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Genetic Stock Composition Analysis of the Chinook Salmon (*Oncorhynchus tshawytscha*) Bycatch from the 2018 Bering Sea Pollock Trawl Fishery

C. M. Guthrie III, Hv. T. Nguyen, M. Marsh, J. T. Watson and J. R. Guyon

August 2020

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National Oceanic and Atmospheric Administration
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Alaska Fisheries Science Center

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A Genetic Stock Composition Analysis of the Chinook Salmon (*Oncorhynchus tshawytscha*) Bycatch from the 2018 Bering Sea Pollock Trawl Fishery

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ABSTRACT

A genetic analysis of samples from the Chinook salmon (*Oncorhynchus tshawytscha*) bycatch of the 2018 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 temporal changes in stock composition across seasons. Samples were genotyped for 43 single nucleotide polymorphism (SNP) DNA markers and results were estimated using the Alaska Department of Fish and Game (ADF&G) SNP baseline. In 2018, 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 1,297 Chinook salmon bycatch samples, Coastal Western Alaska and British Columbia regions (34% and 30%, respectively) dominated the sample set with smaller contributions from North Alaska Peninsula (18%) and West Coast US (11%) regions. Temporal groupings within the pollock “A” and “B” seasons revealed changes in stock composition over the course of the year. The percentage and number of fish from the Coastal Western Alaska (35% vs. 31%) and North Alaska Peninsula (26% vs. 3%) regions was higher in the “A” season than the “B” season, whereas the contribution from the West Coast US (6% vs. 20%) and the British Columbia (27% vs. 33%) regions were higher in the “B” season. 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.

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INTRODUCTION

Pacific salmon (*Oncorhynchus* spp.) are prohibited species in the federally managed Bering Sea groundfish fisheries, which are subject to complex 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 stocks, 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 (hereafter 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] are shown in Figure 1 and 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 BSAI Management Area was enacted in 2010 and included retention of the all salmon caught in the pollock fishery. In 2011, a systematic random

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

sampling design recommended by Pella and Geiger (2009) was 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 2018, genetic samples were collected by the Observer Program from the Chinook salmon bycatch of the Bering Sea pollock fishery by using the systematic sampling protocols recommended previously (Pella and Geiger 2009). 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 2018. Stock composition analyses were performed using the single nucleotide polymorphism (SNP) baseline provided by the ADF&G (Templin et al. 2011), the same baseline that was used previously to estimate stock composition of samples from the 2005-2017 Chinook salmon bycatch (NMFS 2009; Guyon et al. 2010a,b; Guthrie et al. 2012-2019; Larson et al. 2013).

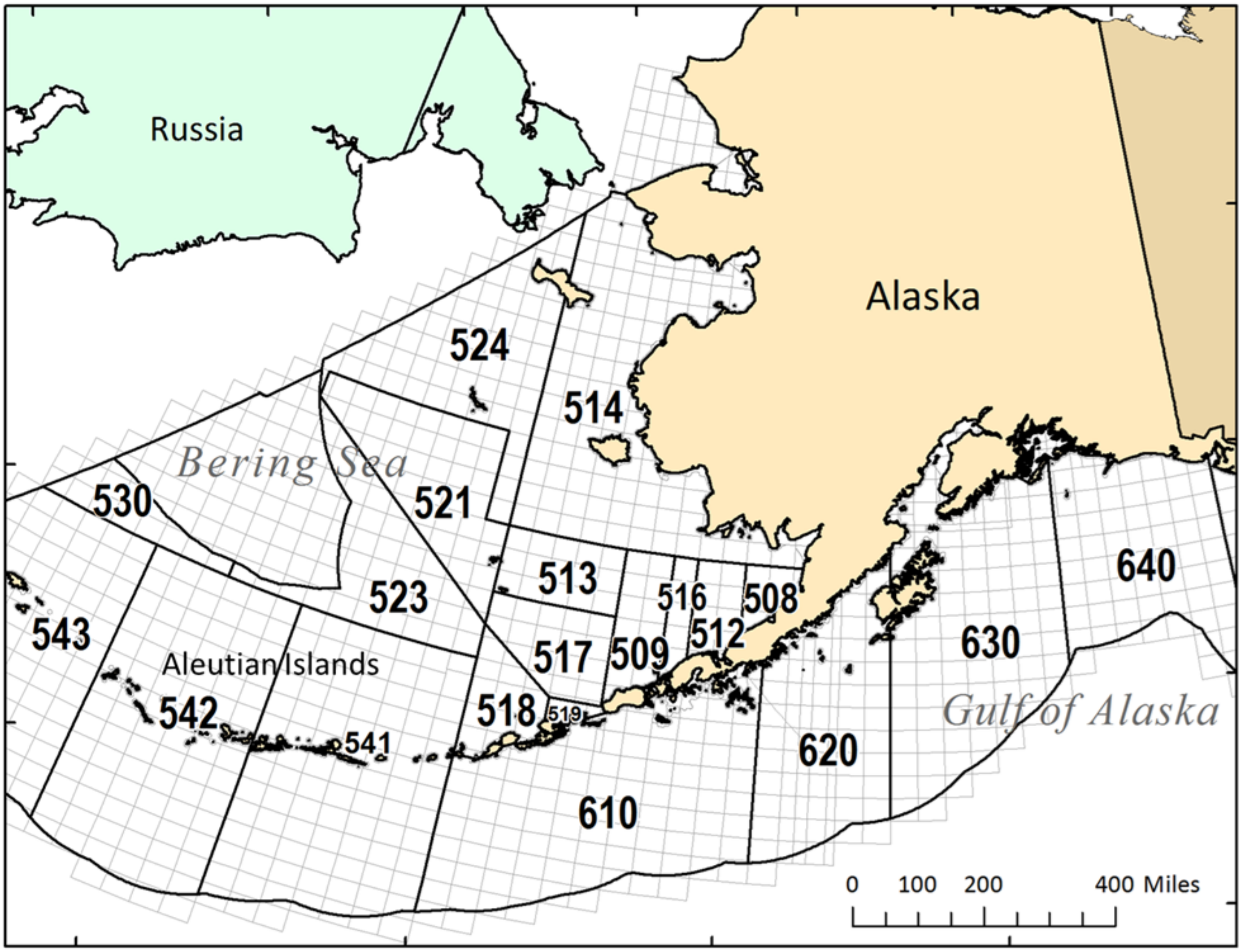

Figure 1. -- NMFS (outlined in black) and ADF&G (outlined in light gray) statistical areas associated with the Bering Sea and Gulf of Alaska groundfish fisheries.

SAMPLE DISTRIBUTION

Samples were collected from the Chinook salmon bycatch by the Observer Program for analysis at AFSC's Auke Bay Laboratories (ABL). Samples of axillary process tissue and scales were collected from the Chinook salmon bycatch throughout 2018. Axillary process tissues were stored in coin envelopes which were labeled, frozen, and shipped to ABL for analysis. Scales were collected as an additional source for genetic analysis and ageing (funding dependent).

