639**	5.2	**923**	**17,751**
		Fall	0.8	**317**	31.4	**12,444**	52.5	**20,805**	15.2	**6,024**	0.1	**40**		–	**39,630**
	West of 170°W	Winter		–		**–**		**–**	90.4	**1,916**	4.8	**102**	4.8	**102**	**2,120**
		Fall		–		**–**	16.8	**177**	81.8	**864**	1.4	**15**		–	**1,056**
1998 Total				**317**		**12,622**		**22,739**		**20,058**		**3,796**		**1,025**	**60,557**
1999	East of 170°W	Winter		–	3.1	**244**	16.5	**1,301**	57.0	**4,494**	22.6	**1,782**	0.8	**63**	**7,884**
		Fall		–	9.4	**410**	69.2	**3,017**	20.5	**894**	0.9	**39**		–	**4,360**
	West of 170°W	Winter		–	0.0	**0**	25.0	**221**	50.0	**443**	25.0	**221**		–	**885**
		Fall		–	1.6	**23**	41.3	**590**	54.6	**780**	2.5	**36**		–	**1,429**
1999 Total						**677**		**5,129**		**6,611**		**2,078**		**63**	**14,558**

Table 9. The estimated interceptions (number of fish, No.) of western Alaska chinook salmon by U.S. groundfish fisheries in the eastern Bering Sea in 1997-1999 stratified by fishery year, area, season, and age group. Fishery Season: winter = January through June, highest bycatches in January and February; fall = July through December, highest bycatches in September and October. The stock proportion estimates (Prop.) in bold font are fishery area- and season-specific maximum likelihood estimates from Table 5(c). The time- and area-stratified estimates of bycatch of chinook salmon (Table 8) were multiplied by these proportions to estimate the bycatch of western Alaska fish. If area- and season-specific stock proportion estimates were not available, year- and age group-specific estimates from Table 5(b) were used; age-1.0 fish caught in 1998 and age-1.5 fish in all years were assumed to be 100% western Alaska fish. Age-1.1 fish in 1997 were assumed to be present in the same proportion as age 1.2 fish in 1998. Age-1.1 fish in 1999 were not allocated because stock composition estimates for brood year 1996 fish were not available (N/A). Dashes indicate that there were no fish of that age group in the stratified scale samples (Table 1).

Fishery		Fishery	Age-1.0		Age-1.1		Age-1.2		Age-1.3		Age-1.4		Age-1.5		Total
year	Fishery area	season	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	No.
1997	East of 170°W	Winter	–	–	0.555	8	0.517	713	**0.595**	2,986	**0.594**	4,148	1.000	544	8,399
		Fall	–	–	0.555	2,177	**0.331**	6,902	0.568	1,584	0.604	33	–	–	10,696
	West of 170°W	Winter	–	–	–	–	0.517	263	0.568	808	0.604	370	1.000	49	1,490
		Fall	–	–	0.555	21	0.517	2,125	0.568	1,109	0.604	170	–	–	3,425
1997 Total						2,206		10,003		6,487		4,721		593	24,010
1998	East of 170°W	Winter	–	–	0.146	26	0.555	975	**0.587**	6,607	**0.543**	1,976	1.000	923	10,507
		Fall	1.000	317	**0.112**	1,394	**0.543**	11,297	0.590	3,554	0.537	21	–	–	16,583
	West of 170°W	Winter	–	–	–	–	–	–	0.590	1,130	0.537	55	1.000	102	1,287
		Fall	–	–	–	–	0.555	98	0.590	510	0.537	8	–	–	616
1998 Total				317		1,420		12,370		11,801		2,060		1,025	28,993
1999	East of 170°W	Winter	–	–	N/A	N/A	0.576	749	**0.728**	3,272	**0.320**	570	1.000	63	4,654
		Fall	–	–	N/A	N/A	**0.629**	1,898	0.754	674	0.314	12	–	–	2,584
	West of 170°W	Winter	–	–	N/A	N/A	0.576	127	0.754	334	0.314	69	–	–	530
		Fall	–	–	N/A	N/A	0.576	340	0.754	588	0.314	11	–	–	939
1999 Total								3,114		4,868		662		63	8,707

