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2014 Kuskokwim River Chinook Salmon Run Reconstruction and Model Revisions

This memorandum describes methods used to estimate the 2014 drainage-wide run size and escapement of Kuskokwim River Chinook salmon. Estimates are based on a run reconstruction model, specifically developed for use in data-limited situations (Bue et al. 2012), with revised model configuration. The model simultaneously combines information on subsistence harvest, commercial catch and effort, sport harvest, test fish harvest and catch per unit effort at Bethel, mark–recapture estimates of inriver abundance, counts of salmon at 6 weirs and peak aerial counts from 14 drainages spread throughout the Kuskokwim River drainage. Historical weir and aerial survey escapement data were updated in 2014 concurrent with the Alaska Department of Fish and Game escapement goal review cycle; updated data were used in the 2014 run reconstruction (Appendix III).

The 2014 Kuskokwim River Chinook salmon drainage-wide run was estimated using the run reconstruction model to be 135,749 (95% CI: 100,836 – 182,750). Total run estimate minus total harvest (11,762) resulted in a drainage-wide escapement estimate of 123,987 (95% CI: 89,074 – 170,988). All estimates are preliminary until publication in an appropriate ADF&G report series. These revised estimates update those reported in a news release on February 24, 2015. Previously reported estimates of run and escapement were 130,144 (95% CI: 93,771 – 180,627) and 118,382 (95% CI: 82,009 – 168,865), respectively. While the point estimate increased by 5,600, there is no statistical difference between preliminary estimates reported in the news release and the updated estimates provided here.

Run Reconstruction Model Revisions

Changes to model configuration

The run reconstruction model uses annual commercial catch and effort to inform total run abundance. The original Bue et al. (2012) model constructed the likelihood by fitting weekly commercial catch, based on the assumption that commercial catch is accurate and measured without error. Constructing a likelihood based on observation error is problematic because annual weekly fishing effort is not measured without error. Effort was approximated based on the total permits fished during each opener

and the total time that fishing was allowed. In our revised model, likelihood was constructed by fitting weekly commercial catch effort (equation 3, Appendix I).

The original Bue et al. (2012) model used catch and effort data from weeks 3–5 to inform run abundance. Since 2011, the majority of commercial fish openers have occurred in weeks 6–9, which provides additional information on run size of those years. In our revised model, the calculation of commercial effort likelihood was expanded from weeks 3–5 to include weeks 6–10. Data from weeks 8, 9, and 10 were combined.

Change to estimation methods

Estimation methods were updated from Microsoft Excel to the R statistical package. The original model was written in EXCEL and confidence intervals were calculated with profile likelihood methods (Bue et al. 2012). The Excel-based model is labor intensive to update and takes a long time to run – specifically the profile likelihoods. Beginning in 2013, the model was converted to R (current R code is reproduced in Appendix II). Since that time, model estimates were made using the R optim function, and Wald confidence interval was used to estimate model parameters and confidence intervals. These changes significantly reduced the time required to run the model. There are drawbacks associated with these changes: 1) the Wald confidence interval method is less accurate compared to profile analysis, although the differences are negligible, 2) the current R-based model produces only total model negative log-likelihood, not individual likelihoods for each model component.

Model Results and Discussion

The 2014 Kuskokwim River Chinook salmon drainage-wide run and escapement was estimated to be 135,749 (95% CI: 100,836 – 182,750) and 123,987 (95%CI. 89,074 – 170,988), respectively (Figure 1, Table 1). Convergence was achieved with total model negative log-likelihood of 2,913. Coefficient of variation (CV) was estimated to be 15%, which is similar to historical estimates (Bue et al. 2012). Overall model fits were similar to those of Bue et al (2012). Lower residual mean square error (RMSE) for weir data compared to aerial survey data shows that the model put higher weight on weir observation.