In 2018, an estimated 13,726 Chinook salmon were taken in the bycatch of BSAI pollock trawl fisheries (NMFS 2020). The Chinook salmon bycatch estimate is 39% below the historical average (35,454) between 1991 and 2017, and far below the highest overall Chinook bycatch in 2007 when an estimated 124,723 fish were taken (Fig. 2; Table 1). Of the total 2018 bycatch, 8,631 were from the trawl "A" season (01/01/18 to 6/08/18) and 5,095 were from the "B" season (6/09/18 to 12/31/18). For the genetic analysis, the "B" season started 6/01/18 (Statistical Week 23) because all but 8 of the "A" season samples were collected by 4/21/18. This difference is reflected in Table 1 and Appendix 2.

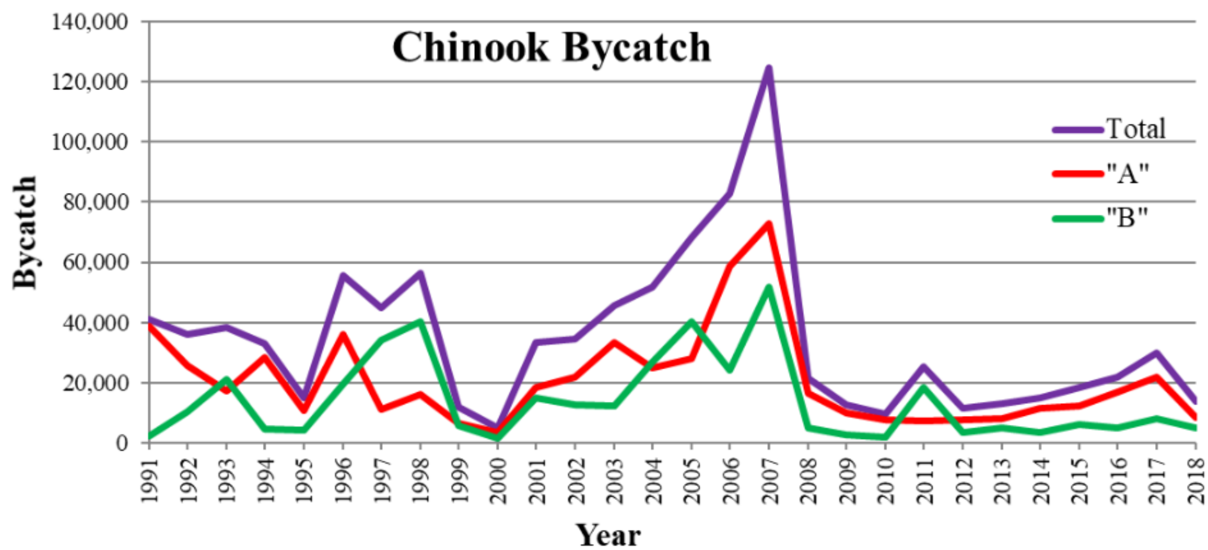

Figure 2. -- Annual "A" and "B" season estimates for the Chinook salmon bycatch from the Bering Sea pollock trawl fishery (NMFS 2020).

In 2018, there were 1,363 genetic samples received from the Bering Sea Chinook salmon bycatch collected by the Observer Program; of those samples, 1,297 were successfully genotyped for an overall genotyped sampling rate of 9.5% ("A" season N = 827 fish, 9.7% sampling rate; "B" season N = 470 fish, 9.1% sampling rate).

Table 1. -- Annual "A" and "B" season estimates for the Chinook salmon bycatch from the Bering Sea-Aleutian Island pollock trawl fishery, 1991–2018 (NMFS 2020).

Year	Total	"A" Season	"B" Season
1991	40,906	38,791	2,114
1992	35,950	25,691	10,259
1993	38,516	17,264	21,252
1994	33,136	28,451	4,686
1995	14,984	10,579	4,405
1996	55,623	36,068	19,554
1997	44,909	10,935	33,973
1998	51,322	15,193	36,130
1999	11,978	6,352	5,627
2000	4,961	3,422	1,539
2001	33,444	18,484	14,961
2002	34,495	21,794	12,701
2003	45,586	32,609	12,977
2004	51,696	23,093	28,603
2005	67,362	27,331	40,030
2006	82,695	58,391	24,304
2007	124,723	72,943	51,780
2008	21,307	16,495	4,811
2009	12,579	9,882	2,697
2010	9,720	7,649	2,071
2011	25,499	7,137	18,362
2012	11,344	7,765	3,579
2013	13,034	8,237	4,797
2014	15,031	11,539	3,492
2015	18,329	12,304	6,025
2016	21,926	16,828	5,098
2017	30,076	21,603	8,473
2018	13,726	8,631	5,095

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 2018 Chinook salmon bycatch genetic samples were evaluated by comparing the collection of genetic samples with the overall bycatch distribution (Figs. 3 and 4). 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. 4). 2018 was the eighth year that systematic random sampling was employed for collecting genetic tissue from the Bering Sea Chinook salmon bycatch and Figure 4 shows that the resulting genetic samples were spatially and temporally representative of the total Chinook bycatch (i.e., those fish not sampled from the bycatch). The 2018 sample spatial and temporal distributions were similarly representative to those from 2011 to 2017 (Guthrie et al. 2012-2019).

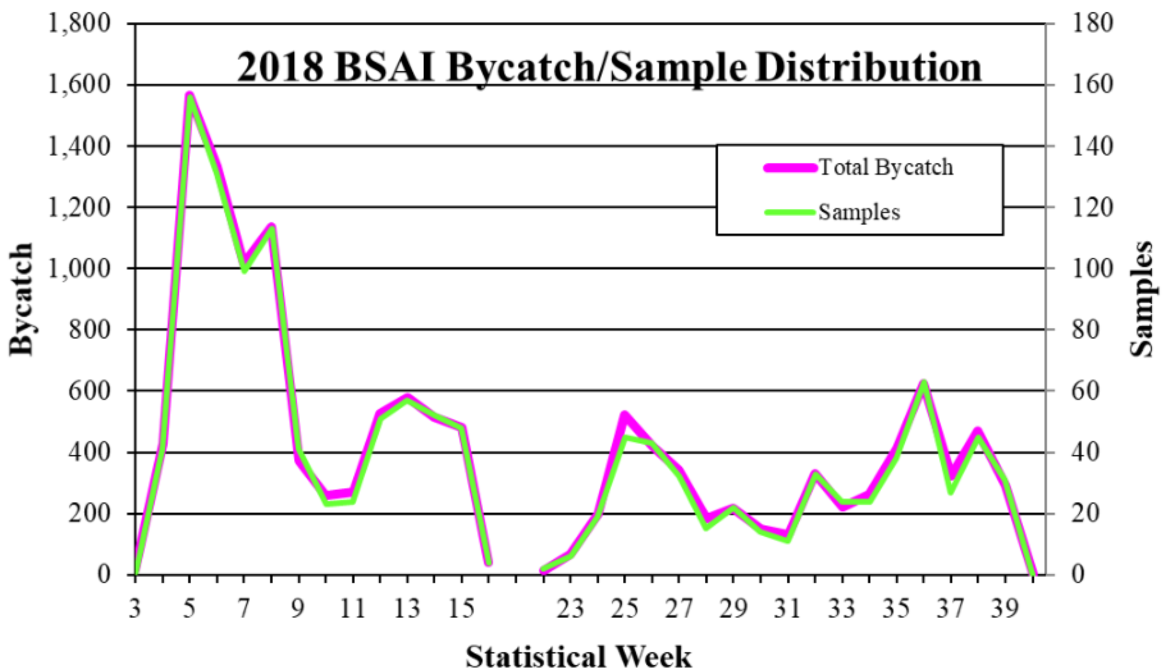

Figure 3. -- Number of Chinook salmon bycatch and genetic samples by statistical week. Weeks 3-16 correspond to the groundfish "A" season, whereas weeks 22-40 correspond to the "B" season.

