Regional Information Report 3A20-02

2019 Kuskokwim River Chinook Salmon Run Reconstruction and 2020 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 2019 drainagewide run size and escapement of Kuskokwim River Chinook salmon (*Oncorhynchus tshawytscha*). Total run and escapement were estimated to be 226,987 (95% CI: 182,811–281,839) and 188,483 (95% CI: 144,307–243,335) fish, respectively. Model estimates were informed by direct observations of the 2019 escapement at 16 locations (4 weirs and 12 aerial surveys) and 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 2019 run and escapement. The 2019 total run of Chinook salmon was the largest since 2007 and was probably above the 1976–2018 average of 215,529 fish. The drainagewide sustainable escapement goal of 65,000–120,000 was exceeded in 2019. The 2020 Kuskokwim River Chinook salmon forecast is for a range of 193,000–261,000 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 2019. Because it is not possible 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 sustainable management of the Kuskokwim River Chinook salmon fishery. Model results from Bue et al. (2012) contributed to a spawner-recruit analysis that was 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, and it was determined that the existing goal range was appropriate for this stock (Liller and Savereide 2018). 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 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 that is used by NPFMC to guide Chinook salmon bycatch thresholds in the Bering Sea pollock trawl fishery. The preliminary 2019 3-system abundance estimate was provided to the NPFMC on September 16, 2019 (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. As such, 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 recently 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). The revised model was adopted by ADF&G for the 2018 season (Smith 2019) and was also approved by the NPFMC for use in the 3-system index. There were no changes to the run reconstruction model for the 2019 season.

OBJECTIVE

The project objective was to estimate the total run size and escapement of Kuskokwim River Chinook salmon in 2019.

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 years 2003–2007 and 2014–2017 (Liller et al. 2018). Total annual harvests from commercial fish tickets and test fisheries were known with 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.

Total run and escapement of Kuskokwim River Chinook salmon was 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. To simplify the description of the estimation process, the methodology was divided into 3 components 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 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 (j) observed by method (i; 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:

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

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:

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

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).

The proportion of Chinook salmon available for harvest each week and observed at 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 to 1983 was estimated using the average run timing from the 1984 to 2019 runs.

Model Scaling

Direct estimates of total run size ($\widehat{N}_y$) from the years 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 as presented in Liller et al. (2018).

Likelihood Model

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

$L(\theta|data)=$ Escapement Counts (5)

$$+\sum_y \sum_i \sum_j \left(ln(\sigma_j) + 0.5 \left(\frac{ln(\hat{e}_{ijy}) - ln(e_{ijy})}{\sigma_j} \right)^2 \right)$$

Adjusted Commercial CPUE

$$+\sum_y \sum_k \left(ln(\sigma_k) + 0.5 \left(\frac{ln(\widehat{CPUE}_{ky}) - ln(CPUE_{ky})}{\sigma_k} \right)^2 \right)$$

Drainagewide Run

$$+\sum_y \left(0.5 \left(\frac{ln(\hat{N}_y) - ln(N_y)}{\sigma_y} \right)^2 \right),$$

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 (Appendix B; Fournier et al. 2012).

MODEL INPUTS

Large amounts of data were available to inform the model and estimate the total run and escapement in 2019. Model estimates in 2019 were informed by independent scalers using 9 years of total run estimates from 2003 to 2007 and 2014 to 2017, which corresponds to years of relatively high and low run abundance, respectively (Appendix C). The model was also informed by commercial, subsistence, sport, and test fish harvest and escapement at 6 weirs and 14 aerial surveys from 1979 to 2019 (Appendix C). Finally, the model was informed by the proportion of total annual Chinook salmon run in District W-1, by week, as estimated by Bethel test fishery from 1984 to 2019 and harvest and effort, by week, for Kuskokwim River District W-1 from 1976 to 2019 (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 2019.

Several changes occurred to model inputs since the preliminary run reconstruction estimate released in September 2019. The preliminary run estimate relied on a “best guess” of 51,000 Chinook salmon harvested for subsistence purposes. Since that time, postseason subsistence harvest surveys have been completed and the harvest was estimated to be 37,941 (95% CI 34,978–40,904; Dave Koster, Division of Subsistence, ADF&G; personal communication). The revised subsistence harvest estimate was used in this final run reconstruction analysis. Additionally, a total of 9 corrections were made to historical aerial survey data as part of a regular data review process (Appendix C). All historical weir estimates were updated (Appendix C) to reflect changes in the software required to estimate missed Chinook salmon passage using Markov-chain Monte Carlo (MCMC) methods. Historically, WinBUGS was used to produces estimates of missed passage (Dickerson et al. 2019); however, this software is no longer being technically supported. In 2019, the JAGS software package was selected as a suitable alternative and was used for the first time. Both programs use the same hierarchical Bayesian estimation method. All historical estimates of missed passage at weirs were recalculated using the JAGS software.[1]

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

RESULTS AND DISCUSSION

Quality of the 2019 assessment information used to inform the 2019 total run and escapement estimate was generally good (Table 1). Weir-based tributary escapements were successfully estimated at the Kwethluk, George, Kogrukluk, and Takotna rivers in 2019. Peak spawning aerial survey counts were flown between 24 July and 31 July in 2019. A total of 12 aerial surveys were flown in 2019 and all were used to inform the run reconstruction model. Of the 12 aerial surveys, 10 (83%) had good ratings and 2 (17%) had fair ratings.

Harvest data came from subsistence and test fishery catches. The preliminary subsistence harvest of 37,941 (95% CI: 34,978–40,904) Chinook salmon in 2019 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 01.2086). A total of 563 Chinook salmon were caught in the Bethel test fishery. No commercial or sport fish harvest of Kuskokwim River Chinook salmon occurred during the 2019 season.

Escapement estimates and observations during 2019 indicated that the Chinook salmon escapement throughout the Kuskokwim River was generally larger than prior years when run sizes were below average and harvest restrictions were implemented. In 2019, 15 out of 16 escapement projects reported higher escapements compared to the 2014–2018 and 2009–2018 averages. Escapement at 13 (81%) projects exceeded the long-term 1976–2018 average (Table 1). There were 9 tributaries with established escapement goals assessed in 2019 (Liller and Savereide 2018). Of those, 2 were within the goal range and 7 exceeded the upper bound of the goal range.

MODEL RESULTS

The 2019 Kuskokwim River Chinook salmon drainagewide run was estimated to be 226,987 (95% CI: 182,811–281,839) fish (Table 2; Figure 2). Based on the 2019 model run, the total run in 2019 was 5% greater than the 1976–2018 average of 215,529 Chinook salmon. CV for the 2019 total run was estimated to be 11% which was near the 1976–2018 average of 10% (range: 5–25%; 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 2019 Kuskokwim River Chinook salmon drainagewide escapement was estimated to be 188,483 (95% CI: 144,307–243,335) fish (Table 2). Based on the 2019 model run, the total escapement in 2019 was 45% greater than the 1976–2018 average of 130,101 Chinook salmon. The total escapement in 2019 was greater than 34 of 43 (79%) prior years. Acknowledging that uncertainty in the drainagewide escapement was relatively high, the 95% confidence range of 144,307–243,335 fish provided considerable evidence the drainagewide escapement goal of 65,000–120,000 fish was exceeded (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 2019 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 to 2018, generated by the 2019 model run, were an average of 0.58% (797 fish) larger than estimates reported by Smith 2019 (Table 2).

