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Genetic Stock Composition Analysis of Chinook Salmon (*Oncorhynchus tshawytscha*) Bycatch Samples from the 2020 Bering Sea Pollock Trawl Fisheries

C. M. Guthrie III, Hv. T. Nguyen, C. L. D'Amelio, K. Karpan, P. D. Barry, and W. A. Larson

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National Oceanic and Atmospheric Administration
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Alaska Fisheries Science Center

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NOAA FISHERIES

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ABSTRACT

Genetic analysis of Chinook salmon (*Oncorhynchus tshawytscha*) captured as bycatch in the 2020 Bering Sea-Aleutian Island (BSAI) trawl fishery for walleye pollock (*Gadus chalcogrammus*) was undertaken to determine the overall stock composition of the bycatch and examine variation in stock compositions across space and time. Samples were genotyped for 37 single nucleotide polymorphism (SNP) DNA markers and stock compositions were estimated using a SNP baselined developed by the Alaska Department of Fish and Game (ADF&G). Genetic samples were collected using a systematic random sampling protocol where one out of every 10 Chinook salmon encountered was sampled. Based on analysis of 2,614 Chinook salmon bycatch samples, Coastal Western Alaska was the largest contributor (52%), with smaller contributions from British Columbia (15%), North Alaska Peninsula (13%), and West Coast US (7%) The proportional contribution of Western Alaska stocks was higher than the average over the last ten years (44%) and the proportion of Middle (2%) and Upper Yukon (2%) stocks was about average (2% and 4%, respectively). In total, we estimated that 16,796 (16,032-17,561 95% CI) fish were caught from Coastal Western Alaska stocks, 670 (396-981 95% CI) were caught from the Middle Yukon and 729 (517-968 95% CI) were caught from the Upper Yukon. The number of fish caught from the Coastal Western Alaska stock was substantially higher than the 10-year average and represented the second highest catch in the last decade. In general, the contributions of southern stocks (British Columbia and West Coast US) were lower than average in 2020 declining since 2018, contributions from Western Alaska were above average, and all other stock groups were similar to their 10-year average.

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INTRODUCTION

Pacific salmon (*Oncorhynchus* spp.) are prohibited species in the federally managed Bering Sea groundfish fisheries, which are subject to management rules (NPMFC 2017a) that are in part designed to reduce prohibited species catch, hereafter referred to as "bycatch". It is important to understand the stock composition of Pacific salmon caught in these fisheries, which take place in areas that are known feeding habitat for multiple brood years of Chinook salmon (*Oncorhynchus tshawytscha*) from many different localities in North America and Asia (Myers et al. 2007, Davis et al. 2009). Chinook salmon are economically valuable and highly prized in commercial, subsistence, and sport fisheries. Determining the geographic origin of salmon caught in federally managed fisheries is essential to understanding the effects that fishing has on Chinook salmon stock groups, especially those with conservation concerns (NPFMC 2017a). This report provides genetic stock identification results for the Chinook salmon bycatch samples collected from the Bering Sea walleye pollock (pollock; *Gadus chalcogrammus*) trawl fishery. National Marine Fisheries Service (NMFS) geographical statistical areas (NMFS area) associated with the Bering Sea groundfish fishery (NMFS areas 509-524) and Alaska Department of Fish and Game (ADF&G) statistical areas grids[1] (Fig. 1) are used to describe the spatial distribution of the Chinook salmon bycatch and genetic samples.

Amendment 91 to the North Pacific Fishery Management Council (NPFMC) Fishery Management Plan (FMP) for groundfish of the Bering Sea Aleutian Island (BSAI) Management Area was enacted in 2010 and included retention of all salmon caught in the pollock fishery. In 2011, a systematic random sampling design recommended by Pella and Geiger (2009) was

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[1] http://www.adfg.alaska.gov/static/fishing/PDFs/commercial/chart03_bs.pdf

implemented by the Alaska Fisheries Science Center's (AFSC) Fisheries Monitoring and Analysis Division's (FMA) North Pacific Groundfish and Halibut Observer Program (Observer Program) to collect genetic samples from one out of every 10 Chinook salmon encountered as bycatch in the Bering Sea pollock fishery.

In 2020, genetic samples were collected by the Observer Program from the Chinook salmon caught as bycatch in the Bering Sea pollock fishery. The number of available samples and the unbiased sampling methodology facilitated the extrapolation of the sample stock composition to the overall Chinook bycatch from the Bering Sea pollock trawl fishery in 2020. Samples were collected from both the Bering Sea "A" season which started 01/01/2020 and ended 06/09/2021, and the Bering Sea "B" season which started 6/10/2020 and ended 12/31/2020. Stock composition analyses were performed using the single nucleotide polymorphism (SNP) baseline provided by ADF&G (Templin et al. 2011), the same baseline that was used previously to estimate stock composition of samples from the 2005-2019 Chinook salmon bycatch (NMFS 2009; Guyon et al. 2010a,b; Guthrie et al. 2012-2021; Larson et al. 2013).

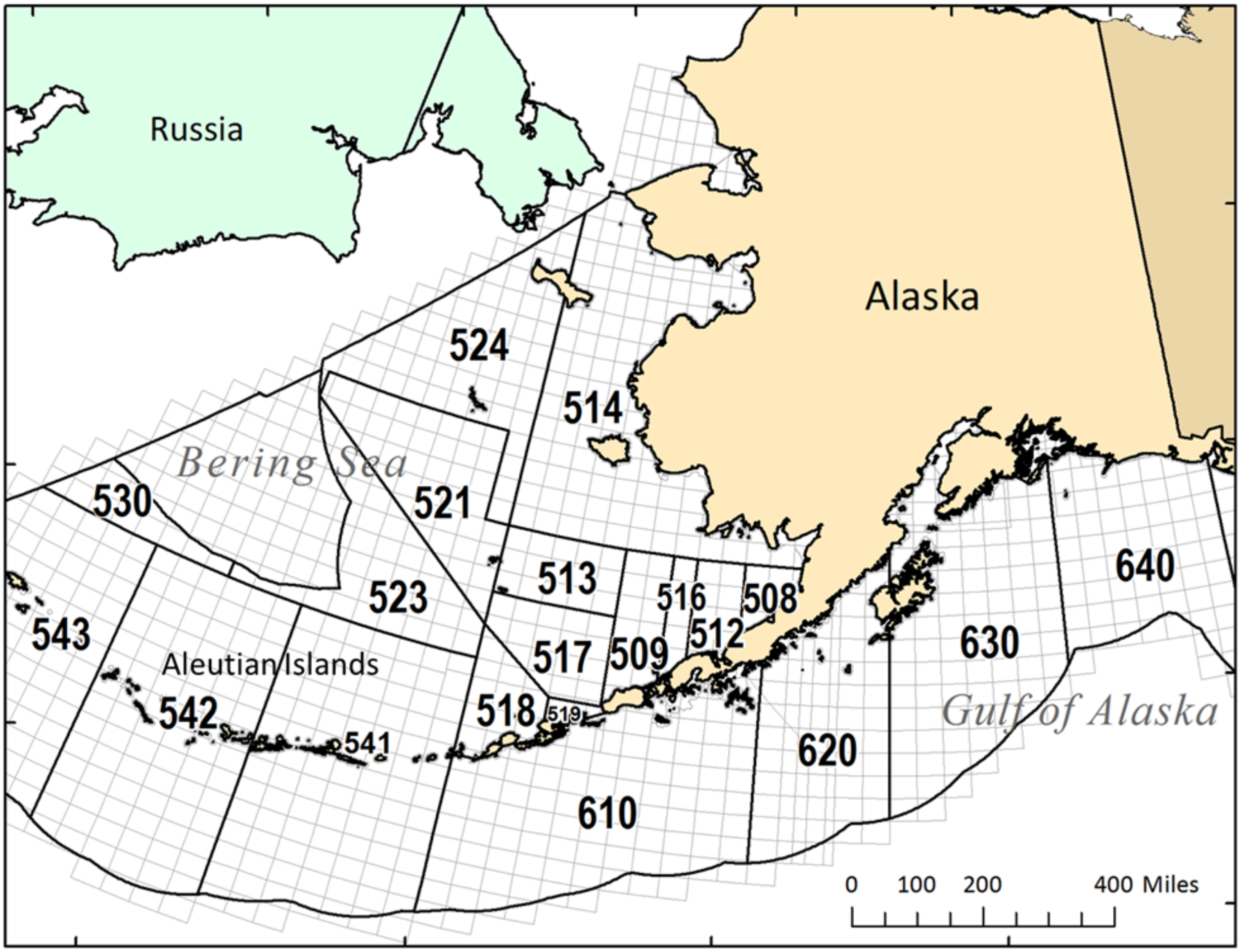

Figure 1. -- NMFS (outlined in black) and ADF&G (outlined in light gray) statistical areas associated with the Bering Sea and Gulf of Alaska groundfish fisheries.

SAMPLE DISTRIBUTION

Samples were collected from Chinook salmon bycatch by the Observer Program for analysis at AFSC's Auke Bay Laboratories (ABL). Axillary process tissues and 3-4 scales were stored in coin envelopes which were labeled, frozen, and shipped to ABL for analysis. Scales were collected as an additional source for ageing and a backup for genetic analysis.

In 2020, an estimated 32,294 Chinook salmon were taken in the bycatch of BSAI pollock trawl fisheries (NMFS 2021). The Chinook salmon bycatch estimate is 6% below the historical average (34,589) between 1991 and 2019, and far below the highest overall Chinook bycatch in

2007 when an estimated 122,195 fish were taken (Fig. 2). Of the total 2020 bycatch, 18,369 were from the trawl “A” season and 13,925 were from the “B” season. For the genetic analysis, the “B” season started on 6/01/20 (Statistical Week 23) because all but one of the “A” season samples were collected by 4/18/20. This difference is reflected in Appendix 2.

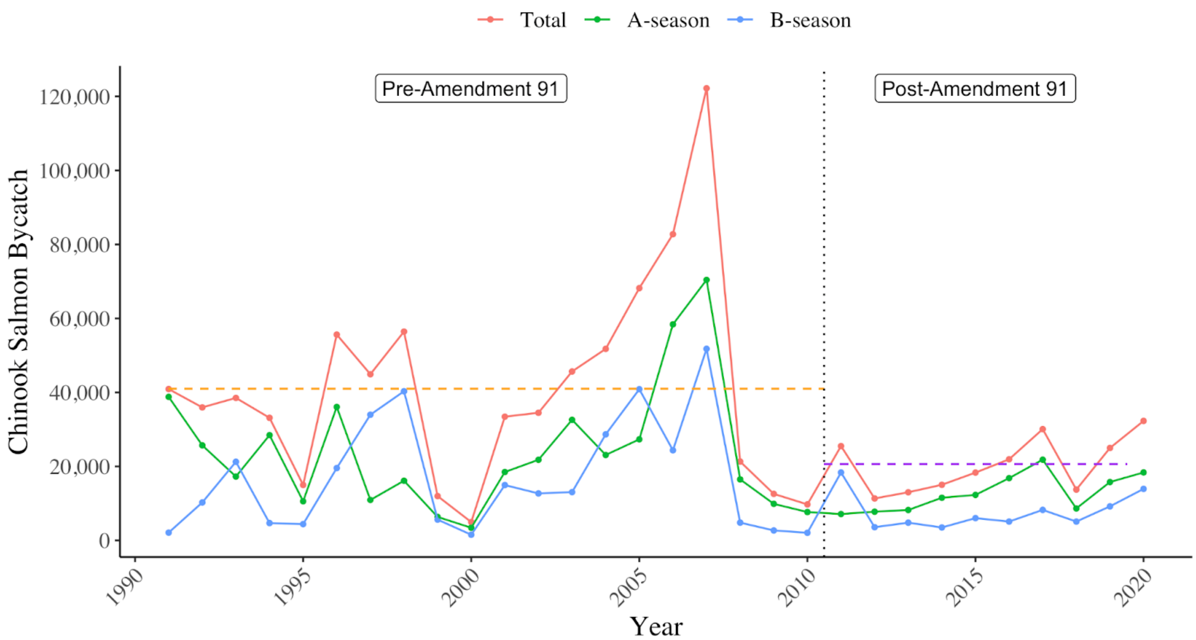

Figure 2. -- Annual “A” and “B” season estimates for the Chinook salmon bycatch from the Bering Sea pollock trawl fishery (NMFS 2021). The yellow dashed line shows the average bycatch before Amendment 91 and the purple shows the average after.