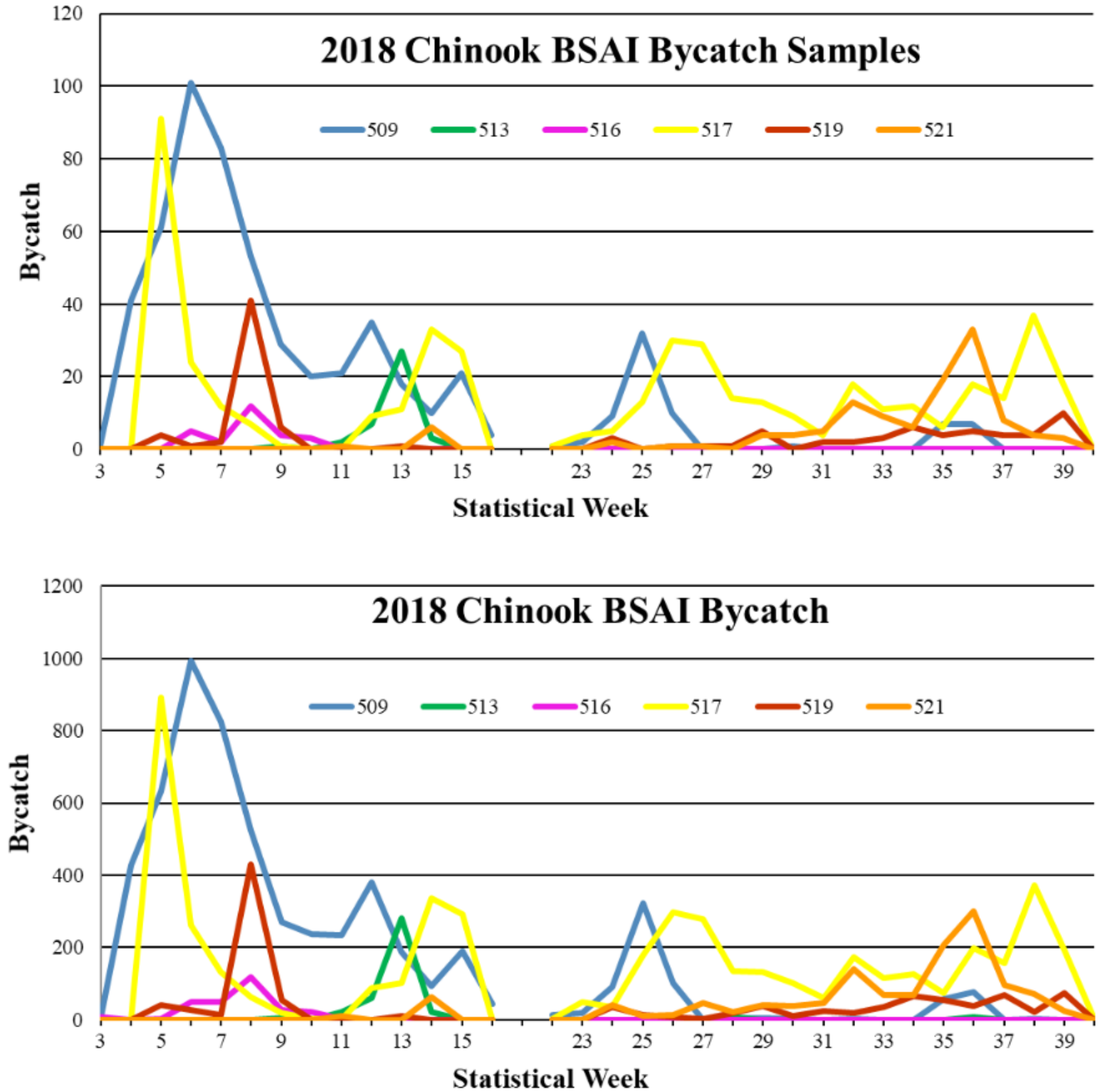

Figure 4. -- Comparison of the Chinook salmon bycatch by time and area with the distribution of available genetic samples. Top panel: Distribution of the 1,335 samples from the 2018 bycatch. Not graphed were 5 fish from NMFS area 523 and 1 fish from NMFS area 524. Bottom panel: Distribution of the Chinook salmon caught in the 2018 Bering Sea pollock trawl fishery. Not graphed were 40 fish from NMFS area 523, and 14 fish from NMFS area 524. Weeks 3-16 correspond to the groundfish "A" season, whereas weeks 22-40 correspond to the "B" season.

GENETIC STOCK COMPOSITION - PROCEDURE

DNA was extracted from axillary process tissue. Genotyping was performed by using Taqman™ chemistries from Applied Biosystems Inc. on a Life Technologies QuantStudio™ or by matrix-assisted laser desorption/ionization - time of flight (MALDI-TOF) (Guyon et al. 2010a) on a Sequenom MassARRAY iPLEX platform (Gabriel et al. 2009) for the 43 SNP DNA markers represented in the Chinook salmon baseline (Templin et al. 2011). 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 (Templin et al. 2011). Replicate samples using 384-well format Taqman™ assays were compared with MALDI-TOF assays, with a concordance rate of 99.99%. In addition to internal MALDI-TOF chip controls, 10 (out of 384 on a chip) previously genotyped samples from ADF&G, which used TaqMan™ chemistries, were included on each chip during the analyses and resulting genotypes were compared. Concordance rates of 99.9% between the two chemistries for the 2018 controls confirmed the utility and compatibility of both genotyping methods.

From the 2018 Chinook salmon bycatch from the Bering Sea pollock trawl fishery, a total of 1,363 samples were analyzed of which 1,297 samples were successfully genotyped for 35 or more of the 43 SNP loci, a successful genotyping rate of 95%. The successfully genotyped samples had genetic information for an average of 42 of 43 markers from both the “A” (n = 827) and “B” (n = 470) seasons.

Stock composition estimates were derived from BAYES software which uses a Bayesian algorithm to produce stock composition estimates and can account for missing alleles in the baseline (Pella and Masuda 2001). For each BAYES analysis, 11 Monte Carlo chains starting at disparate values of stock proportions were configured such that for each chain 95% of the stocks came from a single designated region with weights equally distributed among the stocks of that region. The designated region was unique in each chain. The remaining 5% was equally distributed among remaining stocks from all other regions. For all estimates, a flat prior of 0.005814 (calculated as 1/172) was used for all 172 baseline populations. The analyses were completed for a chain length of 10,000 with the first 5,000 deleted during the burn-in phase when determining overall stock compositions. Convergence of the chains to posterior distributions of stock proportions was determined with Gelman and Rubin shrink statistics (Gelman and Rubin 1992), which were 1.05 or less for all the estimates, conveying strong convergence to a single posterior distribution (Pella and Masuda 2001).