UNCERTAINTY IN 2019 MODEL ESTIMATES

Model uncertainty in 2019 was near average (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 the total run provided by each project. The number of index projects operated in 2019 (16 total projects) was at the 81 percentile (median 11; range: 2–20) over the 43 years (1976–2018) of available data, which would suggest a large amount of information to update the model and a relatively low level of uncertainty. However, each project provided a different picture of the total run. The model is specifically designed to accommodate "conflicting" data from a range of index projects; however, greater differences among projects results in greater uncertainty about the actual size of the total run and escapement. To illustrate this, the entire drainagewide escapement was estimated with data from 1 escapement project at a time (Figure 5). In 2019, estimates of drainagewide Chinook salmon escapements derived from individual weir projects were 131,000–185,000 fish whereas estimates derived from individual aerial surveys were 128,000–384,000 fish (Table 3; Figure 5).

The sensitivity of the 2019 model results to parameter starting values was evaluated. Run estimates were simulated across a range of 100 starting values for all model parameters independently (Table 4). Across all simulations, the maximum observed difference between annual run estimates was less than 3 fish. Simulation tests for all parameter starting values confirmed the 2019 model run was not sensitive to starting values and the total run estimates presented represent the best fit model.

The sensitivity of model results to 2019 escapement data was explored (Figure 6). Specifically, the model was run using only weir data, only aerial survey data, with headwaters projects removed (i.e., Takotna River weir, Salmon (Pitka) Fork aerial, Upper Pitka Fork aerial, and Bear Creek aerial), and with removal a single escapement project at a time. All point estimates fell within the 95% confidence interval of the base model, except for weir only data, which was 3 fish lower than the 95% confidence interval of the base model. Confidence intervals overlapped in all scenarios. However, there was a clear difference between estimates of total run when the model was informed using only weir escapement data or only aerial escapement data (Figure 6). In aggregate, weir data suggests a total run of about 183,000 fish and aerial data suggests a total run of about 277,000 fish. The influence of relatively large escapements to headwater tributaries (monitored with aerial surveys) on model results continues to be of interest and presumably explains some of the disparity observed between weir only and aerial only model results. When headwaters data (1 weir; 3 aerial surveys) were removed from the model, the total run estimate was near the estimate produced using all available data. These comparisons are not meant to lend more or less credibility to the specific escapement data source, but rather show the importance of having a comprehensive assessment program to inform the run reconstruction model.

2019 RUN RECONSTRUCTION MODEL CONCLUSIONS

- The total run of Kuskokwim River Chinook salmon was estimated to be 226,987 (95% CI: 182,811–281,839) fish.
- Total run abundance was probably above the 1976–2018 average of 215,529 fish, and within a range of run sizes that could have met the drainagewide escapement goal and supported subsistence harvest at levels within the amounts necessary for subsistence (67,200–109,800) as defined by the Alaska Board of Fisheries (5 AAC 01.2086).

- Total escapement of Kuskokwim River Chinook salmon was estimated to be 188,483 (95% CI: 144,307–243,335) fish, and the drainagewide sustainable escapement goal of 65,000–120,000 was exceeded.
- Total escapement was above average.

2020 CHINOOK SALMON RUN FORECAST

The 2020 Kuskokwim River Chinook salmon forecast is for a range of 193,000–261,000 fish. The forecast range is equal to ±15% of the 2019 total run, as presented in this report. Uncertainty in the forecast (i.e., ±15%) is based on the 2013–2019 (i.e., recent 7 year) average percent error between forecasted and actual run estimates. If the 2020 Chinook salmon run returns at least as large as the lower end of the preseason forecast, there will be enough fish to meet the lower bound of the drainagewide escapement goal (65,000: lower bound of the sustainable escapement goal (SEG)) and minimum subsistence needs (67,200: lower end of ANS) with at least 60,000 fish remaining for additional escapement or harvest.

The forecast range is dependent on the variability in run size during the prior 7 years, which does not represent the full uncertainty in the forecast. For example, the 2020 forecast is relatively narrow due to several recent years of similar run sizes. The forecast is not based on probability and alone provides no insight into the most likely run size within the forecasted range. Probability-based forecast methods have been explored for Kuskokwim River Chinook salmon (Staton and Catalano 2019); which use the same prior year method for defining the midpoint of the forecast range but uses the entire time-series to describe forecast uncertainty. The method described by Station and Catalano (2019) produces a forecast range that is very wide and arguably limited for focusing preseason management planning discussions. However, probability-based methods can provide context to better understand the 2020 forecast produced by ADF&G.

Successive years of achieving the drainagewide escapement goal provide some support for the ADF&G forecast and the notion that the 2020 Chinook salmon run will be large enough to meet escapement needs and provide for some harvest. The dominant brood years contributing to the 2020 run will be 2014–2016. These brood years will return fish that are age-4 (2016 brood), age-5 (2015 brood), and age-6 (2014 brood). The actual number of each age class that will return in 2020 is not known with certainty, but the drainagewide escapement goal was achieved in each of the contributing brood years. Drainagewide escapement was estimated to be 70,330 fish in 2014, 108,974 fish in 2015, and 99,257 fish in 2016 (Table 5). The drainagewide escapement goal on the Kuskokwim River is 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 2020 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 have produced on average 3 recruits per spawner (Table 5; Figure 7). This recent trend of increasing productivity is probably a result of meeting escapement goals in recent years and favorable environmental conditions for salmon survival.

Age composition and sibling relationships provide additional insight into the 2020 Chinook salmon run forecast. The percentage of age-4 fish in the total run during 2019 was the highest on record. The brood years with the 5 highest contributions of age-4 fish (years 2000, 2002, 2004, 2005, and 2011) had an average recruit per spawner exceeding 2.5. The large number of age-4 Chinook salmon observed returning to the Kuskokwim River in 2019 indicated that there may be a large return of age-5 Chinook salmon in 2020.

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 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 have tended to be higher than what the run reconstruction model predicted. This may be addressed by incorporating a time-variant scaler to the model. Also, the Kuskokwim River sonar is a new assessment tool that has been fully operational since 2018. This project 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 be explored. ADF&G will engage and report out 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 (1976–2019)	Historical average (1976–2018)	10–yr average (2009–2018)	5–yr average (2014–2018)	2018	2019
Weir	Kwethluk	15	9,498	5,027	6,187	–	8,505
	Tuluksak	21	985	466	648	–	–
	George	21	3,544	2,490	2,900	3,322	3,828
	Kogrukluk	33	9,810	6,267	6,640	6,292	10,301
	Tatlawiksuk	18	1,692	1,474	2,255	–	–
	Takotna [a]	20	408	240	209	205	554
Aerial Survey	Kwethluk [b]	11	2,183	1,165	–	–	–
	Kisaralik	26	1,112	566	634	584	1,063
	Tuluksak [b]	11	421	83	–	–	–
	Salmon (Aniak)	33	795	351	543	442	950
	Kipchuk	27	1,017	702	1,009	1,123	1,344
	Aniak	24	2,607	1,598	1,809	1,534	3,160
	Holokuk	18	324	161	112	162	719
	Oskawalik	23	274	125	128	–	638
	Holitna	23	1,516	766	869	980	1,377
	Cheeneetnuk	26	673	340	446	565	1,345
	Gagaryah	27	476	233	346	438	760
	Pitka [c]	13	241	209	353	471	330
	Bear	19	244	302	541	550	542
	Salmon (Pitka)	32	1,036	1,022	1,509	1,399	1,918
Harvest	Subsistence	44	65,662	37,590	19,339	22,266	37,941
	Commercial	44	18,717	1,099	9	0	0
	Sport	43	440	184	0	0	0
	Test Fishery	44	619	387	450	465	563

Note: Not all projects were operated in all years.