Table 10. The estimated interceptions (number of fish, No.) of Yukon, Kuskokwim, and Bristol Bay chinook salmon by U.S. groundfish fisheries in the eastern Bering Sea in 1997-1999 stratified by fishery year, area, season, and age group. Fishery area: East = east of 170°W, West = west of 170°W. Fishery Season: winter = January through June, highest bycatches in January and February; fall = July through December, highest bycatches in September and October. The proportions (Prop.) in bold font are fishery area- and season-specific maximum likelihood estimates from Table 6(b) adjusted for the three western Alaska sub-regional stocks to equal 1.0. The time-, area-, and age-stratified estimates of bycatch of western Alaska chinook salmon (Table 9) were multiplied by these proportions to estimate the bycatch of the sub-regional stocks. If area- and season-specific stock proportion estimates were not available, brood year-specific estimates from Table 6(a) were used. Age-1.0 fish caught in 1998 and age-1.5 fish in all years were assumed to be 100% western Alaska fish (age-1.0: 33.3% Yukon, 33.3% Kuskokwim, 33.3% Bristol Bay; age-1.5: 50% Yukon, 50% Kuskokwim). Age-1.1 fish in 1999 were not allocated because stock proportion estimates for brood year 1996 fish were not available (N/A). Dashes indicate that there were no fish of that age group in the stratified scale samples (Table 1).

Stock	Fishery year	Fishery area	Fishery season	Age-1.0 Prop.	Age-1.0 No.	Age-1.1 Prop.	Age-1.1 No.	Age-1.2 Prop.	Age-1.2 No.	Age-1.3 Prop.	Age-1.3 No.	Age-1.4 Prop.	Age-1.4 No.	Age-1.5 Prop.	Age-1.5 No.	Total No.
Yukon	1997	East	Winter	–		0.326	3	0.230	164	**0.421**	1,258	**0.511**	2,120	0.500	272	3,816
			Fall	–		0.326	710	**0.000**	0	0.528	836	0.544	18	–		1,564
		West	Winter	–		–	–	0.230	60	0.528	427	0.544	201	0.500	25	713
			Fall	–		0.326	7	0.230	489	0.528	585	0.544	92	–		1,173
	1997 Total						719		713		3,106		2,431		297	7,266
	1998	East	Winter	–		0.316	8	0.326	318	**0.365**	2,412	**0.604**	1,194	0.500	462	4,394
			Fall	0.333	106	**0.610**	850	**0.198**	2,237	0.230	817	0.528	11	–		4,021
		West	Winter	–		–	–	–	–	0.230	260	0.528	29	0.500	51	340
			Fall	–		–	–	0.326	32	0.230	117	0.528	4	–		153
	1998 Total				106		858		2,587		3,606		1,238		513	8,908
	1999	East	Winter	–		N/A	N/A	0.316	237	**0.480**	1,570	**0.220**	125	0.500	32	1,964
			Fall	–		N/A	N/A	**0.222**	421	0.326	220	0.230	3	–		644
		West	Winter	–		N/A	N/A	0.316	40	0.326	109	0.230	16	–		165
			Fall	–		N/A	N/A	0.316	107	0.326	192	0.230	2	–		301
	1999 Total								805		2,091		146		32	3,074

Table 10. The estimated interceptions (number of fish, No.) of Yukon, Kuskokwim, and Bristol Bay chinook salmon by U.S. groundfish fisheries in the eastern Bering Sea in 1997-1999 by fishery year, area, and season (continued).

Stock	Fishery year	Fishery area	Fishery season	Age-1.0 Prop.	Age-1.0 No.	Age-1.1 Prop.	Age-1.1 No.	Age-1.2 Prop.	Age-1.2 No.	Age-1.3 Prop.	Age-1.3 No.	Age-1.4 Prop.	Age-1.4 No.	Age-1.5 Prop.	Age-1.5 No.	Total No.
Kusko-Kwim	1997	East	Winter	–		0	0	0.445	317	**0.101**	302	**0.419**	1,738	0.500	272	2,629
			Fall	–		0	0	**0.478**	3,299	0.098	155	0.395	13	–		3,467
		West	Winter	–		–	–	0.445	117	0.098	79	0.395	146	0.500	25	367
			Fall	–		0	0	0.445	946	0.098	109	0.395	67	–		1,122
	1997 Total						0		4,679		645		1,964		297	7,585
	1998	East	Winter	–		0.409	10	0	0	**0.361**	2,385	**0.221**	437	0.500	462	3,294
			Fall	0.333	106	**0.390**	544	**0.000**	0	0.445	1,582	0.098	2	–		2,233
		West	Winter	–		–	0	–	–	0.445	503	0.098	5	0.500	51	559
			Fall	–		–	0	0	0	0.445	227	0.098	1	–		228
	1998 Total				106		554		0		4,697		445		513	6,314
	1999	East	Winter	–		N/A	N/A	0.409	306	**0.000**	0	**0.716**	408	0.500	31	745
			Fall	–		N/A	N/A	**0.313**	594	0	0	0.445	5	–		599
		West	Winter	–		N/A	N/A	0.409	52	0	0	0.445	31	–		83
			Fall	–		N/A	N/A	0.409	139	0	0	0.445	5	–		144
	1999 Total								1,091		0		449		31	1,571

