Update on Chinook salmon mortality and impacts due to bycatch in the EBS pollock fishery

NMFS/NPFMC/ADFG
May 2022

Executive Summary

As part of its bycatch management evaluation, the Council uses estimates of the adult equivalence (AEQ) of Chinook salmon that would have returned to river systems had they not been caught as bycatch in the EBS pollock fishery. This paper provides an update to several past Council evaluations[1] in order to estimate the impact rates of bycatch on the aggregated coastal western Alaska stocks and for the Upper Yukon River.

The updated data in the paper include results from new age and growth studies, updated maturation rates for western Alaskan systems, detailed total bycatch data (including length compositions), and updated Chinook salmon genetic information as sampled through to the 2020 pollock fishery. Additionally, this paper details the associated run reconstructions for the aggregated coastal western Alaska stocks and for the Upper Yukon River. Together these are used to estimate AEQ mortality and impacts attributed to the pollock fishery, by region of origin.

ES 1 Mean values of simulated AEQ Chinook mortality attributed to the pollock fishery, by region, 2011-2021*.

Year	BC-WA-OR	Coast W AK	Middle Yukon	Upper Yukon	*Combined West. AK*	N AK Penin	NW GOA	Russia	SEAK	Other	Total
2011	1,512	6,254	143	322	*6,397*	1,465	305	74	322	16	11,297
2012	1,661	8,651	177	400	*8,828*	1,496	400	96	400	23	14,310
2013	1,697	6,684	148	342	*6,832*	1,373	334	81	342	17	11,927
2014	2,014	6,573	184	351	*6,757*	2,070	351	86	351	12	13,109
2015	2,737	6,872	196	444	*7,068*	2,187	390	95	444	11	14,782
2016	5,018	8,643	279	708	*8,922*	3,170	420	134	708	12	21,157
2017	7,629	8,356	303	865	*8,659*	4,117	430	154	865	16	25,635
2018	5,951	6,106	225	668	*6,331*	3,313	363	118	668	15	19,719
2019	4,659	6,450	194	537	*6,644*	2,977	385	107	537	14	17,679
2020	4,216	10,337	277	594	*10,614*	3,976	591	162	594	18	22,578
2021	3,296	8,381	229	493	*8,610*	2,600	642	126	493	21	17,903

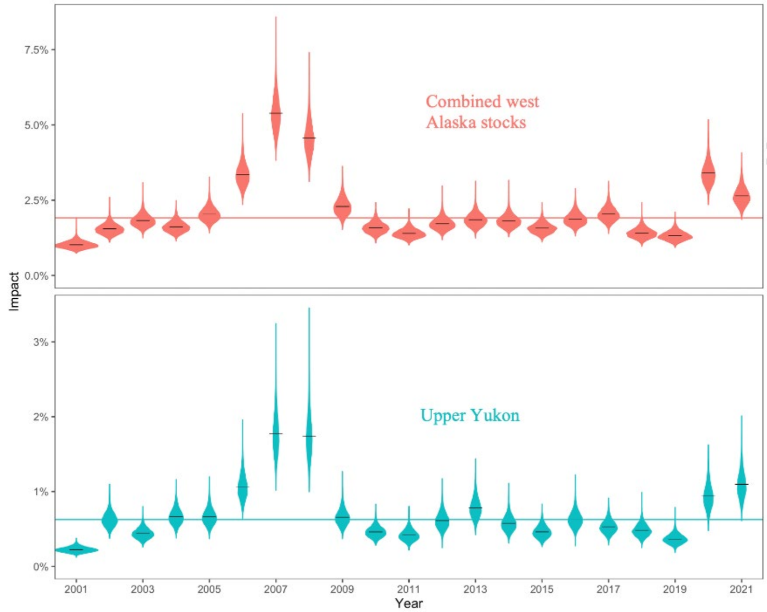
*See Table 7 for full notes and explanation

The paper finds that while new data show some evidence of a decrease in size at age of returning salmon, overall the impact of bycatch on the estimated AEQ of Chinook salmon that would otherwise have returned to river systems is consistent with our 2018 findings (NMFS/NPFMC 2018). **The estimate of impact rates has averaged 1.9% since 2011 for the combined coastal western Alaska stocks and 0.6% for the Upper Yukon River stock**. The impact rate (calculated as AEQ mortality divided by run size) has increased slightly for the western Alaska stocks in the last two years, reflecting both run size declines (mainly from the Nushagak River) as well as above-average bycatch in 2020.

[1] NMFS/NPFMC 2015, Ianelli and Stram 2015, NMFS/NPFMC 2018

ES2 Estimated impact rates (AEQ mortality/run size) by year for Combined western Alaska Chinook stocks and for the Upper Yukon Chinook (table provides mean value) based on PSC mortality attributed to the pollock fishery*

	Combined western AK	Upper Yukon
Year	PSC mortality rate	PSC mortality rate
2011	1.40%	0.42%
2012	1.72%	0.61%
2013	1.85%	0.78%
2014	1.81%	0.58%
2015	1.57%	0.46%
2016	1.88%	0.63%
2017	2.04%	0.53%
2018	1.41%	0.48%
2019	1.32%	0.37%
2020	3.40%	0.94%
2021	2.64%	1.10%
Mean	1.91%	0.63%



*See Table 9 and Fig. 14 for full notes and explanation.

Introduction

At their October 2021 meeting under a staff tasking motion, the Council requested:

- An updated bycatch impact (AEQ) analysis which includes current genetic stock identification information and an updated age/length composition for Chinook salmon along with estimates of how many Chinook salmon taken as bycatch in the Bering Sea pollock fishery would have returned to Western Alaska Chinook salmon reporting groups.
- The analysis should include a PSC harvest rate analysis and an estimate of the Chinook salmon bycatch impacts to each specific reporting group at the current cap levels and at actual bycatch levels in recent years.

This document addresses these requests for an updated analysis on the adult equivalent (AEQ) impacts of PSC removals of Chinook salmon to different coastal west Alaska stocks. We include an overview of the available age and length data, how they are processed to come up with estimates of the age compositions of the bycatch. This updates previous analyses (NMFS/NPFMC 2015, Ianelli and Stram 2015, NMFS/NPFMC 2018). In addition to the age composition estimates (in both the bycatch and in-river systems) we also use updated Chinook salmon genetic information as sampled through to the 2020 pollock fishery. The available run reconstructions for coastal west Alaska and the Upper Yukon river were provided by ADF&G (appendix 1). These allow estimation of the pollock bycatch impact rates on some systems.

Methods

Since new data on the age composition of Chinook salmon in the bycatch has become available, we evaluated how growth may have changed over time (but out of necessity, this was done independently from stock-of-origin information). The analysis approach was simply graphical, but split by fishing season. Note that the potential changes in Chinook salmon growth are accounted for in the age composition estimates used for impact analyses.

To estimate how salmon bycatch numbers would propagate to adult equivalent spawning salmon we begin with the conceptual model to answer the question: “how many and in what year *would* the salmon have returned had they not been taken as bycatch. From this, we developed a stochastic “adult equivalence” (AEQ) model which accounts for sources of uncertainty (Ianelli and Stram 2015). With supplemental information on the run strengths from selected reporting groups we then estimate the impact of the bycatch. The steps in this process are briefly outlined as:

1. Compile statistics on Chinook salmon bycatch by region and season in the pollock fishery including
    a. Total bycatch by season and main sector (Table 1; Fig. 1)
    b. Length and sex composition of the bycatch (sample sizes are shown in Table 2)
    c. The number of ages by year are provided in Table 3 while the general locales for the age sampling are shown in Fig. 2.
2. Compile available age composition data organized by strata (here historical age-length keys were used for A and B seasons between two main fishing areas of the Bering Sea; Fig. 3).
3. Convert the seasonal and regional length compositions into age estimates for each year, and season using the age-length keys from step 2 to get the PSC catch-at-age (Tables 4 and 5).
4. Provide demographic characteristics of Chinook salmon for use in the AEQ model (these include the oceanic survival-at-age and maturity-at-age and were the same values as used in Ianelli and Stram 2015).
5. Update the season-specific genetics information (the “Stock composition” estimates were used from Iii et al. (2013, 2015, 2018), Guthrie et al. (2013, 2014, 2016) for the period 2011-2016 (Table 6; Fig. 4).
6. Run the AEQ model with these inputs (extending the estimates back to 1994-2021) and compile/summarize results.
7. Compare a subset (where data are available) of the AEQ results against corresponding run-strength estimates.

The model on the reduction in Chinook salmon returns in year *t*, AEQ_t, can thus be expressed (without stock specificity) as:

$$AEQ_t = \sum_{a=3}^{7} c_{t,a}\gamma_a + \sum_{j=3}^{6}\sum_{a=j+1}^{7}\left[\gamma_a c_{t-(a-j),j}\prod_{i=j}^{a-1}(1-\gamma_i)s_i\right] \tag{1}$$

where $c_{t,a}$ is the bycatch of age *a* salmon in year *t*, s_a is the proportion of salmon surviving from age *a* to *a+1,* and γ_a is the proportion of salmon at sea that would have returned to spawn at age *a.* In words, the first term to the right of the equals sign is simply the number of mature Chinook salmon in the bycatch in the current year whereas the second term accounts for the Chinook salmon caught in previous years that would have been mature in the current year. All age 7 Chinook salmon in the bycatch were assumed to be returning to spawn in the year they were caught (i.e. $\gamma_7 = 1$) and they represent the oldest fish in the model. We assume that 7 year-old Chinook salmon taken in the fall were returning to spawn that year. In fact, these fish would have been more likely to return the following year. This assumption simplified the model and data preparation. Also, relatively few fish this age were caught late in the season.

Given estimates of AEQ, the model partitions these into reporting groups (RG) or genetic stock identifications (GSI). This was done by assigning the stratum-specific AEQ estimates to each of the eleven identified RGs. We assumed that given the number of samples used for GSI within each year (*t*) and stratum (*i*) that the numbers assigned to RG *k* can be assumed to follow a multinomial distribution with parameters

$$p_{t,i,1},\ldots,p_{t,i,9} \qquad \sum_{k} p_{t,i,k}=1 \quad . \tag{2}$$

For the years where GSI information is missing (data from 1994-2010 and 2021 which are absent from Table 6), the estimated proportions by RGs were based on mean stratum-specific values from the years when GSI data were available. These additional parameters were constrained based on the estimated within-stratum inter-annual variability. That is, if the proportions assigned to RGs varied as estimated from the genetics data, then that variability was propagated to the years when genetic data were unavailable. This was a compromise which acknowledges sampling uncertainty for those years and correctly weights the information (due to sample size) between years when GSI information was available. For example, the new observer data collection system for genetic samples has resulted in more precise estimates of GSI in recent years hence those years have greater influence on stratum-specific GSI results. Adjusting the AEQ for RG requires estimation over a range of years when GSI results are available. This was accomplished here by applying the appropriate GSI results (i.e. estimates of proportions within RGs) for the years as lagged by AEQ. This step is needed to apportion the AEQ results to stock of origin based on genetic samples which consist of mature and immature fish. By splitting the AEQ estimates to relative contributions of bycatch from previous years, and applying GSI data from those years, they can then be realigned and renormalized to get proportions from systems by year. For years in which GSI information was unavailable, mean GSI data (with an error term which accounted for year-effect variability) were used.

Since Chinook salmon bycatch occurs in both the A and B season of the pollock fishery, data from these seasons were modeled separately. For each separate run, Monte-Carlo Markov Chain (MCMC) samples from the posterior distribution were obtained based on chain lengths of 3 million (after burn in) and selecting every 600th parameter draw. The posterior distribution was thus represented by 5,000 samples from each season (summed over strata) and then summed to get annual AEQ totals by RG. The model was implemented using ADMB (Fournier *et al.,* 2012) software.

Separate estimates of run-strengths (from 1994-2021) were used assuming uncertainties in run size:

$$\dot{S}_{t,k}=S_{t,k}e^{\varepsilon_t} \qquad \varepsilon_t \sim N\left(0,\sigma_S^2\right) \tag{3}$$

where σ_S^2 was a pre-specified level of run-size variance (assumed to correspond to a conservative coefficient of variation of 10% for this study). The measure that relates the historical bycatch levels to the subsequent returning salmon run *k* in year *t*, the "impact", is thus:

$$u_{t,k}=\frac{AEQ_{t,k}}{AEQ_{t,k}+\dot{S}_{t,k}} \tag{4}$$

where $AEQ_{t,k}$ and $\dot{S}_{t,k}$ are the adult-equivalent bycatch and stock size (run return) estimates. The calculation of $AEQ_{t,k}$ includes the bycatch of salmon returning to spawn in year *t* and the bycatch from previous years for the same brood year (i.e. at younger, immature ages). Note that the allocation of the AEQ to RGs is necessarily independent of the age composition of the bycatch.

Model code and input data files are available on request.

Results and conclusions

Given the new data on growth, the Chinook salmon mean size-at-age shows variability but consistent mean values within seasons and sex (Fig. 5). The A-season pattern shows the most consistency over time.

However, the B-season samples show the overall growth from the A-season, but markedly lower mean sizes in recent years, especially for age-5 Chinook salmon. These changes in the length-at-age are reflected in the estimated age compositions used in subsequent analyses (Fig. 6, Table 7). Results of the updated AEQ overall were similar to past analyses (Fig. 7; Ianelli and Stram 2015).

