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2022 Kuskokwim River Chinook Salmon Run Reconstruction and 2023 Forecast

by

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Alaska Department of Fish and Game **Division of Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

A maximum likelihood model was used to estimate the 2022 drainagewide run size and escapement of Kuskokwim River Chinook salmon (*Oncorhynchus tshawytscha*). The total run was estimated to be 142,495 (95% CI: 107,579–188,743) fish, and escapement was estimated to be 107,980 (95% CI: 73,064–154,228) fish. Model estimates were informed by direct observations of the 2022 escapement at 3 weirs and 2022 harvest, combined with historical observations of escapement (up to 6 weirs and 14 aerial surveys), harvest, test fishery, and mark–recapture data dating back to 1976. Model results are adequate to draw broad conclusions about the 2022 run and escapement. The 2022 total run of Chinook salmon was below the 1976–2021 average of 211,081 fish. The drainagewide sustainable escapement goal of 65,000–120,000 was met in 2022. The 2022 Kuskokwim River Chinook salmon forecast is for a range of 115,000–170,000 fish.

Key words: Chinook salmon *Oncorhynchus tshawytscha*, run reconstruction model, total run, total escapement, forecast, Kuskokwim River.

INTRODUCTION

This report describes methods used to estimate the drainagewide run size and escapement of Chinook salmon (*Oncorhynchus tshawytscha*) that returned to the Kuskokwim River in 2022. Because it is impossible to count all Chinook salmon that return to the Kuskokwim River, estimates of annual abundance and escapement were made using a maximum likelihood model. The model (Bue et al. 2012), with subsequent revisions (Liller et al. 2018), is an extension of the approach presented by Shotwell and Adkison (2004) and was specifically developed for use in data-limited situations. The model combines information about subsistence harvest, commercial catch and effort, sport harvest, test fishery harvest and catch per unit effort (CPUE) at Bethel, estimates of total inriver abundance, counts of salmon at 6 weirs, and peak aerial survey counts from 14 tributaries spread throughout the Kuskokwim River drainage (Figure 1). Each of these data sources provides an index of total abundance, and some data are more informative than others. The model provides an approach to combine and weight available information about Kuskokwim River Chinook salmon abundance to arrive at a scientifically defensible estimate of total run size and escapement. Estimates produced by the model represent the most likely run size given the observed data.

The run reconstruction model has become an important tool to guide the sustainable management of the Kuskokwim River Chinook salmon fishery. Model results from Bue et al. (2012) contributed to a spawner-recruit analysis used to establish a drainagewide escapement goal of 65,000–120,000 Kuskokwim River Chinook salmon (Hamazaki et al. 2012). The established escapement goal was reviewed in 2018 (Liller and Savereide 2018) and again in 2021 (Liller and Savereide 2022), and it was determined that the existing goal range was appropriate for this stock. The run reconstruction model has been used annually since 2013 as a postseason tool to determine if the drainagewide escapement goal was achieved. Model results have also been used since 2012 to inform preseason management strategies to achieve escapement goals. Since 2014, a preseason forecast range has been developed based on the prior year’s run size, as determined from the run reconstruction model.

The run reconstruction model has implications beyond the management of Kuskokwim River Chinook salmon fisheries. Since 2016, the Alaska Department of Fish and Game (ADF&G) has been required to provide the North Pacific Fishery Management Council (NPFMC) with a preliminary total run estimate of Kuskokwim River Chinook salmon abundance no later than October 1 of each year. The preliminary run abundance estimate is 1 component of a 3-system index (Upper Yukon, Unalakleet, and Kuskokwim Rivers) of Western Alaska Chinook salmon abundance used by NPFMC to guide Chinook salmon bycatch thresholds in the Bering Sea pollock trawl fishery. The preliminary 2022 3-system abundance estimate was provided to the NPFMC on September 22, 2022 (Appendix A), before final escapement and subsistence harvest estimates were available. The preliminary Kuskokwim River abundance estimate was based on model output from the run reconstruction model using preliminary escapement estimates and a prediction of total subsistence harvest. The final total run estimate was expected to change slightly from what was provided to NPFMC.

Given the significance of the run reconstruction model, it is important that the model is reviewed regularly and any changes are communicated in a timely and transparent manner. The model underwent a multi-year interagency peer review. The details of that review process and a description of the model changes that resulted from that review are documented in Liller et al. (2018) and Schindler et al. (2019). ADF&G adopted the revised model in 2018 (Smith 2019), and NPFMC also approved its use in the 3-system index[1]. There have been no changes to the run reconstruction model since that review.

OBJECTIVE

The project objective was to estimate the total run size and escapement of Kuskokwim River Chinook salmon in 2022.

METHODS

MODEL OVERVIEW

Drainagewide escapement (E_y) of Kuskokwim River Chinook salmon for year (y) is equal to the drainagewide run size (N_y) minus harvest (C_y),

$$E_y = N_y - C_y, \tag{1}$$

where C_y is the sum of harvest by subsistence, commercial, sport, and test fisheries. Each part of Equation 1 was known to different degrees. Total annual escapement was indexed by count data from weirs and aerial surveys of tributaries located throughout the lower, middle, and upper portions of the Kuskokwim River (Figure 1). Estimates of total abundance for scaling the model were derived from mark–recapture, escapement, and harvest data. Total abundance estimates were available for the years 2003–2007 and 2014–2017 (Liller et al. 2018). Total annual harvests from commercial fish tickets and test fisheries were known to a high degree of confidence. Subsistence harvest was estimated from extensive postseason surveys, and the estimates were incorporated into the model without error (Shelden et al. 2016; Dave Koster, Research Analyst, Division of Subsistence, ADF&G, Anchorage; personal communication). Estimates of sport fish harvest were less precise, but the effect of a lower level of precision was assumed to be negligible because of the small annual sport harvest.

The total run and escapement of Kuskokwim River Chinook salmon were estimated using a maximum likelihood model (Appendix B) developed for data-limited situations, with subsequent revisions to the model configuration (summarized in Liller et al. 2018). The model simultaneously combined abundance data from multiple sources to estimate a time series of the most likely estimates of total annual run abundance. The methodology was divided into 3 components to

[1] NORTH PACIFIC FISHERY MANAGEMENT COUNCIL - File #: ID 18-064 (legistar.com)

simplify the description of the estimation process and was based on the type of data used in the model: (1) escapement, (2) commercial catch and effort, and (3) direct estimates of total run size for model scaling.

ESCAPEMENT COUNTS

Assuming the annual escapement of Chinook salmon returning to each tributary and observed by a weir or aerial survey is a constant fraction of drainagewide escapement (E_y), the expected escapement ($\hat{e}$) in year (y) to tributary (i) observed by method (j: weir or aerial) is:

$$\hat{e}_{ijy}=E_y/k_{ij}, \tag{2}$$

where k_{ij} is a scaling parameter estimated by the model. The assumption of constant proportionality is tenuous and not supported by the tributary escapement data, but the revised model performance has been shown to be robust to violations of this assumption (Schindler et al. 2018).

COMMERCIAL CATCH AND EFFORT

Assuming commercial CPUE each week is proportional to the drainagewide run migrating during that week, the expected commercial catch CPUE ($\widehat{CPUE}_{wky}$) in week (w) with net configuration (k) is:

$$\widehat{CPUE}_{wky}=c_{wky}/f_{wky} = q_k\left(p_{wy}N_y\right), \tag{3}$$

where $\widehat{CPUE}_{wky}$ is the expected commercial catch CPUE at week (w) of net configuration (k), c_{wky} is the commercial catch at week (w) of net configuration (k), f_{wky} is the commercial efforts at week (w) of net configuration (k), p_{wy} is the proportion of Chinook salmon available at week (w) observed at Bethel test fishery, and q_k is the catchability coefficient of net configurations (k) (i.e., unrestricted, restricted).

Summing for all weeks and adjusting by the proportion of fish migrating through the harvest area during the weeks when fisheries occurred, the expected annual cumulative CPUE ($\widehat{CPUE}_{ky}$) is:

$$\widehat{CPUE}_{ky}=\frac{\sum_w(c_{wky}/f_{wky})}{\sum_w p_{wy}} = q_k N_y. \tag{4}$$

The proportion of Chinook salmon available for harvest each week and observed at the Bethel test fishery included weeks 3–10. Data from weeks 8–10 were combined. Commercial catch and effort by week and net configuration included weeks 3–9. Data from weeks 8 and 9 were combined. Run timing from 1976–1983 was estimated using the average run timing from 1984–2021.

MODEL SCALING

Direct estimates of total run size ($\widehat{N}_y$) from 2003–2007 and 2014–2017 were derived using a combination of mark–recapture data, escapement estimates, extrapolation of escapement values to unmonitored areas, and harvests. Those estimates of the total run and associated uncertainties were used to scale the run reconstruction model. Measurement error associated with the model scalars was represented using the estimates of variance presented by Liller et al. (2018).

LIKELIHOOD MODEL

Assuming all observations follow lognormal distributions, negative log-likelihoods with omissions of constants were constructed as:

$$L(\theta|data) = \begin{array}{l} \text{Escapement Counts} \\ +\sum_y \sum_i \sum_j \left(ln(\sigma_j) + 0.5 \left(\frac{ln(\hat{e}_{ijy}) - ln(e_{ijy})}{\sigma_j} \right)^2 \right) \\ \text{Adjusted Commercial CPUE} \\ +\sum_y \sum_k \left(ln(\sigma_k) + 0.5 \left(\frac{ln(\widehat{CPUE}_{ky}) - ln(CPUE_{ky})}{\sigma_k} \right)^2 \right) \\ \text{Drainagewide Run} \\ +\sum_y \left(0.5 \left(\frac{ln(\hat{N}_y) - ln(N_y)}{\sigma_y} \right)^2 \right), \end{array} \tag{5}$$

where $\sigma_j^2 = ln(CV_j^2+1)$, $\sigma_k^2 = ln(CV_k^2+1)$, and $\sigma_y^2 = ln(CV_y^2+1)$, CV_j and CV_k were estimated from the model, and CV_y was the observed CV of drainagewide run sizes of 2003–2007 and 2014–2017.

The model was written in AD Model Builder and run using the computing environment R (Appendix B; Fournier et al. 2012; R Core Team 2019).

MODEL INPUTS

Numerous data sources were available to inform the model and estimate the total run and escapement in 2022. Model estimates in 2022 were informed by independent scalers using total run estimates from 2003–2007 and 2014–2017, which corresponded to years of relatively high and low run abundance (Appendix C). The model was also informed by commercial, subsistence, sport, and test fishery harvest and escapement at 6 weirs and 14 aerial surveys from 1979–2022 (Appendix C). Finally, the model was informed by the proportion of total annual Chinook salmon run in District W-1 by week, as estimated using data collected from the Bethel test fishery from 1984–2022 and harvest and effort, by week, for Kuskokwim River District W-1 from 1976–2022 (Appendix C). All model inputs were the best available data at the time of reporting and have been reviewed and finalized since the release of the preliminary run reconstruction estimate to NPFMC in September 2022.

The subsistence harvest estimate used to produce the preliminary run reconstruction estimate in September 2022 has changed. The preliminary run estimate relied on a best guess of 37,848 Chinook salmon harvested for subsistence purposes. Since that time, postseason subsistence harvest surveys have been completed, and the harvest was estimated to be 34,134 (95% CI 30,625–37,644; Dave Koster, Division of Subsistence, ADF&G; personal communication). The revised subsistence harvest estimate was used in this final run reconstruction analysis.

RESULTS AND DISCUSSION

The run reconstruction model was informed by 6 weirs and 14 aerial survey index locations (Table 1). In 2022, 4 of 6 weirs operated, and 0 of 14 aerial surveys were successfully flown. Weirs located on the Kwethluk, George, Kogrukluk, and Takotna Rivers operated; however, passage was not estimated at the Takotna River weir due to extended periods of missed passage in 2022. Weirs located on the Tuluksak and Tatlawiksuk Rivers have not operated in recent years due to funding limitations. No aerial surveys were flown in 2022 due to persistent inclement weather when flights were scheduled, i.e., during peak spawning. This was the second year no aerial surveys were flown since at least 1976.

Harvest data came from subsistence and test fishery catches. The preliminary subsistence harvest of 34,134 (95% CI 30,625–37,644) Chinook salmon in 2022 is unlikely to change substantially and was below the amounts reasonably necessary for subsistence uses (ANS: 67,200–109,800) as defined by the Alaska Board of Fisheries (5 AAC 01.286). A total of 381 Chinook salmon were caught in the Bethel test fishery. No commercial or sport fish harvest of Kuskokwim River Chinook salmon occurred during the 2022 season.

Escapement estimates and observations during 2022 indicated that the Chinook salmon escapement throughout the Kuskokwim River was generally less than in prior years. In 2022, 2 out of 3 projects reported lower escapements than the 2017–2021, 2012–2021, and 1976–2021 averages (Table 1). There were 9 tributaries with established escapement goals in 2022 (Liller and Savereide 2018). Of those, only the escapement goals on the Kwethluk, George, and Kogrukluk Rivers were assessed, of which 2 were met, and 1 was exceeded. The remaining tributary escapement goals were not assessed because no aerial surveys were flown in 2022.