In 2020, there were 3,241 genetic samples received from the Bering Sea Chinook salmon bycatch collected by the Observer Program; of those samples, 2,614 were successfully genotyped for an overall genotyped sampling rate of 8.1% (“A” season N = 1,371 fish, 7.5% sampling rate; “B” season N = 1,243 fish, 8.9% sampling rate).

Potential biases primarily introduced through spatial and temporal aspects of genetic sample collection from the bycatch are well documented and have the potential to affect resulting stock composition estimates (Pella and Geiger 2009). The distributions of 2020 Chinook salmon bycatch genetic samples were evaluated by comparing the collection of genetic samples with the overall bycatch distribution (Fig. 3). The temporal distribution of samples collected and successfully genotyped was evaluated across the two fishing seasons (Fig. 3). The sample spatial distribution was compared with the total bycatch by NMFS statistical area (NMFS area) over time (Fig. 3). While there was minor over- and under-sampling, genetic samples were generally spatially and temporally representative of the total Chinook bycatch (Fig. 3), since most under- and oversampled collections are from small bycatch collections.

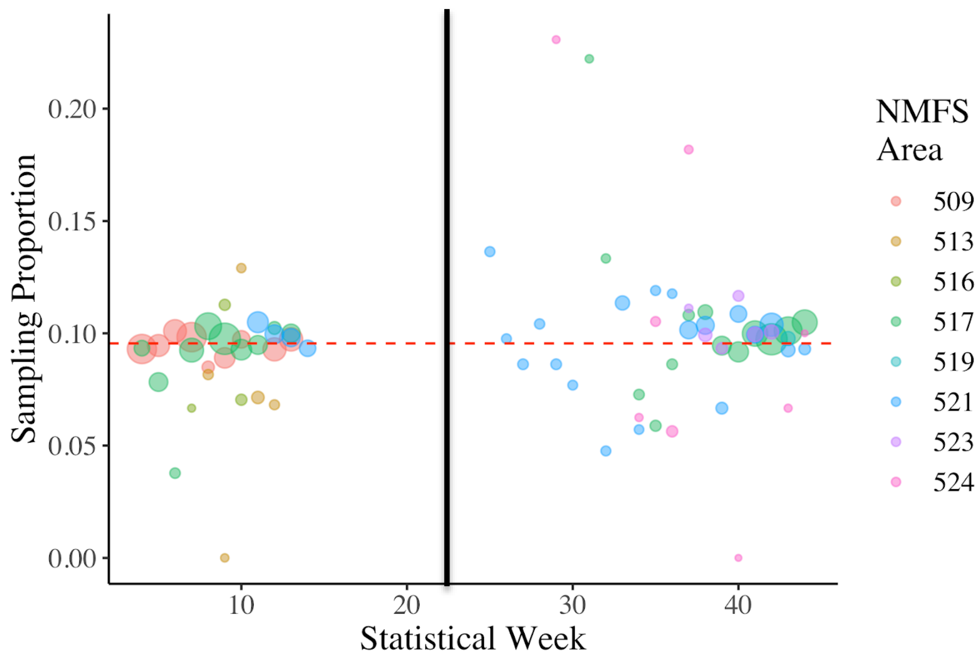

Figure 3. -- Proportion of Bering Sea Chinook salmon bycatch sampled for genetic analysis by statistical week and NMFS Statistical Areas. The size of the circles correspond to the number of bycatch fish. Weeks 4-20 correspond to the groundfish "A" season, whereas weeks 24-48 correspond to the "B" season. The black line delineates the "A" and "B" seasons. Sample sizes smaller than five not shown.

GENETIC STOCK COMPOSITION - PROCEDURE

DNA was extracted from axillary process tissues with Machery-Nagel kits (Allentown, PA) SNP genotyping was performed using Genotyping-in-Thousands by Sequencing (GTseq; Campbell et al. 2015) chemistry that uses short-read sequencing on an Illumina platform to interrogate the 37 SNP DNA markers represented in the Chinook salmon baseline (Templin et al.

2011; Appendix 4. The SNP baseline contains genetic information for 172 populations of Chinook salmon grouped into 11 geographic regions (also known as stock groups or reporting groups; Appendix 1). Proof tests performed previously have shown the baseline to be suitable for stock composition analysis using the regional reporting groups defined in Appendix 1 (Templin et al. 2011).

Sequencing libraries were prepared using the GT-seq protocol (Campbell, et al. 2015). PCR was performed on extracted DNA with primers that amplify 37 SNP loci (Templin et al. 2011). These PCR products were then indexed in a barcoding PCR, normalized using SequalPrep plates (Invitrogen) and each 96 well plate was subsequently pooled after Sequel prep normalization. Next, a double-sided bead size selection was performed using AMPure XP beads (Beckman Coulter), using ratios of beads to library of 0.5x to remove non-target larger fragments and then 1.2x to retain the desired amplicon. Libraries were sequenced on a MiSeq (Illumina) using a single 150-cycle lane run with 2×75 bp paired-end (PE) chemistry. PE reads for each individual were joined with FLASH2 (Magoč & Salzberg, 2011; https://github.com/dstreett/FLASH2). Merged reads were genotyped with the R package GTscore (McKinney; https://github.com/gjmckinney/GTscore). Individuals with low quality multilocus genotypes (< 80% of loci scored) were discarded. We re-genotype 3% of all project individuals as quality control measures.

From the 2020 Chinook salmon bycatch from the Bering Sea pollock trawl fishery, a total of 3,241 samples were analyzed of which 2,614 samples were successfully genotyped for 30 or more of the 37 SNP loci, a successful genotyping rate of 81%. The successfully genotyped samples had genetic information for an average of 36 of 37 markers from both the “A” (n = 1,371) and “B” (n = 1,243) seasons. Unfortunately, the Dutch Harbor air cargo carrier left a large percentage of the “A” season samples in their warehouse unfrozen for over a month, which resulted in the lowered genotyping success rate for the “A” season. We were pleasantly surprised that we were able to extract as much genotypic information as we did given this logistical error.

Mixtures were created by separating sampled fish into spatial and temporal groups from observer data from the AKFIN database. Genetic stock identification was performed with the conditional genetic stock identification model in the R package *rubias* (Moran and Anderson 2019). For all estimates, the Dirichlet prior parameters for the stock proportions were defined by region to be 1/(GCg), where Cg is the number of baseline populations in region g, and G is the number of regions. To ensure convergence to the posterior distribution, 11 separate MCMC chains of 70,000 iterations (burn-in of 35,000) of the non-bootstrapped model were run, with each chain starting at disparate values of stock proportions; configured such that for each chain 95% of the mixture came from a single designated reporting group (with probability equally distributed among the populations within that reporting group) and the remaining 5% equally distributed among remaining reporting groups. The convergence of chains for each reporting group estimate was assessed with the Gelman-Rubin statistic (Gelman and Rubin 1992) estimated with the gelman.diag function in the *coda* library (Plummer et al. 2006) within R. Once chain convergence was confirmed, inference was conducted with the conditional genetic stock identification model with bootstrapping over reporting groups (70,000 MCMC iterations, burn-in of 35,000, 100 bootstrap iterations).

GENETIC STOCK COMPOSITION - RESULTS

For “A” and “B” seasons combined, 69% of the bycatch samples were estimated to be from Alaska river systems flowing into the Bering Sea (Appendix 1, Reg. Num. numbers 2-5) with the Coastal Western Alaska region contributing the most (52%), followed by the North Alaska

Peninsula (13%). Thirty-one percent of all of the samples were from the southern (Appendix 1, Reg. Num. numbers 6, 9-11) regions, with the British Columbia (15%) region contributing the most, followed by the West Coast US (7%) and Northwest GOA (6%) regions (Appendix 2, Fig. 5).

The stock composition results indicate that 81% of the 1,371 Chinook salmon samples from the "A" season originated from Alaska river systems flowing into the Bering Sea with the largest contributions from Coastal Western Alaska region (52%) and the North Alaska Peninsula (25%). The remaining 19% were from southern regions with British Columbia (12%) contributing the most, followed by the West Coast US (3%) (Appendix 2, fig. 5). In the "B" season, 58% percent of the 1,243 "B" season samples originated from Alaska river systems flowing into the Bering Sea with the largest contribution from Coastal Western Alaska region (54%), while 32% were from southern regions; British Columbia (18%), West Coast US (11%), and Northwest GOA (9%) regions (Appendix 2, Fig. 5).

Using information from the ANSWERS tool provided by AKFIN (NMFS 2022), geographical (ADF&G statistical areas) aggregations were developed to investigate how stock compositions might vary among smaller areas of interest to the NPFMC. It should be noted that some of these strata overlap, with some samples being used in multiple analyses.

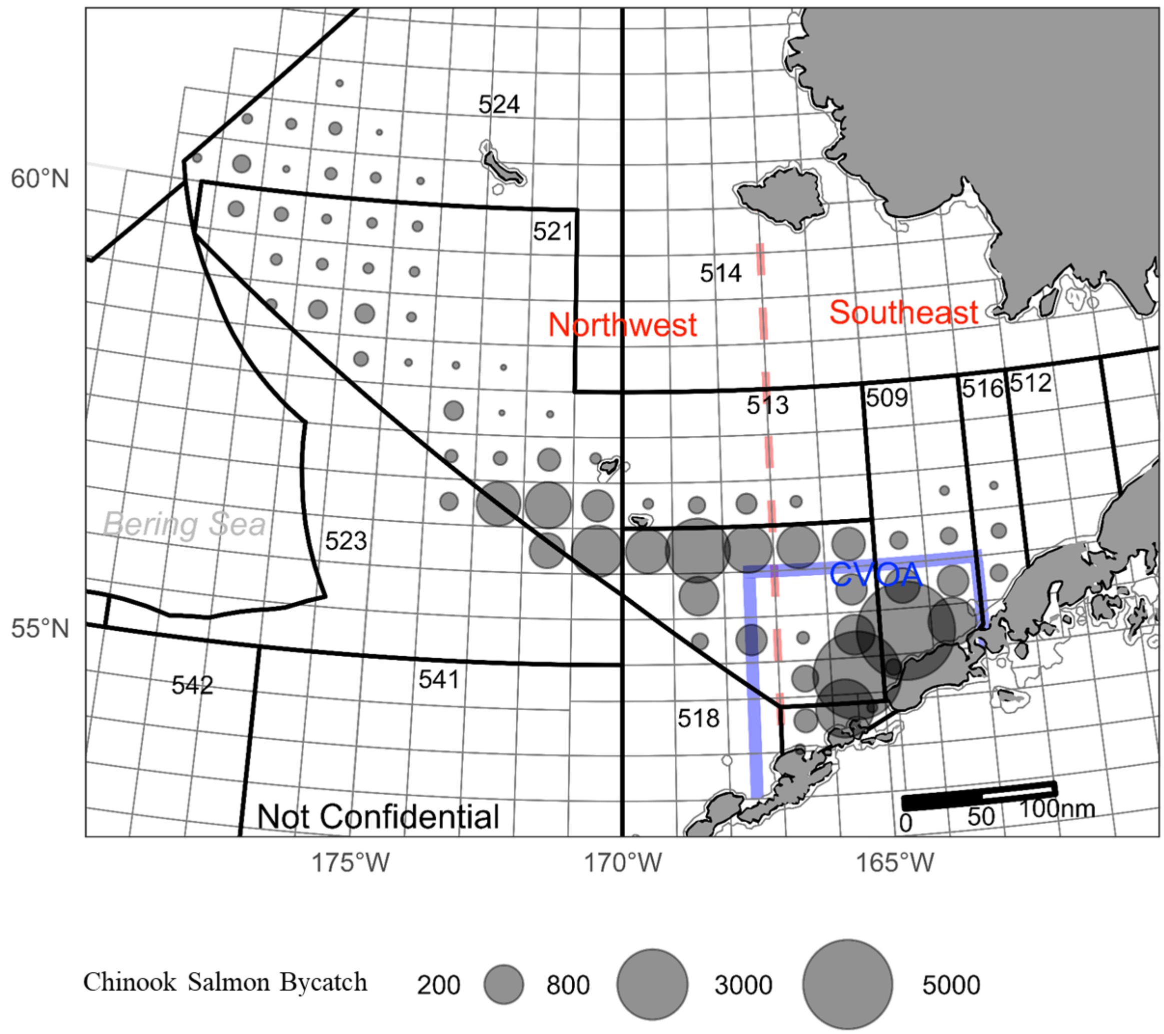

Figure 4. -- Location of sample strata used in comparative stock composition estimates from the 2020 Bering Sea Chinook salmon bycatch. Circles represent the amount of total bycatch in each stratum. The red dashed line delineates the Northwest and Southeast strata, while the solid blue line shows the boundary of the CVOA (NMFS 2021).