Applying the genetic information to the AEQ showed similar patterns among reporting groups with the largest share coming from the coastal west Alaska (CWAK) group (Fig. 8). The sensitivity to the updated age-specific oceanic maturation indicated minor changes in the estimated AEQ broken out into Upper Yukon (UYK) and Coastal Western Alaska (including middle Yukon; Fig. 9).

To evaluate the impact of the bycatch on Chinook salmon returns, the available run-size estimates from ADFG were compiled (Appendix 1; Fig. 10). To align with available bycatch genetic stock identification, a combined coastal western stocks summed the runs from Nushagak, Norton Sound, Kuskokwim, lower Yukon, and middle Yukon river spawning stocks. The AEQ model approach requires estimates of oceanic maturity rates (i.e., age-specific proportions that will return to spawn in a given year). Since this analysis focusses on western Alaska stocks, the data on in-river age compositions was used to estimate the oceanic maturation rates and how they have changed relative to previous studies (Table 8). Interestingly, the changes in oceanic maturity estimates have indicated that Chinook salmon appear to be returning at younger ages than in the previous analyses. The impact rates of the bycatch as translated to AEQ and subsequent reporting group origins was thus based on two groups, combined western Alaska and Upper Yukon (Fig. 11).

As noted in previous studies, there is a general relationship between Chinook salmon returns and mortality due to bycatch (Fig. 12). However, this figure indicates that since 2011 the relationship breaks down to some degree and the AEQ mortality has increased for the western Alaska stocks in 2020 and 2021. This is partly due to the above-average bycatch that occurred in 2020. This is also reflected in the estimates of impact rates which has averaged 1.9% since 2011 for the combined coastal western Alaska stocks and 0.6% for the Upper Yukon (Fig. 13). However, the rate for the western Alaska stocks increased in 2020 to an estimate of 3.4% but dropped in 2021 to 2.6% in 2021 (and 0.9% and 1.1% for the Upper Yukon. This pattern reflects low run size estimates (mainly from the Nushagak River).

Comparisons if PSC equalled alternative caps

As part of the Council's motion they requested that the analysis should include a PSC harvest rate analysis and an estimate of the Chinook salmon bycatch impacts to each specific reporting group at the current cap levels and at actual bycatch levels in recent years. To fullfill this request we artificially set the PSC catches to sum (proportionately over seasons) to the current cap of 45,000 Chinook salmon, although actual bycatch levels have never reached the level of the cap. The other "cap levels" were also analyzed but provided proportional increases (or decreases) in impacts so were omitted from presentation for clarity. We also interpreted the motion as wishing to focus on the current cap level of 45,000 Chinook. Compared to the actual Chinook salmon bycatch (labeled "base" in the figure and table) the impact rate roughly doubles to 3.6% and 1.3% for the western Alaska stocks and the Upper Yukon, respectively (Table 9; Fig. 14).

References

Faunce, C. H. (2015). Evolution of Observer Methods to Obtain Genetic Material from Chinook Salmon Bycatch in the Alaska Pollock Fishery, (January). http://doi.org/10.7289/V5MG7MFF

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. 27:233-249.

Guthrie III, C. M., Nguyen, H. T., and Guyon, J. R. (2012). Genetic stock composition analysis of Chinook salmon bycatch samples from the 2010 Bering Sea trawl fisheries. NOAA Technical Memorandum NMFS-AFSC-232, 22 p.

Guthrie III, C. M., Nguyen, H. T., and Guyon, J. R. (2013). genetic stock composition analysis of Chinook salmon bycatch samples from the 2011 Bering Sea and Gulf of Alaska trawl fisheries. NOAA Technical Memorandum NMFS-AFSC-244, 28 p.

Guthrie III, C., Nguyen, H., and Guyon, J. (2014). Genetic Stock Composition Analysis of Chinook Salmon Bycatch Samples from the 2012 Bering Sea and Gulf of Alaska Trawl Fisheries. NOAA Technical Memorandum: 33. http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-232.pdf (Accessed 3 May 2014).

Guthrie, C. M., Nguyen, H. T., & Guyon, J. R. (2015). Genetic Stock Composition Analysis of the Chinook Salmon Bycatch from the 2013 Bering Sea Walleye Pollock (Gadus chalcogrammus) Trawl Fishery, (January). http://doi.org/10.7289/V5W093V1

Guthrie III, C. M., Nguyen, H. T., & Guyon, J. R. (2016). Genetic Stock Composition Analysis of the Chinook Salmon Bycatch from the 2014 Bering Sea Walleye Pollock (Gadus chalcogrammus) Trawl Fishery, (January). http://doi.org/10.7289/V5/TM-AFSC-310

Guthrie III, C. M., Hv. T. Nguyen, M. Marsh and J. R. Guyon. 2020. Genetic stock composition analysis of Chinook salmon bycatch samples from the 2018 Gulf of Alaska trawl fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-405, 33 p.

Guyon, J. R., Guthrie, C. M., and Nguyen, H. (2010). 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., & Stram, D. L. (2015). Estimating impacts of the pollock fishery bycatch on western Alaska Chinook salmon. *ICES Journal of Marine Science*, *72*(4), 1159–1172. http://doi.org/10.1093/icesjms/fsu173

Iii, C. M. G., Nguyen, H. T., & Guyon, J. R. (2013). Genetic Stock Composition Analysis of Chinook Salmon Bycatch Samples from the 2011 Bering Sea and Gulf of Alaska Trawl Fisheries, (March).

Iii, C. M., Nguyen, H. T., Thomson, A. E., & Guyon, J. R. (2017). Genetic Stock Composition Analysis of the Chinook Salmon Bycatch from the 2015 Bering Sea Walleye Pollock (*Gadus chalcogrammus*) Trawl Fishery, (January). http://doi.org/10.7289/V5/TM-AFSC-342

Iii, C. M. G., Nguyen, H. T., Thomson, A. E., & Hauch, K. (2018). Genetic Stock Composition Analysis of the Chinook Salmon (*Oncorhynchus tshawytscha*) Bycatch from the 2016 Bering Sea Walleye Pollock (*Gadus chalcogrammus*) Trawl Fishery, (January). http://doi.org/10.7289/V5/TM-AFSC-365

NMFS/NPFMC. 2015. Environmental Assessment/ Regulatory Impact Review/ Initial Regulatory Flexibility Analysis for Proposed Amendment 110 to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area Bering Sea Chinook salmon and Chum salmon bycatch management measures. https://alaskafisheries.noaa.gov/sites/default/files/analyses/bsai110earirirfa120115.pdf

NMFS/NPFMC. 2018. Update on Chinook salmon mortality due to bycatch in the EBS pollock fishery. NPFMC April 2018 meeting document.

Ohlberger, J., Ward, E. J., Schindler, D. E., & Lewis, B. (2018). Demographic changes in Chinook salmon across the Northeast Pacific Ocean. *Fish and Fisheries*, (October 2017), 1–14. http://doi.org/10.1111/faf.12272

Stram, D. L., & Ianelli, J. N. (2015). Evaluating the efficacy of salmon bycatch measures using fishery-dependent data. *ICES Journal of Marine Science*, *72*(4), 1173–1180. http://doi.org/10.1093/icesjms/fsu168

Tables

Table 1. Chinook salmon bycatch in the pollock fishery by season (A and B, and sector ("Shorebased"=shorebased catcher vessels, "At sea" means mothership operations, catcher-processors, and CDQ). *Source: NMFS Alaska Region, Juneau.*

	A Season			B Season			
Sector	Shore-based	At sea	A sub-total	Shore-based	At sea	B sub-total	Total
1991	10,306	28,384	38,690	1,667	549	2,216	40,906
1992	7,945	17,746	25,691	1,604	8,655	10,259	35,950
1993	3,635	13,627	17,262	2,664	18,589	21,253	38,516
1994	8,522	19,925	28,447	1,284	3,405	4,689	33,136
1995	2,624	7,939	10,563	781	3,640	4,421	14,984
1996	15,290	20,773	36,063	9,944	9,617	19,561	55,623
1997	5,014	5,921	10,935	22,550	11,423	33,973	44,909
1998	4,404	10,788	15,192	27,218	8,911	36,129	51,322
1999	3,095	2,672	5,767	2,640	1,973	4,613	10,381
2000	878	2,114	2,992	653	596	1,249	4,242
2001	8,555	8,155	16,710	3,779	10,447	14,226	30,937
2002	10,336	10,041	20,377	9,560	2,464	12,024	32,402
2003	15,365	15,548	30,913	7,075	5,107	12,182	43,096
2004	11,571	11,506	23,077	22,301	6,373	28,674	51,751
2005	13,792	13,534	27,326	35,637	5,206	40,843	68,169
2006	35,742	22,650	58,392	22,630	1,731	24,361	82,753
2007	36,661	33,759	70,420	41,102	10,689	51,791	122,211
2008	10,673	5,824	16,497	4,224	587	4,811	21,308
2009	6,239	3,731	9,970	2,212	554	2,766	12,736
2010	3,790	3,897	7,687	1,934	228	2,162	9,849
2011	4,441	2,695	7,136	13,951	4,412	18,363	25,499
2012	4,624	3,140	7,764	3,433	146	3,579	11,343
2013	3,622	4,595	8,217	4,255	619	4,874	13,091
2014	6,420	5,116	11,536	2,718	881	3,599	15,135
2015	7,789	4,509	12,298	2,848	3,183	6,031	18,329
2016	8,040	9,135	17,175	1,987	3,121	5,108	22,283
2017	9,060	12,546	21,606	6,134	2,339	8,473	30,079
2018	3,830	4,719	8,549	3,213	1978	5,191	13,740
2019	5,954	9,784	15,738	4,863	4437	9,300	25,038
2020	8,138	10,176	18,314	7,807	6177	13,984	32,298
2021	4,406	5,068	9,474	2,571	1806	4,377	13,851

Table 2. The number of Chinook salmon measured for lengths in the pollock fishery by season (A and B). *Source: NMFS Alaska Fisheries Science Center observer data.*

Year	A	B	Total
1991	4,498	379	4,877
1992	3,682	1,838	5,520
1993	2,533	1,331	3,864
1994	5,286	1,609	6,895
1995	2,284	1,005	3,289
1996	10,713	7,153	17,866
1997	4,523	11,924	16,447
1998	4,661	10,820	15,481
1999	2,921	2,599	5,520
2000	1,903	902	2,805
2001	7,627	4,764	12,391
2002	8,958	5,723	14,681
2003	14,118	5,937	20,055
2004	10,478	10,767	21,245
2005	12,460	13,524	25,984
2006	20,618	10,852	31,470
2007	21,651	18,172	39,823
2008	5,252	1,902	7,154
2009	3,343	1,080	4,423
2010	2,779	842	3,621
2011	720	1,760	2,480
2012	775	374	1,149
2013	827	500	1,327
2014	1,165	365	1,530
2015	1,287	635	1,922
2016	1,784	532	2,316
2017	2,200	835	3,035
2018	884	524	1,408
2019	1,626	924	2,550
2020	1,819	1,388	3,207
2021	958	433	1,391

Table 3. Number of age readings from Chinook salmon bycatch data by year and season.

Year	A	B	Total
1997	842	756	1,598
1998	873	826	1,699
1999	645	566	1,211
2011	409	1,084	1,493
2012	461	222	683
2013	499	283	782
2017	778	479	1,257
2018	503	312	815
2019	786	360	1,146
2020	1,005	777	1,782

Table 4. Age specific Chinook salmon mean bycatch estimates by season and calendar age based on the mean of 1000 bootstrap samples of available length and age data, 1991-2006. Note that totals may differ from official totals due to random variability of the bootstrap sampling procedure.

Year/season	Age 3	Age 4	Age 5	Age 6	Age 7	Total
1991	6,801	17,750	12,194	3,785	356	40,886
A	6,453	16,710	11,577	3,604	326	38,670
B	348	1,040	617	181	30	2,216
1992	5,686	12,345	13,718	3,851	345	35,945
A	1,432	7,344	12,815	3,762	335	25,688
B	4,254	5,001	903	89	10	10,257
1993	4,370	17,672	12,257	3,835	372	38,506
A	1,214	4,912	7,918	2,944	274	17,262
B	3,156	12,760	4,339	891	98	21,244
1994	1511	9,268	17,926	4,071	357	33,133
A	1027	7,258	16,158	3,685	316	28,444
B	484	2,010	1,768	386	41	4,689
1995	1055	4,393	5,122	4,003	410	14,983
A	413	1,685	4,243	3,836	385	10,562
B	642	2,708	879	167	25	4,421
1996	7,163	21,597	21,848	4,616	393	55,617
A	1719	10,678	19,062	4,248	353	36,060
B	5,444	10,919	2,786	368	40	19,557
1997	6,424	24,280	7,230	6,464	512	44,910
A	341	1,612	4,243	4,371	370	10,937
B	6,083	22,668	2,987	2,093	142	33,973
1998	19,219	16,875	11,670	2,919	639	51,322
A	859	2,247	9,162	2,422	502	15,192
B	18,360	14,628	2,508	497	137	36,130
1999	727	4,430	4,019	1,181	25	10,382
A	377	1,430	3,017	923	21	5,768
B	350	3,000	1,002	258	4	4,614
2000	683	1,745	1,349	429	37	4,243
A	392	1,134	1,052	383	32	2,993
B	291	611	297	46	5	1,250
2001	7,260	12,583	9,195	1,744	126	30,908
A	2,666	4,898	7,465	1,545	110	16,684
B	4,594	7,685	1,730	199	16	14,224
2002	4,970	13,131	9,244	4,650	398	32,393
A	1,947	5,603	7,854	4,575	392	20,371
B	3,023	7,528	1,390	75	6	12,022
2003	6,407	17,224	15,870	3,313	261	43,075
A	3,445	10,536	13,717	2,963	231	30,892
B	2,962	6,688	2,153	350	30	12,183
2004	8,438	23,483	15,599	3,883	336	51,739
A	1,680	6,850	10,855	3,386	297	23,068
B	6,758	16,633	4,744	497	39	28,671
2005	13,512	31,413	19,238	3,752	246	68,161
A	2,072	8,480	13,562	3,015	193	27,322
B	11,440	22,933	5,676	737	53	40,839
2006	14,244	33,840	27,789	6,420	438	82,731
A	5,590	20,729	25,442	6,194	417	58,372
B	8,654	13,111	2,347	226	21	24,359

Table 5. Age specific Chinook salmon mean bycatch estimates by season and calendar age based on the mean of 1000 bootstrap samples of available length and age data, 2007-2021. Note that totals may differ from official totals due to random variability of the bootstrap sampling procedure.