MODEL RESULTS

The 2022 Kuskokwim River Chinook salmon drainagewide run was an estimated 142,495 (95% CI: 107,579–188,743) fish (Table 2; Figure 2). Based on the 2022 model run, the total run in 2022 was 32% less than the 1976–2021 average of 211,081 Chinook salmon. CV for the 2022 total run was estimated to be 16%, which was larger than the 1976–2021 average of 10% (range: 5–26%; Figure 3). The root mean square error was smaller for weirs compared to aerial surveys, which indicated the model fit weir data better than aerial survey data (Figure 4).

The 2022 Kuskokwim River Chinook salmon drainagewide escapement was an estimated 107,980 (95% CI: 73,064–154,228) fish (Table 2). Based on the 2022 model run, the total escapement in 2022 was 16% less than the 1976–2021 average of 128,975 Chinook salmon. The total escapement in 2022 was greater than 22 of 46 (48%) prior years. Acknowledging that uncertainty in the drainagewide escapement was relatively high, the 95% confidence range of 73,064–154,228 fish provided evidence that the drainagewide escapement goal of 65,000–120,000 fish was met (Table 2; Figure 2).

The run reconstruction model produces updated total run and escapement estimates for all years since 1976 each time the model is updated with new information. Results from prior year model runs represented the best available estimates based on information available at that time. The 2022 model run represents the most informed historical time series of total run and escapement and supersedes previous estimates. Estimates of total annual abundance from 1976–2021, generated by the 2022 model run, were compared against the 2021 model run estimates reported by Larson 2022 (Table 2). The difference between total annual run and escapement estimates changed by an average of 0.47% and 0.84%, respectively, across all years (1976–2021). The long-term (1976–2021) averages for both total run and escapement differed by 1,553 fish between the 2022 and 2021 model runs. The absolute difference between pairs of annual total run estimates ranged between 23–65,574 fish (average = 5,337). Data corrections were made to historical Takotna River weir estimates due to a data entry error that occurred in 2019. These corrections to the historical model input dataset resulted in relatively large changes to estimates in 1996–1998; the largest change occurred in 1998 (65,574 fish or 25.7%).

Uncertainty in 2022 Model Estimates

There was a relatively high level of uncertainty associated with the 2022 model run (Figure 3). Uncertainty about any individual year model estimate is generally related to the number of index projects that operated in that year and the similarity in the information about each project's total run. The number of index projects operated in 2022 (3 total projects) was at the 4th percentile (median 11; range: 2–20) over the 46 years (1976–2021) of available data, which would suggest a limited amount of information to update the model and a relatively high level of uncertainty. However, each project provided a similar picture of the total run. The model is specifically designed to accommodate "conflicting" data from a range of index projects; however, smaller differences among projects result in less uncertainty about the actual size of the total run and escapement. To illustrate this, the entire drainagewide escapement was estimated using data from 1 escapement project at a time (Figure 5). In 2022, estimates of drainagewide Chinook salmon escapements derived from individual weir projects were 81,000–148,000 fish (Table 3; Figure 5).

The sensitivity of the 2022 model results to parameter starting values was evaluated. Run estimates were compared across a range of 100 starting values for all model parameters independently (Table 4). The maximum observed difference between annual run estimates was less than 1 fish. Results for all parameter starting values confirmed the 2022 model run was not sensitive to starting values, and the total run estimates presented represent the best-fit model.

The full sensitivity of model results to the limited 2022 escapement data was explored using a leave-one-out approach (Figure 6). Specifically, the model was run with the removal of a single escapement project at a time. All point estimates fell within the 95% confidence interval of the base model. Confidence intervals overlapped in all scenarios. No escapement estimates were available for headwaters projects, and because no aerial surveys were flown in 2022, the effect could not be evaluated. These comparisons are not meant to lend more or less credibility to specific escapement data sources but rather show the importance of having a comprehensive assessment program to inform the run reconstruction model.

2022 Run Reconstruction Model Conclusions

- The total run of Kuskokwim River Chinook salmon was estimated to be 142,495 (95% CI: 107,579–188,743) fish.
- Total run abundance was below the 1976–2021 average of 211,081 fish but within the range of run sizes necessary to meet at least the lower bound of the drainagewide escapement goal (65,000–120,000) and support at least the lower bound of ANS (67,200–109,800) as defined by the Alaska Board of Fisheries (5 AAC 01.2086). For example, a run of at least 132,200 fish would be needed to meet the lower bounds of the drainagewide escapement goal and ANS.
- The total escapement of Kuskokwim River Chinook salmon was estimated to be 107,980 (95% CI: 73,064–154,228) fish, and the drainagewide sustainable escapement goal of 65,000–120,000 was met.

2023 CHINOOK SALMON RUN FORECAST

The 2023 Kuskokwim River Chinook salmon forecast is for a range of 115,000–170,000 fish. The forecast range is equal to ±19% of the 2022 total run, as presented in this report. Uncertainty in the forecast (i.e., ±19%) is based on the 2016–2022 (7-year) average percent error between forecasted and actual run estimates. Interestingly, when using data from 1976–2022, the average percent error between forecasted and actual run estimates (22%) is similar to the 7-year average percent error. Despite several years of similar run sizes since 2016, the 2019 run was well above forecast, and the 2020 run was well below forecast, both of which contributed to increased uncertainty in the 2023 forecast.

The forecast range is not based on probability and provides no insight into the most probable run size within the forecasted range. The value of the forecast is in preseason planning. For example, managers and stakeholders may choose to put equal effort into planning for all run-size scenarios within the forecast range or focus their planning on a subset of the forecast. This forecast can be used alongside probability-based forecasts to identify run sizes with the highest probability to guide preseason planning.

Probability-based forecast methods like the *P*-star model[2] developed by Staton and Catalano (2019) have been explored for Kuskokwim River Chinook salmon. That model uses the same prior year method for defining the mean of the forecast range but uses the entire time series to describe forecast uncertainty. That model assumes uncertainty around the forecast expectation is lognormally distributed. A bias-corrected lognormal distribution is used to ensure the mean of the distribution is the same as the previous year's run size. Forecast uncertainty is quantified by calculating the errors the previous-year method would have made, as though they were lognormal random variables, and calculating their standard deviation. The method described by Staton and Catalano (2019) produces forecast ranges based on any statistical confidence interval that is desired and can be used to describe the probability of different run sizes occurring. Probability-based forecasts necessitate proper interpretation and context to be useful for focusing preseason management planning discussions.

Probability-based methods like the *P*-star model can provide context to understand better the 2023 forecast produced by ADF&G and can be used to make explicit predictions about the 2023 run before the availability of inseason assessment data. The ADF&G 2023 forecast (based on the 7-year average percent error) represents approximately the central 50% of probable run size predictions identified through the *P*-star model. There is a 25% chance the 2023 run size will return smaller than 112,000 and a 25% chance the run will return larger than 166,000 (Table 5). The *P*-star model indicated that there is a 90% chance the 2023 run size will be less than 197,000, which is less than the average run size (1976–2021 average run size is 211,081 fish). Stated more simply, there is a high probability that the 2023 run will be smaller than average. However, the *P*-star model provides considerable evidence that the 2023 run size will be large enough to meet the drainagewide escapement goal and allow some harvest. There is a 99% chance the 2023 run size will exceed 69,000, which is a run size just above the lower bound (65,000) of the escapement goal. There is a 70% chance that the run will return larger than 117,000, which is a run size near the upper bound (120,000) of the drainagewide escapement goal[3] (Table 5).

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[2] https://bstaton.shinyapps.io/BayesTool

[3] Percentages presented in this text are rounded.

Preseason expectations of Chinook salmon harvestable surplus in 2023 are highly uncertain. Simple subtraction of the drainagewide escapement goal (65,000–120,000) from the ADF&G forecast (114,000–172,000) would suggest a harvest outlook anywhere between 0–105,000 fish. However, run size probabilities from the *P*-star model provide considerable evidence that large run sizes suitable for supporting large harvests have a low chance of occurring in 2023. Actual harvest opportunities will be determined inseason based on run size assessments and expectations of achieving the drainagewide escapement goal range (65,000–120,000) and tributary escapement goals.

Successive years of achieving the drainagewide escapement goal provide some support for the notion that the 2023 Chinook salmon run will be large enough to meet escapement needs and provide for some harvest. The dominant brood years contributing to the 2023 run will be 2017–2019. These brood years will return fish that are age-4 (2019 brood), age-5 (2018 brood), and age-6 (2017 brood). The actual number of each age class that will return in 2023 is not known with certainty, but the drainagewide escapement goal was met or exceeded in each of the contributing brood years. Drainagewide escapement was estimated to be 114,688 fish in 2017, 109,801 fish in 2018, and 182,050 fish in 2019 (Table 6). The drainagewide escapement goal on the Kuskokwim River was designed to maximize the probability that future run sizes are large enough to meet escapement and harvest needs.

Stock productivity trends should be considered when using this forecast to plan preseason management of the 2023 Chinook salmon run. Kuskokwim River Chinook salmon productivity, measured as recruits per spawner, has fluctuated through time (Figure 7). Relatively high productivity occurred during brood years 1982–1991 and again during brood years 1999–2001. Brood years 2004–2009 experienced low productivity (<1 recruit per spawner). Since that time, productivity has increased, and the 2011–2013 brood years produced, on average, 3 recruits per spawner. However, the most recent complete brood year (2015) produced fewer than 2 recruits per spawner (Table 6; Figure 7).

FUTURE MODEL CONSIDERATIONS

Improvements to the Chinook salmon run reconstruction model are being explored. The model may benefit from time-varying scaling parameters that accommodate changes in management or spatial shifts in production that could affect the proportion of the total escapement observed at individual assessment locations. For example, headwaters stocks tend to have earlier run timing than middle river stocks (Clark and Smith 2019). Managers have heavily restricted fishing during the early portion of the Chinook salmon run since 2014, which has generally led to lower exploitation and higher escapements for headwater stocks than were observed before 2014. As a result, the observed escapement at headwater assessment projects has tended to be higher than what the run reconstruction model predicted. This may be addressed by incorporating a time-variant scaler into the model. Also, the Kuskokwim River sonar is an assessment tool that has been fully operational since 2018. The sonar provides valuable salmon passage data at a site approximately 20 km upriver from Bethel. The appropriateness of using sonar data as an additional model input will continue to be explored. ADF&G will engage and report to stakeholders and ensure an appropriate level of review if any changes to the current model are adopted.

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TABLES AND FIGURES

Table 1.–Historical and recent year observations of Kuskokwim River Chinook salmon abundance used to inform the run reconstruction model.

Method	Location	Number of years of data (1976–2022)	Historical average (1976–2021)	10-yr average (2012–2021)	5-yr average (2017–2021)	2021	2022
Weir	Kwethluk	16	9,432	6,767	7,856	–	6,808
	Tuluksak	21	985	558	648	–	–
	George	24	3,480	2,729	3,231	2,920	4,318
	Kogrukluk	36	9,624	6,448	7,399	6,969	5,837
	Tatlawiksuk	18	1,692	1,772	2,146	–	–
	Takotna	21	402	300	351	323	–
Aerial survey	Kwethluk	12	2,061	943	721	–	–
	Kisaralik	27	1,082	642	666	–	–
	Tuluksak	11	421	83	–	–	–
	Salmon (Aniak)	34	784	449	521	–	–
	Kipchuk	28	1,018	841	1,020	–	–
	Aniak	25	2,576	1,773	1,935	–	–
	Holokuk	19	333	177	280	–	–
	Oskawalik	24	285	183	314	–	–
	Holitna	24	1,483	891	972	–	–
	Cheeneetnuk	27	689	489	747	–	–
	Gagaryah	27	486	342	550	–	–
	Pitka	15	242	299	299	–	–
	Bear	21	262	425	476	–	–
	Salmon (Pitka)	34	1,065	1,306	1,289	–	–
Harvest	Subsistence	47	63,601	26,851	28,160	28,365	34,134
	Commercial	47	17,496	84	0	0	0
	Sport	46	411	0	0	0	0
	Test fishery	47	607	408	412	386	381

Note: Not all projects operated in all years. En dash represents the project did not operate or a historical average could not be calculated due to insufficient data.

Table 2.–Annual drainagewide run and escapement of Kuskokwim River Chinook salmon from the 2022 run reconstruction model.

