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May 2021

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

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NOAA FISHERIES

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ABSTRACT

Chum salmon (*Oncorhynchus keta*) that are caught in Alaska's federally managed groundfish trawl fisheries are designated as prohibited species catch (PSC). We analyzed genetic stock compositions of chum salmon PSC samples collected from the 2017 walleye pollock (*Gadus chalcogrammus*) fishery in the Bering Sea and from the federal groundfish fisheries in the Gulf of Alaska (GOA). Samples were genotyped for 11 microsatellite markers from which stock contributions were estimated using a range-wide chum salmon microsatellite baseline. In 2017, one genetic sample was collected for approximately every 36 chum salmon caught in the Bering Sea midwater pollock trawl fishery. The evaluation of sampling in the Bering Sea based on time, location, and vessel indicated that the genetic samples were representative of the total chum salmon PSC in the Bering Sea, with the exception that several high chum salmon catches on catcher-processor vessels were under-sampled due to lack of sampling materials. Based on the analysis of 2,064 chum salmon collected throughout the B-season, the largest stock group was Northeast Asia (46%), followed by Southeast Asia (16%), Eastern GOA/PNW (15%), Western Alaska (14%), Upper/Middle Yukon (6%), and Southwest Alaska (3%) stocks. Compared to previous years, this represented a substantial increase in the proportion of Northeast Asia stocks and a decrease in Eastern GOA/PNW stocks. These differences may be due to a temporal shift in bycatch occurrence. Most of the 2017 Bering Sea chum salmon PSC was caught in a narrow window of time, several weeks earlier in the B-season than in past years. Of the 812 chum salmon samples from the GOA groundfish fisheries, the highest stock proportion was from Eastern GOA/PNW (84%) stocks, similar to previous years. For the first time, stock estimates are provided by age strata of chum salmon with previously unreported results from 2016 included for comparison. Stock composition varied by age in 2016, with a high proportion of age-3 fish from the Eastern GOA/PNW stock and most of the age-5 fish from Asian stocks. In 2017,

there was less difference in the stock composition by age, with all three ages dominated by Asian stocks.

CONTENTS

INTRODUCTION

Pacific salmon (*Oncorhynchus* spp.) are prohibited species in the federally managed Bering Sea and Gulf of Alaska (GOA) groundfish fisheries, which are subject to complex management rules (NPFMC 2018a, b) that are in part designed to reduce prohibited species catch (PSC). It is important to understand the stock composition of Pacific salmon caught in these fisheries, which take place in areas that are known feeding habitats for multiple brood years of chum salmon (*O. keta*) from many different localities in North America and Asia (Myers et al. 2007, Davis et al. 2009, Urawa et al. 2009). Determining the geographic origin of salmon caught in federally managed fisheries is essential for understanding the effects that fishing has on chum salmon stocks, especially those with conservation concerns (NPFMC 2012).

We present the genetic stock composition estimates for the samples of chum salmon PSC collected during 2017 from the U.S. Bering Sea walleye pollock (*Gadus chalcogrammus*) trawl fishery and the GOA groundfish fisheries. In 2017, in the Bering Sea, the pollock fishery accounted for more than 99.2% of the total chum salmon taken in the groundfish fisheries (NMFS 2018). In the GOA, the majority (76%) of the chum salmon were caught in the pollock trawl fishery, with the remainder caught in other groundfish fisheries (NMFS 2017).

The National Marine Fisheries Service (NMFS) reporting areas associated with the groundfish fisheries are shown in Figure 1 and are presented later to describe the spatial distribution of the chum salmon catch and genetic samples. The data reporting tool, Alaska Fisheries Information Network (AKFIN[1]), developed by the Pacific States Marine Fisheries Commission (PSMFC), simplifies access to fishery information associated with the genetic samples of salmon PSC and is useful for organizing sample datasets at the finer resolution of ADF&G groundfish statistical areas (Fig. 1). The AKFIN reports were used to construct spatial-

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[1] AKFIN website (http://dev.akfin.org/home/).

temporal sets of genetic samples along the outer continental shelf from the 2017 chum salmon PSC.

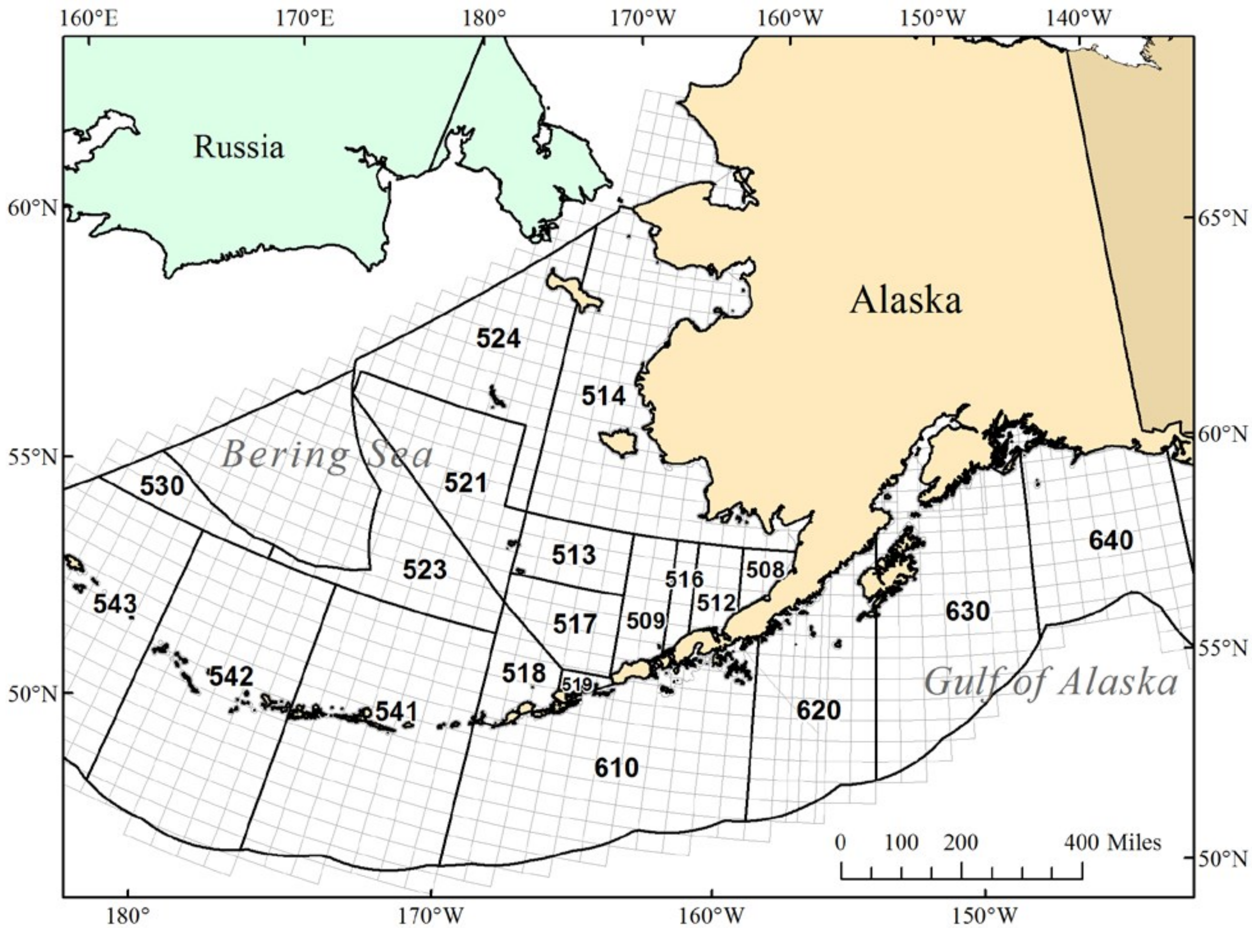

Figure 1. -- NMFS reporting areas associated with the Bering Sea-Aleutian Island and Gulf of Alaska groundfish fisheries are numbered and outlined in black. The ADF&G groundfish statistical areas are outlined in light gray.

For additional background and methods, this report is intended to be supplemented with the chum salmon reports prepared previously for the 2005-2016 Bering Sea trawl fisheries (Guyon et al. 2010; Marvin et al. 2011; Gray et al. 2010, 2011a, b; Kondzela et al. 2012, 2013, 2016, 2017; Vulstek et al. 2014; Whittle et al. 2015, 2018). The chum salmon PSC is designated as non-Chinook salmon (*O. tshawytscha*) in the NMFS database and comprises over 95% of the non-Chinook salmon category in the Bering Sea (NPFMC 2007).

SAMPLE DISTRIBUTION

Bering Sea

Genetic samples were collected from the chum salmon caught in the Bering Sea pollock fishery by the Alaska Fisheries Science Center's (AFSC) North Pacific Groundfish and Halibut Observer Program (Observer Program) in 2017 for analysis at the AFSC's Auke Bay Laboratories (ABL). Sampling was changed in 2011 from previous years (Faunce 2015, Cahalan et al. 2014) to implement a systematic sampling protocol recommended by Pella and Geiger (2009) with a goal to sample axillary processes (for genetic analysis) and scales (for ageing) from every 30th chum salmon throughout the season.

In 2017, an estimated 467,678 chum salmon (99.8% of the non-Chinook salmon caught in 2017) were caught in the pollock-directed trawl fisheries and represent the second largest catch of chum salmon in the pollock fisheries since 1994 (NMFS 2017). This catch was substantially larger than the 1994-2016 average of 153,297 chum salmon and more than five times the median of 80,652 (Fig. 2). As in previous years, nearly all (99.7%) of the chum salmon were caught during the pollock B-season (June 10 to November 1) (Fig. 3) in NMFS reporting areas 509-524 (Fig. 1). However, in 2017, most of the chum salmon PSC was caught in a narrow window of time, several weeks earlier than in previous years. Genetic samples were collected from 12,885 fish (NMFS 2017), which represents a sampling rate of 1 of every 36.2 chum salmon (or 2.8% of the chum salmon catch). This sampling rate is lower than in 2011-2016, the first six years of representative sampling.

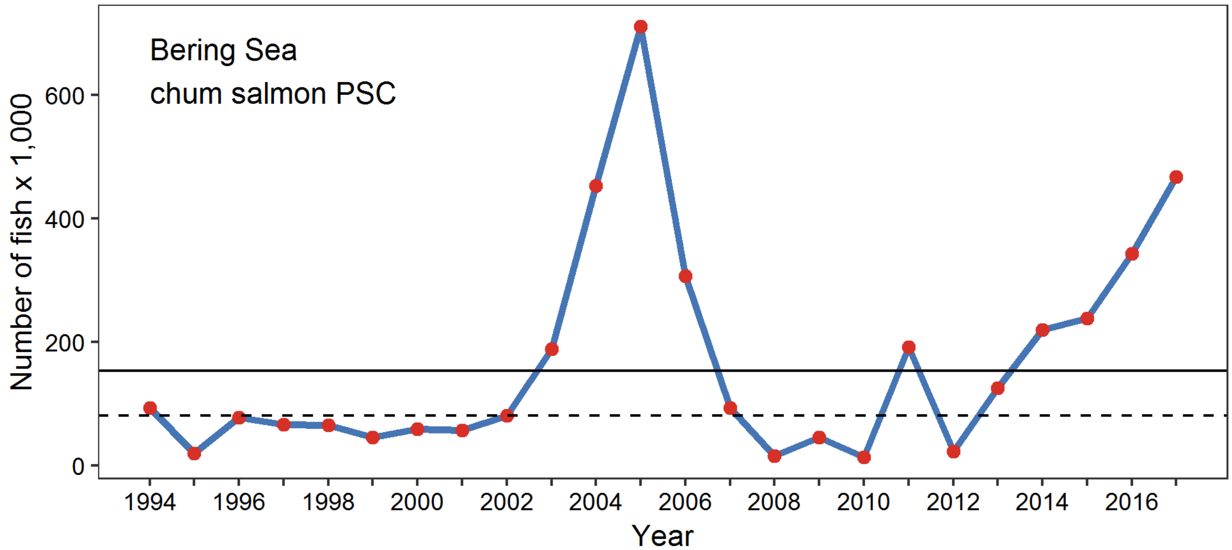

Figure 2. -- Chum salmon prohibited species catch (PSC) per year from the Bering Sea pollock-directed trawl fisheries (listed as non-Chinook in NMFS 2018). Estimates for years prior to 2011; censuses for years from 2011 to present. The solid horizontal line represents mean PSC and the dashed line represents median PSC between 1994 and 2016.

Biases and errors associated with past collections of genetic samples from the salmon PSC have the potential to affect stock composition estimates (NMFS 2009, Pella and Geiger 2009). The systematic sampling protocols recommended by Pella and Geiger (2009) were implemented in the Bering Sea pollock fisheries in 2011 to reduce sampling error and bias, the efficacy of which was evaluated by comparing the genetic sample distributions and the overall PSC estimates with Chi-square tests. Low sample sizes in some time/area strata were pooled prior to testing: Early, Middle, and Late time periods (weeks 23-29, 30-34, and 35-42) and two areas (NMFS reporting areas aggregated: (1) 509, 513, and 516; and (2) 521, 523, and 524). Temporal bias by statistical weeks (ending on Saturday) appeared to be negligible (Fig. 3) when samples were pooled across management areas, although unlike previous reports, the Chi-square test was highly significant (χ^2 = 604.0, 17 d.f., P << 0.001), due primarily to under-sampling during weeks 28-31, and 36. During the B-season, temporal biases also appear minimal at finer spatial scales (Fig. 4), but the Chi-square test was highly significant; (χ^2 = 554.8, 6 d.f., P << 0.001) due primarily to under-sampling in NMFS reporting area 517 during the Early and Middle time periods and NMFS reporting areas 521-524 during the Late time period. The NMFS and ADF&G reporting area is known for samples collected at the haul-level from at-sea processors (hauls), but due to the uncertainty of catch location for samples collected at the trip-level from shore-side processors (offloads) in which deliveries may contain mixed hauls from multiple reporting areas, the reporting area of the chum salmon catch from offloads was identified as the area where most of the pollock were caught during a fishing trip.

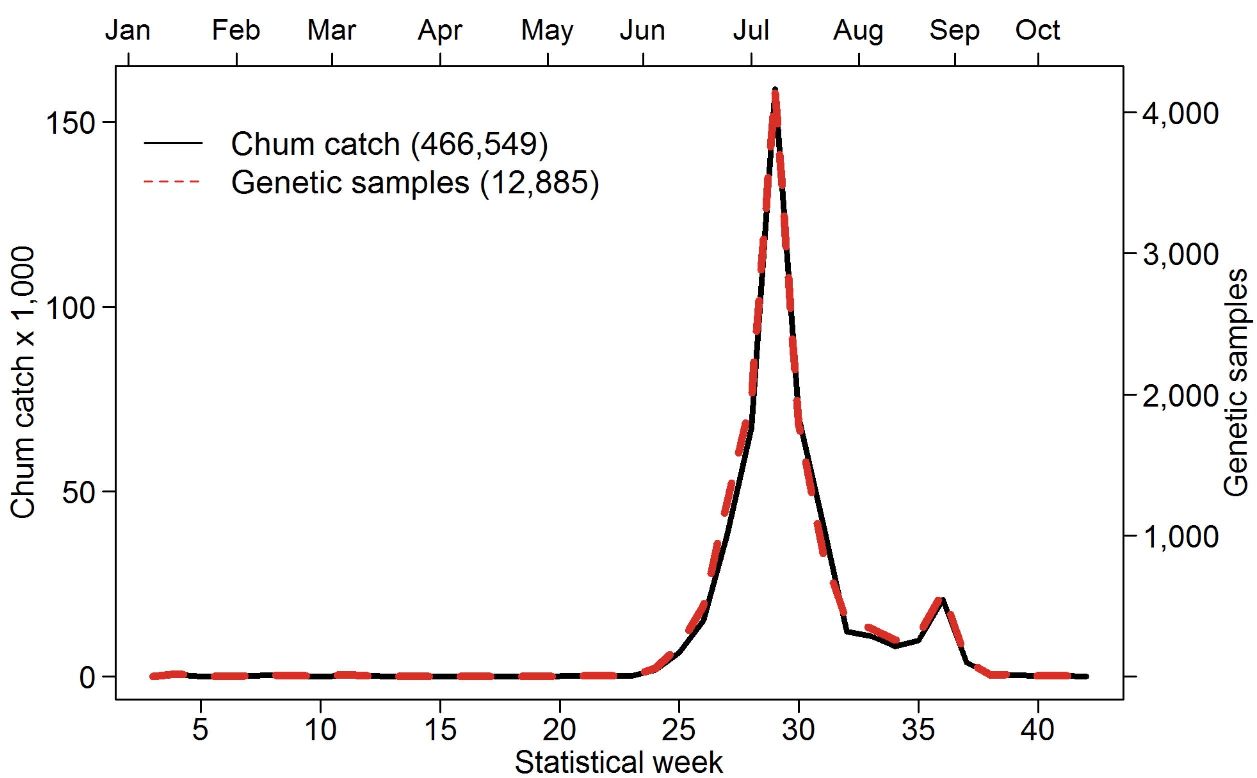

Figure 3. -- Number of Bering Sea chum salmon caught (black, solid line) and genetic samples collected (red, dashed line) from the 2017 Bering Sea pollock trawl fishery by statistical week. Weeks 1-22 correspond to the A-season, whereas weeks 23-42 correspond to the B-season.