Year/season	Age 3	Age 4	Age 5	Age 6	Age 7	Total
2007	23,832	62,350	30,074	5,585	351	122,192
A	8,956	30,805	25,209	5,116	323	70,409
B	14,876	31,545	4,865	469	28	51,783
2008	1,842	7,393	9,626	2,292	154	21,307
A	820	4,660	8,685	2,183	148	16,496
B	1,022	2,733	941	109	6	4,811
2009	1,107	4,651	5,158	1,694	126	12,736
A	477	3,020	4,713	1,639	121	9,970
B	630	1,631	445	55	5	2,766
2010	976	3,138	4,329	1,308	99	9,850
A	371	1,855	4,081	1,284	96	7,687
B	605	1,283	248	24	3	2,163
2011	6,619	13,313	4,649	805	48	25,434
A	290	2,757	3,410	643	36	7,136
B	6,329	10,556	1,239	162	12	18,298
2012	1,784	4,262	4,621	649	19	11,335
A	384	2,592	4,192	575	19	7,762
B	1,400	1,670	429	74	0	3,573
2013	1,987	7,361	3,112	549	52	13,061
A	698	4,324	2,673	468	43	8,206
B	1,289	3,037	439	81	9	4,855
2014	2,628	6,809	4,993	644	45	15,119
A	1,696	4,622	4,558	600	44	11,520
B	932	2,187	435	44	1	3,599
2015	4,058	9,384	3,999	809	50	18,300
A	2,355	5,679	3,417	772	48	12,271
B	1,703	3,705	582	37	2	6,029
2016	4,023	10,739	6,575	892	50	22,279
A	2,382	7,658	6,207	876	50	17,173
B	1,641	3,081	368	16	0	5,106
2017	6,240	13,403	9,131	1,136	37	29,947
A	3,350	9,268	7,841	1,061	34	21,554
B	2,890	4,135	1,290	75	3	8,393
2018	2,873	6,488	3,919	409	30	13,719
A	1,151	3,796	3,218	347	27	8,539
B	1,722	2,692	701	62	3	5,180
2019	8,421	10,611	5,677	244	0	24,953
A	2,735	7,754	4,945	233	0	15,667
B	5,686	2,857	732	11	0	9,286
2020	7,911	13,214	8,817	2,157	59	32,158
A	1,182	7,012	7,987	2,038	58	18,277
B	6,729	6,202	830	119	1	13,881
2021	3,040	6,529	3,701	549	31	13,850
A	1,132	4,305	3,461	545	31	9,474
B	1,908	2,224	240	4	0	4,376

Table 6. The stock composition estimates (using the “Bayes” estimates) as presented in ABL publications on Chinook salmon bycatch by season (Iii et al. 2013, 2015, 2018, Guthrie et al. 2013, 2014, 2016, 2020), 2011-2020.

	Russia	Coast W AK	Mid-Yukon	Up Yukon	N AK Penn	NW GOA	Copper	NE GOA	Coast SE AK	BC	WA/OR/CA	% in A season
A season												% in A season
2011	0.2%	54.0%	1.8%	7.4%	21.8%	0.6%	0.0%	0.0%	3.1%	7.2%	4.0%	28%
2012	0.5%	67.8%	1.2%	3.1%	16.2%	0.2%	0.0%	0.1%	1.6%	7.3%	1.9%	68%
2013	0.9%	50.2%	1.1%	7.2%	19.1%	0.5%	0.1%	0.0%	1.9%	17.0%	2.0%	63%
2014	0.6%	54.6%	3.3%	4.1%	22.7%	0.1%	0.0%	0.0%	0.6%	10.2%	3.7%	76%
2015	0.6%	45.9%	1.0%	3.6%	14.5%	2.8%	0.2%	0.0%	3.9%	19.1%	8.4%	67%
2016	0.6%	39.0%	1.7%	2.2%	16.9%	0.6%	0.0%	0.0%	3.9%	26.1%	9.0%	77%
2017	0.2%	28.3%	0.6%	0.7%	20.7%	0.4%	0.0%	0.1%	3.2%	35.2%	10.7%	72%
2018	0.0%	34.8%	0.4%	0.8%	25.6%	1.5%	0.0%	0.1%	3.3%	27.3%	6.2%	62%
2019	0.1%	44.8%	0.0%	0.3%	21.7%	0.2%	0.0%	0.0%	2.0%	24.3%	6.5%	63%
2020	2.4%	51.5%	1.5%	3.0%	24.8%	0.8%	0.0%	0.0%	1.6%	11.6%	2.7%	57%
		B season										% in B season
2011	1.0%	73.8%	1.3%	0.7%	3.4%	3.6%	0.6%	0.1%	1.4%	7.8%	6.4%	72%
2012	2.4%	52.1%	0.2%	1.0%	0.1%	3.8%	0.0%	0.0%	8.2%	15.3%	17.0%	32%
2013	0.9%	51.9%	1.9%	1.4%	5.9%	6.9%	0.1%	0.0%	1.9%	14.3%	14.8%	37%
2014	0.4%	31.8%	1.7%	1.6%	0.1%	18.4%	0.1%	0.1%	3.5%	24.5%	17.9%	24%
2015	0.1%	27.4%	1.6%	1.1%	1.0%	8.2%	0.0%	0.1%	6.3%	26.6%	27.5%	33%
2016	0.2%	16.5%	0.4%	0.7%	1.1%	5.9%	1.8%	0.0%	6.5%	37.0%	29.9%	23%
2017	0.2%	12.0%	0.3%	0.0%	1.8%	2.7%	0.1%	0.0%	6.8%	37.1%	38.8%	28%
2018	0.8%	31.1%	1.3%	1.1%	2.9%	4.0%	0.5%	0.0%	5.3%	33.0%	20.0%	38%
2019	0.5%	30.4%	1.4%	0.6%	0.4%	11.2%	0.2%	0.1%	2.9%	25.9%	26.6%	37%
2020	0.9%	53.6%	2.3%	0.9%	1.5%	9.3%	0.0%	0.1%	1.8%	18.3%	11.3%	43%
		Total										
2011	0.8%	68.3%	1.4%	2.6%	8.5%	2.8%	0.4%	0.1%	1.9%	7.6%	5.7%	
2012	1.1%	62.8%	0.9%	2.4%	11.1%	1.3%	0.0%	0.1%	3.7%	9.8%	6.7%	
2013	0.9%	50.8%	1.4%	5.0%	14.2%	2.9%	0.1%	0.0%	1.9%	16.0%	6.8%	
2014	0.6%	49.2%	2.9%	3.5%	17.3%	4.5%	0.0%	0.0%	1.3%	13.6%	7.1%	
2015	0.4%	39.8%	1.2%	2.8%	10.1%	4.6%	0.1%	0.0%	4.7%	21.6%	14.7%	
2016	0.5%	33.8%	1.4%	1.9%	13.3%	1.8%	0.4%	0.0%	4.5%	28.6%	13.8%	
2017	0.2%	23.7%	0.5%	0.5%	15.4%	1.0%	0.0%	0.1%	4.2%	35.7%	18.6%	
2018	0.3%	33.4%	0.7%	0.9%	17.0%	2.4%	0.2%	0.1%	4.1%	29.5%	11.4%	
2019	0.2%	39.5%	0.5%	0.4%	13.8%	4.3%	0.1%	0.0%	2.3%	24.9%	14.0%	
2020	1.8%	52.4%	1.8%	2.1%	14.7%	4.5%	0.0%	0.0%	1.7%	14.5%	6.4%	

Table 7. Mean values of stochastic simulation results of AEQ Chinook mortality attributed to the pollock fishery by region, 1994-2021. These simulations include stochasticity in natural mortality (CV=0.1), bycatch age composition (via bootstrap samples), maturation rate (CV=0.1), and stock composition (as detailed above). **NOTE**: these results are based on the assumption that the genetics findings from the 2011-2020 data represent the historical pattern of bycatch stock composition (by strata). Italicized column is the sum of the western Alaska stocks AEQ estimate.

Year	BC-WA-OR	Coast W AK	Middle Yukon	Upper Yukon	*Combined West. AK*	N AK Penin	NW GOA	Russia	SEAK	Other	Total
1994	6,842	15,444	421	1,048	*15,865*	5,032	923	221	1,048	35	34,333
1995	4,077	9,470	256	619	*9,726*	3,257	492	133	619	18	20,825
1996	6,117	14,450	386	921	*14,836*	5,135	681	201	921	24	31,588
1997	7,083	14,691	418	1116	*15,109*	3,876	1,266	222	1,116	53	33,787
1998	7,437	14,612	428	1193	*15,040*	3,223	1,526	229	1,193	67	34,342
1999	5,106	9,547	286	832	*9,833*	1,733	1,161	155	832	52	22,932
2000	2,845	5,227	158	466	*5,385*	862	669	86	466	30	12,640
2001	3,077	6,756	187	476	*6,943*	2,067	461	99	476	18	15,180
2002	4,757	10,756	294	729	*11,050*	3,510	642	154	729	24	23,905
2003	6,256	14,174	386	956	*14,560*	4,646	836	202	956	32	31,469
2004	7,427	16,244	450	1,151	*16,694*	4,913	1,134	237	1,151	45	36,573
2005	9,388	19,497	555	1,478	*20,052*	5,173	1,670	294	1,478	70	44,780
2006	12,306	27,139	749	1,900	*27,888*	8,384	1,814	395	1,900	72	60,814
2007	14,879	33,054	910	2,292	*33,964*	10,419	2,131	477	2,292	83	73,935
2008	11,634	25,122	701	1,812	*25,823*	7,382	1,849	370	1,812	74	56,806
2009	5,565	12,066	336	863	*12,402*	3,589	868	177	863	35	27,268
2010	2,358	5,449	148	358	*5,597*	1,863	289	77	358	11	12,005
2011	1,512	6,254	143	322	*6,397*	1,465	305	74	322	16	11,297
2012	1,661	8,651	177	400	*8,828*	1,496	400	96	400	23	14,310
2013	1,697	6,684	148	342	*6,832*	1,373	334	81	342	17	11,927
2014	2,014	6,573	184	351	*6,757*	2,070	351	86	351	12	13,109
2015	2,737	6,872	196	444	*7,068*	2,187	390	95	444	11	14,782
2016	5,018	8,643	279	708	*8,922*	3,170	420	134	708	12	21,157
2017	7,629	8,356	303	865	*8,659*	4,117	430	154	865	16	25,635
2018	5,951	6,106	225	668	*6,331*	3,313	363	118	668	15	19,719
2019	4,659	6,450	194	537	*6,644*	2,977	385	107	537	14	17,679
2020	4,216	10,337	277	594	*10,614*	3,976	591	162	594	18	22,578
2021	3,296	8,381	229	493	*8,610*	2,600	642	126	493	21	17,903

Table 8. Mean in-river age compositions, run sizes and resulting weighting factors used to compute an average in-river age composition and subsequent oceanic maturity compared to previous studies (last three rows).

	Age 3	4	5	6	7	Mean run size	Weighting factor
Kuskokwim Bay	5.10%	35.10%	36.00%	23.10%	0.60%	40,709	0.077
Kuskokwim River	1.30%	30.00%	42.00%	26.00%	0.60%	124,100	0.2346
Lower Yukon	0.00%	31.70%	48.00%	20.00%	0.30%	57,554	0.1088
Middle Yukon	0.00%	18.20%	45.70%	35.30%	0.80%	46,245	0.0874
Norton Sound and Point Clarence	1.10%	23.30%	51.10%	22.30%	2.20%	9,417	0.0178
Nushagak	1.20%	37.60%	44.70%	16.30%	0.20%	178,144	0.3368
Upper Yukon	0.00%	8.60%	43.40%	45.40%	2.60%	72,836	0.1377
Weighted mean in-river age composition	1.10%	29.10%	43.80%	25.30%	0.70%		
Oceanic natural mortality	0.3	0.2	0.1	0.1	0		
Oceanic maturity (this study)	3%	23%	75%	97%	100%		
Council update from 2018	4%	18%	64%	100%	100%		
Original (Ianelli and Stram 2015)	0%	19%	50%	94%	100%		

Table 9. Estimated impact based on stochastic simulation results of AEQ mortality attributed to the pollock fishery by region, 2011-2021. The columns labelled "base" are from the **actual PSC mortality**, the shaded columns with "PSC=45k cap" represent results had the actual PSC been at the curerent limit of 45,000 Chinook salmon.

