Regional Information Report 3A16-03

Kuskokwim River Chinook salmon run reconstruction, 2015

by

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and

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March 2016

Alaska Department of Fish and Game **Divisions of Sport Fish and 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 2015 drainagewide run size and escapement of Kuskokwim River Chinook salmon (*Oncorhynchus tshawytscha*). Total run and escapement were estimated to be 172,055 (95% CI: 129,115–229,276) and 155,464 (95% CI: 112,524–212,685), respectively. The 2015 model estimates were informed by direct observations of the 2015 escapement at 11 locations (5 weirs and 6 aerial surveys) combined with historical observations of escapement, harvest, and run size dating back to 1976. There is considerable uncertainty in the 2015 model estimates. However, model results are adequate for drawing broad conclusions about the 2015 run and escapement. The 2015 run of Kuskokwim River Chinook salmon was improved compared to 2014. Total run of Chinook salmon in 2015 was less than long-term average abundance; however, total escapement was near average due to conservative management and harvest restrictions throughout the run. The drainagewide sustainable escapement goal of 65,000–120,000 was likely exceeded in 2015.

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

INTRODUCTION

This report describes methods used to estimate the 2015 drainagewide run size and escapement of Chinook salmon returning to the Kuskokwim River in western Alaska. Because it is not possible to count all Chinook salmon that return to the Kuskokwim River, estimates of annual abundance and escapement are made using a maximum likelihood model. The model, with subsequent revisions, was specifically developed for use in data-limited situations (Bue et al. 2012; Hamazaki and Liller 2015). The model combines information on subsistence harvest, commercial catch and effort, sport harvest, test fish harvest and catch per unit of effort at Bethel, mark–recapture estimates of inriver abundance, counts of salmon at 6 weirs, and peak aerial counts from 14 tributaries spread throughout the Kuskokwim River drainage (Figure 1 and Figure 2). Each of these data sources provides an index of total abundance and some projects 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.

A drainagewide escapement goal of 65,000–120,000 has been established for Kuskokwim River Chinook salmon (Conitz et al. 2012). The run reconstruction model has been used annually since 2013 as a postseason tool to determine if the drainagewide escapement goal was achieved. Model estimates of total run size have also been used since 2012 to forecast subsequent year run sizes and inform preseason management strategies for achieving escapement goals.

Application of the run reconstruction model for Kuskokwim River Chinook salmon management is still very much in its infancy, and as such, the Alaska Department of Fish and Game (ADF&G) has taken steps to improve the usability and performance of the model. In 2013, the estimation method was updated from Microsoft Excel[1] to the R statistical package, drastically decreasing computation time. In 2014, the model was updated to more explicitly consider uncertainty associated with the catch and effort portion of the model (Hamazaki and Liller 2015). Documentation of these model changes was made publicly available including the model code and all requisite data inputs. There have been no changes to the run reconstruction model structure in 2015. The following describes updated model inputs and the methods used to estimate the total run and escapement of Kuskokwim River Chinook salmon in 2015.

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

OBJECTIVE

Estimate the total run size and escapement of Kuskokwim River Chinook salmon in 2015.

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 is known to different degrees. Total annual escapement is indexed by count data from weirs and aerial surveys located throughout the lower, middle, and upper portions of the Kuskokwim River. Estimates of total abundance for scaling the model are available for 5 years, 2003 to 2007 (Schaberg et al. 2012). Direct estimates from Schaberg et al. (2012) were derived from a combination of mark–recapture data, escapement estimates, extrapolation of escapement values to unmonitored areas, and harvests. Total annual harvests are known with a high degree of confidence from commercial fish tickets and subsistence surveys. Estimates of sport fish harvest are less precise, but the effect of a lower level of precision is negligible given the small annual sport harvest.

Total run and escapement of Kuskokwim River Chinook salmon was estimated using a maximum likelihood model developed for data limited situations (Bue et al. 2012), with subsequent revisions to the model configuration (Hamazaki and Liller 2015). 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 is divided into 3 components based on the type of data used in the model: (1) escapement, (2) commercial harvest and effort, and (3) direct estimates of total run size for model scaling.

ESCAPEMENT COUNTS

Assuming the proportion of the total annual escapement returning to each tributary is constant, the expected escapement ($\hat{e}$) in year y to tributary j observed by method i (weir, aerial) is

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

where k_{ij} is a scaling parameter estimated by the model. The form of the negative binomial density presented in Hilborn and Mangel (1997) and Millar (2011) was used to model uncertainty in the count data. An additional parameter, typically called the overdispersion parameter ($\hat{m}_i$), was estimated to account for additional variability. The likelihood of the combined observed escapements given the estimated parameters is:

$$L\left(e \middle| \hat{e}, \hat{m}, \hat{k}\right) = \prod_y \prod_i \prod_j \frac{\Gamma\left(\hat{m}_{ij} + e_{ijy}\right)}{\Gamma\left(\hat{m}_{ij}\right) e_{ijy}!} \left(\frac{\hat{e}_{ijy}}{\hat{m}_{ij} + \hat{e}_{iy}}\right)^{e_{ijy}} \left(\frac{\hat{m}_{ij}}{\hat{m}_{ij} + \hat{e}_{ijy}}\right)^{\hat{m}_{ij}} . \tag{3}$$

COMMERCIAL CATCH AND EFFORT

Assuming that commercial catch and run timing are known and accurate, commercial catch effort (f_{wky}) in week w with net configuration k is

$$\hat{f}_{wky} = -\ln(1 - c_{wky} / (p_{wy} N_y)) / q_k \tag{4}$$

where

c_{wky}: commercial catch at week w of net configuration k,

p_{wy}: proportion of Chinook salmon available at week w based on Bethel test fishery, and

q_k: catchability coefficient of net configurations k (i.e., unrestricted, restricted).

Assuming the measurement error of weekly commercial catch efforts follows a lognormal distribution, the likelihood of the observed fishing effort given the estimated parameters is:

$$L\left(f \middle| \hat{f}, \hat{q}\right) = \prod_y \prod_w \prod_k \frac{1}{\sigma_\varepsilon \sqrt{2\pi}} \exp\left(-\frac{\left(\ln f_{wky} - \ln \hat{f}_{wky}\right)^2}{2\sigma_\varepsilon^2} \right). \tag{5}$$

The concentrated likelihood function was used to eliminate the need for estimation of variance for commercial efforts.

MODEL SCALING

Direct estimates of total run size ($\widehat{N}_y$) from the years 2003 to 2007 were derived from a combination of mark–recapture data, escapement estimates, extrapolation of escapement values to unmonitored areas, and harvests (Schaberg et al. 2012). Those estimates of total run and associated uncertainties were used to scale the run reconstruction model. The variance of the direct estimates (Schaberg et al. 2012) was used to represent measurement error associated with the model scalers. Assuming that measurement error follows a normal distribution, the likelihood of the observed total run given the estimated parameters is:

$$L\left(N \middle| \hat{N}\right) = \prod_y \exp\left(-\frac{\left(N_y - \hat{N}_y\right)^2}{2\sigma_{N_y}^2} \right). \tag{6}$$

LIKELIHOOD MODEL

The escapement, commercial harvest, and model scaling components were combined into a single likelihood model that simultaneously estimated the total run to the Kuskokwim drainage for each year,

$$L\left(\theta \middle| data\right) = L\left(e \middle| \hat{e}, \hat{m}, \hat{k}\right) L\left(f \middle| \hat{f}, \hat{q}\right) L\left(N \middle| \hat{N}\right). \tag{7}$$

Parameter estimation was performed by minimizing the negative log-likelihood of the model using R optim (R Core Team 2014) with method “L-BFGS-B” (see Appendix A).

RESULTS AND DISCUSSION

MODEL INPUTS

A considerable amount of information was available to inform the model and estimate total run and escapement in 2015. The 2015 model estimates were informed by direct observations of the 2015 escapement at 11 locations (5 weirs and 6 aerial surveys) combined with historical observations of escapement, harvest, and run size dating back to 1976. Commercial catch and effort during the 2015 season was not incorporated into the model, due to the extremely low harvest (8 fish) which occurred very late in the Chinook salmon run.

The escapement data indicate that the 2015 run of Chinook salmon to the Kuskokwim River was improved compared to 2014. Of the 11 assessment projects that operated in both 2014 and 2015, 7 projects observed larger escapements in 2015 (Table 1). Notably, escapements to both the Kwethluk and Kogrukluk rivers were more than twice those observed in 2014 (Table 1), and escapement goals were met on both systems for the first time since the goals were revised in 2013. Aerial survey counts of Chinook salmon in the headwater tributaries upriver from McGrath were some of the largest on record in 2015. In addition to improved escapement throughout much of the drainage, subsistence harvest of Chinook was 44% larger in 2015 (16,111) compared to 2014 (11,203). Three of the 4 assessment projects that did not show improved escapement in 2015 exhibited escapement similar to 2014. The only project that did not indicate a stable or increasing trend was the Gagaryah River aerial survey.

Aerial survey information from the Gagaryah River and Bear Creek (Pitka Fork) were available, but were not used to estimate the 2015 run size or escapement because the counts were extreme. The Gagaryah River is a prominent tributary of the Swift River and Bear Creek is a headwater tributary draining into the Pitka Fork of the Middle Fork Kuskokwim River. Both counts were considered outliers compared to historical observations. Only 19 Chinook salmon were counted in the Gagaryah River, which is the smallest observation on record (n = 19 years, range = 62–1,193). Although the Gagaryah survey received a fair rating, surveyor comments mentioned turbid water conditions in the lower reaches which hindered the ability to count Chinook salmon. A record high of 1,381 Chinook salmon were counted in Bear Creek, which is more than 7 times larger than the historical average (n = 17 years) of 179 Chinook salmon (range = 36–367). The Bear Creek survey received a good survey rating, but the survey was not used because the extremely large count would likely bias the total run estimate high.