Table 10. The estimated interceptions (number of fish, No.) of Yukon, Kuskokwim, and Bristol Bay chinook salmon by U.S. groundfish fisheries in the eastern Bering Sea in 1997-1999 by fishery year, area, and season (continued).

	Fishery	Fishery	Fishery	Age-1.0		Age-1.1		Age-1.2		Age-1.3		Age-1.4		Age-1.5		Total
Stock	year	area	season	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	No.
Bristol	1997	East	Winter	–		0.674	5	0.325	232	**0.479**	1,430	**0.069**	286	0.000	0	1,954
Bay			Fall	–		0.674	1,467	**0.522**	3,603	0.374	592	0.061	2	–		5,665
		West	Winter	–		–	0	0.325	85	0.374	302	0.061	23	0.000	0	410
			Fall	–		0.674	14	0.325	691	0.374	415	0.061	10	–		1,130
	1997 Total						1,487		4,611		2,740		321		0	9,159
	1998	East	Winter	–		0.275	7	0.674	657	**0.274**	1,811	**0.174**	344	0	0	2,819
			Fall	0.333	106	**0.000**	0	**0.802**	9,060	0.325	1,155	0.374	8	–		10,329
		West	Winter	–		–	–	–	0	0.325	367	0.374	21	0	0	388
			Fall	–		–	–	0.674	66	0.325	166	0.374	3	–		235
	1998 Total				106		7		9,783		3,499		376		0	13,771
	1999	East	Winter	–		N/A	N/A	0.275	206	**0.520**	1,701	**0.064**	38	0.000	0	1,945
			Fall	–		N/A	N/A	**0.465**	883	0.674	454	0.325	4	–		1,341
		West	Winter	–		N/A	N/A	0.275	35	0.674	225	0.325	22	–		282
			Fall	–		N/A	N/A	0.275	94	0.674	396	0.325	4	–		494
	1999 Total								1,218		2,776		68		0	4,062

Table 11. Adult equivalent (AEQ) bycatch (number of fish, No.) of Yukon, Kuskokwim, and Bristol Bay chinook salmon by U.S. groundfish fisheries in the eastern Bering Sea in 1997-1999 based on estimated bycatch (B) in Table 10. General assumptions and rough approximations for the proportion (prop.) of adult salmon returning at age 1.3 and age 1.4 (R) and ocean survival (S) were similar to Witherell et al. (2002) (see Methods). AEQ bycatch = B×R×S. Estimates of bycatch of age 1.1 Yukon, Kuskokwim, and Bristol Bay chinook salmon in 1999 were not available (N/A).

				Return at age 1.3			Return at age 1.4 or 1.5			Total
Alaska subregion	Bycatch year	Bycatch age	Estimated bycatch No. (B)	Prop. of return at age 1.3 (R)	Ocean survival prop. (S)	AEQ bycatch No.	Prop. of return at age 1.4 (R)	Ocean survival prop. (S)	AEQ bycatch No.	AEQ bycatch No.
Yukon	1997	1.0	0	0.30	0.336	0	0.70	0.302	0	0
		1.1	719	0.30	0.560	121	0.70	0.504	254	375
		1.2	713	0.30	0.800	171	0.70	0.720	359	530
		1.3	3,106	0.30	1.000	932	0.70	0.900	1,957	2,889
		1.4	2,431				1.00	1.000	2,431	2,431
		1.5	297					1.000	297	297
	Subtotal		7,266							6,522
Kuskokwim	1997	1.0	0	0.30	0.336	0	0.70	0.302	0	0
		1.1	0	0.30	0.560	0	0.70	0.504	0	0
		1.2	4,679	0.30	0.800	1,123	0.70	0.720	2,358	3,481
		1.3	645	0.30	1.000	194	0.70	0.900	406	600
		1.4	1,964				1.00	1.000	1,964	1,964
		1.5	297					1.000	297	297
	Subtotal		7,585							6,342
Bristol Bay	1997	1.0	0	0.43	0.336	0	0.57	0.302	0	0
		1.1	1,487	0.43	0.560	358	0.57	0.504	427	785
		1.2	4,611	0.43	0.800	1,586	0.57	0.720	1,892	3,478
		1.3	2,740	0.43	1.000	1,178	0.57	0.900	1,406	2,584
		1.4	321				1.00	1.000	321	321
		1.5	0					1.000	0	0
	Subtotal		9,159							7,168
Total Western Alaska-1997			24,010							20,032