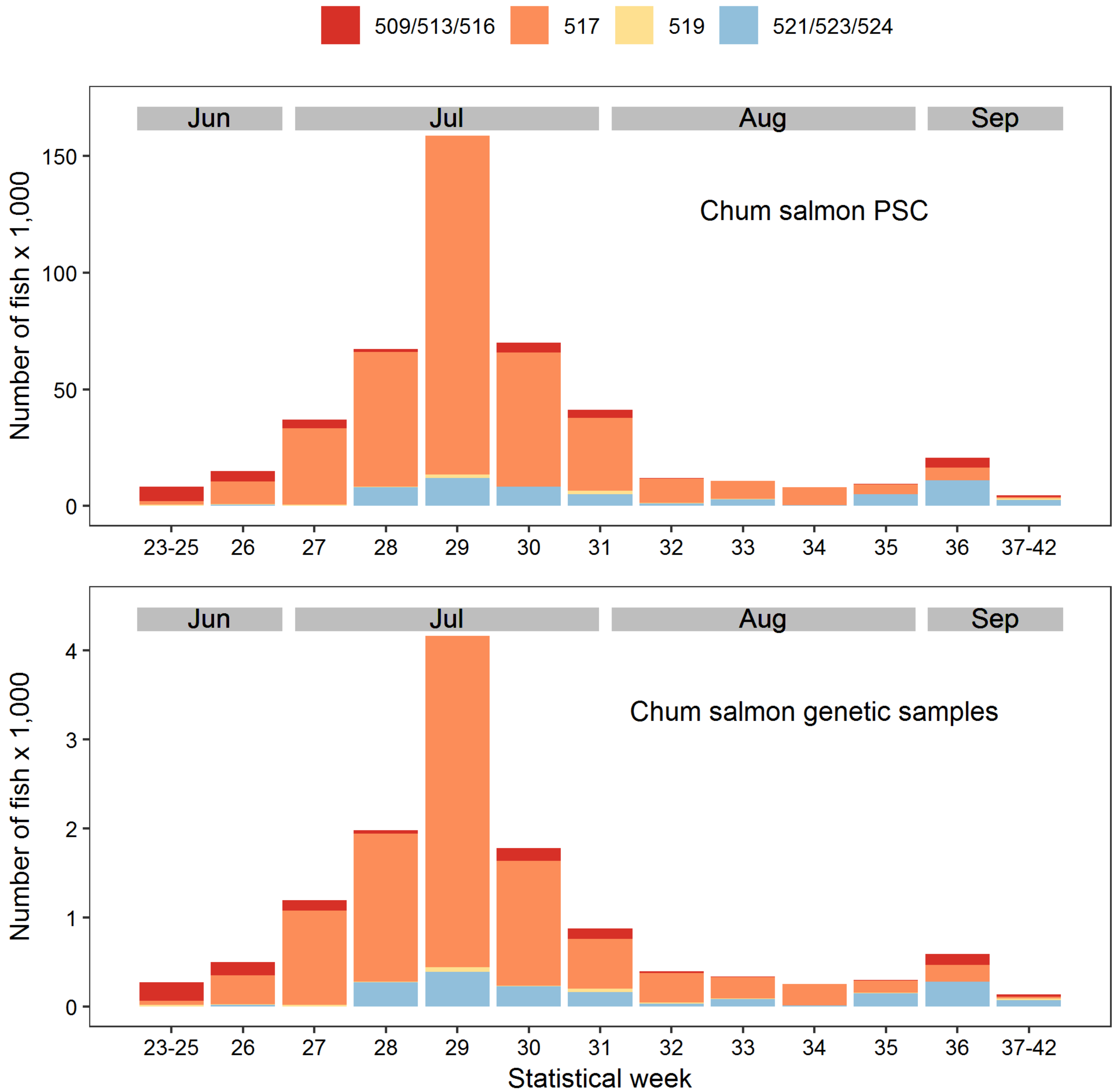

Figure 4. -- Number of Bering Sea chum salmon caught (top) and genetic samples collected (bottom) from the 2017 Bering Sea, B-season pollock fishery by statistical week and NMFS reporting area (designated in the legend).

The systematic collecting protocol was also evaluated by comparing the total number of chum salmon caught on each vessel to the number of genetic samples collected from each vessel during 2017. Of the 100 vessels that participated in the midwater trawl fishery during the A- and B-seasons, 90 vessels caught chum salmon. The chum salmon catch was subsampled by observers for genetic samples across a large range (up to 40,000 fish) of chum salmon catch per vessel (Fig. 5). Per vessel, the ratio of numbers of genetic samples to numbers of chum salmon caught was 1 in 31.8 ± 7.6 fish (mean ± S.D.; unweighted by proportion of bycatch each vessel caught), which is slightly less than the protocol of one genetic sample from every 30th chum salmon caught. In 2017, about 60% of the chum salmon PSC was counted from at-sea hauls and 40% from shoreside offloads. By vessel, the sampling ratio was 1 in 35.3 fish and 1 in 30.3 fish for at-sea and shoreside offloads, respectively, a non-significant difference (t-test; $P = 0.06$). Seven catcher-processor vessels had at-sea sampling rates lower than expected for some hauls (Fig. 5) due to large catches and insufficient sampling materials. The under-sampling on these vessels explains the sampling bias observed across temporal and spatial strata described above (Figs. 3, 4).

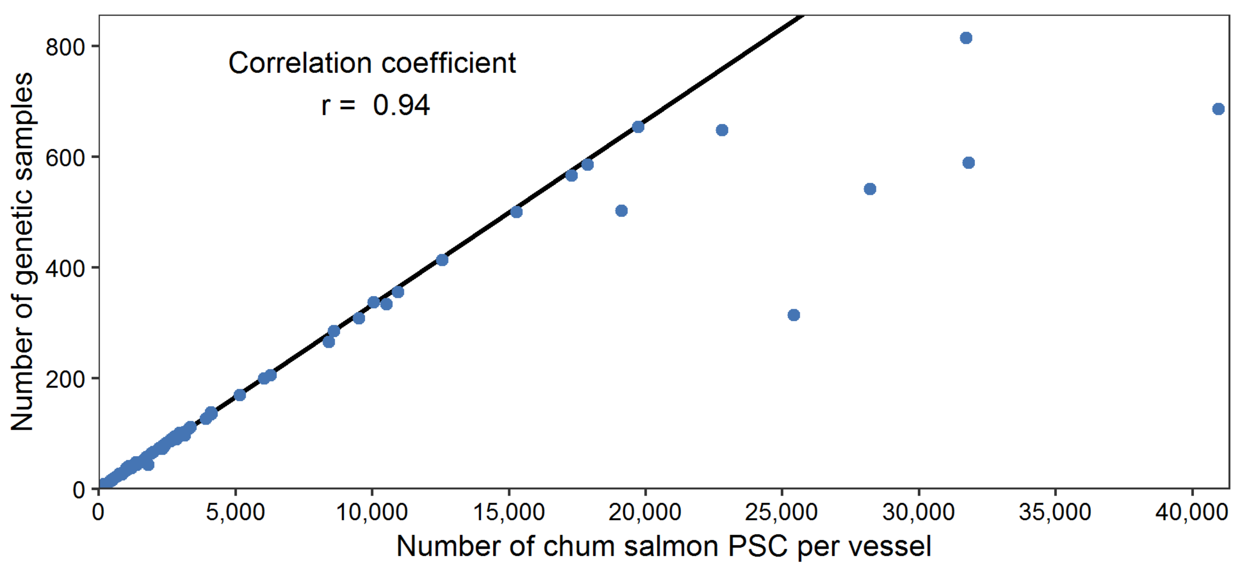

Figure 5. -- Chum salmon catch and genetic samples from the 2017 Bering Sea, A- and B-seasons of the pollock fishery. Number of genetic samples collected from the total number of chum salmon caught from each of 90 vessels; black diagonal line represents the expected sampling rate.

Gulf of Alaska

The estimated PSC of chum salmon in the GOA (NMFS 2017) is 1-2 orders of magnitude lower than in the Bering Sea and has been a lower management priority than the typically larger catches of Chinook salmon (e.g., Guthrie et al. 2018). In 2017, chum salmon samples were collected in the GOA (AFSC 2016) primarily from the pollock trawl fishery, which caught nearly 76% of the chum salmon PSC in the GOA (Fig. 6). The majority of chum salmon from the non-pollock fisheries were caught in the rockfish, arrowtooth flounder, and Pacific cod fisheries between the pollock B- and C- seasons (May 31-Aug. 24; Fig. 7). This is the fourth consecutive year that the number of chum salmon genetic samples collected from the GOA groundfish fisheries was large enough to run a mixed-stock analysis. Approximately 20% of the chum salmon caught in the pollock fisheries were collected for genetic samples, whereas less than 2% of chum salmon caught in other GOA groundfish fisheries were sampled. The available sample set included 891 samples from the pollock fishery from NMFS reporting areas 610, 620, and 630 during primarily the pollock C- and D- seasons[2], and 12 samples from other fisheries (Figs. 1, 7, and 8).

[2] Pollock caught in Gulf of Alaska Western and Central Regulatory Areas (NMFS reporting areas 610-630): A-season (Jan. 20 to Mar. 10), B-season (Mar. 10 to May 31), C-season (Aug. 25 to Oct. 1), D-season (Oct. 1 to Nov. 1), published in the Federal Register (82 FR 12032, Table 3).

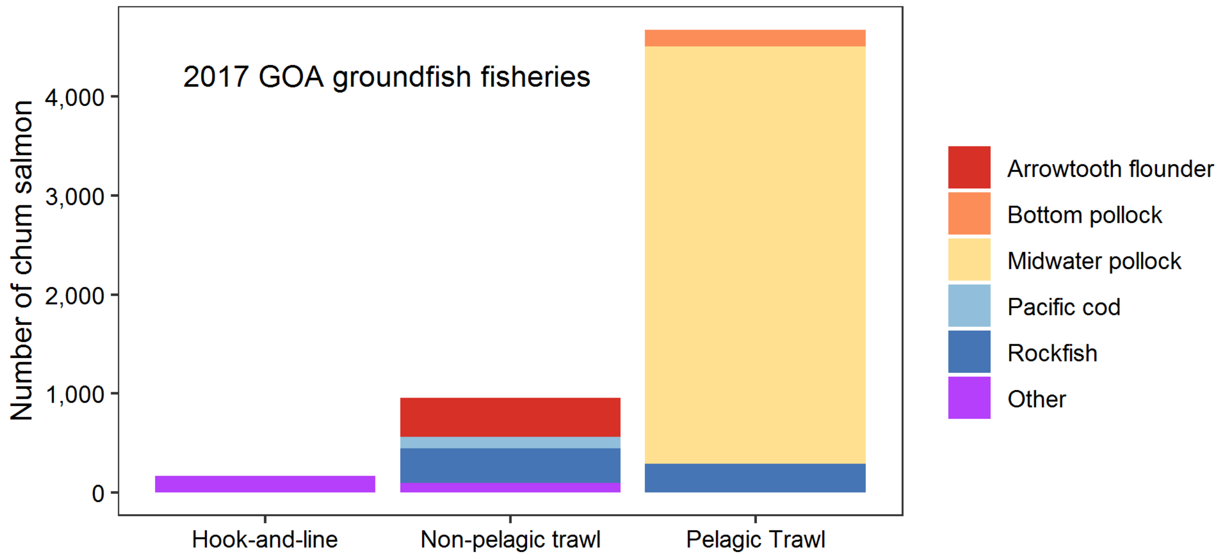

Figure 6. -- Estimated number of chum salmon caught (n = 5,803) in the 2017 Gulf of Alaska groundfish fisheries by target species. The 235 chum salmon caught in the shallow-water flatfish, halibut, sablefish, and rex sole fisheries were combined as “Other”.

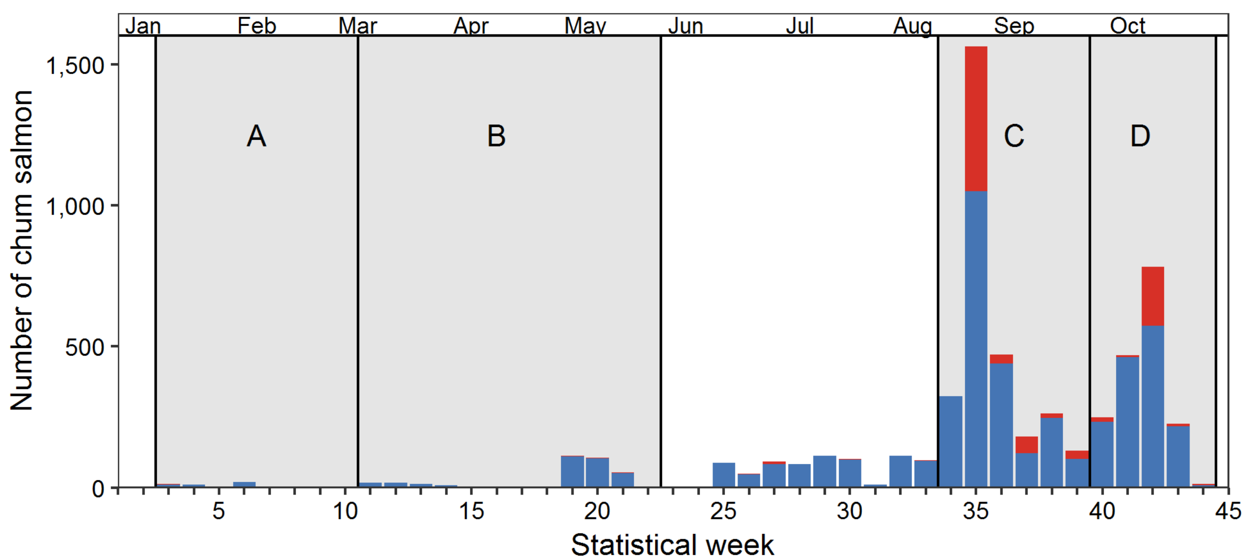

Figure 7. -- Number of chum salmon caught (blue plus red) and genetic samples collected (red) from the 2017 Gulf of Alaska groundfish fisheries by statistical week. Grayed areas with letter designations distinguish the NMFS management seasons for pollock in the Western and Central Regulatory Areas (NMFS reporting areas 610-630).

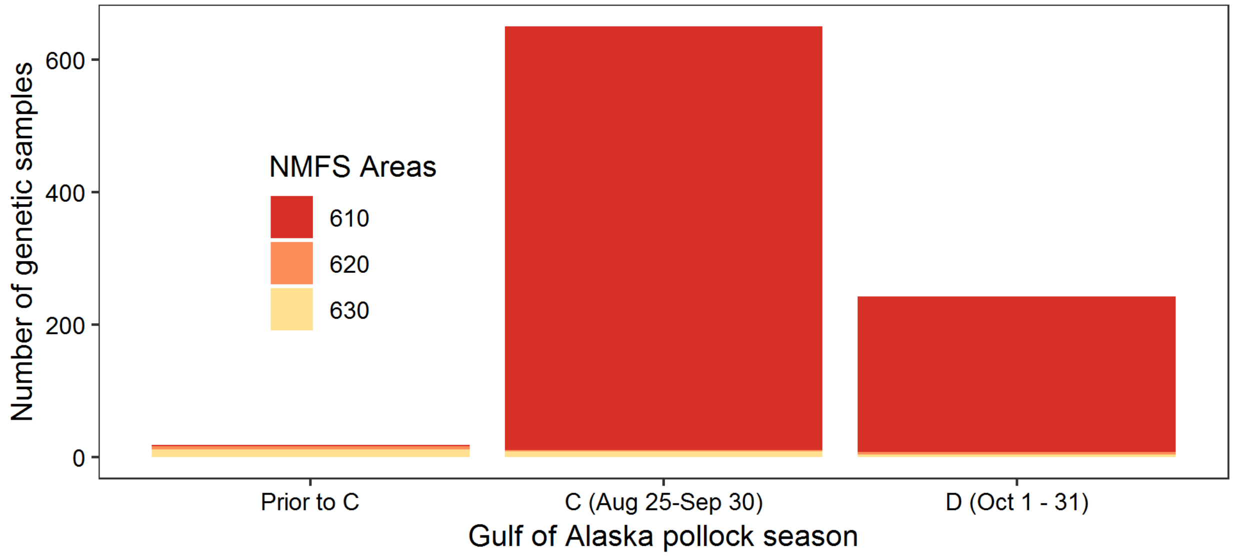

Figure 8. -- Number of chum salmon genetic samples collected from the 2017 Gulf of Alaska groundfish fisheries by pollock season and NMFS reporting areas. Two chum salmon genetic samples from Area 640 are not shown.

LABORATORY ANALYSES

Chum salmon samples from the Bering Sea pollock B-season were subsampled in order to minimize laboratory costs while limiting potential bias of mixed-stock estimates. The full collection of 12,815 chum salmon received at ABL was sorted by cruise, haul or offload, and specimen number, and every 6th sample was selected for analysis (see Whittle et al. 2015 for subsampling effects). DNA was extracted from the axillary processes of 2,136 chum salmon sampled in the Bering Sea B-season and all of the 903 chum salmon sampled in the GOA groundfish fisheries. An additional 627 samples were selected for the 4-cluster spatio-temporal analyses to increase the sample sizes to approximately 200 samples in each time-area stratum. Too few samples were collected from the A-season to analyze (PSC = 1,651; samples collected = 52).