MODEL RESULTS

The 2015 Kuskokwim River Chinook salmon drainagewide run and escapement was estimated to be 172,055 (95% CI: 129,115–229,276) and 155,464 (95%CI: 112,524–212,685) fish, respectively (Table 2 and Figure 3). Coefficient of variation (CV) was estimated to be 16%, which is similar to historical estimates (Bue et al. 2012). Overall model fits were similar to those of Bue et al. (2012) and model fits for weirs were generally better than for aerial surveys (Figure 4). Higher overdispersion parameters for weir data (Table 3) compared to aerial survey data shows that the model put higher weight on weir observations. Estimates of total annual abundance and escapement for previous years, generated by the 2015 model run, were larger than estimates reported by Bue et al. (2012) and Hamazaki and Liller (2015) , but well within the 95% confidence intervals of those time series (Table 2 and Figure 5).

The run reconstruction model indicates that Chinook salmon run sizes have been improving (Table 2 and Figure 3). Based on the 2015 model run, total abundance in 2015 was 34% smaller compared to the recent long-term average (1976–2014) of 261,163 Chinook salmon and was the 8th smallest run size on record. However, the 2015 run was the largest since 2010 which was the first of 5 consecutive years of record low run sizes. Abundance has increased annually since 2013 which was the lowest run size on record. The 2015 return was also within the range of run sizes capable of supporting some fisheries. The 2015 run size was larger than the 1986 and 2000 runs, both of which were low runs but supported unrestricted subsistence harvest opportunity and were followed by periods of healthy returns.

Harvest restrictions implemented in 2015 (Poetter 2015) resulted in near average escapements throughout much of the Kuskokwim River drainage (Table 1 and Table 2). Based on the 2015 model run, total escapement in 2015 was only 8% smaller than the recent long-term average (1976–2014) of 169,074 Chinook salmon. Total escapement in 2015 was larger than 21 of 39 (54%) past years. Although the uncertainty of the drainagewide escapement is relatively high, the 95% confidence range (112,524–212,685) provides considerable evidence that the drainagewide escapement goal of 65,000–120,000 was exceeded.

UNCERTAINTY OF 2015 MODEL ESTIMATES

There is considerable uncertainty in the 2015 model estimates. In 2015 some escapement projects indicated the total run was very small while others indicated the run was very large. The model is specifically designed to accommodate “conflicting” data from a range of index projects; however, greater differences among projects results in greater uncertainty in the actual size of the total run and escapement. In 2015, estimates of drainagewide escapement derived from each escapement project varied from 36,300 to 319,300 (Figure 6), which resulted in relatively wide confidence intervals. The model placed a higher weight on data from weir projects compared to aerial surveys, which is consistent with the perceived relative quality of each data type. Each of the 5 weir projects resulted in similar estimates of total escapement. Aerial survey data was more variable, and that variability accounted for much of the model uncertainty.

Had the Gagaryah River and Bear Creek aerial surveys been included, model estimates would have been skewed. Including these 2 extreme values would result in a 12% increase to the estimate of total run and escapement. However, the 95% confidence intervals overlapped broadly between both model runs (i.e., inclusive and exclusive) indicating the difference was statistically insignificant.

The uncertainty observed in 2015 is similar to what was observed in 2014 and much greater than what was observed in 2013 (Figure 6; Hamazaki and Liller 2015). Higher uncertainty in 2014 and 2015 may be related to changes in fish distribution in recent years. Each tributary escapement project is related to the drainage escapement by a scaling factor which is estimated by the model and is assumed to be constant over time (Equation 2). The assumption that spawning distribution is constant over time may no longer be valid in recent years because harvest restrictions imposed on the fishery have changed fishing patterns. Specifically, subsistence harvest during the early portion of the annual run has been heavily restricted in both 2014 and 2015 (Poetter 2015), greatly reducing exploitation on early migrating fish. There is some evidence that high proportions of these early migrating fish spawn in more distant portions of the drainage. The reduced exploitation of these sub-stocks may explain the larger than expected escapements to headwater tributaries upriver from McGrath in both 2014 and 2015.

Severe changes in spawning distribution relative to past years could result in misleading model results. For example, the very large Chinook salmon counts from the Salmon River (Pitka Fork) aerial surveys in 2014 and 2015 suggest that the total escapement was near record high (Figure 6). Clearly this was not the case as the bulk of the information from other index projects indicates the annual escapement was well below average.

MODEL REVIEW CONSIDERATIONS

Model scaling is an important factor that influences the ability to accurately estimate total run and escapement. The model is currently scaled using 5 years of independent total run estimates from 2003 to 2007 (Figure 3). The run abundance in each of those 5 years was above average and included record high abundances in 2004 and 2005 (Schaberg et al. 2012). The record low run sizes since 2010 are outside the parameters on which the model was based.

The ADF&G Division of Commercial Fisheries initiated a 3-year mark–recapture study (2014–2016) to ground truth estimates of total run and escapement generated by the reconstruction model (Liller 2014). This work was funded by the State of Alaska at the recommendation of the ADF&G Chinook Salmon Research Team (2013). Study results will be used to evaluate model scaling and ensure the run reconstruction model will perform adequately during years of low run abundance.

Preliminary results from the first 2 years of mark–recapture studies demonstrate that the run reconstruction model continues to perform adequately for drawing broad conclusions, but may have overestimated the true abundance of Chinook salmon in 2014 and 2015. Preliminary estimates of total run size based on mark–recapture methods are 83,400 fish (95% CI: 70,400–105,300) in 2014 and 123,900 fish (95% CI: 109,700–132,500) in 2015. A direct comparison illustrates that the estimates from the run reconstruction model are, on average, 51% larger (approximately 50,000 fish) compared to the independent estimate of total run based on mark–recapture methods (Figure 7). In both years, the 95% confidence intervals overlap between the 2 methods by a few thousand fish. Although the estimates of total run differ between the 2 methods, general conclusions about total run and escapement are consistent. In particular, the following model conclusions are supported by the mark–recapture studies: 1) the 2014 and 2015 total run sizes were below average; 2) drainagewide escapement goals were met or exceeded in 2014 and 2015; and 3) the 2015 run was larger than the 2014 run.

The ADF&G is actively collaborating with U.S. Fish and Wildlife Service (USFWS), non-government organizations (NGOs), academia, and stakeholder groups to review model results and consider options for improving model performance. To date, this collaboration has included 2 notable components. The first component included implementation and preliminary review of recent mark–recapture estimates as a means to ground truth model results during years of low run abundance. The second component was an independent review of how the model weighted different data types to arrive at the most likely estimate of total run and escapement[2]. A collaborative model review is planned to begin in the fall of 2016. The review team will include staff from ADF&G and USFWS with input from biologists representing Tribal NGOs and academia. The timing of this review will occur after the final year of mark–recapture studies and

[2] Staton, B., M. Catalano, L. Coggins, B. Bechtol, and D. Gwinn. Unpulished. Description of the Kuskokwim River Chinook salmon run reconstruction and an investigation of data weighting: A report to the Kuskokwim River Salmon Management Working Group.

will coincide with the escapement goal review process for the 2019 Alaska Board of Fisheries meeting on Kuskokwim Area finfish. Review results will be available to the public through outreach and the ADF&G publication series.

2015 Run Reconstruction Model Conclusions

- The total run of Kuskokwim River Chinook salmon was estimated to be 172,055 (95% CI: 129,115–229,276).
- The 2015 run size and escapement of Kuskokwim River Chinook salmon was larger than in 2014.
- Total run abundance was below average but within a range of run sizes that could likely support subsistence harvest at levels near the lower bound of amounts necessary for subsistence (67,200–109,800) as defined by the Alaska Board of Fisheries 5 AAC 01.2086.
- The total escapement of Kuskokwim River Chinook salmon was estimated to be 155,464 (95% CI. 112,524–212,685).
- Total escapement was near average due to harvest restrictions throughout much of Chinook salmon run and the drainagewide sustainable escapement goal of 65,000–120,000 was likely exceeded.
- Preliminary results from the ongoing mark–recapture study indicates that the true size of the 2015 run and escapement may be better represented by the lower bound of the 95% confidence range surrounding the run reconstruction model estimate.

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TABLES AND FIGURES

Table 1.–Escapement observations of Kuskokwim River Chinook salmon in 2014 and 2015 used to inform run reconstruction models.

Method	Location	Index	Average Escapement (1976-2013)	Year 2014	Year 2015	Used in the 2015 model
Weir	Kwethluk	Lower River	9,413	3,187	8,162	Yes
	Tuluksak	Lower River	1,068	320	709	Yes
	George	Middle River	3,648	2,993	2,282	Yes
	Kogrukluk	Middle River - Holitna Drainage	10,551	3,732	8,081	Yes
	Tatlawiksuk	Middle River	1,516	1,904	2,104	Yes
	Takotna [a]	Upper River	417	Discontinued		
Aerial Survey	Kwethluk [b]	Lower River	2,183	-	-	
	Kisaralik	Lower River	1,213	622	709	Yes
	Tuluksak [b]	Lower River	392	-	-	
	Salmon (Aniak)	Middle River - Aniak Drainage	826	497	810	Yes
	Kipchuk	Middle River - Aniak Drainage	1,019	1,220	917	Yes
	Aniak [c]	Middle River - Aniak Drainage	2,776	3,201	-	
	Holokuk	Middle River	413	80	77	Yes
	Oskawalik [c]	Middle River	310	200	-	
	Holitna [d]	Middle River - Holitna Drainage	1,723	-	662	Yes
	Cheeneetnuk [c]	Middle River - Swift Drainage	745	340	-	
	Gagaryah [e]	Middle River - Swift Drainage	493	359	19	No
	Pitka [f]	Upper River	221	-	-	
	Bear [g]	Upper River - Pitka Drainage	188	-	1,381	No
	Salmon (Pitka)	Upper River - Pitka Drainage	924	1,865	2,016	Yes

Note: Not all project operated in all years. Average represents only years when the project operated successfully.

