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Genetic stock identification of Copper River Chinook salmon harvest, 2005–2008

Report to the Alaska Board of Fisheries December 2011, Valdez, Alaska

by

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Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

Chinook salmon are harvested in subsistence, commercial, sport, and personal use fisheries throughout the Copper River drainage and in nearshore marine waters where, on average, 62% (years: 2000–2010) of the retuning fish were harvested. On average, 72% of this harvest was taken in the Copper River District commercial fishery from mixtures of population groups (stocks) returning to a variety of tributaries in the drainage. The exploitation and productivity of any given stock are not well known. The Alaska Department of Fish and Game management strategy for the Copper River District commercial fishery is to provide inriver passage from all temporal segments of a run. However, until recently, no information was available demonstrating the run timings of Copper River Chinook salmon stocks through the commercial fishery. This report describes the preparation of a comprehensive genetic baseline representing Chinook salmon populations across the Gulf of Alaska and south to California, and the use of this baseline to estimate the relative stock composition of Chinook salmon harvests in the Copper River District commercial fishery from 2005 to 2008. A consistent temporal pattern in the composition of the commercial fishery harvests was observed in the 4 years of this study. The proportion of Upper Copper Chinook salmon decreased, while the proportion of Lower Copper Chinook salmon increased as the season progressed. The results support the historical commercial management approach of providing inriver passage for all temporal components of the run. Additionally, genetic data provide the only accurate method for estimating the stock-specific harvests of wild stocks or of stocks (with or without coded wire tags) from other areas.

Key words: Copper River, Chinook salmon, *Oncorhynchus tshawytscha*, mixed stock analysis, commercial fishery.

INTRODUCTION

BACKGROUND

Chinook salmon (*Oncorhynchus tshawytscha*) are harvested in subsistence, commercial, sport, and personal use fisheries throughout the Copper River drainage and nearshore marine waters. Over the past 10 years (2000–2009), annual harvests of Chinook salmon ranged from 14,626 in 2009 to over 60,000 in 2003, and averaged 43,067 salmon (Botz et al. 2010). These harvests accounted for, on average, 62% of the fish returning to the drainage. On average, 72% of all the harvest was taken in the Copper River District commercial fishery from mixtures of population groups (stocks) returning to a variety of tributaries in the drainage. However, the exploitations and productivities of individual stocks are not well known. The Copper River currently has 49 documented spawning locations for Chinook salmon (Johnson and Blanche 2011), although the run timing through the commercial fishery is somewhat compressed. From 2001 through 2010, an average of 90% of the commercial harvest of Chinook salmon occurred in only 35 days. The Copper River District commercial fishery has generally been managed with 2 evenly-spaced fishery openers each week to provide inriver passage of all time components (and presumably stocks) of sockeye and Chinook salmon runs (Botz et al. 2010). The Alaska Department of Fish and Game (ADF&G) management strategy for the Copper River District commercial fishery is to provide inriver passage from all time segments of an overall run. However, no information was available, until recently, to demonstrate run-timing differences among Copper River Chinook salmon stocks. Estimates of stock composition of Chinook salmon in the commercial fishery would allow an evaluation of fish residence time and of the current management approach.

The first studies to examine run timing in Copper River Chinook salmon were radiotelemetry projects which provided information on the inriver run timings of Chinook salmon migrations to many systems in the Upper Copper River (Wuttig and Evenson 2001; Savereide 2005). In these studies, adult Chinook salmon were captured and tagged at the Baird Canyon fish wheel sites, then tracked to upriver spawning locations. These studies provided information on spawning distribution, abundance, and run timing of Chinook salmon within the drainage and demonstrated that upriver populations were present in the river earlier than downriver populations.

While radiotagging studies described run timings within the Copper River, the timings of these components in commercial harvests were unknown. Estimates of stock compositions at the Baird Canyon fish wheel could be "backed out" to the Copper River Delta (CRD) by making several assumptions (e.g., constant migration timing) and applied to the harvest. However, these assumptions could not be validated by direct measurement.

Beginning in 2004, a concerted effort was made to develop a comprehensive genetic baseline for Chinook salmon populations in the Copper River (Seeb et al. 2009) with the intent to develop the capacity to estimate the run timing and harvest of Chinook salmon run components in the commercial fishery. This baseline contained approximately 1,650 individuals from 16 populations across the drainage, and indicated that Chinook salmon populations could be separated into 3 broad geographical groups, including a heterogeneous group of populations in the Upper Copper River, a homogeneous group in the Gulkana River drainage, and a diverse set of populations in the Lower Copper River glacial lakes. The utility of this baseline for mixed stock analysis was demonstrated with samples from Baird Canyon and the 2005 Copper River District commercial fishery. While the usefulness of mixed stock analysis within the Copper River drainage was demonstrated in this project, it could not be used for management until the baseline data within the Copper River were combined with a larger baseline, including populations from elsewhere in the range, which might potentially be harvested in the Copper River commercial fishery.

The central location of the Copper River in the Gulf of Alaska (GOA) and long migrations of Chinook salmon require a comprehensive baseline of populations across the North Pacific Ocean (Alaska Peninsula to California) to provide accurate mixed stock analysis (MSA) estimates of Chinook salmon harvested in the Copper River commercial fishery. In 2006, when the first commercial fishery samples were analyzed, microsatellites were chosen as the genetic marker, because the only baseline with adequate representation of populations for most of this range was the microsatellite baseline that had been developed for the Pacific Salmon Commission (Seeb et al. 2007). This dataset included samples from 100 populations extending from the Situk River to California. This baseline could be combined with baseline-development projects by ADF&G in Southeast Alaska (e.g., Templin and Gilk-Baumer 2011), in the Copper River (Seeb et al. 2009) and in the Kenai River (Begich et al. 2010) to form a more complete baseline (Table 1).

In this report, we describe the preparation of a comprehensive baseline representing Chinook salmon populations across the GOA and south to California. We then use this baseline to estimate the relative stock compositions of Chinook salmon harvests in the commercial fishery in the Copper River District from 2005 to 2008.

DEFINITIONS

First, we define commonly used genetic and salmon management terms.

Allele. Alternative form of a gene or deoxyribonucleic acid (DNA) sequence.

Genetic Marker. A specific DNA sequence that can be identified by an assay.

Genotype. The set of alleles for one or more loci for an individual.

Hardy-Weinberg Expectations (H-W). The genotype frequencies expected for a particular set of allele frequencies. This model assumes random mating, no mutation (the alleles do not change), no migration (no exchange of alleles between populations), infinitely large population size, and no selection for or against genotypes.

Locus (plural, Loci). A fixed position or region on a chromosome.

Mixed Stock Analysis (MSA). A method that uses genetic information from populations and from harvest samples to estimate stock compositions of the harvest.

Population. A locally interbreeding group of fish that is largely isolated from other spawning aggregations. Populations may be adapted to a spawning habitat, and hence may have unique attributes (Ricker 1958) that result in different productivity rates among populations (Pearcy 1992; NRC 1996). This population definition is analogous to the spawning aggregations described by Baker et al. (1996) and the demes defined by the NRC (1996).

Reporting Group. A group of populations in a genetic baseline to which portions of a mixture are allocated with MSA. Groups are based on a combination of management needs and genetic distinctive and may be analogous to stocks.

Microsatellites. These are loci with repetitive nucleotide elements that vary in number. The number of repetitive elements defines an allele.

Salmon Stock. A local group of interbreeding salmon (population) that can be distinguished by genetic, phenotypic, life history, and habitat characteristics. A stock may consist of 2 or more groups (populations), which occur within the same geographic area and which are managed as a single unit (from 5 AAC 39.222(f)). In this study, “stocks” are delineated by major genetic aggregations of populations.

MANAGEMENT OF COPPER RIVER CHINOOK SALMON

Management Strategy

The Prince William Sound (PWS) management area, also known as Area E, encompasses the coastal waters and inland drainages entering the north central GOA between Cape Suckling and Cape Fairfield. In addition to PWS, the management area includes the Bering and Copper rivers and encompasses about 38,000 square miles. The salmon management area is divided into 11 districts corresponding to local geography and distributions of the 5 species of salmon harvested by the commercial fishery. The management objective for these districts is to reach spawning escapement goals for the major spawning stocks, while allowing for orderly harvest of all fish surplus to spawning requirements. As an avenue for the commercial fishing industry to formally provide management recommendations to the ADF&G, representatives from PWS area processors, gear groups, and aquaculture associations sit on an advisory body known as the PWS Salmon Harvest Task Force.

Typically, the Copper River District opens for commercial fishing in mid-May, with the management strategy to allow harvests in 2 evenly spaced periods per week as escapement allows.

Description of Fishery

2005

The estimated 2005 Chinook salmon run was 66,080 fish, of which 34,624 (52.4%) were commercially harvested. A total of 9,439 fish were harvested by upriver personal use harvesters, sport anglers, and subsistence users, and the escapement was 22,017 (Botz et al. 2010). This was below the sustainable escapement goal (SEG) minimum of 24,000 Chinook salmon for the Copper River as defined in 5 AAC 24.361(a).

2006

The estimated 2006 Chinook salmon run was 99,639 fish, of which 30,278 (33.1%) were commercially harvested. A total of 9,955 fish were harvested by upriver personal use harvesters, sport anglers, and subsistence users, and the escapement was 59,406 fish (Botz et al. 2010). This was above the SEG minimum of 24,000 Chinook salmon for the Copper River.

2007

The estimated 2007 Chinook salmon run was 87,678 fish, of which 39,095 (44.6%) were commercially harvested. A total of 13,446 fish were harvested by upriver personal use harvesters, sport anglers, and subsistence users, and the escapement was 35,137 fish (Botz et al. 2010). This was above the SEG minimum of 24,000 for Copper River Chinook salmon.

2008

The estimated 2008 Chinook salmon run was 53,838 fish, of which 11,437 (21.2%) were commercially harvested. A total of 9,331 fish were harvested by upriver personal use harvesters, sport anglers, and subsistence users, and the escapement was 33,070 fish (Botz et al. 2010). This was above the SEG minimum of 24,000 Chinook salmon for the Copper River.

OBJECTIVES

1) Combine available baseline data for Chinook salmon microsatellites and test potential resolution of stock groups for mixed stock analysis.
2) Collect Chinook salmon tissue samples for genetic analysis from the commercial fishery harvest throughout the fishing season from 2005 to 2008.
3) Analyze selected tissues for 13 standardized microsatellite markers.
4) Estimate stock proportions and stock-specific harvest of Chinook salmon by statistical week and for the year.