[a] Weir operated 1995–2013; 2017–2019.

[b] Aerial surveys not flown since 2013 because the system is monitored by a weir.

[c] 2017 aerial survey was the first since 2011.

Table 2.–Annual drainagewide run and escapement of Kuskokwim River Chinook salmon from the 2019 run reconstruction model.

	2019 Model run				2019 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	206,672	159,106	268,459	187,910	116,125	68,559	177,912	97,363
1977	324,860	230,927	457,003	347,576	231,153	137,220	363,296	253,869
1978	237,518	188,678	299,001	241,159	154,046	105,206	215,529	157,687
1979	236,554	169,235	330,650	233,989	140,252	72,933	234,348	137,687
1980	362,290	223,744	586,627	358,448	265,322	126,776	489,659	261,480
1981	311,309	225,002	430,720	307,931	200,910	114,603	320,321	197,532
1982	143,957	126,043	164,416	172,512	36,956	19,042	57,415	65,511
1983	148,051	121,776	179,995	148,236	65,906	39,631	97,850	66,091
1984	175,501	136,582	225,511	172,329	86,325	47,406	136,335	83,153
1985	145,163	117,520	179,308	143,784	63,236	35,593	97,381	61,857
1986	123,817	93,461	164,033	123,767	53,205	22,849	93,421	53,155
1987	182,967	146,563	228,413	185,652	78,724	42,320	124,170	81,409
1988	206,619	178,544	239,108	205,050	78,856	50,781	111,345	77,287
1989	214,473	177,259	259,500	214,030	88,320	51,106	133,347	87,877
1990	267,793	229,532	312,432	266,729	103,607	65,346	148,246	102,543
1991	215,518	181,389	256,069	210,919	102,370	68,241	142,921	97,771
1992	260,878	224,994	302,486	259,043	129,778	93,894	171,386	127,943
1993	272,385	223,180	332,436	274,699	172,718	123,513	232,769	175,032
1994	398,188	304,610	520,514	403,431	276,084	182,506	398,410	281,327
1995	371,220	299,771	459,699	371,257	236,491	165,042	324,970	236,528
1996	323,884	250,856	418,171	309,632	218,309	145,281	312,596	204,057
1997	262,498	216,552	318,193	296,105	171,164	125,218	226,859	204,771
1998	254,674	194,327	333,761	184,341	154,702	94,355	233,789	84,369
1999	160,332	129,313	198,792	159,861	81,739	50,720	120,199	81,268
2000	122,228	107,461	139,023	129,109	54,019	39,252	70,814	60,900
2001	192,625	163,314	227,197	205,477	113,985	84,674	148,557	126,837
2002	238,337	204,036	278,404	226,323	156,489	122,188	196,556	144,475
2003	231,825	207,471	259,039	232,559	163,120	138,766	190,334	163,854
2004	365,368	322,528	413,898	366,840	264,727	221,887	313,257	266,199
2005	326,910	294,378	363,037	327,299	235,134	202,602	271,261	235,523
2006	324,338	287,833	365,471	326,544	229,953	193,448	271,086	232,159
2007	248,762	225,120	274,886	244,114	151,902	128,260	178,026	147,254
2008	214,991	189,185	244,317	210,784	116,086	90,280	145,412	111,879
2009	195,102	169,504	224,567	190,966	107,168	81,570	136,633	103,032

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Table 2.–Page 2 of 2.

Year	2019 Model run Total run estimate	Lower 95% CI	Upper 95% CI	Previously published total run estimate[a]	2019 Model run Total esc. estimate	Lower 95% CI	Upper 95% CI	Previously published total esc. estimate[a]
2010	116,048	104,925	128,351	114,146	45,384	34,261	57,687	43,482
2011	114,599	102,547	128,066	113,548	50,570	38,518	64,037	49,519
2012	75,010	61,792	91,055	79,210	51,518	38,300	67,563	55,718
2013	88,515	78,982	99,199	84,430	41,027	31,494	51,711	36,942
2014	82,096	70,722	95,300	84,444	70,330	58,956	83,534	72,678
2015	125,578	110,710	142,442	125,106	108,974	94,106	125,838	108,502
2016	130,475	113,401	150,121	128,696	99,257	82,183	118,903	97,478
2017	131,677	112,643	153,929	133,178	115,007	95,973	137,259	116,508
2018	136,135	107,750	171,996	132,312	113,404	85,019	149,265	109,583
2019	226,987	182,811	281,839		188,483	144,307	243,335	
Average (1976-2017)	215,529			214,732	130,101			129,304

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 from Smith (2019). Based on the prior year model run, the 1976–2018 average total run and escapement was larger than the 2019 model run average by 797 fish (0.6%) and 797 fish (1.4%), respectively.

Table 3.–Parameter estimates derived from the 2019 run reconstruction model.

		Parameter	95% Bound	
		estimate (*k*)	Lower	Upper
Weir projects (*k*)				
	Kwethluk weir	2.74	2.54	2.94
	Tuluksak weir	5.04	4.87	5.22
	George weir	3.55	3.37	3.73
	Kogrukluk weir	2.62	2.45	2.78
	Tatlawiksuk weir	4.19	4.00	4.38
	Takotna weir	5.81	5.62	5.99
Aerial survey (*k*)				
	Kwethluk River	4.40	4.04	4.77
	Kisaralik River	5.15	4.90	5.39
	Tuluksak River	6.11	5.75	6.48
	Salmon (Aniak River)	5.34	5.12	5.57
	Kipchuk River	5.01	4.77	5.25
	Aniak River	4.04	3.79	4.30
	Holokuk River	6.28	6.00	6.56
	Oskawalik River	6.49	6.24	6.75
	Holitna River	4.53	4.27	4.79
	Cheeneetnuk River	5.40	5.16	5.65
	Gagaryah River	5.84	5.60	6.08
	Pitka Fork	6.41	6.10	6.73
	Bear River	6.30	6.03	6.58
	Salmon(Pitka Fork)	4.81	4.59	5.04
Catchability (*q*)				
	Unrestricted	-9.51	-9.80	-9.23
	Restricted	-10.04	-10.21	-9.88

Table 4.–Starting values used for sensitivity analysis and results for 2019 run reconstruction model.