[a] Weir operated from 1995 until 2013.

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

[c] Survey attempted in 2015 but was not successful due to weather conditions.

[d] A non-standardized survey was flown in 2014 and counts are not directly compared with other observations.

[e] 2015 survey was not used due to extreme low count resulting in unreasonable model estimate of total escapement.

[f] Surveys were not attempted.

[g] Survey was not attempted in 2014. 2015 count was not used do to extreme high count (7 times larger than historical average) resulting in unreasonable estimate of total escapement.

Table 2.–Annual drainagewide run and escapement of Kuskokwim River Chinook salmon from the 2015 run reconstruction model.

		2015 Model Run				2015 Model Run		
Year	Published Total Run Estimate	2015 Total Run Estimate	Lower 95% CI	Upper 95% CI	Published Total Esc. Estimate	2015 Total Esc. Estimate	Lower 95% CI	Upper 95% CI
1976	233,967	245,329	188,673	318,998	143,420	154,782	98,126	228,451
1977	295,559	338,176	263,192	434,521	201,852	244,469	169,485	340,814
1978	264,325	299,019	236,364	378,283	180,853	215,547	152,892	294,811
1979	253,970	311,204	231,982	417,479	157,668	214,902	135,680	321,177
1980	300,573	321,672	234,357	441,518	203,605	224,704	137,389	344,550
1981	389,791	419,938	317,613	555,230	279,392	309,539	207,214	444,831
1982	187,354	218,591	180,238	265,104	80,353	111,590	73,237	158,103
1983	166,333	193,762	151,800	247,322	84,188	111,617	69,655	165,177
1984	188,238	220,692	166,848	291,911	99,062	131,516	77,672	202,735
1985	176,292	192,439	143,617	257,858	94,365	110,512	61,690	175,931
1986	129,168	130,055	97,461	173,550	58,556	59,443	26,849	102,938
1987	193,465	210,681	150,799	294,343	89,222	106,438	46,556	190,100
1988	207,818	254,865	229,797	282,667	80,055	127,102	102,034	154,904
1989	241,857	281,490	227,579	348,173	115,704	155,337	101,426	222,020
1990	264,802	283,562	238,418	337,254	100,614	119,376	74,232	173,068
1991	218,705	231,330	191,403	279,585	105,589	118,182	78,255	166,437
1992	284,846	302,850	249,986	366,892	153,573	171,577	118,713	235,619
1993	269,305	307,004	242,749	388,269	169,816	207,493	143,238	288,758
1994	365,246	435,138	321,671	588,630	242,616	312,508	199,041	466,000
1995	360,513	413,280	329,999	517,578	225,595	278,362	195,081	382,660
1996	302,603	374,318	282,148	496,597	197,092	268,807	176,637	391,086
1997	303,189	367,935	280,845	482,032	211,247	276,554	189,464	390,651
1998	213,873	209,650	157,826	278,490	113,627	109,434	57,610	178,274
1999	189,939	192,505	151,446	244,696	112,082	114,675	73,616	166,866
2000	136,618	150,096	126,148	178,591	65,180	81,863	57,915	110,358
2001	223,707	257,513	208,456	318,115	145,232	179,038	129,981	239,640
2002	246,296	256,781	213,381	309,007	164,635	175,120	131,720	227,346
2003	248,789	276,103	234,153	325,568	180,687	208,001	166,051	257,466
2004	388,136	408,387	344,049	484,756	287,178	307,746	243,408	384,115
2005	366,601	392,014	335,276	458,354	275,598	301,011	244,273	367,351
2006	307,662	336,135	280,746	402,450	214,004	242,477	187,088	308,792
2007	273,060	284,132	246,560	327,430	174,943	186,015	148,443	229,313
2008	237,074	247,483	212,807	287,809	128,978	139,387	104,711	179,713
2009	204,747	217,806	183,485	258,548	118,478	131,537	97,216	172,279
2010	118,507	126,515	110,898	144,331	49,073	57,081	41,464	74,897
2011	133,059	138,025	118,756	160,420	72,097	73,994	54,725	96,389
2012	99,807	105,104	82,325	134,188	76,074	81,612	58,833	110,696
2013	94,166	93,109	81,464	106,418	47,315	45,621	33,976	58,930
2014	135,749	140,667	105,999	186,674	123,987	128,932	94,264	174,939
2015		172,055	129,115	229,276		155,464	112,524	212,685
Average (1976-2014)	236,300	261,163	209,008	327,427	144,195	169,074	116,920	235,338

Note: The run reconstruction model produces estimates for all years every time the model is updated with new information. The full time series associated with the 2015 run and escapement estimate is shown here for transparency. The estimates shown here for years 1976–2014 do not supersede previously published estimates by Bue et al. 2012 or Hamazaki and Liller 2015.

Table 3.–Parameter estimates derived from the 2015 run reconstruction model.

		Parameter	95% Bound		Overdispersion
		Estimate	Lower	Upper	Parameter (m)
Weir Projects (k)					
	Kwethluk Weir	19.59	14.92	25.71	6.06
	Tuluksak Weir	183.01	141.20	237.19	5.70
	George Weir	44.49	35.36	55.98	12.70
	Kogrukluk Weir	16.65	13.51	20.53	9.36
	Tatlawiksuk Weir	91.50	74.00	113.13	22.17
	Takotna Weir	393.85	306.57	505.98	8.61
				Average	10.77
Aerial Survey (k)					
	Kwethluk River	88.71	59.96	131.25	2.77
	Kisaralik River	160.24	111.25	230.80	1.59
	Tuluksak River	487.72	339.49	700.69	3.37
	Salmon (Aniak River)	231.14	176.35	302.96	2.94
	Kipchuk River	174.84	134.22	227.74	4.09
	Aniak River	63.73	49.86	81.46	6.53
	Holokuk River	472.12	299.87	743.31	1.56
	Oskawalik River	637.64	444.96	913.76	2.11
	Holitna River	106.83	79.27	143.97	4.19
	Cheeneetnuk River	245.98	180.34	335.52	3.21
	Gagaryah River	406.64	306.67	539.18	4.05
	Pitka Fork	781.96	586.33	1042.88	6.74
	Bear River	849.45	656.29	1099.47	7.02
	Salmon(Pitka Fork)	158.39	122.23	205.25	4.17
				Average	3.88
Catchability (q)					
	Unrestricted	6.97E-05	5.60E-05	8.66E-05	
	Restricted (1)	1.32E-05	1.01E-05	1.73E-05	
	Restricted (2)	4.01E-05	3.27E-05	4.91E-05	

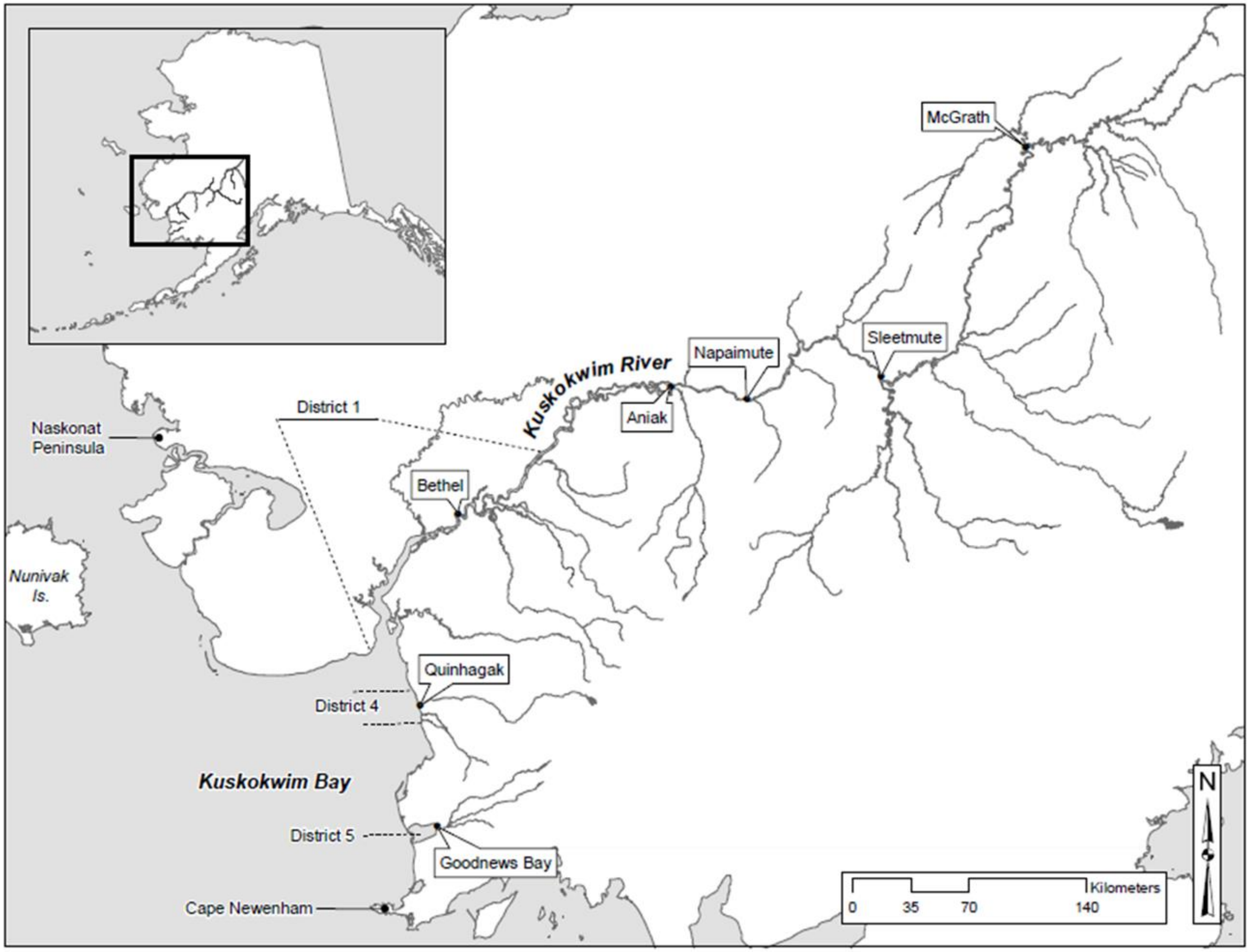

Figure 1.–Kuskokwim Management Area showing major communities and commercial fishing districts.