METHODS

TISSUE SAMPLING

Tissue Handling

Tissue samples for genetic analysis were collected from Chinook salmon caught in the commercial catch without regard to size, sex, or condition. During periods when fish were sampled to record age, sex, and length (ASL), an axillary process was excised from each fish and placed in ethanol in a separate, labeled, 2-ml plastic vial. During periods when Chinook salmon were not sampled for ASL, tissue samples were placed in ethanol in a labeled 250-ml plastic bottle with at least one bottle per fishery opening. For data continuity, tissue samples in the individual 2-ml vials were paired with ASL information collected from each fish. These data were collated and archived by Division of Commercial Fisheries staff at the ADF&G office in Cordova.

Commercial Drift Gillnet Fishery

Fish captured in the commercial fishery in the Copper River District were sampled from landed catch at processors in Cordova, Alaska as part of standard catch-sampling operations. In general, samples collected were used to represent only harvests within the same statistical week as the sampling date. However, the last temporal stratum within a year was sometimes longer than a single week, because harvests were small or tapered off during these periods (Table 2). Sampling was conducted over 5–6 weeks each year, beginning with statistical week 20.

The target sample size for each period was 200 to provide weekly sample sizes of 400 fish. Under worst-case conditions, point estimates based on sample sizes of 400 can be expected to be within 5% of the true stock composition 90% of the time (Thompson 1987) due to sampling error alone. Samples for MSA were pooled by statistical week.

LABORATORY ANALYSIS

Assaying Genotypes

Genomic DNA was extracted following Seeb et al. (2009). Briefly, genomic DNA was extracted from individual tissue samples using DNAeasy 96 Tissue kits[1] (QIAGEN, Valencia, CA). Fish were genotyped for only microsatellites, because only microsatellite loci were available in the coastwide baseline (Seeb et al. 2007). Microsatellite genotyping was conducted in 384-well reaction plates on an Applied Biosystems 3730 capillary DNA sequencer and electropherograms were visualized using AB GeneMapper software v3.5. Genotypes were recorded for the 13 microsatellite loci currently included in the Chinook Technical Committee (CTC) standardized database (Seeb et al. 2007). The microsatellite data were standardized following procedures in Seeb et al. (2007). Genotype data were stored in the Oracle database, *LOKI*, developed by the ADF&G Gene Conservation Laboratory.

Laboratory Quality Control

Genotypes were confirmed by 2 observers. Discrepancies were resolved with 1 of 2 possible outcomes: 1) one score was accepted and the other rejected or 2) both scores were rejected and no score was recorded. Quality control measures included reanalysis of 8% of each collection for all markers to ensure genotypes were reproducible and to identify possible laboratory errors.

STATISTICAL ANALYSIS

Data Retrieval and Quality Control

Genotypes in the *LOKI* database were imported into the statistical package *R* for analysis (R Development Core Team 2010). Prior to statistical analysis, we performed 2 statistical quality control analyses to ensure high-quality data. We identified individuals that were missing a substantial number of genotypes and these individuals were removed from further analyses.

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

Using the "80% rule" (Dann et al. 2009), we excluded individuals missing genotypes for 20% or more loci, because they likely had poor quality DNA. The inclusion of individuals with poor quality DNA might introduce genotyping errors and reduce the accuracies of mixed stock analyses.

The final statistical quality control analysis identified individuals with duplicate genotypes. Duplicate genotypes can occur as a result of sampling or extracting the same individual twice. One individual from each duplicate pair was removed from further analyses.

Baseline Evaluation

Baseline construction

The microsatellite baseline used in this study included the initial baseline of 110 populations from the Situk River to California developed for the Pacific Salmon Commission (Seeb et al. 2007), and baseline datasets from the Department of Fisheries and Oceans Canada (DFO) and the Washington Department of Fish and Wildlife (WDFW) that had been used by the Pacific Salmon Commission (Scott Blankenship, WDFW, Personal communication). These baseline datasets were combined with data from baseline-development projects in Southeast Alaska (e.g., Templin and Gilk-Baumer 2011), in the Copper River (Seeb et al. 2009), and in the Kenai River (Begich et al. 2010). Nine additional populations from the South Alaska Peninsula, Kodiak Island, and Cook Inlet (Table 1) were added to form a comprehensive population baseline.

Microsatellite data for Alaska Chinook salmon populations have not previously been combined into a single dataset, so we included a description of the baseline and tests of its performance to provide a context to interpret the mixed stock analysis reported here.

Collections from the same geographic location, sampled on similar calendar dates, but in different years, were pooled as suggested by Waples (1990). After calculating allelic frequencies for each locus, observed genotype frequencies for each baseline population were tested for null alleles using the *ML-NullFreq* package (Kalinowski and Taper 2006). This analysis provided a measure of heterozygote deficiency, which can be used to infer the presence of null alleles.

Genetic distances among collections were visualized with a Neighbor-Joining (NJ) tree based on pairwise F_{ST} estimates with the package *hierfstat* (Goudet 2006). The stability of tree nodes was assessed by constructing 1,000 trees by bootstrap resampling loci with replacement. The consensus tree was plotted with the *ape* package (Paradis et al. 2004).

Baseline Evaluation for Mixed Stock Analysis

Reporting group designation

Populations were combined into reporting groups based on genetic similarity, geographic location, and proximity to the fishery at the mouth of the Copper River. The 3 reporting groups within the Copper River were identified by Seeb et al. (2009), while 4 larger-scale groups were identified in the rest of the GOA (Table 1; Figure 1). Allele frequencies for the remaining populations along the west coast of North America (British Columbia to California) were combined into a single group.

Maximum likelihood simulations

Support for these regional designations was examined in 3 ways. First, we evaluated the utility of the baseline for MSA by assessing the identifiability of our reporting groups using simulated mixtures. In this analysis, mixture samples consisted entirely of individuals from a single region ("100% simulations"). The mean correct allocations for these samples and their 90% confidence intervals were calculated from 1,000 iterations of the simulation. This test provides a measure of how identifiable the region is in mixtures with other populations in the baseline and a mean allocation of 90% or greater was used to determine whether a reporting group would be identifiable in a mixed stock sample (Seeb et al. 2000). This analysis was performed using the Statistical Program for Analysis of Mixtures (*SPAM*; Debevec et al. 2000). These tests provide an indication of the power of the baseline for MSA under the assumption that all populations in a reporting group are represented in the baseline. Under some circumstances, these simulations produce results that are inappropriately optimistic (Anderson et al. 2008).

Proof tests

The second set of tests is similar to the maximum likelihood simulations in that mixtures again consisted of individuals entirely from a single reporting group. In these tests, mixtures included 100–200 individuals sampled without replacement from the baseline and analyzed as a mixture against the reduced baseline. These tests also provided an indication of the power of the baseline for MSA under the assumption that all the populations from a reporting group are represented in the baseline, except that these analyses do not suffer from the potential biases described by Anderson et al. (2008).

Stock compositions of these test mixtures were estimated with the program *BAYES* (Pella and Masuda 2001). The Bayesian model implemented by *BAYES* places a Dirichlet distribution as the prior distribution for the stock proportions, and the parameters for this distribution must be specified. We defined prior parameters for each reporting group to be equal (i.e., a "flat" prior) with the prior for each reporting group subsequently divided equally among populations within that reporting group. We set the sum of all prior parameters to 1 (prior weight), which is equivalent to adding one fish to each mixture (Pella and Masuda 2001). We ran 5 independent Markov Chain Monte Carlo (MCMC) chains of 40,000 iterations with different starting values and discarded the first 20,000 iterations to remove the influence of the initial start values. We combined the second half of each chain to form the posterior distribution and tabulated mean estimates and 90% credibility intervals from a total of 100,000 iterations. Convergence among chains of these estimates was assessed using the Gelman-Rubin shrink factor, which compares the variation within a chain to the total variation among chains (Gelman and Rubin, 1992). If a shrink factor for a stock group estimate was greater than 1.2, we reanalyzed the mixture with 80,000-iteration chains following the same protocol. We repeated this procedure for each reporting group mixture. A critical level of 90% correct allocation was used to determine if the reporting group was acceptably identifiable (Seeb et al. 2000).

Escapement mixtures

In the final test, we estimated the stock composition of a mixture of fish from the Copper River to determine whether fish would be allocated to reporting groups outside the watershed. To do this, we used mixtures taken from Chinook salmon sampled by sport fishing guides on the Klutina and Gulkana rivers. These samples were previously analyzed and reported in Seeb et al. (2009). Based on the geographic locations of the fishing, we expected that all fish sampled were spawned within the Copper River. This was the most challenging test because fish may have originated from populations not represented in the baseline and the proportion of fish from each population was likely to be proportional to the relative run strength of each population within the drainage. Unlike the previous 2 tests, these tests provided an indication of the power of the baseline for MSA without assuming that all the populations from a reporting group were represented in the baseline. Fish in the mixture may have originated from populations not represented in the baseline. This analysis was also performed with *BAYES*, as described above.

Mixed Stock Analysis

We estimated the stock composition of all weekly stratified mixtures using the same *BAYES* protocol described above for the baseline evaluation tests, except for the definition of prior parameters, which were based upon the best available information for each mixture. We believe the best available information for these priors is the results of mixed stock analysis of similar mixtures. This information was not always available, so we developed a "step-wise" protocol to standardize our methodology.

1) For the first statistical week (20) in the first year (2005), the prior was based on the maximum likelihood stock composition estimate of the combined samples for statistical week 20 in 2006, 2007, and 2008.
2) In subsequent years, the prior for the first weekly period was based upon the stock composition of that week in the previous year.
3) The priors for subsequent weeks in the same year were based on the stock composition estimates of the previous week.
4) We defined a minimum value of 0.01 for all priors for each reporting group. Reporting groups with estimates below this value were set to 0.01 by normalizing the sum of priors for all reporting groups to 1 after adjusting the value of the small proportion stocks. The prior for a reporting group for all mixtures was divided equally among populations within that reporting group.

Populations were not pooled for estimates of stock composition within these reporting groups, as recommended by Wood et al. (1987). Reporting group estimates were calculated by summing population estimates. We then assessed the potential of the baseline to identify these reporting groups for MSA applications with proof tests and escapement samples.

Applying Stock Proportions to Catch

Stock proportion estimates and the 90% credibility intervals for each week within each year were calculated by taking the mean, and 5% and 95% quantiles of the combined posterior distribution from 5 MCMC chains (Gelman et al. 2000). Harvest estimates and 90% credibility intervals for each week were calculated by multiplying the number of fish harvested that week by the unrounded estimate of the reporting-group stock proportion, and by the upper and lower bounds. Reporting groups not contributing more than 5% to a weekly harvest were combined into a single group called "other".