The “A” season estimates were developed for overlapping strata with sufficient numbers of samples (Appendix 2; Figs. 4, 5); Catcher Vessel Operation Area (CVOA) (659 samples, Figs. 4, 5), NMFS Statistical Area 509 (578 samples; Figs. 1, 5), Southeast Bering (792 samples, Figs. 4, 5), and Northwest Bering (579 samples, Figs. 4, 5). Over 73% of the Chinook salmon bycatch in the CVOA, NMFS Area 509 and Southeast Bering strata during the “A” season were from Alaska river systems flowing into the Bering Sea. For the CVOA, NMFS area 509, and

Southeast Bering Sea during the “A” season, most fish were from Coastal Western Alaska (47%, 46%, and 47%, respectively) followed by North Alaska Peninsula at (26%, 26% and 28%). The largest southern components for CVOA, NMFS Area 509 and Southeast Bering Sea during the “A” season were British Columbia (18%, 20% and 16%, respectively) and West Coast US (5%, 5% and 4%). For the Northwest Bering “A” season stratum, 88% of the bycatch was estimated to

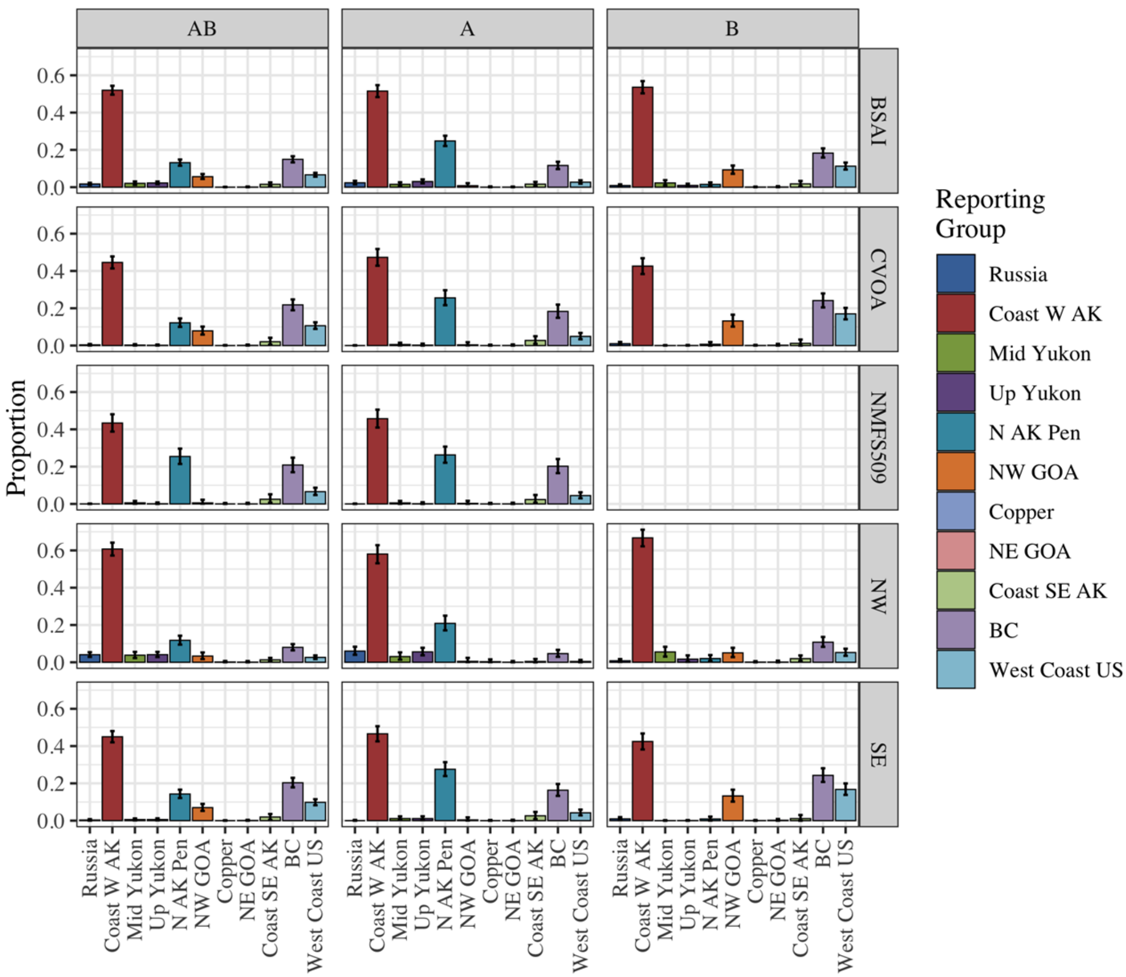

Figure 5. -- Stock composition estimates with 95% credible intervals of the 2020 BSAI Chinook salmon bycatch for overall (3,241 samples) “A” and “B” seasons; CVOA overall (1,325 samples), “A” and “B” season; NMFS area 509 overall (1,332 samples) and “A” season (bottom); Northwest Bering overall (1,150 samples), “A” and “B” seasons; and Southeast Bering overall (1,464 samples) “A and “B” seasons (NMFS 2021)

be from Alaska river systems flowing into the Bering Sea, with the largest contributions from Coastal Western Alaska (58%) followed by North Alaska Peninsula (21%), Upper Yukon (6%)

and Mid Yukon (3%). Six percent of the stock composition was estimated to be from southern regions, with most fish from British Columbia (5%).

For the “B” season, stock composition estimates were developed for CVOA (766 samples, Figs. 4, 5), Southeast Bering (672 samples, Figs. 4, 5), and Northwest Bering (372 samples, Figs. 4, 5) (NMFS 2021). For the Northwest Bering “B” season stratum, 76% of the stock composition was estimated to be from Alaska river systems flowing into the Bering Sea, which includes the largest contributor Coastal Western Alaska (67%). Twenty-three percent of the stock composition was estimated to be from southern regions, where the largest contributors were British Columbia (11%), Northwest GOA (5%) and West Coast US (5%).

Fifty-six percent of the “B” season stock composition estimates for the CVOA and Southeast Bering were from southern regions (Fig. 5, Appendix 2). The largest contributors were British Columbia (25% for CVOA, 24% for Southeast Bering), West Coast US (16% for CVOA, 17% for Southeast Bering), and Northwest GOA (13%). The major contributor from the Bering Sea was Coastal Western Alaska at 43% for CVOA and Southeast Bering. It is important to note that CVOA is a subsection of the Southeast Bering where most of the bycatch occurs.

Both the CVOA and Southeast Bering “B” season samples had a higher proportion of fish from southern regions (56%) than the “B” season overall (41%). The stock compositions were highly variable in the CVOA and Southeast Bering across the seasons. It is notable that the contribution from the West Coast US region increased from 5% to 17% for CVOA and Southeast Bering strata from the “A” and “B” seasons while the contribution from the Northern Alaska Peninsula region decreased from ~27% to almost zero in the same time frame. The Northwest GOA region increased from almost zero to 13% between the CVOA and Southeast Bering “A” and “B” seasons. The largest differences in the Northwest Bering between the “A” and “B” seasons were the increase of Coastal Western Alaska from 58% to 67% and the decrease of North Alaska Peninsula from 21% to 2%.

COMPARISON WITH PREVIOUS ESTIMATES

About 60% of the Chinook salmon bycatch in 2020 occurred during the “A” season (Fig. 2), which is similar to most previous years since 2011. As in most previous years (with the exception of 2017), stock compositions from the analysis of the 2020 “A” season Chinook salmon bycatch showed that the majority of fish originated from river systems flowing into the Bering Sea (81%; Fig. 6). The Coastal Western Alaska region was the largest contributor in the 2020 “A” season, consistent with every year except 2017. The 2020 “B” season stock composition estimates from Coastal Western Alaska at 52% was higher than 2018 and 2019 (~30%), with Coastal Western Alaska contributions in all three of these years being substantially more than 2016 and 2017 when Coastal Western Alaska stock proportions were closer to 15% (Fig. 6, Appendix 3). Contrastingly, the higher levels of southern stock groups contributions observed from 2015 to 2018 are continuing to decrease. The estimated relative contributions from these more southern regions in the “B” season previously increased from a low of 20% in 2011 to a high of 86% in 2017, declining to 63% in 2018, and bumping up slightly to 67% in 2019, then dropping to 41% in 2020 (Fig. 6, Appendix 3).

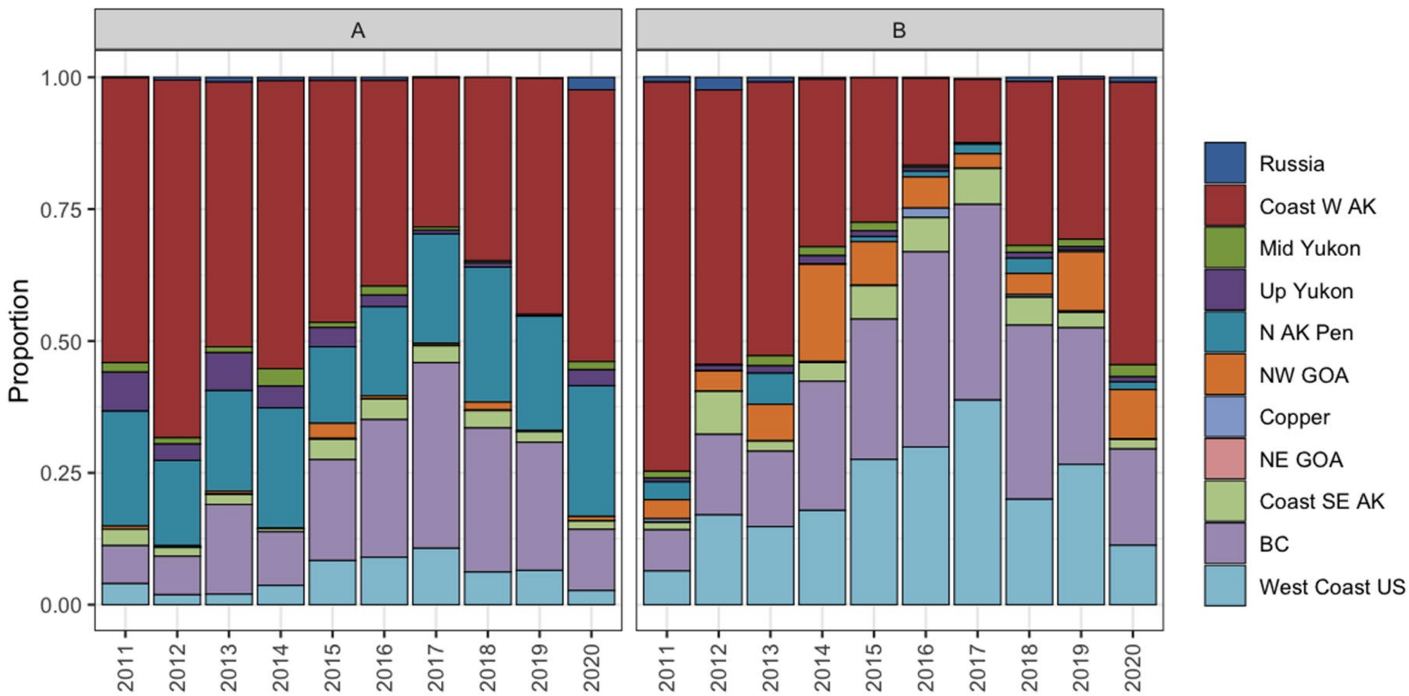

Figure 6. -- Annual "A" season (left) and "B" season (right) genetic stock composition estimates for 2011-2020 from the Bering Sea Chinook salmon bycatch.