There is considerable uncertainty in the 2014 model estimates (Figure 2 and 3). Commercial catch in 2014 was only 31 fish, and the commercial catch model had effectively no contribution to 2014 estimates. The 2014 estimates were informed by data collected from tributary escapement projects. Each tributary escapement project is related to the drainage escapement by a scaling factor which is estimated by the model and is assumed constant over time (equation 2, Appendix I). Estimates of drainage-wide escapement derived from each escapement project varied greatly from 40,000 to 280,000 (Figure 3), which resulted in relatively wide confidence intervals. All 2014 observations were within the range of historical deviation, except for the Salmon River Pitka Fork aerial survey. That particular aerial survey observation was the second largest on record and had considerable influence on the drainage-wide estimate. As a result the drainage-wide escapement estimate was larger than expected. 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. As an example, the 2014 estimates are more uncertain compared to the 2013 run estimates when all weir and aerial survey data yielded similar estimates of drainage-wide escapement (Figure 3).

It should be noted that the 2014 estimates are the result of one particular run of the model, and estimates will differ among independent model runs and model starting values. For example, during several trials of running the model with various starting values, the point estimate changed ± 10,000 fish with an identical total likelihood value. However, the 95% confidence intervals around each point estimate overlapped greatly among all trial runs. Consequently, differences among trial runs are statistically insignificant (i.e. negligible). It is not surprising that point estimates vary between runs, because the Chinook salmon run reconstruction model is complex with 82 parameters to be estimated (Table 2). Furthermore, because the model uses all historical data to estimate the 2014 drainage-wide run, the model will produce revised historical (1976–2013) run and escapement estimates with every model run.

Table 1 presents the estimated drainage-wide run and escapement for all years produced from this most recent model run only. Please note, estimates in Table 1 do not supersede previously published estimates from 1976–2011 (Bue et al. 2012) or unpublished estimates for 2012 or 2013, instead they are provided for transparency regarding origins of the 2014 estimates only. Historical estimates of annual run size (1976–2013) from the 2014 model fall within the 95% confidence intervals for all published years (Figure 4). Consequently, differences among trial runs are statistically insignificant (i.e. negligible).