DNA was extracted and microsatellite genotyping was performed (Guyon et al. 2010) for 11 microsatellite loci: *Oki100* (Beacham et al. 2009a), *Omm1070* (Rexroad et al. 2001), *Omy1011* (Spies et al. 2005), *One101*, *One102*, *One104*, *One114* (Olsen et al. 2000), *Ots103* (Beacham et al. 1998), *Ots3* (Greig and Banks 1999), *Otsg68* (Williamson et al. 2002), and *Ssa419* (Cairney et al. 2000). Thermal cycling for the amplification of DNA fragments with polymerase chain reaction (PCR) was performed on a dual 384-well GeneAmp PCR System 9700 (Applied Biosystems, Inc.). Samples from the PCR reactions were diluted into 96-well plates with the GeneScan™ 600 LIZ™ Size Standard for analysis with a 48-capillary, 36 cm array on the ABI 3730*xl* Genetic Analyzer (Applied Biosystems, Inc.). Genotypes were double-scored with GeneMapper 5.0 software (Applied Biosystems, Inc.).

Of the 3,666 chum salmon bycatch samples from the Bering Sea and GOA, 95% were successfully genotyped for 8 or more of the 11 loci for an average of 10.8 loci (Table 1). One duplicate genotype was detected in the Bering Sea bycatch samples with GenAlEx 6.5 (Peakall and Smouse 2006, 2012); one sample of the duplicate pair was removed from further analysis. One Bering Sea sample and six GOA samples were determined to be non-chum and were removed from further analysis.

Table 1. -- Number of chum salmon genetic samples from the 2017 Bering Sea pollock trawl fishery and Gulf of Alaska groundfish fisheries that were genotyped per number of loci.

Number loci	**Genetic samples**
11	3,134
10	224
9	63
8	70
<8	167

Quality control of sample handling and genotyping was examined by reanalyzing 8.7% of the samples: DNA was plated from the eight samples in the left-most column of each elution plate for a total of 320 samples that were then processed for genotyping as described above. Genotypes from the quality control dataset were then compared to the genotypes of the original dataset

(Table 2). Higher than usual genotyping discrepancy was identified between the original and quality control datasets at several loci due to low PCR amplification and difficulties with the size standard. After re-amplification of the quality control plates and size standard clean-up, the genotyping error was low. Across 11 loci there were a total of 10 differences in 6,570 alleles between the original and quality control datasets, which represented an overall discrepancy rate of 0.15%.

Table 2. -- Number of allele differences by locus between the original and quality control datasets for samples with non-questionable genotypes of chum salmon from the 2017 Bering Sea midwater pollock trawl fishery and Gulf of Alaska groundfish fisheries.

Locus	Number alleles compared	Number allele differences	Percent difference
Oki100	606	3	0.50
Omm1070	578	3	0.52
Omy1011	598	0	0
One101	570	0	0
One102	582	0	0
One104	606	0	0
One114	604	1	0.17
Ots103	618	1	0.16
Ots3	616	1	0.16
OtsG68	592	0	0
Ssa419	600	1	0.17

GENETIC STOCK COMPOSITION

For the mixture genotypes, allele designations were standardized to match those in the Fisheries and Oceans Canada (DFO) chum salmon microsatellite baseline (Beacham et al. 2009b, c). Standardized genotypes were saved as text files and the data was formatted into mixture files compatible with software used for stock composition estimation. Stock compositions were determined by comparing mixture genotypes with allele frequencies from reference baseline populations. As described previously (Gray et al. 2010), with minor changes to regional group names, baseline populations were grouped into six regions: Southeast Asia (SE Asia), Northeast Asia (NE Asia), Western Alaska (W Alaska), Upper/Middle Yukon (Up/Mid Yukon), Southwest Alaska (SW Alaska), and the Eastern GOA/Pacific Northwest (EGOA/PNW) (Fig. 9). The regional groups were selected based on principal coordinate and simulation analyses as described in Guyon et al. (2010). A listing of the individual populations grouped by region is provided in Appendix I.

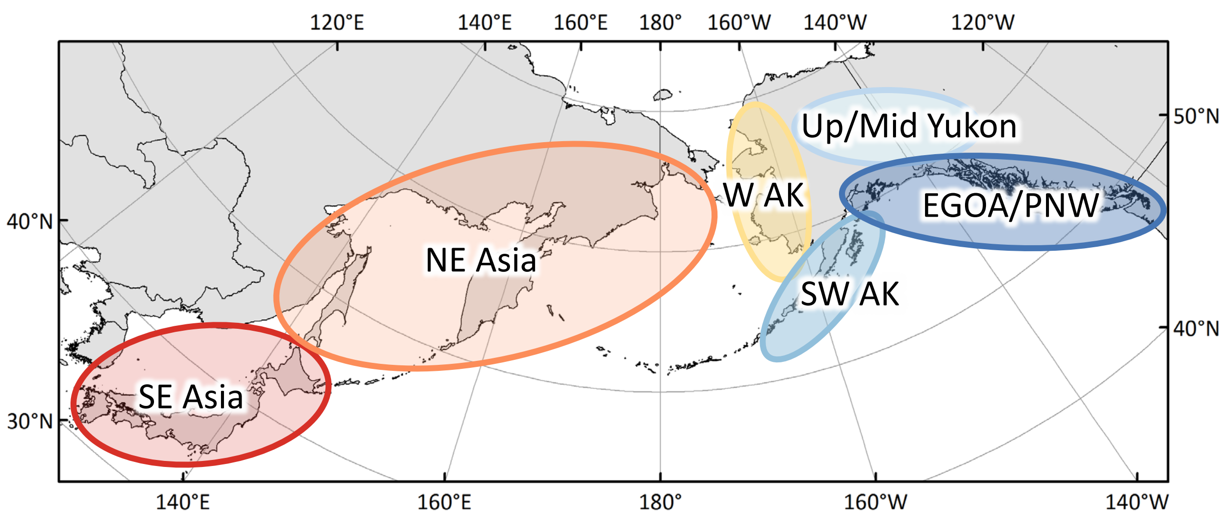

Figure 9. -- Six regional groups of baseline chum salmon populations used in this report.

As with previous analyses of chum salmon PSC (Guyon et al. 2010; Marvin et al. 2011; Gray et al. 2010, 2011a, b; Kondzela et al. 2012, 2013, 2016, 2017; Vulstek et al. 2014; Whittle et al. 2015, 2018), the stock composition analysis for the 2017 chum salmon samples was performed with a Bayesian procedure (BAYES software; Pella and Masuda 2001). BAYES stock composition estimates based on data from all 11 loci were derived for the six regional groups (Table 3; Appendix II). For all estimates, the Dirichlet prior parameters for the stock proportions were defined by region to be $1/(GC_g)$, where C_g is the number of baseline populations in region g, and G is the number of regions[3]. For each analysis, six MCMC chains of 100,000 iterations (burn-in of 50,000) were run starting at disparate values of stock proportions configured such that 95% of the stocks came from one designated region with weights equally distributed among the stocks of that region. The remaining 5% was equally distributed among remaining stocks from all other regions. Convergence was assessed with Gelman-Rubin shrink factors, which were 1.00-1.04 (Table 3; Appendix II) across all datasets, conveying strong convergence to a single posterior distribution (Gelman and Rubin 1992, Pella and Masuda 2001). A basic overview of the Bayesian method used for mixed-stock analysis in our report is presented in Appendix III.

The stock composition estimates were summarized by the mean, standard deviation, median, 95% credible interval (2.5th and 97.5th percentile of the MCMC iterates in the posterior output), and P = 0, which is the probability that a stock composition estimate is effectively zero (Munro et al. 2012). The P = 0 statistic is the frequency of the last half of the MCMC iterates of each chain combined that were less than a threshold that is calculated as 0.5 divided by the number of the chum salmon caught corresponding to the estimated proportion. This threshold is the value that would result in the estimated number of fish being rounded to zero fish when stock proportions are expanded to numbers of chum salmon caught. This statistic may be more useful than the credible interval for assessing the presence or absence of minor stocks. For example, the P = 0 value associated with the Southeast Asia stock estimate from the Gulf of Alaska sample set (Table 3B) indicates that there is a 25% probability that essentially zero chum salmon from this stock were caught in this season.

[3] In analyses prior to the 2013 chum salmon PSC analysis, a flat prior (1/381) was assigned to each baseline population. Priors defined by region may reduce bias due to differences in how densely regions are represented by baseline populations.

Table 3. -- Regional stock composition estimates of chum salmon collected from 2017 Bering Sea and GOA trawl fisheries. BAYES mean proportion estimates are provided with standard deviations (SD), 95% credible intervals, median estimate, P = 0 statistic (values > 0.5 are shaded), and the Gelman-Rubin shrink factor. PSC is the number of chum salmon caught (census in Bering Sea and estimate in GOA) and n is the number of samples genetically analyzed.

A. Bering Sea pollock trawl fishery, B-season (PSC = 464,898; n = 2,064)

Region	**Est. num.**	**Mean**	**SD**	**2.5%**	**Median**	**97.5%**	**P = 0**	**Shrink**
SE Asia	72,989	0.157	0.009	0.140	0.156	0.174	0	1.00
NE Asia	214,318	0.461	0.014	0.433	0.461	0.490	0	1.00
W Alaska	65,086	0.140	0.011	0.119	0.139	0.161	0	1.00
Up/Mid-Yukon	28,359	0.061	0.007	0.047	0.060	0.075	0	1.00
SW Alaska	14,877	0.032	0.006	0.021	0.032	0.044	0	1.00
E GOA/PNW	69,735	0.150	0.010	0.132	0.150	0.169	0	1.00

B. Gulf of Alaska groundfish fisheries, (PSC = 5,802; n = 812)

Region	**Est. num.**	**Mean**	**SD**	**2.5%**	**Median**	**97.5%**	**P = 0**	**Shrink**
SE Asia	64	0.011	0.004	0.004	0.010	0.021	0.252	1.00
NE Asia	487	0.084	0.014	0.058	0.084	0.113	0	1.00
W Alaska	168	0.029	0.009	0.013	0.028	0.048	0	1.00
Up/Mid-Yukon	12	0.002	0.003	0	0.001	0.010	1.000	1.00
SW Alaska	168	0.029	0.009	0.013	0.029	0.049	0	1.00
E GOA/PNW	4,903	0.845	0.016	0.813	0.845	0.874	0	1.00

COMPARISON WITH PREVIOUS ESTIMATES

Bering Sea

The stock composition results from the analysis of the 2017 chum salmon samples collected during the B-season were similar to the results from past years for three of the six regions (Western Alaska, Upper/Middle Yukon, and Southwest Alaska), prior to and after systematic sampling was in effect (Fig. 10, upper panel). Southeast Asia stock proportion estimates were similar to those from previous years with systematic sampling. In 2017, Northeast Asia stocks dominated the regional contributions and the Eastern GOA/PNW stocks were about half that of the average since systematic sampling went into effect. The extent to which year-to-year differences in regional stock contributions are attributable to differences in fishing locations and times or migration patterns of chum salmon is beyond the scope of this report. However, with systematic sampling of the Bering Sea chum salmon PSC in place, the role of these factors on the year-to-year variation of stock estimates will be easier to determine.

The 1994-1995 chum salmon stock composition estimates were produced with allozyme data (Wilmot et al. 1998), whereas the 2005-2017 estimates were derived from DNA-based microsatellite loci (Guyon et al. 2010; Marvin et al. 2011; Gray et al. 2010, 2011a, b; Kondzela et al. 2012, 2013, 2016, 2017; Vulstek et al. 2014; Whittle et al. 2015, 2018). The allozyme (77 populations) and microsatellite DNA (381 populations) baselines have data from many of the same populations and have similar regional groups.

The large variation in total chum salmon caught across the years (Fig. 2) is reflected in the high standard errors of the mean number of chum salmon caught by region (unweighted by year) when stock composition estimates are extrapolated to the total chum salmon PSC from the Bering Sea groundfish fisheries (Fig. 10, lower panel). Since 2011, the genetic samples have been collected systematically, resulting in the numerical extrapolations being relatively free of sample collection bias. The location and timing of collections prior to 2011 was not always representative of the entire chum salmon PSC within a given year. In 2017, the numbers of chum salmon were at least twice as high as the previous six year (2011-2016) average for all regions except the Eastern GOA/PNW, which was nearly identical to the previous six years. The higher than average bycatch in 2017 and the high proportion of Northeast Asia fish is reflected in high numbers of chum salmon intercepted from this region.

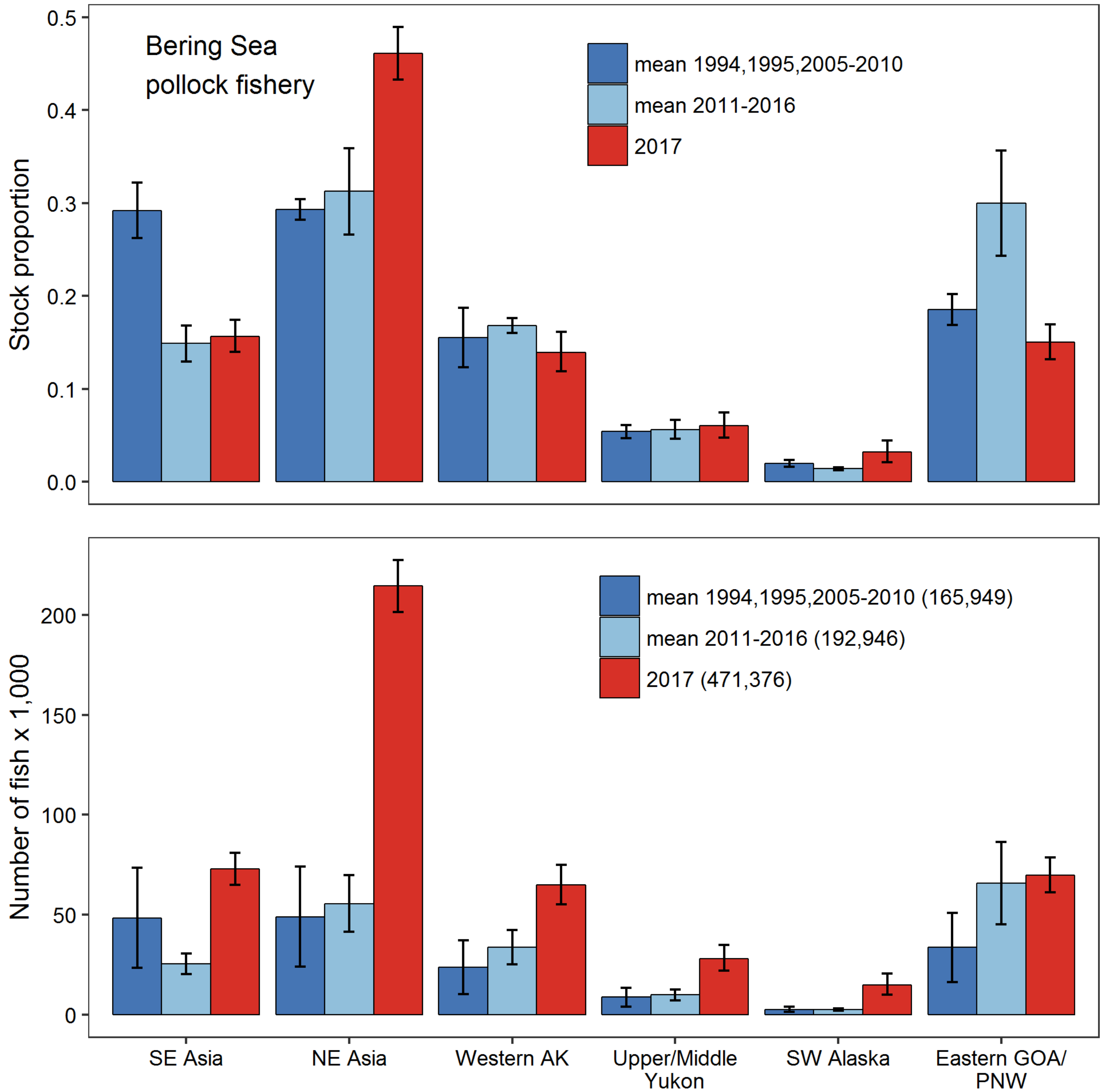

Figure 10. -- Comparison of the 2017 Bering Sea chum salmon stock composition estimates with the estimates from 2011 to 2016 (systematic sampling) and the unweighted mean estimates from 1994, 1995, and 2005-2010 (non-systematic sampling). Proportions in top panel (B-season); numbers of fish (A+B seasons) in bottom panel, which for comparison purposes across years are based on the total chum salmon caught in all Bering Sea groundfish fisheries (NMFS 2018). Standard errors of the mean estimates are shown for the combined years; 95% BAYES credible intervals are shown for the 2017 analysis. Error bars are based on only the mixed-stock analyses and do not include errors associated with the overall annual PSC estimation or potential biases in sample distribution. Total chum salmon caught in the Bering Sea groundfish fisheries is shown in parentheses in the bottom figure legend; 1994-2010 are estimates and 2011-2017 are censuses.

Gulf of Alaska

In 2017, for the fourth consecutive year, samples from the PSC of chum salmon from the GOA groundfish fisheries were available for genetic analysis. The stock composition estimates of the 2017 GOA samples were nearly identical to the 2014-2016 estimates, with 85% of the contribution from Eastern GOA/PNW stocks (Fig. 11). In all four years, the contributions from all other regions was very low; chum salmon from the Upper/Middle Yukon region were not present in the GOA samples in any of the four years (“P = 0” value of 1.00; Appendix II). The Northeast Asia stock contribution was higher in 2017 than in previous years, although it was a minor contributor (8.4%).