Table 11. Adult equivalent (AEQ) bycatch (number of fish, No.) of Yukon, Kuskokwim, and Bristol Bay chinook salmon by U.S. groundfish fisheries in the eastern Bering Sea in 1997-1999 based on estimated bycatch (B) in Table 10 (continued).

				Return at age 1.3			Return at age 1.4 or 1.5			Total
Alaska subregion	Bycatch year	Bycatch age	Estimated bycatch No. (B)	Prop. of return at age 1.3 (R)	Ocean survival prop. (S)	AEQ bycatch No.	Prop. of return at age 1.4 (R)	Ocean survival prop. (S)	AEQ bycatch No.	AEQ bycatch No.
Yukon	1998	1.0	106	0.30	0.336	11	0.70	0.302	22	33
		1.1	858	0.30	0.560	144	0.70	0.504	303	447
		1.2	2,587	0.30	0.800	621	0.70	0.720	1,304	1,925
		1.3	3,606	0.30	1.000	1,082	0.70	0.900	2,272	3,354
		1.4	1,238				1.00	1.000	1,238	1,238
		1.5	513					1.000	513	513
	Subtotal		8,908							7,510
Kuskokwim	1998	1.0	106	0.30	0.336	11	0.70	0.302	22	33
		1.1	554	0.30	0.560	93	0.70	0.504	195	288
		1.2	0	0.30	0.800	0	0.70	0.720	0	0
		1.3	4,697	0.30	1.000	1,409	0.70	0.900	2,959	4,368
		1.4	445				1.00	1.000	445	445
		1.5	513					1.000	513	513
	Subtotal		6,314							5,647
Bristol Bay	1998	1.0	106	0.43	0.336	15	0.57	0.302	18	33
		1.1	7	0.43	0.560	2	0.57	0.504	2	4
		1.2	9,783	0.43	0.800	3,365	0.57	0.720	4,015	7,380
		1.3	3,499	0.43	1.000	1,505	0.57	0.900	1,795	3,300
		1.4	376				1.00	1.000	376	376
		1.5	0					1.000	0	0
	Subtotal		13,771							11,093
Total Western Alaska-1998			28,993							24,250

Table 11. Adult equivalent (AEQ) bycatch (number of fish, No.) of Yukon, Kuskokwim, and Bristol Bay chinook salmon by U.S. groundfish fisheries in the eastern Bering Sea in 1997-1999 based on estimated bycatch (B) in Table 10 (continued).

				Return at age 1.3			Return at age 1.4 or 1.5			Total
Alaska subregion	Bycatch year	Bycatch age	Estimated bycatch No. (B)	Prop. of return at age 1.3 (R)	Ocean survival prop. (S)	AEQ bycatch No.	Prop. of return at age 1.4 (R)	Ocean survival prop. (S)	AEQ bycatch No.	AEQ bycatch No.
Yukon	1999	1.0	0	0.30	0.336	0	0.70	0.302	0	0
		1.1	N/A							
		1.2	805	0.30	0.800	193	0.70	0.720	406	599
		1.3	2,091	0.30	1.000	627	0.70	0.900	1,317	1,944
		1.4	146				1.00	1.000	146	146
		1.5	32					1.000	32	32
	Subtotal		3,074							2,721
Kuskokwim	1999	1.0	0	0.30	0.336	0	0.70	0.302	0	0
		1.1	N/A							
		1.2	1,091	0.30	0.800	262	0.70	0.720	550	812
		1.3	0	0.30	1.000	0	0.70	0.900	0	0
		1.4	449				1.00	1.000	449	449
		1.5	31					1.000	31	31
	Subtotal		1,571							1,292
Bristol Bay	1999	1.0	0	0.43	0.336	0	0.57	0.302	0	0
		1.1	N/A							
		1.2	1,218	0.43	0.800	419	0.57	0.720	500	919
		1.3	2,776	0.43	1.000	1,194	0.57	0.900	1,424	2,618
		1.4	68				1.00	1.000	68	68
		1.5	0					1.000	0	0
	Subtotal		4,062							3,605
Total Western Alaska-1999			8,707							7,618