Parameter	Starting values range	Average difference[a]	Max difference[b]
Total run (N_y)	100,000–400,000	0.004	0.016
Weir escapement scaling (k_{ij})	0.01–10	0.017	0.088
Aerial escapement scaling (k_{ij})	0.01–10	0.003	0.019
Catchability (q_k)	-20–1	0.013	0.051
Weir coefficient of variation[c]	-20–20	0.398	2.474
Aerial coefficient of variation[c]	-20–20	0.398	2.474
Catchability coefficient of variation[c]	-20–20	0.398	2.474

[a] Average difference in numbers of fish among all 1976–2019 total run estimates across a range of 100 different starting values for each parameter.

[b] Maximum difference in numbers of fish among all 1976–2019 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.–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	116,125	0	64	6	65,274	6	0	105,915	34	82,528	85	6,079	260	92	0	260,341	2.24
1977	231,153	0	66	6	23,775	6	0	44,294	32	77,138	70	7,486	515	67	0	153,454	0.66
1978	154,046	0	670	5	11,448	5	0	39,340	26	61,331	498	4,833	52	5	0	118,215	0.77
1979	140,252	0	209	4	24,354	4	32	76,944	159	61,064	64	6,405	60	6	0	169,306	1.21
1980	265,322	0	692	5	28,133	5	0	51,887	176	46,127	74	3,480	80	7	0	130,666	0.49
1981	200,910	0	372	4	27,015	4	0	59,063	28	83,117	99	12,029	85	7	0	181,822	0.90
1982	36,956	0	48	5	11,282	5	0	53,063	37	69,025	104	6,571	1,062	10	0	141,210	3.82
1983	65,906	0	697	6	43,017	6	0	95,645	39	102,904	733	5,713	130	33	302	249,225	3.78
1984	86,325	0	74	7	29,653	7	0	66,990	1,579	72,686	161	5,267	840	8	0	177,271	2.05
1985	63,236	0	78	7	34,368	7	0	130,118	60	107,378	1,272	5,044	219	8	90	278,651	4.41
1986	53,205	0	90	10	56,050	10	0	72,166	1,921	91,553	235	10,271	715	10	0	233,031	4.38
1987	78,724	0	2,918	7	26,186	7	0	87,103	620	99,431	778	6,100	1,635	9	0	224,794	2.86
1988	78,856	76	82	8	69,643	8	0	83,016	209	130,452	1,978	4,118	359	16	0	289,965	3.68
1989	88,320	0	6,189	8	77,378	8	179	211,794	1,419	194,105	387	36,064	116	7	0	527,654	5.97
1990	103,607	0	419	10	43,010	10	0	107,716	56	113,762	717	3,142	95	7	0	268,943	2.60
1991	102,370	90	736	9	64,516	9	0	139,029	360	124,036	117	5,112	97	7	0	334,118	3.26
1992	129,778	0	144	9	33,577	9	0	64,248	44	86,537	120	3,103	87	6	0	187,884	1.45
1993	172,718	0	130	7	70,577	7	0	126,138	45	95,221	107	3,960	81	0	0	296,273	1.72
1994	276,084	0	88	7	35,716	7	0	47,845	166	55,401	99	7,737	81	0	0	147,148	0.53
1995	236,491	0	284	7	13,538	7	0	47,320	37	101,159	0	8,138	0	0	0	170,490	0.72
1996	218,309	0	230	6	15,192	6	0	63,692	0	94,770	0	9,734	0	0	0	183,629	0.84
1997	171,164	0	100	0	19,738	0	0	84,867	61	75,889	0	4,628	0	0	0	185,283	1.08
1998	154,702	0	0	0	50,214	0	0	102,263	0	106,588	0	4,409	172	0	0	263,645	1.70
1999	81,739	0	204	0	43,395	0	0	111,329	427	110,126	548	14,817	91	0	0	280,937	3.44
2000	54,019	0	380	0	141,292	0	0	152,568	10	126,311	182	5,213	1,101	0	0	427,058	7.91
2001	113,985	0	1,207	0	58,756	0	0	98,173	91	90,428	470	4,768	180	0	0	254,074	2.23

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Table 5.–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	156,489	0	485	0	83,465	0	0	81,623	0	61,514	1,254	2,166	313	0	0	230,820	1.47
2003	163,120	0	1,086	0	69,584	0	0	104,943	66	84,069	274	3,210	41	64	0	263,336	1.61
2004	264,727	0	194	0	41,782	0	0	72,161	774	40,090	0	1,649	53	0	0	156,703	0.59
2005	235,134	0	448	0	35,265	0	0	49,033	79	37,356	272	872	1	0	0	123,326	0.52
2006	229,953	0	81	68	23,290	68	0	45,956	106	23,118	450	830	95	0	0	94,063	0.41
2007	151,902	0	202	0	28,842	0	0	40,892	0	47,102	236	814	0	0	0	118,088	0.78
2008	116,086	0	262	0	9,624	0	0	27,063	75	30,083	353	445	1	0	0	67,906	0.58
2009	107,168	45	0	0	12,862	75	0	32,842	482	24,052	360	5	1	0	77	70,801	0.66
2010	45,384	0	95	0	14,508	0	122	43,897	765	16,440	358	17	99	0	0	76,302	1.68
2011	50,570	0	2,861	0	55,031	2	0	75,498	233	28,683	205	112	0	0	0	162,627	3.22
2012	51,518	65	804	0	36,055	0	0	59,963	165	22,413	53	77	326	0	0	119,919	2.33
2013	41,027	0	1,915	0	41,358	0	124	59,385	124	35,024	1	0	0	0	0	137,932	3.36
2014	70,330	0	1,085	0	50,686	0	1	72,444	38	0	0	0	0	0	0	124,253	–
2015	108,974	0	3,197	239	109,815	88	0	0	0	0	0	0	0	0	0	113,339	–
2016	99,257	30	9,025	0	0	0	0	0	0	0	0	0	0	0	0	9,055	–
2017	115,007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	–
2018	113,404	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	–
2019	188,483	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 2013–2019 are incomplete.