When the stock compositions were analyzed on a yearly basis, the Coastal Western Alaska region shows variable contributions over time, but it was generally trending downward since 2011 until 2017, and since 2018 it has been trending upwards (Fig. 7). The 2020 North Alaska Peninsula region contribution of 13% was about average compared to previous years (Fig. 7). The Upper and Middle Yukon River, GOA, and Coastal Southeast Alaska contributions continued to be low in 2020, while contributions from the British Columbia and West Coast US regions have generally decreased from 2017 to 2020 (Fig. 7).

The estimated numbers of Chinook salmon caught as bycatch from Coastal Western Alaska stocks has varied from a high of 17,421 in 2011 to a low of 4,635 in 2018 (Fig. 7, Appendices 2, 3). Total catches of Coastal Western Alaska stocks were relatively stable from 2012 to 2018 and were consistently below 8,000 fish. In 2019, the catch increased slightly to near 10,000. In 2020 the catch further increased to nearly 17,000, close to the high in 2011.

Catches from the North Alaska Peninsula stock group have been relatively consistent over the last decade, ranging from ~2,500 to 5,000. Catches of southern stocks from British Columbia and the US West Coast peaked in 2017 at ~15,000 fish but generally range between 5,000 and 10,000. Catches of these two stocks in 2020 were the lowest since 2015. It is important to note these catch estimates represent the removals by region in each year but they cannot be used as is to represent any trends in the impact rates to particular regions over time because the amount of bycatch and areas fished vary. Stock-specific impacts are best estimated with adult equivalency models (Ianelli and Stram 2015).

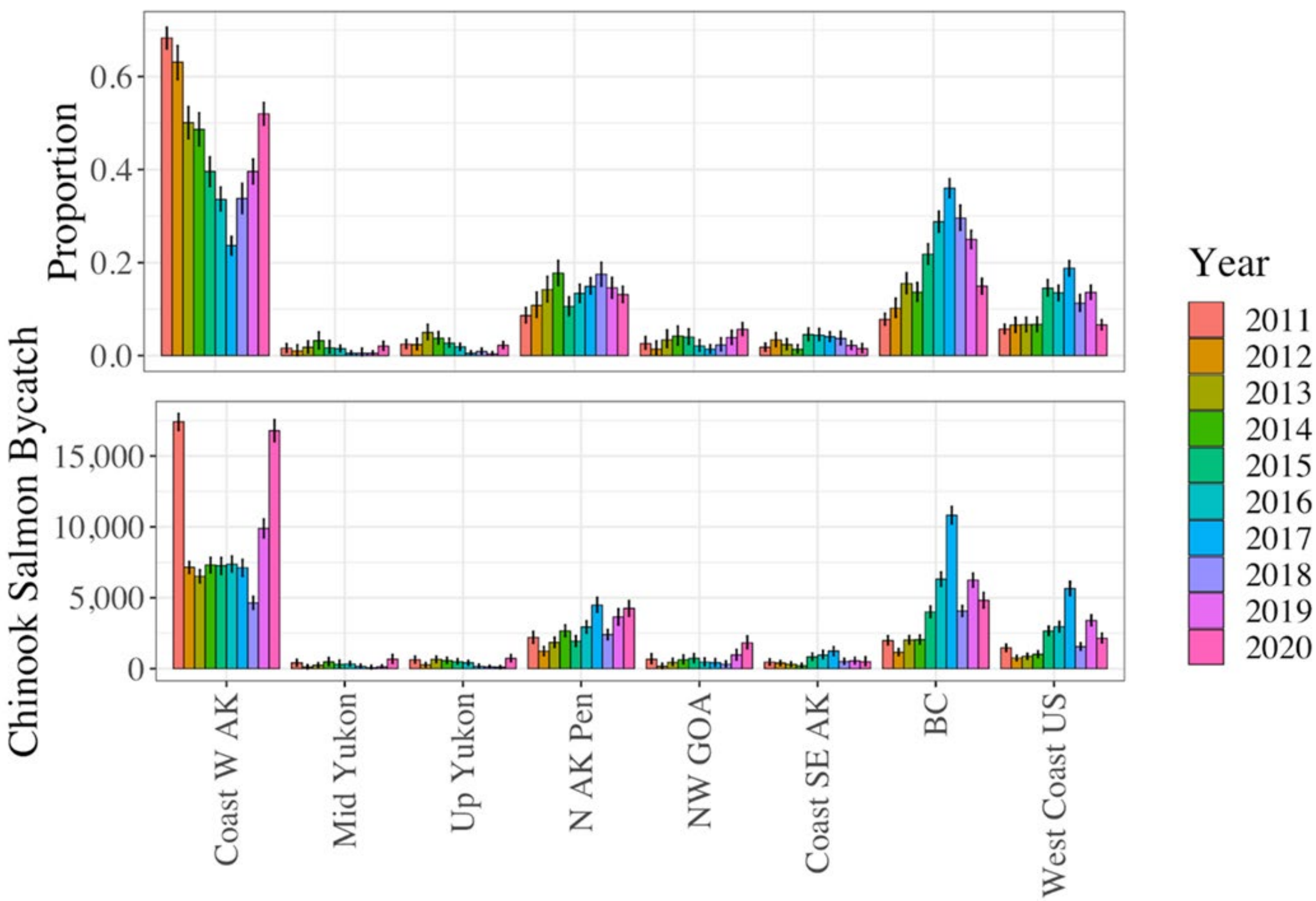

Figure 7. -- Annual (2011-2020) stock composition estimates with 95% credible intervals from the Bering Sea Chinook salmon bycatch (Top). Annual (2011-2020) bycatch estimates in numbers of fish with 95% credible intervals from the Bering Sea Chinook salmon bycatch (Bottom). Regions with low catches, Russia (Avg. N = 145) Copper (Avg. N = 22), and Northeast GOA (Avg. N = 6) were omitted.

AGE COMPOSITION ANALYSIS

Ageing Methods

Obtaining ages is important for parameterizing adult equivalency models and can also provide information on specific cohorts that can be used to better understand stock composition trends. The AFSC genetics program received paired genetic and scale samples from the Observer program. Scales were removed from sample envelopes and cleaned of dried slime and grit by moistening the scale with RO water and gently rubbing the scale between thumb and forefinger. Clean scales were then moistened and the sculptured side of the scale was mounted up on the scale gum card. Acetate impressions of each card of scales were made with a PHI PW22OH scale press. All acetate impressions were delivered to the ADF&G Mark Tag and Age Lab (MTA Lab) for age estimation. All age estimates are stored in the AKFIN database with paired observer information.

BSAI Ages

Of the 2,926 scales that were pressed, 1,782 scales were successfully read by the ADF&G MTA Lab (Fig. 8). The most common freshwater and saltwater zone error codes were inverted and wrong species. The most common freshwater age was 1 (79.2%), followed by age 0 (20.7%) whereas the most common saltwater ages were 2 (46.9%), 3 (30.9%), and 1 (14.8%). Of the three-, four-, and five-year-old fish caught in the BSAI trawl fishery, the majority were from Coastal Western Alaska (48.58%, 53.27%, and 56.03%, respectively). Middle and Upper Yukon stock groups contributed a relatively small amount, with the largest contribution of Middle Yukon stocks to the age-4 and age-5 mixtures (2.7 and 2.8%) and Upper Yukon to the age-5 and age-6 mixtures (7.7% and 6.6%). The North Alaska Peninsula stock groups comprised the largest proportion of the oldest age class of fish, 6-year-olds (59.5%), with progressively declining contributions at younger ages. Northwest Gulf of Alaska stock groups comprised 10.9% and 4.8% of the age-3 and age-4 mixtures but contributed less than 1% to age-5 and age-6 mixtures. The southernmost stock groups (BC and West Coast US) were predominately age-3 and age-4 when captured, comprising 32.1% and 23.3%, respectively.

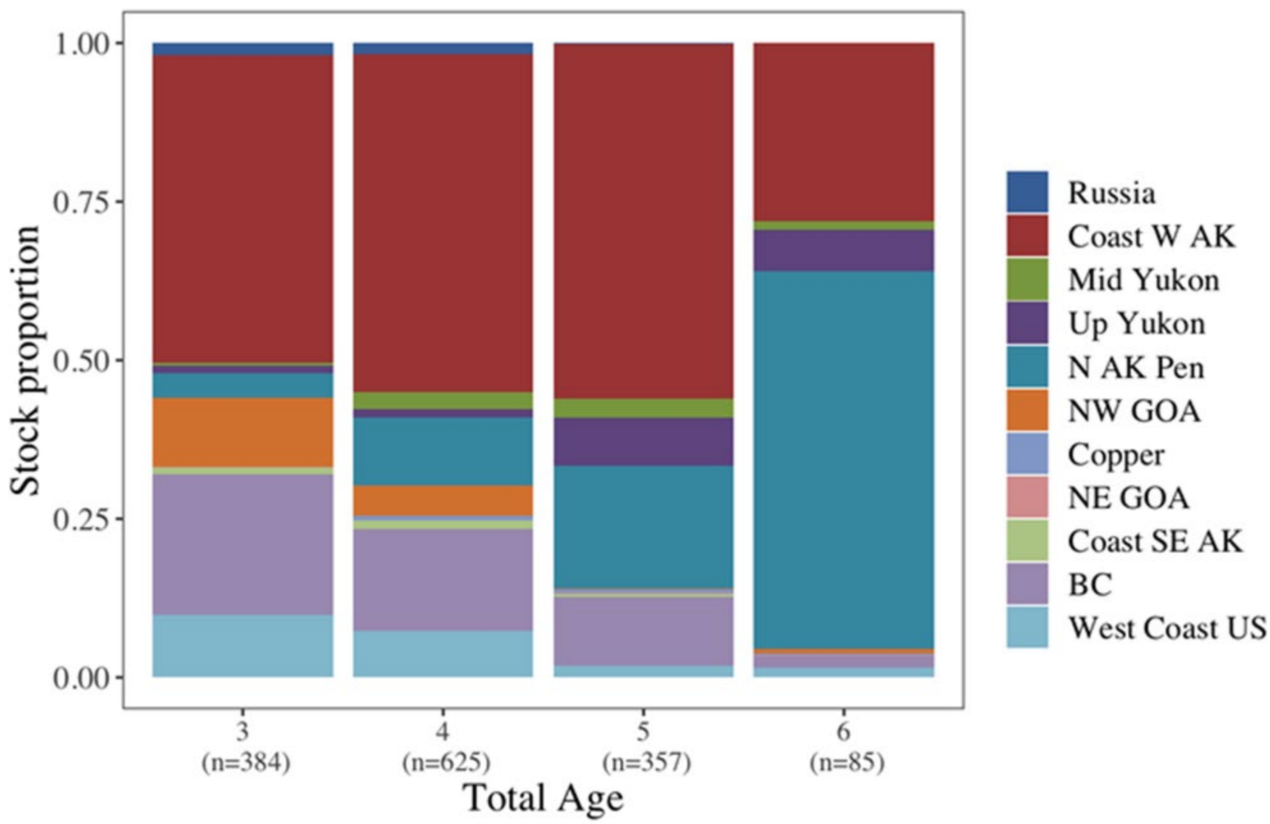

Figure 8. -- Stock Composition of the four age classes of Bering Sea Chinook salmon bycatch. The number of successfully aged samples is below the respective bars.