GENETIC STOCK COMPOSITION - RESULTS

The stock composition results indicate that 62% of the 827 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 (35%) and the North Alaska Peninsula (26%). The remaining 38% were from southern regions with British Columbia (27%) contributing the most, followed by the West Coast US (6%) (Appendix 2). In contrast to the "A" season 63% of the 470 "B" season samples originated from southern regions; British Columbia (33%), West Coast US (20%) and Coastal Southeast Alaska (5%) regions contributed the most (Appendix 2). The Coastal Western Alaska (31%) region was the second largest contributor during the "B" season.

For "A" and "B" seasons combined, 53% of the bycatch samples were estimated to be from Alaska river systems flowing into the Bering Sea with the Coastal Western Alaska region contributing the most (34%), trailed by the North Alaska Peninsula (18%). Forty-seven percent of all of the samples were from the southern regions, with the British Columbia (30%) region contributing the most, followed by the West Coast US (11%) region (Appendix 2).

Using information from the ANSWERS tool provided by AKFIN (NMFS 2019), 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 of the some samples being used in multiple analyses.

The “A” season estimates were developed for overlapping strata with sufficient numbers of samples (Appendix 2; Figs. 1, 5, 6, 7); Catcher Vessel Operation Area (CVOA) (595 samples, Fig. 5), and NMFS Statistical Area 509 (488 samples; Figs. 1, 7). For the CVOA and NMFS Area 509 strata, 56% and 65% of the samples, respectively, were from Alaska river systems flowing into the Bering Sea during the “A” season. Most were from Coastal Western Alaska (34% for both) followed by North Alaska Peninsula at 22% for CVOA and 28% for NMFS area 509, respectively. The largest southern components for CVOA and NMFS Area 509 were British Columbia (33% and 27%, respectively) and West Coast US (8% and 5%, respectively).

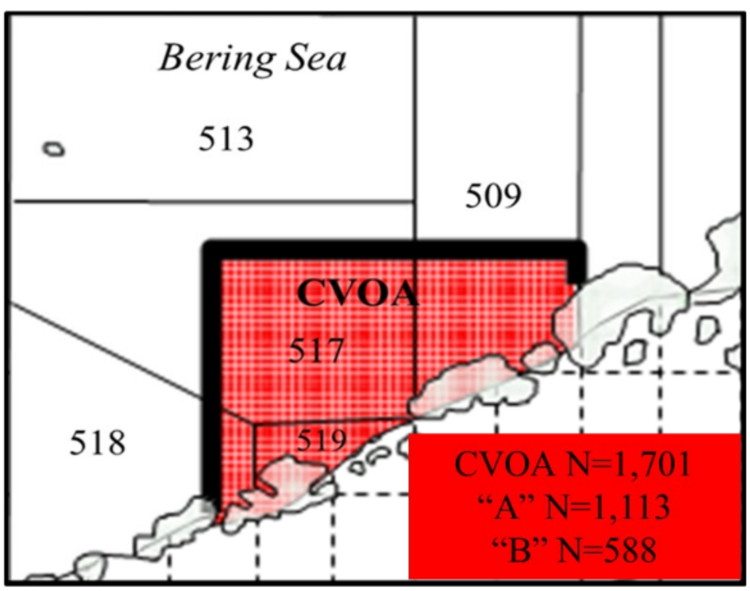

Figure 5. -- Location of Catcher Vessel Operational Area (CVOA) stratum used in comparative stock composition estimates from the 2018 Bering Sea Chinook salmon bycatch for “A” and “B” seasons (NMFS 2019).

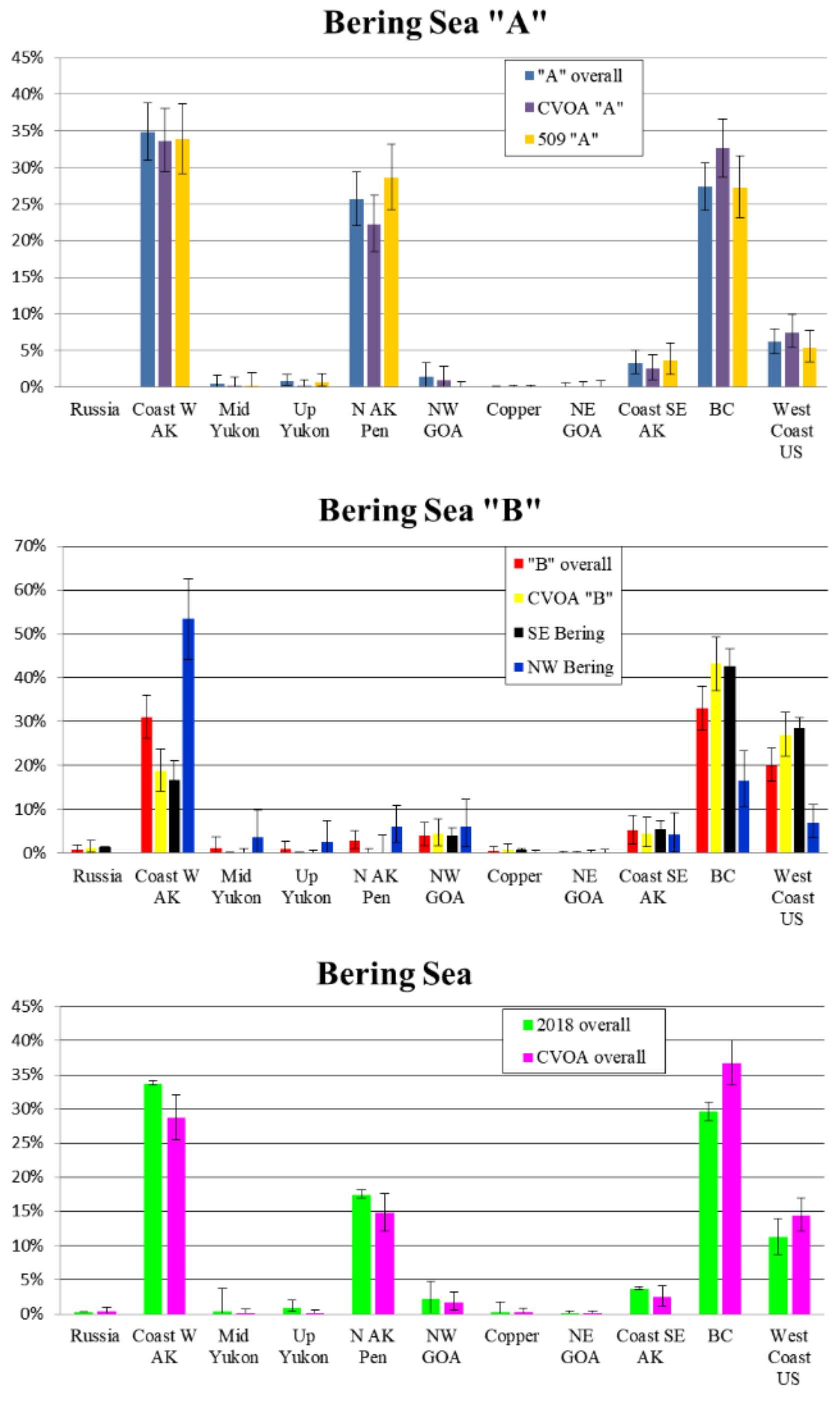

Figure 6. -- Stock composition estimates with BAYES 95% credible intervals of the 2018 Bering Sea Chinook salmon bycatch for "A" season (top): overall (827 samples), CVOA (595 samples, Fig. 9), and NMFS area 509 (488 samples, Fig. 8); "B" season (middle): overall (470 samples), CVOA (320 samples), Southeast Bering (291 samples) and Northwest Bering (179 samples), and Bering overall: (bottom) 2018 (1,297) and CVOA (915 samples).