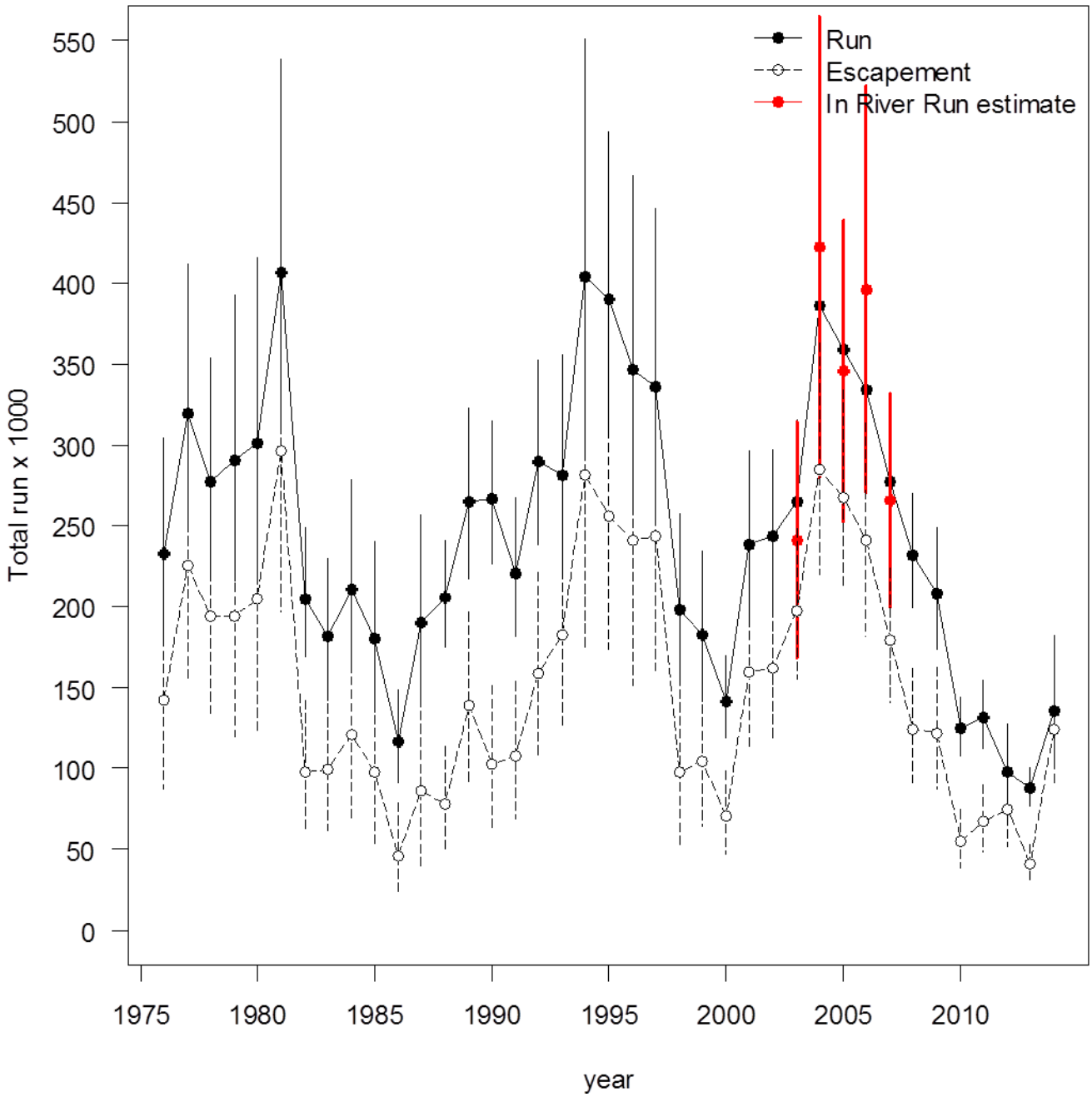

Figure 1.– Annual run (black) and escapement (white) estimates with 95% confidence intervals from the 2014 model. Red dots are the independent observed drainage-wide run size and 95% confidence intervals for years 2003–2007 used to scale the run reconstruction model.