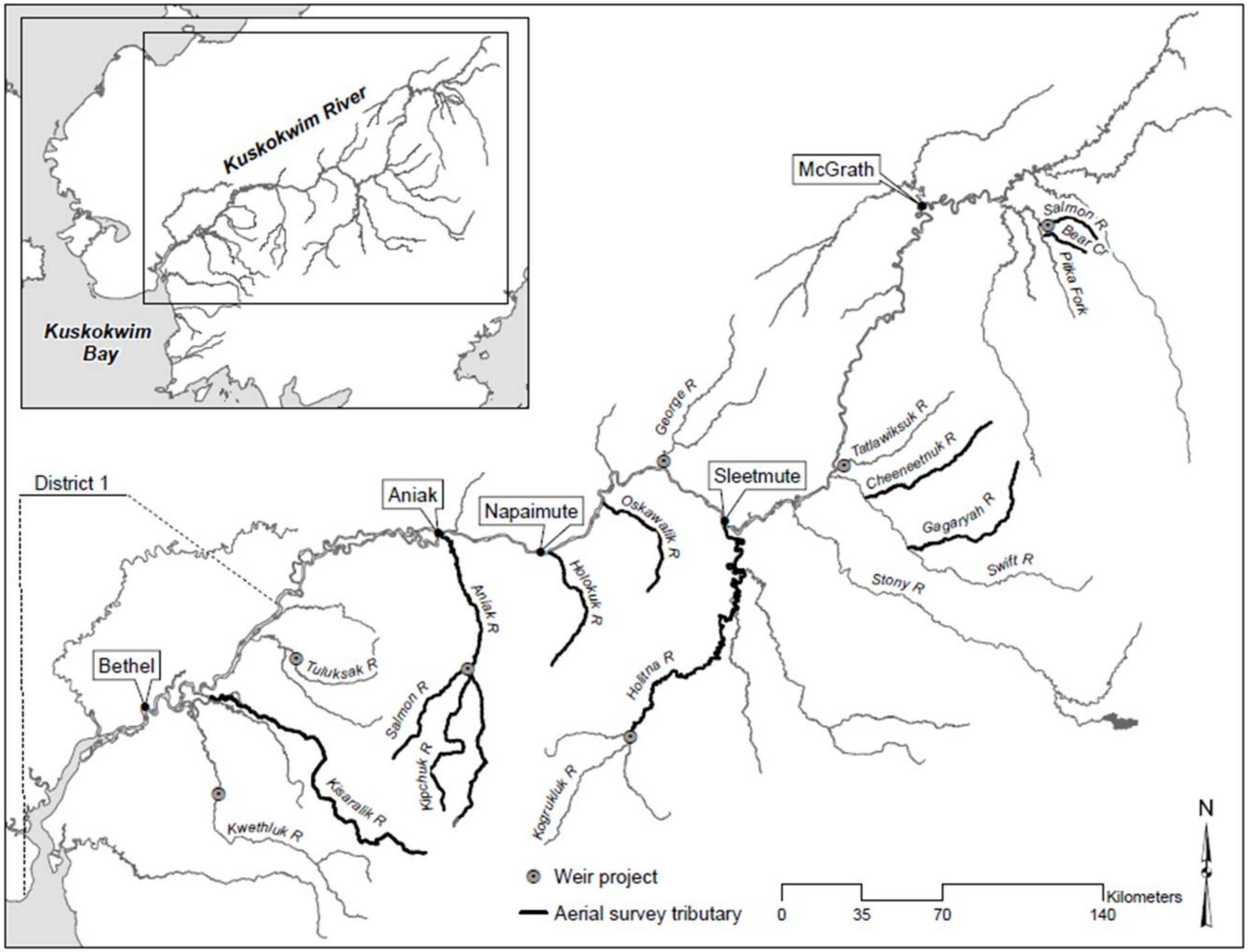

Figure 2.–Kuskokwim River tributaries where Chinook salmon escapement was monitored in 2015.

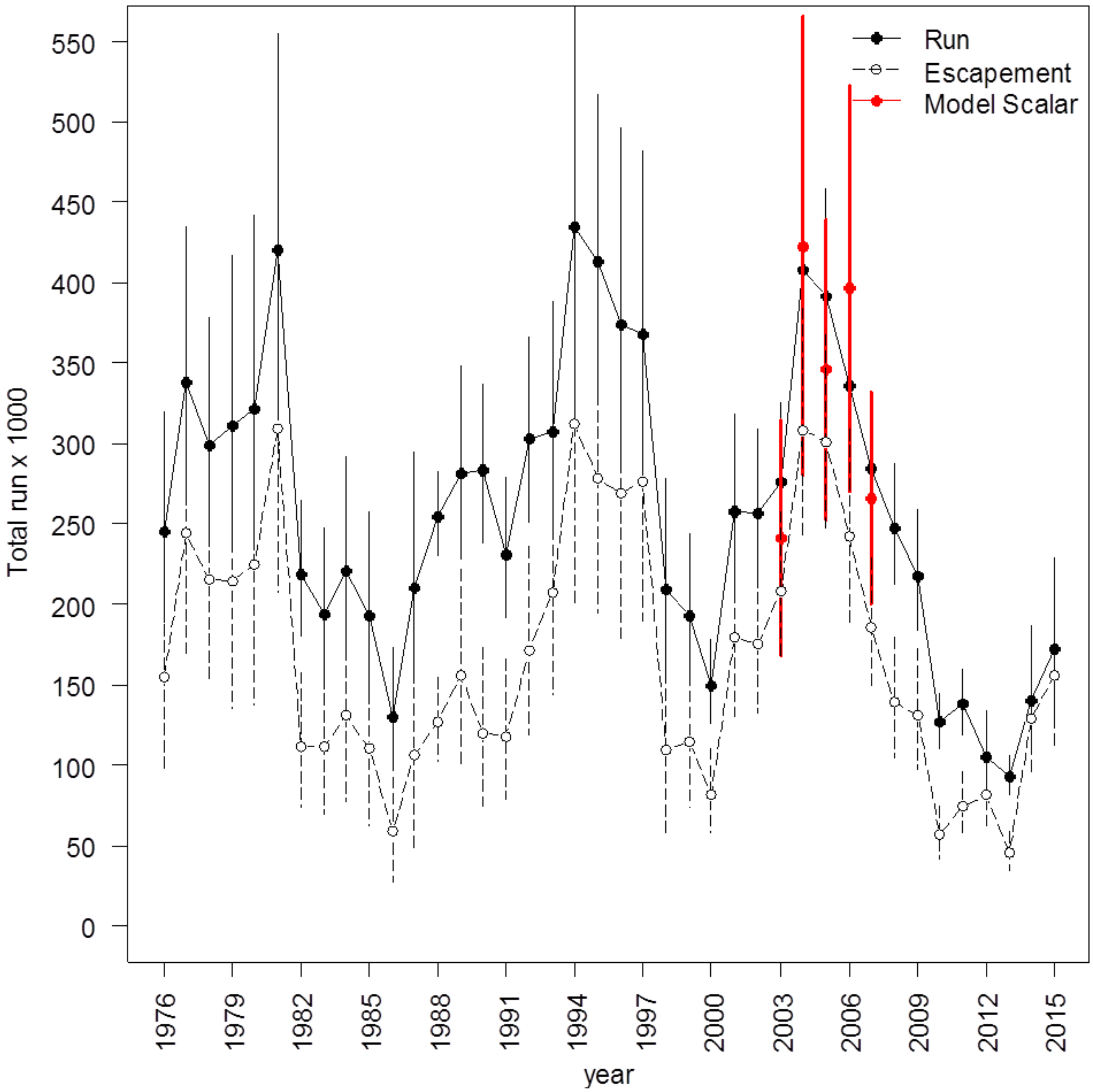

Figure 3.–Annual run (black) and escapement (white) estimates with 95% confidence intervals estimated from the 2015 run reconstruction model.

Note: Red dots are the independent observed drainagewide run size and 95% confidence intervals for years 2003–2007 used to scale the model. Model scalars are direct estimates of total run derived from a combination of mark–recapture data, escapement estimates, and extrapolation of escapement values to unmonitored areas, and harvests (Schaberg et al. 2012).