Table 12. Estimated adult equivalent (AEQ) bycatch (number of fish, No.) of Yukon, Kuskokwim, and Bristol Bay chinook salmon by U.S. groundfish fisheries in the eastern Bering Sea in 1997-1999 (Table 11) by year of adult return, 1997-2002. Estimates for age-1.1 chinook salmon caught in 1999 were not available (N/A).

Alaska subregion	Bycatch year	Bycatch age	AEQ bycatch (No.) by year of adult return 1997	1998	1999	2000	2001	2002
Yukon	1997	1.0				0	0	0
		1.1			121	254		
		1.2		171	359			
		1.3	932	1,957				
		1.4	2,431					
		1.5	297					
	Subtotal		3,660	2,128	480	254	0	0
Kuskokwim	1997	1.0				0	0	
		1.1			0	0		
		1.2		1,123	2,358			
		1.3	194	406				
		1.4	1,964					
		1.5	297					
	Subtotal		2,455	1,529	2,358	0	0	0
Bristol Bay	1997	1.0				0	0	
		1.1			358	427		
		1.2		1,586	1,892			
		1.3	1,178	1,406				
		1.4	321					
		1.5	0					
	Subtotal		1,499	2,992	2,250	427	0	0
Total Western Alaska-1997			7,614	6,649	5,088	681	0	0

Table 12. Estimated adult equivalent (AEQ) bycatch (number of fish, No.) of Yukon, Kuskokwim, and Bristol Bay chinook salmon by U.S. groundfish fisheries in the eastern Bering Sea in 1997-1999 (Table 11) by year of adult return (continued).

Alaska subregion	Bycatch year	Bycatch age	AEQ bycatch (No.) by year of adult return 1998	1999	2000	2001	2002
Yukon	1998	1.0				11	22
		1.1			144	303	
		1.2		621	1,304		
		1.3	1,082	2,272			
		1.4	1,238				
		1.5	513				
	Subtotal		2,833	2,893	1,448	314	22
Kuskokwim	1998	1.0				11	22
		1.1			93	195	
		1.2		0	0		
		1.3	1,409	2,959			
		1.4	445				
		1.5	513				
	Subtotal		2,367	2,959	93	206	22
Bristol Bay	1998	1.0				15	18
		1.1			2	2	
		1.2		3,365	4,015		
		1.3	1,505	1,795			
		1.4	376				
		1.5	0				
	Subtotal		1,881	5,160	4,017	17	18
Total Western Alaska-1998			7,081	11,012	5,558	537	62

Table 12. Estimated adult equivalent (AEQ) bycatch (number of fish, No.) of Yukon, Kuskokwim, and Bristol Bay chinook salmon by U.S. groundfish fisheries in the eastern Bering Sea in 1997-1999 (Table 11) by year of adult return (continued).

Alaska subregion	Bycatch year	Bycatch age	AEQ bycatch (No.) by year of adult return 1999	2000	2001	2002
Yukon	1999	1.0				0
		1.1			N/A	N/A
		1.2		193	406	
		1.3	627	1,317		
		1.4	146			
		1.5	32			
	Subtotal		805	1,510	406	0
Kuskokwim	1999	1.0				0
		1.1			N/A	N/A
		1.2		262	550	
		1.3	0	0		
		1.4	449			
		1.5	31			
	Subtotal		480	262	550	0
Bristol Bay	1999	1.0				0
		1.1			N/A	N/A
		1.2		419	500	
		1.3	1,194	1,424		
		1.4	68			
		1.5	0			
	Subtotal		1,262	1,843	500	0
Total Western Alaska-1999			2,547	3,615	1,456	0

Table 13. Evaluation of the effect of chinook salmon bycatch by the U.S. groundfish fishery in the eastern Bering Sea in 1997-1999 on Yukon, Kuskokwim, and Bristol Bay chinook salmon runs, escapement, and utilization in 1997-2000. AEQ = estimated adult equivalent bycatch by adult return year (Table 12, units = number of fish). Run size estimates (catch and escapement, units = number of fish), utilization data (commercial and subsistence catch, units = number of fish), and escapement estimates (units = number of fish) were provided by the Alaska Department of Fish and Game (D. Eggers, pers. comm.).