Weekly estimates were pooled into yearly estimates by weighting the weekly estimates by their respective harvests (stratified estimator). We also produced stratified estimates for each reporting group for all combined sampled strata within each year. The stratified estimators were calculated with

$$p_{y,g} = \frac{\sum_{i=1}^{S} H_{y,i} p_{y,g,i}}{\sum_{i=1}^{S} H_{y,i}} \quad , \qquad (1)$$

where $H_{y,i}$ is the harvest in year y and week i, $p_{y,g,i}$ is the proportion of reporting group g fish in year y and week i, and $p_{y,g}$ is the overall proportion of reporting group g fish in year y with S weekly periods. We calculated confidence intervals for $H_{y,g}$, the overall harvest of reporting group g in year y, from its distribution, which was estimated by Monte Carlo re-sampling of 100,000 draws of the posterior probability distributions from each of the constituent temporal strata and by applying the harvest to the draws with a modification of equation 1.

$$H_{y,g} = \sum_{i=1}^{S} H_{y,i} p_{y,g,i} \quad . \qquad (2)$$

This method yielded the same point estimate for the number of harvested fish within a year as would be obtained by summing the point estimates from each week, but yielded a more appropriate credibility interval than that obtained by summing the lower and upper bounds of credibility intervals together. This method also accommodated nonsymmetric credibility intervals.

Relative errors around the harvest estimate were calculated with

$$RE_{y,g,i} = \frac{U_{y,g,i} - L_{y,g,i}}{2H_{y,g,i}} \quad , \qquad (3)$$

where RE is the relative error, U is the upper boundary and L is the lower boundary of the 90% credibility interval.

Stock proportion estimates were rounded to the nearest one-tenth of a percent for reporting. For convenience, we rounded harvest estimates to the nearest fish after all calculations were performed, recognizing that this level of precision is optimistic. Discrepancies between the sum of the reporting group harvest estimates and the total harvest for each week were due to unavoidable rounding errors.

RESULTS

TISSUE SAMPLING

Commercial Drift Gillnet Fishery

Tissues suitable for genetic analysis were collected from 6,029 fish in the commercial harvest in the Copper River District between 2005 and 2008. These fish represented 33 collections (Table 2). With the exceptions of week 24 in 2005 and weeks 20, 24, and 25 in 2008, a weekly harvest was represented by at least 200 fish.

STATISTICAL ANALYSIS

Baseline Evaluation

Baseline construction

Sampling and data analysis for most of the population baseline was part of other projects and have previously been reported. Areas previously sampled include the Kenai River (Begich et al. 2010), Copper River (Seeb et al. 2009), and portions of Southeast Alaska and the Transboundary Rivers (Seeb et al. 2007; Beacham et al. 2010; Templin and Gilk-Baumer 2011). Collections in Chignik, Kodiak Island, and Cook Inlet not described in these reports were from the ADF&G Gene Conservation Laboratory archives. These samples included tissues from 1,164 fish from 9 spawning populations of Chinook salmon at locations across the GOA and were combined with previous samples to build the population baseline for this analysis (Table 1; Figure 1). When combined with previously reported data and data for samples from British Columbia and the west coast of the U.S., the complete baseline used for the present analysis included 49,916 fish from 383 populations across the North Pacific Ocean.

Only one microsatellite marker, *Ssa408*, showed a consistent excess of homozygote genotypes among samples. Significant departures from H-W indicated the presence of a null allele ($\alpha \leq 0.05$) in 43 of 69 samples. This marker was excluded from the analysis and only 12 microsatellites were used for the mixed stock analysis.

Genetic relationships among baseline populations are shown in an N-J tree (Figure 2). Clusters of Chinook salmon populations in the tree show a strong geographic pattern. Groupings of populations within drainages or in close geographic proximity to one another are consistent with previously published observations. For example, Upper Copper River populations spawning above the confluence of the Gulkana River (Populations 17–21) are distinct from Middle Copper (Populations 22 and 23) and Lower Copper River populations (Populations 24–27). Populations in the Situk and Alsek rivers along the east coast of the GOA (Populations 28–32) appeared in a cluster that was separated from groups of populations in the Chilkat River (Populations 33–36) and from the remaining Southeast Alaska populations (Populations 37–69). Populations in British Columbia and the west coast of the U.S. form clusters of populations that are separated from populations in the GOA (Seeb et al. 2007). Of the populations not previously reported, the Chignik River and Kodiak Island populations (1–3) are separate from, but are genetically more similar to, Cook Inlet populations (4–16) than to other populations in the GOA. Populations in the Susitna River (4–8) drainage in Cook Inlet form a group that is separate from populations in the Kenai and Kasilof rivers (9–16).

Baseline Evaluation for MSA

Reporting group designation

The presence of geographic structure in the genetic similarities between populations supports the decision to define reporting groups by geography and proximity to the CRD. Populations were assigned to 8 reporting groups (stocks): 1) West Gulf – populations in the western GOA (Chignik and Kodiak Island), 2) Cook Inlet – populations in the drainages in Cook Inlet, 3) Upper Copper – populations spawning within the Copper River upstream of the confluence with the Gulkana River, 4) Middle Copper – populations spawning in the Gulkana River and Mendeltna Creek, 5) Lower Copper – populations spawning in the Copper River drainage from Tazlina River downstream, 6) East Gulf - populations in the eastern GOA (Situk and Alsek rivers), 7) Southeast Alaska/Transboundary rivers (SEAK-TBR) – populations spawning in Southeast Alaska, including the Taku and Stikine rivers, and 8) British Columbia/West Coast U.S. – all populations spawning south of the Alaska/British Columbia border.

Maximum likelihood simulations

The first test of the baseline was made with simulated mixtures composed of individuals from a single stock (100% simulations). These results demonstrated that the defined reporting groups were highly identifiable (Table 3). Every reporting group showed a mean correct allocation above the 90% threshold; the lowest mean allocation was 93% for the Lower Copper River reporting group. The British Columbia/West Coast U.S. reporting group consistently received among the largest misallocations. This is due to accumulation of small proportions of misallocation across the large number of populations (314) in this reporting group.

Proof tests

The second test involved analyses of mixtures of Chinook salmon of known origin taken from the baseline (proof tests). Every reporting group in these proof tests demonstrated correct allocations above the 90% threshold (Table 4); the lowest was British Columbia/West Coast U.S. at 98% (90% CI: 95–100%). Misallocation to other reporting groups showed no apparent pattern.

Escapement mixtures

The final test of the baseline was made by analyzing mixtures of Chinook salmon encountered in sport fisheries on the Gulkana and Klutina rivers collected by fishing guides. Stock composition estimates for these samples demonstrated higher than 99% correct allocations to the Copper River and the correct reporting group within the Copper River. The Middle Copper River component of the Gulkana River Guides sample was estimated to be 99% (90% CI: 97–100%). The Lower Copper River component of the Klutina River Guides sample was estimated to be 99% (90% CI: 97–100%).

Mixed Stock Analysis

The 33 collections from commercial harvests of Chinook salmon were pooled by statistical week to create 19 mixtures for which the stock composition and stock-specific harvest were estimated (Table 2). These pooled samples consisted of between 170 and 400 fish. The stock composition of the harvest in statistical week 24 in 2005 was not estimated because too few fish (n = 90) had been sampled to achieve accurate and precise estimates. Statistical weeks 24 and 25 in 2008 had too few individuals to estimate stock composition of the harvest for each week separately, so these samples were combined (n = 220).

2005

Samples were collected May 16 to June 14 from Chinook salmon harvested in the Copper River District drift gillnet fishery and landed in Cordova (Table 2). Samples were not collected from the June 1–2 fishery opening, and too few fish were sampled from the June 13–17 fishery opening to provide an estimate for statistical week 24. Over the 4 weeks, we observed a trend of decreasing proportions of Upper Copper River fish (range: 33–1%) that was matched by increasing proportions of Lower Copper River fish (range: 24–86%; Table 5; Figures 3 and 4). The proportion of Middle Copper River fish was relatively steady during the first 2 weeks, before it declined toward the end of the season. The combined proportion of non-Copper River reporting groups was largest (3%) in statistical week 23.

2006

Samples were collected May 15 to June 13 from Chinook salmon harvested in the Copper River District drift gillnet fishery and landed in Cordova. Samples were collected from every fishery opening during these weeks. Over the 5 weeks when fish were sampled, we observed a trend of decreasing proportions of Upper Copper River fish (range: 42–1%) that was matched by increasing proportions of Lower Copper River fish (range: 10–70%; Table 6; Figures 3 and 4). The proportion of Middle Copper River fish was relatively steady during the first 2 weeks, before it declined toward the end of the season. The combined proportion of non-Copper River reporting groups was largest (32%) in statistical week 24, but was also 10% and 21% in statistical weeks 20 and 22, respectively.

2007

Samples were collected May 14 to June 12 from Chinook salmon harvested in the Copper River District drift gillnet fishery and landed in Cordova. Samples were not collected from the June 2 and June 8 fishery openings. Over the 5 weeks that fish were sampled, we observed a trend of declining proportions of Upper Copper River fish (range: 59–4%) that was matched by increasing proportions of Lower Copper River fish (range: 16–68%; Table 7; Figures 3 and 4). The proportion of Middle Copper River fish increased from statistical week 20 to 21, before it declined toward the end of the season. The combined proportion of non-Copper River reporting groups was less than 3% in the first 3 weeks of the season, but increased to 13% in statistical weeks 23 and 24.

2008

Samples were collected May 15 to June 16 from Chinook salmon harvested in the Copper River District drift gillnet fishery and landed in Cordova. Samples from the June 9 and June 16 fishery openings (statistical weeks 24 and 25) were combined to represent the harvest during this period. We observed an increase in the proportion of Upper Copper populations from statistical week 20 to 21, before the proportion declined in the last part of this period (range: 53–9%; Table 8; Figures 3 and 4). This was matched by a larger than usual proportion of Lower Copper River fish (32%) that was followed by a decline in the second week, but an increase in the remainder of the season (range: 14–56%). The proportion of Middle Copper River fish was greatest in statistical week 22 (41%) before it declined toward the end of the harvest season. The combined proportion of non-Copper River reporting groups increased during the season from 1% to 18%.

Total Stock-Specific Harvest

In 2005, adequate genetics samples were collected in weeks when 89% of the commercial harvest of Chinook salmon in the Copper River area (30,703 fish) had occurred (Table 2). During this period, 97% of the fish in these harvests came from the Copper River drainage and represented 29,837 fish (Table 9). Fish originating from the Lower Copper River contributed to almost half (47%) of the commercial harvest, followed by fish from the Middle Copper River (33%) and by fish from the Upper Copper River (18%).

In 2006, genetic samples were collected in weeks when 87% of the commercial harvest of Chinook salmon (26,483 fish) occurred (Table 2). During these weeks, fish from the Copper

River accounted for 22,661 fish (86%) in the harvest (Table 9). Fish from the Lower Copper River contributed the largest component (44%) to the commercial harvest, followed by Middle Copper River fish (25%) and Upper Copper River fish (16%). The largest contribution by a non-Copper River reporting group during this period was Cook Inlet, which represented 8% of the harvest.