	2022 Model run				2022 Model run			
Year	Total run estimate	Lower 95% CI	Upper 95% CI	Previously published total run estimate[a]	Total esc. estimate	Lower 95% CI	Upper 95% CI	Previously published total esc. estimate[a]
1976	202,841	158,777	259,134	206,497	112,294	68,230	168,587	115,950
1977	325,406	231,283	457,834	326,456	231,699	137,576	364,127	232,749
1978	239,077	191,152	299,017	238,287	155,605	107,680	215,545	154,815
1979	239,666	175,398	327,482	237,200	143,364	79,096	231,180	140,898
1980	364,437	224,321	592,074	364,886	267,469	127,353	495,106	267,918
1981	313,173	230,586	425,339	311,648	202,774	120,187	314,940	201,249
1982	143,417	125,809	163,488	143,792	36,416	18,808	56,487	36,791
1983	148,079	121,887	179,898	148,623	65,934	39,742	97,753	66,478
1984	173,487	137,487	218,914	175,387	84,311	48,311	129,738	86,211
1985	144,881	118,800	176,688	145,221	62,954	36,873	94,761	63,294
1986	123,608	93,448	163,502	124,380	52,996	22,836	92,890	53,768
1987	182,484	146,411	227,445	183,056	78,241	42,168	123,202	78,813
1988	208,937	181,047	241,124	207,428	81,174	53,284	113,361	79,665
1989	214,002	177,068	258,640	215,158	87,849	50,915	132,487	89,005
1990	270,020	232,399	313,730	268,544	105,834	68,213	149,544	104,358
1991	215,900	183,546	253,956	216,118	102,752	70,398	140,808	102,970
1992	261,053	227,046	300,154	261,317	129,953	95,946	169,054	130,217
1993	277,856	229,159	336,902	273,777	178,189	129,492	237,235	174,110
1994	406,098	312,885	527,080	399,365	283,994	190,781	404,976	277,261
1995	373,831	303,428	460,571	372,332	239,102	168,699	325,842	237,603
1996	306,070	243,989	383,948	341,902	200,495	138,414	278,373	236,327
1997	298,489	245,453	362,985	262,761	207,155	154,119	271,651	171,427
1998	189,600	146,332	245,660	255,174	89,628	46,360	145,688	155,202
1999	161,598	132,402	197,233	160,752	83,005	53,809	118,640	82,159
2000	128,739	114,207	145,120	122,487	60,530	45,998	76,911	54,278
2001	206,792	176,162	242,748	192,752	128,152	97,522	164,108	114,112
2002	224,504	194,975	258,505	238,306	142,656	113,127	176,657	156,458
2003	232,722	208,743	259,456	231,909	164,017	140,038	190,751	163,204
2004	364,208	322,849	410,865	365,032	263,567	222,208	310,224	264,391
2005	326,453	294,595	361,756	327,044	234,677	202,819	269,980	235,268
2006	320,091	285,136	359,331	323,372	225,706	190,751	264,946	228,987
2007	244,891	222,231	269,863	248,471	148,031	125,371	173,003	151,611
2008	213,331	189,395	240,292	214,922	114,426	90,490	141,387	116,017
2009	189,192	166,620	214,822	194,718	101,258	78,686	126,888	106,784

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Table 2.–Page 2 of 2.

	2022 Model run				2022 Model run			
Year	Total run estimate	Lower 95% CI	Upper 95% CI	Previously published total run estimate[a]	Total esc. estimate	Lower 95% CI	Upper 95% CI	Previously published total esc. estimate[a]
2010	113,266	103,569	123,869	116,026	42,602	32,905	53,205	45,362
2011	115,713	104,439	128,204	115,858	51,684	40,410	64,175	51,829
2012	80,837	66,899	97,680	75,242	57,345	43,407	74,188	51,750
2013	84,404	76,267	93,409	88,498	36,916	28,779	45,921	41,010
2014	85,035	73,361	98,566	82,133	73,269	61,595	86,800	70,367
2015	125,745	111,164	142,238	125,767	109,141	94,560	125,634	109,163
2016	131,446	114,684	150,658	130,678	100,228	83,466	119,440	99,460
2017	131,358	113,017	152,676	131,643	114,688	96,347	136,006	114,973
2018	132,532	106,238	165,335	135,711	109,801	83,507	142,604	112,980
2019	220,554	179,897	270,401	226,224	182,050	141,393	231,897	187,720
2020	124,322	103,316	149,599	124,540	88,121	67,115	113,398	88,339
2021	129,556	97,075	172,905	129,751	100,805	68,324	144,154	101,000
2022	142,495	107,579	188,743		107,980	73,064	154,228	
Average (1976–2021)	211,081			212,634	128,975			130,528

Note: The run reconstruction model produces estimates for all years every time the model is updated with new information. Previously published estimates of total run and escapement associated with prior year model runs are shown for reference.

[a] Prior year model run by Larson (2022). Based on the prior year's model run, the 1976–2021 average total run and escapement was smaller than the 2021 model run average by 1,553 fish, a difference of 0.47% for the total run and 0.84% for escapement.

Table 3.–Parameter estimates derived from the 2022 run reconstruction model.

	Parameter estimate (*k*)	95% Bound		Observed escapement	Total escapement[a]
		Lower	Upper		
Weir projects (*k*)					
Kwethluk weir	2.74	2.55	2.93	6,808	104,527
Tuluksak weir	5.05	4.87	5.22	–	–
George weir	3.54	3.37	3.71	4,318	148,427
Kogrukluk weir	2.64	2.48	2.79	5,837	81,151
Tatlawiksuk weir	4.19	4.01	4.38	–	–
Takotna weir	5.78	5.61	5.96	–	–
Aerial survey (*k*)					
Kwethluk River	4.44	4.10	4.79	–	–
Kisaralik River	5.14	4.91	5.38	–	–
Tuluksak River	6.12	5.76	6.48	–	–
Salmon (Aniak River)	5.37	5.14	5.59	–	–
Kipchuk River	5.01	4.77	5.24	–	–
Aniak River	4.06	3.81	4.31	–	–
Holokuk River	6.31	6.04	6.58	–	–
Oskawalik River	6.49	6.24	6.74	–	–
Holitna River	4.54	4.29	4.79	–	–
Cheeneetnuk River	5.41	5.17	5.65	–	–
Gagaryah River	5.84	5.60	6.08	–	–
Pitka Fork	6.41	6.10	6.71	–	–
Bear River	6.27	6.01	6.54	–	–
Salmon(Pitka Fork)	4.80	4.58	5.02	–	–
Catchability (*q*)					
Unrestricted	-9.50	-9.79	-9.22	–	–
Restricted	-10.05	-10.21	-9.88	–	–

Note: Parameter values (*k*) are presented as natural logarithms (ln). En dash means not applicable.

[a] The expected drainagewide total escapement equals the observed escapement*EXP(*k*).

Table 4.–Starting values used for the 2022 run reconstruction model sensitivity analysis and associated results.

Parameter	Starting values range	Average difference[a]	Max difference[b]
Total run (N_y)	100,000–400,000	0.004	0.024
Weir escapement scaling (k_{ij})	0.01–10	0.077	0.329
Aerial escapement scaling (k_{ij})	0.01–10	0.003	0.013
Catchability (q_k)	-20–1	0.079	0.014
Weir coefficient of variation[c]	-20–20	0.002	0.011
Aerial coefficient of variation[c]	-20–20	0.002	0.011
Catchability coefficient of variation[c]	-20–20	0.002	0.011

[a] Average difference in numbers of fish among all 1976–2022 total run estimates across a range of 100 different starting values for each parameter.

[b] Maximum difference in numbers of fish among all 1976–2022 total run estimates across a range of 100 different starting values for each parameter.

[c] Weir, aerial, and catchability coefficient of variation starting values were evaluated simultaneously.

Table 5.–Kuskokwim River Chinook salmon forecast produced using the *P*-star model, 2023.

Run size	Percent chance of being below run size	Percent chance of being above run size
69,000	1%	99%
85,000	5%	95%
94,000	10%	90%
101,000	15%	85%
107,000	20%	80%
112,000	25%	75%
117,000	30%	70%
122,000	35%	65%
127,000	40%	60%
131,000	45%	55%
136,000	50%	50%
141,000	55%	45%
147,000	60%	40%
152,000	65%	35%
159,000	70%	30%
166,000	75%	25%
174,000	80%	20%
184,000	85%	15%
197,000	90%	10%
219,000	95%	5%
267,000	99%	1%

Note: The model assumes the probability of outcomes between any 2 intervals is not uniform; that is, values closer to the mean (142,495 fish) have higher probabilities of being the correct run size than values farther from the mean. Statistical methodology is described in Staton and Catalano (2019), and the *P*-star model can be accessed at https://bstaton.shinyapps.io/BayesTool. Model code can be accessed at https://github.com/bstaton1/kusko-bayes-tool.

Table 6.–Brood table for Kuskokwim River Chinook salmon.

Brood		Return by age class															
year	Escapement	(0.2)	(1.1)	(0.3)	(1.2)	(2.1)	(0.4)	(1.3)	(2.2)	(1.4)	(2.3)	(1.5)	(2.4)	(1.6)	(2.5)	Return	R/S
1976	112,294	0	64	6	65,729	6	0	106,480	34	82,170	85	6,080	260	90	0	261,002	2.32
1977	231,699	0	66	6	23,913	6	0	44,162	32	77,153	70	7,416	515	67	0	153,405	0.66
1978	155,605	0	676	5	11,426	5	0	39,345	26	60,800	498	4,824	52	5	0	117,663	0.76
1979	143,364	0	209	4	24,360	4	32	75,987	159	60,938	64	6,390	60	6	0	168,214	1.17
1980	267,469	0	692	5	27,680	5	0	51,787	176	46,058	74	3,476	80	7	0	130,040	0.49
1981	202,774	0	370	4	26,969	4	0	58,957	28	82,882	99	12,215	85	7	0	181,619	0.90
1982	36,416	0	48	5	11,264	5	0	52,943	37	69,753	104	6,562	1,062	10	0	141,792	3.89
1983	65,934	0	696	6	42,893	6	0	96,867	39	102,630	733	5,717	130	33	302	250,054	3.79
1984	84,311	0	74	7	29,839	7	0	66,871	1,579	72,936	161	5,273	841	8	0	177,594	2.11
1985	62,954	0	78	7	34,299	7	0	131,505	60	107,606	1,274	5,046	219	8	90	280,202	4.45
1986	52,996	0	90	10	56,578	10	0	72,277	1,925	91,608	235	10,501	732	10	0	233,976	4.41
1987	78,241	0	2,978	7	26,214	7	0	87,157	620	101,208	785	6,166	1,674	9	0	226,824	2.90
1988	81,174	76	82	8	69,698	8	0	84,407	214	132,650	2,025	4,123	361	16	0	293,668	3.62
1989	87,849	0	6,197	8	79,414	8	184	216,382	1,449	195,544	390	33,441	116	7	0	533,140	6.07
1990	105,834	0	429	10	43,907	10	0	108,381	56	108,350	671	3,232	95	7	0	265,148	2.51
1991	102,752	92	751	9	65,015	9	0	131,228	335	141,491	117	4,261	97	7	0	343,414	3.34
1992	129,953	0	144	9	31,676	9	0	70,421	44	67,393	120	3,113	87	6	0	173,022	1.33
1993	178,189	0	130	7	82,827	7	0	91,666	45	96,127	107	4,168	81	0	0	275,164	1.54
1994	283,994	0	88	7	25,352	7	0	48,100	168	58,227	99	8,279	81	0	0	140,409	0.49
1995	239,102	0	284	7	13,630	7	0	49,650	37	107,819	0	7,794	0	0	0	179,228	0.75
1996	200,495	0	232	6	16,336	6	0	68,660	0	90,283	0	9,762	0	0	0	185,285	0.92
1997	207,155	0	103	0	21,729	0	0	79,751	56	76,148	0	4,619	0	0	0	182,406	0.88
1998	89,628	0	0	0	46,345	0	0	102,658	0	106,319	0	4,403	172	0	0	259,898	2.90
1999	83,005	0	186	0	43,608	0	0	110,999	426	109,985	547	14,613	91	0	0	280,455	3.38
2000	60,530	0	382	0	140,745	0	0	152,360	10	124,885	182	5,144	1,090	0	0	424,798	7.02
2001	128,152	0	1,202	0	58,655	0	0	96,978	91	89,423	465	4,736	180	0	0	251,730	1.96

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Table 6.–Page 2 of 2.

Brood year	Escapement	Return by age class (0.2)	(1.1)	(0.3)	(1.2)	(2.1)	(0.4)	(1.3)	(2.2)	(1.4)	(2.3)	(1.5)	(2.4)	(1.6)	(2.5)	Return	R/S
2002	142,656	0	484	0	82,063	0	0	80,457	0	61,088	1,246	2,109	301	0	0	227,747	1.60
2003	164,017	0	1,070	0	67,973	0	0	104,194	65	81,930	264	3,139	39	64	0	258,738	1.58
2004	263,567	0	189	0	41,341	0	0	69,847	737	39,327	0	1,658	55	0	0	153,155	0.58
2005	234,677	0	444	0	33,924	0	0	48,140	78	37,664	275	908	1	0	0	121,436	0.52
2006	225,706	0	81	68	22,247	68	0	46,298	109	24,878	493	804	95	0	0	95,140	0.42
2007	148,031	0	194	0	29,288	0	0	44,123	0	45,332	236	848	0	0	0	120,021	0.81
2008	114,426	0	263	0	10,375	0	0	25,794	68	31,267	367	446	1	0	0	68,582	0.60
2009	101,258	50	0	0	11,844	68	0	34,081	497	24,053	360	5	1	0	77	71,035	0.70
2010	42,602	0	95	0	14,951	0	122	44,269	766	17,037	359	17	99	0	0	77,716	1.82
2011	51,684	0	2,868	0	54,821	2	0	75,140	234	28,610	205	108	0	0	0	161,990	3.13
2012	57,345	65	805	0	36,737	0	0	59,818	164	21,809	51	77	455	0	0	119,982	2.09
2013	36,916	0	1,932	0	41,232	0	120	57,749	120	29,323	1,580	861	111	0	0	133,029	3.60
2014	73,269	0	1,054	0	49,430	0	227	72,043	2,237	28,133	4	646	163	0	0	153,936	2.10
2015	109,141	0	3,104	239	102,399	88	0	51,751	54	27,046	58	236	0	0	0	184,976	1.69
2016	100,228	30	12,033	0	42,161	0	1	48,577	106	11,528	111	0	0	0	0	114,547	–
2017	114,688	0	1,216	119	50,832	100	2	54,740	205	0	0	0	0	0	0	107,214	–
2018	109,801	0	2,105	180	73,507	47	0	0	0	0	0	0	0	0	0	75,840	–
2019	182,050	0	1,968	0	0	0	0	0	0	0	0	0	0	0	0	1,968	–
2020	88,121	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	–
2021	100,805	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	–
2022	107,980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	–

Note: The number of recruits returning from brood year escapement are shown as R/S. Brood years 2016–2022 are incomplete. En dash means no component of the return has been realized, or the R/S cannot be calculated at this time.