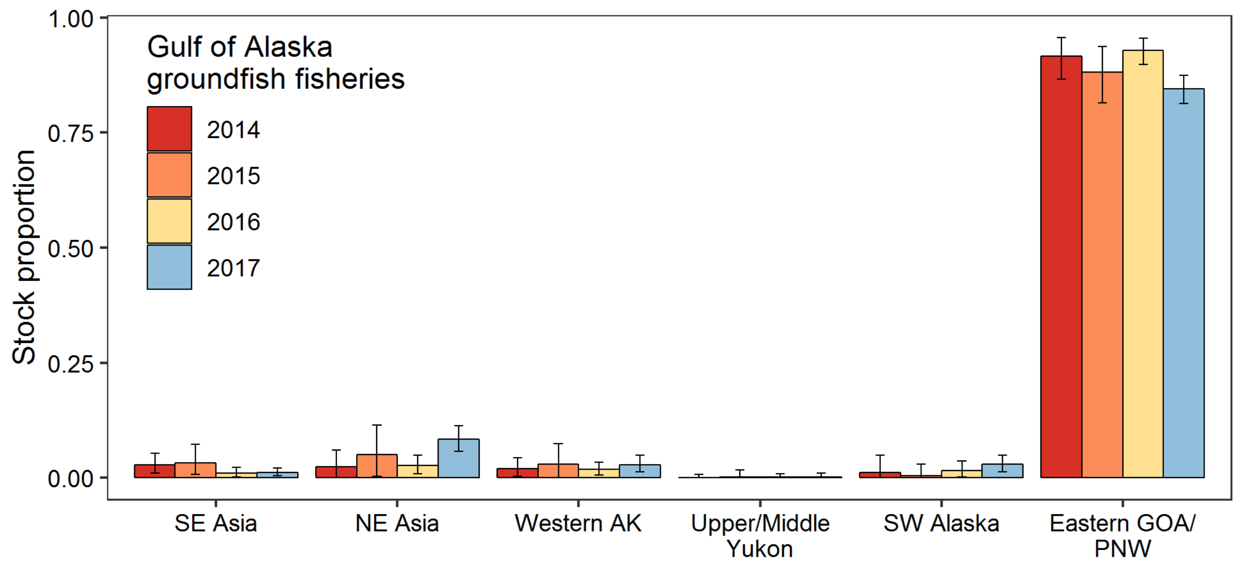

Figure 11. -- Stock composition estimates and 95% BAYES credible intervals for the 2014-2017 chum salmon genetic samples from the Gulf of Alaska groundfish fisheries.

TEMPORAL STRATIFICATION

Resolving the temporal distribution of the chum salmon PSC is important for better understanding the seasonal impacts of the pollock trawl fishery on salmon stocks. If the chum salmon stock distribution changes consistently over time, it may be possible to manage the pollock fishery in a manner that minimizes effects on critical salmon stocks. This section is limited to analyses of the Bering Sea samples.

As with the 2005-2016 analyses, the 2017 Bering Sea sample set from the B-season was split into three time periods: Early, Middle, and Late (Table 4). Stock composition estimates were made as described previously for each of the three temporal strata (Appendix II). Notably, more chum salmon PSC was caught earlier in the 2017 season than in previous years.

Table 4. -- Temporal groups from the genetic sample sets of chum salmon caught in the 2017 Bering Sea, B-season pollock fishery.

Time period	Weeks	Dates	Number of samples
Early	23-29	June 10 – July 22	1,307
Middle	30-34	July 23 – August 26	589
Late	35-42	August 27 – October 21	168

The stock composition of chum salmon caught in the 2017 Bering Sea pollock fishery changed during the course of the season (Fig. 12; Appendix II). The Northeast Asia contribution was the highest of all reporting groups in all three time periods, except for the higher Eastern GOA/PNW contribution during the Late period. The Northeast Asia contributions were similar in the Early and Middle time periods (48% and 46%, respectively) and lower during the Late time period (29%). The contributions from the Southeast Asia (12-18%) and Western Alaska (13-15%) regions were stable over time. The Upper/Middle Yukon contribution was low in all three time periods with the highest contribution in the Early time period (7%). The Eastern GOA/PNW contribution increased four-fold across the B-season (9% to 37%). The Southwest Alaska stock contributions have not exceeded 5.6% in any year and therefore data for this regional group are not included.

The 2011-2016 stock compositions for similar temporal strata are included for comparison purposes (Fig. 12). In the Early time period, the Northeast Asia contribution was higher, and the Southeast Asia and Eastern GOA/PNW contributions were lower in 2017 than in previous years. Across the years, the Southeast Asia contribution was higher in the Early time period than the Middle and Late time periods, the Western Alaska contribution was slightly higher in the Early and Middle time periods than the Late time period, the Upper/Middle Yukon contribution was consistently low at all three time periods, and except for 2012-2013, the Eastern GOA/PNW contribution was higher in the Middle and Late time periods. The inverse relationship of stock proportions across years between the Northeast Asia and Eastern GOA/PNW regions during the Middle and Late time periods persisted in 2017. Results from the temporal analysis should be used cautiously because spatial differences exist in the time-stratified sample sets and these differences are known to affect the stock composition estimates.

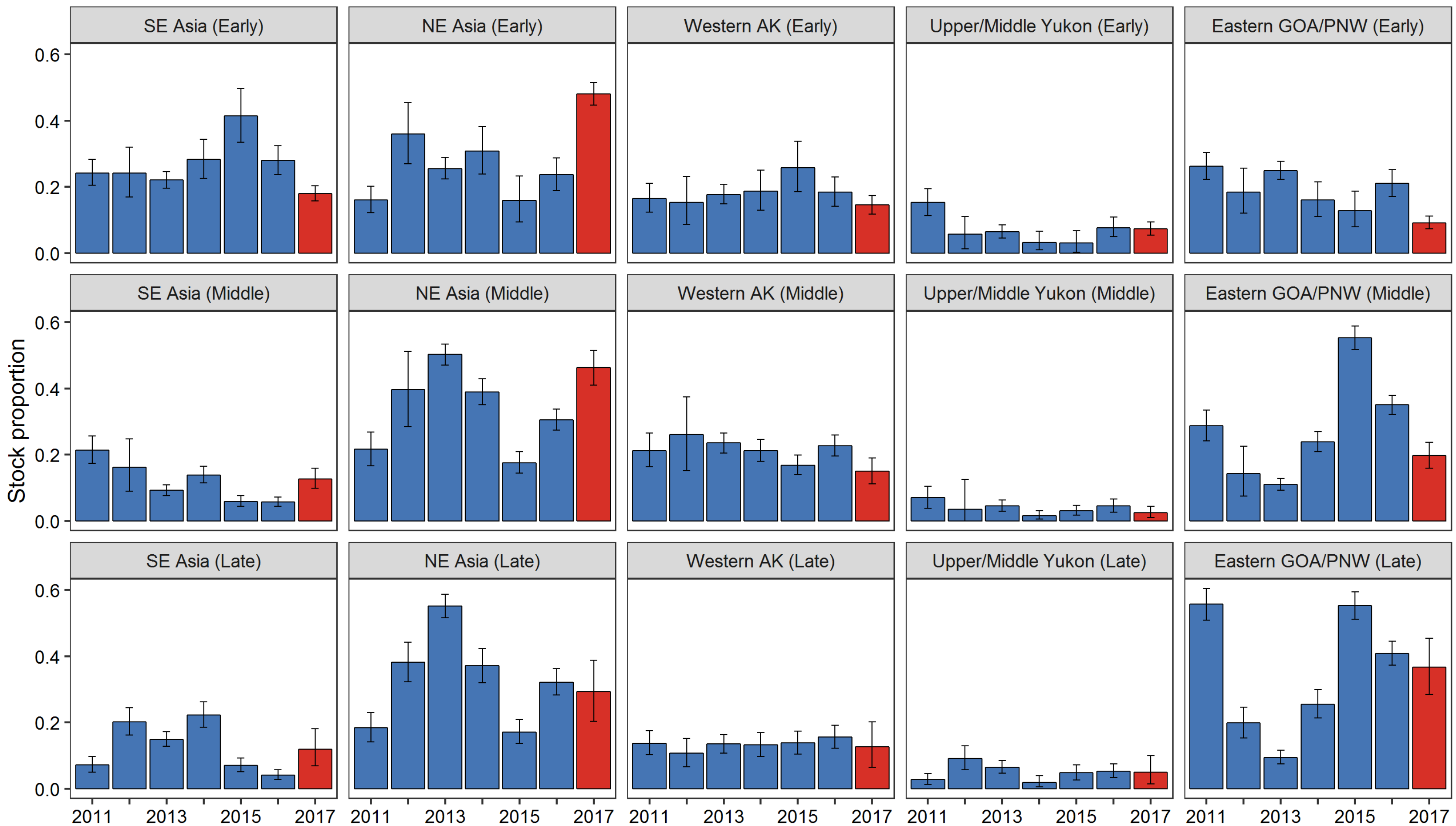

Figure 12. -- Stock composition estimates (mean ± 95% BAYES credible intervals) for the 2011-2017 chum salmon samples from the Early, Middle, and Late periods of the Bering Sea, B-season pollock fishery (defined in Table 4). Not shown is the Southwest Alaska region for which estimates never exceeded 5.6%. The current sampling year (2017) is denoted in red.

SPATIAL STRATIFICATION

Resolution of the spatial distribution of the chum salmon PSC is also important for better understanding the impacts of the pollock trawl fishery on salmon stocks. This section is limited to analyses of the Bering Sea fishery samples. In 2017, for the seventh year, the Observer Program undertook a complete census of chum salmon caught in the Bering Sea pollock trawl fisheries. Approximately 33% of the chum salmon catch was counted and sampled at shoreside processing facilities; the remaining 67% was counted and sampled at sea. Of the shoreside offloads, about 40% of the chum salmon catch was from vessels that fished in one ADF&G statistical area during a trip. For the 60% of chum salmon catch offloaded from vessels that fished in multiple ADF&G statistical areas during a trip (20% of total chum salmon catch), the area assigned to an offload was the area where the greatest weight of pollock was caught.

The 2017 Bering Sea genetic samples from the B-season were split into two areas (see Fig. 1): the U.S. waters of the Bering Sea west of 170°W (areas 521, 523, and 524), and the southeastern Bering Sea east of 170°W (areas 509, 513, 516, 517, and 519). Stock compositions for the two spatial strata were estimated as described previously (Fig. 13; Appendix II). Over half of the contribution to the east and west of 170°W in the Bering Sea was from Asian stocks. Northeast Asia stocks were the largest contributor to the chum salmon catch with identical contributions in both Bering Sea areas (46%). Southeast Asia stocks contributed more to waters west of 170°W than in the southeastern Bering Sea (23% vs. 15%), and the contributions from other stocks were similar between the spatial strata.

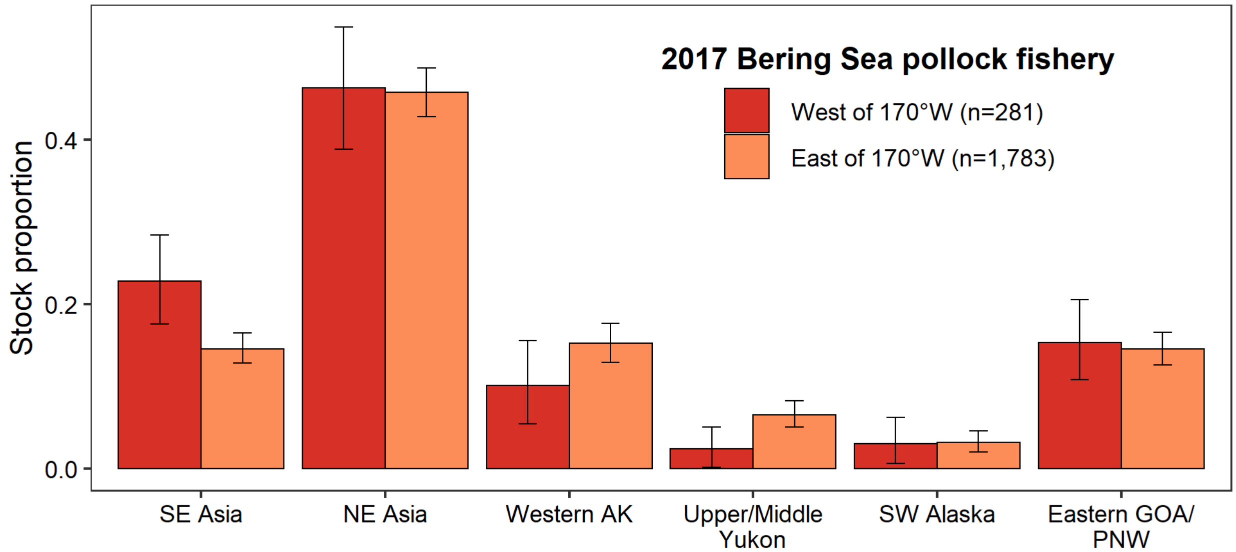

Figure 13. -- Stock composition estimates and 95% BAYES credible intervals for the chum salmon from the 2017 Bering Sea, B-season pollock fishery from the U.S. waters of the Bering Sea west of 170°W (aggregate area 521/523/524) and the southeastern Bering Sea east of 170°W (aggregate area 509/513/516/517/519).

To better understand the distribution of chum salmon stocks across time and space in the Bering Sea PSC from the pollock fishery, the 2017 stock composition estimates were compared from four spatial clusters and two time periods. B-season samples were aggregated into Early (statistical weeks 23-32) and Late (statistical weeks 33-42) time periods at four clusters that were based on ADF&G statistical areas along the continental shelf edge (Table 5; Fig. 14; Appendix IV). Excluded from this analysis are 172 samples (8%) from offloads of vessels that fished in two areas (Clusters 1 and 2). As in previous years, in both time periods there was a gradient of stock proportions along the continental shelf with a higher proportion of chum salmon from Asian stocks in the more northwestern portion of the fishery and a higher proportion of chum salmon from North American stocks in the southeastern portion of the fishery, nearest to the Alaska Peninsula (Fig. 15; Appendix II). One notable change from the previous year was the higher Asian contributions, particularly during the Early time period, and especially from the Northeast Asia stock. The Western Alaska stock dominated the Alaska contributions across all clusters and both time periods, being highest in Cluster 1 near the Alaska Peninsula. And with the exception of the Eastern GOA/PNW contribution in Cluster 2, Late time period, the Western Alaska stocks comprised roughly one-third of the North American stock contributions in the Bering Sea.

Table 5. -- Collection information for the four spatial clusters of chum salmon caught in two time periods, Early (weeks 23-32) and Late (weeks 33-42), during the 2017 Bering Sea, B-season pollock fishery and analyzed for genetic stock composition. The sample size (n = 79) of Cluster 3, Late time period, was too small for analysis.

Spatial cluster	Time period	Samples received	Samples analyzed
1	Early	3,971	640
1	Late	585	213
2	Early	5,020	809
2	Late	442	199
3	Early	994	190
4	Early	194	188
4	Late	516	199

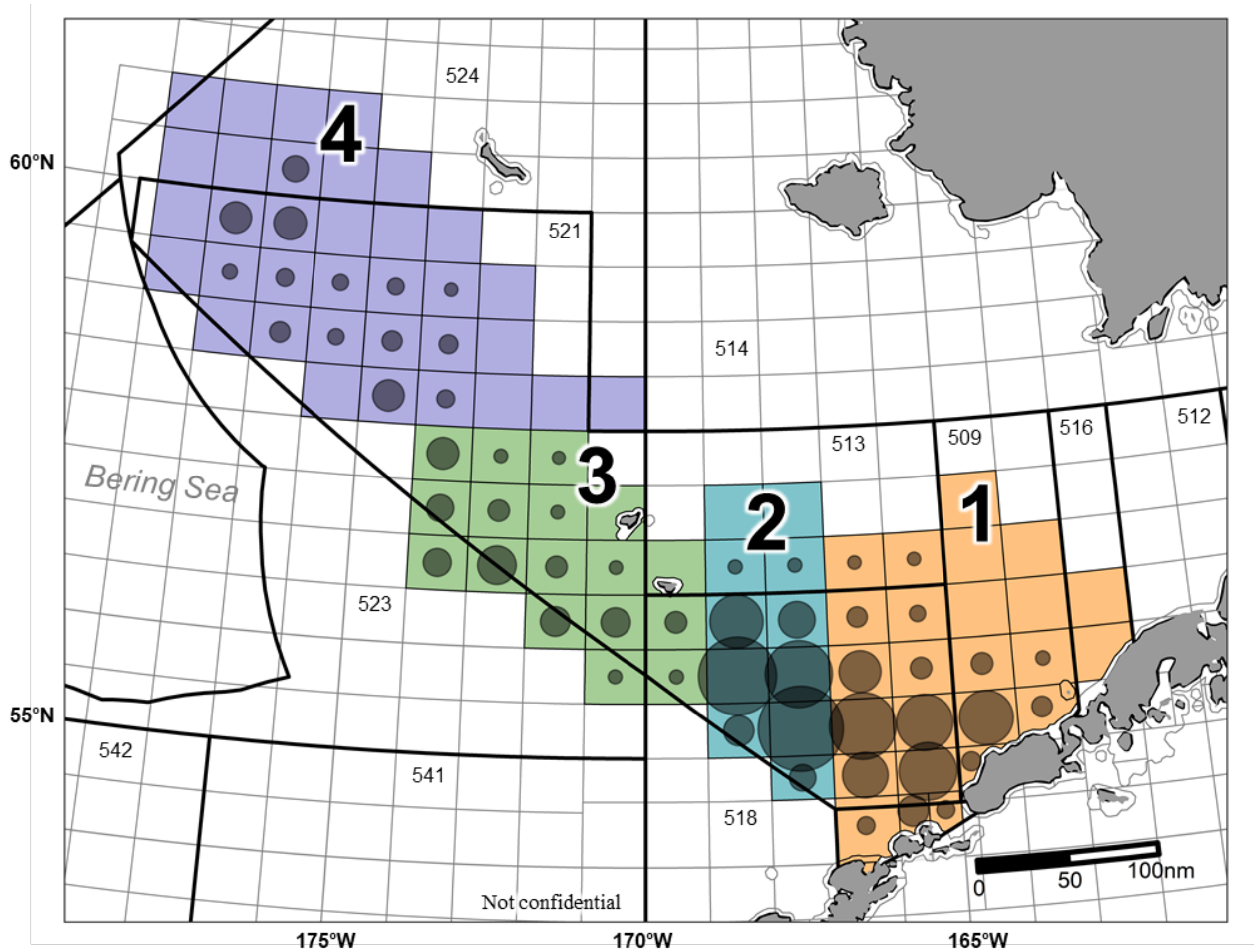

Figure 14. -- Four spatial clusters of ADF&G statistical areas in which chum salmon samples were collected from the Bering Sea during the B-season in at least one year from 2013 to 2017 (highlighted); ADF&G areas in which samples were collected in 2017 from at least three vessels are indicated with circles sized relative to the number of chum salmon caught. NMFS reporting areas associated with the Bering Sea-Aleutian Island groundfish fisheries are numbered in black.