In 2007, genetic samples were collected in weeks when over 86% of the commercial harvest of Chinook salmon in the Copper River area (33,759 fish) occurred (Table 2). During these weeks, stocks from the Copper River accounted for 31,876 fish (94%) in the harvest (Table 9). Fish from the Lower Copper River represented the largest component (42%) of the commercial harvest, followed by the Middle Copper River fish (30%) and Upper Copper River fish (23%). The largest contribution by a non-Copper River reporting group was Cook Inlet, which was estimated to contribute 4% of the harvest.

In 2008, genetic samples were collected from over 99% of the commercial harvest of Chinook salmon (11,387 fish) (Table 2). During this period, fish from the Copper River accounted for 92% (10,513 fish) of the harvest (Table 9). Fish from the Lower Copper River represented the largest component (33%) of the commercial harvest, followed by the Upper Copper (32%) and Middle Copper (28%) contributions. The largest contribution from a non-Copper River reporting group was from British Columbia and West Coast U.S. populations, which was estimated to contribute 4% of the harvest.

DISCUSSION

This is the first study to provide highly precise stock-specific estimates of harvest compositions of Chinook salmon in the Copper River District commercial fishery on a weekly basis over multiple years (2005 to 2008). These analyses were based on a large baseline built from previously-reported Chinook salmon data and from ADF&G archived samples, which provided a more complete baseline in the GOA and the west coast of North America. Stock composition estimates from mixed stock analyses can serve to improve the understanding of stock productivity by providing information on the stock-specific harvests of Copper River Chinook salmon. However, some aspects of these stock composition results should be interpreted cautiously. Caveats include 1) relative errors of the estimates are inversely correlated with the proportional contribution to the harvest (i.e., small contributions have large relative errors), and 2) not all strata were sampled (unsampled strata represented 1%–14% of the harvest). Nonetheless, these weaknesses do not detract from the major trends observed in the mixed stock analyses.

BASELINE PERFORMANCE

Tests of the population baseline to evaluate the feasibility of applying MSA methods to estimate stock proportions in the commercial harvest indicated an adequate amount of genetic differentiation among reporting groups. In fact, the test that was considered to be most optimistic beforehand (100% simulations) provided the lowest average correct allocations (93%), whereas the 100% proof tests and the escapement mixtures yielded correct averages of 98% and 99%, respectively. These results indicate that the factors discussed by Anderson et al. (2008) that might contribute to inappropriately optimistic results for the 100% simulations were not important in this study. These factors include closely related populations in the baseline, and large numbers of microsatellite alleles. The better performance of the *BAYES*-based tests may be due to the ability of Bayesian analyses to estimate stock of origin for fish by incorporating information from other fish in the mixture. This may be an especially useful feature of *BAYES* for estimating proportions close to 0% or 100%. All mixture estimates were based on *BAYES* analyses.

PATTERNS IN FISHERY STOCK COMPOSITIONS AND HARVESTS

A consistent temporal trend appeared in the composition of the commercial fishery harvests over the 4 years of this study. The proportion of Upper Copper River Chinook salmon tended to decline as the season progressed, while the proportion of Lower Copper River Chinook salmon increased (Tables 5–8; Figures 3 and 4). This trend was expected, given the early run timing of the Upper Copper River fish relative to the Lower Copper River fish, as observed at the Baird Canyon fish wheel using radio tags (Savereide 2005; Wade et al. 2008) and as indicated by previous mixed stock analysis (Seeb et al. 2009).

In 2005, estimates of temporal changes in the stock composition of Chinook salmon were made both inriver and in the commercial fishery. Inriver sampling was conducted at the Baird Canyon fish wheel (rkm 66) for approximately weekly periods from mid-May to mid-July (Seeb et al. 2009). Similar to the harvest samples, populations spawning in the upper portions of the drainage, represented by the Upper Copper River reporting group, dominated the early run, comprising greater than 80% of the 3 samples obtained during weeks 20–22. Week 23 was a transition period; populations from the Middle Copper River reporting group predominated in the mixed stock samples, and the proportion of fish from the Upper Copper River reporting group declined precipitously. Thereafter (weeks 24, 25, and 26–29), populations in the Lower Copper River reporting group predominated in the samples, with stock proportion estimates increasing from 64% to 96%. The trend in stock composition observed in the inriver and harvest samples was consistent between the fishery and the Baird Canyon fish wheel, but with a 2–3 day lag due to travel time.

Although this trend in run timing was anticipated, it could not be confirmed without mixed stock analysis of the commercial fishery samples. Alternatively, the patterns for inriver run timing could have been due to a common migration into the Copper River District, before run-timing groups separated into discrete units as they migrated upriver. This alternative pattern of run entry to the Copper River District would expose all stocks to commercial harvest for the entire Chinook salmon season, a run-entry pattern that would be much more difficult to manage to ensure spawning escapement for all stock groups.

Commercial harvests in the Copper River District may include fish not returning to the Copper River, because this fishery takes place in the marine waters of the GOA off the mouth of the Copper River. This area may also include migratory pathways of fish returning to rivers in other areas. However, the results of the present study show that most of the fish in the Copper River commercial fishery originated from populations in the Copper River. Nevertheless, a small proportion of fish from non-Copper River stocks were captured in the fishery in all years sampled. These results are consistent with recoveries of coded wire tags from the commercial harvest in previous studies. For example, in 2002, 23 Chinook salmon were taken in the Copper River fishery that had coded wire tags indicating these fish originated from hatcheries in British Columbia, Washington, and Oregon. Additionally, 20 fish marked with coded wire tags originated from hatcheries in Cook Inlet, Alaska, and one fish originated in Southeast Alaska (ADF&G, http://tagotoweb.adfg.state.ak.us/CWT/reports/). A portion of the Cook Inlet-origin Chinook salmon intercepted in the commercial fishery in 2005–2008 were likely hatchery-origin

Chinook salmon returning to 1 of 3 release sites in Prince William Sound: Valdez, Whittier, and Fleming Spit in Cordova (Marston and Brazil 2008). Between 2001 and 2007 an average of 91,579 Chinook smolt were released at Flemming Spit in Cordova, and during the same time frame an average of 113,337 were released at sites near Valdez. Whittier was stocked with an average 105,095 Chinook salmon smolt, but only from 2001 to 2003. The primary brood stock for each of these releases is Deception Creek with a secondary source of from Ship Creek, both Northern Cook Inlet stocks. Additional contributions from wild populations in other areas may be occurring, as coded wire tags are almost exclusively used with hatchery-origin Chinook salmon, so harvests of fish from wild stocks must be extrapolated from adjacent indicator (tagged) stocks (Hankin et al. 2005).

The results of this study provide information valuable for management of the commercial Chinook salmon fishery in the Copper River District. The results support the historical commercial management approach of providing inriver passage for all of the temporal components of the run. Additionally, the genetic data provide the only accurate method for estimating the stock-specific harvest of wild and noncoded-wire-tagged stocks from other areas.

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TABLES AND FIGURES

Table 1.–Samples of Chinook salmon from the Gulf of Alaska in the population baseline used for mixed stock analysis of Copper River commercial harvests, 2005–2008.

Map Number	Reporting Group	Geographic Location	Population	*N*	Data Source
	W Gulf of Alaska				
1		S Alaska Peninsula	Chignik River	46	1
2		Kodiak Island	Ayakulik River	124	1
3			Karluk River	66	1
	Cook Inlet				
4		Susitna River	Deception Creek	98	1
5			Willow Creek	71	1
6			Deshka River	251	1
7			Prairie Creek	48	1
8			Talachulitna River	58	1
9		Kenai River	Crescent Creek	44	2
10			Kenai River Mainstem	300	2
11			Slikok Creek	61	2
12			Funny River	131	2
13			Killey River	160	2
14			Benjamin Creek	150	2
15			Crooked Creek	282	2
16		Kasilof River	Kasilof River	402	1
	Upper Copper				
17		Copper River	Indian Creek	50	3
18			Bone Creek	78	3
19			Otter Creek	128	3
20			Sinona Creek	157	3
21			Chistochina River	133	3
	Middle Copper				
22			Gulkana River	211	3
23			Mendeltna Creek	143	3
	Lower Copper				
24			Kiana Creek	74	3
25			Manker Creek	61	3
26			Tonsina River	75	3
27			Tebay River	68	3
	E Gulf of Alaska				
28		Situk River	Situk River	131	4
29		Alsek River	Blanchard River	369	5
30			Goat Creek	62	5
31			Klukshu River	241	4,5
32			Takanne River	196	5

-continued-

Table 1.–Page 2 of 2.

Map Number	Reporting Group	Geographic Location	Population	*N*	Data Source
	SE Alaska/Transboundary Rivers				
33		Chilkat River	Big Boulder Creek	144	4
34			Tahini Macaulay Hatchery	78	4,6
35			Tahini River	141	4
36			Kelsall River	154	6
37		King Salmon River	King Salmon River	144	4
38		Taku River	Dudidontu River	233	5
39			Kowatua River	294	4,5
40			Lower Tatsum River	688	4,5
41			Little Trapper River	74	5
42			Upper Nahlin River	141	4,5
43			Nakina River	434	4,5
44			Tatsamenie River	180	5
45		Stikine River	Andrew Creek	143	4,6
46			Andrew Crystal Lake Hatchery	207	6
47			Andrew Macaulay Hatchery	135	6
48			Andrew Medvejie Hatchery	178	6
49			Christina River	175	5
50			Craig River	100	5
51			Johnny Tashoots River	62	5
52			Little Tahltan River	128	4,5
53			Shakes Creek	176	5
54			Tahltan River	80	5
55			Verrett River	491	5
56		Chickamin River	Chickamin River	128	4,6
57			King Creek	138	4
58			Butler Creek	190	6
59			Leduc Creek	43	6
60			Humpy Creek	124	6
61			Chickamin Little Port Walter H.	220	6
62			Chickamin Whitman Hatchery	193	6
63		Unuk River	Clear Creek	142	4
64			Cripple Creek	142	4
65			Gene's Lake	93	6
66			Kerr Creek	151	6
67			Unuk Little Port Walter H.	150	6
68		Behm Canal	Keta River	205	4
69			Blossom River	190	6

Note: Number of individuals representing the population (*N*) and the source of the information. The British Columbia/West Coast U.S. reporting group populations are not listed.

Sources: 1) this report, 2) Begich et al. (2010), 3) Seeb et al. (2009), 4) Seeb et al. (2007), 5) Beacham et al. (2010), and 6) Templin and Gilk-Baumer (2011).

Table 2.–Tissue collections for genetic analysis from Chinook salmon harvested in the Copper River commercial fishery, 2005–2008.