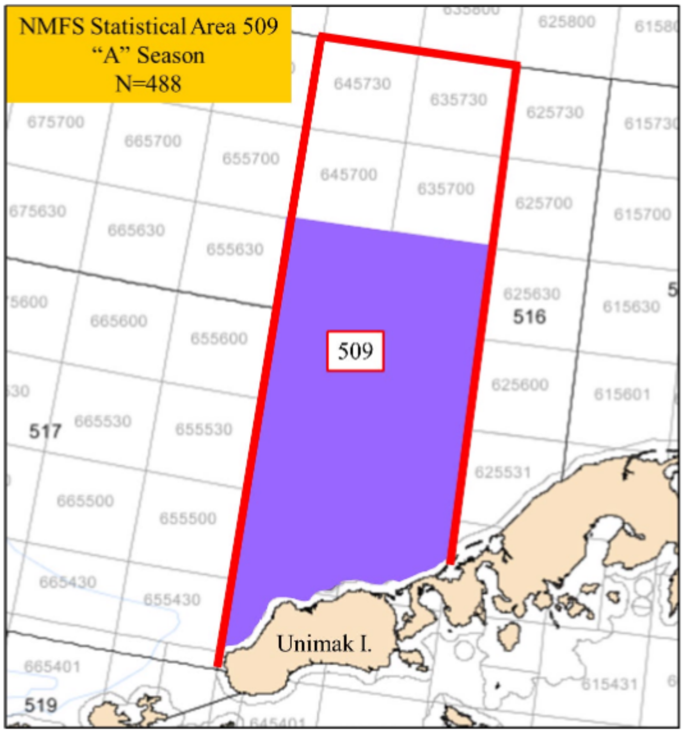

Figure 7. -- Location of samples from NMFS Statistical Area 509 (outlined in red) stratum used in comparative stock composition estimates from the 2018 Bering Sea Chinook salmon bycatch for "A" season (NMFS 2019). 377 of the samples are in the CVOA.

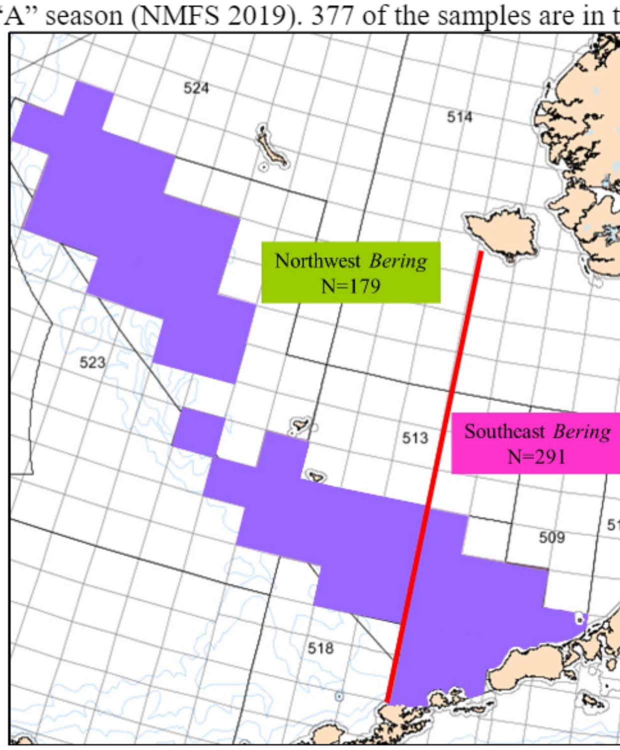

Figure 8. -- Location of Northwest Bering and Southeast Bering strata used in comparative stock composition estimates from the 2018 Bering Sea Chinook salmon bycatch for "B" season (NMFS 2019). 29 of the NW Bering and all of the SE Bering samples are in the CVOA.

For the "B" season, stock composition estimates were developed for CVOA (320 samples, Fig. 5), Southeast Bering (291 samples, Fig. 8), and Northwest Bering (179 samples Fig. 8) (NMFS 2019). The Northwest and Southeast strata overlap with CVOA stratum. For the Northwest Bering "B" season stratum, 66% of the stock composition was estimated to be from Alaska river systems flowing into the Bering Sea. The largest contributor was Coastal Western Alaska (54%) followed by North Alaska Peninsula (6%) Thirty-four percent of the stock composition was estimated to be from southern regions, where the largest contributors were British Columbia (17%), West Coast US (7%) and Northwest GOA (6%).

Approximately 80% of the "B" season stock composition estimates for the CVOA (80%) and Southeast Bering (82%) were from southern regions (Fig. 6, Appendix 2). The largest contributors were British Columbia (43%), West Coast US (27% for CVOA, 29% for Southeast Bering), and Coastal Southeast Alaska (5% for CVOA, 6% for Southeast Bering. The only contributor from the Bering Sea was Coastal Western Alaska at 19% for CVOA, and 17% for Southeast Bering.

The CVOA "B" season had a higher proportion of fish from southern regions (80%) than the "B" season overall (63%). The CVOA is the only stratum which had sufficient sample sizes to generate estimates for both the "A" and "B" seasons. The stock compositions were highly variable in CVOA across the seasons. It is notable that while the contribution from the British Columbia region increased from 33% to 43% between the CVOA "A" and "B" seasons, the contribution from the Northern Alaska Peninsula region decreased from 22% to almost zero, and the Coastal Western Alaska region also decreased from 34% to 19%, whereas the West Coast US region increased from 8% to 27% (Fig. 6). The contributions in the CVOA from the southern regions is significantly higher in the B season (80%) than the A season (44%) (Fig. 6).

COMPARISON WITH PREVIOUS ESTIMATES

Most of the Chinook salmon bycatch occurred in 2018 during the "A" season (Fig. 2), which is similar to most previous years since 2012. As in most previous years (with the exception of 2017) stock compositions from the analysis of the 2018 "A" season Chinook salmon bycatch showed most samples originated from river systems flowing into the Bering Sea (62%) than those from southern regions (Fig. 9). With the exception of 2017, the Coastal Western Alaska region has been the largest contributor in the 2018 "A" season. The 2018 "B" season stock composition estimates from Coastal Western Alaska increased relative to 2016 and 2017 (Fig. 9, Appendix 3). The 2018 "B" season estimates reversed a pattern of increased contributions from British Columbia, West Coast US, and Coastal Southeast Alaska regions. The estimated relative contributions from these more southern regions previously increased from a low of 20% in 2011 to a high of 86% in 2017, declining to 63% in 2018 (Fig. 9, Appendix 3).