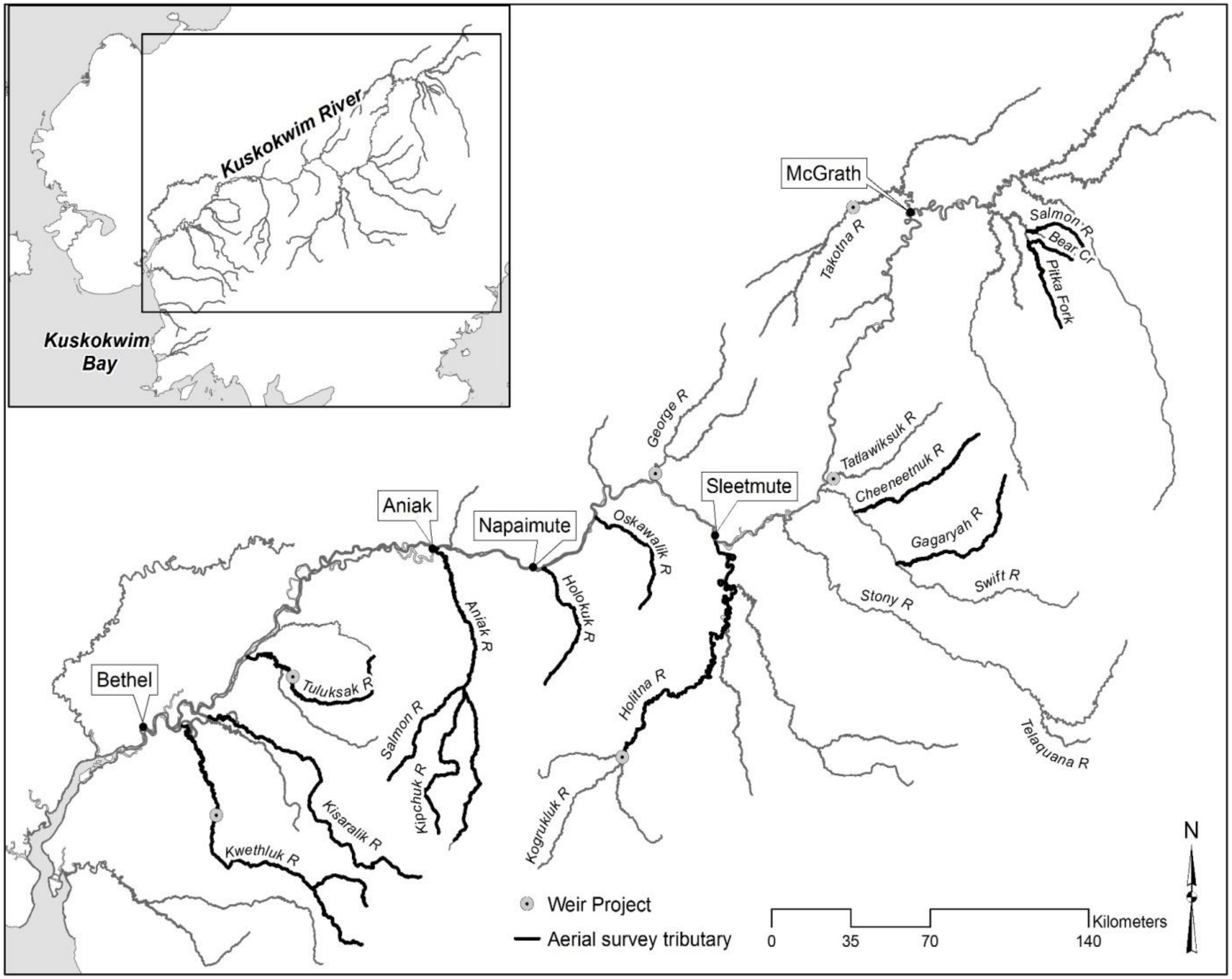

Figure 1.–Kuskokwim River Chinook salmon escapement monitoring projects used to inform the run reconstruction model.

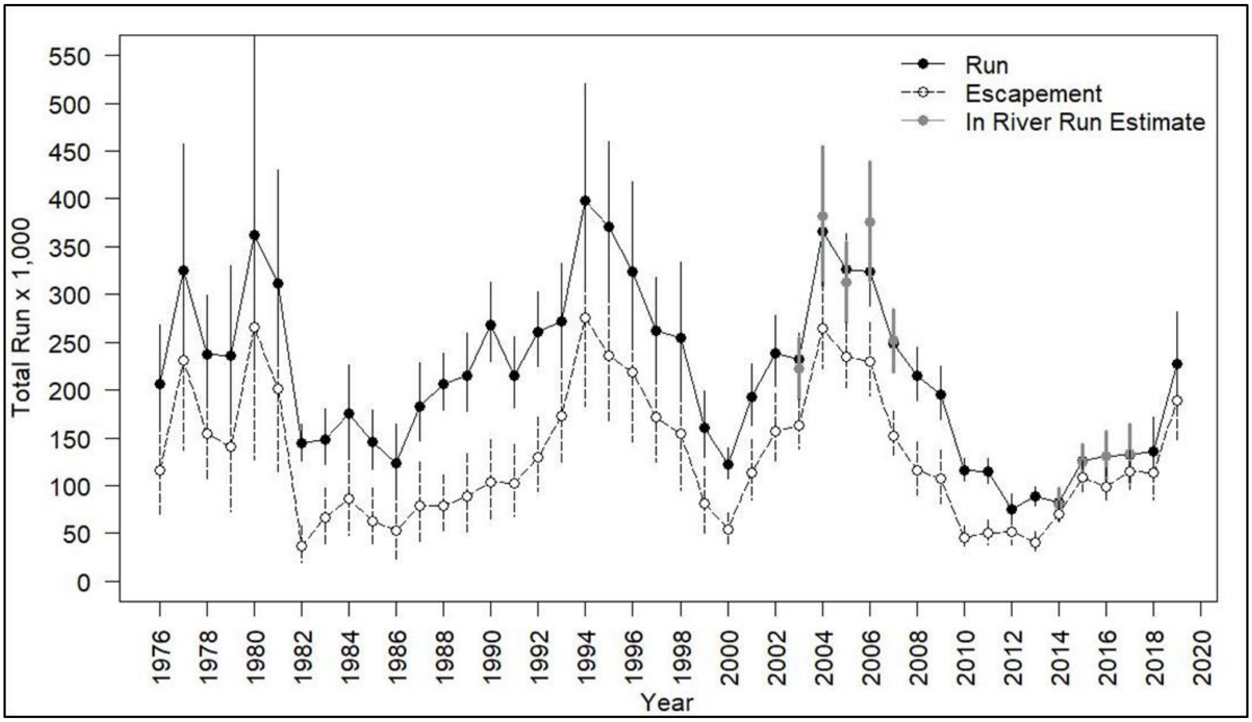

Figure 2.–Annual run (black) and escapement (white) estimates with 95% confidence intervals estimated from the 2019 run reconstruction model.

Note: Grey 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).