Stat. Week	Date(s)	Harvest	Sample Date(s)	Sample Size	Restrictions [a]
			2005		
20	5/16–17	7,500	5/17	150	
	5/19–20	4,191	5/21	200	
21	5/23–24	3,717	5/24	150	
	5/26–28	3,404	5/28	200	
22	5/30–31	3,356	5/31	200	
	6/1–2	2,400	Not Sampled	0	
	6/3–4	1,675	6/4	200	
23	6/6–7	2,364	6/7	200	
	6/9–10	2,096	6/11	200	
24	6/13–14	1,105	6/14	90[b]	
	6/16–17	453	Not Sampled	0	
25+	6/20–8/16	2,363	Not Sampled	0	
	Total	34,624		1,590	
			2006		
20	5/15	2,989	5/15–16	176	
	5/19	2,626	5/19–20	200	c
21	5/22	4,027	5/22–23	200	
22	6/1–2	3,349	6/2	200	
	6/3	1,917	6/4	200	
23	6/5–6	3,328	6/6	200	
	6/8–9	3,401	6/10	200	
24	6/12–13	2,867	6/14	200	
	6/15–17	1,979	Not Sampled	0	
25+	6/19–8/22	3,795	Not Sampled	0	
	Total	30,278		1,576	
			2007		
20	5/14	1,564	5/14–15	195	c
	5/17	2,433	5/17	80	
21	5/21	3,562	5/21	200	b
22	5/28	6,796	5/28	200	
	5/31	3,310	5/31	200	
	6/2	4,530	Not Sampled	0	
23	6/4	1,769	6/4–5	200	
	6/6	1,715	6/6	200	
	6/8	960	Not Sampled	0	
24	6/11–12	3,755	6/12–13	200	
	6/14–16	3,365	Not Sampled	0	
25+	6/14–9/4	5,336	Not Sampled	0	
	Total	39,095		1,475	

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Table 2.–Page 2 of 2.

Stat. Week	Date(s)	Harvest	Sample Date(s)	Sample Size	Restrictions [a]
			2008		
20	5/15	765	5/15	170	
21	5/19	2,068	5/19–20	200	
	5/22	1,915	5/22–23	200	
22	5/26	1,584	5/26–27	200	
23	6/2	1,503	6/2–3	198	[d]
	6/5	1,763	6/5–6	200	
24 and 25	6/9	975	6/9–10	153	
	6/16	814	6/16	67	
26+	7/5–8/19	63	Not Sampled	0	
	Total	11,450		1,388	

[a] The waters of the Copper River District were open for all periods. Unless otherwise noted, all waters available to commercial salmon fishing were open in the Copper River District.

[b] Samples not used for stock composition estimate.

[c] Waters of the Copper River District outside the inside closure area as described in 5 AAC 24.350(1)(B) were open to commercial fishing.

[d] Waters north of a line from Pt. Steele to the southern tip of Wingham Island were open to commercial fishing.

Table 3.–Estimated composition of simulated mixtures composed entirely of individuals from a single reporting group (100% simulations).

	Reporting group mixture							
Estimated group composition	West Gulf	Cook Inlet	Upper Copper	Middle Copper	Lower Copper	East Gulf	SEAK/ TBR	BC/ W Coast US
West Gulf	**0.933**	0.001	0.000	0.000	0.001	0.001	0.000	0.000
Cook Inlet	0.023	**0.969**	0.003	0.001	0.015	0.005	0.001	0.001
Upper Copper	0.001	0.000	**0.976**	0.001	0.003	0.001	0.000	0.000
Middle Copper	0.001	0.000	0.001	**0.973**	0.005	0.001	0.000	0.000
Lower Copper	0.006	0.004	0.006	0.011	**0.927**	0.005	0.001	0.000
East Gulf	0.003	0.001	0.002	0.002	0.008	**0.978**	0.000	0.000
SE Alaska/TBR	0.015	0.007	0.005	0.004	0.015	0.002	**0.955**	0.014
BC/W Coast US	0.019	0.017	0.007	0.007	0.026	0.007	0.043	**0.985**

Note: Expected values for the reporting group comprising the mixture (bold type) are 1.0; values greater than 0.9 indicate highly identifiable reporting groups.

Table 4.–Estimated composition of proof test mixtures composed entirely of known individuals removed from the baseline for a single reporting group.

Reporting group	West Gulf		Cook Inlet		Upper Copper		Middle Copper	
	N = 100		N = 200		N = 200		N = 100	
	Est.	90% CI	Est.	90% CI	Est.	90% CI	Est.	90% CI
West Gulf	**0.988**	(0.965 - 1.000)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.007)
Cook Inlet	0.002	(0.000 - 0.009)	**0.995**	(0.985 - 1.000)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.007)
Upper Copper	0.001	(0.000 - 0.007)	0.001	(0.000 - 0.004)	**0.996**	(0.986 - 1.000)	0.002	(0.000 - 0.009)
Middle Copper	0.001	(0.000 - 0.007)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.004)	**0.990**	(0.969 - 1.000)
Lower Copper	0.004	(0.000 - 0.020)	0.001	(0.000 - 0.005)	0.001	(0.000 - 0.004)	0.002	(0.000 - 0.010)
East Gulf	0.001	(0.000 - 0.008)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.007)
SE Alaska/TBR	0.001	(0.000 - 0.007)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.004)	0.002	(0.000 - 0.010)
BC/W Coast US	0.001	(0.000 - 0.007)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.007)

Reporting group	Lower Copper		East Gulf		SE Alaska/TBR		BC/W Coast US	
	N = 99		N = 200		N = 200		N = 199	
	Est.	90% CI	Est.	90% CI	Est.	90% CI	Est.	90% CI
West Gulf	0.001	(0.000 - 0.007)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.000)	0.001	(0.000 - 0.004)
Cook Inlet	0.001	(0.000 - 0.007)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.000)	0.002	(0.000 - 0.012)
Upper Copper	0.002	(0.000 - 0.008)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.000)	0.001	(0.000 - 0.004)
Middle Copper	0.002	(0.000 - 0.012)	0.002	(0.000 - 0.009)	0.001	(0.000 - 0.000)	0.001	(0.000 - 0.004)
Lower Copper	**0.990**	(0.967 - 1.000)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.000)	0.001	(0.000 - 0.004)
East Gulf	0.002	(0.000 - 0.009)	**0.995**	(0.983 - 1.000)	0.001	(0.000 - 0.000)	0.001	(0.000 - 0.007)
SE Alaska/TBR	0.001	(0.000 - 0.007)	0.001	(0.000 - 0.004)	**0.995**	(0.000 - 0.984)	0.012	(0.000 - 0.038)
BC/W Coast US	0.001	(0.000 - 0.007)	0.001	(0.000 - 0.004)	0.001	(0.000 - 0.000)	**0.982**	(0.955 - 0.999)

Note: Expected values for the reporting group comprising the mixture (bold type) are 1.0; values greater than 0.9 indicate highly identifiable reporting groups.

Table 5.–Stock composition estimates, extrapolated harvest, standard deviation (SD), 90% credibility interval (CI), and sample size (n) by statistical week for Chinook salmon captured in the Copper River District commercial fishery in 2005.

			Reporting Group							
			West Gulf	Cook Inlet	Upper Copper	Middle Copper	Lower Copper	East Gulf	SEAK/ TBR	BC/ W Coast US
Stat Week	20	Proportion	0.000	0.000	0.338	0.419	0.237	0.000	0.001	0.004
		SD	0.000	0.002	0.026	0.028	0.025	0.001	0.002	0.004
n =	348	Lower 90% CI	0.000	0.000	0.295	0.373	0.197	0.000	0.000	0.000
		Upper 90% CI	0.000	0.001	0.382	0.466	0.280	0.002	0.006	0.013
Harvest	11,691	Harvest	0	4	3,953	4,897	2,775	4	9	50
		Lower 90% CI	0	0	3,454	4,360	2,298	0	0	2
		Upper 90% CI	0	11	4,466	5,442	3,276	18	70	148
Stat Week	21	Proportion	0.000	0.000	0.175	0.455	0.351	0.011	0.003	0.006
		SD	0.000	0.001	0.021	0.028	0.028	0.007	0.003	0.004
n =	359	Lower 90% CI	0.000	0.000	0.142	0.409	0.306	0.002	0.000	0.001
		Upper 90% CI	0.000	0.000	0.211	0.501	0.396	0.025	0.010	0.013
Harvest	7,121	Harvest	0	1	1,246	3,236	2,497	78	23	40
		Lower 90% CI	0	0	1,008	2,909	2,175	11	1	7
		Upper 90% CI	0	2	1,500	3,567	2,823	177	68	94
Stat Week	22	Proportion	0.000	0.027	0.019	0.212	0.697	0.005	0.007	0.032
		SD	0.000	0.010	0.008	0.022	0.026	0.007	0.007	0.010
n =	401	Lower 90% CI	0.000	0.013	0.008	0.176	0.653	0.000	0.000	0.018
		Upper 90% CI	0.000	0.044	0.033	0.250	0.739	0.018	0.020	0.050
Harvest	7,431	Harvest	0	201	142	1,576	5,178	40	54	239
		Lower 90% CI	0	97	61	1,309	4,854	0	0	132
		Upper 90% CI	0	328	247	1,856	5,489	135	147	372

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Table 5.–Page 2 of 2.

			Reporting Group							
			West Gulf	Cook Inlet	Upper Copper	Middle Copper	Lower Copper	East Gulf	SEAK/ TBR	BC/ W Coast US
Stat Week	23	Proportion	0.000	0.010	0.010	0.100	0.862	0.000	0.000	0.018
		SD	0.000	0.005	0.006	0.017	0.019	0.001	0.000	0.007
n =	396	Lower 90% CI	0.000	0.003	0.003	0.073	0.829	0.000	0.000	0.008
		Upper 90% CI	0.000	0.020	0.020	0.129	0.893	0.000	0.000	0.030
Harvest	4,460	Harvest	0	43	44	446	3,846	0	0	80
		Lower 90% CI	0	12	12	327	3,698	0	0	37
		Upper 90% CI	0	88	90	577	3,982	0	0	134

Note: Proportions for a given mixture may not sum to 1 due to rounding error.

Table 6.–Stock composition estimates, extrapolated harvest, standard deviation (SD), 90% credibility interval (CI), and sample size (n) by statistical week for Chinook salmon captured in the Copper River District commercial fishery in 2006.