	Combined W. Alaska		Upper Yukon	
Year	base	PSC=45k cap	base	PSC=45k cap
2011	1.40%	2.1%	0.42%	0.6%
2012	1.72%	4.0%	0.61%	1.6%
2013	1.85%	4.9%	0.78%	2.3%
2014	1.81%	4.8%	0.58%	1.6%
2015	1.57%	3.5%	0.46%	1.0%
2016	1.88%	3.1%	0.63%	1.1%
2017	2.04%	2.9%	0.53%	0.8%
2018	1.41%	2.5%	0.48%	0.9%
2019	1.32%	2.4%	0.37%	0.7%
2020	3.40%	5.0%	0.94%	1.4%
2021	2.64%	4.9%	1.10%	2.2%
Mean	1.91%	3.6%	0.63%	1.3%

Figures

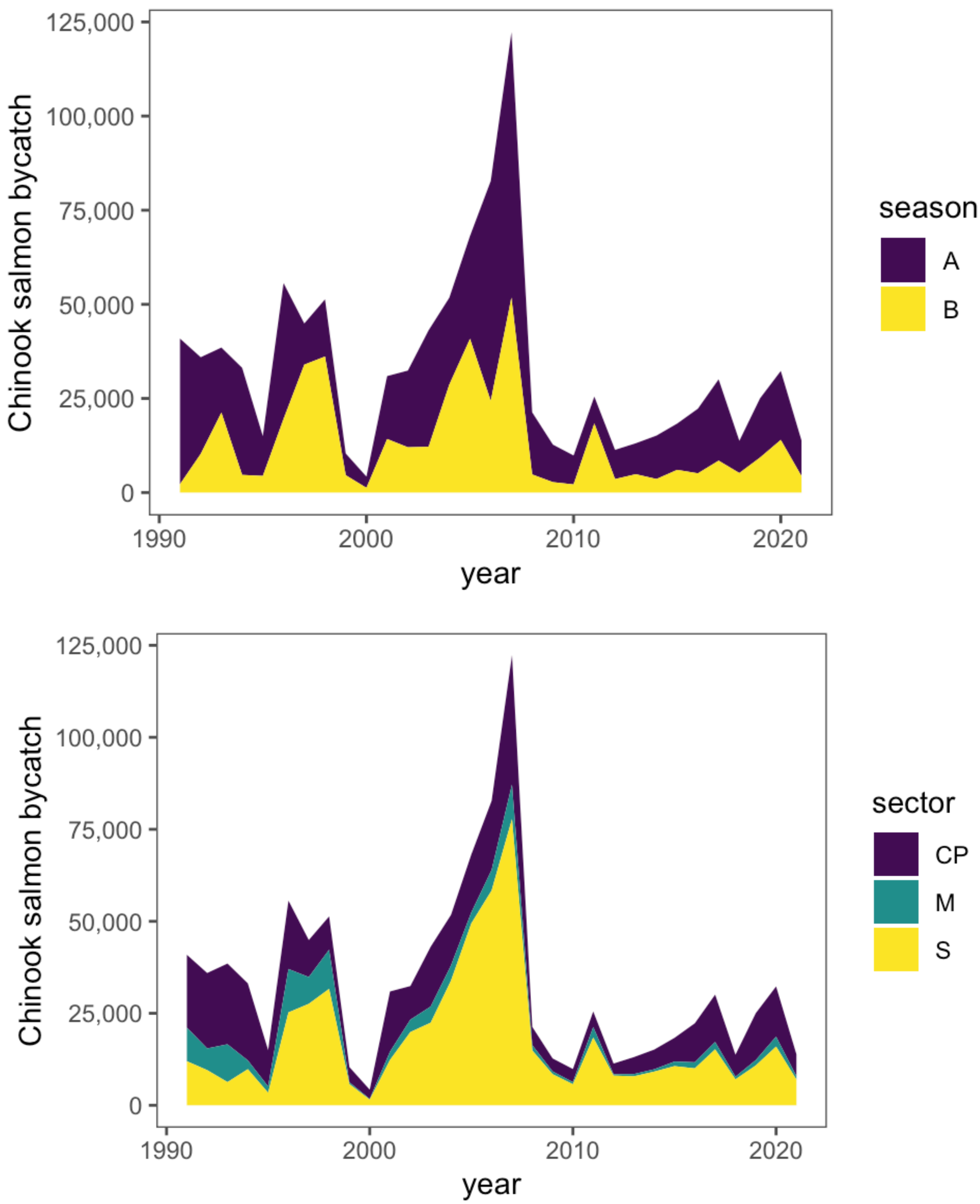


Fig. 1. PSC Chinook salmon bycatch from the pollock fleet by season (top) and sector (bottom). CP=Catcher processors, M=catcher boats delivering to motherships, S=shoreside catcher boats.

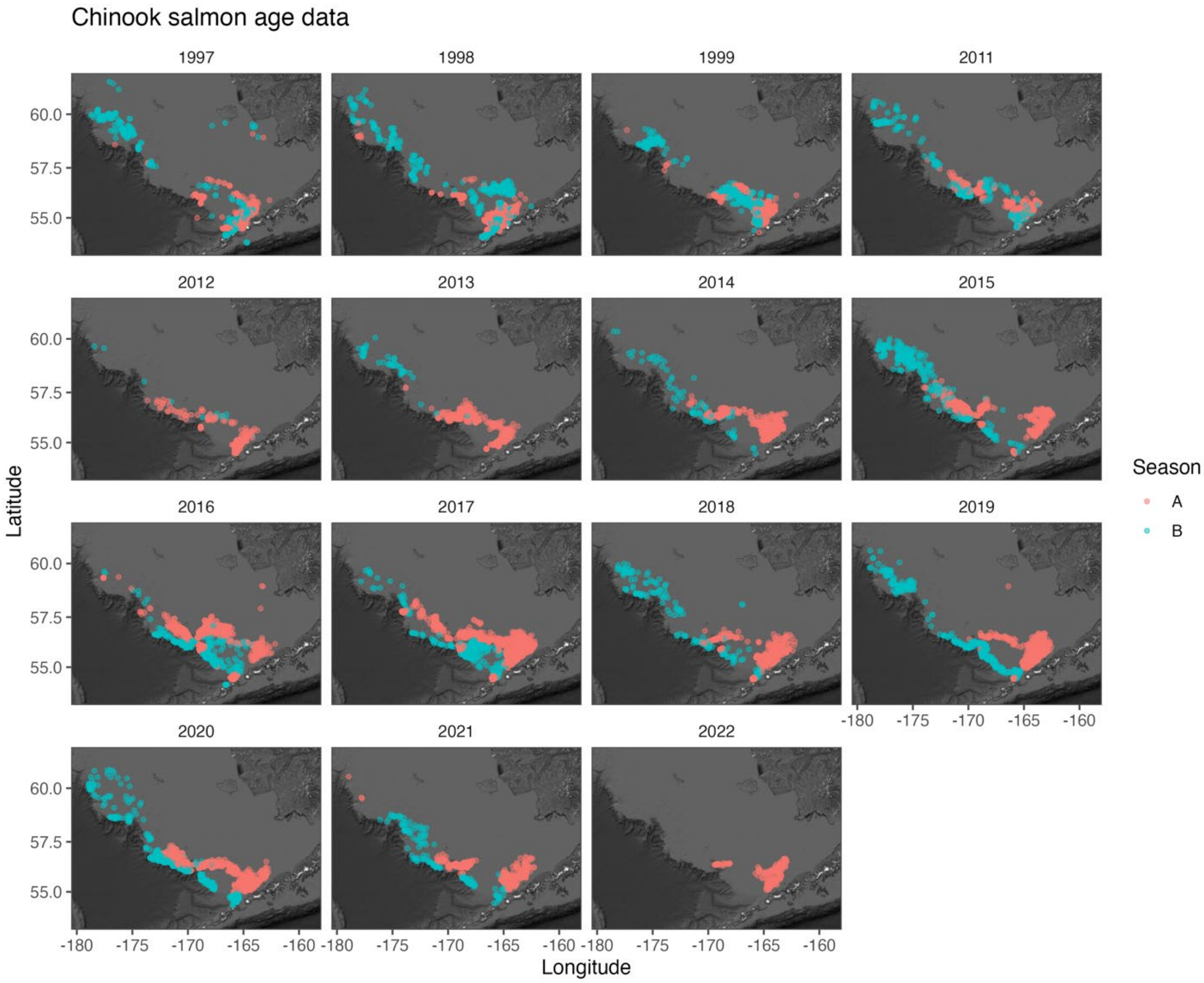


Fig. 2. Summary distribution of age samples by length collected by the NMFS groundfish observer program during 1997-1999 and analyzed by University of Washington scientists (Myers et al. 2003) for the A-season (top panel) and B season (bottom panel).

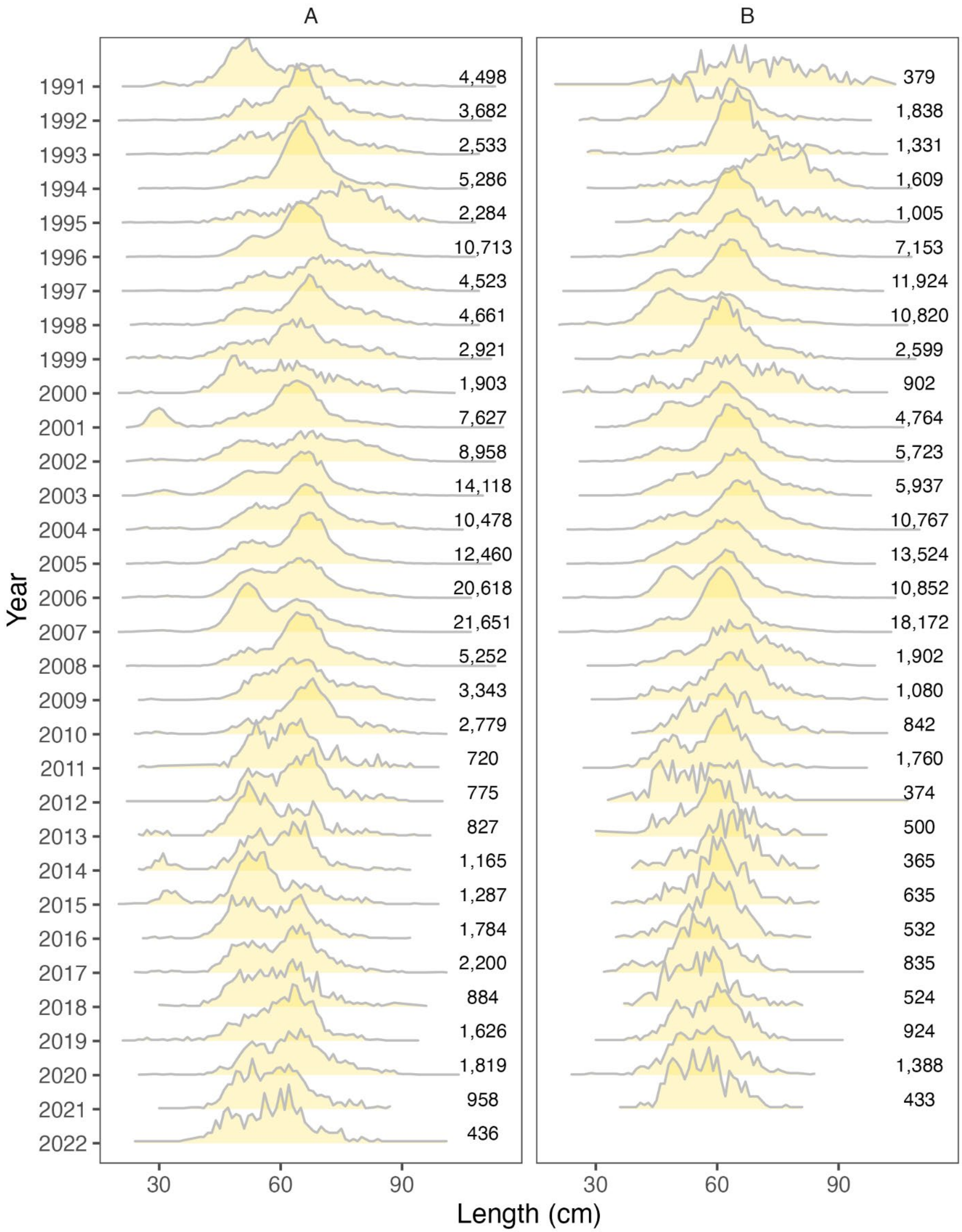


Fig. 3. Length frequency measurements collected by NMFS observers by season and year of Chinook salmon occurring as bycatch in the pollock fishery. This figure indicates the change in sampling intensity for length measurements of Chinook salmon bycatch.