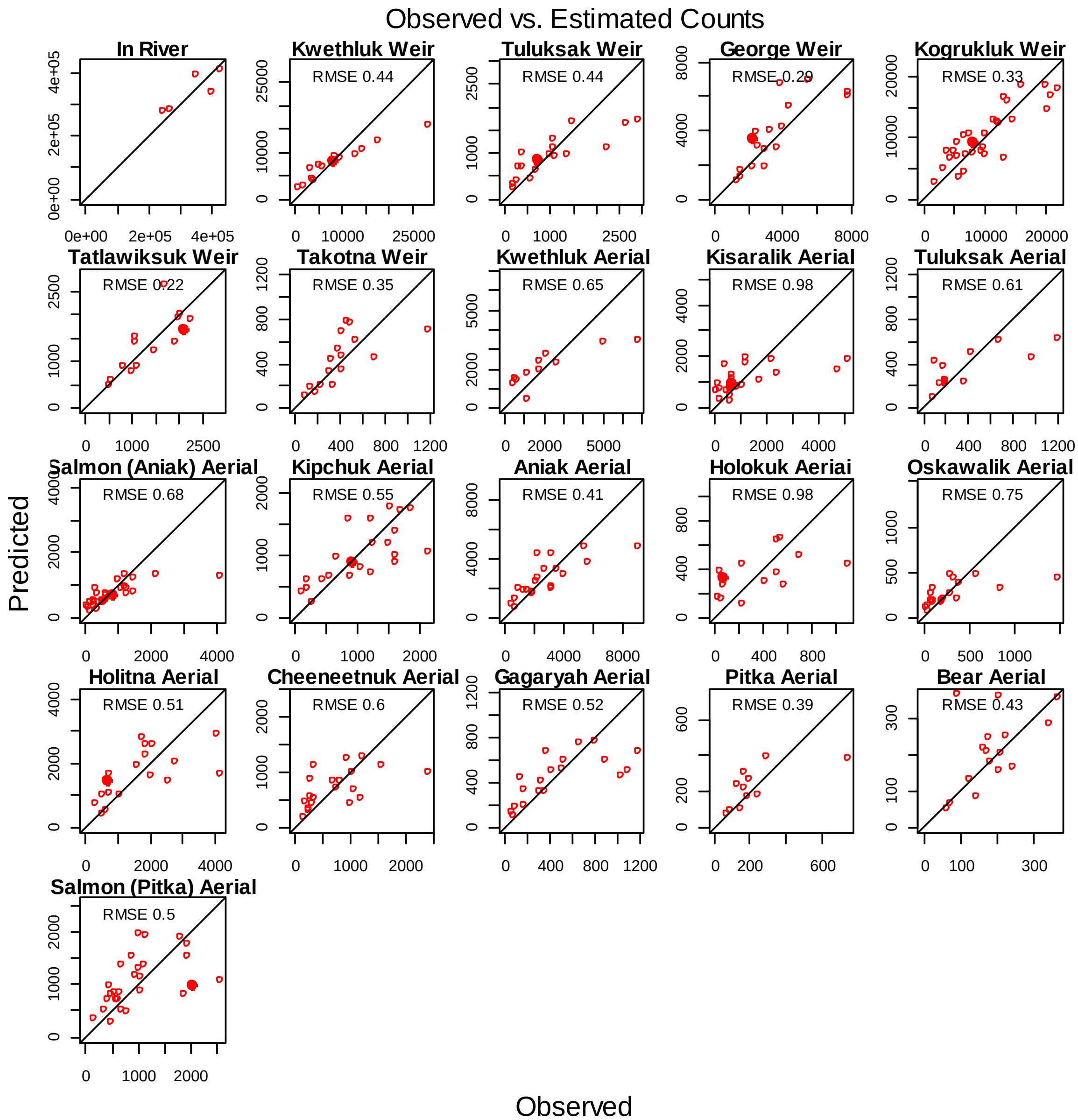

Figure 4.–Observed and model estimated escapement counts.

Note: Diagonal line represents the 1:1 line, which is the point at which observed and estimated escapements are equal. Hollow red dots are the prior year observations and solid red dots are the 2015 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.

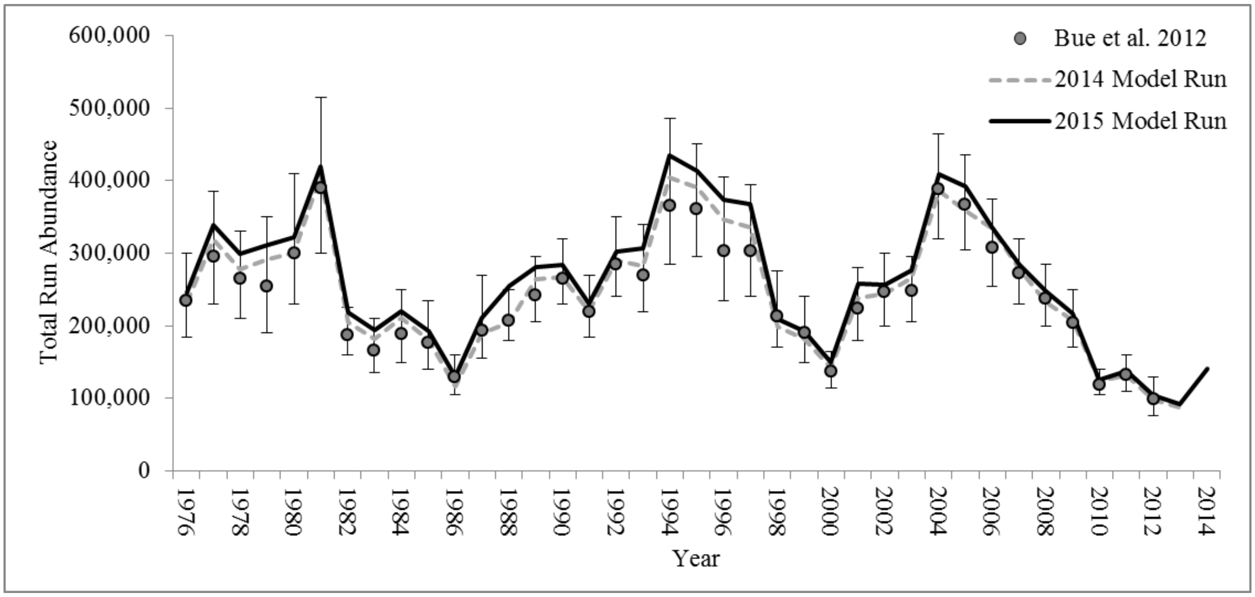

Figure 5.–Comparison of run reconstruction estimates of total Kuskokwim River Chinook salmon run size reported by Bue et al. 2012 (95% confidence intervals), Hamazaki and Liller 2015, and the 2015 model run. Only data through 2014 are shown.

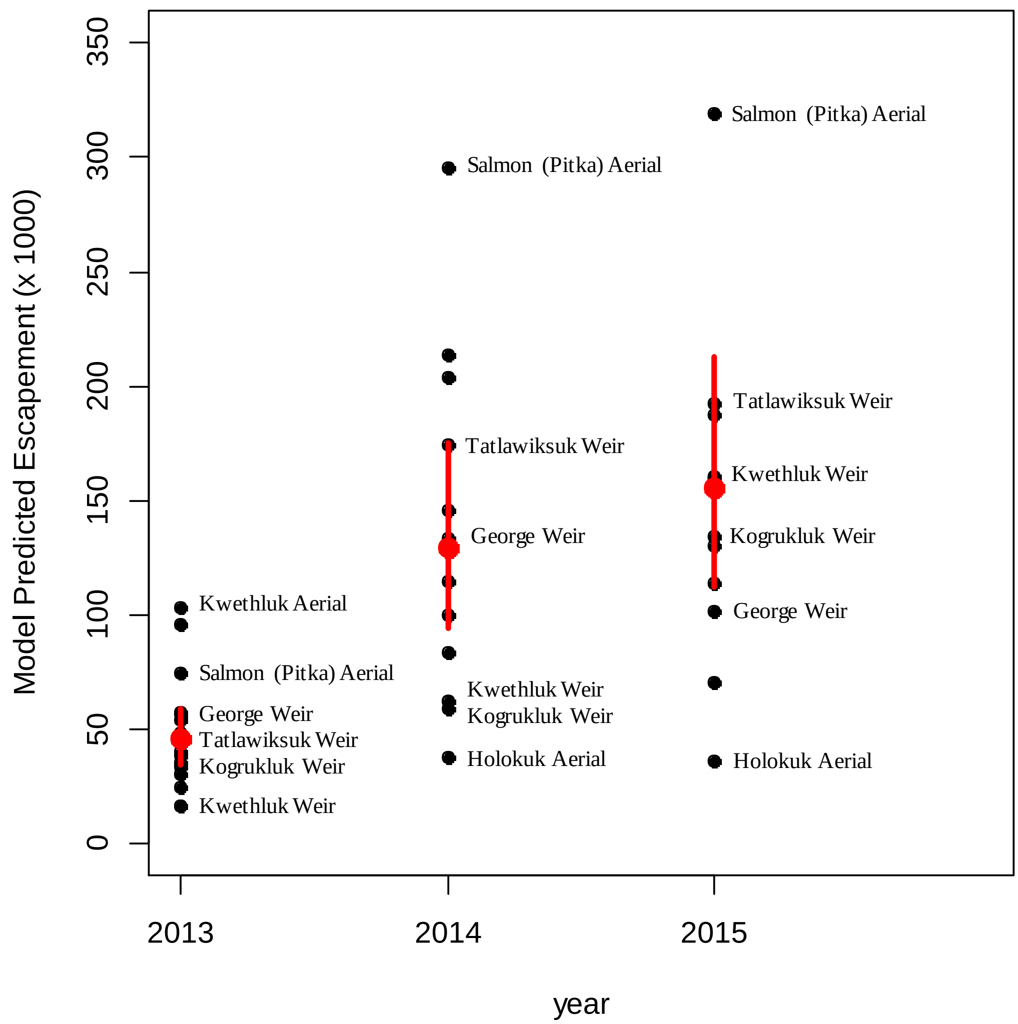

Figure 6.–Range of drainagewide escapement estimates produced by the model based on each individual escapement project.

Note: Black dots are individual project estimates of total run based on the model estimated scaling factor. Red dot and line shows the model derived drainagewide escapement and 95% confidence interval after simultaneously combining the information from all escapement monitoring projects. The more similar the project estimates the tighter the confidence range around the drainagewide estimate. 2013 and 2014 are shown to provide context.