			Reporting Group							
			West Gulf	Cook Inlet	Upper Copper	Middle Copper	Lower Copper	East Gulf	SEAK/ TBR	BC/ W Coast US
Stat Week	20	Proportion	0.000	0.008	0.417	0.387	0.100	0.034	0.009	0.045
		SD	0.001	0.006	0.027	0.027	0.018	0.011	0.007	0.012
n =	369	Lower 90% CI	0.000	0.000	0.373	0.344	0.072	0.017	0.001	0.028
		Upper 90% CI	0.000	0.019	0.461	0.431	0.132	0.054	0.022	0.066
Harvest	5,615	Harvest	1	45	2,340	2,174	563	188	51	254
		Lower 90% CI	0	0	2,092	1,930	404	95	3	154
		Upper 90% CI	0	107	2,591	2,421	739	301	126	370
Stat Week	21	Proportion	0.000	0.014	0.296	0.376	0.290	0.006	0.000	0.017
		SD	0.001	0.013	0.035	0.038	0.039	0.013	0.001	0.010
n =	187	Lower 90% CI	0.000	0.000	0.239	0.315	0.229	0.000	0.000	0.005
		Upper 90% CI	0.000	0.038	0.355	0.439	0.355	0.037	0.000	0.036
Harvest	4,027	Harvest	0	56	1,194	1,515	1,169	24	0	69
		Lower 90% CI	0	0	964	1,269	921	0	0	19
		Upper 90% CI	0	153	1,431	1,768	1,428	150	0	143
Stat Week	22	Proportion	0.000	0.150	0.079	0.279	0.436	0.001	0.004	0.051
		SD	0.000	0.019	0.014	0.024	0.028	0.003	0.005	0.012
n =	401	Lower 90% CI	0.000	0.120	0.057	0.240	0.390	0.000	0.000	0.033
		Upper 90% CI	0.000	0.183	0.104	0.319	0.482	0.007	0.014	0.072
Harvest	5,266	Harvest	0	791	416	1,468	2,294	5	21	270
		Lower 90% CI	0	630	299	1,262	2,053	0	1	176
		Upper 90% CI	0	963	547	1,682	2,537	38	72	377

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Table 6.–Page 2 of 2.

			Reporting Group							
			West Gulf	Cook Inlet	Upper Copper	Middle Copper	Lower Copper	East Gulf	SEAK/ TBR	BC/ W Coast US
Stat Week	23	Proportion	0.000	0.037	0.052	0.180	0.695	0.004	0.007	0.025
		SD	0.000	0.012	0.012	0.022	0.027	0.006	0.006	0.008
n =	396	Lower 90% CI	0.000	0.020	0.034	0.145	0.650	0.000	0.000	0.013
		Upper 90% CI	0.000	0.058	0.074	0.217	0.738	0.017	0.017	0.040
Harvest	6,729	Harvest	0	252	353	1,211	4,677	24	46	167
		Lower 90% CI	0	136	229	977	4,376	0	0	87
		Upper 90% CI	0	393	495	1,460	4,966	115	114	267
Stat Week	24	Proportion	0.000	0.203	0.008	0.065	0.605	0.005	0.002	0.111
		SD	0.001	0.032	0.007	0.021	0.040	0.010	0.006	0.023
n =	201	Lower 90% CI	0.000	0.153	0.001	0.035	0.539	0.000	0.000	0.076
		Upper 90% CI	0.000	0.257	0.023	0.102	0.670	0.026	0.015	0.151
Harvest	4,846	Harvest	0	983	40	317	2,932	26	9	539
		Lower 90% CI	0	739	2	168	2,611	0	0	368
		Upper 90% CI	0	1,244	109	495	3,244	126	72	731

Note: Proportions for a given mixture may not sum to 1 due to rounding error.

Table 7.–Stock composition estimates, extrapolated harvest, standard deviation (SD), 90% credibility interval (CI), and sample size (n) by statistical week for Chinook salmon captured in the Copper River District commercial fishery in 2007.

			Reporting Group							
			West Gulf	Cook Inlet	Upper Copper	Middle Copper	Lower Copper	East Gulf	SEAK/ TBR	BC/ W Coast US
Stat Week	20	Proportion	0.000	0.010	0.590	0.227	0.155	0.008	0.007	0.004
		SD	0.001	0.008	0.030	0.026	0.025	0.008	0.005	0.004
n =	274	Lower 90% CI	0.000	0.000	0.540	0.186	0.116	0.000	0.000	0.000
		Upper 90% CI	0.000	0.025	0.639	0.272	0.197	0.023	0.017	0.012
Harvest	3,997	Harvest	0	38	2,357	909	620	30	27	17
		Lower 90% CI	0	0	2,157	741	465	0	0	1
		Upper 90% CI	0	98	2,554	1,086	786	93	68	49
Stat Week	21	Proportion	0.000	0.000	0.360	0.434	0.199	0.007	0.000	0.000
		SD	0.001	0.001	0.035	0.037	0.032	0.009	0.001	0.001
n =	197	Lower 90% CI	0.000	0.000	0.302	0.373	0.149	0.000	0.000	0.000
		Upper 90% CI	0.000	0.000	0.419	0.496	0.254	0.026	0.000	0.000
Harvest	3,562	Harvest	1	0	1,281	1,547	709	24	0	0
		Lower 90% CI	0	0	1,076	1,330	529	0	0	0
		Upper 90% CI	0	0	1,492	1,766	904	93	0	0
Stat Week	22	Proportion	0.000	0.002	0.230	0.372	0.383	0.007	0.003	0.003
		SD	0.000	0.003	0.023	0.026	0.028	0.010	0.003	0.003
n =	391	Lower 90% CI	0.000	0.000	0.194	0.330	0.337	0.000	0.000	0.000
		Upper 90% CI	0.000	0.008	0.268	0.416	0.430	0.027	0.008	0.008
Harvest	14,636	Harvest	0	31	3,366	5,449	5,604	107	40	38
		Lower 90% CI	0	0	2,838	4,825	4,928	0	1	1
		Upper 90% CI	0	121	3,917	6,081	6,289	398	117	113

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Table 7.–Page 2 of 2.

			Reporting Group							
			West Gulf	Cook Inlet	Upper Copper	Middle Copper	Lower Copper	East Gulf	SEAK/ TBR	BC/ W Coast US
Stat Week	23	Proportion	0.002	0.090	0.094	0.223	0.553	0.018	0.016	0.005
		SD	0.003	0.016	0.016	0.023	0.028	0.009	0.007	0.004
n =	390	Lower 90% CI	0.000	0.064	0.069	0.187	0.506	0.005	0.007	0.001
		Upper 90% CI	0.007	0.118	0.121	0.261	0.599	0.035	0.028	0.012
Harvest	4,444	Harvest	7	398	417	992	2,456	81	71	22
		Lower 90% CI	0	285	307	831	2,250	23	30	3
		Upper 90% CI	29	524	538	1,161	2,662	153	124	53
Stat Week	24	Proportion	0.000	0.123	0.037	0.150	0.679	0.001	0.010	0.000
		SD	0.001	0.026	0.017	0.029	0.039	0.004	0.008	0.001
n =	191	Lower 90% CI	0.000	0.084	0.014	0.106	0.615	0.000	0.001	0.000
		Upper 90% CI	0.000	0.168	0.067	0.200	0.742	0.005	0.025	0.000
Harvest	7,120	Harvest	1	879	261	1,069	4,837	6	68	1
		Lower 90% CI	0	597	101	751	4,375	0	6	0
		Upper 90% CI	0	1,193	480	1,423	5,282	32	174	0

Note: Proportions for a given mixture may not sum to 1 due to rounding error.

Table 8.–Stock composition estimates, extrapolated harvest, standard deviation (SD), 90% credibility interval (CI), and sample size (n) by statistical week for Chinook salmon captured in the Copper River District commercial fishery in 2008.

			Reporting Group							
			West Gulf	Cook Inlet	Upper Copper	Middle Copper	Lower Copper	East Gulf	SEAK/ TBR	BC/ W Coast US
Stat Week	20	Proportion	0.000	0.000	0.404	0.268	0.319	0.005	0.000	0.004
		SD	0.001	0.001	0.039	0.036	0.039	0.011	0.001	0.005
n =	169	Lower 90% CI	0.000	0.000	0.340	0.211	0.256	0.000	0.000	0.000
		Upper 90% CI	0.000	0.000	0.469	0.329	0.385	0.029	0.000	0.015
Harvest	765	Harvest	0	0	309	205	244	4	0	3
		Lower 90% CI	0	0	260	161	196	0	0	0
		Upper 90% CI	0	0	359	251	294	22	0	11
Stat Week	21	Proportion	0.000	0.009	0.531	0.278	0.136	0.006	0.011	0.029
		SD	0.000	0.006	0.026	0.024	0.020	0.006	0.007	0.009
n =	395	Lower 90% CI	0.000	0.002	0.488	0.240	0.105	0.000	0.000	0.016
		Upper 90% CI	0.000	0.021	0.573	0.318	0.169	0.017	0.023	0.045
Harvest	3,983	Harvest	0	37	2,115	1,108	540	24	42	117
		Lower 90% CI	0	7	1,945	955	417	0	0	65
		Upper 90% CI	0	83	2,283	1,266	674	69	92	180
Stat Week	22	Proportion	0.000	0.000	0.307	0.408	0.237	0.000	0.019	0.029
		SD	0.001	0.001	0.033	0.037	0.033	0.002	0.013	0.014
n =	198	Lower 90% CI	0.000	0.000	0.253	0.348	0.184	0.000	0.000	0.011
		Upper 90% CI	0.000	0.000	0.362	0.468	0.293	0.000	0.043	0.056
Harvest	1,584	Harvest	0	0	485	646	375	0	31	46
		Lower 90% CI	0	0	401	551	292	0	0	17
		Upper 90% CI	0	0	574	742	463	0	68	88

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Table 8.–Page 2 of 2.