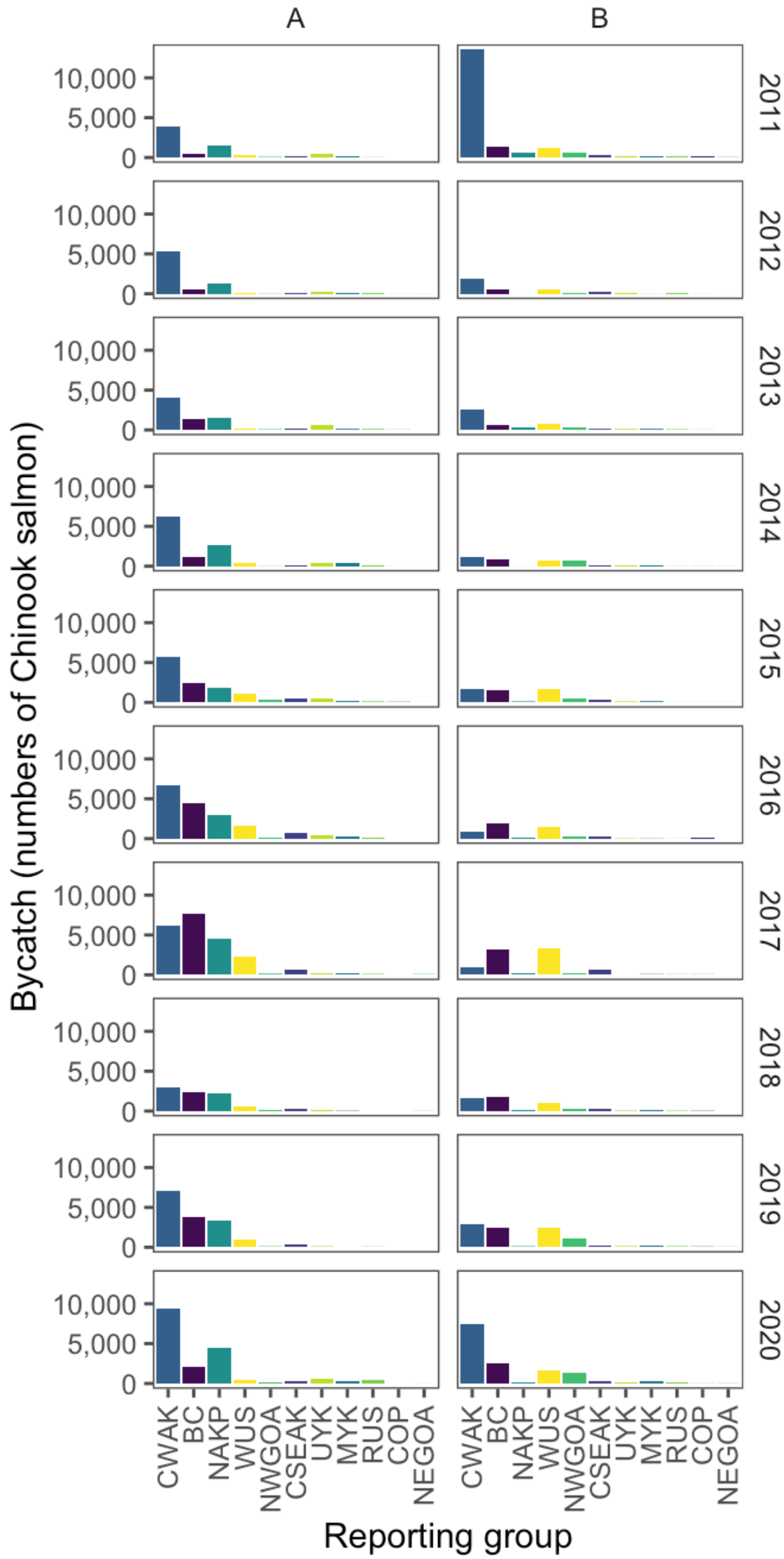


Fig. 4. Chinook salmon bycatch estimated to reporting groups by year and season.

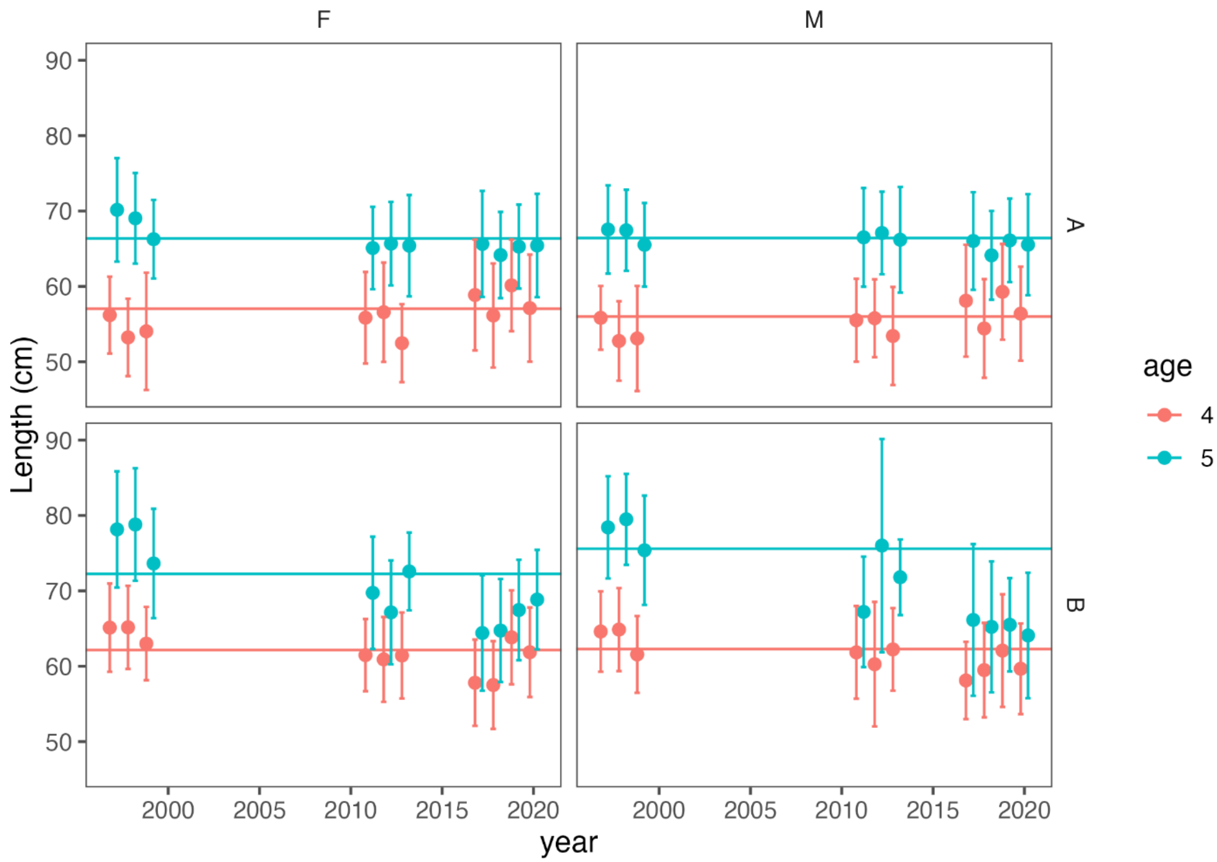


Fig. 5. Length-at-age by sex (columns) and season (rows) for Chinook salmon in the bycatch. Ages 4 and 5 were selected as they are the most predominate samples in the bycatch. Points represent the mean values, error bars ± 1 standard deviation, and horizontal lines are mean values among all samples over the period.

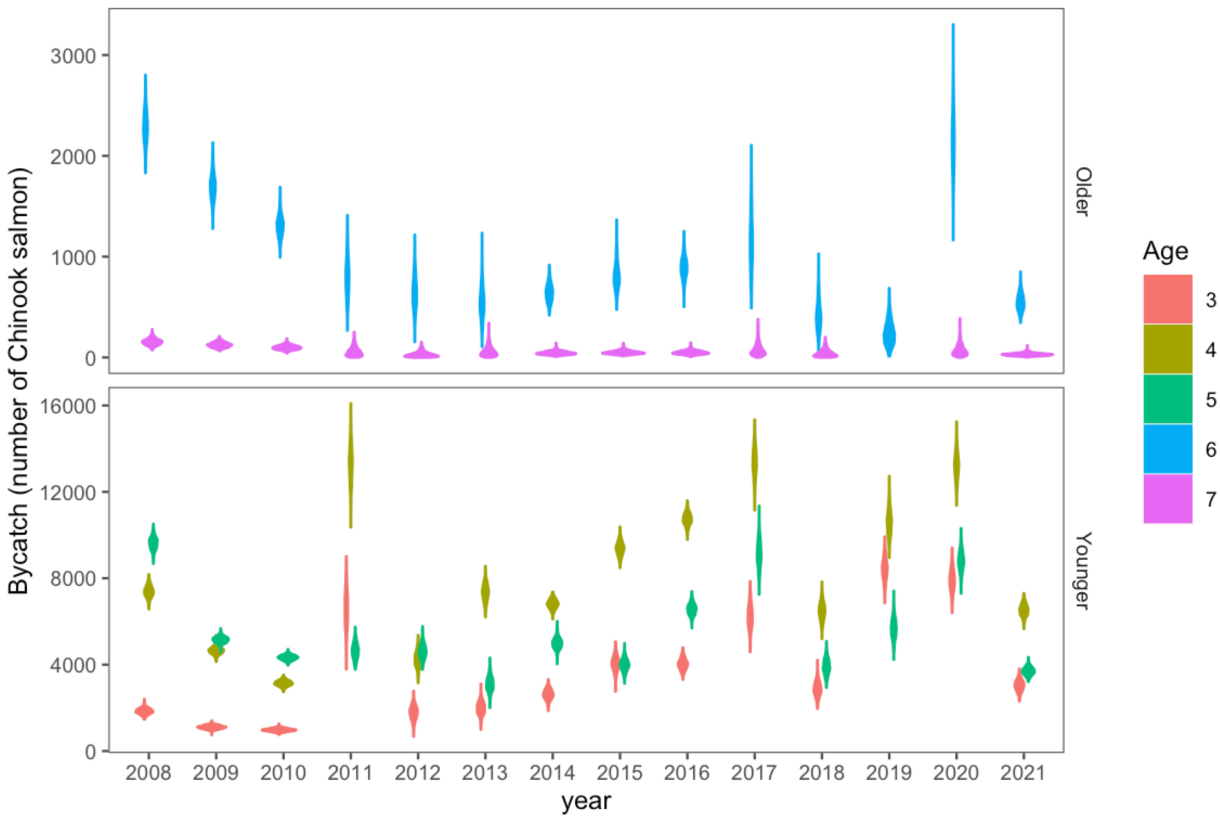


Fig. 6. Chinook salmon bycatch age composition by year and relative age with older (top) and younger (bottom) by estimated age. Vertical spread of blobs represent uncertainty as estimated from the two-stage bootstrap re-sampling procedure.

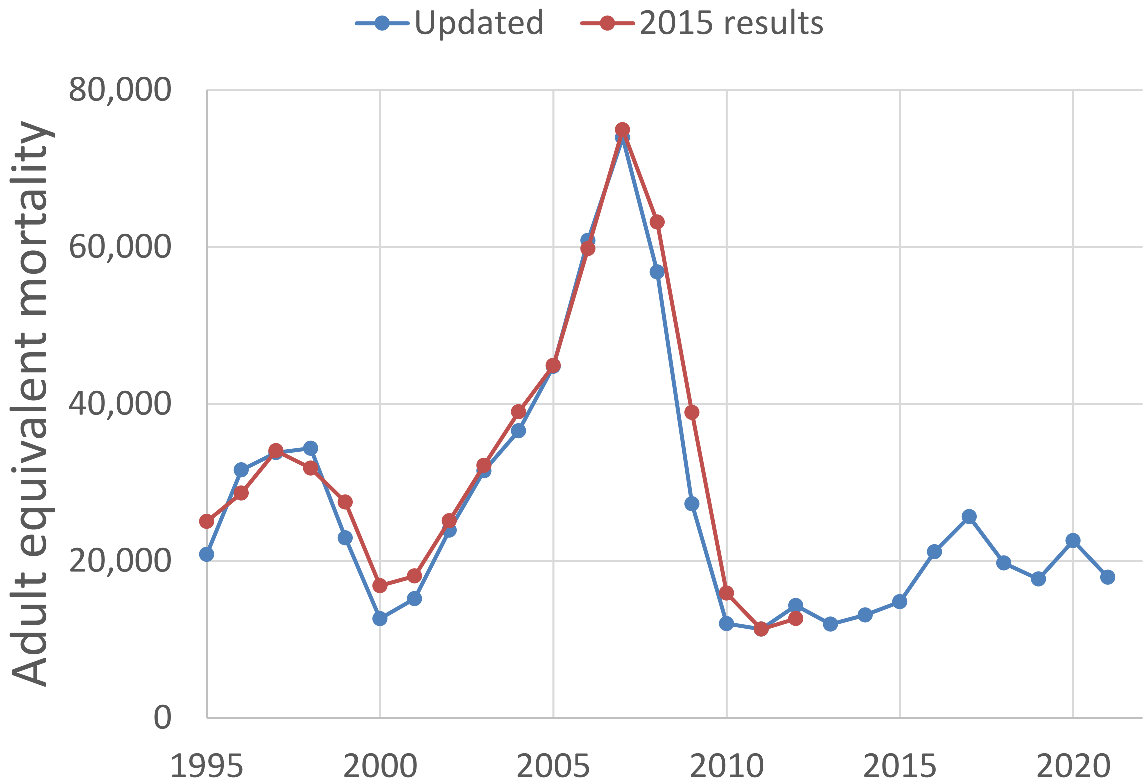


Fig. 7. Time series of Chinook adult equivalent bycatch from the pollock fishery, 1995-2021 compared to the annual totals from Ianelli and Stram (2015).