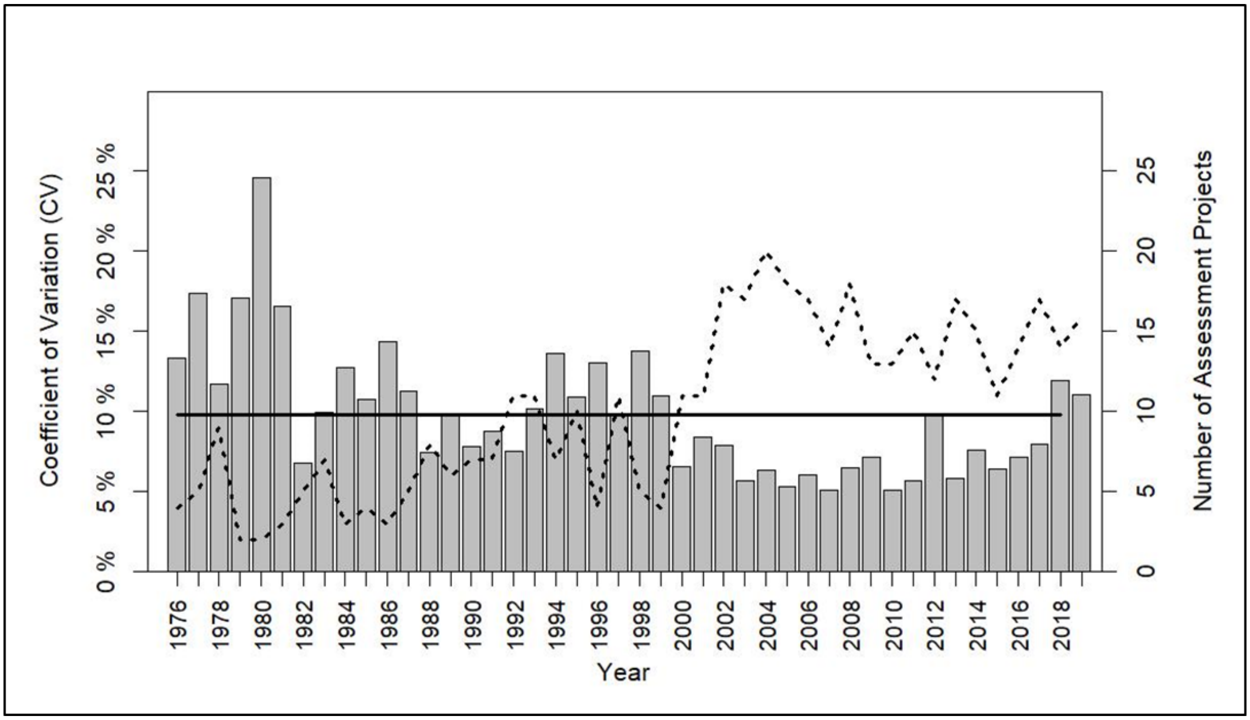

Figure 3.–Annual uncertainty (coefficient of variation; grey bars) of the run reconstruction model estimate of total run size and the number of assessment projects (dotted black line) used to inform the model in each year.

Note: The solid black line is the average coefficient of variation (10%) across years 1976–2018.

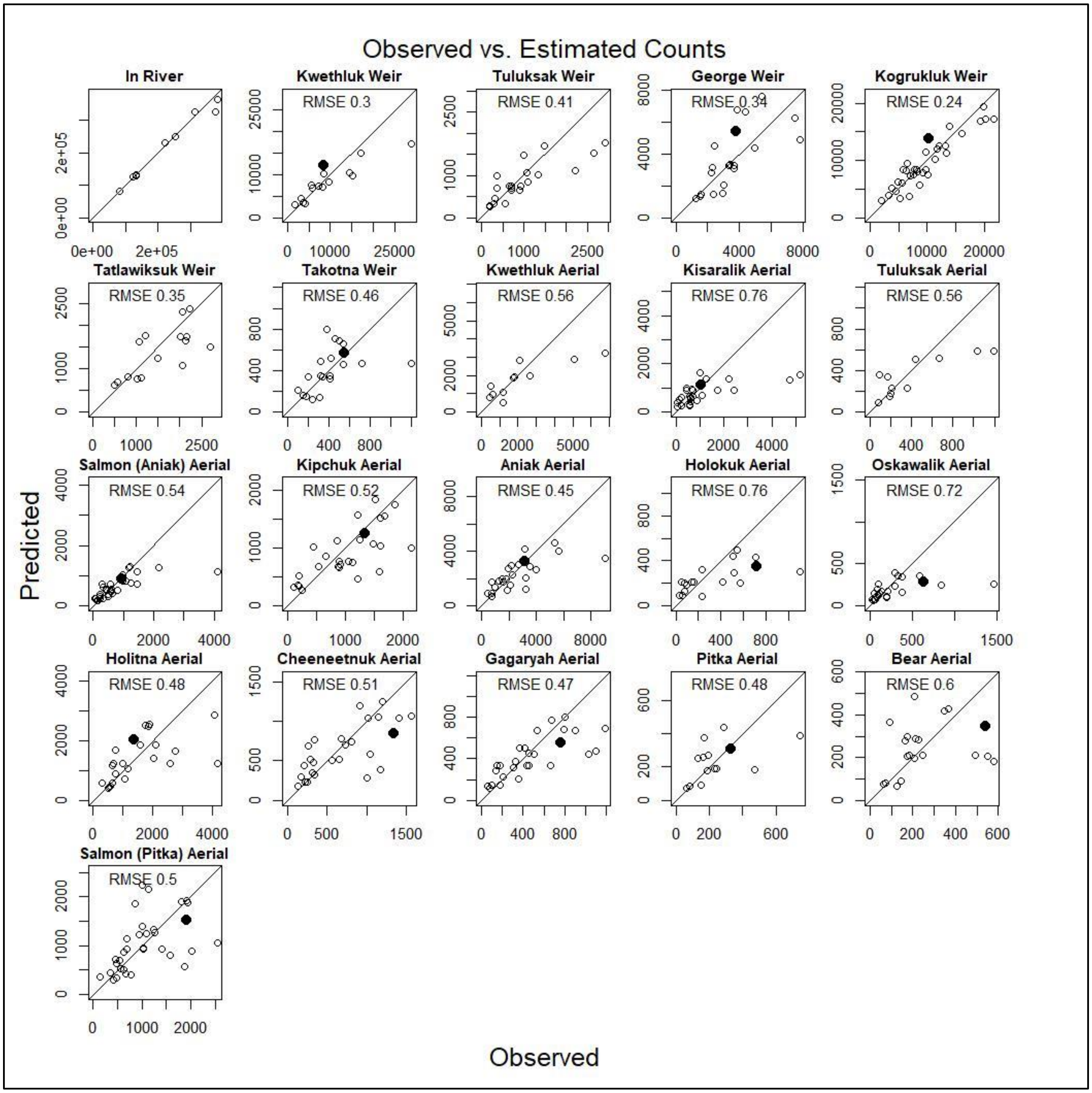

Figure 4.–Observed versus model estimated escapement counts.

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 2019 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.