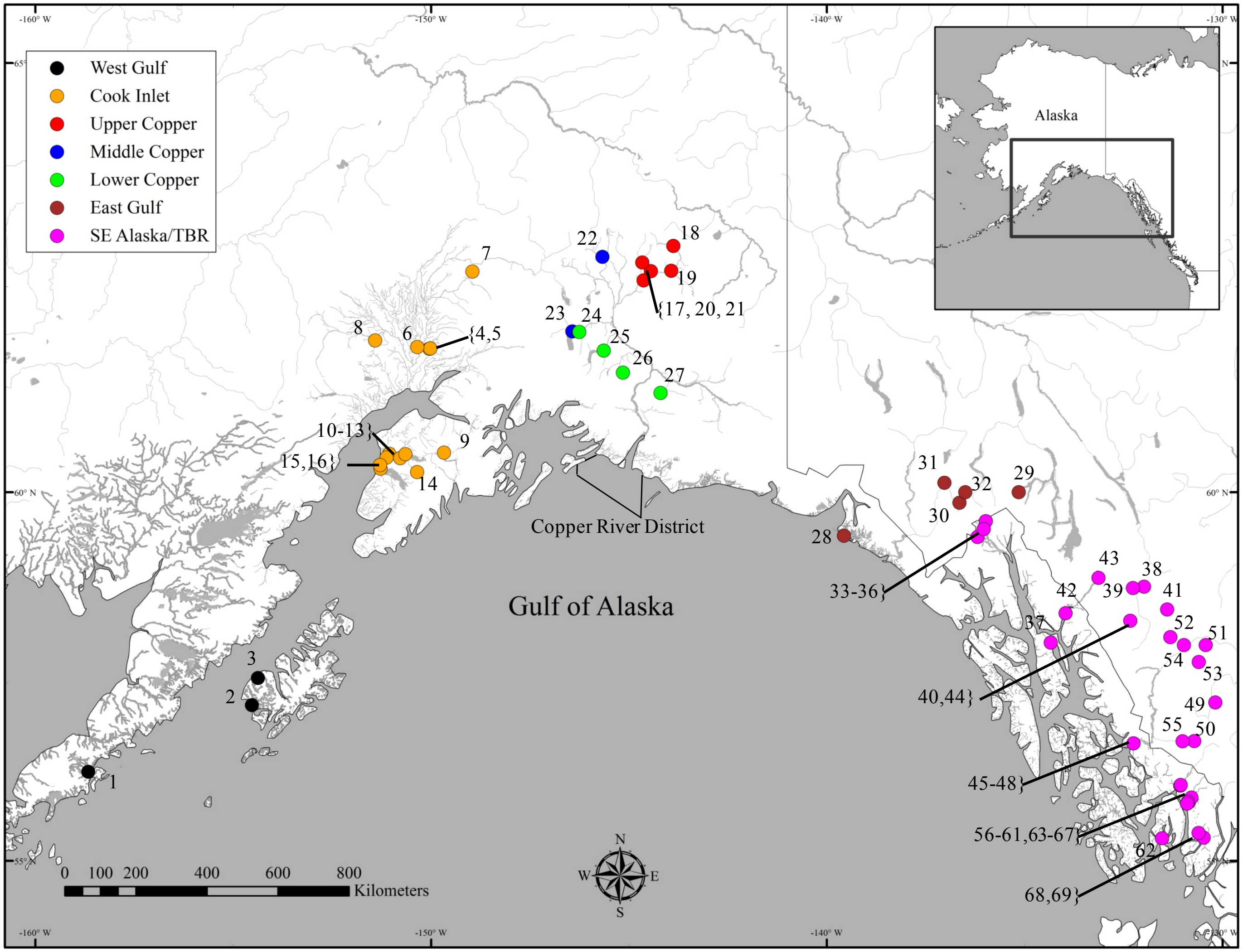
			Reporting Group							
			West Gulf	Cook Inlet	Upper Copper	Middle Copper	Lower Copper	East Gulf	SEAK/ TBR	BC/ W Coast US
Stat Week	23	Proportion	0.000	0.031	0.171	0.273	0.481	0.000	0.013	0.031
		SD	0.000	0.011	0.020	0.024	0.028	0.002	0.006	0.009
n =	390	Lower 90% CI	0.000	0.014	0.139	0.233	0.435	0.000	0.005	0.018
		Upper 90% CI	0.000	0.051	0.205	0.313	0.528	0.001	0.025	0.047
Harvest	3,266	Harvest	0	101	557	890	1,572	1	43	102
		Lower 90% CI	0	47	453	762	1,419	0	15	59
		Upper 90% CI	0	165	668	1,024	1,725	2	82	154
Stat Week	24-25	Proportion	0.000	0.042	0.088	0.168	0.564	0.006	0.014	0.119
		SD	0.001	0.015	0.020	0.027	0.036	0.006	0.013	0.025
n =	213	Lower 90% CI	0.000	0.020	0.057	0.125	0.504	0.000	0.001	0.080
		Upper 90% CI	0.000	0.070	0.124	0.214	0.624	0.018	0.040	0.161
Harvest	1,789	Harvest	0	75	158	300	1,010	10	25	212
		Lower 90% CI	0	35	102	223	902	0	1	143
		Upper 90% CI	0	125	222	383	1,115	33	72	287

Note: Proportions for a given mixture may not sum to 1 due to rounding error.

Table 9.–Stock-specific harvest, standard deviation (SD), and 90% credibility intervals calculated using a stratified estimator (see text) for combined temporal strata and based on genetic analysis of mixtures of Chinook salmon harvested in the Copper River District, 2005–2008.

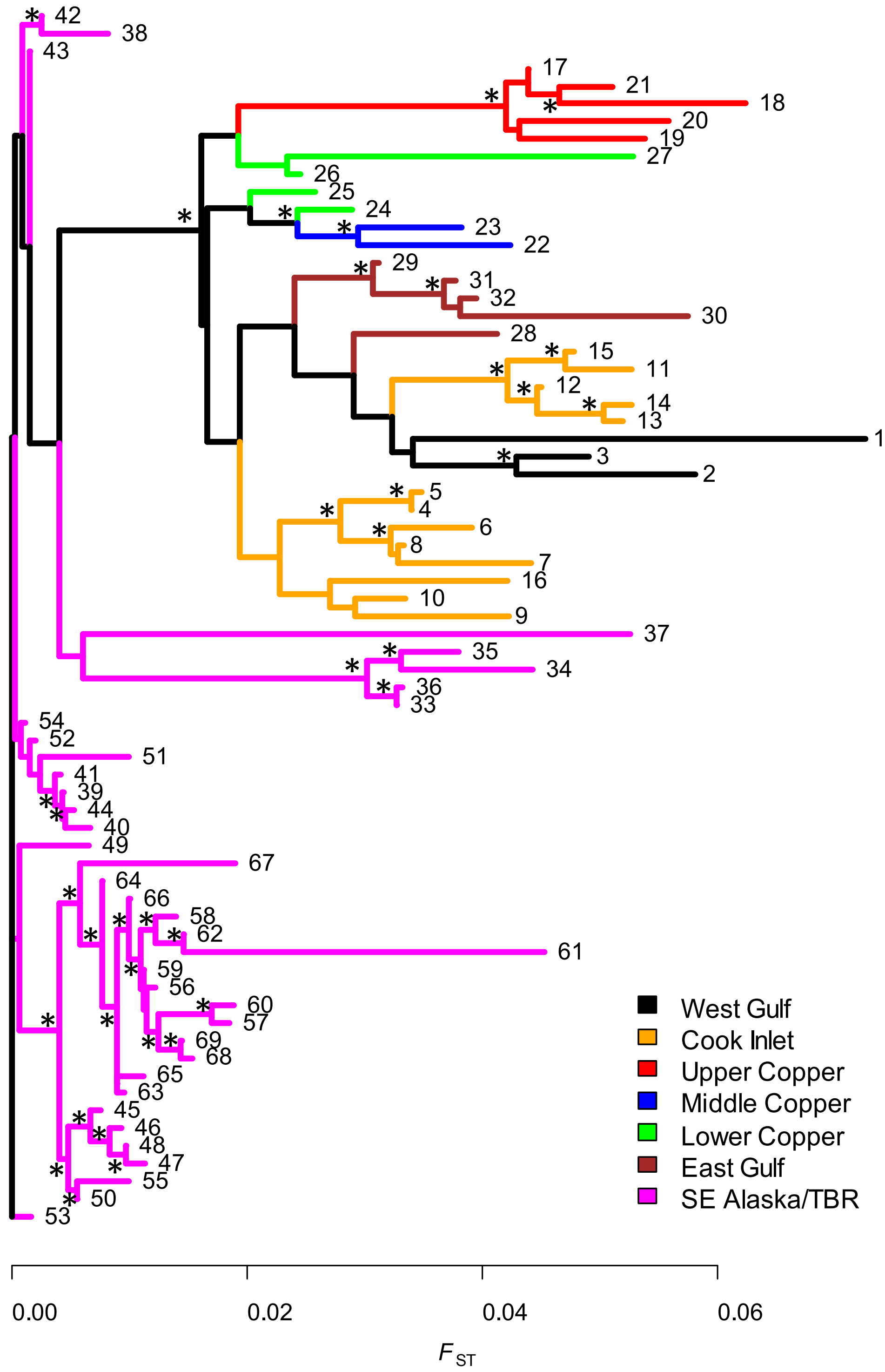
	Reporting Group						Not
	Cook Inlet	Upper Copper	Middle Copper	Lower Copper	BC/W Coast US	Other	Sampled
2005							
Harvest	248	5,385	10,156	14,296	409	209	3,921
SD	77	347	426	413	98	95	
Lower 90% CI	136	4,820	9,459	13,622	264	70	
Upper 90% CI	385	5,965	10,859	14,979	583	382	
Relative Error	50%	11%	7%	5%	39%	75%	
2006							
Harvest	2,127	4,342	6,685	11,635	1,299	396	3,795
SD	210	238	304	355	158	125	
Lower 90% CI	1,792	3,956	6,190	11,051	1,048	214	
Upper 90% CI	2,481	4,737	7,191	12,216	1,569	620	
Relative Error	16%	9%	7%	5%	20%	51%	
2007							
Harvest	1,346	7,682	9,968	14,226	77	460	5,336
SD	202	397	475	531	44	178	
Lower 90% CI	1,336	7,674	9,962	14,231	68	426	
Upper 90% CI	1,692	8,340	10,756	15,103	162	796	
Relative Error	13%	4%	4%	3%	60%	40%	
2008							
Harvest	213	3,623	3,148	3,742	480	181	63
SD	52	141	148	151	68	54	
Lower 90% CI	210	3,623	3,146	3,740	477	177	
Upper 90% CI	304	3,855	3,394	3,991	595	276	
Relative Error	22%	3%	4%	3%	12%	27%	

Note: Harvest numbers of fishing periods not represented in the estimates and relative error rates are given. Reporting groups with estimated contributions less than 5% were combined into a single group (Other).