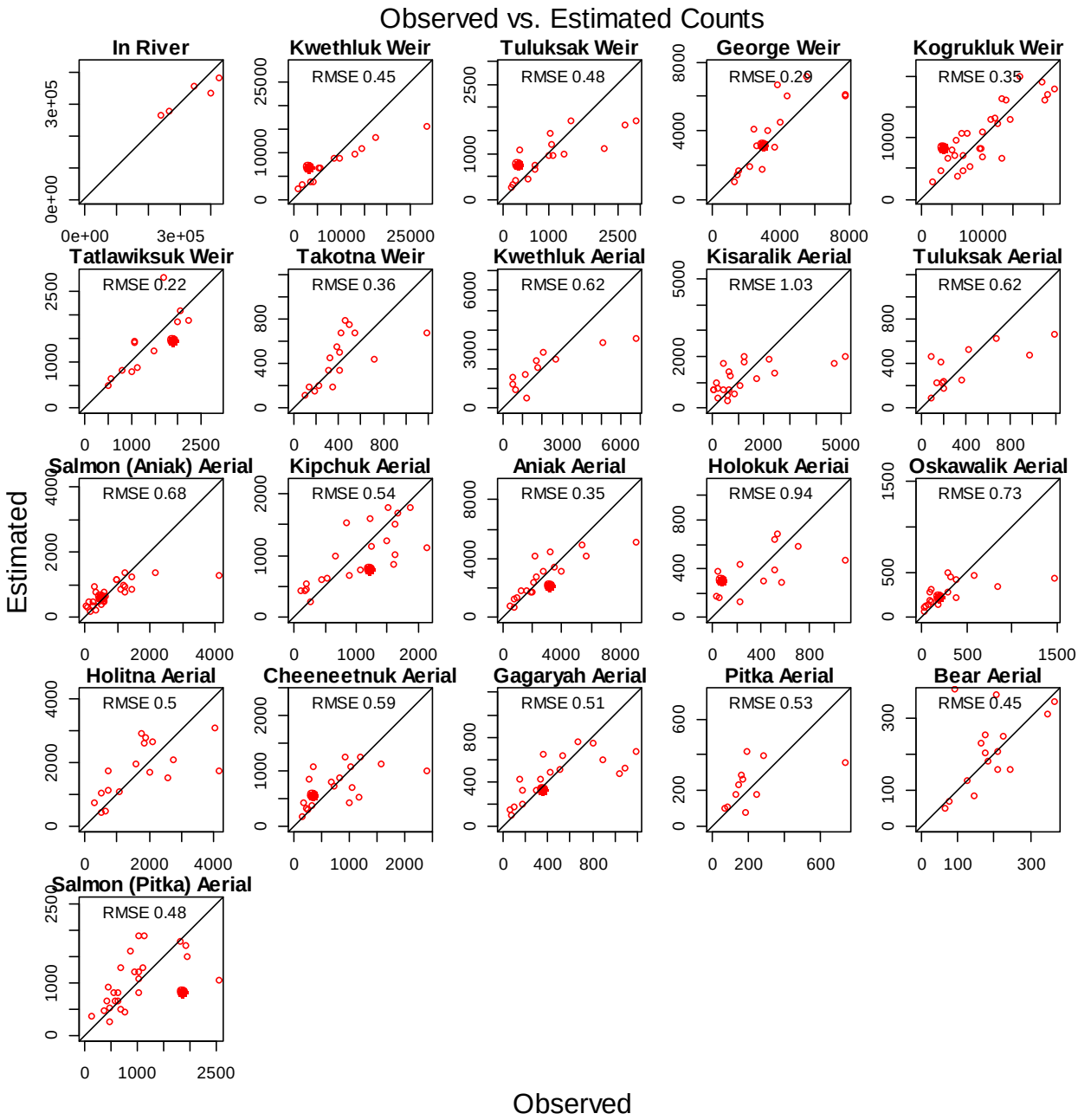

Figure 2.– Observed (x-axis) and model estimated (y-axis) escapement counts. Diagonal line represents the 1:1 line, which is the point at which observed and estimated escapements are equal. Solid red dots are the 2014 observations. Dots that fall below the 1:1 line indicate that observed counts are higher than the model estimates, and vice versa.