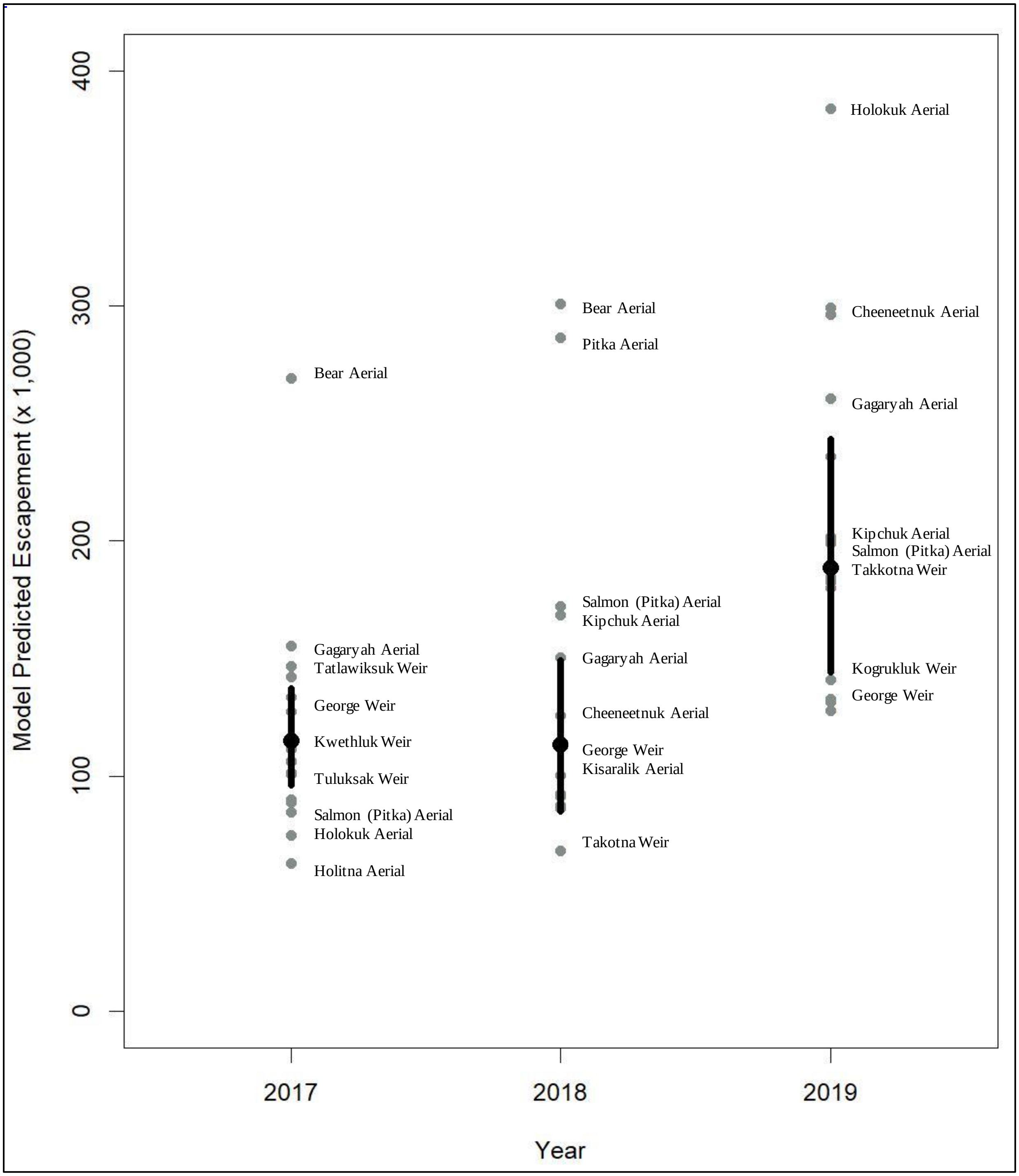

Figure 5.–Range of drainagewide escapement estimates produced by the model based on each escapement project.

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 between 2017 and 2019 are shown to provide context.

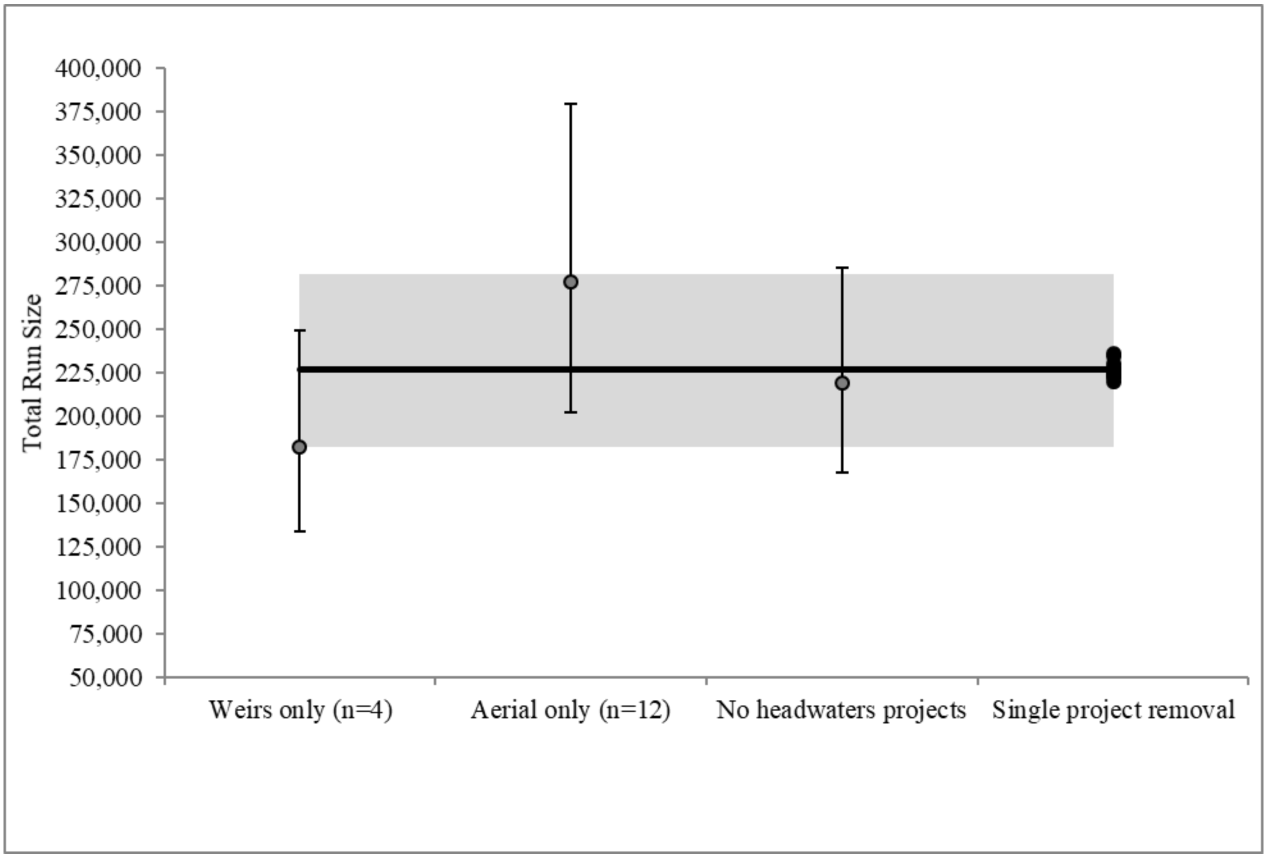

Figure 6.–Sensitivity of 2019 Chinook salmon total run size estimates using weir data only, aerial survey data only, exclusion of headwaters project data, and removal of single escapement monitoring projects (black dots).

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 (grey 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.