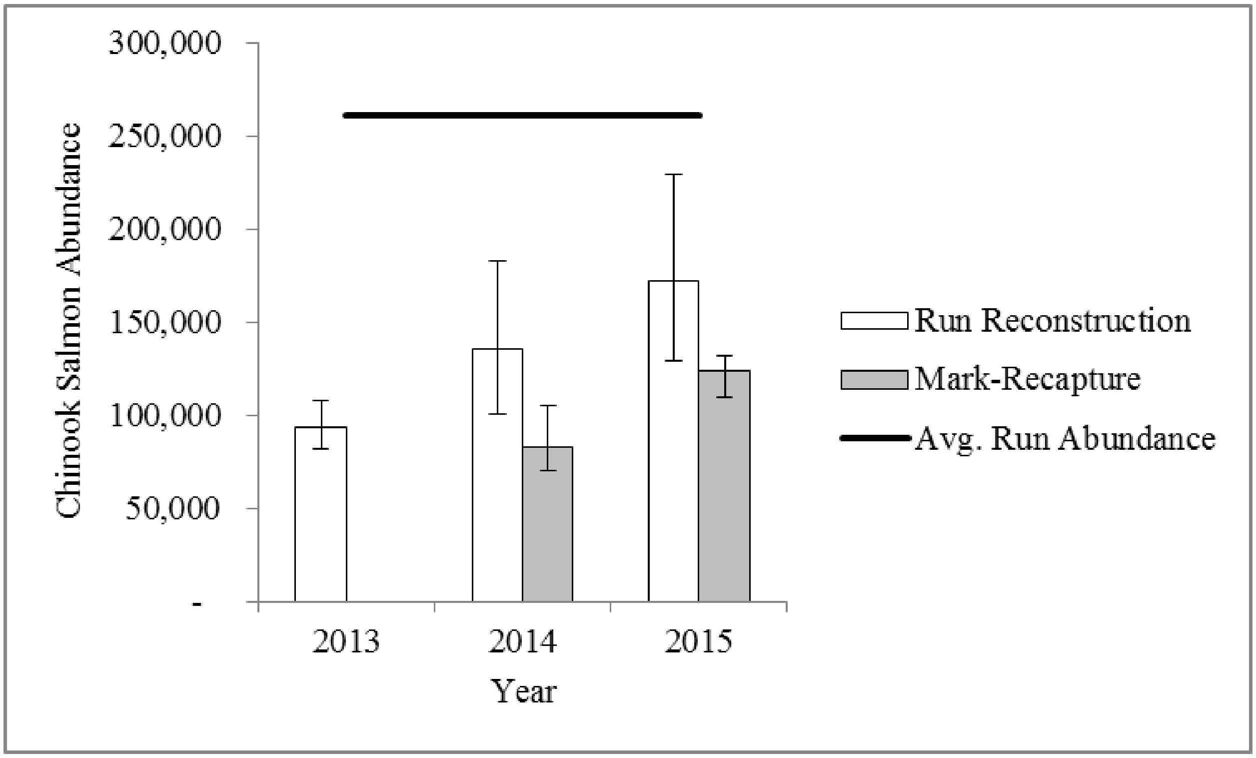

Figure 7.–Total run size of Kuskokwim Chinook salmon estimates from the run reconstruction model and preliminary mark–recapture results, 2013–2015.

APPENDIX A: 2015 R-CODE WITH ANNOTATIONS

Appendix A1.–2015 R-code with annotations.

```
########################################################################################
# 1.0 Initialize working Environment
########################################################################################
rm(list=ls(all=TRUE))
# Enter the name of data file
data_file <- 'Kusko_RR_Input_March_10_2016.csv'
kusko.data <- read.csv(data_file,header=T, na.string='')
########################################################################################
# 2.2 Test fishery: Estimate run proportion of 1976-1983
########################################################################################
# Extract testfish data
testf<-kusko.data[substr(names(kusko.data),1,3)=='rpw']
# combine week 8, 9 and 10 and drop
testf[,8] <- testf[,8]+testf[,9]+testf[,10]
testf <- testf[,-(9:10)]
# Replace NA to mean proporion for each week
for (i in 1:dim(testf)[2]) {
  testf[is.na(testf[i]),i] <- colMeans(testf,na.rm=T)[i]
}
########################################################################################
# 2.3 Rearrange fishing effort and harvest data catch 0 to NA
########################################################################################
# Extract weekly commercial effort data
ceff <-kusko.data[substr(names(kusko.data),1,3)=='cew']
# combine week 8, 9 and drop
ceff[,6] <- ceff[,6]+ceff[,7]
ceff <- ceff[,-7]
# replace 0 to NA
ceff[ceff == 0] <- NA
# Extract weekly commercial catch data
ccat <-kusko.data[substr(names(kusko.data),1,3)=='chw']
```

```
# combine week 8, 9 and drop
ccat[,6] <- ccat[,6]+ccat[,7]
ccat <- ccat[,-7]
# replace 0 to NA
ccat[ccat == 0] <- NA
# Extract weekly commercial est data
creg <-kusko.data[substr(names(kusko.data),1,3)=='cfw']
# combine week 8, 9 and drop
creg[,6] <- pmax(creg[,6],creg[,7])
creg <- creg[,-7]
################################################################################
# 2.4 Recalculate Inriver data
################################################################################
# Extract Inriver data
inr <-kusko.data[substr(names(kusko.data),1,3)=='In.']
# Calculate CV
inr$cv <- inr$In.river.sd/inr$In.river
################################################################################
# 2.5 Calculate Others
################################################################################
tcatch <- rowSums(kusko.data[substr(names(kusko.data),1,2)=='H.'],dims = 1,na.rm=T)
# Extract escapement data
esc <- kusko.data[substr(names(kusko.data),1,2)=='w.'|substr(names(kusko.data),1,2)=='a.']
t.esc <- kusko.data$In.river - tcatch
# Calculate observed minimum escapement
minesc <- rowSums(esc, na.rm=T, dims = 1)
# Calculate observed minimum run
minrun <- rowSums(cbind(tcatch,esc), na.rm=T, dims = 1)
ny <- length(kusko.data[,1])
################################################################################
# 2.4 Construct dataset used for likelihood modeling
################################################################################
kusko.like.data <- as.matrix(cbind(tcatch,inr,esc,testf[3:8],ccat,ceff,creg))
```

```
nb.likelihood <- function(theta,likedat,ny){
### Total run  ####################################################################
	totrun <- exp(theta[1:ny])
### Weir slope parameters ##########################################################
	w.kwe <- exp(theta[ny+1])
	w.tul <- exp(theta[ny+2])
	w.geo <- exp(theta[ny+3])
	w.kog <- exp(theta[ny+4])
	w.tat <- exp(theta[ny+5])
	w.tak <- exp(theta[ny+6])
### Aerial slope parameters #########################################################
	a.kwe <- exp(theta[ny+7])
	a.kis <- exp(theta[ny+8])
	a.tul <- exp(theta[ny+9])
	a.sla <- exp(theta[ny+10])
	a.kip <- exp(theta[ny+11])
	a.ank <- exp(theta[ny+12])
	a.hlk <- exp(theta[ny+13])
	a.osk <- exp(theta[ny+14])
	a.hlt <- exp(theta[ny+15])
	a.che <- exp(theta[ny+16])
	a.gag <- exp(theta[ny+17])
	a.pit <- exp(theta[ny+18])
	a.ber <- exp(theta[ny+19])
	a.slp <- exp(theta[ny+20])

### Catch coefficient parameters #####################################################
# catchability coefficient Unrestricted
	q1 <- exp(theta[ny+21])
# catchability coefficient Restricted
	q2 <- exp(theta[ny+22])
# catchability coefficient Center Core monofilament
```

```
    q3 <- exp(theta[ny+23])
### Overdispersion parameters, weirs ################################################
    r.kwe <- exp(theta[ny+24])
    r.tul <- exp(theta[ny+25])
    r.geo <- exp(theta[ny+26])
    r.kog <- exp(theta[ny+27])
    r.tat <- exp(theta[ny+28])
    r.tak <- exp(theta[ny+29])
### Overdispersion parameters, aerial ################################################
    ra.kwe <- exp(theta[ny+30])
    ra.kis <- exp(theta[ny+31])
    ra.tul <- exp(theta[ny+32])
    ra.sla <- exp(theta[ny+33])
    ra.kip <- exp(theta[ny+34])
    ra.ank <- exp(theta[ny+35])
    ra.hlk <- exp(theta[ny+36])
    ra.osk <- exp(theta[ny+37])
    ra.hlt <- exp(theta[ny+38])
    ra.che <- exp(theta[ny+39])
    ra.gag <- exp(theta[ny+40])
    ra.pit <- exp(theta[ny+41])
    ra.ber <- exp(theta[ny+42])
    ra.slp <- exp(theta[ny+43])
### Likelihood model ##############################################################
    tfw  <-  rep(0,6)
    tfa  <-  rep(0,14)
    tft  <-  0
    tfc  <-  0
    esc  <-  totrun-likedat[,1]
#### Definie the negative binomial function ##############################################
    nblike <- function(obs,r,est){
    lgamma(obs+r)-lgamma(obs+1)-lgamma(r)+r*log(r/(est+r))+obs*log(est/(est+r))
    }
```

```
#### Weir likelihood ##############################################################
        tfw[1]  <-  -sum(nblike(likedat[,5],r.kwe,esc/w.kwe),na.rm=T)
        tfw[2]  <-  -sum(nblike(likedat[,6],r.tul,esc/w.tul),na.rm=T)
        tfw[3]  <-  -sum(nblike(likedat[,7],r.geo,esc/w.geo),na.rm=T)
         tfw[4]  <-  -sum(nblike(likedat[,8],r.kog,esc/w.kog),na.rm=T)
         tfw[5]  <-  -sum(nblike(likedat[,9],r.tat,esc/w.tat),na.rm=T)
        tfw[6]  <-  -sum(nblike(likedat[,10],r.tak,esc/w.tak),na.rm=T)
#### Aerial likelihood ##############################################################
        tfa[1]  <-  -sum(nblike(likedat[,11],ra.kwe,esc/a.kwe),na.rm=T)
         tfa[2]  <-  -sum(nblike(likedat[,12],ra.kis,esc/a.kis),na.rm=T)
         tfa[3]  <-  -sum(nblike(likedat[,13],ra.tul,esc/a.tul),na.rm=T)
         tfa[4]  <-  -sum(nblike(likedat[,14],ra.sla,esc/a.sla),na.rm=T)
        tfa[5]  <-  -sum(nblike(likedat[,15],ra.kip,esc/a.kip),na.rm=T)
         tfa[6]  <-  -sum(nblike(likedat[,16],ra.ank,esc/a.ank),na.rm=T)
         tfa[7]  <-  -sum(nblike(likedat[,17],ra.hlk,esc/a.hlk),na.rm=T)
         tfa[8]  <-  -sum(nblike(likedat[,18],ra.osk,esc/a.osk),na.rm=T)
         tfa[9]  <-  -sum(nblike(likedat[,19],ra.hlt,esc/a.hlt),na.rm=T)
         tfa[10]  <-  -sum(nblike(likedat[,20],ra.che,esc/a.che),na.rm=T)
         tfa[11]  <-  -sum(nblike(likedat[,21],ra.gag,esc/a.gag),na.rm=T)
         tfa[12]  <-  -sum(nblike(likedat[,22],ra.pit,esc/a.pit),na.rm=T)
         tfa[13]  <-  -sum(nblike(likedat[,23],ra.ber,esc/a.ber),na.rm=T)
        tfa[14]  <-  -sum(nblike(likedat[,24],ra.slp,esc/a.slp),na.rm=T)
#### Inriver normal likelihood #######################################################
        tft  <-  0.5*sum((likedat[,2]-totrun)^2/(likedat[,3])^2,na.rm=T)
#### Weekly Catch likelihood, calculated estimated run by week #########################
        wk.est <- likedat[,25:30]*totrun
#### Calculate likelihoood for unrestricted############################################
# Extract all mesh regulation year/week
        unr <- likedat[,43:48]
# Keep unrestricted mesh regulation year/week 1: indicate unrestricted period
        unr[unr != 1] <- NA
# Observed Effort
# Keep only Effort of Unrestricted
```

```
        unr.eff <- likedat[,37:42]*unr
# Rmove all NA
        unr.eff <- unr.eff[!is.na(unr.eff)]
# Observed harvest
# Keep only Effort of Unrestricted
        unr.h <- likedat[,31:36]*unr
# Rmove all NA
        unr.h <- unr.h[!is.na(unr.h)]
# Estimated
# Keep only Effort of Unrestricted
        unr.wk <- wk.est*unr
# Rmove all NA
        unr.wk <- unr.wk[!is.na(unr.wk)]
# likelihood for Unrestricted
   tf1 <- 0.5*length(unr.eff)*log(sum((log(unr.eff)-log(-log(1-unr.h/unr.wk)/q1))^2,na.rm=T))

#### Calculate likelihood for restricted ################################################
# Extract restricted mesh period
# Extract all mesh regulation year/week
        r <- likedat[,43:48]
# Keep unrestricted mesh regulation year/week 2: indicate restricted periods
        r[r != 2] <- NA
# Change it to 1
        r[r == 2] <- 1
# Observed effort
# Keep only Effort of Restricted
        r.eff <- likedat[,37:42]*r
# Rmove all NA
        r.eff <- r.eff[!is.na(r.eff)]
# Observed harvest
# Keep only Effort of Restricted
        r.h <- likedat[,31:36]*r
# Rmove all NA
```

```
        r.h <- r.h[!is.na(r.h)]
# Estimated
# Keep only Effort of Unrestricted
        r.wk <- wk.est*r
# Rmove all NA
        r.wk <- r.wk[!is.na(r.wk)]
# likelihood for Unrestricted
  tf2 <- 0.5*length(r.eff)*log(sum((log(r.eff)-log(-log(1-r.h/r.wk)/q2))^2,na.rm=T))
#### Calculate likelihood for Monofilament############################################
# Extract Monfilament periods
# Extract all mesh regulation year/week (This is taking only 3-6 weeks
        m <- likedat[,43:48]
# Keep monofilament mesh regulation year/week 3: indicate monofilament peiriods
        m[(m != 3)&(m != 5)] <- NA
# Change it to 1
        m[!is.na(m)] <- 1
# Observed effort
# Keep only Effort of Restricted
        m.eff <- likedat[,37:42]*m
# Rmove all NA
        m.eff <- m.eff[!is.na(m.eff)]
# Observed harvest
# Keep only Effort of Restricted
        m.h <- likedat[,31:36]*m
# Rmove all NA
        m.h <- m.h[!is.na(m.h)]
# Estimated
# Keep only Effort of Restricted
        m.wk <- wk.est*m
# Rmove all NA
        m.wk <- m.wk[!is.na(m.wk)]
```

```
   tf3 <- 0.5*length(m.eff)*log(sum((log(m.eff)-log(-log(1-
ifelse(m.h/m.wk<1,m.h/m.wk,0.999))/q3))^2,na.rm=T))
tfc <-sum(tf1,tf2,tf3)

#### Likelihood calculation ########################################################
loglink  <- sum(sum(tfw),sum(tfa),tft,tfc,na.rm=T)
return(loglink)
}
#### 3.1 Set Initial value and boundaries ################################################
# Initial starting point
        init <- c(rep(log(250000),ny),rep(5,6),rep(4,14),rep(-10,3),rep(2,6),rep(2,14))
# Lower bounds
        lb <-  c(log(minrun),rep(2,6), rep(3,14),rep(-14,3),rep(-3,6),rep(-3,14))
# Upper bounds
        ub <-  c(rep(log(500000),ny),rep(7,6),rep(8,14),rep(-5,3),rep(5,6),rep(5,14))
#### 3.3 Run likelihood model#######################################################
ptm <- proc.time()
nll  <-  optim(par=init,fn=nb.likelihood,method="L-BFGS-B",lower=lb,  upper  =  ub,  control  =
list(maxit=1000),likedat=kusko.like.data, ny=ny, hessian = T)
min_NLL <- nll$value
proc.time() - ptm
nll$convergence
Rprof()
nll$par
nll$value
#### 3.4  Calculate Wald Confidence Interval ##########################################
#1: Hessian Matrix
        hessian_obs <- nll$hessian
        log_est_obs <- nll$par
        est_obs <- exp(log_est_obs)
# Create a variance-covariance matrix
        var_covar_mat_obs <- solve(hessian_obs)
# Pull out diagonal
```

```
    log_var_obs <- diag(var_covar_mat_obs)
# Calculate standard error
    log_std_err_obs <- sqrt(log_var_obs)
    upper95CI <- exp(log_est_obs + 1.96*log_std_err_obs)
    lower95CI <- exp(log_est_obs - 1.96*log_std_err_obs)
    labelT <- length(ny)

for (i in 1:ny){
labelT[i] <- paste('Run',1975+i)
}
labelT <- c(labelT,names(esc),'q1','q2','q3',names(esc))
output <-
data.frame(parameter=labelT,mean=exp(nll$par),lower95CI=lower95CI,lower95CI=upper95CI)
```