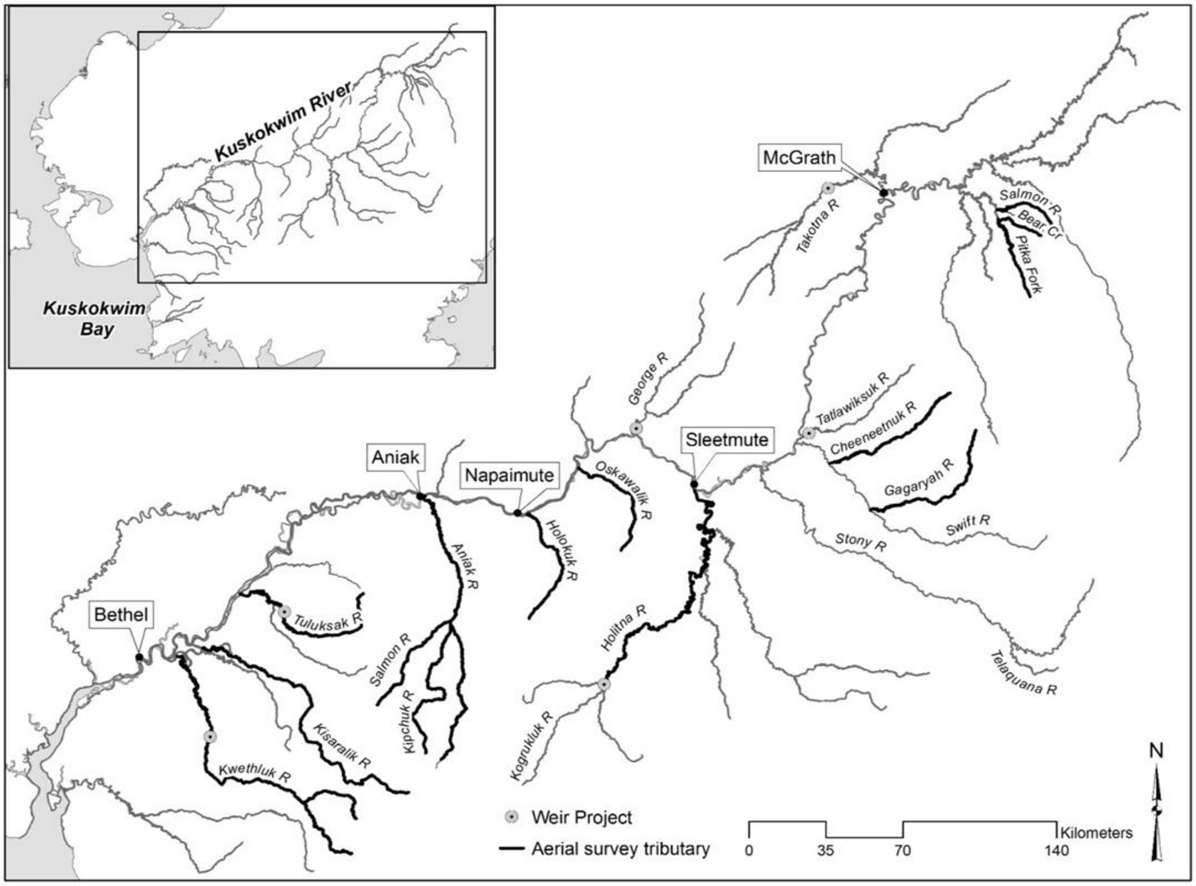

Figure 1.–Kuskokwim River Chinook salmon escapement monitoring projects used to inform the run reconstruction model.

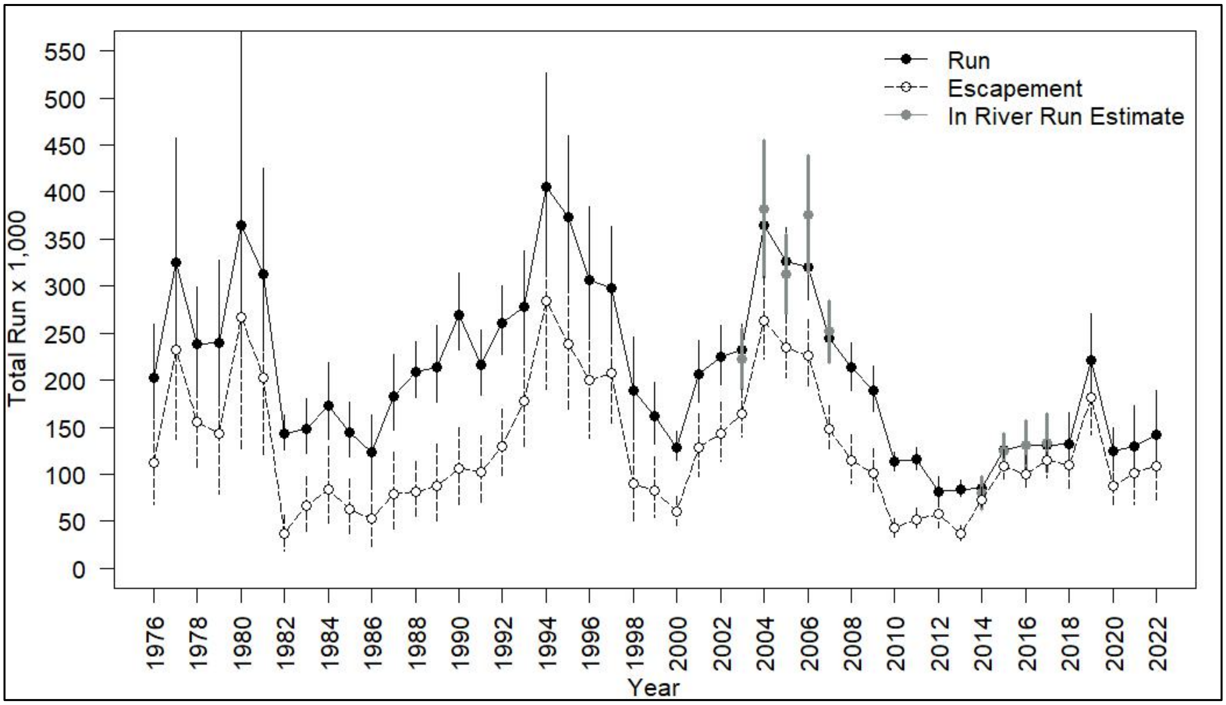

Figure 2.–Annual run (black) and escapement (white) estimates with 95% confidence intervals estimated from the 2022 run reconstruction model.

Note: Gray dots are drainagewide run size and 95% confidence intervals for years 2003–2007 and 2014–2017 used to scale the model. Model scalars are direct estimates of total run derived from a combination of mark–recapture data, escapement estimates, extrapolation of escapement values to unmonitored areas, and harvests (Liller et al. 2018).

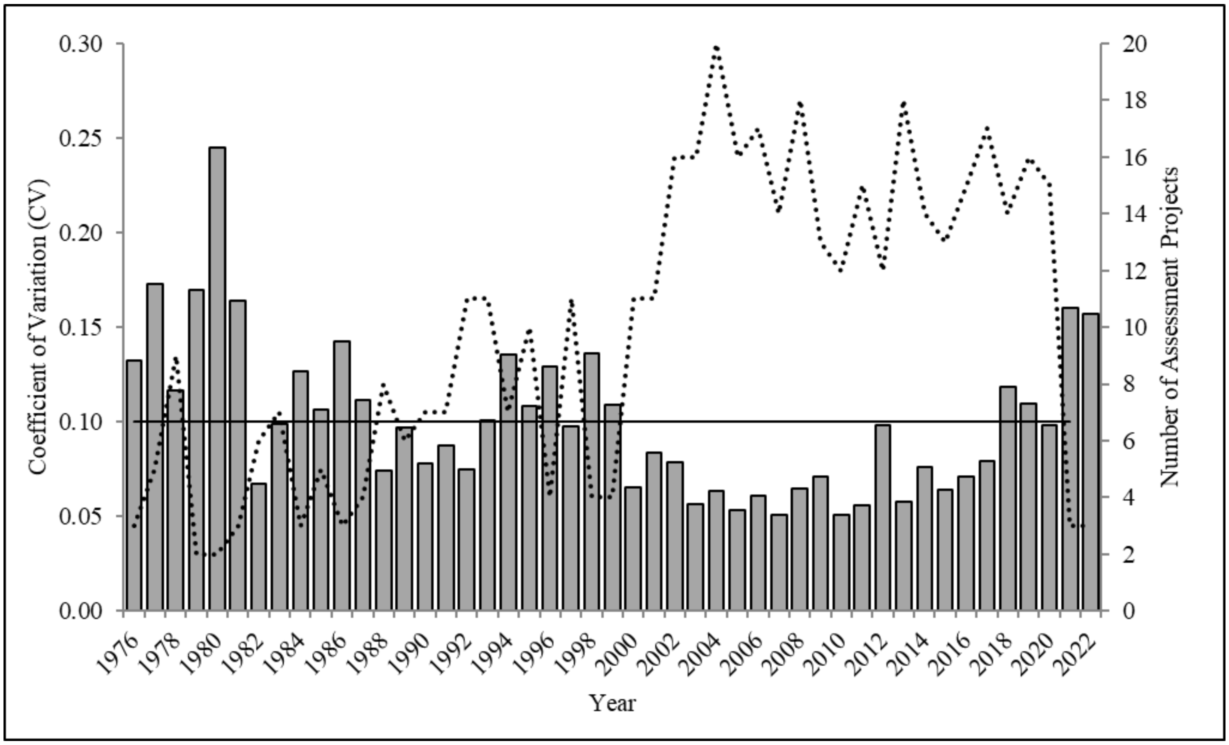

Figure 3.–Annual uncertainty (coefficient of variation; grey bars) of the run reconstruction model estimate of total run size and the number of assessment projects (dotted black line) used to inform the model in each year.

Note: The solid black line is the average coefficient of variation (10%) across years 1976–2021.

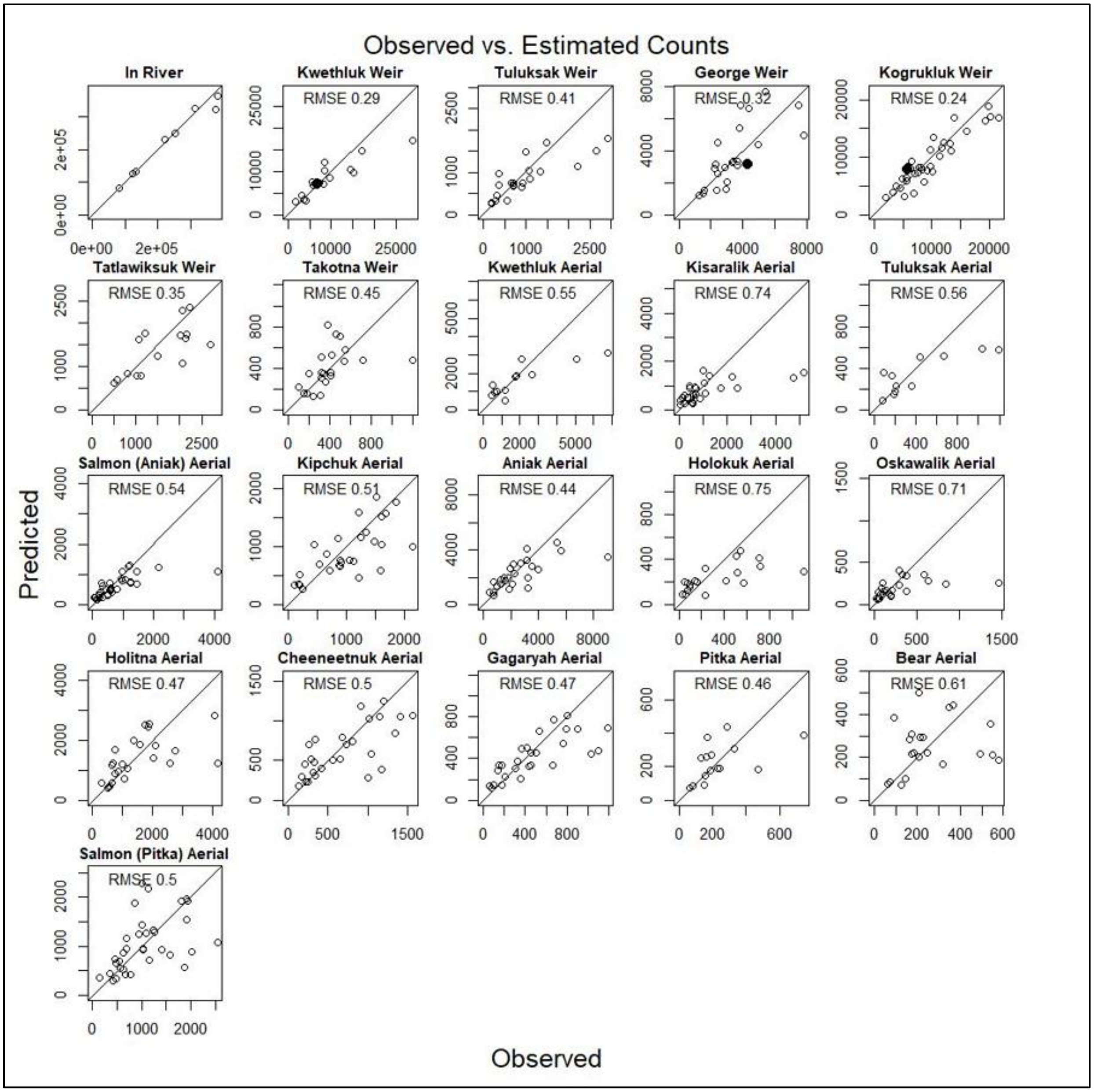

Figure 4.–Observed versus model estimated escapement counts.