SUMMARY

Stock composition estimates of the Chinook salmon bycatch inform pollock and salmon fishery managers of the biological effects of the incidental take of salmon in the trawl fishery (Ianelli and Stram 2015). The incidental harvest of Chinook salmon in the Bering Sea pollock fishery averaged 34,258 salmon per year between 1991 and 2019 (29-year average), with a peak of 121,195 in 2007 and a low of 4,961 in 2000 (Fig. 2; NMFS 2021). The Bering Sea Chinook salmon bycatch has abated somewhat in more recent years. The incidental harvest between 1991 and 2010 averaged 40,976 and after the implementation Amendment 91 between 2011 and 2019 the average dropped to 19,328 (Fig.2; NMFS 2021). In 2020, a total of 32,294 Chinook salmon were caught, which is below the 28-year average, but above the 9-year post-Amendment 91 average.

Sampling Issues

With the implementation of systematic random sampling, 2020 is the tenth year from which representative samples have been collected from the Chinook salmon bycatch. Systematic random sampling represents a substantial effort on the part of the Observer Program to develop standardized protocols for collecting sets of samples from numerous observers both at sea and in shore-based processing plants, the results of which are clearly apparent in the representative nature of the sample sets (Figs. 3). The number of successfully genotyped Chinook salmon from the Bering Sea bycatch samples was 2,614 corresponding to an effective overall sampling rate in 2020 of 8.1%, despite mishandling of samples noted earlier by a Dutch Harbor air cargo carrier.

Stock Composition Estimates

The proportions of Chinook salmon originating from Alaska rivers flowing into the Bering Sea accounted for most of the catches in early post-amendment 91 years, but southern regions have accounted for larger and larger proportions in more recent years with a maximum in 2017, where southern stocks accounted for more than half of the bycatch. The 2018-2020 data may signal a change to this pattern, with Chinook salmon originating from Alaska rivers flowing into the Bering Sea accounting for more than two-thirds of the bycatch in 2020 (Appendices 2, 3). The stock composition of the Chinook salmon bycatch from the 2019 “A” season differed from the “B” season, demonstrating temporal changes (Appendix 2; Figs. 5 and 6). This was especially apparent for the North Alaska Peninsula (25% and 2%) region. The largest contributor to both “A” and “B” season fisheries was the Coastal Western Alaska region which increased slightly from “A” to “B” (52% to 54%).

Spatial analysis showed that the stock compositions varied within season depending upon where the salmon were caught. For example, during the “B” season a higher proportion of Coastal Western Alaska Chinook salmon were intercepted in the northwestern area of the Bering Sea, and a higher proportion of southern origin Chinook salmon were intercepted in the southeastern area of the Bering Sea (Fig. 5). Analysis of bycatch by age indicated that fish from the Coastal Western Alaska region were encountered at similar rates across the primary ages (3, 4, 5). Fish from southern stocks (NW GOA, British Columbia, and West Coast US) were encountered more frequently at younger ages. This is the first analysis year where age estimates have been widely available and more scale are currently ageing additional years to investigate temporal trends in stock compositions by age. It is notable that the North Alaska Peninsula stock group comprised the largest proportion of the oldest age class of fish.

Application of Estimates

Stock composition estimates for the 2020 Bering Sea Chinook salmon bycatch were mostly representative of the overall bycatch for this year and are presented in relative contributions as well as estimated numbers of fish. The extent to which any salmon stock group is impacted by the bycatch of the Bering Sea trawl fishery is dependent on many stock-specific factors including 1) the overall numbers of the stock in the bycatch, 2) the ages of the salmon caught in the bycatch by stock group, 3) the ages of the returning salmon by stock group, and 4) the total annual run-size of the affected stock groups. Because the effect of stock-specific numbers of Chinook salmon in the bycatch is moderated by several factors, a higher contribution of a particular stock group in one year does not necessarily imply greater impact than a smaller estimate the next.

ACKNOWLEDGMENTS

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APPENDICES

Appendix 1. -- Chinook salmon populations in the ADF&G SNP baseline with the regional designations used in the analyses of this report. S. = South, R. = River, H. = Hatchery, and L. = Lake.

Population name	Reg Num.	Region	Population name	Reg Num.	Region
Bistraya River	1	Russia	Henshaw Creek	3	Mid Yukon
Bolshaya River	1	Russia	Kantishna River	3	Mid Yukon
Kamchatka River late	1	Russia	Salcha River	3	Mid Yukon
Pakhatcha River	1	Russia	Sheenjek River	3	Mid Yukon
Andreafsky River	2	Coast W AK	S. Fork Koyukuk River	3	Mid Yukon
Aniak River	2	Coast W AK	Big Salmon River	4	Up Yukon
Anvik River	2	Coast W AK	Blind River	4	Up Yukon
Arolik River	2	Coast W AK	Chandindu River	4	Up Yukon
Big Creek	2	Coast W AK	Klondike River	4	Up Yukon
Cheeneetnuk River	2	Coast W AK	Little Salmon River	4	Up Yukon
Eek River	2	Coast W AK	Mayo River	4	Up Yukon
Gagaryah River	2	Coast W AK	Nisutlin River	4	Up Yukon
George River	2	Coast W AK	Nordenskiold River	4	Up Yukon
Gisasa River	2	Coast W AK	Pelly River	4	Up Yukon
Golsovia River	2	Coast W AK	Stewart River	4	Up Yukon
Goodnews River	2	Coast W AK	Takhini River	4	Up Yukon
Kanektok River	2	Coast W AK	Tatchun Creek	4	Up Yukon
Kisaralik River	2	Coast W AK	Whitehorse Hatchery	4	Up Yukon
Kogrukluk River	2	Coast W AK	Black Hills Creek	5	N AK Pen
Kwethluk River	2	Coast W AK	King Salmon River	5	N AK Pen
Mulchatna River	2	Coast W AK	Meshik River	5	N AK Pen
Naknek River	2	Coast W AK	Milky River	5	N AK Pen
Nushagak River	2	Coast W AK	Nelson River	5	N AK Pen
Pilgrim River	2	Coast W AK	Steelhead Creek	5	N AK Pen
Salmon R. -Pitka Fork	2	Coast W AK	Anchor River	6	NW GOA
Stony River	2	Coast W AK	Ayakulik River	6	NW GOA
Stuyahok River	2	Coast W AK	Benjamin Creek	6	NW GOA
Takotna River	2	Coast W AK	Chignik River	6	NW GOA
Tatlawiksuk River	2	Coast W AK	Crescent Creek	6	NW GOA
Togiak River	2	Coast W AK	Crooked Creek	6	NW GOA
Tozitna River	2	Coast W AK	Deception Creek	6	NW GOA
Tuluksak River	2	Coast W AK	Deshka River	6	NW GOA
Unalakleet River	2	Coast W AK	Funny River	6	NW GOA
Beaver Creek	3	Mid Yukon	Juneau Creek	6	NW GOA
Chandalar River	3	Mid Yukon	Karluk River	6	NW GOA
Chena River	3	Mid Yukon	Kasilof River mainstem	6	NW GOA

Population name	Reg Num.	Region	Population name	Reg Num.	Region
Kenai River mainstem	6	NW GOA	Kowatua River	9	Coast SE AK
Killey Creek	6	NW GOA	Little Tatsemenie River	9	Coast SE AK
Ninilchik River	6	NW GOA	Macaulay Hatchery	9	Coast SE AK
Prairie Creek	6	NW GOA	Medvejie Hatchery	9	Coast SE AK
Slikok Creek	6	NW GOA	Nakina River	9	Coast SE AK
Talachulitna River	6	NW GOA	Tahltan River	9	Coast SE AK
Willow Creek	6	NW GOA	Unuk R.-Deer Mountain H.	9	Coast SE AK
Bone Creek	7	Copper	Unuk River - LPW	9	Coast SE AK
E. Fork Chistochina River	7	Copper	Upper Nahlin River	9	Coast SE AK
Gulkana River	7	Copper	Big Qualicum River	10	BC
Indian River	7	Copper	Birkenhead River spring	10	BC
Kiana Creek	7	Copper	Bulkley River	10	BC
Manker Creek	7	Copper	Chilko River summer	10	BC
Mendeltna Creek	7	Copper	Clearwater River summer	10	BC
Otter Creek	7	Copper	Conuma River	10	BC
Sinona Creek	7	Copper	Damdochax Creek	10	BC
Tebay River	7	Copper	Ecstall River	10	BC
Tonsina River	7	Copper	Harrison River	10	BC
Big Boulder Creek	8	NE GOA	Kateen River	10	BC
Kelsall River	8	NE GOA	Kincolith Creek	10	BC
King Salmon River	8	NE GOA	Kitimat River	10	BC
Klukshu River	8	NE GOA	Klinaklini River	10	BC
Situk River	8	NE GOA	Kwinageese Creek	10	BC
Tahini River	8	NE GOA	Louis River spring	10	BC
Tahini River - Pullen Creek H.	8	NE GOA	Lower Adams River fall	10	BC
Andrews Creek	9	Coast SE AK	Lower Atnarko River	10	BC
Blossom River	9	Coast SE AK	Lower Kalum River	10	BC
Butler Creek	9	Coast SE AK	Lower Thompson River fall	10	BC
Chickamin River	9	Coast SE AK	Marble Creek	10	BC
Chickamin River-LPW	9	Coast SE AK	Middle Shuswap R. summer	10	BC
Chickamin R.Whitman L. H.	9	Coast SE AK	Morkill River summer	10	BC
Clear Creek	9	Coast SE AK	Nanaimo River	10	BC
Cripple Creek	9	Coast SE AK	Nechako River summer	10	BC
Crystal Lake Hatchery	9	Coast SE AK	Nitinat River	10	BC
Dudidontu River	9	Coast SE AK	Oweegee Creek	10	BC
Genes Creek	9	Coast SE AK	Porteau Cove	10	BC
Hidden Falls Hatchery	9	Coast SE AK	Quesnel River summer	10	BC
Humpy Creek	9	Coast SE AK	Quinsam River	10	BC
Kerr Creek	9	Coast SE AK	Robertson Creek	10	BC
Keta River	9	Coast SE AK	Salmon River summer	10	BC
King Creek	9	Coast SE AK	Sarita River	10	BC

Population name	Reg Num.	Region	Population name	Reg Num.	Region
Stuart River summer	10	BC	Lower Deschutes R. fall	11	West Coast US
Sustut River	10	BC	Lyons Ferry H. summer/fall	11	West Coast US
Torpy River summer	10	BC	Makah National Fish H. fall	11	West Coast US
Wannock River	10	BC	McKenzie River spring	11	West Coast US
Alsea River fall	11	West Coast US	Sacramento River winter	11	West Coast US
Carson Hatchery spring	11	West Coast US	Siuslaw River fall	11	West Coast US
Eel River fall	11	West Coast US	Soos Creek Hatchery fall	11	West Coast US
Forks Creek fall	11	West Coast US	Upper Skagit River summer	11	West Coast US
Hanford Reach	11	West Coast US			
Klamath River	11	West Coast US			

Appendix 2. -- Regional *Rubias* stock composition percentage estimates, standard deviations (SD), 95% credible intervals (CI), and estimated numbers of Chinook salmon from the the 2020 Bering Sea pollock trawl fisheries.Sample sizes are adjacent to the stratum designation. Total catch is the census for each stratum from AKFIN reports (NMFS 2021). Estimated numbers of fish for aged fish are for only the number of fish aged.