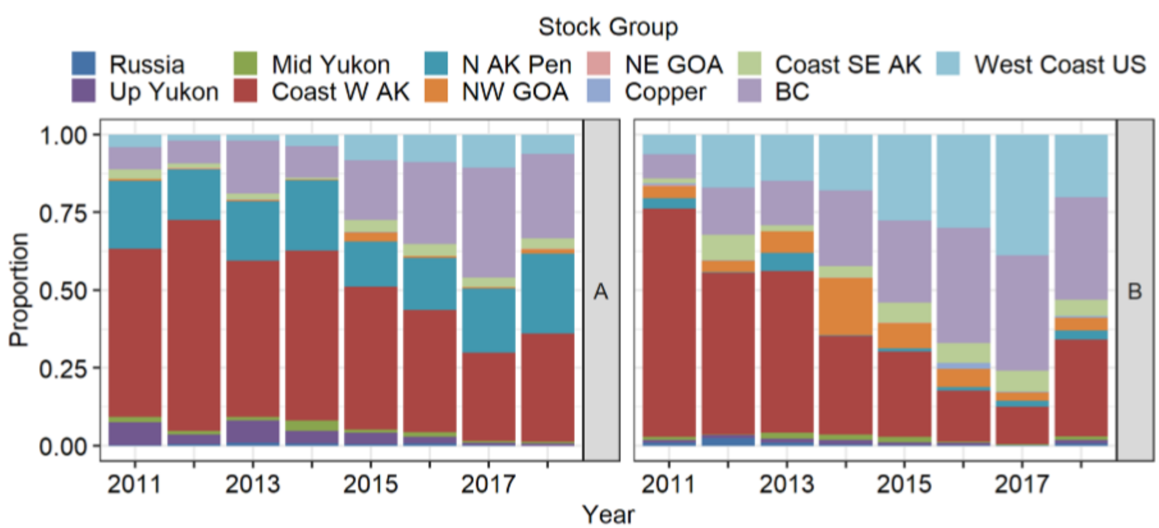

Figure 9. -- Annual "A" season (left) and "B" season (right) genetic stock composition estimates for 2011-2018 from the Bering Sea Chinook salmon bycatch. The same genetic baseline and regional groupings were used in all analyses.

Changes to sampling protocols necessitate caution in comparing analyses across time periods pre-dating 2011. However, when the stock compositions were analyzed on a yearly basis, the Coastal Western Alaska region shows variable contributions over time but generally trending downward since 2011 (Fig. 10). The 2018 North Alaska Peninsula region contribution of 18% was about average compared to previous years (Fig. 10). The upper and middle Yukon River, GOA, and Coastal Southeast Alaska contributions continued to be low in 2018, while contributions from the British Columbia and West Coast US regions have reversed a pronounced upward trend in 2018 (Fig. 10).

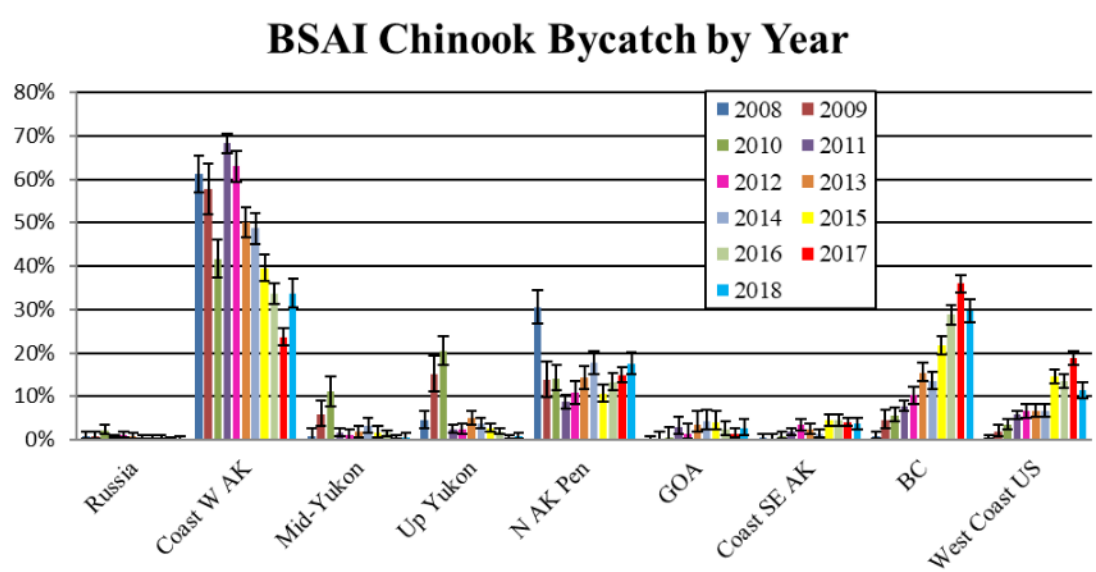

Figure 10. -- Annual (2008-2018) stock composition estimates with BAYES 95% credible intervals from the Bering Sea Chinook salmon bycatch. Estimates from 2011 to 2018 are overall bycatch estimates, whereas earlier estimates are of available sample sets. The same genetic baseline and general regional groupings were used in all analyses. Gulf of Alaska (GOA) group consists of combined values from the Northwest GOA, Copper, and Northeast GOA regions.

The estimated numbers of fish (shown here with 95% Credible Intervals) from the Coastal Western Alaska and North Alaska Peninsula regions have been relatively consistent between 2011 and 2018 (Fig. 11, Appendices 2-3). Coastal Western Alaska had a high of 17,421 (16,832-17,992) in 2011 and a low of 4,635 (4,197-5,080) in 2018, but from 2012 through 2017 it ranged from 6,530 (6,087-6,097) to 7,372 (6,832-7,928.) fish, with an average of 7,132 fish. The number of fish from North Alaska Peninsula ranged from 1,227 (943-1,543) to 2,927 (2,519-3,341); excluding the high of 4,490 (3,985-5,014) in 2017; averaging 2,173 during 2011-16 and 2018.

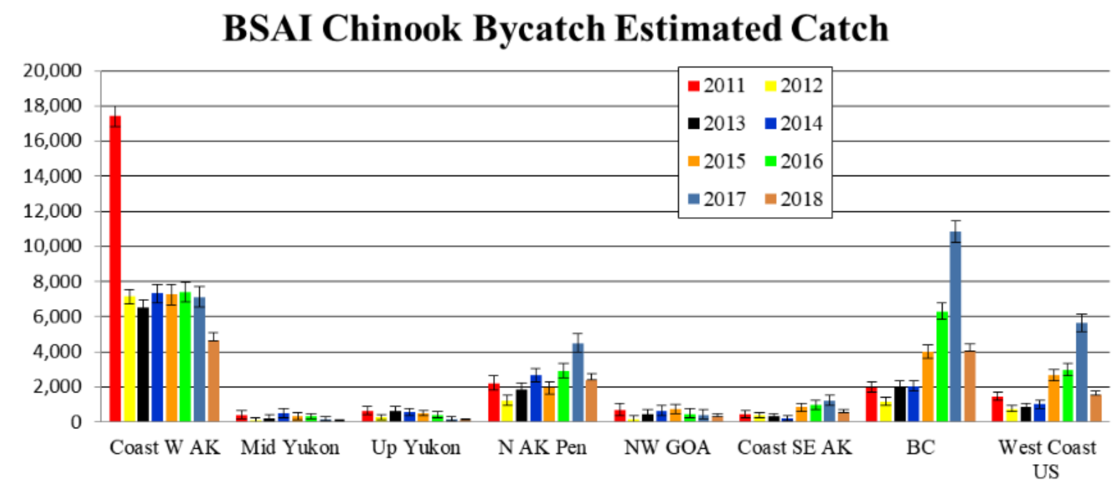

Figure 11. -- Annual (2011-2018) catch estimates with BAYES 95% credible intervals from the Bering Sea Chinook salmon bycatch. Russia (Avg. = 105) Copper (Avg. N = 26), and Northeast GOA (Avg. N = 5) regions were omitted from graph due to low catch.