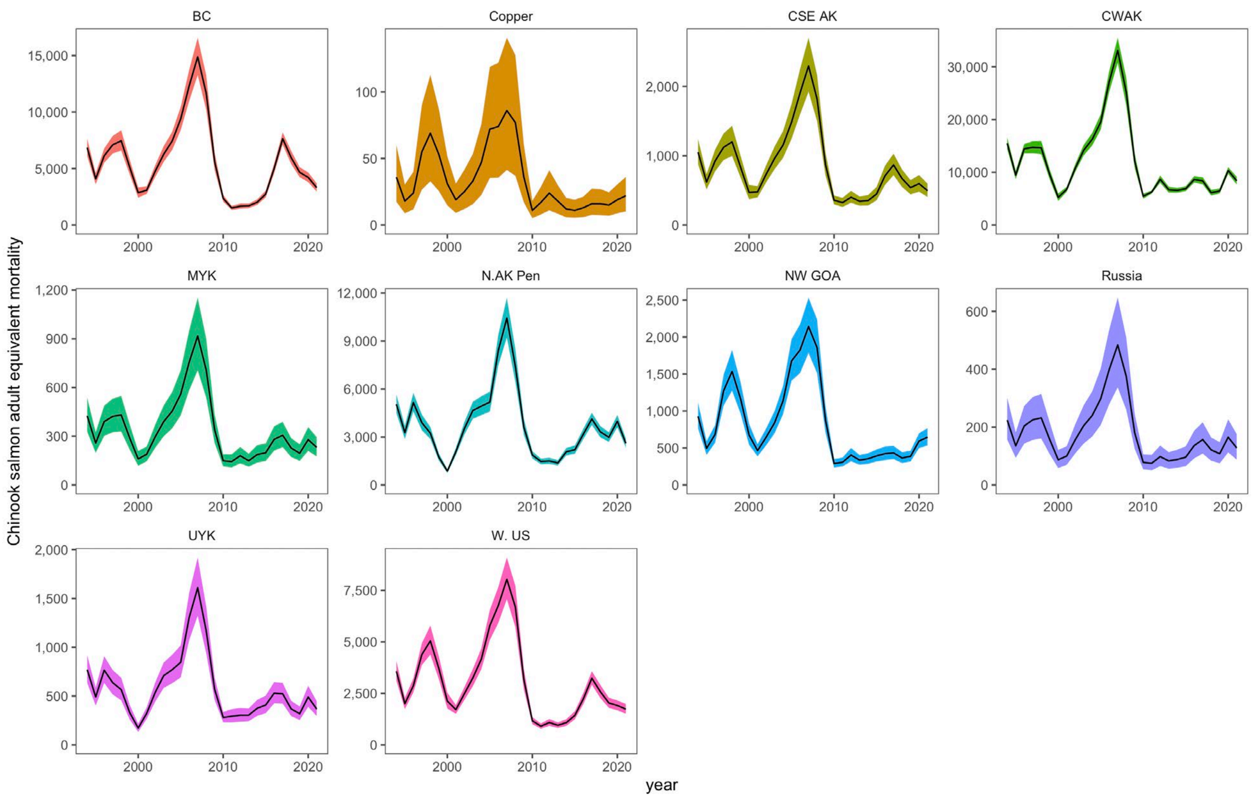


Fig. 8. Time series of Chinook salmon adult equivalent bycatch estimates from the pollock fishery, 1994-2021, Note that vertical scales vary between reporting groups.

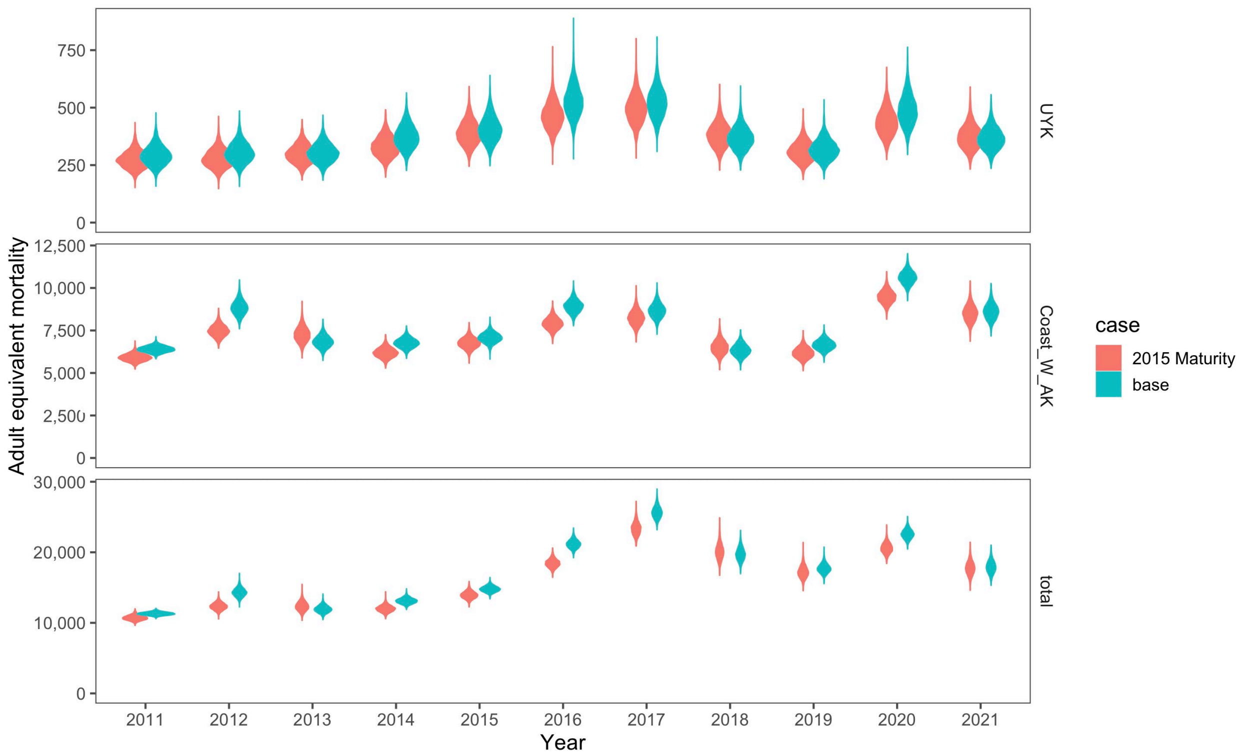


Fig. 9. Time series of Chinook salmon adult equivalent bycatch estimates from the pollock fishery, 2011-2021 comparing the updated ("base") result with the same data **except** with oceanic maturity specified to the estimate used in 2015 (red symbols).

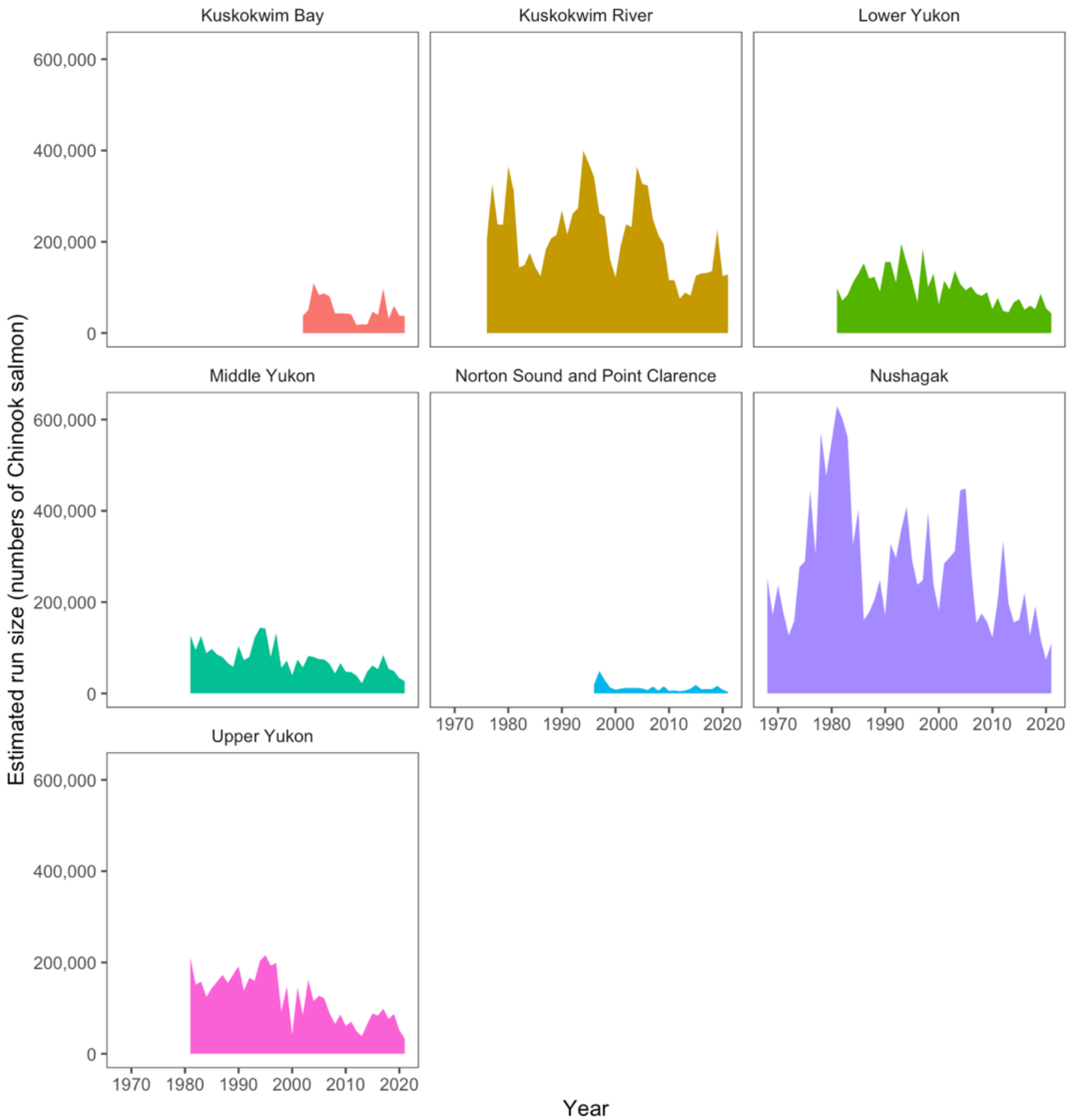


Fig. 10. Time series of Chinook salmon run strength estimates for western Alaska,1994-2021. *Source K. Howard ADFG.*

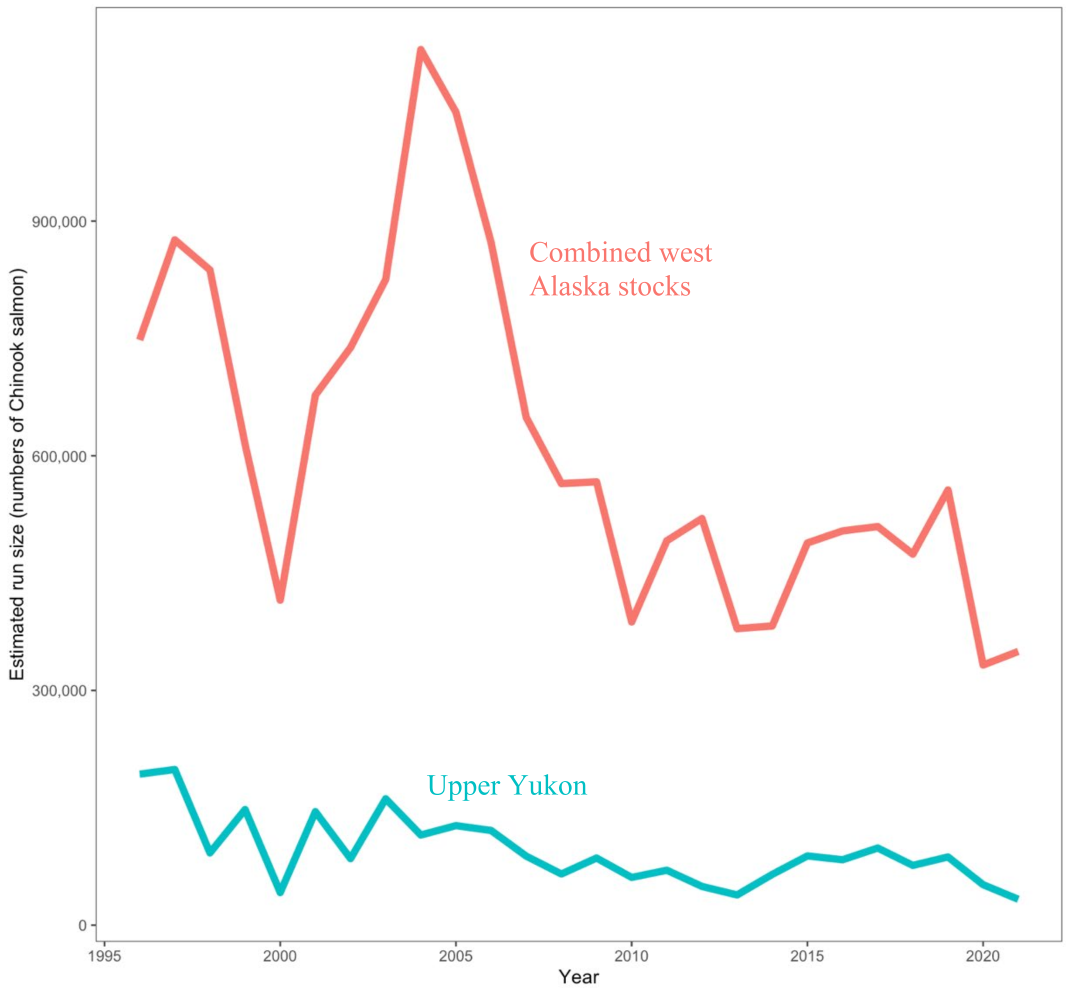


Fig. 11. Time series of Chinook salmon run strength estimates for western Alaska (includes coastal west Alaska stocks plus lower and middle Yukon River) and for the Canadian portion of the upper Yukon River, 1994-2021. *Source K. Howard ADFG.*