APPENDIX B: MODEL INPUT DATA

Appendix B1.–Independent estimates of Kuskokwim River Chinook salmon abundance, used to scale the run reconstruction model.

Var name:	Year	In.river	In.river.sd
Conventional name:	Year	Total Run	Standard Error
	2003	241,617	36,605
	2004	422,657	71,241
	2005	345,814	46,672
	2006	396,248	62,850
	2007	266,219	32,950

Appendix B2.–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	82,654	367	1,380
	1993	8,735	87,674	587	2,515
	1994	16,211	103,343	1,139	1,937
	1995	30,846	102,110	541	1,421
	1996	7,419	96,413	1,432	247
	1997	10,441	79,381	1,227	332
	1998	17,359	81,213	1,434	210
	1999	4,705	72,775	252	98
	2000	444	67,620	105	64
	2001	90	78,009	290	86
	2002	72	80,982	319	288
	2003	158	67,134	401	409
	2004	2,305	96,788	857	691
	2005	4,784	85,090	572	557
	2006	2,777	90,085	444	352
	2007	179	96,155	1,478	305
	2008	8,865	98,103	708	420
	2009	6,664	78,231	904	470
	2010	2,732	66,056	354	292
	2011	747	62,368	579	337
	2012	627	22,544	0	321
	2013	174	47,113	0	201
	2014	35	11,203	0	497
	2015	8	16,111	0	472

Appendix B3.–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				5,638		
	1977						
	1978				14,533		
	1979				11,393		
	1980						
	1981				16,089		
	1982				13,126		
	1983						
	1984				4,922		
	1985				4,442		
	1986						
	1987						
	1988				8,028		
	1989						
	1990				10,093		
	1991		697		6,835		
	1992	9,675	1,083		6,563		
	1993		2,218		12,377		
	1994		2,918				
	1995				20,662		
	1996			7,770	13,771		423
	1997			7,810	13,190		1,197
	1998						
	1999				5,543	1,484	
	2000	3,547		2,959	3,242	807	345
	2001		997	3,277	7,475	1,978	718
	2002	8,502	1,346	2,443	10,025	2,237	316
	2003	14,474	1,064		12,008		390
	2004	28,605	1,475	5,488	19,819	2,833	461
	2005		2,653	3,845	21,819	2,864	499
	2006	17,619	1,043	4,355	20,205	1,700	541
	2007	12,927	374	4,011		2,032	412
	2008	5,276	701	2,563	9,750	1,075	413
	2009	5,744	362	3,663	9,528	1,071	311
	2010	1,667	201	1,498	5,812	546	181
	2011	4,079	284	1,547	6,731	992	136
	2012		555	2,201		1,116	228
	2013	845	193	1,292	1,819	495	97
	2014	3,187	320	2,993	3,732	1,904	
	2015	8,162	709	2,282	8,081	2,104	

Appendix B4.–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				182	
	1977	2,075		424							2,407	897			1,930
	1978	1,722	2,417		289					2,766	268	504		227	1,100
	1979														682
	1980			975	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	142							1,002				620
	1986				336		424			650					
	1987				516	193			193		317				
	1988	622	869	195	244		954		80						474
	1989	1,157	152		631	1,598	2,109								452
	1990		631	200	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		1,243		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		425	443	1,930								
	1999								98	741					
	2000				238	182	714			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		165	211	
	2003	2,661	654	94	1,242	1,493	3,514	1,096	844		810	1,093	197	176	
	2004	6,801	5,157	1,196	2,177	1,868	5,362	539	293	4,051	918	670	290	206	1,138

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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)
	2005	5,059	2,206	672	4,097	1,679		510	582	1,760			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	248	245	1,033
	2009							565	379		323	303	187	209	632
	2010		235					229				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

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.