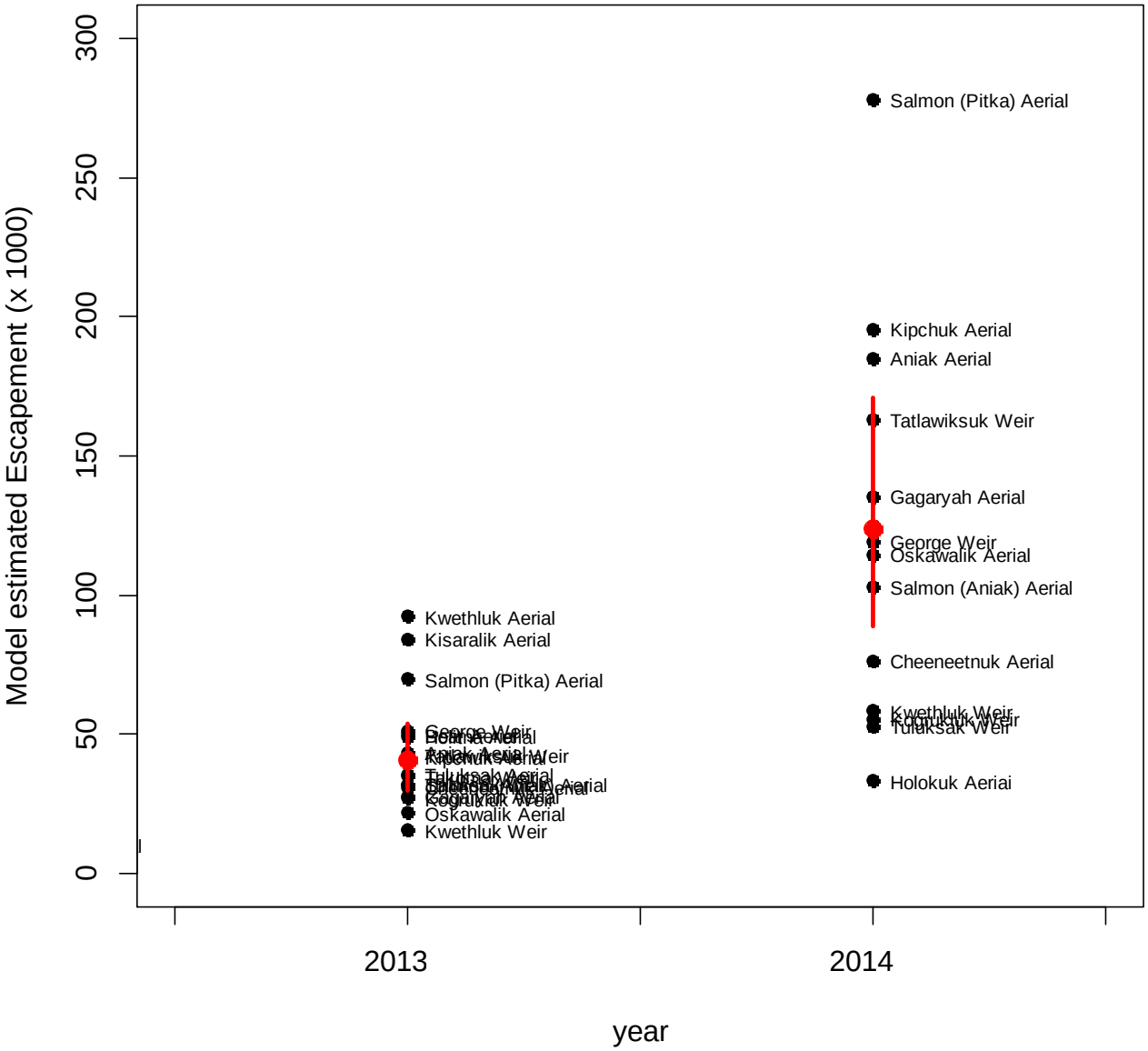

Figure 3.– Range of drainage-wide escapement estimates produced by the model based on each individual escapement monitoring project. Red dot and line shows the model derived drainage-wide escapement and 95% confidence interval after simultaneously combining the information from all escapement monitoring projects.