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 35,454 salmon per year between 1991 and 2018 (27-year average), with a peak of 124,723 in 2007 and a low of 4,961 in 2000 (Table 1; NMFS 2020). The Bering Sea Chinook salmon bycatch has abated in more recent years; in 2018, a total of 13,726 Chinook salmon were caught, far below the 27-year average. The incidental harvest between 1991 and 2010 harvest averaged 41,102, and after the implementation Amendment 91 between 2011 and 2018 the average dropped to 11,784 (Table 1; NMFS 2020).

Sampling Issues

With the implementation of systematic random sampling, 2018 is the eighth year from which representative samples have been collected from the Chinook salmon bycatch. Data prior to 2011 should be used with caution because the samples were not systematically collected. Systematic random sampling represents a significant 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 and 4). The number of successfully genotyped Chinook salmon from the Bering Sea bycatch samples was 1,297, corresponding to an effective overall sampling rate in 2018 of 9.5%.

Stock Composition Estimates

The proportions of Chinook salmon originating from Alaska Rivers accounted for most of the catches in early years, but southern regions have accounted for larger and larger proportions in more recent years culminating in 2017, where southern stocks accounted for more than half the bycatch. The 2018 data may signal a change to this pattern, with Chinook salmon originating from streams that drain into the Bering Sea accounting for more than half the bycatch. The stock composition of the Chinook salmon bycatch from the 2018 “A” season differed from the “B” season, demonstrating temporal changes (Appendix 2; Figs. 6 and 9). This was especially apparent in the North Alaska Peninsula (26% vs. 3%) and West Coast US (6% vs. 20%) regions. Conversely, the largest contributor to both “A” and “B” season fisheries was the

Coastal Western Alaska region which remained nearly constant across both seasons (35-31%). This seasonal pattern was also evident for North Alaska Peninsula (22% vs. 0%), and West Coast US (8% vs. 27%) regions in the CVOA, a smaller area stratum of the Bering Sea (Fig. 9). 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. 9). However, despite that the number of Chinook salmon bycatch in the northwestern Bering Sea is about two-thirds of that in the southeastern Bering Sea during the “B” season, the total number of estimated Chinook salmon bycatch from this rivers flowing into the Bering is higher in the northwestern Bering Sea (1,309 {926-1,803} fish) than in the southeastern Bering Sea (548 {397-766}fish). One must also consider that the bycatch in the “A” season is more than 1.75 times more abundant than in the “B” season, and that the seasonal stock composition differences may be due to relative abundance of stock, seasonal migration of stocks, or avoidance behaviors by the fleet. Anomalous ocean conditions may have changed migration patterns in recent years, which has also been observed in the Southeast Alaska troll and sport fisheries (Gilk-Baumer et al. 2017).

Application of Estimates

Stock composition estimates for the 2018 Bering Sea Chinook salmon bycatch were fairly 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 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, 3) the ages of the returning salmon by stock, and 4) the total annual run-size of the affected stocks. 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 in one year does not necessarily imply greater impact than a smaller estimate the next.

ACKNOWLEDGMENTS

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CITATIONS

Davis, N. D., A. V. Volkov, A. Y. Efimkin, N. A. Kuznetsova, J. L. Armstrong, and O. Sakai. 2009. Review of BASIS salmon food habits studies. N. Pac. Anadr. Fish. Comm. Bull. 5:197-208.

Gabriel, S., L. Ziaugra, and D. Tabbaa. 2009. SNP genotyping using the Sequenom MassARRAY iPLEX platform. Current Protocols in Human Genetics Chapter 2, Unit 212.

Gelman, A., and D. B. Rubin. 1992. Inference from iterative simulation using multiple sequences. Stat. Sci. 7:457-511.

Gilk-Baumer, S., D. F. Evenson, K. Shedd, and E. L. Jones. 2017. Mixed stock analysis of Chinook salmon harvested in Southeast Alaska commercial troll and sport fisheries, 2016. Alaska Department of Fish and Game, Fishery Data Series No. 18-01, Anchorage.

Guthrie, C. M. III, Hv. Nguyen, and J. R. Guyon. 2012. Genetic stock composition analysis of Chinook salmon bycatch samples from the 2010 Bering Sea trawl fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-232, 22 p.

Guthrie, C. M. III, Hv. Nguyen, and J. R. Guyon. 2013. Genetic stock composition analysis of Chinook salmon bycatch samples from the 2011 Bering Sea and Gulf of Alaska trawl fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-244, 28 p.

Guthrie, C. M. III, Hv. Nguyen, and J. R. Guyon. 2014. Genetic stock composition analysis of Chinook salmon bycatch samples from the 2012 Bering Sea and Gulf of Alaska trawl fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-270, 33 p.

Guthrie, C. M. III, Nguyen, Hv.T., and J. R. Guyon. 2015. Genetic stock composition analysis of the Chinook salmon bycatch from the 2013 Bering Sea walleye pollock (*Gadus chalcogrammus*) trawl fishery. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-290, 21 p.

Guthrie, C. M. III, Nguyen, Hv.T., and J. R. Guyon. 2016. Genetic stock composition analysis of the Chinook salmon bycatch from the 2014 Bering Sea walleye pollock (*Gadus chalcogrammus*) trawl fishery. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-310, 25 p.

Guthrie, C. M. III, Nguyen, Hv.T., A. E. Thomson, and J. R. Guyon. 2017. Genetic stock composition analysis of the Chinook salmon bycatch from the 2015 Bering Sea walleye pollock (*Gadus chalcogrammus*) trawl fishery. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-342, 33 p.

Guthrie, C. M. III, Hv. T. Nguyen, A. E. Thomson, K. Hauch, and J. R. Guyon. 2018. Genetic stock composition analysis of the Chinook salmon (*Oncorhynchus tshawytscha*) bycatch from the 2016 Bering Sea walleye pollock (*Gadus chalcogrammus*) trawl fishery. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-365, 32 p.

Guthrie III, C. M., Hv. T. Nguyen, M. Marsh, J. T. Watson, and J. R. Guyon. 2019. Genetic stock composition analysis of the Chinook salmon bycatch samples from the 2017 Bering Sea trawl fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-391, 36 p.

Guyon, J. R., C. M. Guthrie, and H. Nguyen. 2010a. Genetic stock composition analysis of Chinook salmon bycatch samples from the 2008 Bering Sea pollock fishery, 32 p. Report to the North Pacific Fishery Management Council, 605 W. 4th Avenue, Anchorage AK 99510.