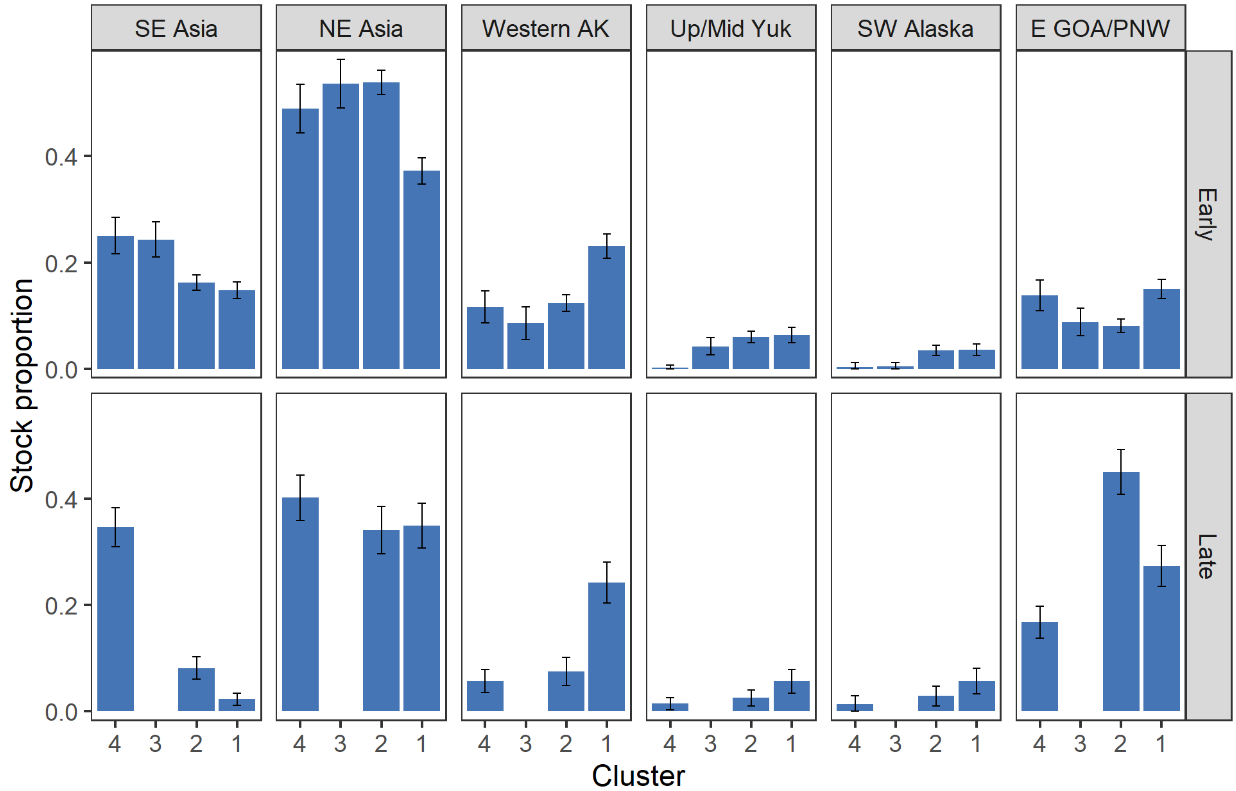

Figure 15. -- Stock composition estimates and 95% BAYES credible intervals for the chum salmon collected from four spatial clusters along the continental shelf edge (Fig. 14) during Early (Weeks 23-32) and Late (Weeks 33-42) time periods of the 2017 Bering Sea, B-season pollock fishery. The sample size of the 3rd cluster, Late time period, was too small for analysis.

AGE STRATIFICATION

For the first time, stock estimates are provided by age strata of chum salmon with previously unreported results from 2016 included for comparison. Scale ageing of the genetic samples permitted the evaluation of age-specific stock contributions of each region to the chum salmon PSC. Total age of individual fish was estimated as the number of freshwater and saltwater annuli formed on the scale plus one to account for the winter spent rearing in freshwater. Approximately 70% and 80%, respectively, of the successfully genotyped chum salmon caught in the 2016 and 2017 Bering Sea, B-season pollock fishery could be aged; the remaining samples could not be aged for a variety of reasons, such as the scales were missing, collected from a nonpreferred location on the fish, or regenerated. The 2017 total age composition was 24% age-3, 63% age-4, 13% age-5, and < 1% age-6, nearly identical to the 2016 age composition (Fig. 16). Stock composition was estimated for chum salmon, ages 3-5 (Fig. 17; Appendix II). Stock composition varied by age in 2016, with a high proportion of age-3 fish from the Eastern GOA/PNW stock and most of the age-5 fish from Asian stocks. In 2017, there was less difference in the stock composition by age, with all three ages dominated by Asian stocks.

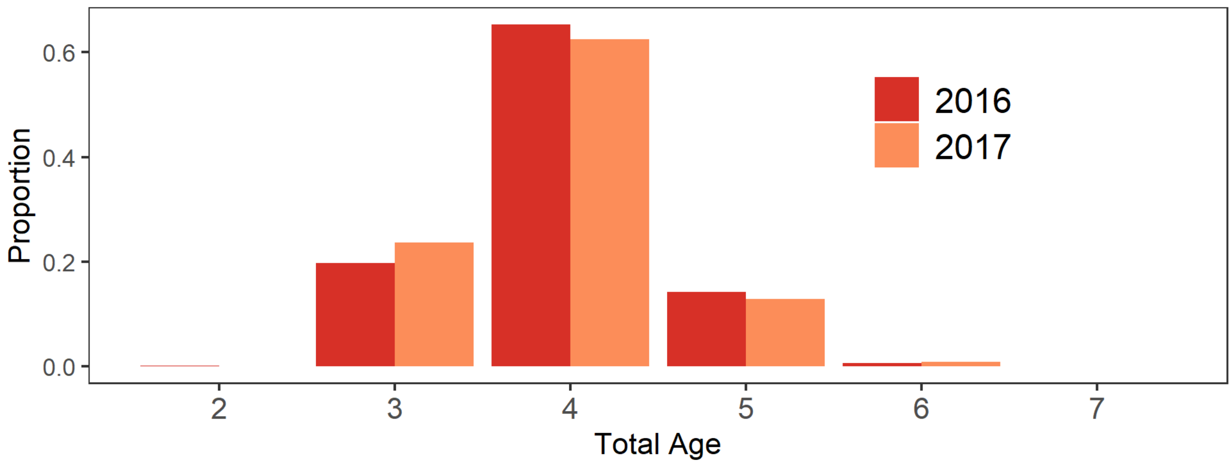

Figure 16. -- Proportion of total age of the chum salmon genetic samples collected from the 2016 and 2017 Bering Sea, B-season pollock fishery.

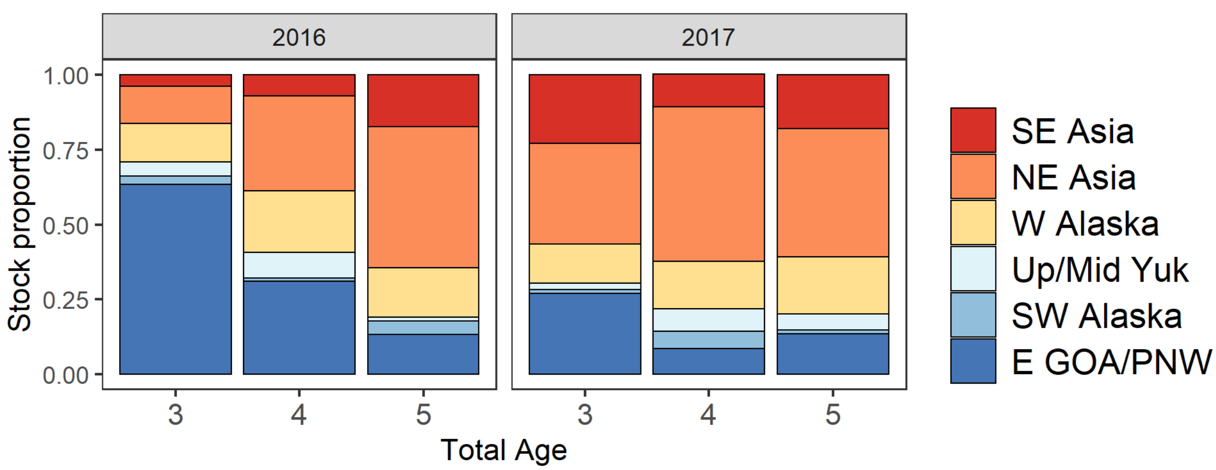

Figure 17. -- Stock composition estimates for the three predominate ages of chum salmon collected from the 2016 and 2017 Bering Sea, B-season pollock fishery.

Stock estimates for many combinations of age-time-spatial strata are available in Appendix II. The datasets for these analyses include the extra samples added to spatial strata (Clusters 1-4) to increase the dataset sizes and are not necessarily representative of the entire bycatch. Exploration of the stock estimates from the many multi-strata datasets are beyond the scope of this report, although several results are noted here. Within age and spatial strata, stock estimates differed between Early and Late time periods. For example, for age-3 chum salmon in Clusters 1-2 combined, the Eastern GOA/PNW contribution was higher and the Northeast Asia contribution was lower during the Late time period. However, with Early and Late time periods combined, the pattern of stock proportions were similar across spatial strata (Clusters 1-4) regardless of age.

FISHING SECTOR

Interest from the fishing industry for stock composition estimates by fishing sector was relayed to the ABL, so for the first time we report stock composition estimates for each fishing sector. In 2017, genetic sample sizes were large enough for mixed-stock analysis from the at-sea catcher-processor and shoreside (catcher-vessel) sectors, but not the mothership sector (Fig. 18; Appendix II). The higher proportion (approximately 10%) of Asian fish and equally lower proportion of North American fish caught by the catcher-processors relative to the shoreside sector was significant when the estimates from the six stock groups were pooled into two stock groups, Asia and North America. In addition to the stock proportion differences, the catcher-processor sector caught nearly twice as many chum salmon as the shoreside sector, 294,371 and 154,101 fish, respectively.

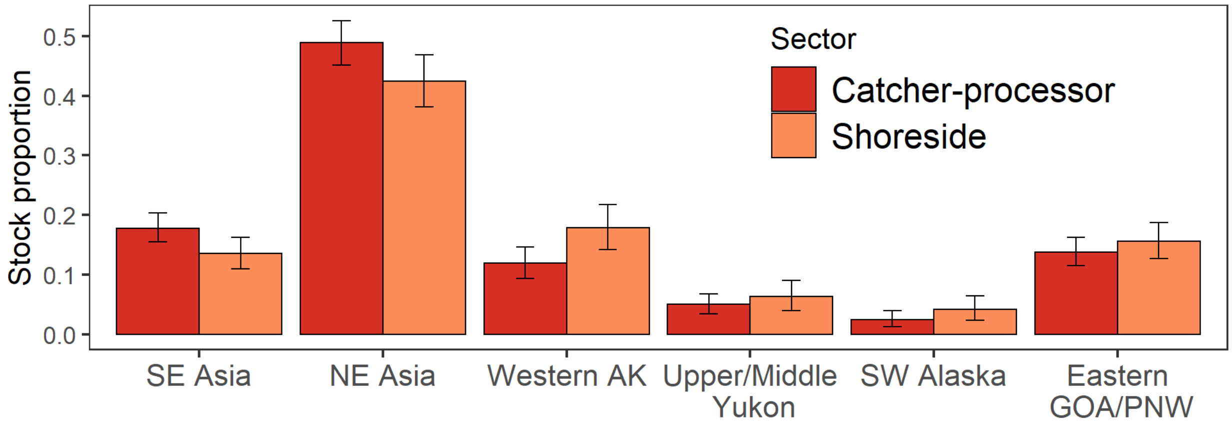

Figure 18. -- Stock composition estimates and 95% BAYES credible intervals for the chum salmon collected from the 2017 Bering Sea, B-season pollock fishery from the catcher-processor and shoreside fishing sectors. Too few samples were collected from the mothership sector to estimate stock composition.

SUMMARY

Stock composition estimates of the salmon caught in the Bering Sea and GOA groundfish fisheries are needed for fishery managers to understand the impact of these fisheries on salmon populations, particularly those in western Alaska. This report provides the genetic stock composition analyses of the 2017 chum salmon PSC based on 2,679 samples genotyped: 2,064 representative, plus 615 extra samples added to increase sample size for spatial-temporal datasets from the Bering Sea, and 812 samples from the GOA fisheries. The limitations and results of this analysis are summarized below and in Appendix II.

Sampling Issues

Bering Sea

We highlight the reduced spatial and temporal biases in the Bering Sea 2017 sample set (Figs. 3 and 4) that were inherent in collections before 2011. Reduction of those biases improved the application of the 2017 genetic sample stock composition estimates to the entire chum salmon PSC. Implementation of Amendment 91 to the North Pacific Fishery Management Council fishery management plan for groundfish of the Bering Sea and Aleutian Islands Management Area[4] requires that all salmon caught in the Bering Sea pollock fishery be sorted by species and counted to ensure compliance with the salmon PSC limits for the pollock fishery. This regulation led to the collection of representative samples from 82.9% of the chum salmon caught in this fishery for genetic analysis in 2017, which is lower than in previous years due to the lack of sampling materials on several catcher-processor vessels with high PSC (Fig. 5). Despite reduced sampling from these vessels, most of the chum salmon PSC was representatively sampled in 2017 and improved the capability to characterize the origin of salmon caught in the Bering Sea pollock fishery.

Gulf of Alaska

The GOA groundfish fisheries are complex and not all groundfish catches in the GOA are subject to observer coverage. The number of chum salmon caught in GOA federal fisheries is much lower than in the federal fisheries of the Bering Sea; however, recent expansion of sampling salmon PSC in the GOA[5] provided, for the fourth year, a small sample set for genetic analysis. The distribution of chum salmon PSC samples is not representative of the groundfish fisheries as a

[4] 75 FR 53025, August 30, 2010.
[5] Amendment 93 to the NPFMC fishery management plan for GOA groundfish (77 FR 42629, July 20, 2012).

whole. Most of the genetic samples (98%) were from the pollock trawl fishery, which in 2017 caught 76% of the chum salmon PSC in the GOA.

Stock Composition Estimates

Bering Sea

Over half of the genetic samples collected from chum salmon caught in the B-season 2017 Bering Sea pollock fishery were from Asia, with the majority from Northeast Asia (46%) stocks. The contribution from North America was predominantly from Eastern GOA/PNW (15%) and Western Alaska (14%) stocks (Table 3A). The stock proportion from Northeast Asia was significantly higher than in previous years (Fig. 10). The Eastern GOA/PNW contribution was significantly lower than in years with systematic sampling. The Southeast Asia contribution was similar to years with systematic sampling and lower than years prior to systematic sampling. The stock proportions from Alaska were similar to previous years. Although chum salmon samples in 2017 were collected representatively from the pollock fishery, there were differences in where and when genetic samples were collected from previous years, so that caution must be used in making year-to-year comparisons.

Gulf of Alaska

As in the previous three years, the stock proportions of the 2017 chum salmon PSC from the GOA had a very different pattern than that observed in the Bering Sea. In the GOA groundfish fisheries, 85% of the chum salmon sampled were from Eastern GOA/PNW stocks (Table 3B; Fig. 11). The remaining contributions from the other five regions were very low (0-8%).

Temporal and Spatial Effects

The finer-scale time-stratified analysis of the chum salmon samples was limited to the pollock B-season, when the majority of chum salmon are intercepted in the Bering Sea. As in previous years, stock composition estimates of the 2017 chum salmon catch changed across the three sampling periods, suggesting a shift in the temporal stratification of chum salmon stocks in the Bering Sea, changes in fishing or sampling locations, or both (Fig. 12). By time period, some differences were observed in the stock composition estimates of chum salmon PSC collected in 2017 and in previous years. Notably, there is a pattern of higher estimates for Southeast Asia stocks during the Early time period, Western Alaska stocks during the Early and Middle time periods, and Eastern GOA/PNW stocks during the Middle and Late time periods. An inverse relationship of contribution across years between Northeast Asia and Eastern GOA/PNW stocks is most evident during the Middle and Late time periods.