		Adult return year			
Stock	Data or estimate	1997	1998	1999	2000
Yukon	AEQ bycatch	3,660	4,961	4,178	3,212
	Minimum run estimate	261,391	131,909	163,894	71,598
	AEQ/minimum run estimate	**0.014**	**0.038**	**0.025**	**0.045**
	Minimum lower river escapement	31,786	9,772	15,683	7,816
	AEQ/minimum lower river escapement	**0.115**	**0.508**	**0.266**	**0.411**
	Canadian escapement	37,683	16,750	11,153	12,166
	AEQ/Canadian escapement	**0.097**	**0.296**	**0.375**	**0.264**
	Alaska commercial catch	116,421	44,625	70,767	9,115
	AEQ/Alaska commercial catch	**0.031**	**0.111**	**0.059**	**0.352**
	Alaska subsistence catch	58,973	54,825	53,722	37,623
	AEQ/Alaska subsistence catch	**0.062**	**0.090**	**0.078**	**0.085**
	Canadian catch	16,528	5,937	12,569	4,879
	AEQ/Canadian catch	**0.221**	**0.836**	**0.332**	**0.658**
Kuskokwim	AEQ bycatch	2,455	3,896	5,797	355
	Utilization	129,567	121,265	103,194	94,893
	AEQ/utilization	**0.019**	**0.032**	**0.056**	**0.004**
	Commercial catch	47,990	40,000	30,000	30,000
	AEQ/commercial catch	**0.051**	**0.097**	**0.193**	**0.012**
	Subsistence catch	81,577	81,265	73,194	64,893
	AEQ/subsistence catch	**0.030**	**0.048**	**0.079**	**0.005**
Bristol Bay	AEQ bycatch	1,499	4,873	8,672	6,287
	Minimum run estimate	220,419	277,855	124,445	115,818
	AEQ/minimum run estimate	**0.007**	**0.018**	**0.070**	**0.054**
	Minimum escapement estimate	112,995	126,903	82,494	73,896
	AEQ/minimum escapement estimate	**0.013**	**0.038**	**0.105**	**0.085**
	Utilization	107,424	150,952	41,951	41,922
	AEQ/utilization	**0.014**	**0.032**	**0.207**	**0.150**

Appendix Table 1. Monthly mean fork lengths (FL, cm) and body weights (Wt, kg) by sex (M= male, F= female, U = unknown) of freshwater age-1. chinook salmon in 1997-1999 NMFS observer program scale samples collected from the eastern Bering Sea groundfish fishery salmon bycatch. Fish with scales that could not be assigned both a freshwater and an ocean age or with missing values for length or weight or both were removed from the analysis. s.d. = standard deviation. n = sample size.

			Month											
Age Group	SEX	Data	1	2	3	4	5	6	7	8	9	10	11	Total
Age-1.0	F	FL (cm)									35.0	27.0		31.0
		s.d.												5.7
		Wt (kg)									0.6	0.4		0.5
		s.d.												0.1
		n									1	1		2
	M	FL (cm)									42.0	36.0		37.5
		s.d.										7.0		6.5
		Wt (kg)									1.0	0.7		0.8
		s.d.										0.4		0.4
		n									1	3		4
Age-1.0 Total		FL (cm)									38.5	33.8		35.3
		s.d.									4.9	7.3		6.5
		Wt (kg)									0.8	0.6		0.7
		s.d.									0.3	0.3		0.3
		n									2	4		6
Age-1.1	F	FL (cm)	38.7	29.2	43.0					50.5	51.0	51.0	51.5	49.9
		s.d.	7.2	7.7						2.1	5.6	4.9	0.7	6.9
		Wt (kg)	0.7	0.4	1.1					1.7	1.8	1.9	1.8	1.8
		s.d.	0.4	0.3						0.3	0.6	0.6	0.1	0.7
		n	3	6	1					2	71	79	2	164
	M	FL (cm)	37.0	33.2	25.0					44.0	49.8	50.5	52.5	48.7
		s.d.	6.4	9.5							5.5	5.7	0.7	7.6
		Wt (kg)	0.8	0.5	0.2					1.2	1.8	1.8	1.9	1.6
		s.d.	0.5	0.5							0.6	0.7	0.0	0.7
		n	6	13	1					1	77	111	2	211
	U	FL (cm)									53.0			53.0
		s.d.												
		Wt (kg)									2.3			2.3
		s.d.												
		n									1			1
Age-1.1 Total		FL (cm)	37.6	31.9	34.0					48.3	50.4	50.7	52.0	49.2
		s.d.	6.2	9.0	12.7					4.0	5.5	5.4	0.8	7.3
		Wt (kg)	0.8	0.5	0.6					1.5	1.8	1.8	1.9	1.7
		s.d.	0.5	0.5	0.6					0.4	0.6	0.7	0.0	0.7
		n	9	19	2					3	149	190	4	376