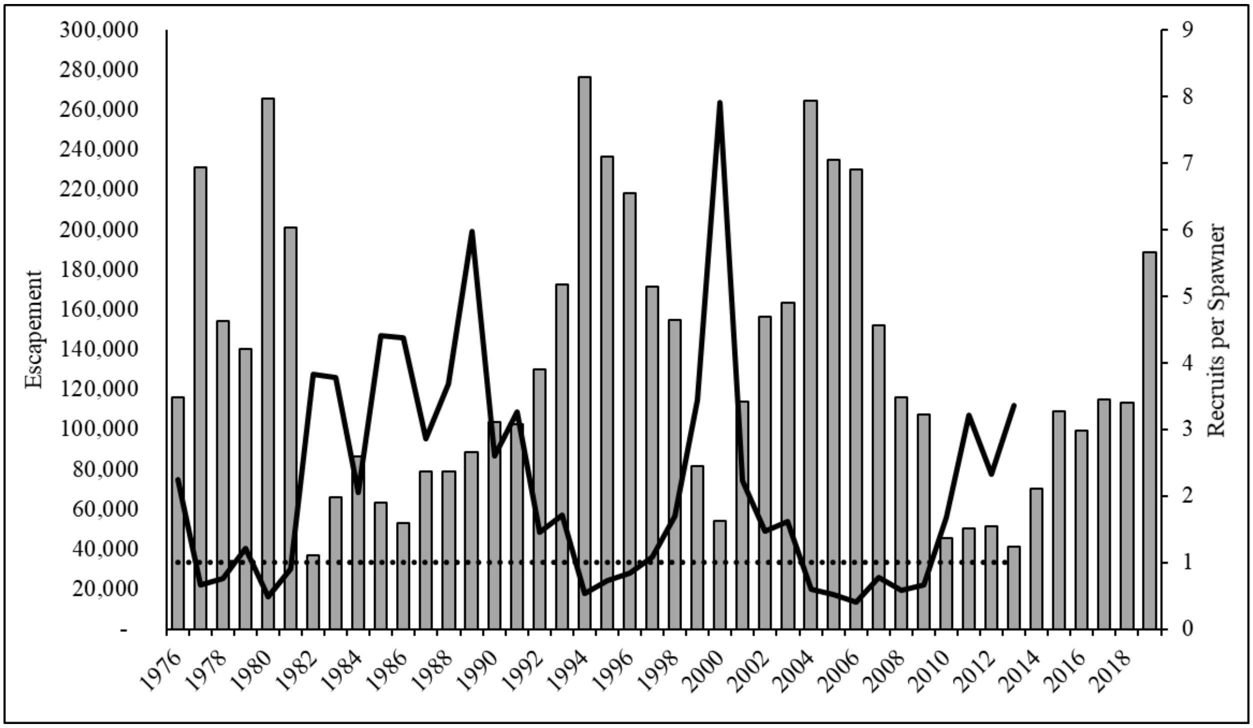

Figure 7.–Escapement (bars), recruits per spawner (solid line), and the 1:1 replacement line for recruits per spawner (dotted line) for Kuskokwim River Chinook salmon, 1976–2019.

APPENDIX A: 2019 NPFMC 3-SYSTEM INDEX LETTER

THE STATE
of ALASKA
GOVERNOR MIKE DUNLEAVY

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September 16, 2019

Dr. James Balsiger, Administrator
NOAA Fisheries, Alaska Region
PO Box 21668
Juneau, Alaska 99802-1668

Dear Dr. Balsiger:

In April 2015, the North Pacific Fishery Management Council (Council) adopted an action that lowers Chinook salmon bycatch caps in the Bering Sea 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, to determine if the combined adult Chinook salmon abundance in the indexed systems falls at or below the threshold level of 250,000 fish. If the threshold is not met, the performance standard and hard cap applicable to the Bering Sea 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 2019. 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]. As required by NMFS, the department will notify the Council of any future improvements to methods used in the assessment of the three-system index so that they may be evaluated and approved through the Council process.

The three-system index of inriver adult Chinook salmon run sizes from the Unalakleet, Upper Yukon, and Kuskokwim rivers is 315,626. The following details the preliminary total run estimates for each system.

[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

-continued-

Unalakleet River

The preliminary postseason run size estimate of Unalakleet River Chinook salmon is **11,862** based on preliminary assessment of total escapement, commercial harvest, and expectations of subsistence harvest. Preliminary Chinook salmon escapement in the Unalakleet River was 9,953 fish, measured by escapement projects on the North River tributary (3,312 fish; tower count) and mainstem Unalakleet River (6,641 fish; weir count). The combined escapement is considered a reliable measure of the total Chinook salmon escapement. A total of 909 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 preliminary expectation that 1,000 Unalakleet River Chinook salmon were harvested in the subsistence fishery was based on a 25% increase to the 2018 post-season survey estimate.

Upper Yukon River

The preliminary postseason run size estimate of Upper Yukon River Chinook salmon is **70,560** based on preliminary assessment of total escapement into Canada and expectations of subsistence harvest in Alaska. The expectation of escapement into Canada was based on a sonar project operated near Eagle, Alaska. The preliminary sonar count is 45,560. Total harvest of Upper Yukon River Chinook salmon in Alaska is expected to be about 25,000, nearly all of which was harvested in the subsistence fishery. Subsistence fishing restrictions were implemented throughout much of the Chinook salmon run in 2019, but overall, the department provided more subsistence fishing opportunity in 2019 compared to 2018. Subsistence harvest of Upper Yukon River Chinook salmon in 2019 is expected to be larger than the 2018 harvest of 19,266. A relatively small number of Chinook salmon were harvested incidentally during the summer chum salmon commercial fishery and retained for personal use or sold. It is unlikely that commercially harvested Chinook salmon were of Upper Yukon River origin, due to the late timing of the fishery openers in 2019.

Kuskokwim River

The preliminary postseason run size estimate of Kuskokwim River Chinook salmon is **233,204** fish, estimated using a maximum likelihood model. The total run estimate was informed by direct observations of escapement at 16 locations and an expectation that drainagewide harvest will be approximately 51,563. No commercial harvest of Kuskokwim River Chinook salmon occurred during the 2019 season. A total of 563 Chinook salmon were harvested in the inriver test fishery operated by the department. The preliminary expectation that 51,000 Kuskokwim River Chinook salmon were harvested in the subsistence fishery was based on a three-year relationship between partial inseason harvest estimates and final drainagewide post-season survey estimates. U.S. Fish and Wildlife Service estimated that approximately 40,000 Chinook salmon were harvested within a portion of the Yukon Delta National Wildlife refuge, during subsistence fishing openers announced by Federal Special Actions.

Sincerely,

Sam Rabung
Commercial Fisheries Division Director

cc: Glenn Merrill, NMFS AKR

APPENDIX B: 2019 ADMB-CODE WITH ANNOTATIONS

Appendix B1.–2019 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

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		540
	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

Note: Historically, WinBUGS was used to produces estimates of missed passage; however, that software is no longer supported. JAGS was identified as a suitable alternative and was used for the first time in 2019. All historical weir estimates were recalculated in 2019 and used to produce the 2019 run reconstruction model estimate. This resulted in slightly different historical estimates than was reported in prior reports.

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[a]		182	
	1977	2,075		439[a]							1,407[a]	897			1,930
	1978	1,722	2,417		289					2,766	268	504		227	1,100
	1979														682
	1980			1035[a]	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	[a]							1,002				620
	1986				336		424			650					
	1987				516	193			193		317	205[a]			
	1988	622	869	195	244		954		80						474
	1989	1,157	152		631	1,598	2,109								452
	1990		631	205[a]	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[a]	443	1,930								
	1999								98	741					
	2000				238	182	714		62[a]	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

-continued-

Appendix C4.–Page 2 of 2.

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				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

Note: 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] Data correction made to the database in 2019.

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

Appendix C6.–Chinook salmon catch and effort (permit-hours) by, week, 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

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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

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