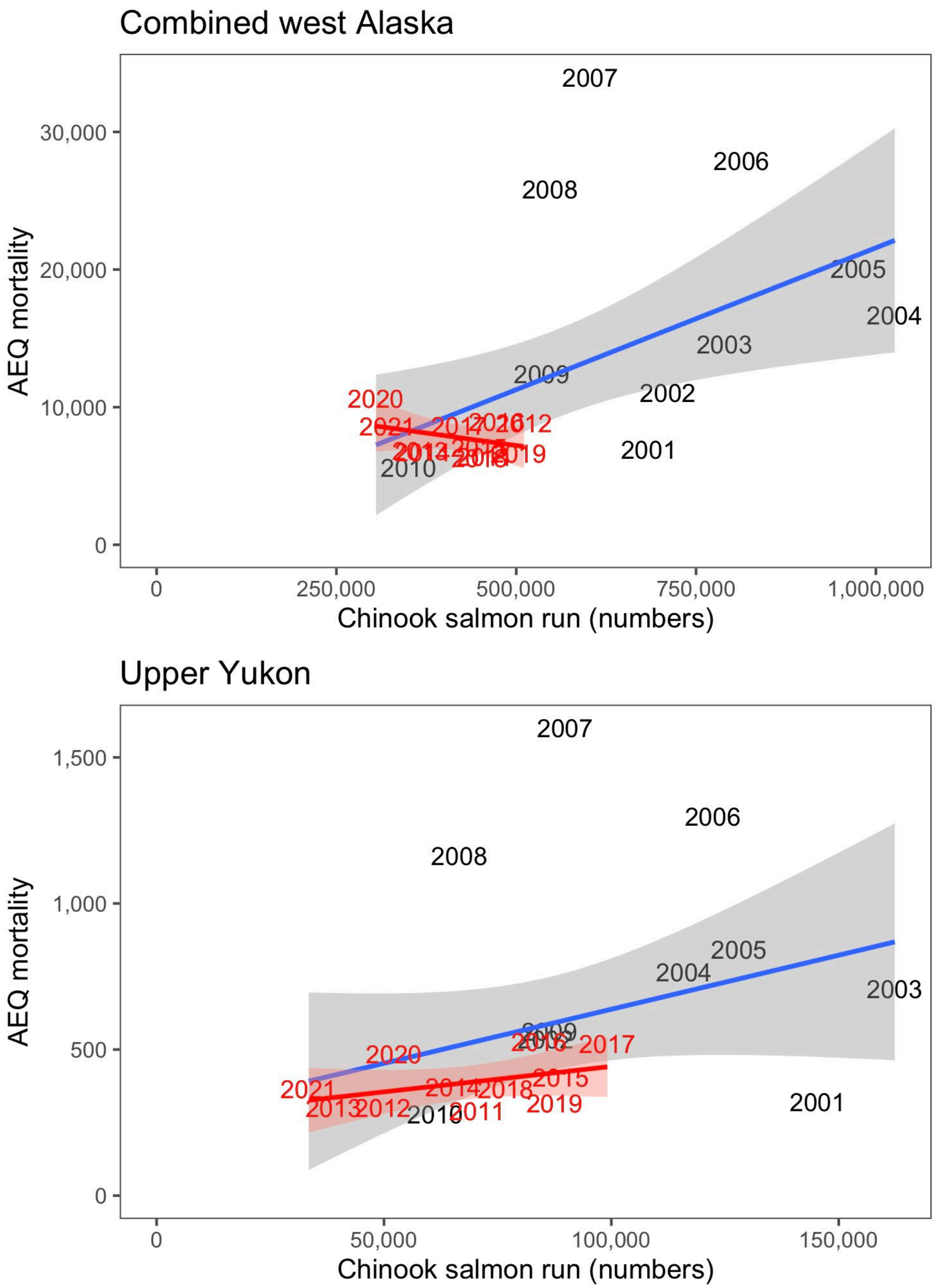


Fig. 12. Chinook salmon PSC adult equivalence compared to the combined run size estimates for combined western Alaska (top) and Upper Yukon (bottom) stocks. Blue line is a linear regression result through years 2001-2021 while the red is for just the years 2011-2021. Note that the scales on both axes change between figures.

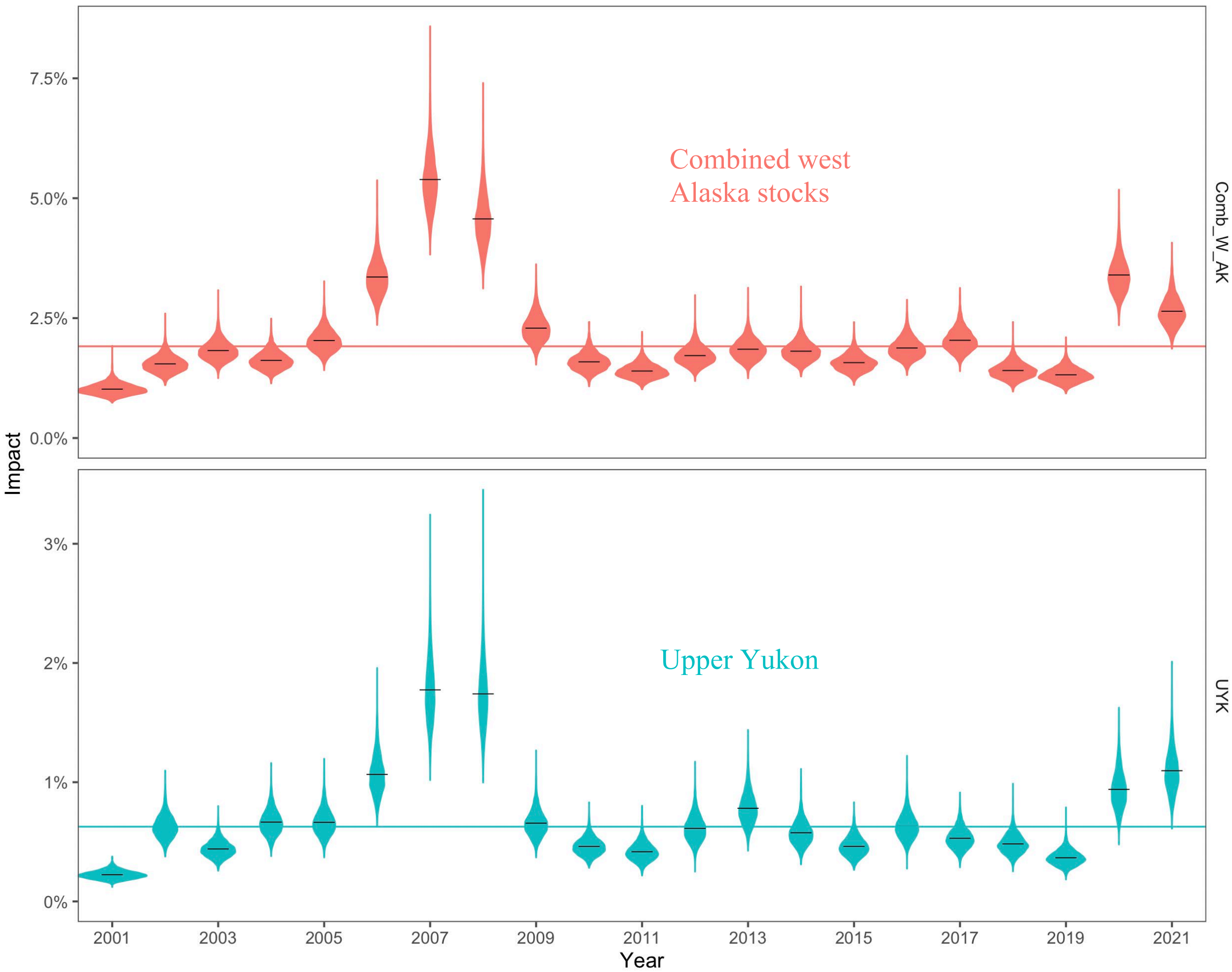


Fig. 13. Estimated impact of the BS pollock fishery on the Upper Yukon stock (bottom) and combined west Alaska (which includes the "middle Yukon"; top), 2001-2021. Vertical axis is the ratio of AEQ over the point estimates of total run sizes. Note that the vertical scales differ between panels

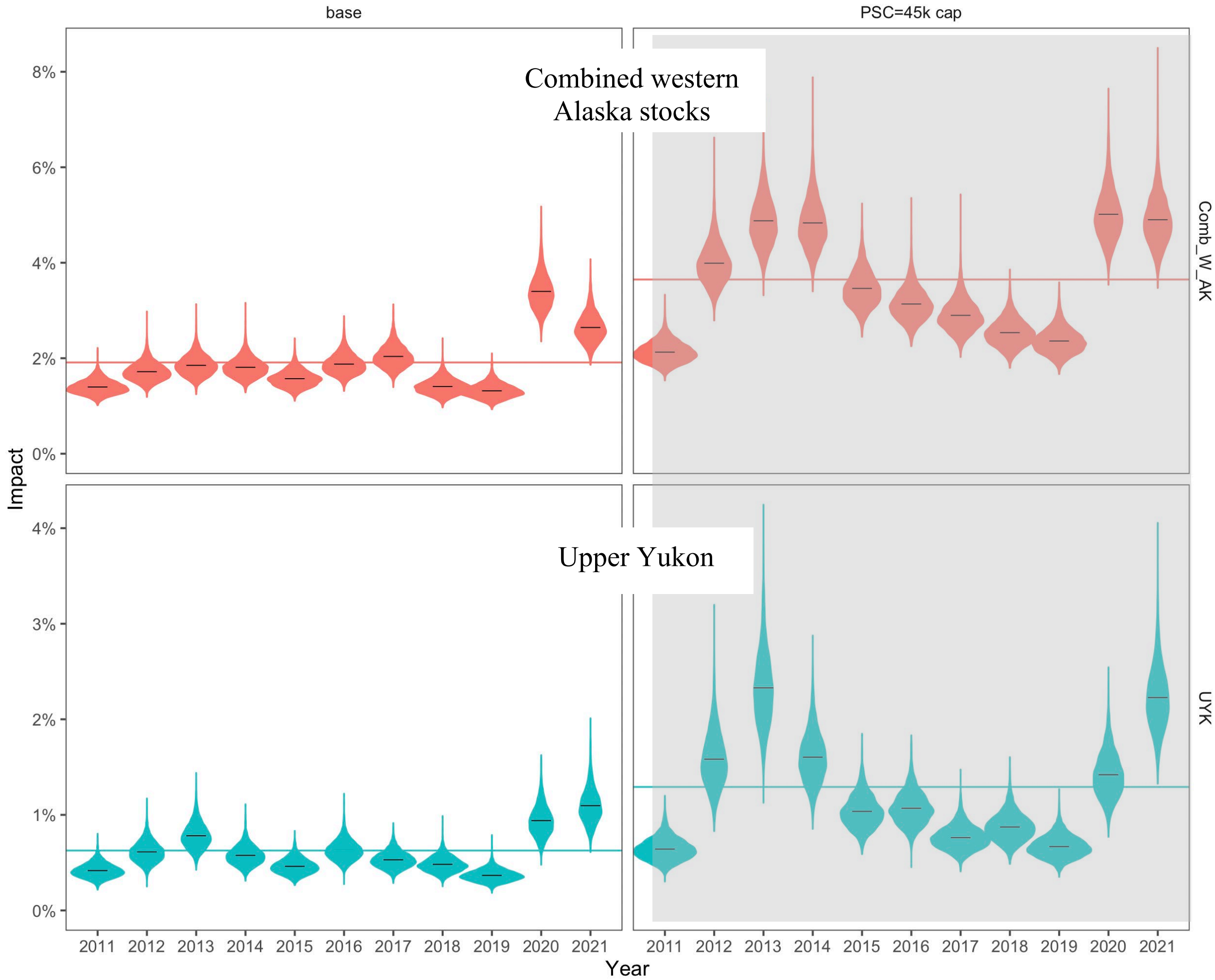


Fig. 14. Time series of Chinook adult equivalent bycatch from the pollock fishery, 2011-2021 comparing the estimates (base) to runs where the PSC was artificially set to the 45,000 fish cap in each year (greyed panels, right column).