Spatial analysis suggested that the majority of the chum salmon from U.S. waters of the Bering Sea east and west of 170°W originated from Asian stocks, primarily from the Northeast Asia region (Fig. 13). The Southeast Asia stock contribution was higher west of 170°W. The contributions of Northeast Asia, Southwest Alaska, and Eastern GOA/PNW stocks were similar east and west of 170°W, whereas the Upper/Middle Yukon and Western Alaska stock contributions were higher east of 170°W.

An examination of chum salmon stock estimates on both spatial and temporal strata of the 2017 Bering Sea pollock fishery during the B-season indicates that stocks were not uniformly distributed (Figs. 14, 15). In general, Asian stocks were more prevalent early in the season, and Eastern GOA/PNW stocks were more abundant later in the season. In the most northwestern area of the fishery, Asian stock proportions were higher than North American stock proportions (e.g., Cluster 4). North American stock contribution tended to be higher in the southeastern portion of the fishery (e.g., Clusters 1, 2) throughout the fishing season.

Age Stratification

Although the age structure of chum salmon caught in the Bering Sea B-season was nearly identical in 2016 and 2017, with the majority of fish age-4, the stock proportions differed between the two years (Figs. 16 and 17). In 2016, the Asian and Eastern GOA/PNW stock proportions were in inverse order by age, with most of age-3 fish from the Eastern GOA/PNW stock and most of age-5 fish from Asian stocks. In 2017, the Asian stocks dominated all three ages. Stock estimates for 2017 are available for many age-time-spatial strata (Appendix II). Although a full exploration of the stock estimates from the many multi-strata datasets was not developed in this report, some differences in stock estimates were observed across various combinations of age-time-spatial strata.

Fishing Sector

The chum salmon samples collected in the Bering Sea, B-season pollock fishery from catcher-processor and shoreside (catcher vessels) sectors had similar stock estimates for the six stock groups, although by continent of origin, the catcher-processors caught about 10% more Asian fish and the shoreside sector caught about 10% more North American fish (Fig. 18).

Application of Estimates

The extent to which any salmon stock is impacted by the Bering Sea and GOA trawl fisheries is dependent on many factors including 1) the overall size of the PSC, 2) the age of the salmon caught, 3) the age composition of the salmon stocks at return, and 4) the total escapement of the affected stocks, taking into account lag time for maturity and returning to the river. As such, a higher stock composition estimate one year does not necessarily imply greater impact than a smaller estimate in another year.

ACKNOWLEDGMENTS

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APPENDICES

Appendix I

Table of individual chum salmon populations in the Fisheries and Oceans Canada (DFO) microsatellite baseline (Beacham et al. 2009b, c), grouped by the six regions in this report that were used for stock identification of chum salmon caught in the Bering Sea pollock trawl fishery and Gulf of Alaska groundfish fisheries.

Appendix Table I. -- Chum salmon populations in the Fisheries and Oceans Canada (DFO) microsatellite baseline grouped by six regions used in the analyses of this report.

DFO num.	Population name	Reg num.	Region
41	Abashiri	1	SE Asia
215	Avakumovka	1	SE Asia
40	Chitose	1	SE Asia
315	Gakko_River	1	SE Asia
292	Hayatsuki	1	SE Asia
44	Horonai	1	SE Asia
252	Kawabukuro	1	SE Asia
313	Koizumi_River	1	SE Asia
300	Kushiro	1	SE Asia
37	Miomote	1	SE Asia
391	Namdae_R	1	SE Asia
231	Narva	1	SE Asia
298	Nishibetsu	1	SE Asia
293	Ohkawa	1	SE Asia
297	Orikasa	1	SE Asia
214	Ryazanovka	1	SE Asia
312	Sakari_River	1	SE Asia
311	Shari_River	1	SE Asia
36	Shibetsu	1	SE Asia
299	Shikiu	1	SE Asia
253	Shiriuchi	1	SE Asia
310	Shizunai	1	SE Asia
217	Suifen	1	SE Asia
35	Teshio	1	SE Asia
39	Tokachi	1	SE Asia
38	Tokoro	1	SE Asia
314	Tokushibetsu	1	SE Asia
291	Toshibetsu	1	SE Asia
296	Tsugaruishi	1	SE Asia
316	Uono_River	1	SE Asia
309	Yurappu	1	SE Asia
218	Amur	2	NE Asia
207	Anadyr	2	NE Asia
384	Apuka_River	2	NE Asia
382	Bolshaya	2	NE Asia
380	Dranka	2	NE Asia
223	Hairusova	2	NE Asia
378	Ivashka	2	NE Asia
213	Kalininka	2	NE Asia
225	Kamchatka	2	NE Asia
219	Kanchalan	2	NE Asia
379	Karaga	2	NE Asia
294	Kikchik	2	NE Asia
209	Kol	2	NE Asia
233	Magadan	2	NE Asia
211	Naiba	2	NE Asia
295	Nerpichi	2	NE Asia
381	Okhota	2	NE Asia
212	Oklan	2	NE Asia
222	Ola	2	NE Asia
386	Olutorsky_Bay	2	NE Asia
228	Ossora	2	NE Asia
224	Penzhina	2	NE Asia
385	Plotnikova_R	2	NE Asia
221	Pymta	2	NE Asia
220	Tauy	2	NE Asia
383	Tugur_River	2	NE Asia
226	Tym_	2	NE Asia
230	Udarnitsa	2	NE Asia
290	Utka_River	2	NE Asia
208	Vorovskaya	2	NE Asia
387	Zhypanova	2	NE Asia
348	Agiapuk	3	W Alaska
376	Alagnak	3	W Alaska
3	Andreafsky	3	W Alaska
357	Aniak	3	W Alaska
301	Anvik	3	W Alaska
80	Chulinak	3	W Alaska
347	Eldorado	3	W Alaska
358	George	3	W Alaska
307	Gisasa	3	W Alaska
371	Goodnews	3	W Alaska

Appendix Table I. -- Continued.

DFO num.	Population name	Reg num.	Region
288	Henshaw_Creek	3	W Alaska
339	Imnachuk	3	W Alaska
361	Kanektok	3	W Alaska
362	Kasigluk	3	W Alaska
328	Kelly_Lake	3	W Alaska
340	Kobuk	3	W Alaska
343	Koyuk	3	W Alaska
363	Kwethluk	3	W Alaska
336	Kwiniuk_River	3	W Alaska
303	Melozitna	3	W Alaska
373	Mulchatna	3	W Alaska
372	Naknek	3	W Alaska
330	Niukluk	3	W Alaska
329	Noatak	3	W Alaska
345	Nome	3	W Alaska
302	Nulato	3	W Alaska
374	Nunsatuk	3	W Alaska
13	Peel_River	3	W Alaska
322	Pikmiktalik	3	W Alaska
331	Pilgrim_River	3	W Alaska
346	Shaktoolik	3	W Alaska
341	Snake	3	W Alaska
368	Stuyahok_River	3	W Alaska
375	Togiak	3	W Alaska
154	Tozitna	3	W Alaska
342	Unalakleet	3	W Alaska
344	Ungalik	3	W Alaska
8	Big_Creek	4	U/M Yukon
89	Big_Salt	4	U/M Yukon
86	Black_River	4	U/M Yukon
87	Chandalar	4	U/M Yukon
28	Chandindu	4	U/M Yukon
82	Cheena	4	U/M Yukon
81	Delta	4	U/M Yukon
7	Donjek	4	U/M Yukon
5	Fishing_Br	4	U/M Yukon
88	Jim_River	4	U/M Yukon

DFO num.	Population name	Reg num.	Region
85	Kantishna	4	U/M Yukon
2	Kluane	4	U/M Yukon
59	Kluane_Lake	4	U/M Yukon
181	Koyukuk_late	4	U/M Yukon
90	Koyukuk_south	4	U/M Yukon
10	Minto	4	U/M Yukon
6	Pelly	4	U/M Yukon
439	Porcupine	4	U/M Yukon
83	Salcha	4	U/M Yukon
4	Sheenjek	4	U/M Yukon
1	Tatchun	4	U/M Yukon
9	Teslin	4	U/M Yukon
84	Toklat	4	U/M Yukon
360	Alagoshak	5	SW Alaska
333	American_River	5	SW Alaska
366	Big_River	5	SW Alaska
354	Coleman_Creek	5	SW Alaska
355	Delta_Creek	5	SW Alaska
359	Egegik	5	SW Alaska
332	Frosty_Creek	5	SW Alaska
365	Gertrude_Creek	5	SW Alaska
370	Joshua_Green	5	SW Alaska
364	Meshik	5	SW Alaska
283	Moller_Bay	5	SW Alaska
369	Pumice_Creek	5	SW Alaska
367	Stepovak_Bay	5	SW Alaska
335	Sturgeon	5	SW Alaska
350	Uganik	5	SW Alaska
334	Volcano_Bay	5	SW Alaska
356	Westward_Creek	5	SW Alaska
239	Ahnuhati	6	E GOA/PNW
69	Ahta	6	E GOA/PNW
155	Ain	6	E GOA/PNW
183	Algard	6	E GOA/PNW
58	Alouette	6	E GOA/PNW
325	Alouette_North	6	E GOA/PNW
270	Andesite_Cr	6	E GOA/PNW

Appendix Table I. -- Continued.

DFO num.	Population name	Reg num.	Region
428	Arnoup	6	E GOA/PNW
153	Ashlulm	6	E GOA/PNW
156	Awun	6	E GOA/PNW
133	Bag_Harbour	6	E GOA/PNW
164	Barnard	6	E GOA/PNW
16	Bella_Bell	6	E GOA/PNW
79	Bella_Coola	6	E GOA/PNW
49	Big_Qual	6	E GOA/PNW
201	Big_Quilcene	6	E GOA/PNW
281	Bish_Cr	6	E GOA/PNW
198	Bitter_Creek	6	E GOA/PNW
103	Blackrock_Creek	6	E GOA/PNW
390	Blaney_Creek	6	E GOA/PNW
138	Botany_Creek	6	E GOA/PNW
264	Buck_Channel	6	E GOA/PNW
169	Bullock_Chann	6	E GOA/PNW
61	Campbell_River	6	E GOA/PNW
323	Carroll	6	E GOA/PNW
78	Cascade	6	E GOA/PNW
76	Cayeghle	6	E GOA/PNW
42	Cheakamus	6	E GOA/PNW
398	Cheenis_Lake	6	E GOA/PNW
51	Chehalis	6	E GOA/PNW
19	Chemainus	6	E GOA/PNW
47	Chilliwack	6	E GOA/PNW
392	Chilqua_Creek	6	E GOA/PNW
117	Chuckwalla	6	E GOA/PNW
139	Clapp_Basin	6	E GOA/PNW
107	Clatse_Creek	6	E GOA/PNW
118	Clyak	6	E GOA/PNW
62	Cold_Creek	6	E GOA/PNW
77	Colonial	6	E GOA/PNW
353	Constantine	6	E GOA/PNW
168	Cooper_Inlet	6	E GOA/PNW
197	County_Line	6	E GOA/PNW
12	Cowichan	6	E GOA/PNW
414	Crag_Cr	6	E GOA/PNW

DFO num.	Population name	Reg num.	Region
161	Dak_	6	E GOA/PNW
259	Dana_Creek	6	E GOA/PNW
123	Date_Creek	6	E GOA/PNW
250	Dawson_Inlet	6	E GOA/PNW
91	Dean_River	6	E GOA/PNW
261	Deena	6	E GOA/PNW
170	Deer_Pass	6	E GOA/PNW
46	Demamiel	6	E GOA/PNW
210	Dipac_Hatchery	6	E GOA/PNW
319	Disappearance	6	E GOA/PNW
269	Dog-tag	6	E GOA/PNW
177	Draney	6	E GOA/PNW
114	Duthie_Creek	6	E GOA/PNW
427	East_Arm	6	E GOA/PNW
266	Ecstall_River	6	E GOA/PNW
94	Elcho_Creek	6	E GOA/PNW
193	Ellsworth_Cr	6	E GOA/PNW
203	Elwha	6	E GOA/PNW
276	Ensheshese	6	E GOA/PNW
263	Fairfax_Inlet	6	E GOA/PNW
32	Fish_Creek	6	E GOA/PNW
429	Flux_Cr	6	E GOA/PNW
102	Foch_Creek	6	E GOA/PNW
179	Frenchman	6	E GOA/PNW
227	Gambier	6	E GOA/PNW
96	Gill_Creek	6	E GOA/PNW
166	Gilttoyee	6	E GOA/PNW
145	Glendale	6	E GOA/PNW
135	Gold_Harbour	6	E GOA/PNW
11	Goldstream	6	E GOA/PNW
66	Goodspeed_River	6	E GOA/PNW
136	Government	6	E GOA/PNW
205	Grant_Creek	6	E GOA/PNW
100	Green_River	6	E GOA/PNW
450	GreenRrHatchery	6	E GOA/PNW
237	Greens	6	E GOA/PNW
141	Harrison	6	E GOA/PNW

Appendix Table I. -- Continued.

DFO num.	Population name	Reg num.	Region
438	Harrison_late	6	E GOA/PNW
64	Hathaway_Creek	6	E GOA/PNW
234	Herman_Creek	6	E GOA/PNW
17	Heydon_Cre	6	E GOA/PNW
407	Hicks_Cr	6	E GOA/PNW
400	Homathko	6	E GOA/PNW
411	Honna	6	E GOA/PNW
204	Hoodsport	6	E GOA/PNW
185	Hooknose	6	E GOA/PNW
406	Hopedale_Cr	6	E GOA/PNW
412	Hutton_Head	6	E GOA/PNW
278	Illiance	6	E GOA/PNW
152	Inch_Creek	6	E GOA/PNW
146	Indian_River	6	E GOA/PNW
92	Jenny_Bay	6	E GOA/PNW
115	Kainet_River	6	E GOA/PNW
144	Kakweiken	6	E GOA/PNW
268	Kalum	6	E GOA/PNW
395	Kanaka_Cr	6	E GOA/PNW
402	Kano_Inlet_Cr	6	E GOA/PNW
162	Kateen	6	E GOA/PNW
389	Kawkawa	6	E GOA/PNW
95	Kemano	6	E GOA/PNW
192	Kennedy_Creek	6	E GOA/PNW
238	Kennell	6	E GOA/PNW
351	Keta_Creek	6	E GOA/PNW
101	Khutze_River	6	E GOA/PNW
126	Khutzeymateen	6	E GOA/PNW
282	Kiltuish	6	E GOA/PNW
93	Kimsquit	6	E GOA/PNW
187	Kimsquit_Bay	6	E GOA/PNW
419	Kincolith	6	E GOA/PNW
273	Kispiox	6	E GOA/PNW
106	Kitasoo	6	E GOA/PNW
99	Kitimat_River	6	E GOA/PNW
275	Kitsault_Riv	6	E GOA/PNW
163	Kitwanga	6	E GOA/PNW
271	Kleanza_Cr	6	E GOA/PNW
437	Klewnuggit_Cr	6	E GOA/PNW
21	Klinaklini	6	E GOA/PNW
418	Ksedin	6	E GOA/PNW
125	Kshwan	6	E GOA/PNW
423	Kumealon	6	E GOA/PNW
112	Kwakusdis_River	6	E GOA/PNW
436	Kxngeal_Cr	6	E GOA/PNW
127	Lachmach	6	E GOA/PNW
262	Lagins	6	E GOA/PNW
131	Lagoon_Inlet	6	E GOA/PNW
448	LagoonCr	6	E GOA/PNW
167	Lard	6	E GOA/PNW
160	Little_Goose	6	E GOA/PNW
50	Little_Qua	6	E GOA/PNW
413	Lizard_Cr	6	E GOA/PNW
119	Lockhart-Gordon	6	E GOA/PNW
176	Lower_Lillooet	6	E GOA/PNW
137	Mace_Creek	6	E GOA/PNW
242	Mackenzie_Sound	6	E GOA/PNW
116	MacNair_Creek	6	E GOA/PNW
55	Mamquam	6	E GOA/PNW
121	Markle_Inlet_Cr	6	E GOA/PNW
27	Martin_Riv	6	E GOA/PNW
338	Mashiter_Creek	6	E GOA/PNW
109	McLoughin_Cr	6	E GOA/PNW
178	Milton	6	E GOA/PNW
194	Minter_Cr	6	E GOA/PNW
254	Mountain_Cr	6	E GOA/PNW
111	Mussel_River	6	E GOA/PNW
157	Naden	6	E GOA/PNW
337	Nahmint_River	6	E GOA/PNW
444	Nakut_Su	6	E GOA/PNW
14	Nanaimo	6	E GOA/PNW
122	Nangeese	6	E GOA/PNW
422	Nass_River	6	E GOA/PNW
399	Necleetsconnay	6	E GOA/PNW

Appendix Table I. -- Continued.