	"A" Season (N=1,371)				"B" Season (N=1,243)				Bering Sea all (N=3,241)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	435	2.4	0.48	(1.5,3.4)	123	0.9	0.28	(0.4,1.5)	552	1.7	0.30	(1.2,2.3)
Coast W AK	9,469	51.5	1.64	(48.3,54.7)	7,467	53.6	1.68	(50.3,56.9)	16,796	52.0	1.21	(49.6,54.4)
Mid Yukon	281	1.5	0.49	(0.7,2.6)	318	2.3	0.73	(1.0,3.8)	670	2.1	0.47	(1.2,3.0)
Up Yukon	557	3.0	0.54	(2.1,4.2)	130	0.9	0.41	(0.3,1.8)	729	2.3	0.36	(1.6,3.0)
N AK Pen	4,553	24.8	1.41	(22.1,27.6)	208	1.5	0.48	(0.7,2.5)	4,247	13.1	0.84	(11.5,14.8)
NW GOA	143	0.8	0.53	(0.3,2.1)	1,295	9.3	1.12	(7.2,11.6)	1,825	5.7	0.68	(4.4,7.1)
Copper	0	0.0	0.11	(0.0,0.4)	7	0.0	0.08	(0.0,0.3)	0	0.0	0.06	(0.0,0.2)
NE GOA	3	0.0	0.10	(0.0,0.3)	12	0.1	0.15	(0.0,0.5)	14	0.0	0.10	(0.0,0.3)
Coast SE AK	297	1.6	0.55	(0.7,2.8)	249	1.8	0.73	(0.5,3.3)	497	1.5	0.47	(0.7,2.6)
BC	2,138	11.6	1.01	(9.7,13.6)	2,548	18.3	1.25	(15.9,20.8)	4,824	14.9	0.84	(13.3,16.6)
West Coast US	494	2.7	0.47	(1.9,3.7)	1,569	11.3	0.95	(9.5,13.2)	2,141	6.6	0.52	(5.7,7.7)
Total Catch	18,369				13,925				32,294			

	CVOA "A" (N=659)				CVOA "B" (N=766)				CVOA (N=1,325)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	0	0.0	0.05	(0.0,0.1)	88	1.0	0.41	(0.3,1.9)	65	0.4	0.20	(0.0,0.8)
Coast W AK	4,696	47.3	2.29	(42.8,51.8)	3,796	42.6	2.16	(38.3,46.8)	8,035	44.6	1.64	(41.4,47.8)
Mid Yukon	56	0.6	0.38	(0.1,1.5)	0	0.0	0.08	(0.0,0.2)	42	0.2	0.18	(0.0,0.7)
Up Yukon	20	0.2	0.28	(0.0,1.0)	2	0.0	0.09	(0.0,0.3)	23	0.1	0.13	(0.0,0.5)
N AK Pen	2,538	25.6	2.05	(21.6,29.7)	60	0.7	0.51	(0.0,1.9)	2,199	12.2	1.16	(10.0,14.5)
NW GOA	36	0.4	0.48	(0.1,1.8)	1,175	13.2	1.64	(10.1,16.5)	1,421	7.9	1.09	(5.9,10.2)
Copper	0	0.0	0.12	(0.0,0.4)	3	0.0	0.10	(0.0,0.3)	0	0.0	0.07	(0.0,0.3)
NE GOA	4	0.0	0.17	(0.0,0.6)	14	0.2	0.25	(0.0,0.9)	16	0.1	0.14	(0.0,0.5)
Coast SE AK	272	2.7	1.06	(0.9,5.0)	105	1.2	0.88	(0.0,3.2)	370	2.1	0.96	(0.4,4.2)
BC	1,818	18.3	1.81	(14.9,21.9)	2,150	24.1	1.91	(20.5,27.9)	3,934	21.8	1.48	(18.9,24.7)
West Coast US	486	4.9	0.87	(3.4,6.8)	1,514	17.0	1.57	(14.1,20.2)	1,917	10.6	0.90	(8.9,12.5)
Total Catch	9,925				8,907				18,022			

	NW Bering S. "A" (N=579)				NW Bering S. "B" (N=571)				NW Bering S. (N=1,150)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	394	6.0	1.10	(4.0,8.3)	50	0.8	0.38	(0.3,1.7)	522	4.1	0.65	(2.9,5.4)
Coast W AK	3,808	58.1	2.49	(53.1,62.8)	4,177	66.7	2.28	(62.2,71.1)	7,785	60.8	1.77	(57.2,64.2)
Mid Yukon	201	3.1	1.00	(1.4,5.3)	347	5.5	1.33	(3.1,8.3)	488	3.8	0.85	(2.3,5.6)
Up Yukon	367	5.6	1.03	(3.7,7.8)	106	1.7	0.89	(0.3,3.7)	526	4.1	0.71	(2.8,5.6)
N AK Pen	1,369	20.9	2.00	(17.1,25.0)	127	2.0	0.82	(0.7,3.9)	1,511	11.8	1.22	(9.5,14.3)
NW GOA	32	0.5	0.63	(0.1,2.4)	316	5.0	1.27	(2.8,7.8)	428	3.3	0.91	(1.7,5.3)
Copper	20	0.3	0.42	(0.1,1.6)	5	0.1	0.17	(0.0,0.6)	16	0.1	0.19	(0.0,0.7)
NE GOA	1	0.0	0.25	(0.0,0.7)	5	0.1	0.25	(0.0,0.9)	7	0.1	0.19	(0.0,0.7)
Coast SE AK	29	0.4	0.51	(0.0,1.8)	123	2.0	0.75	(0.7,3.7)	168	1.3	0.46	(0.5,2.3)
BC	305	4.7	0.95	(2.9,6.7)	675	10.8	1.36	(8.3,13.6)	1,027	8.0	0.85	(6.4,9.8)
West Coast US	29	0.4	0.32	(0.0,1.3)	327	5.2	0.97	(3.5,7.3)	336	2.6	0.50	(1.7,3.7)
Total Catch	6,557				6,258				12,815			

	SE Bering S. "A" (N=792)				SE Bering S. "B" (N=672)				SE Bering S. (N=1,464)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	0	0.0	0.11	(0.0,0.4)	75	1.0	0.40	(0.3,1.9)	67	0.3	0.19	(0.0,0.8)
Coast W AK	5,431	46.6	2.07	(42.5,50.6)	3,282	42.5	2.19	(38.2,46.7)	8,725	45.0	1.54	(42.0,48.0)
Mid Yukon	132	1.1	0.49	(0.4,2.3)	0	0.0	0.08	(0.0,0.2)	114	0.6	0.26	(0.2,1.2)
Up Yukon	131	1.1	0.53	(0.3,2.3)	2	0.0	0.09	(0.0,0.3)	116	0.6	0.28	(0.2,1.2)
N AK Pen	3,214	27.6	1.91	(23.9,31.4)	68	0.9	0.54	(0.1,2.1)	2,772	14.3	1.15	(12.1,16.6)
NW GOA	48	0.4	0.48	(0.1,1.7)	1,024	13.3	1.64	(10.2,16.6)	1,355	7.0	0.96	(5.2,9.0)
Copper	0	0.0	0.09	(0.0,0.3)	2	0.0	0.10	(0.0,0.3)	0	0.0	0.06	(0.0,0.2)
NE GOA	4	0.0	0.14	(0.0,0.4)	14	0.2	0.25	(0.0,0.9)	15	0.1	0.11	(0.0,0.4)
Coast SE AK	303	2.6	0.99	(0.8,4.7)	86	1.1	0.84	(0.0,3.0)	378	2.0	0.82	(0.4,3.6)
BC	1,905	16.3	1.62	(13.3,19.7)	1,877	24.3	1.87	(20.8,28.1)	3,939	20.3	1.29	(17.9,23.0)
West Coast US	491	4.2	0.79	(2.8,5.9)	1,295	16.8	1.57	(13.8,19.9)	1,904	9.8	0.82	(8.3,11.5)
Total Catch	11,659				7,726				19,385			

Appendix 2. -- Continued

	Area 509 "A" (N=578)				Area 509 (N=607)				Bering Sea Age 3 (N=384)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	0	0.0	0.00	(0.1,0.0)	0	0.0	0.00	(0.1,0.0)	7	1.9	0.76	(0.7,3.6)
Coast W AK	3,912	45.7	40.95	(2.4,45.7)	3,843	43.4	38.79	(2.4,43.4)	187	48.6	2.94	(42.8,54.3)
Mid Yukon	46	0.5	0.04	(0.4,0.4)	51	0.6	0.11	(0.4,0.5)	2	0.4	0.50	(0.0,1.8)
Up Yukon	8	0.1	0.01	(0.2,0.0)	7	0.1	0.00	(0.2,0.0)	5	1.2	0.66	(0.2,2.8)
N AK Pen	2,249	26.3	22.08	(2.2,26.3)	2,254	25.5	21.43	(2.1,25.4)	14	3.8	1.32	(1.5,6.7)
NW GOA	24	0.3	0.06	(0.4,0.1)	49	0.6	0.16	(0.6,0.2)	42	10.9	2.23	(6.9,15.6)
Copper	0	0.0	0.00	(0.1,0.0)	0	0.0	0.00	(0.1,0.0)	0	0.0	0.11	(0.0,0.3)
NE GOA	2	0.0	0.00	(0.2,0.0)	0	0.0	0.00	(0.2,0.0)	1	0.2	0.39	(0.0,1.4)
Coast SE AK	202	2.4	0.66	(1.1,2.2)	221	2.5	0.65	(1.2,2.3)	4	1.0	0.64	(0.0,2.5)
BC	1,729	20.2	16.51	(1.9,20.2)	1,847	20.9	17.01	(2.0,20.8)	85	22.1	2.25	(17.9,26.7)
West Coast US	383	4.5	3.02	(0.8,4.4)	582	6.6	4.77	(1.0,6.5)	38	9.9	1.65	(6.9,13.4)
Total Catch	8,554				8,854				384			

	Bering Sea Age 4 (N=384)				Bering Sea Age 5 (N=384)				Bering Sea Age 6 (N=384)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	11	1.7	0.58	(0.7,3.0)	0	0.1	0.23	(0.0,0.8)	0	0.0	0.36	(0.0,1.1)
Coast W AK	333	53.3	2.36	(48.6,57.9)	200	56.0	3.04	(49.9,61.9)	24	28.1	5.87	(17.2,40.1)
Mid Yukon	17	2.7	1.10	(0.8,5.0)	10	2.9	1.14	(1.0,5.5)	1	1.3	2.06	(0.0,7.0)
Up Yukon	8	1.3	0.81	(0.2,3.1)	27	7.7	1.61	(4.8,11.0)	6	6.6	3.17	(1.6,13.9)
N AK Pen	67	10.7	1.60	(7.8,14.0)	69	19.3	2.50	(14.6,24.3)	51	59.5	6.10	(47.3,71.1)
NW GOA	30	4.8	1.31	(2.6,7.7)	1	0.3	0.64	(0.0,2.2)	1	0.8	1.61	(0.0,5.8)
Copper	5	0.7	0.56	(0.3,2.1)	2	0.5	0.49	(0.1,1.8)	0	0.2	0.78	(0.0,2.7)
NE GOA	0	0.0	0.18	(0.0,0.6)	1	0.2	0.71	(0.0,2.6)	0	0.1	0.77	(0.0,2.6)
Coast SE AK	8	1.3	0.88	(0.0,3.3)	1	0.4	0.58	(0.0,2.0)	0	0.0	1.00	(0.0,3.5)
BC	100	16.1	1.62	(13.0,19.4)	39	10.9	1.71	(7.7,14.4)	2	1.9	1.67	(0.3,6.2)
West Coast US	46	7.3	1.05	(5.4,9.5)	7	1.9	0.72	(0.7,3.5)	1	1.5	1.41	(0.0,5.2)
Total Catch	625				357				85			

Appendix 3. -- Regional BAYES stock composition percentage estimates and estimated numbers of previous years of Chinook salmon from the Bering Sea pollock trawl fisheries. The BAYES mean estimates are also provided with standard deviations (SD), and the 95% credible intervals (CI). Sample sizes are adjacent to stratum designation. Total catch is the actual catch for that year.