Appendix 1. Estimates of Adult Chinook salmon run size and age proportions for informing impacts of Bering Sea Bycatch on Arctic-Yukon-Kuskokwim Chinook salmon stocks

Prepared by ADF&G Division of Commercial Fisheries:
Jennifer Bell – Arctic Area Research Biologist
Fred West – Yukon Area Summer Season Research Biologist
Sean Larson – Kuskokwim Area Research Biologist
Zachary Liller – AYK Regional Research Coordinator
2/17/2022

Introduction

The following describes the basic approaches taken to develop Chinook salmon total run and age proportions for Norton Sound / Port Clarence, Yukon, and Kuskokwim Management Areas. Notable changes to estimation methods have occurred since the last time ADF&G provided information for use in estimating Bering Sea Bycatch, Adult Equivalent impacts on Chinook salmon returns to Western Alaska. Norton Sound / Port Clarence Management Area There are no published total run reconstructions for Chinook salmon returning to Norton Sound / Port Clarence. Similarly, age datasets are largely inadequate to produce reliable estimates of total run age proportions. Abundance estimates provided are minimums and age proportions are based on pooled datasets irrespective of sample location, time, or method. As such, all data provided for this management area is highly uncertain.

Available timeseries

Data limitations allow for minimum run estimates for a subset of years, 1996–2021. The Unalakleet River is the predominant Chinook salmon producer in Norton Sound. Consistent annual monitoring of the Unalakleet River began in 1996 with a tower project on North River, a large tributary. Prior to 1996, ground-based assessment projects were rare or short-lived except for Kwiniuk River tower (1965 to present). The 1996–2021 Norton Sound minimum total run estimate was based on the sum of all available abundance data, including reconstructed total run estimate for the Unalakleet River; ground-based and expanded aerial indices of abundance to other systems; and harvest from commercial, subsistence, sport, and test fisheries.

Unalakleet River Run Reconstruction

Escapement estimates from the North River tower and Unalakleet River weir along with 4 years of telemetry were used to create an estimated drainagewide escapement to the Unalakleet River. Telemetry spawning distribution studies were conducted in 1997, 1998, 2009, and 2010, and estimates of North River escapement as a percentage of the whole were 37% in 1997, 40% in 1998, 34% in 2009, and 53% in 2010. In the years when telemetry occurred the proportional distribution was used to expand the North River Chinook salmon count to a drainagewide estimate. In years prior to 2010, (e.g., 1996 and 2000–2008) the average proportion from the 4 years of telemetry (41%) was used to expand the North River Chinook salmon tower counts to a drainagewide escapement. Starting in 2010, drainagewide escapement was the sum of North River tower and Unalakleet River weir. In 2020, the weir was not operational, therefore the North River contribution was considered 33% of the total run based on rationale provided in the ADF&G 3-System Index Letter to NPFMC.

Bayesian Estimates of Missed Passage

Bayesian analysis to estimate escapement totals was completed for all years of Chinook salmon counts for North River and Unalakleet River, and from 1985 to present for Kwiniuk River. In other systems, reported escapement represent only what was counted at the project and no attempt was made to estimate missed passage.

Aerial Surveys

Aerial survey counts were less reliable compared to ground-based escapement counts and were used only for years and locations in which no ground-based assessment was conducted. Peak aerial surveys were included when available from all rivers that were flown each year. There was no attempt to cull aerial survey data by survey rating or spawning timing. Aerial survey counts were summed across all systems by year and then expanded assuming aerial survey count represents 30% of the actual count.

Age Composition

Available data to represent the total escapement and harvest of Chinook salmon in Norton Sound is limited. From 1996–2002, 2007, and 2008 only harvest samples were available. Very small sample sizes (e.g., <100) were available from the harvest and escapement in 2003–2007. From 2009–2012 a few hundred samples were available from both the harvest and escapement. Beginning in 2013, nearly all samples were collected from the escapement. In all years, most samples were collected from harvests occurring in the Unalakleet and Shaktoolik Subdistricts or Unalakleet and Shaktoolik escapements, which likely represent most of the Chinook salmon production in the Norton Sound area. From 2009–2012, there was sufficient pooled samples (>100) to compare the composition of the predominant age classes between the harvest and escapement. Harvest appeared to be moderately selective for larger fish, however; the proportion of each age class in the harvest and escapement datasets were similar and displayed consistent temporal trends. As such, we decided to pool all age data regardless of sample location, timing, or method to represent the total run age by year. There was no age data collected in 1999 and a "best guess" was represented as the average of 1998 and 2000.

Yukon Management Area

There have been substantial improvements in available estimates of abundance for Yukon River Chinook salmon since the last time ADF&G provided information for AEQ analysis. A subcommittee of the Yukon River Panel's Joint Technical Committee (JTC) has produced annual estimates of total annual run, harvest, and escapement for 3 reporting groups: Lower U.S., Middle U.S., and Canada (Connors et al. in press). This new product was a component of a broader effort to estimate productivity and biological reference points for the Canada stock. The stock-specific run estimates are an output from an integrated state-space run reconstruction and spawner-recruitment model fit to available data. The run reconstruction component of the integrated model combines historical data from various assessment projects that estimate mainstem passage, harvests, tributary escapements, and stock-proportions, to simultaneously estimate stock-specific total run, harvest, and escapement under a single Bayesian estimation framework. All datasets used in this model underwent a robust quality review (Pestal et al. in press) and the model structure and results were peer reviewed. Results of the peer review are being summarized by the Canadian Science Advice Secretariate and will be publicly available in Spring of 2022.

Available timeseries

Connors et al. in press provides stock-specific abundance estimates for 1981–2019. Harvest stock separation methods were not available prior to 1981, so extending stock-specific datasets prior to 1981 would not be possible. Model input data for 2020 and 2021 are available, and the model could be extended to estimate through 2021 if requested.

Abundance estimates

Estimates provided represent simulated median values that "best fit" the available data. Only median values are provided but estimates of uncertainty (posterior credible intervals) could be provided if requested. Due to the modelling approach, stock-specific escapement and harvest will not sum exactly to the stock-specific total, and all 3 stock totals will not sum exactly to the total drainagewide run size.

Age Composition

A robust age sampling program has occurred annually to represent harvest and escapement age composition. Stock-specific harvest age composition estimates came from ADF&G "origins" reports as described in Larson et al. 2020. U.S. escapement age proportions were derived from tributary assessment projects in each U.S. stock group (Lower - Andreafsky, Anvik, Gisasa, Nulato, Tozitna, and Kaltag), (Middle - Chena, Henshaw, and Salcha) and are accessible from the AYK Database Management System. Canada Stock border passage age proportions were based on data collected at the Eagle Sonar test fishery since 2007. From 1882–2006, Canada Stock border passage age proportions were based on samples collected from border fish wheels and bias adjusted using a length selectivity correction method described in Hamazaki 2018. Stock-specific escapement and harvest age proportions were applied by the respective abundances and summed to produce total abundance by age and stock. Proportions were calculated and reported.

Kuskokwim River

Abundance estimates

Standard published run reconstruction methods were used to estimate total annual run size of Kuskokwim River Chinook salmon. Maximum likelihood methods and data inputs are documented in Larson 2021 and are consistent with methods approved by the NPFMC for use in the 3-System Index. Available data allows for run size estimates from 1976–2021. Estimates provided are preliminary based on the 2021 model run.

Age Composition

A robust age sampling program has occurred annually to represent harvest and escapement age composition. Standard methods were used to weight all available escapement and harvest samples by their respective spatial-temporal abundances to generate age proportions representative of the drainagewide escapement and harvest. Escapement and harvest age proportions were applied to reconstructed drainagewide escapement and harvest estimates from the maximum likelihood run reconstruction model and summed to generate total abundance by age. Proportions were calculated and reported.

Kuskokwim Bay

There are no published total run reconstructions for Chinook salmon returning to Kuskokwim Bay; however, there is a moderate amount of ground-based and aerial escapement data to make a reasonable inference about total run size.

Available Abundance Data

The available data allows for reasonable abundance estimates for 2002–2021. Major spawning tributaries draining into Kuskokwim Bay include the Goodnews, Kanektok, and Arolik rivers. The Goodnews River is monitored by a tower/weir on the Middle Fork (tower 1981–1990, weir 1991–2019) and peak aerial surveys flown throughout the Middle Fork and North Fork. The Kanektok River is monitored by a weir located near the headwaters (2002–2015) and peak aerial surveys flown throughout the drainage. The Arolik is located near the Kanektok River and monitored by aerial survey only. Subsistence and commercial harvest is available for the entire Kuskokwim Bay (Districts 4 and 5, community). Ground-based weir datasets were used to index the magnitude of the annual escapement. Ground-based escapement estimates were based on standard operating periods and missed passage was estimated using Bayesian methods as described in Dickerson et al. 2019. Middle Fork Goodnews River Weir (MFGNRW) was used to index the Goodnews River drainage. Kanektok weir was used to index the Kanektok and Arolik Rivers.

Goodnews River Run Reconstruction

Escapement to the entire Goodnews River was accomplished by expanding the MFGNRW counts to include the North Fork using 1 of 2 methods depending on data availability. Method 1 was used for years when reliable aerial surveys were flown on both the North Fork and Middle Fork rivers. The total North Fork escapement was assumed to be equal to the MFGNRW estimate adjusted by the aerial survey count ratio observed between the 2 tributaries. Method 2 was used when paired aerial surveys were not available and used a linear regression approach to estimate the annual “expected” ratio of North Fork to Middle Fork escapement using historical observations from Method 1. The sum of the estimated North Fork and Middle Fork escapement was used to represent the total escapement to the Goodnews River. In 2018, 2020, and 2021 MFGNRW did not operate. In 2018, multiple linear relationships were used to generate a Middle Fork escapement estimate from the Kanektok aerial survey count, which was the only escapement data available in that year. In 2020 and 2021, a Middle Fork escapement estimates was generated using a linear relationship between historical Middle Fork aerial survey and weir counts.

Kanektok and Arolik River Escapement Expansions

A total of 15 non-consecutive years (1999–2021) of aerial surveys were used to conclude that a substantial portion (average: 55%, range: 23–87%) of the total Kanektok River Chinook salmon escapement spawns downriver from the weir. The average distribution was used to expand the Kanektok River weir count to the total drainage for all year during which the weir operated. The Kanektok River weir did not operate successfully in 2006 and was discontinued in 2016. For years 2006, 2017, and 2020, a Kanektok weir equivalent count was approximated using a historical linear relationship between MFGRW and Kanektok weir (R2 = 0.71). In 2016, 2018, 2019, and 2021, the Kanektok River weir equivalent count was approximated using a historical linear relationship between the Kanektok River aerial survey and Kanektok River weir (R2 = 0.78). A total of 6 non-consecutive years (1977–2010) of aerial surveys were used to approximate the relative abundance between the Arolik and Kanektok Rivers. Paired aerial surveys indicate the run abundance to the Arolik is on average 33% of the total expanded run to the Kanektok River. This ratio was applied to the expanded drainagewide escapement to the Kanektok River in each year to approximate the total escapement to the Arolik River.

Total Kuskokwim Bay Run Reconstruction

Total escapement to Kuskokwim Bay was approximated (without error) by summing Chinook salmon escapement estimates from Middle Fork Goodnews River weir estimates (or approximations), North Fork Goodnews River (expansions), expanded Kanektok River weir estimates (or approximations), and Arolik River (expansions). Total escapement was summed with all available harvest data from Goodnews and Platinum community subsistence harvests, District 4 and 5 commercial harvest, and reported sport harvest.

Age Composition

A moderately robust age sampling program has occurred annually to represent harvest and escapement age composition to Kuskokwim Bay. Harvest samples are available from the commercial fishery only. Escapement samples are available from the Middle Fork Goodnews and Kanektok river weirs. Middle Fork Goodnews weir samples were used to represent the entire escapement to the Goodnews River drainage. Kanektok River weir samples were used to represent the escapement to the entire Kanektok River and Arolik rivers. Limited escapement age data were available for 2016–2021, due to discontinuation of both weirs. Samples were not available from MFGNRW in 2018, 2020, or 2021, and recent 5-year averages were used. Samples were not available from Kanektok River weir from 2016–2021, and age proportions were assumed to be equal to Goodnews.

References

Connors, B.M., Cunningham C., Bradley C.A., Hamazaki T., and Liller, Z.W. In Press. Estimates of biological benchmarks for the Canadian-origin Yukon River mainstem Chinook salmon (Oncorhynchus tshawytscha) stock aggregate. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/nnn. vi + 89 p.

Dickerson, B. R., C. L. Berry, and N. J. Smith. 2019. Salmon escapement monitoring in the Kuskokwim Area, 2018. Alaska Department of Fish and Game, Fishery Data Series No. 19-31, Anchorage.

Hamazaki, T. 2018. Estimation of U.S.-Canada border age-composition of Yukon River Chinook salmon, 1982–2006. Alaska Department of Fish and Game, Fishery Data Series No. 18-21, Anchorage.

Larson, S. 2021. 2020 Kuskokwim River Chinook salmon run reconstruction and 2021 forecast. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A21-02, Anchorage.

Larson, S., L. DuBois, and E. Wood. 2020. Origins of Chinook salmon in Yukon Area fisheries, 2015. Alaska Department of Fish and Game Fishery Data Series No. 20-21, Anchorage.

Pestal, G., Mather, V., West F., Liller Z., and Smith, S. (In Press). Review of available abundance, age, and stock composition data useful for reconstructing historical stock specific runs, harvest, and escapement of Yukon River Chinook salmon (Oncorhynchus tshawytscha) 1981-2019. Fisheries and Oceans Canada Technical Report nn: xx p.