DFO num.	Population name	Reg num.	Region
113	Neekas_Creek	6	E GOA/PNW
321	Neets_Bay_early	6	E GOA/PNW
320	Neets_Bay_late	6	E GOA/PNW
173	Nekite	6	E GOA/PNW
104	Nias_Creek	6	E GOA/PNW
143	Nimpkish	6	E GOA/PNW
53	Nitinat	6	E GOA/PNW
191	Nooksack	6	E GOA/PNW
186	Nooseseck	6	E GOA/PNW
318	NorrishWorth	6	E GOA/PNW
159	North_Arm	6	E GOA/PNW
377	Olsen_Creek	6	E GOA/PNW
184	Orford	6	E GOA/PNW
287	Pa-aat_River	6	E GOA/PNW
260	Pacofi	6	E GOA/PNW
56	Pallant	6	E GOA/PNW
65	Pegattum_Creek	6	E GOA/PNW
48	Puntledge	6	E GOA/PNW
98	Quaal_River	6	E GOA/PNW
147	Quap	6	E GOA/PNW
108	Quartcha_Creek	6	E GOA/PNW
199	Quinault	6	E GOA/PNW
110	Roscoe_Creek	6	E GOA/PNW
397	Salmon_Bay	6	E GOA/PNW
195	Salmon_Cr	6	E GOA/PNW
134	Salmon_River	6	E GOA/PNW
200	Satsop	6	E GOA/PNW
236	Sawmill	6	E GOA/PNW
410	Seal_Inlet_Cr	6	E GOA/PNW
158	Security	6	E GOA/PNW
130	Sedgewick	6	E GOA/PNW
393	Serpentine_R	6	E GOA/PNW
317	Shovelnose_Cr	6	E GOA/PNW
249	Shustnini	6	E GOA/PNW
206	Siberia_Creek	6	E GOA/PNW
25	Silverdale	6	E GOA/PNW
196	Skagit	6	E GOA/PNW
274	Skeena	6	E GOA/PNW
171	Skowquiltz	6	E GOA/PNW
447	SkykomishRiv	6	E GOA/PNW
132	Slatechuck_Cre	6	E GOA/PNW
43	Sliammon	6	E GOA/PNW
15	Smith_Cree	6	E GOA/PNW
54	Snootli	6	E GOA/PNW
180	Southgate	6	E GOA/PNW
26	Squakum	6	E GOA/PNW
142	Squamish	6	E GOA/PNW
128	Stagoo	6	E GOA/PNW
265	Stanley	6	E GOA/PNW
52	Stave	6	E GOA/PNW
396	Stawamus	6	E GOA/PNW
409	Steel_Cr	6	E GOA/PNW
424	Stewart_Cr	6	E GOA/PNW
416	Stumaun_Cr	6	E GOA/PNW
327	Sugsaw	6	E GOA/PNW
324	Surprise	6	E GOA/PNW
75	Taaltz	6	E GOA/PNW
30	Taku	6	E GOA/PNW
18	Takwahoni	6	E GOA/PNW
251	Tarundl_Creek	6	E GOA/PNW
149	Theodosia	6	E GOA/PNW
22	Thorsen	6	E GOA/PNW
129	Toon	6	E GOA/PNW
279	Tseax	6	E GOA/PNW
202	Tulalip	6	E GOA/PNW
97	Turn_Creek	6	E GOA/PNW
430	Turtle_Cr	6	E GOA/PNW
247	Tuskwa	6	E GOA/PNW
165	Tyler	6	E GOA/PNW
33	Tzoonie	6	E GOA/PNW
124	Upper_Kitsumkal	6	E GOA/PNW
140	Vedder	6	E GOA/PNW
70	Viner_Sound	6	E GOA/PNW
45	Wahleach	6	E GOA/PNW

Appendix Table I. -- Continued.

DFO num.	Population name	Reg num.	Region
172	Walkum	6	E GOA/PNW
73	Waump	6	E GOA/PNW
232	Wells_Bridge	6	E GOA/PNW
352	Wells_River	6	E GOA/PNW
105	West_Arm_Creek	6	E GOA/PNW
267	Whitebottom_Cr	6	E GOA/PNW
326	Widgeon_Slough	6	E GOA/PNW
277	Wilauks_Cr	6	E GOA/PNW
120	Wilson_Creek	6	E GOA/PNW
401	Worth_Creek	6	E GOA/PNW
60	Wortley_Creek	6	E GOA/PNW
248	Yellow_Bluff	6	E GOA/PNW
434	Zymagotitz	6	E GOA/PNW

Appendix II

Regional stock composition estimates of chum salmon samples from the 2017 Bering Sea (BS), B-season midwater pollock trawl fishery and the Gulf of Alaska (GOA) groundfish fisheries. Estimated number of prohibited species catch (PSC), BAYES mean estimates, standard deviations (SD), 95% credible intervals, median estimate, the probability that the stock estimate is equal to zero (P = 0; values > 0.5 are shaded; Munro et al. 2012), and the Gelman-Rubin shrink factor (SF) are reported. For each stratum, PSC is the number of chum salmon reported as caught and n is the number of genetic samples used in the analysis. Early season is Weeks 23-29, Middle season is Weeks 30-34, and Late season is Weeks 35-42. For the analyses of four spatial clusters, the Early time period is Weeks 23-32 and the Late time period is Weeks 33-42. Sample sets with spatial strata by cluster have extra samples added to increase sample size, and may produce stock estimates that differ from sample sets that are representative of the bycatch.

Appendix Table II. -- Regional stock composition estimates of chum salmon samples from the 2017 Bering Sea (BS) midwater pollock trawl fishery and the Gulf of Alaska (GOA) groundfish fisheries.

GOA Total sample set (PSC = 5,802, n = 812)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	64	0.011	0.004	0.004	0.010	0.021	0.252	1.00
NE Asia	487	0.084	0.014	0.058	0.084	0.113	0	1.00
W Alaska	168	0.029	0.009	0.013	0.028	0.048	0	1.00
Up/Mid-Yukon	12	0.002	0.003	0	0.001	0.010	1.000	1.00
SW Alaska	168	0.029	0.009	0.013	0.029	0.049	0	1.00
E GOA/PNW	4,903	0.845	0.016	0.813	0.845	0.874	0	1.00

BS B-season sample set (PSC = 464,898, n = 2,064)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	72,989	0.157	0.009	0.140	0.157	0.174	0	1.00
NE Asia	214,318	0.461	0.014	0.433	0.461	0.490	0	1.00
W Alaska	65,086	0.140	0.011	0.119	0.139	0.161	0	1.00
Up/Mid-Yukon	28,359	0.061	0.007	0.047	0.060	0.075	0	1.00
SW Alaska	14,877	0.032	0.006	0.021	0.032	0.044	0	1.00
E GOA/PNW	69,735	0.150	0.010	0.132	0.150	0.169	0	1.00

BS Early sample set (PSC = 287,683; n = 1,307)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	51,783	0.180	0.012	0.158	0.180	0.204	0	1.00
NE Asia	138,376	0.481	0.018	0.447	0.481	0.515	0	1.00
Western AK	42,002	0.146	0.014	0.118	0.145	0.174	0	1.00
Up/Mid-Yukon	21,001	0.073	0.010	0.054	0.072	0.094	0	1.00
SW Alaska	8,343	0.029	0.007	0.016	0.028	0.044	0	1.00
E GOA/PNW	26,467	0.092	0.010	0.073	0.091	0.112	0	1.00

BS Middle sample set (PSC = 142,265; n = 589)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	18,068	0.127	0.016	0.098	0.126	0.159	0	1.00
NE Asia	65,869	0.463	0.027	0.410	0.463	0.515	0	1.00
Western AK	21,340	0.150	0.020	0.113	0.150	0.190	0	1.00
Up/Mid-Yukon	3,557	0.025	0.009	0.010	0.024	0.045	0	1.00
SW Alaska	5,406	0.038	0.013	0.017	0.037	0.067	0	1.00
E GOA/PNW	28,026	0.197	0.020	0.159	0.197	0.237	0	1.00

Appendix Table II. -- Continued.

BS Late sample set (PSC = 34,950; n = 168)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	4,159	0.119	0.029	0.069	0.117	0.181	0	1.00
NE Asia	10,275	0.294	0.047	0.204	0.293	0.388	0	1.00
Western AK	4,404	0.126	0.035	0.064	0.124	0.201	0	1.00
Up/Mid-Yukon	1,748	0.050	0.022	0.014	0.048	0.099	0.001	1.00
SW Alaska	1,538	0.044	0.022	0.011	0.042	0.095	0	1.00
E GOA/PNW	12,827	0.367	0.043	0.284	0.366	0.454	0	1.00

BS east of 170°W sample set (PSC = 406,244; n = 1,783)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	59,312	0.146	0.009	0.128	0.146	0.165	0	1.00
NE Asia	186,060	0.458	0.015	0.428	0.458	0.488	0	1.00
Western AK	62,155	0.153	0.012	0.129	0.152	0.177	0	1.00
Up/Mid-Yukon	26,812	0.066	0.008	0.051	0.066	0.082	0	1.00
SW Alaska	13,000	0.032	0.007	0.020	0.032	0.046	0	1.00
E GOA/PNW	59,312	0.146	0.010	0.126	0.145	0.166	0	1.00

BS west of 170°W sample set (PSC = 58,654; n = 281)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	13,373	0.228	0.028	0.176	0.227	0.284	0	1.00
NE Asia	27,157	0.463	0.038	0.389	0.463	0.537	0	1.00
Western AK	5,924	0.101	0.026	0.054	0.099	0.156	0	1.00
Up/Mid-Yukon	1,408	0.024	0.012	0.002	0.023	0.051	0.017	1.00
SW Alaska	1,760	0.030	0.014	0.007	0.029	0.062	0	1.00
E GOA/PNW	9,033	0.154	0.025	0.108	0.153	0.205	0	1.00

BS NMFS Area 517 sample set (PSC = 371,393; n = 1,600)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P=0	SF
SE Asia	57,566	0.155	0.010	0.135	0.154	0.174	0	1.00
NE Asia	179,383	0.483	0.016	0.452	0.483	0.515	0	1.00
Western AK	51,995	0.140	0.012	0.116	0.140	0.164	0	1.00
Up/Mid-Yukon	22,284	0.060	0.008	0.045	0.060	0.077	0	1.00
SW Alaska	12,627	0.034	0.007	0.021	0.033	0.048	0	1.00
E GOA/PNW	47,910	0.129	0.010	0.109	0.129	0.150	0	1.00

Appendix Table II. -- Continued.

BS NMFS Area 521 sample set (PSC = 50,821; n = 247)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P=0	SF
SE Asia	11,841	0.233	0.030	0.177	0.232	0.295	0	1.00
NE Asia	22,310	0.439	0.042	0.357	0.439	0.520	0	1.00
Western AK	5,844	0.115	0.031	0.061	0.114	0.180	0	1.00
Up/Mid-Yukon	1,321	0.026	0.014	0.001	0.025	0.056	0.023	1.00
SW Alaska	1,677	0.033	0.016	0.007	0.031	0.068	0	1.00
E GOA/PNW	7,776	0.153	0.026	0.105	0.152	0.208	0	1.00

Cluster 1 Early sample set (PSC = 134,212; n = 640)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P=0	SF
SE Asia	19,729	0.147	0.016	0.118	0.147	0.179	0	1.00
NE Asia	49,927	0.372	0.025	0.324	0.372	0.421	0	1.00
Western AK	31,003	0.231	0.023	0.187	0.231	0.277	0	1.00
Up/Mid-Yukon	8,590	0.064	0.015	0.037	0.063	0.094	0	1.00
SW Alaska	4,832	0.036	0.011	0.017	0.035	0.060	0	1.01
E GOA/PNW	20,132	0.150	0.018	0.117	0.150	0.186	0	1.01

Cluster 1 Late sample set (PSC = 18,133; n = 213)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P=0	SF
SE Asia	417	0.023	0.011	0.006	0.021	0.049	0	1.00
NE Asia	6,328	0.349	0.042	0.270	0.348	0.432	0	1.00
Western AK	4,388	0.242	0.038	0.170	0.240	0.320	0	1.00
Up/Mid-Yukon	1,015	0.056	0.022	0.020	0.054	0.106	0	1.00
SW Alaska	1,034	0.057	0.024	0.017	0.055	0.110	0	1.00
E GOA/PNW	4,950	0.273	0.039	0.201	0.273	0.351	0	1.00

Cluster 2 Early sample set (PSC = 207,139; n = 809)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	33,557	0.162	0.015	0.135	0.162	0.192	0	1.00
NE Asia	111,648	0.539	0.022	0.495	0.539	0.583	0	1.00
Western AK	25,685	0.124	0.016	0.094	0.123	0.156	0	1.00
Up/Mid-Yukon	12,428	0.060	0.011	0.040	0.059	0.082	0	1.00
SW Alaska	7,250	0.035	0.010	0.017	0.034	0.056	0	1.00
E GOA/PNW	16,778	0.081	0.012	0.058	0.080	0.106	0	1.00

Appendix Table II. -- Continued.

Cluster 2 Late sample set (PSC = 13,850; n = 199)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	1,122	0.081	0.021	0.044	0.080	0.127	0	1.00
NE Asia	4,723	0.341	0.044	0.257	0.340	0.429	0	1.00
Western AK	1,039	0.075	0.027	0.029	0.073	0.132	0	1.00
Up/Mid-Yukon	346	0.025	0.015	0.002	0.023	0.059	0.019	1.00
SW Alaska	402	0.029	0.019	0.003	0.025	0.074	0.010	1.00
E GOA/PNW	6,233	0.450	0.042	0.369	0.449	0.534	0	1.00

Cluster 3 Early sample set (PSC = 31,915; n = 190)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	7,755	0.243	0.033	0.182	0.242	0.311	0	1.00
NE Asia	17,106	0.536	0.046	0.445	0.536	0.625	0	1.00
Western AK	2,745	0.086	0.031	0.033	0.084	0.152	0	1.00
Up/Mid-Yukon	1,372	0.043	0.017	0.015	0.041	0.079	0	1.00
SW Alaska	128	0.004	0.008	0	0.001	0.028	0.691	1.00
E GOA/PNW	2,809	0.088	0.026	0.044	0.086	0.144	0	1.00

Cluster 4 Early sample set (PSC = 6,090; n = 188)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	1,523	0.250	0.034	0.186	0.249	0.321	0	1.00
NE Asia	2,978	0.489	0.045	0.401	0.490	0.578	0	1.00
Western AK	713	0.117	0.030	0.063	0.115	0.181	0	1.00
Up/Mid-Yukon	12	0.002	0.005	0	0	0.016	0.999	1.00
SW Alaska	24	0.004	0.008	0	0	0.027	0.955	1.00
E GOA/PNW	840	0.138	0.029	0.086	0.136	0.199	0	1.00

Cluster 4 Late sample set (PSC = 19,078; n = 199)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	6,601	0.346	0.037	0.276	0.346	0.419	0	1.00
NE Asia	7,650	0.401	0.043	0.318	0.401	0.486	0	1.00
Western AK	1,087	0.057	0.022	0.022	0.054	0.106	0	1.00
Up/Mid-Yukon	267	0.014	0.011	0	0.012	0.041	0.109	1.00
SW Alaska	267	0.014	0.015	0	0.009	0.055	0.215	1.01
E GOA/PNW	3,205	0.168	0.030	0.113	0.166	0.230	0	1.00

Appendix Table II. -- Continued.

Age-3 Fish sample set (PSC =109,961; n = 395)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	25,280	0.230	0.023	0.186	0.230	0.276	0	1.00
NE Asia	36,914	0.336	0.029	0.279	0.335	0.394	0	1.00
Western AK	14,196	0.129	0.022	0.088	0.128	0.175	0	1.00
Up/Mid-Yukon	2,287	0.021	0.012	0.003	0.019	0.050	0.001	1.00
SW Alaska	1,440	0.013	0.008	0.002	0.012	0.031	0.001	1.00
E GOA/PNW	29,832	0.271	0.025	0.224	0.271	0.321	0	1.00

Age-4 Fish sample set (PSC = 290,631; n = 1,044)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	31,679	0.109	0.011	0.089	0.109	0.131	0	1.00
NE Asia	149,675	0.515	0.021	0.475	0.515	0.555	0	1.00
Western AK	46,210	0.159	0.017	0.127	0.158	0.192	0	1.00
Up/Mid-Yukon	21,216	0.073	0.011	0.052	0.073	0.097	0	1.00
SW Alaska	17,147	0.059	0.011	0.040	0.059	0.081	0	1.00
E GOA/PNW	24,994	0.086	0.013	0.062	0.085	0.112	0	1.00

Age-5 Fish sample set (PSC = 59,852; n = 215)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	10,833	0.181	0.030	0.126	0.180	0.243	0	1.00
NE Asia	25,497	0.426	0.043	0.342	0.426	0.511	0	1.00
Western AK	11,492	0.192	0.037	0.123	0.190	0.266	0	1.00
Up/Mid-Yukon	3,172	0.053	0.022	0.018	0.051	0.102	0	1.00
SW Alaska	718	0.012	0.012	0	0.009	0.043	0.130	1.00
E GOA/PNW	8,140	0.136	0.026	0.088	0.134	0.190	0	1.00

Age-3 Cluster 1 sample set (PSC = 32,789; n = 147)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	6,492	0.198	0.036	0.132	0.196	0.274	0	1.00
NE Asia	8,525	0.260	0.047	0.172	0.258	0.354	0	1.00
Western AK	6,295	0.192	0.043	0.114	0.190	0.282	0	1.00
Up/Mid-Yukon	1,344	0.041	0.023	0.007	0.038	0.094	0.002	1.00
SW Alaska	557	0.017	0.016	0	0.013	0.058	0.122	1.00
E GOA/PNW	9,574	0.292	0.041	0.213	0.291	0.375	0	1.00

Appendix Table II. -- Continued.