Note: The diagonal line within each subplot represents the 1:1 line, which is the point at which observed and estimated escapements are equal. Hollow dots are the prior year observations and solid dots are the 2022 observations. Dots that fall below the 1:1 line indicate that the observed counts are higher than the model estimates, and the opposite is also true. The top left subplot titled "Inriver" is the 2003–2007 and 2014–2017 total run estimates used to scale the model.

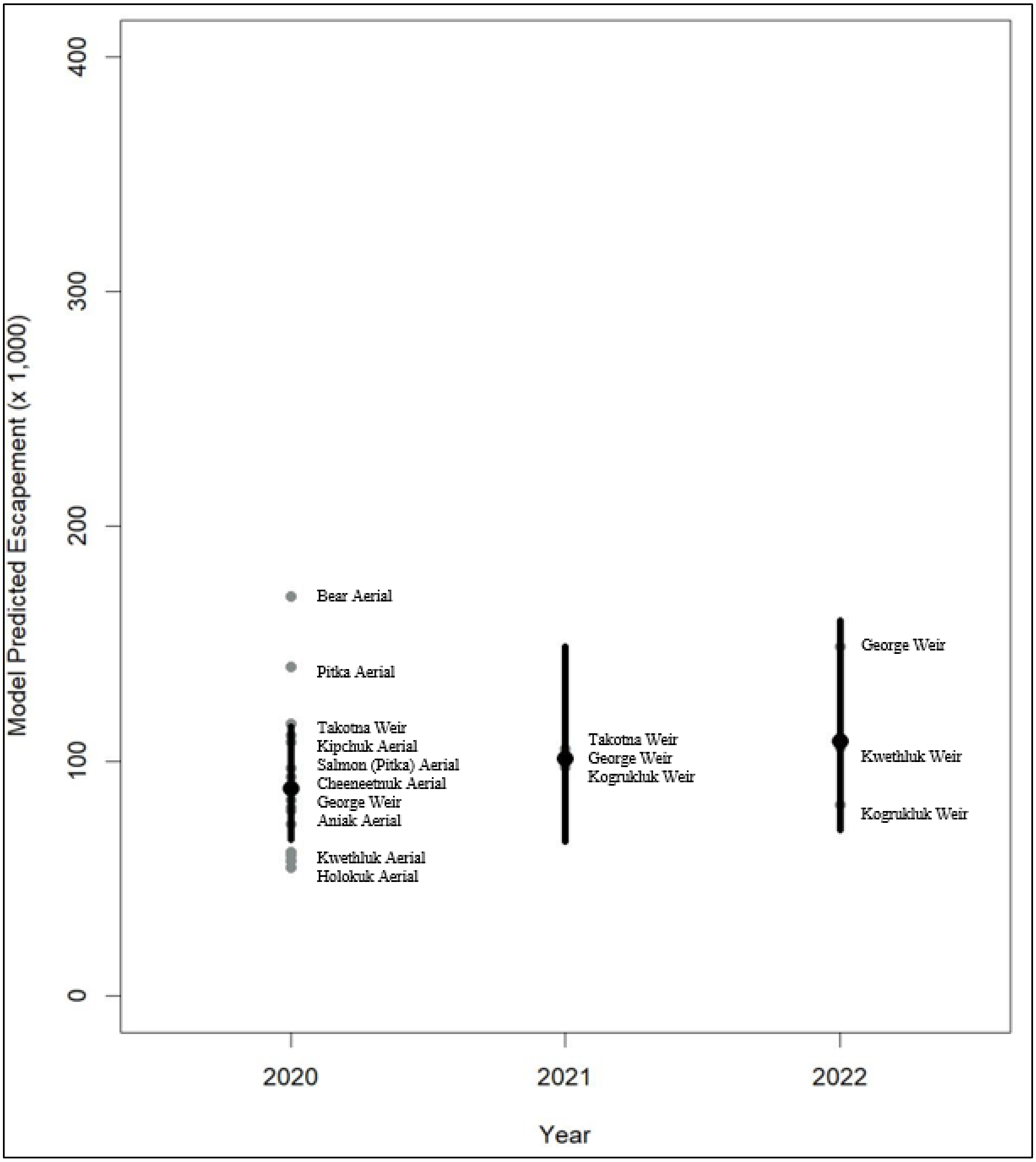

Figure 5.–Range of drainagewide escapement estimates produced by the model based on each escapement project.

Note: Grey dots are individual project estimates of the total run based on the model estimated scaling factor. Black dots and lines show the model derived drainagewide escapement and 95% confidence interval after simultaneously combining the information from all escapement monitoring projects. Estimates for years 2020 and 2021 are shown to provide context for 2022 results.

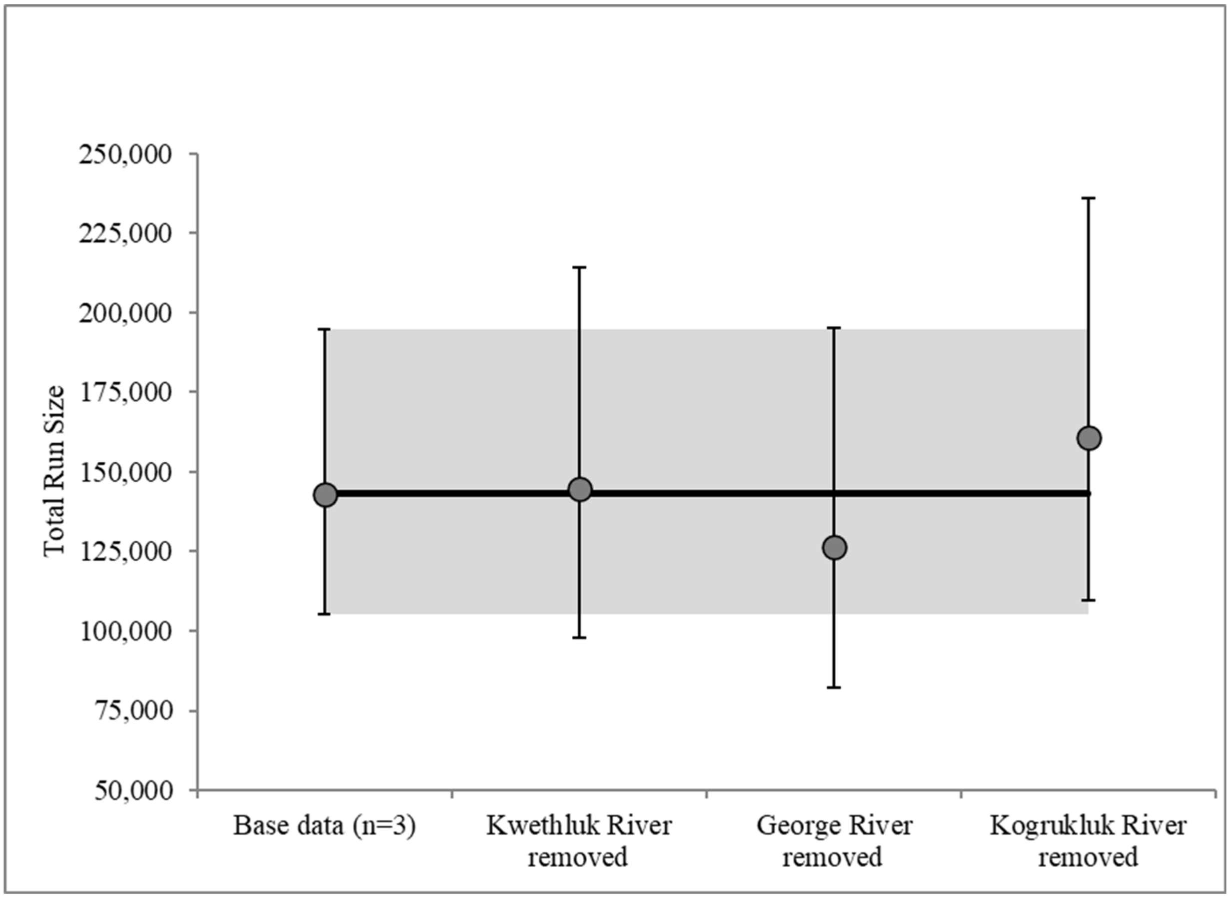

Figure 6.–Sensitivity of 2022 Chinook salmon total run size estimates using all available data (base data) and removal of single escapement monitoring projects (dots).

Note: The solid black line is the point estimate of the ADF&G base model, and the grey shaded area is the 95% confidence interval. Alternative estimates (dots) and 95% confidence intervals are shown for comparison. The amount of overlap with the grey shaded area indicates the degree of similarity between estimates.

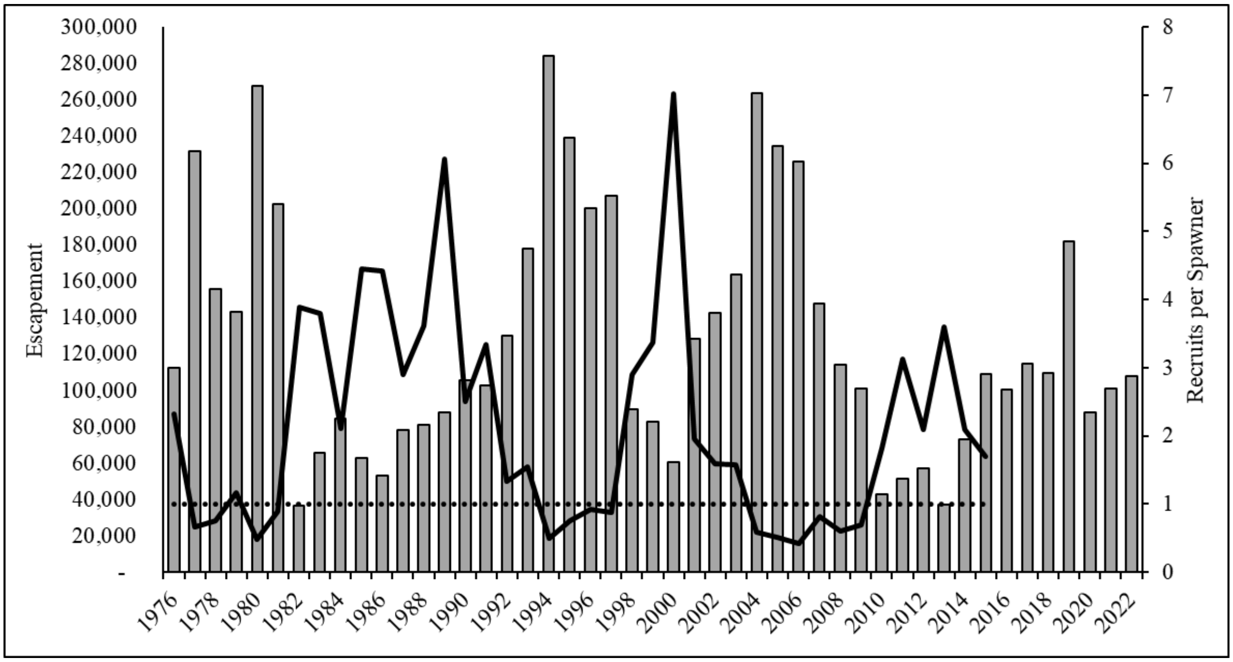

Figure 7.–Escapement (bars), recruits per spawner (solid line), and the 1:1 replacement line for recruits per spawner (dotted line) for Kuskokwim River Chinook salmon, 1976–2022.