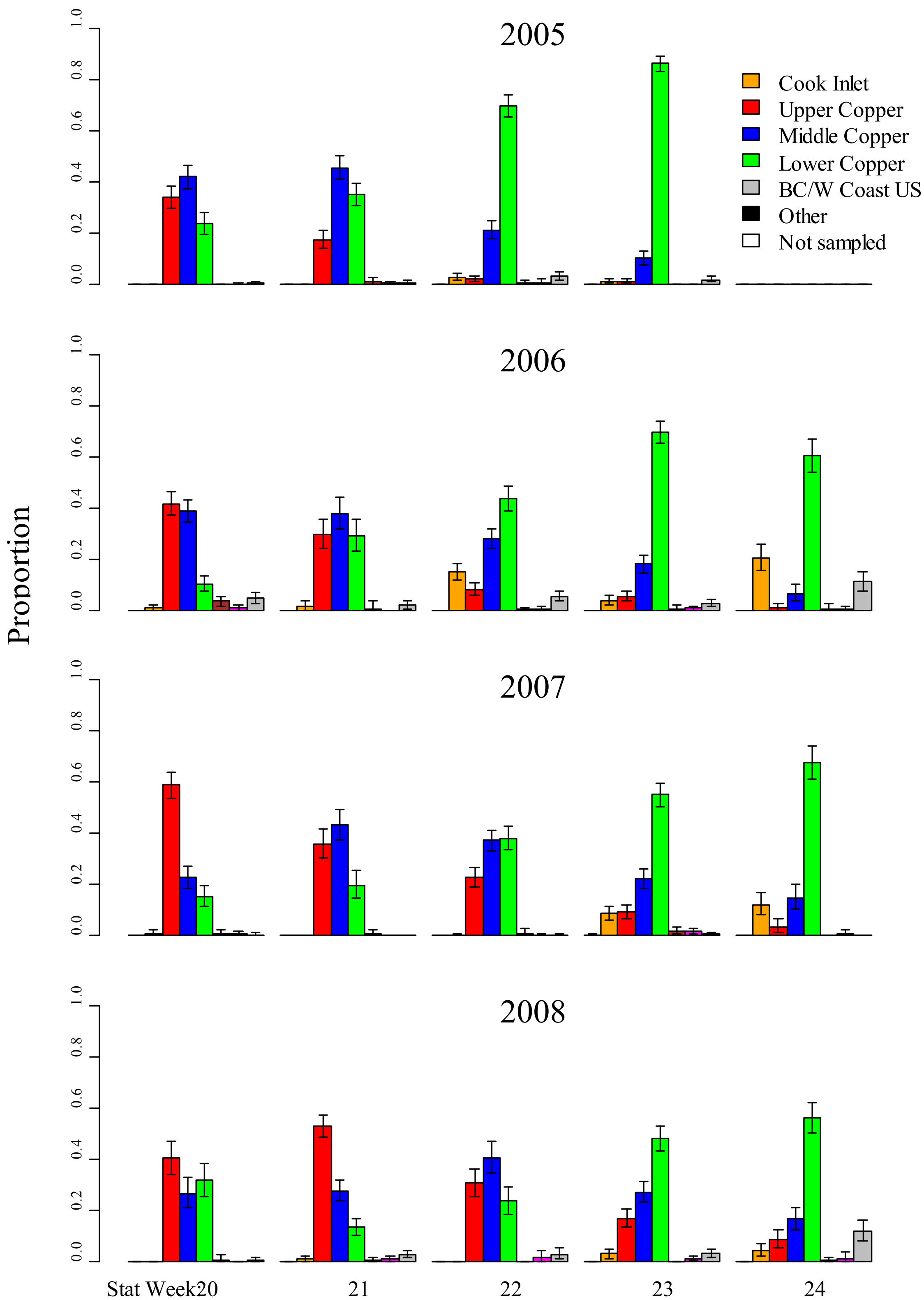
Note: Numbers refer to population numbers listed in Table 1.

Figure 1.–Map of Gulf of Alaska showing reporting group areas adjacent to the Gulf of Alaska.



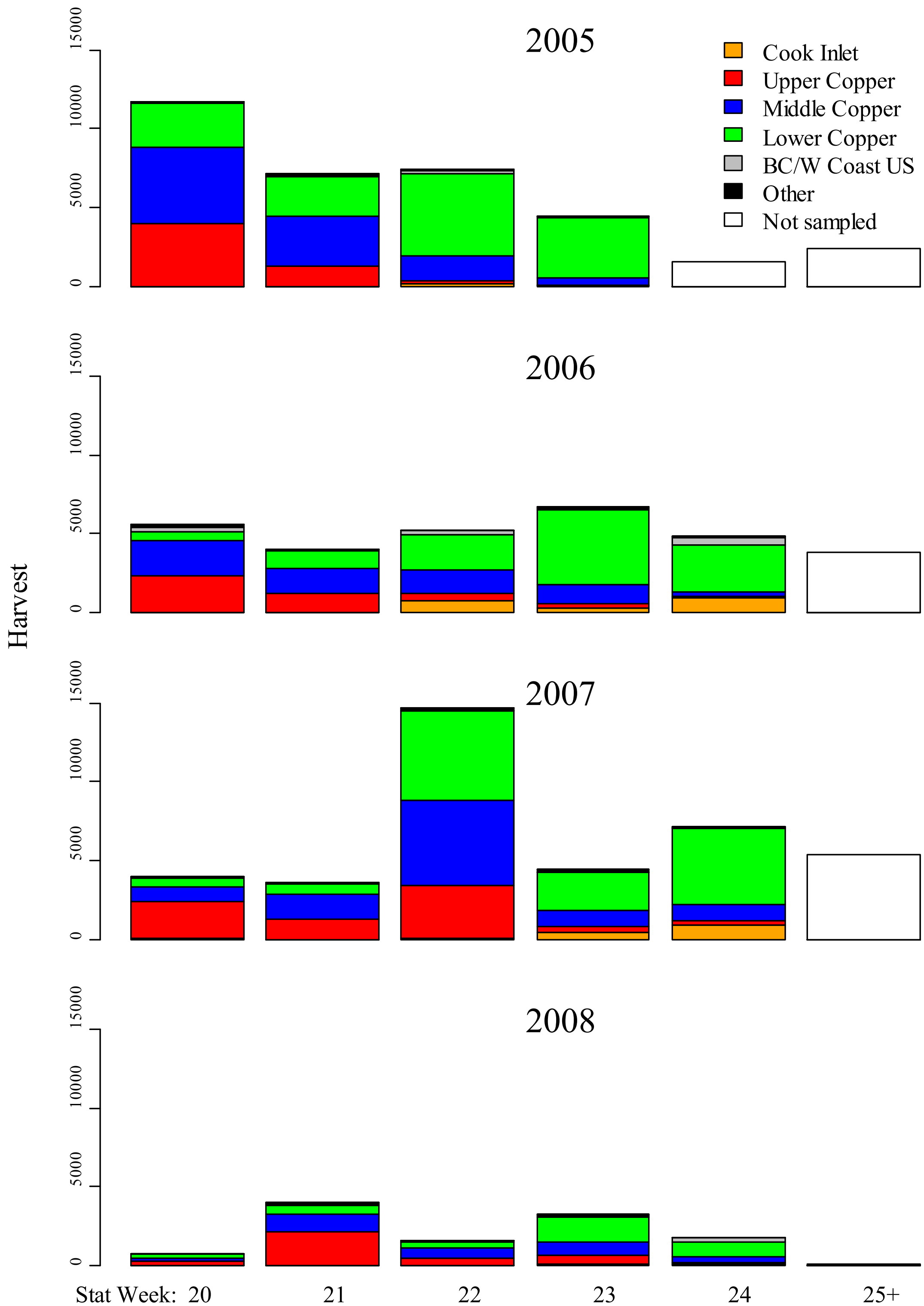
Note: Numbers refer to population numbers listed in Table 1. Asterisks indicate nodes that were present in more than 50% of 1,000 bootstrap trees.

Figure 2.–Neighbor-joining consensus tree depicting genetic similarities among populations of Chinook salmon spawning adjacent to the Gulf of Alaska.



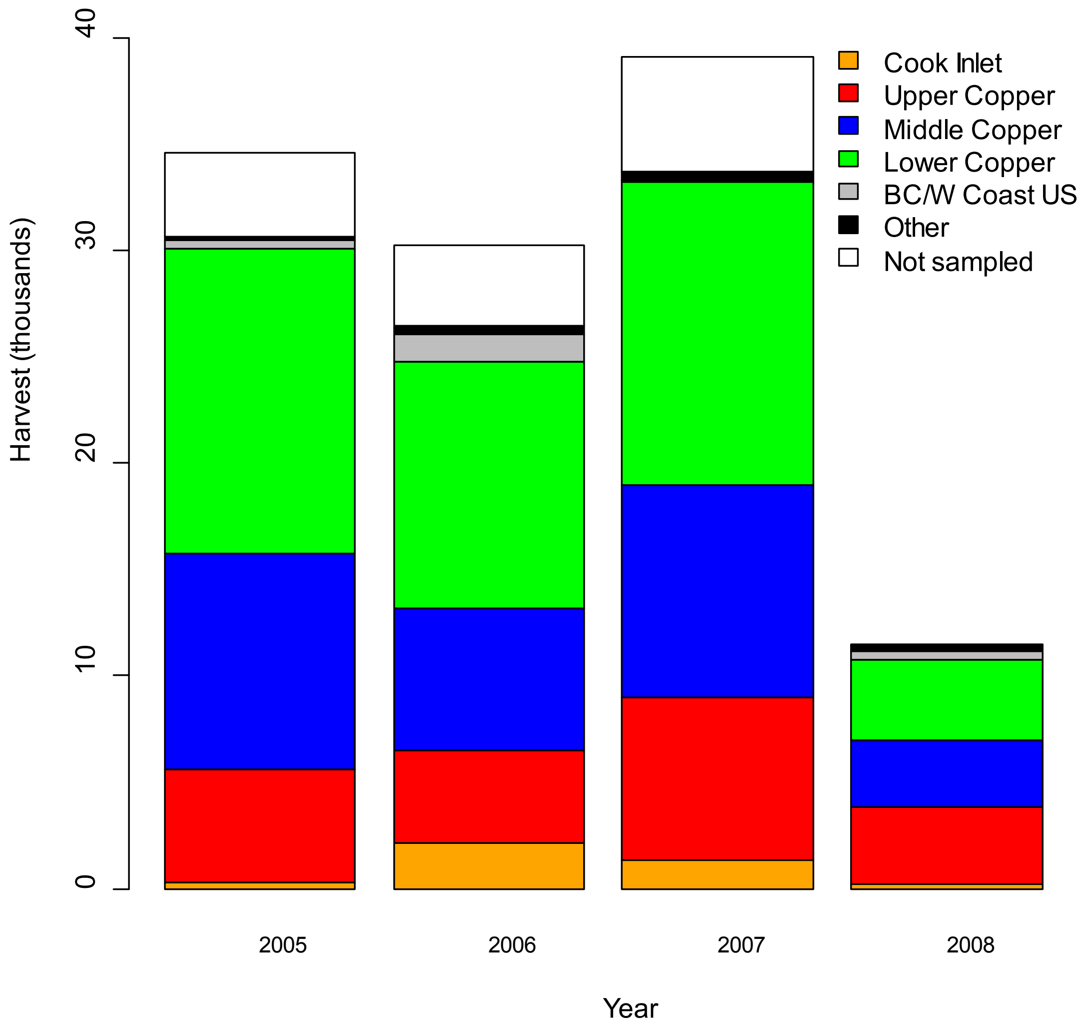
Note: In 2008, statistical week 25 was combined with statistical week 24.

Figure 3.–Estimates of stock composition of weekly Chinook salmon harvest by reporting group for the Copper River commercial fishery, 2005–2008.



Note: Harvest numbers for periods not sampled for mixed stock analysis are provided for comparison. In 2008 statistical week 25 was combined with statistical week 24.

Figure 4.–Estimates of stock composition of the harvest of Chinook salmon in the Copper River District commercial fishery, 2005–2008.



Note: Harvest numbers for periods not sampled for mixed stock analysis are provided for comparison.

Figure 5.–Estimates of harvest by stock in the Copper River District Chinook salmon fishery calculated using a stratified estimator for all weeks within years, 2005–2008.