Age-3 Cluster 2 sample set (PSC = 56,795; n = 211)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	10,280	0.181	0.029	0.128	0.180	0.240	0	1.00
NE Asia	16,414	0.289	0.039	0.215	0.289	0.368	0	1.00
Western AK	5,907	0.104	0.027	0.055	0.102	0.160	0	1.00
Up/Mid-Yukon	1,193	0.021	0.014	0.003	0.018	0.055	0.002	1.00
SW Alaska	170	0.003	0.006	0	0	0.020	0.809	1.01
E GOA/PNW	22,832	0.402	0.038	0.328	0.402	0.478	0	1.00

Age-3 Cluster 4 sample set (PSC = 10,389; n = 142)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	4,322	0.416	0.045	0.327	0.416	0.505	0	1.00
NE Asia	2,847	0.274	0.050	0.180	0.273	0.373	0	1.00
Western AK	696	0.067	0.031	0.017	0.063	0.137	0	1.00
Up/Mid-Yukon	291	0.028	0.024	0	0.026	0.081	0.212	1.01
SW Alaska	239	0.023	0.024	0	0.016	0.082	0.260	1.01
E GOA/PNW	1,995	0.192	0.036	0.126	0.191	0.268	0	1.00

Age-3 Cluster 2 Early sample set (PSC = 43,273; n = 136)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	10,342	0.239	0.039	0.167	0.237	0.320	0	1.00
NE Asia	18,175	0.420	0.052	0.318	0.420	0.523	0	1.00
Western AK	5,669	0.131	0.037	0.065	0.130	0.209	0	1.00
Up/Mid-Yukon	1,125	0.026	0.019	0.003	0.021	0.074	0.002	1.00
SW Alaska	173	0.004	0.008	0	0	0.029	0.767	1.00
E GOA/PNW	7,832	0.181	0.038	0.111	0.179	0.261	0	1.00

Age-3 Clusters 1-2 Early sample set (PSC = 66,374; n = 224)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	17,589	0.265	0.031	0.206	0.264	0.327	0	1.00
NE Asia	25,753	0.388	0.040	0.312	0.387	0.466	0	1.00
Western AK	9,757	0.147	0.031	0.088	0.146	0.209	0	1.00
Up/Mid-Yukon	1,527	0.023	0.019	0.002	0.018	0.072	0.002	1.00
SW Alaska	133	0.002	0.004	0	0	0.015	0.854	1.00
E GOA/PNW	11,682	0.176	0.030	0.119	0.175	0.237	0	1.00

Appendix Table II. -- Continued.

Age-3 Clusters 1-2 Late sample set (PSC = 12,175; n = 134)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	713	0.059	0.026	0.017	0.055	0.120	0	1.02
NE Asia	1,071	0.088	0.036	0.030	0.085	0.168	0	1.01
Western AK	1,705	0.140	0.038	0.073	0.137	0.221	0	1.00
Up/Mid-Yukon	353	0.029	0.018	0.001	0.026	0.070	0.032	1.00
SW Alaska	414	0.034	0.025	0	0.029	0.092	0.050	1.01
E GOA/PNW	7,926	0.651	0.046	0.559	0.652	0.738	0	1.00

Age-3 Clusters 3-4 Early sample set (PSC = 11,948; n = 105)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	4,325	0.362	0.050	0.268	0.361	0.462	0	1.00
NE Asia	3,847	0.322	0.055	0.218	0.322	0.431	0	1.00
Western AK	1,183	0.099	0.036	0.038	0.096	0.177	0	1.00
Up/Mid-Yukon	60	0.005	0.011	0	0.001	0.038	0.799	1.00
SW Alaska	191	0.016	0.021	0	0.006	0.071	0.412	1.00
E GOA/PNW	2,342	0.196	0.042	0.120	0.194	0.284	0	1.00

Age-3 Clusters 3-4 Late sample set (PSC = 11,264; n = 124)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	3,638	0.323	0.045	0.238	0.322	0.413	0	1.00
NE Asia	2,895	0.257	0.052	0.160	0.255	0.362	0	1.00
Western AK	608	0.054	0.033	0.005	0.050	0.128	0.008	1.00
Up/Mid-Yukon	237	0.021	0.022	0	0.016	0.073	0.265	1.00
SW Alaska	574	0.051	0.029	0.008	0.047	0.118	0.001	1.00
E GOA/PNW	3,323	0.295	0.046	0.207	0.293	0.388	0	1.00

Age-4 Cluster 1 sample set (PSC = 96,359; n = 432)

Region	Est. num.	Mean	SD	2.5%	Median	0.975	P = 0	SF
SE Asia	7,131	0.074	0.014	0.049	0.073	0.103	0	1.00
NE Asia	38,736	0.402	0.032	0.339	0.402	0.466	0	1.00
Western AK	23,415	0.243	0.030	0.185	0.243	0.303	0	1.00
Up/Mid-Yukon	7,034	0.073	0.021	0.036	0.072	0.118	0	1.00
SW Alaska	5,782	0.060	0.016	0.033	0.059	0.095	0	1.00
E GOA/PNW	14,261	0.148	0.022	0.106	0.147	0.192	0	1.00

Appendix Table II. -- Continued.

Age-4 Cluster 2 sample set (PSC = 137,815; n = 512)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	17,089	0.124	0.016	0.093	0.123	0.158	0	1.00
NE Asia	73,180	0.531	0.028	0.476	0.531	0.586	0	1.00
Western AK	19,294	0.140	0.022	0.100	0.140	0.187	0	1.00
Up/Mid-Yukon	8,545	0.062	0.016	0.032	0.061	0.094	0	1.00
SW Alaska	8,545	0.062	0.014	0.036	0.061	0.092	0	1.00
E GOA/PNW	11,301	0.082	0.016	0.054	0.081	0.115	0	1.00

Age-4 Cluster 3 sample set (PSC = 17,891; n = 119)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	2,487	0.139	0.034	0.079	0.137	0.213	0	1.00
NE Asia	11,200	0.626	0.056	0.514	0.627	0.732	0	1.00
Western AK	1,628	0.091	0.042	0.023	0.087	0.185	0.001	1.00
Up/Mid-Yukon	1,127	0.063	0.027	0.016	0.061	0.122	0.001	1.00
SW Alaska	519	0.029	0.020	0.003	0.025	0.079	0.008	1.00
E GOA/PNW	930	0.052	0.030	0.006	0.047	0.121	0.005	1.00

Age-4 Cluster 4 sample set (PSC = 12,950; n = 177)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	2,862	0.221	0.034	0.158	0.220	0.291	0	1.00
NE Asia	6,915	0.534	0.046	0.442	0.534	0.622	0	1.00
Western AK	1,334	0.103	0.030	0.052	0.100	0.168	0	1.00
Up/Mid-Yukon	91	0.007	0.007	0	0.004	0.026	0.598	1.00
SW Alaska	155	0.012	0.014	0	0.008	0.051	0.322	1.00
E GOA/PNW	1,606	0.124	0.030	0.071	0.122	0.187	0	1.00

Age-4 Cluster 1 Early sample set (PSC = 86,796 n = 324)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	7,898	0.091	0.018	0.059	0.090	0.129	0	1.00
NE Asia	35,499	0.409	0.035	0.340	0.409	0.479	0	1.00
Western AK	20,223	0.233	0.034	0.169	0.232	0.301	0	1.00
Up/Mid-Yukon	6,857	0.079	0.024	0.038	0.078	0.129	0	1.00
SW Alaska	5,902	0.068	0.019	0.035	0.066	0.110	0	1.00
E GOA/PNW	10,415	0.120	0.022	0.079	0.119	0.166	0	1.00

Appendix Table II. -- Continued.

Age-4 Cluster 1 Late sample set (PSC = 10,760; n = 108)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	334	0.031	0.017	0.007	0.028	0.071	0	1.00
NE Asia	4,509	0.419	0.060	0.302	0.419	0.539	0	1.01
Western AK	2,916	0.271	0.055	0.169	0.270	0.382	0	1.00
Up/Mid-Yukon	463	0.043	0.031	0	0.038	0.114	0.045	1.00
SW Alaska	775	0.072	0.035	0.015	0.068	0.151	0.004	1.00
E GOA/PNW	1,775	0.165	0.046	0.084	0.162	0.264	0	1.00

Age-4 Cluster 2 Early sample set (PSC = 135,229; n = 425)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	17,715	0.131	0.018	0.097	0.130	0.168	0	1.00
NE Asia	73,159	0.541	0.031	0.480	0.541	0.601	0	1.00
Western AK	19,067	0.141	0.023	0.100	0.141	0.188	0	1.00
Up/Mid-Yukon	10,007	0.074	0.016	0.046	0.073	0.106	0	1.00
SW Alaska	8,790	0.065	0.016	0.037	0.064	0.099	0	1.00
E GOA/PNW	6,626	0.049	0.014	0.024	0.048	0.080	0	1.00

Age-4 Clusters 3-4 Early sample set (PSC = 21,961; n = 193)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	3,755	0.171	0.029	0.117	0.169	0.233	0	1.00
NE Asia	13,286	0.605	0.046	0.513	0.606	0.695	0	1.01
Western AK	2,416	0.110	0.037	0.043	0.108	0.186	0	1.01
Up/Mid-Yukon	505	0.023	0.020	0.001	0.017	0.070	0.047	1.00
SW Alaska	351	0.016	0.017	0	0.012	0.057	0.250	1.01
E GOA/PNW	1,647	0.075	0.024	0.033	0.073	0.127	0	1.04

Age-4 Cluster 3-4 Late sample set (PSC = 9,357; n = 103)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	2,115	0.226	0.044	0.146	0.224	0.317	0	1.00
NE Asia	4,444	0.475	0.060	0.358	0.475	0.592	0	1.00
Western AK	1,001	0.107	0.039	0.042	0.103	0.195	0	1.00
Up/Mid-Yukon	94	0.010	0.012	0	0.007	0.042	0.430	1.00
SW Alaska	552	0.059	0.028	0.015	0.055	0.121	0	1.00
E GOA/PNW	1,151	0.123	0.038	0.058	0.120	0.206	0	1.00

Appendix Table II. -- Continued.

Age-5 Cluster 1 sample set (PSC = 22,305; n = 100)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	3,524	0.158	0.039	0.088	0.155	0.243	0	1.00
NE Asia	6,000	0.269	0.057	0.163	0.267	0.385	0	1.00
Western AK	5,442	0.244	0.058	0.133	0.243	0.362	0	1.00
Up/Mid-Yukon	1,941	0.087	0.039	0.026	0.082	0.178	0.001	1.00
SW Alaska	178	0.008	0.013	0	0.002	0.046	0.573	1.00
E GOA/PNW	5,242	0.235	0.046	0.151	0.233	0.328	0	1.00

Age-5 Clusters 1-2 Early sample set (PSC = 50,373; n = 170)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	8,110	0.161	0.032	0.102	0.159	0.229	0	1.00
NE Asia	19,545	0.388	0.048	0.294	0.388	0.483	0	1.00
Western AK	11,082	0.220	0.046	0.131	0.220	0.312	0	1.00
Up/Mid-Yukon	3,325	0.066	0.030	0.020	0.061	0.139	0	1.00
SW Alaska	403	0.008	0.010	0	0.005	0.037	0.325	1.03
E GOA/PNW	7,959	0.158	0.031	0.102	0.156	0.222	0	1.00

Catcher-processor sample set (PSC = 294,371; n = 1,156)

Region	Est. num.	Mean	SD	2.5%	Median	97.5%	P = 0	SF
SE Asia	52,398	0.178	0.012	0.155	0.178	0.203	0	1.00
NE Asia	143,947	0.489	0.019	0.451	0.489	0.526	0	1.00
Western AK	35,030	0.119	0.013	0.094	0.119	0.146	0	1.00
Up/Mid-Yukon	14,719	0.050	0.009	0.034	0.050	0.068	0	1.00
SW Alaska	7,359	0.025	0.007	0.013	0.025	0.040	0	1.00
E GOA/PNW	40,623	0.138	0.012	0.115	0.138	0.163	0	1.00

Shoreside sample set (PSC = 154,101; n = 819)

Region	Est. num.	Mean	SD	0.025	Median	0.975	P = 0	SF
SE Asia	20,958	0.136	0.013	0.110	0.135	0.162	0	1.00
NE Asia	65,339	0.424	0.023	0.381	0.424	0.469	0	1.01
Western AK	27,584	0.179	0.019	0.142	0.179	0.218	0	1.00
Up/Mid-Yukon	9,708	0.063	0.013	0.040	0.062	0.090	0	1.00
SW Alaska	6,472	0.042	0.010	0.024	0.041	0.064	0	1.00
E GOA/PNW	24,040	0.156	0.016	0.127	0.156	0.187	0	1.03

Appendix III

Basic overview of Bayesian mixed-stock analysis pertinent to the chum salmon prohibited species catch (PSC) in the Bering Sea pollock trawl fishery and Gulf of Alaska groundfish fisheries.

Mixed stock analysis (MSA) requires three components:

1. A mixture containing genotypes of samples of unknown origin (e.g., chum salmon PSC samples).

2. A baseline of allele frequencies of potentially contributing stocks in the mixture (same genetic markers as the mixture). The baseline is typically comprised of stock groups[6], populations that are grouped due to genetic similarity, geographic proximity, or political boundaries. For the chum salmon PSC we used the 381-population, 11-locus microsatellite baseline from Fisheries and Oceans Canada (DFO), with populations grouped into six regions.

3. A method to compare the mixture to the baseline to estimate the proportions of baseline populations, or more commonly stock groups, in the mixture. Two methods were used in our study:
    a. **Maximum-likelihood** method in program SPAM (Debevec et al. 2000, ADF&G 2003) has been used in analyses in previous years. For the chum salmon PSC samples, the likelihood method typically estimates stock proportions similar to those produced by the Bayesian method. A comparison of the stock proportions produced by the two methods provides a quality control check on the MSA.
    b. **Bayesian** method in program BAYES (Pella and Masuda 2001), described below.

MSA using the BAYES program requires several steps:

1. Assign parameters of the prior distribution for the unknown stock proportions. Typically an uninformative prior with parameters equal to 1/number of stocks is used unless independent information is available for setting an informative prior. If stock-group estimates are made, then an uninformative prior for the stock-group proportions is set (parameters equal to $1/GC_g$ where G is the number of groups and C_g is the number of baseline populations in group g).

2. Choose the number of Markov chain Monte Carlo (MCMC) samples to simulate from the posterior distribution of stock proportions (depends on the data, but 50,000 to 100,000 is commonly used in our salmon mixed-stock applications).

3. Run several sets of MCMC samples (at least 3 "chains") with disparate values of initial mixture stock proportions such that most of the contribution comes from one stock or stock group. In the chum salmon PSC analyses, six chains were used, the first of which was started with 95% of the contribution coming from the first baseline region and 5% from all other regions. The other chains were similarly started.

[6] Depending upon the context, stock groups are sometimes referred to as reporting groups or regional groups.

4. Evaluate convergence of stock proportion estimates to the posterior distribution. Two diagnostics implemented in the BAYES program help gauge convergence. Increase the number of MCMC samples until the stock estimates converge.
    a. **Within chains:** the Raftery and Lewis (1996) diagnostic is useful for determining the number of MCMC samples required to estimate quantiles of the posterior distribution with a specified accuracy and probability.
    b. **Across chains:** the Gelman and Rubin (1992) diagnostic compares the variation within a single chain for a given parameter (e.g., unknown stock proportion) to the total variation among chains and summarizes the two measures by a univariate statistic called the shrink factor. A shrink factor near 1 is consistent with convergence of the samples to the posterior distribution. A shrink factor >1.2 may indicate lack of convergence.
5. Once convergence is determined, the MCMC samples of stock composition estimates are combined from all chains and summarized (e.g., mean, median, standard deviation, 2.5% and 97.5% quantiles), typically from the last half of the chains to remove the influence of the initial values.

Appendix IV

Four spatial clusters of ADF&G groundfish statistical areas[7] of chum salmon prohibited species catch sampled from 2013 to 2017 during the B-season of the Bering Sea pollock trawl fishery and analyzed for genetic stock composition. The areas sampled in 2017 in which at least three fishing vessels are represented are in bold (Fig. 14).

[7] http://www.adfg.alaska.gov/index.cfm?adfg=fishingCommercialByFishery.statmaps

Cluster 1: 625504, **625531**, **625600**, **625630**, 625700, 625730, **635501**, **635504**, **635530**, **635600**, **635630**, 635700, 635730, **645434**, **645501**, 645502, **645530**, **645600**, **645630**, 645700, 645730, 655407, **655409**, **655410**, **655430**, **655500**, **655530**, **655600**, **655630**, 655700, 655730, 665335, 665336, **665401**, 665403, 665404, **665430**, **665500**, **665530**, **665600**, **665630**, 665700, 665730

Cluster 2: **675430**, **675500**, **675530**, **675600**, **675630**, **675700**, 675730, **685500**, **685530**, **685600**, **685630**, 685700, 685730

Cluster 3: **695530**, **695600**, **695631**, 695632, **705530**, **705600**, **705630**, **705701**, 705730, **715600**, **715630**, **715700**, **715730**, **725630**, **725700**, **725730**, **735630**, **735700**, **735730**, **745730**

Cluster 4: 705800, 705830, 715800, 715830, **725800**, 725830, 725900, **735800**, **735830**, **735900**, 735930, **745800**, **745830**, **745900**, 745930, 746000, 755800, **755830**, **755900**, 755930, 756000, **765830**, **765900**, **765930**, **766000**, 766030, 775830, **775900**, **775930**, 776000, 776030, 785900, 785930, 786000, 786030

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