APPENDIX A: 2022 NPFMC 3-SYSTEM INDEX LETTER

THE STATE of ALASKA
GOVERNOR MIKE DUNLEAVY

Department of Fish and Game

Division of Commercial Fisheries
Headquarters Office

1255 West 8th Street
P.O. Box 115526
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Main: 907.465.4210
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September 22, 2022

Jon Kurland, Administrator
NOAA Fisheries, Alaska Region
PO Box 21668
Juneau, Alaska 99802-1668

Dear Mr. Kurland,

In April 2015, the North Pacific Fishery Management Council (Council) adopted an action that lowers Chinook salmon bycatch caps in the Bering Sea walleye pollock fishery when Chinook salmon abundance in Western Alaska is at historically low levels.[1] The Council's action identifies historically low Western Alaskan Chinook salmon abundance using a three-system index of inriver adult Chinook salmon run sizes from the Unalakleet, Upper Yukon, and Kuskokwim rivers combined at or below the threshold level of 250,000 fish. The Council's action also specified a process by which the Alaska Department of Fish and Game (department) would provide postseason abundance estimates to the National Marine Fisheries Service (NMFS) by October 1, following the salmon season each year. If the threshold is not met, the performance standard and hard cap applicable to the Bering Sea walleye pollock fishery would be lowered in the following year.

Methods and analyses used by the department to estimate the postseason run size for each of the three systems have been approved by the Council, and there were no changes to those methods in 2022. The methods used for the Unalakleet and Upper Yukon rivers are consistent with what is outlined in the Council's public review analysis.[2] Methods used for the Kuskokwim River were approved by the Council in June 2018[3].

The 2022 three-system index of inriver adult Chinook salmon run sizes from the Unalakleet, Upper Yukon, and Kuskokwim rivers is 158,646 and is below the threshold level of 250,000.

The following details the preliminary total run estimates for each system:

Unalakleet River

The preliminary postseason run size estimate of Unalakleet River Chinook salmon is **1,799**, based on the sum of reported commercial harvest, expected subsistence harvest, and estimated total escapement. A total of nine Chinook salmon were commercially harvested in Norton Sound Subdistrict 6 (Unalakleet Subdistrict), and the total catch was assumed to be bound for the Unalakleet River. The department estimates approximately 500 Unalakleet River Chinook salmon were harvested for subsistence uses in 2022. Subsistence harvest in 2022 is expected to be smaller than the 2021 harvest (890 fish) due to reduced fishing opportunities in response to poor Chinook salmon abundance and concerns for not meeting the established escapement goal on the North River. The North River Tower and Unalakleet River weir operated successfully during much of the target operational period, with less than 10% of the total escapement estimated. The preliminary total escapement of Chinook salmon to the Unalakleet River drainage was estimated to be 1,290 and is considered reliable (95% CI[4]: 1,032–1,548). Over 90% of the drainagewide escapement was observed in the North River

[1] https://npfmc.legistar.com/LegislationDetail.aspx?ID=2237783&GUID=89E4DA9C-19B8-4BDE-8643-B19D68DD9EE3
[2] Public Review draft Environmental Assessment/ Regulatory Impact Review/ Initial Regulatory Flexibility Analysis for Proposed Amendment to the Fishery Management Plan for Bering Sea Aleutian Islands Groundfish Bering Sea Chinook and Chum salmon bycatch management measures, March 2015.
[3] https://npfmc.legistar.com/LegislationDetail.aspx?ID=3486558&GUID=81056FD0-C9E8-4376-BD59-C2F6084C82E9&Options=ID|Text|&Search=Kuskokwim
[4] CI: confidence interval

-continued-

Jon Kurland- 2 - September 22, 2021

(1,179) while the Unalakleet River weir documented the lowest Chinook salmon escapement (111), since that project began in 2010.

Upper Yukon River

An unprecedented record low run size of Upper Yukon River Chinook salmon returned in 2022. The preliminary postseason run size estimate of Upper Yukon River Chinook salmon is **13,225**, based on the preliminary assessment of total passage into Canada and expectations of the total harvest in Alaska. Chinook salmon passage into Canada was based on a sonar project operated near the U.S./Canada border, downriver from Eagle, Alaska. The preliminary sonar count is 12,025 (90% CI: 11,829–12,221). The total harvest of Upper Yukon River Chinook salmon in Alaska is expected to be about 1,200. The potential for a very small Chinook salmon run was forecasted preseason, and inseason assessment indicated both the Chinook salmon and chum salmon runs were very weak. As such, conservation actions were implemented to protect both Chinook salmon and chum salmon which co-migrate throughout much of the Yukon River. There were no commercial salmon fisheries opened in the Yukon River drainage in 2022, relevant sport fisheries were closed, subsistence fishing was closed for all salmon beginning June 2 in the lower portion of the river, and subsistence closures were applied in upriver districts commensurate with salmon run timing. Limited harvest of Upper Yukon River Chinook salmon occurred in test fisheries operated by the department and in small-mesh gillnet opportunities directed at non-salmon species. The 2022 preliminary harvest of 1,200 is a maximum expectation and was informed by the 2021 harvest of Canadian-origin Chinook salmon, which resulted from full subsistence salmon fishing closures like those imposed in 2022. The preliminary total run size of Upper Yukon River Chinook salmon was well below the lower end of the preseason run forecast (80% CI: 41,000–62,000), and about half of the inseason run size estimate (i.e., 20,000) based on independent sonar and genetic stock identification programs operated in the lower portion of the Yukon River.

Kuskokwim River

The preliminary postseason run size estimate of Kuskokwim River Chinook salmon is **143,622** fish (95% CI: 106,565–193,565), based on preliminary results of a maximum likelihood model. The total run estimate was informed by direct observations of escapement and an expectation of drainagewide harvest. The preliminary escapement estimate (105,774) is uncertain (95% CI: 68,717–155,717) because the model was informed by only three weir projects. Poor weather conditions prevented the department from flying aerial surveys during the 2022 season, and those indices of escapement were not available to inform the model. The total harvest of Kuskokwim River Chinook salmon is expected to be 37,848. No commercial harvest of Kuskokwim River Chinook salmon occurred during the 2022 season. Nearly all harvest occurred in the subsistence fishery, and minimal harvest occurred in test fisheries operated by the department and collaborators. Subsistence fishing restrictions were implemented throughout the Chinook salmon run in 2022. U.S. Fish and Wildlife Service (USFWS) estimated that approximately 29,300 Chinook salmon were harvested within a portion of the Yukon Delta National Wildlife refuge during subsistence fishing openings announced by Federal Special Actions. A preliminary estimate of drainagewide subsistence harvest was generated using a six-year relationship between partial harvest estimates developed inseason by USFWS and drainagewide estimates developed postseason by the department. The preliminary total run size of Kuskokwim River Chinook salmon was within the preseason run forecast of 99,000–161,000 fish and is consistent with an independent partial run estimate of 144,997 (90% CI: 114,988–175,006) Chinook salmon, based on a sonar project operated near Bethel, Alaska.

Sincerely,

Sam Rabung
Director, Division of Commercial Fisheries

cc: Doug Vincent-Lang, Commissioner
Rachel Baker, Deputy Commissioner
David Witherell, NPFMC

APPENDIX B: 2022 ADMB-CODE WITH ANNOTATIONS

Appendix B1.–2022 ADMB-code with annotations.

```
//==============================================================================
//DATA SECTION
//==============================================================================
DATA_SECTION

  init_int nyear; // number of years with datae
  init_int nweek; // number of weeks for harvest data
  init_int nweir; // number of weir sites
  init_int nair;  // number of aerial survey sites

  init_matrix testf(1,nyear,1,nweek); //Estimates of run proportion by week

  init_matrix ceff(1,nyear,1,nweek);  // Weekly effort commercial fishery
  init_matrix ccat(1,nyear,1,nweek);  // Weekly catch commercial fishery
  init_matrix creg(1,nyear,1,nweek);  // Weekly indicator of fishery regulation

  init_vector inriv(1,nyear);        // Annual in-river run estimate
  init_vector inriv_sd(1,nyear);      // SD of annual in-river run estimate

  init_vector tcatch(1,nyear);         // Total harvest across all fishery sectors
  init_matrix esc_w(1,nyear,1,nweir);   // Weir escapement indices
  init_matrix esc_a(1,nyear,1,nair);    // Aerial escapement indices

  init_vector minesc(1,nyear);            // Minimum annual escapement
  init_vector minrun(1,nyear);            // Minimum annual run size
  init_vector ubrun(1,nyear);             // Upper bounds for annual run size estimation

//==========================================================
// Parameter Section
//==========================================================
PARAMETER_SECTION
  init_bounded_number_vector log_trun(1,nyear,minrun,ubrun,1);  // log drainage-wide run
  init_bounded_vector log_wesc(1,nweir,0,7,1);   // log slope for weir counts
  init_bounded_vector log_aesc(1,nair,0,7,1);    // log slope for aerial counts
  init_bounded_vector log_q(1,2,-12,-9,1);       // log Catchability for different fishery sectors
  init_bounded_number log_cvw(-10,1,1);    // log cv for weir counts
  init_bounded_number log_cva(-10,1,1);     // log cv for aerial counts
  init_bounded_number log_cvq(-10,1,1);     // log cv for commercial cpue
  vector t_run(1,nyear);              // storage for untransformed total runs
  vector wesc(1,nweir);               // storage for untransformed weir escapement slopes
  vector aesc(1,nair);               // storage for untransformed aerial escapement slopes
  vector q(1,2);                    // storage for untransformed catchabilities
  number cvw;                // storage for untransformed weir cv parameters
  number cva;                // storage for untransformed aerial cv parameters
  number cvq;                                    // storage for untransformed fishery cv parameters
  matrix wk_est(1,nyear,1,nweek);     // storage matrix for the estimated number of fish available for harvest
each week
  number tfw;                       // likelihood for weir counts
  number tfa;                       // likelihood for aerial counts
```

```
  vector tfc(1,3);                    // likelihood for commercial CPUE
  number tft;                         // likelihood for in-river run estimates
  vector esc(1,nyear);                // vector of total escapement estimates
  number var1;                        // storage for Weir Escapement variance parameter
  number var2;                        // storage for Aerial Escapement variance parameter
  number var3;                                      // storage for CPUE variance parameter
  matrix cpue(1,3,1,nyear);                         // storage matrix for annual CPUE by fishery
  matrix testp(1,3,1,nyear);                 // testfish weekly run proportion

  objective_function_value objf;

INITIALIZATION_SECTION
  log_trun  12.5;
  log_wesc  5.0;
  log_aesc  4.0;
  log_q  -11.0;
  log_cvw  1.0;
  log_cva  1.0;
  log_cvq  1.0;

//=======================================================
// Calculate Annual run adjusted CPUE
//=======================================================
PRELIMINARY_CALCS_SECTION
   int i,j,k;
  for (i=1;i<=nyear;i++)
  {
  for (j=1;j<=nweek;j++)
       {
// Unrestricted mesh catch
    if(creg(i,j)==1)
          {
                    cpue(1,i) += ccat(i,j)/ceff(i,j);
                    testp(1,i) += testf(i,j);
          }
// Restricted mesh catch
    if(creg(i,j)==2)
          {
                    cpue(2,i) += ccat(i,j)/ceff(i,j);
                    testp(2,i) += testf(i,j);
                    }
// Mono-filament mesh catch
    if(creg(i,j)==3 or creg(i,j)==5)
          {
                    cpue(3,i) += ccat(i,j)/ceff(i,j);
                    testp(3,i) += testf(i,j);
                              }
       }
  }

//==========================================================
```

```
// Procedure Section
//==========================================================
PROCEDURE_SECTION

  objf = 0.0;

  convert_parameters_into_rates();

  evaluate_obj_func();

RUNTIME_SECTION
  maximum_function_evaluations 200000000
  convergence_criteria 1.e-30  //was 1.e-20 //low converge was .000001

//===========================================================
// Function convert_parameters_into_rates
//===========================================================
FUNCTION convert_parameters_into_rates

   t_run=exp(log_trun);
   wesc=exp(log_wesc);
   aesc=exp(log_aesc);
   q=exp(log_q);
   cvw=exp(log_cvw);
   cva=exp(log_cva);
   cvq=exp(log_cvq);
   var1 = log(square(cvw)+1);
   var2 = log(square(cva)+1);
   var3 = log(square(cvq)+1);

//===========================================================
// Function evaluate_obj_func
//===========================================================
FUNCTION evaluate_obj_func
   int i,j,k,l,ctr1,ctr2,ctr3;

   tfw= 0.0;
   tfa= 0.0;
   tft= 0.0;
   tfc=0.0;


   for (i=1;i<=nyear;i++)
   {
    esc(i)=t_run(i)-tcatch(i);

    if(inriv(i)>0)
    {
     tft+= 0.5*square(log(inriv(i))-log(t_run(i)))/log(square(inriv_sd(i)/inriv(i))+1);
            // In-River run estimate likelihood
    }
```

```
    // Weir likelihoods
    for(j=1;j<=nweir;j++)
    {
      if(esc_w(i,j)>0)
      {
        tfw += log(sqrt(var1))+0.5*square(log(esc_w(i,j))-log(esc(i)/wesc(j)))/var1;
      }
    }

// Aerial likelihoods
    for(k=1;k<=nair;k++)
    {
     if(esc_a(i,k)>0)
     {
      tfa += log(sqrt(var2))+0.5*square(log(esc_a(i,k))-log(esc(i)/aesc(k)))/var2;
     }
    }

//===  Calculate annual run adjusted CPUE ====================================

          if(cpue(1,i)>0)
          {
          tfc(1) += log(sqrt(var3))+0.5*square(log(cpue(1,i)/testp(1,i))-log(q(1)*t_run(i)))/var3;
          }
// Remove CPUE during the Restricted Period
//        if(cpue(2,i)>0)
//        {
//        tfc(2) += log(sqrt(var3))+0.5*square(log(cpue(2,i)/testp(2,i))-log(q(2)*t_run(i)))/var3;
//        }
          if(cpue(3,i)>0)
          {
          tfc(3) += log(sqrt(var3))+0.5*square(log(cpue(3,i)/testp(3,i))-log(q(2)*t_run(i)))/var3;
          }

   }

   objf+= tft+tfw+tfa+sum(tfc);

//==========================================================================
======
// Report Section
//==========================================================================
======
REPORT_SECTION

   report<<"Total Run"<< endl << t_run << endl;
   report<<"ObjFunc"<< endl << objf << endl;
   report<<"tfc"<<endl<< tfc <<endl;
   report<<"tft"<<endl<< tft <<endl;
   report<<"tfa"<<endl<< tfa <<endl;
```

```
  report<<"tfw"<<endl<< tfw <<endl;
  report<<"cvw"<<endl<< cvw << endl;
  report<<"cva"<<endl<< cva << endl;
  report<< "q" << endl << q << endl;
  report<< "wesc" <<endl<< wesc << endl;
  report<< "aesc" <<endl<< aesc << endl;
  report<<"tcatch"<<endl<< tcatch<<endl;
  report<<"TotalEscapement"<<endl<< esc << endl;

//==========================================================================
=======
// Globals Section
//==========================================================================
=======
GLOBALS_SECTION
  #include <df1b2fun.h>
  #include <math.h>
  #include <time.h>
  #include <statsLib.h>
  #include <adrndeff.h>
  #include <admodel.h>
  time_t start,finish;
  long hour,minute,second;
  double elapsed_time;

TOP_OF_MAIN_SECTION
  arrmblsize = 100000000;
  gradient_structure::set_MAX_NVAR_OFFSET(30000000);
  gradient_structure::set_GRADSTACK_BUFFER_SIZE(3000000);
  gradient_structure::set_CMPDIF_BUFFER_SIZE(100000000);
  time(&start);

FINAL_SECTION
 // Output summary stuff
  time(&finish);
  elapsed_time = difftime(finish,start);
  hour = long(elapsed_time)/3600;
  minute = long(elapsed_time)%3600/60;
  second = (long(elapsed_time)%3600)%60;
  cout << endl << endl << "Starting time: " << ctime(&start);
  cout << "Finishing time: " << ctime(&finish);
  cout << "This run took: " << hour << " hours, " << minute << " minutes, " << second << " seconds." <<
endl << endl;
```