2019	"A" Season (N=1499)				"B" Season (N=811)				Bering Sea all (N=2,310)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	8	0.1	0.09	(0.0,0.3)	47	0.5	0.27	(0.1,1.1)	60	0.2	0.13	(0.1,0.6)
Coast W AK	7,055	44.8	1.67	(41.5,48.1)	2,812	30.4	1.88	(26.8,34.1)	9,901	39.6	1.32	(37.0,42.2)
Mid Yukon	6	0.0	0.11	(0.0,0.4)	126	1.4	0.57	(0.5,2.6)	122	0.5	0.21	(0.2,1.0)
Up Yukon	39	0.3	0.20	(0.0,0.7)	55	0.6	0.35	(0.0,1.4)	105	0.4	0.18	(0.1,0.8)
N AK Pen	3,420	21.7	1.50	(18.8,24.7)	32	0.4	0.48	(0.0,1.6)	3,635	14.6	1.12	(12.4,16.8)
NW GOA	36	0.2	0.37	(0.0,1.3)	1,036	11.2	1.43	(8.5,14.1)	964	3.9	0.73	(2.5,5.4)
Copper	3	0.0	0.07	(0.0,0.2)	17	0.2	0.25	(0.0,0.9)	10	0.0	0.09	(0.0,0.3)
NE GOA	2	0.0	0.05	(0.0,0.1)	6	0.1	0.21	(0.0,0.7)	5	0.0	0.07	(0.0,0.2)
Coast SE AK	318	2.0	0.55	(1.0,3.2)	264	2.9	0.75	(1.5,4.4)	550	2.2	0.43	(1.4,3.1)
BC	3,827	24.3	1.18	(22.0,26.7)	2,392	25.9	1.60	(22.8,29.1)	6,236	25.0	0.96	(23.1,26.9)
West Coast US	1,025	6.5	0.67	(5.3,7.9)	2,461	26.6	1.59	(23.5,29.8)	3,395	13.6	0.74	(12.2,15.1)
Total Catch	15,738				9,246				24,984			

2018	"A" Season (N=827)				"B" Season (N=470)				Bering Sea all (N=1,297)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	0	0.0	0.03	(0.0,0.1)	41	0.8	0.46	(0.1,1.9)	43	0.3	0.19	(0.0,0.8)
Coast W AK	2,974	34.8	2.01	(31.0,38.8)	1,613	31.1	2.50	(26.2,36.0)	4,635	33.8	1.64	(30.6,37.0)
Mid Yukon	36	0.4	0.51	(0.0,1.7)	65	1.3	1.14	(0.0,3.8)	62	0.5	0.51	(0.0,1.6)
Up Yukon	69	0.8	0.38	(0.2,1.7)	55	1.1	0.79	(0.0,2.8)	122	0.9	0.31	(0.4,1.6)
N AK Pen	2,187	25.6	1.86	(22.1,29.3)	153	2.9	1.05	(1.2,5.2)	2,395	17.5	1.29	(15.0,20.0)
NW GOA	126	1.5	0.84	(0.1,3.3)	209	4.0	1.34	(1.8,7.0)	312	2.3	0.69	(1.1,3.8)
Copper	2	0.0	0.06	(0.0,0.2)	26	0.5	0.37	(0.0,1.4)	33	0.2	0.16	(0.0,0.6)
NE GOA	6	0.1	0.20	(0.0,0.6)	2	0.0	0.20	(0.0,0.5)	4	0.0	0.09	(0.0,0.3)
Coast SE AK	279	3.3	0.79	(1.9,5.0)	273	5.3	1.66	(2.2,8.7)	509	3.7	0.70	(2.4,5.2)
BC	2,333	27.3	1.62	(24.2,30.6)	1,715	33.0	2.56	(28.1,38.1)	4,060	29.6	1.35	(27.0,32.3)
West Coast US	526	6.2	0.89	(4.5,8.0)	1,039	20.0	1.91	(16.4,23.9)	1,550	11.3	0.91	(9.6,13.1)
Total Catch	8,535				5,191				13,726			

2017	"A" Season (N=1,866)				"B" Season (N=753)				Bering Sea all (N=2,619)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	35	0.2	0.12	(0.0,0.5)	19	0.2	0.19	(0.0,0.7)	54	0.2	0.10	(0.1,0.4)
Coast W AK	6,118	28.3	1.23	(25.9,30.8)	1,019	12.0	1.33	(9.5,14.7)	7,113	23.7	0.99	(21.7,25.6)
Mid Yukon	136	0.6	0.26	(0.2,1.2)	29	0.3	0.33	(0.0,1.1)	162	0.5	0.21	(0.2,1.0)
Up Yukon	156	0.7	0.27	(0.3,1.3)	1	0.0	0.04	(0.0,0.1)	162	0.5	0.20	(0.2,1.0)
N AK Pen	4,465	20.7	1.15	(18.5,23.0)	154	1.8	0.59	(0.8,3.1)	4,490	14.9	0.87	(13.3,16.7)
NW GOA	78	0.4	0.39	(0.0,1.4)	231	2.7	0.79	(1.3,4.4)	406	1.4	0.45	(0.6,2.3)
Copper	2	0.0	0.04	(0.0,0.1)	10	0.1	0.18	(0.0,0.6)	3	0.0	0.03	(0.0,0.1)
NE GOA	13	0.1	0.12	(0.0,0.4)	2	0.0	0.08	(0.0,0.2)	9	0.0	0.07	(0.0,0.3)
Coast SE AK	691	3.2	0.54	(2.2,4.3)	575	6.8	1.24	(4.5,9.3)	1,221	4.1	0.52	(3.1,5.1)
BC	7,609	35.2	1.18	(32.9,37.6)	3,141	37.1	2.01	(33.2,41.0)	10,812	36.0	1.03	(34.0,38.0)
West Coast US	2,303	10.7	0.75	(9.2,12.2)	3,291	38.8	1.87	(35.2,42.5)	5,642	18.8	0.81	(17.2,20.4)
Total Catch	21,603				8,473				30,076			

2016	"A" Season (N=1,488)				"B" Season (N=422)				*Bering Sea* all (N=1.910)			
Region	Est. #	Mean	SD	95% PI	Est. #	Mean	SD	95% PI	Est. #	Mean	SD	95% PI
Russia	108	0.6	0.25	(0.2,1.2)	12	0.2	0.24	(0.0,0.9)	114	0.5	0.19	(0.2,1.0)
Coast W AK	6,570	39.0	1.46	(36.2,41.9)	843	16.5	2.14	(12.5,20.8)	7,372	33.6	1.28	(31.2,36.2)
Mid Yukon	283	1.7	0.40	(1.0,2.5)	18	0.4	0.60	(0.0,2.0)	327	1.5	0.34	(0.9,2.2)
Up Yukon	365	2.2	0.43	(1.4,3.1)	34	0.7	0.48	(0.0,1.8)	406	1.9	0.35	(1.2,2.6)
N AK Pen	2,839	16.9	1.17	(14.6,19.2)	56	1.1	0.72	(0.0,2.8)	2,927	13.4	0.96	(11.5,15.3)
NW GOA	94	0.6	0.46	(0.0,1.6)	298	5.9	1.54	(3.1,9.1)	458	2.1	0.62	(1.0,3.4)
Copper	3	0.0	0.06	(0.0,0.2)	90	1.8	0.73	(0.6,3.4)	75	0.3	0.18	(0.1,0.8)
NE GOA	2	0.0	0.07	(0.0,0.2)	2	0.0	0.13	(0.0,0.3)	2	0.0	0.07	(0.0,0.1)
Coast SE AK	663	3.9	0.72	(2.6,5.4)	333	6.5	1.70	(3.6,10.2)	971	4.4	0.64	(3.3,5.8)
BC	4,394	26.1	1.26	(23.7,28.6)	1,888	37.0	2.68	(31.8,42.3)	6,312	28.8	1.14	(26.6,31.0)
West Coast US	1,506	9.0	0.81	(7.4,10.6)	1,524	29.9	2.33	(25.4,34.5)	2,960	13.5	0.82	(11.9,15.1)
Total Catch	16,828				5,098				21,926			

Appendix 3. -- Continued

2015	"A" Season (N=1,181)				"B" Season (N=576)				Bering Sea all (N=1,757)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	75	0.6	0.29	(0.2,1.3)	5	0.1	0.20	(0.0,0.7)	93	0.5	0.21	(0.2,1.0)
Coast W AK	5,644	45.9	1.87	(42.2,49.5)	1,651	27.4	2.36	(22.9,32.1)	7,256	39.6	1.60	(36.4,42.7)
Mid Yukon	119	1.0	0.76	(0.0,2.7)	97	1.6	0.67	(0.6,3.2)	304	1.7	0.71	(0.6,3.2)
Up Yukon	448	3.6	0.68	(2.4,5.1)	65	1.1	0.55	(0.2,2.3)	502	2.7	0.48	(1.9,3.7)
N AK Pen	1,785	14.5	1.33	(12.0,17.2)	60	1.0	0.85	(0.0,3.0)	1,943	10.6	1.00	(8.7,12.6)
NW GOA	349	2.8	0.82	(1.4,4.6)	496	8.2	1.95	(4.6,12.3)	724	4.0	0.83	(2.5,5.7)
Copper	21	0.2	0.36	(0.0,1.3)	3	0.1	0.12	(0.0,0.4)	11	0.1	0.18	(0.0,0.7)
NE GOA	2	0.0	0.10	(0.0,0.2)	4	0.1	0.22	(0.0,0.7)	4	0.0	0.11	(0.0,0.3)
Coast SE AK	475	3.9	0.72	(2.6,5.4)	381	6.3	1.39	(3.8,9.3)	828	4.5	0.67	(3.3,5.9)
BC	2,355	19.1	1.21	(16.8,21.6)	1,603	26.6	2.06	(22.6,30.7)	3,998	21.8	1.08	(19.7,24.0)
West Coast US	1,030	8.4	0.84	(6.8,10.1)	1,659	27.5	1.95	(23.8,31.4)	2,665	14.5	0.88	(12.9,16.3)
Total Catch	12,304				6,025				18,329			
2014	"A" Season (N=1,066)				"B" Season (N=319)				Bering Sea all (N=1,385)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	74	0.6	0.26	(0.2,1.2)	13	0.4	0.50	(0.0,1.7)	96	0.6	0.23	(0.3,1.2)
Coast W AK	6,301	54.6	2.17	(50.4,58.8)	1,109	31.8	3.09	(25.8,37.9)	7,314	48.7	1.79	(45.2,52.2)
Mid Yukon	380	3.3	1.24	(1.2,5.9)	58	1.7	0.98	(0.1,3.9)	484	3.2	0.91	(1.5,5.1)
Up Yukon	477	4.1	0.79	(2.7,5.8)	55	1.6	0.86	(0.3,3.6)	564	3.8	0.66	(2.6,5.1)
N AK Pen	2,624	22.7	1.58	(19.7,25.9)	3	0.1	0.31	(0.0,1.0)	2,666	17.7	1.35	(15.2,20.4)
NW GOA	16	0.1	0.32	(0.0,1.1)	642	18.4	2.68	(13.4,23.9)	630	4.2	1.00	(2.4,6.3)
Copper	1	0.0	0.05	(0.0,0.1)	5	0.1	0.37	(0.0,1.3)	5	0.0	0.09	(0.0,0.3)
NE GOA	1	0.0	0.05	(0.0,0.1)	3	0.1	0.32	(0.0,1.1)	3	0.0	0.08	(0.0,0.2)
Coast SE AK	68	0.6	0.36	(0.0,1.4)	124	3.6	1.41	(1.3,6.7)	207	1.4	0.43	(0.6,2.3)
BC	1,174	10.2	0.98	(8.3,12.2)	855	24.5	2.59	(19.6,29.7)	2,049	13.6	1.01	(11.7,15.7)
West Coast US	422	3.7	0.63	(2.5,5.0)	624	17.9	2.21	(13.8,22.4)	1,013	6.7	0.76	(5.2,8.3)
Total Catch	11,539				3,492				15,031			
2013	"A" Season (N=792)				"B" Season (N=454)				Bering Sea all (N=1,246)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	74	0.9	0.40	(0.4,1.7)	43	0.9	0.50	(0.2,2.0)	117	0.9	0.30	(0.4,1.5)
Coast W AK	4,135	50.2	2.20	(46.0,54.5)	2,490	51.9	2.80	(46.4,57.3)	6,530	50.1	1.80	(46.7,53.5)
Mid Yukon	91	1.1	0.60	(0.0,2.6)	91	1.9	1.00	(0.4,4.2)	235	1.8	0.70	(0.6,3.1)
Up Yukon	593	7.2	1.10	(5.1,9.4)	67	1.4	0.90	(0.0,3.4)	652	5.0	0.80	(3.5,6.7)
N AK Pen	1,573	19.1	1.80	(15.7,22.8)	283	5.9	1.50	(3.4,9.0)	1,851	14.2	1.40	(11.6,17.0)
NW GOA	41	0.5	0.70	(0.0,2.4)	331	6.9	1.80	(3.5,10.7)	443	3.4	1.00	(1.8,5.5)
Copper	8	0.1	0.10	(0.0,0.5)	5	0.1	0.30	(0.0,0.9)	13	0.1	0.20	(0.0,0.7)
NE GOA	0	0.0	0.10	(0.0,0.4)	0	0.0	0.20	(0.0,0.4)	0	0.0	0.10	(0.0,0.3)
Coast SE AK	157	1.9	0.70	(0.8,3.4)	91	1.9	1.10	(0.1,4.5)	313	2.4	0.60	(1.3,3.6)
BC	1,400	17.0	1.40	(14.2,19.8)	686	14.3	1.90	(10.8,18.2)	2,020	15.5	1.10	(13.4,17.8)
West Coast US	165	2.0	0.60	(1.0,3.3)	710	14.8	1.70	(11.6,18.2)	873	6.7	0.80	(5.2,8.2)
Total Catch	8,237				4,797				13,034			
2012	"A" Season (N=759)				"B" Season (N=352)				Bering Sea all (N=1,111)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	42	0.5	0.27	(0.2,1.2)	86	2.4	0.83	(1.1,4.3)	126	1.1	0.32	(0.6,1.8)
Coast W AK	5,266	67.8	2.22	(63.4,72.1)	1,863	52.1	2.92	(46.3,57.7)	7,152	63.1	1.83	(59.4,66.6)
Mid Yukon	92	1.2	0.82	(0.0,3.1)	6	0.2	0.32	(0.0,1.1)	115	1.0	0.59	(0.0,2.3)
Up Yukon	241	3.1	0.82	(1.6,4.8)	35	1.0	0.64	(0.1,2.5)	271	2.4	0.60	(1.3,3.7)
N AK Pen	1,256	16.2	1.88	(12.7,20.0)	3	0.1	0.25	(0.0,0.8)	1,227	10.8	1.35	(8.3,13.6)
NW GOA	19	0.2	0.35	(0.0,1.2)	135	3.8	1.44	(1.3,6.9)	155	1.4	0.73	(0.2,3.1)
Copper	2	0.0	0.12	(0.0,0.3)	2	0.1	0.17	(0.0,0.5)	2	0.0	0.07	(0.0,0.2)
NE GOA	6	0.1	0.26	(0.0,0.9)	2	0.1	0.20	(0.0,0.6)	6	0.1	0.17	(0.0,0.6)
Coast SE AK	128	1.7	0.78	(0.3,3.4)	292	8.2	1.84	(4.5,11.9)	381	3.4	0.73	(2.0,4.9)
BC	568	7.3	1.12	(5.2,9.6)	547	15.3	2.24	(11.2,20.0)	1,159	10.2	1.01	(8.3,12.3)
West Coast US	146	1.9	0.51	(1.0,3.0)	609	17.0	2.09	(13.1,21.3)	749	6.6	0.78	(5.1,8.2)
Total Catch	7,765				3,579				11,344			