Guyon, J. R., C. M. Guthrie, and H. Nguyen. 2010b. Genetic stock composition analysis of Chinook salmon bycatch samples from the 2007 "B" season and 2009 Bering Sea trawl fisheries, p. 32. Report to the North Pacific Fishery Management Council, 605 W. 4th Avenue, Anchorage AK 99510.

Ianelli, J. N., and Stram, D. L. 2015. Estimating impacts of the pollock fishery bycatch on western Alaska Chinook salmon. ICES J. Mar. Sci., 72: 1159–1172.

Larson, W. A., F. M. Utter, K. W. Myers, W. D. Templin, J. E. Seeb, C. M. Guthrie III, A. V. Bugaev, and L. W. Seeb. 2013. Single-nucleotide polymorphisms reveal distribution and migration of Chinook salmon (*Oncorhynchus tshawytscha*) in the Bering Sea and North Pacific Ocean. Can. J. Fish. Aquat. Sci. 70(1):128-141.

Myers, K. W., N. V. Klovach, O. F. Gritsenko, S. Urawa, and T. C. Royer. 2007. Stock-specific distributions of Asian and North American salmon in the open ocean, interannual changes, and oceanographic conditions. N. Pac. Anadr. Fish. Comm. Bull. 4: 159-177.

NMFS (National Marine Fisheries Service). 2009. Bering Sea Chinook salmon bycatch management - Volume 1, Final Environmental Impact Statement, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Regional Office, Juneau, AK.

NMFS (National Marine Fisheries Service). 2019. Catch Accounting System data. NMFS Alaska Regional Office. Data compiled by Alaska Fisheries Information Network for Alaska Fisheries Science Center, Juneau. [URL not publicly available as some information is confidential.]

NMFS (National Marine Fisheries Service). 2020. BSAI Chinook salmon mortality estimates, 1991-present, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Regional Office, Juneau, AK. https://alaskafisheries.noaa.gov/sustainablefisheries/inseason/chinook_salmon_mortality.pdf

NPFMC (North Pacific Fishery Management Council). 2017a. Fishery management plan for groundfish of the Bering Sea and Aleutian Islands management area. North Pacific Fishery Management Council, 605 W. 4th Ave., Anchorage, Alaska, 99501. https://www.npfmc.org/wp-content/PDFdocuments/fmp/BSAI/BSAIfmp.pdf .

NPFMC (North Pacific Fishery Management Council). 2017b. Minutes of April 2017 meeting. https://www.npfmc.org/meeting-minutes .

Pella, J., and H. J. Geiger. 2009. Sampling considerations for estimating geographic origins of Chinook salmon bycatch in the Bering Sea pollock fishery. Alaska Dep. Fish Game Spec. Pub. No. SP 09-08. 58 p.

Pella, J., and M. Masuda. 2001. Bayesian methods for analysis of stock mixtures from genetic characters. Fish. Bull., U. S. 99:151-167.

Templin, W. D., J. E. Seeb, J. R. Jasper, A. W. Barclay, and L. W. Seeb. 2011. Genetic differentiation of Alaska Chinook salmon: the missing link for migratory studies. Mol. Ecol. Res. 11 (Suppl. 1):226–246.

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 BAYES stock composition percentage estimates, standard deviations (SD), 95% credible intervals (CI), and estimated numbers of Chinook salmon from the the 2018 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 2020).

	"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			

	CVOA "A" (N=595)				CVOA "B" (N=320)				CVOA (N=915)			
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)	46	1.3	0.72	(0.2,3.0)	39	0.4	0.25	(0.1,1.0)
Coast W AK	2,087	33.7	2.19	(29.4,38.1)	668	18.7	2.47	(14.1,23.8)	2,806	28.7	1.70	(25.5,32.1)
Mid Yukon	10	0.2	0.38	(0.0,1.4)	1	0.0	0.10	(0.0,0.3)	10	0.1	0.22	(0.0,0.8)
Up Yukon	16	0.3	0.28	(0.0,1.0)	1	0.0	0.09	(0.0,0.3)	16	0.2	0.18	(0.0,0.7)
N AK Pen	1,379	22.2	1.98	(18.5,26.2)	4	0.1	0.34	(0.0,1.2)	1,446	14.8	1.40	(12.1,17.6)
NW GOA	61	1.0	0.73	(0.0,2.8)	157	4.4	1.54	(1.7,7.8)	172	1.8	0.68	(0.6,3.3)
Copper	1	0.0	0.08	(0.0,0.3)	27	0.8	0.53	(0.1,2.1)	28	0.3	0.21	(0.0,0.8)
NE GOA	7	0.1	0.24	(0.0,0.8)	1	0.0	0.17	(0.0,0.4)	4	0.0	0.13	(0.0,0.4)
Coast SE AK	154	2.5	0.89	(1.0,4.5)	159	4.5	1.70	(1.6,8.2)	243	2.5	0.76	(1.2,4.1)
BC	2,022	32.6	2.03	(28.7,36.6)	1,541	43.2	3.10	(37.1,49.3)	3,589	36.7	1.69	(33.5,40.1)
West Coast US	464	7.5	1.15	(5.4,9.9)	963	27.0	2.56	(22.1,32.1)	1,415	14.5	1.22	(12.2,16.9)
Total Catch	6,201				3,568				9,769			

	SE Bering S. "B" (N=291)				NW Bering S. "B" (N=179)				Area 509 "A" (N=488)			
Region	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI	Est. #	Mean	SD	95% CI
Russia	48	1.5	0.79	(0.3,3.4)	0	0.0	0.09	(0.0,0.1)	1	0.0	0.03	(0.0,0.1)
Coast W AK	543	16.8	2.44	(12.3,21.8)	1,062	53.5	4.67	(44.2,62.5)	1,710	33.9	2.44	(29.2,38.7)
Mid Yukon	1	0.0	0.11	(0.0,0.3)	73	3.7	2.92	(0.0,9.9)	12	0.2	0.53	(0.0,1.9)
Up Yukon	1	0.0	0.11	(0.0,0.3)	53	2.7	2.05	(0.0,7.4)	37	0.7	0.45	(0.1,1.8)
N AK Pen	4	0.1	0.36	(0.0,1.3)	121	6.1	2.19	(2.5,11.0)	1,445	28.6	2.30	(24.3,33.2)
NW GOA	130	4.0	1.50	(1.5,7.4)	120	6.1	2.79	(1.6,12.3)	4	0.1	0.21	(0.0,0.7)
Copper	26	0.8	0.56	(0.1,2.2)	1	0.1	0.27	(0.0,0.8)	2	0.0	0.10	(0.0,0.3)
NE GOA	1	0.0	0.17	(0.0,0.5)	2	0.1	0.38	(0.0,0.9)	5	0.1	0.24	(0.0,0.8)
Coast SE AK	176	5.5	1.89	(2.2,9.6)	84	4.2	2.33	(0.4,9.3)	183	3.6	1.08	(1.8,6.0)
BC	1,378	42.7	3.27	(36.3,49.1)	330	16.6	3.23	(10.7,23.3)	1,378	27.3	2.13	(23.2,31.6)
West Coast US	922	28.5	2.74	(23.3,34.1)	138	7.0	1.92	(3.7,11.2)	271	5.4	1.12	(3.4,7.8)
Total Catch	3,230				1,985				5,047			

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.

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			

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			

Appendix 3. -- Continued

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			

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			

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