Appendix Table 1 (continued). Monthly mean fork lengths (FL, cm) and body weights (Wt, kg) by sex (M= male, F= female, U = unknown) of freshwater age-1. chinook salmon in 1997-1999 NMFS observer program scale samples collected from the eastern Bering Sea groundfish fishery salmon bycatch.

			Month											
Age Group	SEX	Data	1	2	3	4	5	6	7	8	9	10	11	Total
Age-1.2	F	FL (cm)	53.6	53.8	53.4	55.5			59.0	62.6	64.1	63.4	60.4	62.1
		s.d.	6.8	5.0	3.8	3.5				4.5	5.5	5.6	3.0	6.7
		Wt (kg)	2.0	2.0	1.8	2.2			2.7	3.3	3.7	3.5	2.9	3.3
		s.d.	0.8	0.6	0.3	0.5				0.8	1.1	1.1	0.5	1.2
		n	74	59	10	2			1	11	450	226	8	841
	M	FL (cm)	54.8	53.8	56.4	64.0		66.0		68.4	64.9	63.8	58.5	62.7
		s.d.	5.7	7.0	5.7			1.4		7.2	5.6	5.3	0.7	6.9
		Wt (kg)	2.1	2.0	2.2	3.0		4.2		4.5	3.8	3.6	2.6	3.4
		s.d.	0.7	0.7	0.7			0.3		1.5	1.1	1.1	0.3	1.2
		n	55	61	16	1		2		12	371	202	2	722
	U	FL (cm)								73.0	64.0	65.0		65.7
		s.d.									5.3			5.5
		Wt (kg)								6.1	3.2	4.2		3.9
		s.d.									0.9			1.3
		n								1	4	1		6
Age-1.2 Total		FL (cm)	54.1	53.8	55.2	58.3		66.0	59.0	66.0	64.5	63.6	60.0	62.4
		s.d.	6.3	6.0	5.2	5.5		1.4		6.7	5.6	5.5	2.7	6.8
		Wt (kg)	2.1	2.0	2.0	2.4		4.2	2.7	4.0	3.7	3.6	2.8	3.4
		s.d.	0.8	0.7	0.6	0.6		0.3		1.4	1.1	1.1	0.5	1.2
		n	129	120	26	3		2	1	24	825	429	10	1569
Age-1.3	F	FL (cm)	66.5	67.3	67.4	67.8	68.0		79.0	79.9	77.7	78.1	91.0	70.2
		s.d.	5.7	5.5	5.6	3.4				8.9	6.4	7.3		7.9
		Wt (kg)	3.7	3.9	3.7	3.6	3.9		6.2	6.4	6.5	6.6	11.5	4.6
		s.d.	1.1	1.0	0.9	0.4				1.6	1.7	1.9		1.8
		n	372	292	43	4	1		1	20	210	68	1	1012
	M	FL (cm)	68.2	68.6	69.3	77.7		78.0	71.0	74.6	76.6	78.1		70.6
		s.d.	6.6	5.8	5.6	3.5				7.0	7.7	8.3		7.5
		Wt (kg)	4.0	4.1	4.2	6.6		5.4	4.4	5.5	6.3	7.2		4.7
		s.d.	1.5	1.3	1.1	0.9				2.0	2.1	2.6		1.9
		n	269	215	36	3		1	1	17	119	39		700
	U	FL (cm)	78.0	72.0	71.0					76.0	85.8	72.0		77.3
		s.d.		5.6	2.8						6.7			7.9
		Wt (kg)	6.8	4.8	4.8					5.7	7.9	5.0		6.1
		s.d.		1.2	0.5						1.4			1.7
		n	1	3	2					1	4	1		12
Age-1.3 Total		FL (cm)	67.2	67.8	68.3	72.0	68.0	78.0	75.0	77.4	77.4	78.0	91.0	70.4
		s.d.	6.2	5.7	5.6	6.2			5.7	8.3	7.0	7.6		7.7
		Wt (kg)	3.8	4.0	4.0	4.9	3.9	5.4	5.3	6.0	6.4	6.8	11.5	4.6
		s.d.	1.3	1.2	1.0	1.7			1.3	1.8	1.9	2.2		1.9
		n	642	510	81	7	1	1	2	38	333	108	1	1724