Appendix B5.–Proportion of total annual Chinook salmon run in District W-1 by week, as estimated by Bethel test fishery.

		6	7	8	9	Post-9
Var name:	Year	rpw.6	rpw.7	rpw.8	rpw.9	rpw.10
Conventional name:	Year	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	0.1633	0.0509	0.0522	0.0090	0.0173
	1985	0.4306	0.1504	0.0247	0.0175	0.0410
	1986	0.1399	0.0488	0.0097	0.0241	0.0000
	1987	0.1137	0.0210	0.0344	0.0130	0.0094
	1988	0.0852	0.0218	0.0419	0.0145	0.0192
	1989	0.0976	0.0258	0.0190	0.0119	0.0112
	1990	0.1492	0.0609	0.0136	0.0266	0.0256
	1991	0.1994	0.0337	0.0430	0.0000	0.0000
	1992	0.1085	0.0542	0.0554	0.0000	0.0118
	1993	0.0328	0.0273	0.0097	0.0000	0.0000
	1994	0.1009	0.0138	0.0122	0.0000	0.0061
	1995	0.0988	0.0300	0.0050	0.0097	0.0050
	1996	0.0288	0.0214	0.0000	0.0066	0.0033
	1997	0.0533	0.0357	0.0119	0.0079	0.0059
	1998	0.1513	0.0378	0.0116	0.0055	0.0000
	1999	0.1462	0.1903	0.0297	0.0754	0.0297
	2000	0.0461	0.0205	0.0410	0.0000	0.0183
	2001	0.1036	0.0528	0.0367	0.0000	0.0156
	2002	0.1034	0.0337	0.0137	0.0089	0.0132
	2003	0.0662	0.0351	0.0255	0.0112	0.0042
	2004	0.0693	0.0406	0.0537	0.0160	0.0021
	2005	0.1601	0.0768	0.0062	0.0000	0.0168
	2006	0.1675	0.0535	0.0114	0.0142	0.0105
	2007	0.2472	0.0754	0.0316	0.0095	0.0032
	2008	0.1183	0.0431	0.0334	0.0083	0.0139
	2009	0.0753	0.0323	0.0164	0.0000	0.0049
	2010	0.1335	0.0556	0.0185	0.0113	0.0103
	2011	0.1695	0.0818	0.0130	0.0000	0.0031
	2012	0.2114	0.0627	0.0201	0.0088	0.0127
	2013	0.0963	0.0743	0.0108	0.0000	0.0000
	2014	0.0771	0.0148	0.0146	0.0000	0.0029
	2015	0.1316	0.0625	0.0591	0.0338	0.0238

Appendix B6.–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		
Var name:	Year	chw.3	cew.3	cfw.3	chw.4	cew.4	cfw.4
Conventional name:	Year	Catch	Effort	Net	Catch	Effort	Net
	1976	0	0	0	20,010	5,724	1
	1977	12,458	2,802	1	16,227	2,904	1
	1978	18,483	3,972	1	10,066	2,004	1
	1979	24,633	6,432	1	5,651	3,012	2
	1980	9,891	2,814	1	21,698	5,364	4
	1981	29,882	6,180	1	3,830	3,066	2
	1982	4,912	2,784	1	24,628	5,970	1
	1983	13,406	5,634	1	8,063	5,544	2
	1984	0	0	0	17,181	5,562	1
	1985	0	0	0	6,519	2,538	3
	1986	0	0	0	0	0	0
	1987	0	0	0	19,126	4,734	3
	1988	12,640	4,816	3	11,708	3,672	3
	1989	0	0	0	15,215	5,208	3
	1990	0	0	0	16,690	3,780	3
	1991	0	0	0	13,813	3,606	3
	1992	0	0	0	24,334	9,488	3
	1993	0	0	0	0	0	0
	1994	0	0	0	0	0	0
	1995	0	0	0	6,895	2,276	3
	1996	0	0	0	4,091	1,056	3
	1997	0	0	0	10,023	2,118	3
	1998	0	0	0	0	0	0
	1999	0	0	0	0	0	0
	2000	0	0	0	0	0	0
	2001	0	0	0	0	0	0
	2002	0	0	0	0	0	0
	2003	0	0	0	0	0	0
	2004	0	0	0	0	0	0
	2005	0	0	0	0	0	0
	2006	0	0	0	0	0	0
	2007	0	0	0	0	0	0
	2008	0	0	0	6,415	1,026	3
	2009	0	0	0	3,003	668	3
	2010	0	0	0	0	0	0
	2011	0	0	0	0	0	0
	2012	0	0	0	0	0	0
	2013	0	0	0	0	0	0
	2014	0	0	0	0	0	0
	2015	0	0	0	0	0	0

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		Week 5 6/24 - 6/30			Week 6 7/1 - 7/7		
Var name:	Year	chw.5	cew.5	cfw.5	chw.6	cew.6	cfw.6
Conventional name:	Year	Catch	Effort	Net	Catch	Effort	Net
	1976	4,143	2,088	2	1,550	2,490	2
	1977	1,841	4,722	2	673	4,194	2
	1978	3,723	5,346	2	2,354	8,676	2
	1979	3,860	6,438	2	1,233	3,252	2
	1980	1,460	2,448	2	498	2,298	2
	1981	4,563	5,952	2	2,795	5,520	2
	1982	12,555	5,176	4	1,970	3,968	2
	1983	4,925	5,958	2	2,415	5,634	2
	1984	5,643	5,616	2	3,206	5,454	2
	1985	19,204	5,880	3	9,942	5,844	3
	1986	11,986	6,540	3	5,029	6,852	3
	1987	0	0	0	9,606	6,948	3
	1988	15,060	7,518	3	5,871	6,954	3
	1989	11,094	6,144	3	7,911	7,092	3
	1990	25,459	7,536	3	4,071	3,546	3
	1991	12,612	3,696	3	8,068	7,308	3
	1992	16,307	8,628	3	3,250	4,696	3
	1993	8,184	4,976	3	0	0	0
	1994	14,221	4,608	3	0	0	0
	1995	14,424	4,532	3	4,368	3,824	3
	1996	666	360	3	861	836	3
	1997	0	0	0	0	0	0
	1998	12,771	4,584	3	2,277	1,780	3
	1999	4,668	2,454	3	0	0	0
	2000	0	0	0	357	896	3
	2001	0	0	0	0	0	0
	2002	0	0	0	0	0	0
	2003	0	0	0	0	0	0
	2004	520	104	3	1,107	446	3
	2005	3,531	1,189	3	874	604	3
	2006	2,493	1,038	3	0	0	0
	2007	0	0	0	0	0	0
	2008	2,362	783	3	19	4	3
	2009	2,539	752	3	762	519	3
	2010	1,724	1,324	5	290	522	3
	2011	0	0	0	361	634	5
	2012	0	0	0	0	0	0
	2013	0	0	0	0	0	0
	2014	0	0	0	0	0	0
	2015	0	0	0	0	0	0

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		Week 7 7/8 - 7/14			Week 8 7/15 - 7/21			Week 9 7/22-7/28		
Var name:	Year	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
	1976	1,238	4,548	2	236	1,590	2	0	0	0
	1977	153	2,310	2	0	0	0	0	0	0
	1978	987	7,668	2	0	0	0	0	0	0
	1979	470	3,120	2	0	0	0	0	0	0
	1980	445	2,586	2	0	0	0	0	0	0
	1981	941	2,640	2	0	0	0	0	0	0
	1982	1,055	4,734	2	0	0	0	0	0	0
	1983	633	2,796	2	0	0	0	0	0	0
	1984	2,069	5,592	2	744	2,238	2	0	0	0
	1985	0	0	0	0	0	0	0	0	0
	1986	1,156	3,192	3	0	0	0	0	0	0
	1987	1,910	3,582	3	2,758	6,720	3	0	0	0
	1988	5,270	10,794	3	1,728	6,636	3	662	6,276	3
	1989	6,043	10,962	3	868	2,622	3	210	3,372	3
	1990	4,931	8,534	3	0	0	0	0	0	0
	1991	904	3,426	3	452	3,408	3	419	7,522	3
	1992	0	0	0	0	0	0	0	0	0
	1993	0	0	0	0	0	0	0	0	0
	1994	578	1,984	3	441	3,000	3	538	6,348	3
	1995	1,452	3,716	3	568	3,488	3	0	0	0
	1996	408	896	3	251	1,195	3	307	6,398	3
	1997	0	0	0	0	0	0	0	0	0
	1998	1,127	1,668	3	0	0	0	816	4,296	3
	1999	0	0	0	0	0	0	0	0	0
	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	127	360	3
	2005	0	0	0	0	0	0	0	0	0
	2006	0	0	0	0	0	0	0	0	0
	2007	0	0	0	0	0	0	0	0	0
	2008	1	6	3	0	6	0	0	12	0
	2009	113	436	3	83	672	3	58	752	3
	2010	271	686	3	186	958	3	176	1,632	3
	2011	227	996	5	129	1,226	5	24	1,668	5
	2012	45	604	5	195	1,616	5	39	1,464	5
	2013	0	0	0	139	2,018	5	21	1,556	5
	2014	14	584	5	14	2,276	5	0	0	0
	2015	0	0	0	0	0	0	0	0	0

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 of 6" or less new gear