Appendix 3. -- Continued

2011	"A" Season (N=695)				"B" Season (N=1,778)				Bering Sea all (N=2,473)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	12	0.2	0.16	(0.0,0.6)	184	1.0	0.25	(0.6,1.6)	196	0.8	0.19	(0.5,1.2)
Coast W AK	3,856	54.0	2.28	(49.6,58.5)	13,549	73.8	1.28	(71.3,76.2)	17,421	68.3	1.16	(66.0,70.6)
Mid Yukon	127	1.8	0.76	(0.6,3.6)	233	1.3	0.46	(0.5,2.2)	411	1.6	0.46	(0.8,2.5)
Up Yukon	526	7.4	1.12	(5.3,9.7)	119	0.7	0.35	(0.1,1.4)	627	2.5	0.47	(1.6,3.4)
N AK Pen	1,556	21.8	1.94	(18.1,25.7)	628	3.4	0.65	(2.2,4.8)	2,201	8.6	0.81	(7.1,10.3)
NW GOA	41	0.6	0.60	(0.0,2.2)	654	3.6	0.89	(2.0,5.5)	663	2.6	0.67	(1.4,4.1)
Copper	1	0.0	0.07	(0.0,0.2)	105	0.6	0.30	(0.0,1.2)	69	0.3	0.24	(0.0,0.8)
NE GOA	1	0.0	0.09	(0.0,0.2)	26	0.1	0.24	(0.0,0.8)	13	0.1	0.12	(0.0,0.4)
Coast SE AK	218	3.1	0.86	(1.6,4.9)	259	1.4	0.46	(0.6,2.4)	459	1.8	0.41	(1.1,2.6)
BC	515	7.2	1.13	(5.1,9.6)	1,425	7.8	0.71	(6.4,9.2)	1,984	7.8	0.62	(6.6,9.0)
West Coast US	283	4.0	0.78	(2.6,5.6)	1,181	6.4	0.61	(5.3,7.7)	1,461	5.7	0.49	(4.8,6.7)
Total Catch	7,137				18,362				25,504			

Appendix 4. -- 37 SNP DNA markers represented in the Chinook salmon baseline

Locus	Ploidy	SNPpos	Allele1	Allele2	Probe1	Probe2	Primer	Primer Conc. (uM)
Ots_AsnRS-60	2	1	T	C	TGAGTCCCTGACCAGC	AGTCCCCGACCAGC	CCGACGCCTCACTGAGT	0.16
Ots_E2-275	2	1	A	G	CCCCCATATTGCTG	CCCCACATTGCTG	GGTGCCACTTTAGTATAGCTGCTTA	0.16
Ots_ETIF1A	2	1	A	C	CAACTGAAGAAAATAATATG	CTGAAGAAAAGAATATG	TCTGAACTCACCAAAGGAACACTTG	0.16
Ots_FARSLA-220	2	1	G	A	CCTTGGATGGGATGTG	CCTTGGATAGGATGTG	GTTCGTGGGATTGTTCAATGTTCAT	0.16
Ots_FGF6A	2	1	G	T	CACGATTAGCAATGAACAA	CACGATTAGCAATTAACAA	TCAAAAATGTCTATCCAACAAATACTCTGAAAAATATTG	0.16
Ots_GH2	2	1	A	T	TGACTCTCAGCA[TA]CTG	TGACTCTCTGCA[TA]CTG	GCGTACTGAGCCTGGATGACA	0.08
Ots_GPDH-338	2	1	G	A	CCACTACTTAACGTGCTTT	CCACTACTTAACATGCTTT	CACTAAATATTCCTTATCATTTCATACTAAGTCTGAAGAA	0.32
Ots_GPH-318	2	1	C	T	ATCAAGCTGACGAACCA	CAAGCTGACAAACCA	GGTGATAACAGGTGTTGCACCAA	0.08
Ots_GST-207	2	1	C	T	ATGAGAGAGTCTTTCTCTGTT	ATGAGAGAGTCTTTTTCTGTT	GGAGAACATGCATCACCATTCAAG	0.16
Ots_GST-375	2	1	C	T	TTTCTTGTAGGCGTCAGAG	TCTTGTAGGCATCAGAG	CAGCCCGTCCCAAAATCAAG	0.16
Ots_GTH2B-550	2	1	C	G	ATAACATCTGCAGCATTAA	ATAACATGTGCAGCATTAA	CACAGGAAGGACGTGTTTTGATG	0.32
Ots_hnRNPL-533	2	1	A	T	CATTTACCAGTTCTCACACAC	TTTACCAGTTCACACACAC	TCTTTGATATTGAGCTCATAAAAGCAAGGT	0.16
Ots_HSP90B-100	2	1	C	T	TCTATGGTGTGATTCATT	TTCTATGGTGTAATTCATT	CACCTTAGTTCCACGCAACATG	0.16
Ots_IGF-I.1-76	2	1	A	T	CTGCCTAGTTAAATAAAATA	CTGCCTAGTTAAATTAAATA	GGTAGGCCGTCAGTGTAAAATAAGT	0.32
Ots_Ikaros-250	2	1	G	A	ACAGAAGATTTTCGGCTGC	ACAGAAGATTTTCGACTGC	GAGGCTGACTTGGACTTTGC	0.16
Ots_LEI-292	2	1	G	A	CATCATGTCAGGCCTG	ATCATGTCAAGCCTG	CACCTGAACCTCCACTGTGT	0.16
Ots_LWSop-638	2	1	T	C	TTTAACAAGAAAATTATACATTTC	CAAGAAAGTTATACATTTC	CAATTACTCTTTCTCAGCCCTGTGT	0.16
Ots_MHC1	2	1	G	A	CATCATCCCGTGAGCAG	TCATCATCCCATGAGCAG	GTCCACATTCTCCAGTACATGTATGG	0.16
Ots_MHC2	2	1	T	G	CTGGAGCGTTTCTGTA	CTGGAGCGTGTCTGTA	GTCCTCAGCTGGGTCAAGAG	0.16
Ots_NOD1	2	1	C	G	CCAACGGCGACTTG	CCAACGCCGACTTG	GTGCTGCAGGAACCATGTG	0.08
Ots_P450	2	1	T	A	CCCCGAAGTACTTTT	CCCGAAGAACTTTT	TGAGCGAGATTTATCAAACTGTCAAAGA	0.32
Ots_Prl2	2	1	A	G	ATGTATTGTTCATTTAATG	TGTATTGTTCGTTTAATG	CCTGGTCTGTTTGTGATCAAGATG	0.16
Ots_RAG3	2	1	C	T	CTCTACAGTATGAACTATG	CTCTACAATATGAACTATG	CATTTCCACGAAAAGCCAGATGAC	0.32
Ots_RFC2-558	2	1	A	-	TGCATGTAACAAATAACAT	TGCATGTAACATAACAT	AAGGTCTACTCCGGTTGTATTCGGT	0.08
Ots_S7-1	2	1	T	C	TACAGGAGATAAGGTCGCA	CAGGAGATAGGGTCGCA	TGCCATCATAAACAACCTAACAAGTAACT	0.32
Ots_SClkF2R2-135	2	1	A	T	ATTCAAAGTCAAATTTT	ATTCAAAGTCTAATTTT	CCAAATACAGACCAGCTACTTGTGT	0.16
Ots_SERPC1-209	2	1	A	T	CATTCAGCTTTTTTTC	ATTCAGCATTTTTTC	CTAAGTTCTTCCTGCCTAATGTGGAT	0.16
Ots_SL	2	1	A	G	TCAAAGATATGATTCAATTAA	AAGATATGGTTCAATTAA	AATATTGGCTTTCTGAGAATGCATTTGG	0.16
Ots_SWS1op-182	2	1	T	A	ATGTACTTTAACGATTCATTT	ATGTACTTTAACGTTTCATTT	TCAAAGACATCGAACACAAGAACGA	0.32
Ots_TAPBP	2	1	C	T	CAGCTGTCCAGTTCTG	CAGTTGTCCAGTTCTG	TTTCTCATCCTTCTCTCTTCCAGTCT	0.08
Ots_Tnsf	2	1	A	G	TGCTCCAGATCTC	TGCTCCAGGTCTC	GCCAATACGGGTTCTGAACTGT	0.16
Ots_u202-161	2	1	T	A	AGCTAGTGCTTAGCAGCTA[AC]	AGCTAGTGCATAGCAGCTA[AC]	CACTTTTGACTTTACATGGAACTTAACTCAT	0.32
Ots_u211-85	2	1	C	T	TCCCAAAGTCGAGTGTG	CCCAAAGTCAAGTGTG	TGGTGAGAGCAGCTTTAAATGTCTT	0.16
Ots_U212-158	2	1	G	A	CTGGAAGAAGGCCTC	CTGGAAAAAGGCCTC	CCCCATATGAGACGCTACAGTAATG	0.16
Ots_u4-92	2	1	T	C	CTGTGTTGAATTTAACATAAT	TCTGTGTTGAATTTAACGTAAT	ATCCAAGGAGCCCCATTAAAGATTT	0.16
Ots_u6-75	2	1	C	T	TTAGTCAACTGTTGTTTTT	TTAGTCAACTGTTATTTTT	GAAAAAGTAAAGTAAAAGTAAAGTATTATACCACTAAAGACAAT	0.32
Ots_zP3b-215	2	1	G	T	CCAAATATCCTACCCGTGATG	CAAATATCCTACCAGTGATG	TGCTGAGGACCATCTGCAATTC	0.16

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