Appendix Table 1 (continued). Monthly mean fork lengths (FL, cm) and body weights (Wt, kg) by sex (M= male, F= female, U = unknown) of freshwater age-1. chinook salmon in 1997-1999 NMFS observer program scale samples collected from the eastern Bering Sea groundfish fishery salmon bycatch.

			Month											
Age Group	SEX	Data	1	2	3	4	5	6	7	8	9	10	11	Total
Age-1.4	F	FL (cm)	78.8	79.7	81.5	86.6	85.0	93.7	80.5	81.0	88.1	81.5		79.8
		s.d.	7.3	7.4	7.8	5.5		5.1	10.6		4.2	3.5		7.5
		Wt (kg)	6.5	6.9	7.3	8.1	8.1	11.6	6.6	7.4	9.1	7.0		6.8
		s.d.	2.0	1.9	2.0	2.3		0.7	3.1		1.0	1.0		2.0
		n	228	193	20	9	1	3	2	1	10	2		469
	M	FL (cm)	80.9	82.2	82.9	90.3	95.5	83.5		89.0	89.0	82.0		81.9
		s.d.	6.5	6.6	6.5	4.6	0.7							6.7
		Wt (kg)	7.0	7.3	7.7	9.0	10.0	7.5		10.0	9.9	8.3		7.3
		s.d.	2.0	2.0	1.8	0.9	1.3							2.0
		n	137	110	18	4	2	1		1	1	1		275
	U	FL (cm)	75.0	71.0	96.5	90.0								86.5
		s.d.			4.9	9.9								12.0
		Wt (kg)	5.4	4.5	10.5	9.4								8.3
		s.d.			1.1	4.5								3.3
		n	1	1	2	2								6
Age-1.4 Total		FL (cm)	79.6	80.6	82.9	88.0	92.0	91.1	80.5	85.0	88.2	81.7		80.6
		s.d.	7.0	7.2	7.7	5.7	6.1	6.6	10.6	5.7	4.0	2.5		7.3
		Wt (kg)	6.7	7.0	7.7	8.5	9.3	10.6	6.6	8.7	9.2	7.4		7.0
		s.d.	2.0	2.0	1.9	2.2	1.4	2.1	3.1	1.8	1.0	1.0		2.0
		n	366	304	40	15	3	4	2	2	11	3		750
Age-1.5	F	FL (cm)	85.4	86.4	91.0	84.3								85.9
		s.d.	6.4	4.3	7.9	7.0								5.9
		Wt (kg)	8.0	8.7	11.0	7.1								8.2
		s.d.	2.0	1.7	2.4	1.7								2.0
		n	27	18	3	7								55
	M	FL (cm)	80.6	92.0	86.8	85.0								85.9
		s.d.	8.6	8.4	18.8									11.2
		Wt (kg)	6.6	9.8	9.3	8.1								8.3
		s.d.	2.4	3.0	4.6									3.2
		n	11	9	4	1								25
	U	FL (cm)	81.0		89.0									85.0
		s.d.												5.7
		Wt (kg)	6.5		9.6									8.1
		s.d.												2.2
		n	1		1									2
Age-1.5 Total		FL (cm)	83.9	88.3	88.6	84.4								85.9
		s.d.	7.2	6.4	13.2	6.5								7.8
		Wt (kg)	7.5	9.1	10.0	7.2								8.2
		s.d.	2.2	2.2	3.4	1.6								2.4
		n	39	27	8	8								82