APPENDIX C: MODEL INPUT DATA

Appendix C1.–Independent estimates of Kuskokwim River Chinook salmon abundance, used to scale the run reconstruction model.

Conventional name:	Year	Total run	Standard error
	2003	222,145	16,055
	2004	381,958	36,322
	2005	312,353	21,083
	2006	376,291	31,094
	2007	251,781	16,315
	2014	80,399	8,605
	2015	124,421	9,362
	2016	131,090	12,632
	2017	133,292	15,702

Appendix C2.–Harvest of Kuskokwim River Chinook salmon.

Var name:	Year	H.Com	H.Sub	H.Sports	H.Test
Conventional name:	Year	Commercial	Subsistence	Sport	Testfish
	1976	30,735	58,606	–	1,206
	1977	35,830	56,580	33	1,264
	1978	45,641	36,270	116	1,445
	1979	38,966	56,283	74	979
	1980	35,881	59,892	162	1,033
	1981	47,663	61,329	189	1,218
	1982	48,234	58,018	207	542
	1983	33,174	47,412	420	1,139
	1984	31,742	56,930	273	231
	1985	37,889	43,874	85	79
	1986	19,414	51,019	49	130
	1987	36,179	67,325	355	384
	1988	55,716	70,943	528	576
	1989	43,217	81,175	1,218	543
	1990	53,502	109,778	394	512
	1991	37,778	74,820	401	149
	1992	46,872	82,481	367	1,380
	1993	8,735	87,830	587	2,515
	1994	16,211	102,817	1,139	1,937
	1995	30,846	101,921	541	1,421
	1996	7,419	96,477	1,432	247
	1997	10,441	79,334	1,227	332
	1998	17,359	80,969	1,434	210
	1999	4,705	73,538	252	98
	2000	444	67,596	105	64
	2001	90	78,174	290	86
	2002	72	81,169	319	288
	2003	158	67,737	401	409
	2004	2,305	96,788	857	691
	2005	4,784	85,863	572	557
	2006	2,777	90,812	444	352
	2007	179	94,898	1,478	305
	2008	8,865	88,912	708	420
	2009	6,664	79,896	904	470
	2010	2,732	67,286	354	292
	2011	747	62,366	579	337
	2012	627	22,544	0	321
	2013	174	47,113	0	201
	2014	35	11,234	0	497
	2015	8	16,124	0	472
	2016	0	30,693	0	525
	2017	0	16,380	0	290
	2018	0	22,266	0	465
	2019	0	37,941	0	563
	2020	0	35,846	0	355
	2021	0	28,365	0	386
	2022	0	34,134	0	381

Appendix C3.–Weir escapement counts of Kuskokwim River Chinook salmon.

Var name:	Year	w.kwe	w.tul	w.geo	w.kog	w.tat	w.tak
Conventional name:	Year	Kwethluk	Tuluksak	George	Kogrukluk	Tatlawiksuk	Takotna
	1976	–	–	–	5,822	–	–
	1977	–	–	–	–	–	–
	1978	–	–	–	13,436	–	–
	1979	–	–	–	11,437	–	–
	1980	–	–	–	–	–	–
	1981	–	–	–	16,075	–	–
	1982	–	–	–	–	–	–
	1983	–	–	–	–	–	–
	1984	–	–	–	4,922	–	–
	1985	–	–	–	4,479	–	–
	1986	–	–	–	–	–	–
	1987	–	–	–	–	–	–
	1988	–	–	–	8,603	–	–
	1989	–	–	–	–	–	–
	1990	–	–	–	10,093	–	–
	1991	–	697	–	7,602	–	–
	1992	9,675	1,083	–	6,471	–	–
	1993	–	2,218	–	12,157	–	–
	1994	–	2,932	–	–	–	–
	1995	–	–	–	20,249	–	–
	1996	–	–	7,501	13,900	–	423
	1997	–	–	7,810	13,116	–	1,197
	1998	–	–	–	–	–	–
	1999	–	–	–	5,567	1,484	–
	2000	3,547	–	2,956	3,254	808	345
	2001	–	924	3,313	8,151	2,013	718
	2002	8,543	1,346	2,445	9,830	2,237	326
	2003	14,475	1,067	–	11,751	–	378
	2004	28,801	1,475	5,392	19,880	2,833	461
	2005	–	2,653	3,845	21,686	2,858	499
	2006	17,019	1,008	4,359	19,305	1,700	537
	2007	15,112	374	4,972	–	2,058	412
	2008	5,642	707	3,383	9,740	1,194	413
	2009	5,826	362	3,664	9,201	1,071	311
	2010	1,716	201	1,500	5,160	554	183
	2011	4,056	284	1,605	6,926	1,011	149
	2012	–	559	2,362	–	1,116	238
	2013	–	198	1,267	1,919	495	104
	2014	3,191	325	2,988	3,726	2,050	–
	2015	8,163	711	2,301	8,333	2,131	–
	2016	–	909	2,218	7,062	2,693	–
	2017	7,207	648	3,669	7,787	2,146	318
	2018	–	–	3,322	6,292	–	205
	2019	8,505	–	3,828	10,301	–	554
	2020	–	–	2,418	5,645	–	357
	2021	–	–	2,920	6,969	–	323
	2022	6,808	–	4,318	5,837	–	–

Note: En dash means no data.

Appendix C4.–Peak aerial survey index counts of Kuskokwim River Chinook salmon.

Var name:	Year	a.kwe	a.kis	a.tul	a.sla	a.kip	a.ank	a.hlk	a.osk	a.hlt	a.che	a.gag	a.pit	a.ber	a.slp
Conventional name:	Year	Kwethluk	Kisaralik	Tuluksak	Salmon (Aniak)	Kipchuk	Aniak	Holokuk	Oskawalik	Holitna	Cheeneetnuk	Gagaryah	Pitka	Bear	Salmon (Pitka)
	1976	–	–	–	–	–	–	–	–	2,571	–	663	–	182	–
	1977	2,075	–	439	–	–	–	–	–	–	1,407	897	–	–	1,930
	1978	1,722	2,417	–	289	–	–	–	–	2,766	268	504	–	227	1,100
	1979	–	–	–	–	–	–	–	–	–	–	–	–	–	682
	1980	–	–	1,035	1,186	–	–	–	–	–	–	–	–	–	–
	1981	–	–	–	–	–	9,074	–	–	–	–	–	–	93	–
	1982	–	81	–	126	–	–	–	–	521	–	–	–	127	413
	1983	471	–	186	231	–	1,909	–	–	1,069	173	–	–	–	572
	1984	–	–	–	–	–	–	–	–	–	1,177	–	–	–	545
	1985	–	63	–	–	–	–	–	–	–	1,002	–	–	–	620
	1986	–	–	–	336	–	424	–	–	650	–	–	–	–	–
	1987	–	–	–	516	193	–	–	193	–	317	205	–	–	–
	1988	622	869	195	244	–	954	–	80	–	–	–	–	–	474
	1989	1,157	152	–	631	1,598	2,109	–	–	–	–	–	–	–	452
	1990	–	631	205	596	537	1,255	–	113	–	–	–	–	–	–
	1991	–	217	358	583	885	1,564	–	–	–	–	–	–	–	–
	1992	–	–	–	335	670	2,284	–	91	2,022	1,050	328	–	–	2,536
	1993	–	–	–	1,082	1,248	2,687	233	103	1,573	678	419	–	–	1,010
	1994	–	1,021	–	1,218	1,520	–	–	–	–	1,206	807	–	–	1,010
	1995	–	1,243	–	1,446	1,215	3,171	–	326	1,887	1,565	1,193	–	–	1,911
	1996	–	–	–	985	–	–	–	–	–	–	–	–	–	–
	1997	–	439	–	980	855	2,187	–	1,470	2,093	345	364	–	–	–
	1998	–	457	–	557	443	1,930	–	–	–	–	–	–	–	–
	1999	–	–	–	–	–	–	–	98	741	–	–	–	–	–
	2000	–	–	–	238	182	714	–	62	301	–	–	151	–	362
	2001	–	–	–	598	–	–	52	–	4,156	–	143	–	175	1,033
	2002	1,795	1,727	–	1,236	1,615	–	513	295	733	730	452	165	211	1,255

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Var name:	Year	a.kwe	a.kis	a.tul	a.sla	a.kip	a.ank	a.hlk	a.osk	a.hlt	a.che	a.gag	a.pit	a.ber	a.slp
Conventional name:	Year	Kwethluk	Kisaralik	Tuluksak	Salmon (Aniak)	Kipchuk	Aniak	Holokuk	Oskawalik	Holitna	Cheeneetnuk	Gagaryah	Pitka	Bear	Salmon (Pitka)
	2003	2,661	654	94	1,242	1,493	3,514	1,096	844	–	810	1,095	197	176	1,242
	2004	6,801	5,157	1,196	2,177	1,868	5,362	539	293	4,051	918	670	290	206	1,138
	2005	5,059	2,206	672	4,097	1,679	–	510	582	1,760	1,155	788	744	367	1,801
	2006	–	4,734	–	–	1,618	5,639	705	386	1,866	1,015	531	170	347	862
	2007	–	692	173	1,458	2,147	3,984	–	–	–	–	1,035	131	165	943
	2008	487	1,074	–	589	1,061	3,222	418	213	–	290	177	242	245	1,033
	2009	–	–	–	–	–	–	565	379	–	323	303	187	209	632
	2010	–	235	–	–	–	–	229	–	587	–	62	67	75	135
	2011	–	534	–	79	116	–	61	26	–	249	96	85	145	767
	2012	–	588	–	49	193	–	36	51	–	229	178	–	–	670
	2013	1,165	599	83	154	261	754	–	38	532	138	74	–	64	469
	2014	–	622	–	497	1,220	3,201	80	200	–	340	359	–	–	1,865
	2015	–	709	–	810	917	–	77	–	662	–	–	–	–	2,016
	2016	–	622	–	–	898	718	100	47	1,157	217	135	–	580	1,578
	2017	–	–	–	423	889	1,781	140	136	676	660	453	234	492	687
	2018	–	584	–	442	1,123	1,534	162	–	980	565	438	471	550	1,399
	2019	–	1,063	–	950	1,344	3,160	719	638	1,377	1,345	760	330	542	1,918
	2020	721	350	–	269	723	1,264	99	169	854	419	–	160	321	1,150
	2021[a]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2022[a]	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note: En dash means no data. Only surveys rated good or fair were used. Only surveys flown between July 17 and August 5, inclusive, were used. Chinook salmon live and carcass counts were combined.

[a] No aerial surveys were flown due to inclement weather.

Appendix C5.–Proportion of total annual Chinook salmon run in District W-1, by week, as estimated by Bethel test fishery.

Var name:	Year	rpw.3	rpw.4	rpw.5	rpw.6	rpw.7	rpw.8	rpw.9	rpw.10
Conventional name:	Year	6/10/–6/16	6/17–6/23	6/24–6/30	7/1–7/7	7/8–7/14	7/15–7/21	7/22–7/28	7/29–8/26
	1976	–	–	–	–	–	–	–	–
	1977	–	–	–	–	–	–	–	–
	1978	–	–	–	–	–	–	–	–
	1979	–	–	–	–	–	–	–	–
	1980	–	–	–	–	–	–	–	–
	1981	–	–	–	–	–	–	–	–
	1982	–	–	–	–	–	–	–	–
	1983	–	–	–	–	–	–	–	–
	1984	0.2243	0.2903	0.1488	0.1633	0.0509	0.0522	0.0090	0.0173
	1985	0.0000	0.0930	0.2427	0.4306	0.1504	0.0247	0.0175	0.0410
	1986	0.1503	0.4039	0.1656	0.1399	0.0488	0.0097	0.0241	0.0000
	1987	0.1988	0.3070	0.2368	0.1137	0.0210	0.0344	0.0130	0.0094
	1988	0.2080	0.3086	0.1786	0.0852	0.0218	0.0419	0.0145	0.0192
	1989	0.1769	0.2780	0.3474	0.0976	0.0258	0.0190	0.0119	0.0112
	1990	0.1434	0.2095	0.3325	0.1492	0.0609	0.0136	0.0266	0.0256
	1991	0.0593	0.2965	0.2942	0.1994	0.0337	0.0430	0.0000	0.0000
	1992	0.3466	0.1791	0.2132	0.1085	0.0542	0.0554	0.0000	0.0118
	1993	0.2148	0.4172	0.1270	0.0328	0.0273	0.0097	0.0000	0.0000
	1994	0.2883	0.3098	0.1396	0.1009	0.0138	0.0122	0.0000	0.0061
	1995	0.1566	0.3066	0.3005	0.0988	0.0300	0.0050	0.0097	0.0050
	1996	0.4007	0.2138	0.0963	0.0288	0.0214	0.0000	0.0066	0.0033
	1997	0.1913	0.5295	0.1196	0.0533	0.0357	0.0119	0.0079	0.0059
	1998	0.1166	0.2199	0.3866	0.1513	0.0378	0.0116	0.0055	0.0000
	1999	0.1360	0.1349	0.2469	0.1462	0.1903	0.0297	0.0754	0.0297
	2000	0.2089	0.3896	0.1530	0.0461	0.0205	0.0410	0.0000	0.0183
	2001	0.0791	0.4157	0.2510	0.1036	0.0528	0.0367	0.0000	0.0156
	2002	0.3547	0.2245	0.1601	0.1034	0.0337	0.0137	0.0089	0.0132
	2003	0.2764	0.2748	0.1433	0.0662	0.0351	0.0255	0.0112	0.0042
	2004	0.2130	0.2927	0.2513	0.0693	0.0406	0.0537	0.0160	0.0021
	2005	0.2335	0.2851	0.1876	0.1601	0.0768	0.0062	0.0000	0.0168
	2006	0.1299	0.3054	0.2935	0.1675	0.0535	0.0114	0.0142	0.0105
	2007	0.0996	0.2000	0.3114	0.2472	0.0754	0.0316	0.0095	0.0032

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Appendix C5.–Page 2 of 2.

Var name:	Year	rpw.3	rpw.4	rpw.5	rpw.6	rpw.7	rpw.8	rpw.9	rpw.10
Conventional name:	Year	6/10/–6/16	6/17–6/23	6/24–6/30	7/1–7/7	7/8–7/14	7/15–7/21	7/22–7/28	7/29–8/26
	2008	0.1524	0.2931	0.3057	0.1183	0.0431	0.0334	0.0083	0.0139
	2009	0.1955	0.2830	0.3460	0.0753	0.0323	0.0164	0.0000	0.0049
	2010	0.2190	0.3755	0.1517	0.1335	0.0556	0.0185	0.0113	0.0103
	2011	0.1188	0.2976	0.1996	0.1695	0.0818	0.0130	0.0000	0.0031
	2012	0.0508	0.2964	0.3308	0.2114	0.0627	0.0201	0.0088	0.0127
	2013	0.1681	0.3708	0.2654	0.0963	0.0743	0.0108	0.0000	0.0000
	2014	0.2834	0.2370	0.1217	0.0771	0.0148	0.0146	0.0000	0.0029
	2015	0.1859	0.2292	0.1520	0.1316	0.0625	0.0591	0.0338	0.0238
	2016	0.1696	0.1830	0.2085	0.1385	0.0722	0.0296	0.0197	0.0112
	2017	0.0899	0.2067	0.3202	0.1459	0.1117	0.0473	0.0266	0.0265
	2018	0.1979	0.1706	0.3085	0.174	0.0539	0.0231	0.0175	0.0108
	2019	0.1478	0.3298	0.2459	0.0473	0.0591	0.0165	0.0106	0.0000
	2020	0.1327	0.1895	0.2331	0.1599	0.1398	0.0435	0.0073	0.0124
	2021	0.1722	0.1931	0.2705	0.1270	0.1275	0.0284	0.0096	0.0000
	2022	0.1366	0.2747	0.3244	0.1117	0.0776	0.0170	0.0234	0.0000

Note: En dash means no data.

Appendix C6.–Chinook salmon catch and effort (permit-hours) for Kuskokwim River District W-1.

		Week 3 6/10–6/16			Week 4 6/17–6/23			Week 5 6/24–6/30		
Var name:	Year	chw.3	cew.3	cfw.3	chw.4	cew.4	cfw.4	chw.5	cew.5	cfw.5
Conventional name:	Year	Catch	Effort	Net	Catch	Effort	Net	Catch	Effort	Net
	1976	0	0	0	20,010	5,724	1	4,143	2,088	2
	1977	12,458	2,802	1	16,227	2,904	1	1,841	4,722	2
	1978	18,483	3,972	1	10,066	2,004	1	3,723	5,346	2
	1979	24,633	6,432	1	5,651	3,012	2	3,860	6,438	2
	1980	9,891	2,814	1	21,698	5,364	4	1,460	2,448	2
	1981	29,882	6,180	1	3,830	3,066	2	4,563	5,952	2
	1982	4,912	2,784	1	24,628	5,970	1	12,555	5,176	4
	1983	13,406	5,634	1	8,063	5,544	2	4,925	5,958	2
	1984	0	0	0	17,181	5,562	1	5,643	5,616	2
	1985	0	0	0	6,519	2,538	3	19,204	5,880	3
	1986	0	0	0	0	0	0	11,986	6,540	3
	1987	0	0	0	19,126	4,734	3	0	0	0
	1988	12,640	4,816	3	11,708	3,672	3	15,060	7,518	3
	1989	0	0	0	15,215	5,208	3	11,094	6,144	3
	1990	0	0	0	16,690	3,780	3	25,459	7,536	3
	1991	0	0	0	13,813	3,606	3	12,612	3,696	3
	1992	0	0	0	24,334	9,488	3	16,307	8,628	3
	1993	0	0	0	0	0	0	8,184	4,976	3
	1994	0	0	0	0	0	0	14,221	4,608	3
	1995	0	0	0	6,895	2,276	3	14,424	4,532	3
	1996	0	0	0	4,091	1,056	3	666	360	3
	1997	0	0	0	10,023	2,118	3	0	0	0
	1998	0	0	0	0	0	0	12,771	4,584	3
	1999	0	0	0	0	0	0	4,668	2,454	3
	2000	0	0	0	0	0	0	0	0	0
	2001	0	0	0	0	0	0	0	0	0
	2002	0	0	0	0	0	0	0	0	0
	2003	0	0	0	0	0	0	0	0	0
	2004	0	0	0	0	0	0	520	104	3
	2005	0	0	0	0	0	0	3,531	1,189	3
	2006	0	0	0	0	0	0	2,493	1,038	3
	2007	0	0	0	0	0	0	0	0	0
	2008	0	0	0	6,415	1,026	3	2,362	783	3
	2009	0	0	0	3,003	668	3	2,539	752	3
	2010	0	0	0	0	0	0	1,724	1,324	5
	2011	0	0	0	0	0	0	0	0	0
	2012	0	0	0	0	0	0	0	0	0
	2013	0	0	0	0	0	0	0	0	0
	2014	0	0	0	0	0	0	0	0	0
	2015	0	0	0	0	0	0	0	0	0
	2016	0	0	0	0	0	0	0	0	0
	2017	0	0	0	0	0	0	0	0	0
	2018	0	0	0	0	0	0	0	0	0
	2019	0	0	0	0	0	0	0	0	0
	2020	0	0	0	0	0	0	0	0	0
	2021	0	0	0	0	0	0	0	0	0
	2022	0	0	0	0	0	0	0	0	0

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		Week 6 7/1–7/7			Week 7 7/8–7/14			Week 8 7/15–7/21			Week 9 7/22–7/28		
Var name:	Year	chw.6	cew.6	cfw.6	chw.7	cew.7	cfw.7	chw.8	cew.8	cfw.8	chw.9	cew.9	cfw.9
Conventional name:	Year	Catch	Effort	Net	Catch	Effort	Net	Catch	Effort	Net	Catch	Effort	Net
	1976	1,550	2,490	2	1,238	4,548	2	236	1,590	2	0	0	0
	1977	673	4,194	2	153	2,310	2	0	0	0	0	0	0
	1978	2,354	8,676	2	153	2,310	2	0	0	0	0	0	0
	1979	1,233	3,252	2	470	3,120	2	0	0	0	0	0	0
	1980	498	2,298	2	445	2,586	2	0	0	0	0	0	0
	1981	2,795	5,520	2	941	2,640	2	0	0	0	0	0	0
	1982	1,970	3,968	2	1,055	4,734	2	0	0	0	0	0	0
	1983	2,415	5,634	2	633	2,796	2	0	0	0	0	0	0
	1984	3,206	5,454	2	2,069	5,592	2	744	2,238	2	0	0	0
	1985	9,942	5,844	3	0	0	0	0	0	0	0	0	0
	1986	5,029	6,852	3	1,156	3,192	3	0	0	0	0	0	0
	1987	9,606	6,948	3	1,910	3,582	3	2,758	6,720	3	0	0	0
	1988	5,871	6,954	3	5,270	10,794	3	1,728	6,636	3	662	6,276	3
	1989	7,911	7,092	3	6,043	10,962	3	868	2,622	3	210	3,372	3
	1990	4,071	3,546	3	4,931	8,534	3	0	0	0	0	0	0
	1991	8,068	7,308	3	904	3,426	3	452	3,408	3	419	7,522	3
	1992	3,250	4,696	3	0	0	0	0	0	0	0	0	0
	1993	0	0	0	0	0	0	0	0	0	0	0	0
	1994	0	0	0	578	1,984	3	441	3,000	3	538	6,348	3
	1995	4,368	3,824	3	1,452	3,716	3	568	3,488	3	0	0	0
	1996	861	836	3	408	896	3	251	1,195	3	307	6,398	3
	1997	0	0	0	0	0	0	0	0	0	0	0	0
	1998	2,277	1,780	3	1,127	1,668	3	0	0	0	816	4,296	3
	1999	0	0	0	0	0	0	0	0	0	0	0	0
	2000	357	896	3	0	0	0	0	0	0	0	0	0
	2001	0	0	0	0	0	0	0	0	0	0	0	0
	2002	0	0	0	0	0	0	0	0	0	0	0	0
	2003	0	0	0	0	0	0	0	0	0	0	0	0
	2004	1,107	446	3	0	0	0	0	0	0	127	360	3
	2005	874	604	3	0	0	0	0	0	0	0	0	0
	2006	0	0	0	0	0	0	0	0	0	0	0	0
	2007	0	0	0	0	0	0	0	0	0	0	0	0
	2008	19	4	3	1	6	3	0	6	0	0	12	0
	2009	762	519	3	113	436	3	83	672	3	58	752	3
	2010	290	522	3	271	686	3	186	958	3	176	1,632	3
	2011	361	634	5	227	996	5	129	1,226	5	24	1,668	5
	2012	0	0	0	45	604	5	195	1,616	5	39	1,464	5
	2013	0	0	0	0	0	0	139	2,018	5	21	1,556	5
	2014	0	0	0	14	584	5	14	2,276	5	0	0	0
	2015	0	0	0	0	0	0	0	0	0	0	0	0
	2016	0	0	0	0	0	0	0	0	0	0	0	0
	2017	0	0	0	0	0	0	0	0	0	0	0	0
	2018	0	0	0	0	0	0	0	0	0	0	0	0
	2019	0	0	0	0	0	0	0	0	0	0	0	0
	2020	0	0	0	0	0	0	0	0	0	0	0	0
	2021	0	0	0	0	0	0	0	0	0	0	0	0
	2022	0	0	0	0	0	0	0	0	0	0	0	0

Note: Key to column net:

1 = Gillnet mesh size unrestricted.
2 = Gillnets were restricted to 6" or less - old gear.
3 = Gillnets were restricted to 6" or less - new gear.
4 = Both unrestricted and restricted mesh size periods in the week.
5 = Personal use harvest also included in catch and effort calculations - 6" or less new gear.