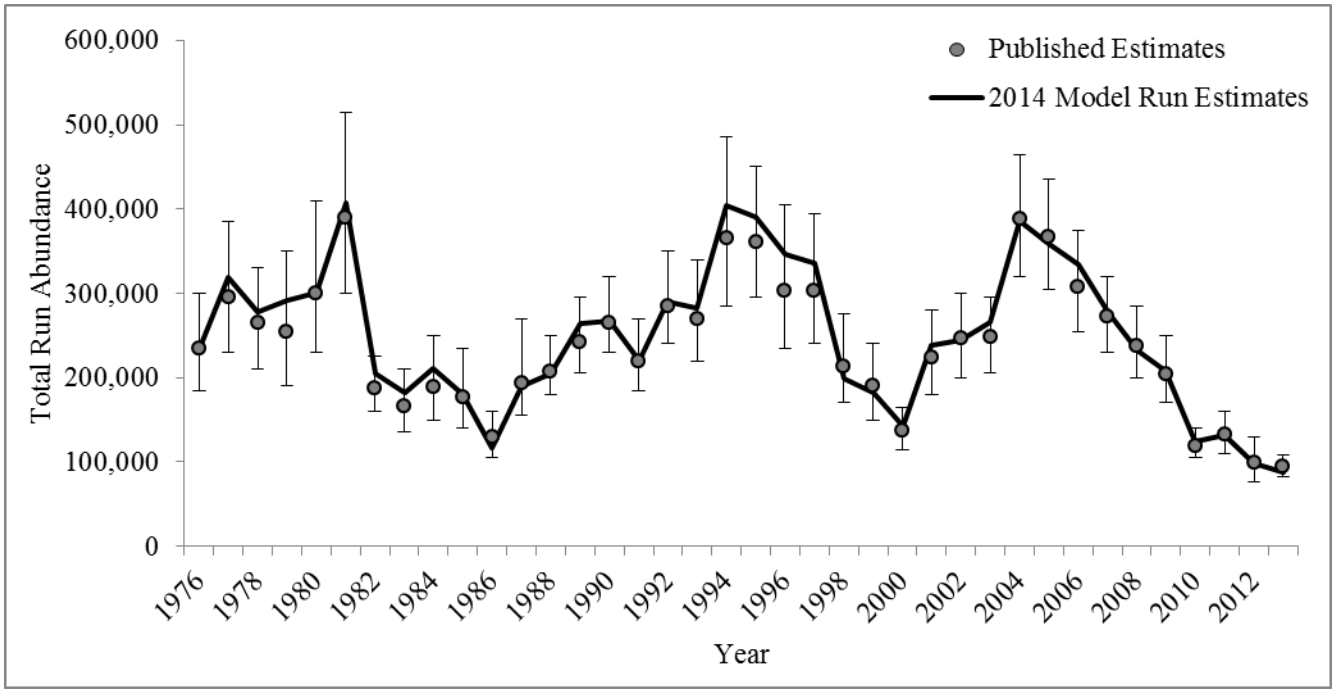

Figure 4.– Comparison of published run reconstruction estimates of total Kuskokwim River Chinook salmon run size (grey dots) with 95% confidence intervals and estimates of historical abundance from the 2014 model run. Differences are statistically insignificant (i.e. negligible). 2014 estimates do not supersede estimates produced in prior years.

Table 1.– Estimated annual drainage-wide run abundance from the 2014 model. Numbers do not supersede estimates produced in prior years.

	Run			Escapement		
Year	Mean	Lower	Upper	Mean	Lower	Upper
1976	232,588	177,764	304,319	142,041	87,217	213,772
1977	319,128	247,267	411,872	225,421	153,560	318,165
1978	277,559	217,517	354,175	194,087	134,045	270,703
1979	290,952	215,285	393,215	194,650	118,983	296,913
1980	301,531	218,696	415,741	204,563	121,728	318,773
1981	406,653	306,831	538,949	296,254	196,432	428,550
1982	205,258	168,793	249,601	98,257	61,792	142,600
1983	181,654	143,528	229,907	99,509	61,383	147,762
1984	210,381	158,497	279,251	121,205	69,321	190,075
1985	180,145	135,061	240,279	98,218	53,134	158,352
1986	116,821	91,454	149,224	46,209	20,842	78,612
1987	190,251	140,978	256,744	86,008	36,735	152,501
1988	205,618	175,518	240,879	77,855	47,755	113,116
1989	264,925	217,228	323,095	138,772	91,075	196,942
1990	267,061	226,192	315,315	102,873	62,004	151,127
1991	220,663	182,207	267,237	107,547	69,091	154,121
1992	289,936	238,287	352,781	158,663	107,014	221,508
1993	281,872	223,352	355,724	182,393	123,873	256,245
1994	404,519	296,915	551,118	281,889	174,285	428,488
1995	390,590	308,968	493,774	255,672	174,050	358,856
1996	346,496	257,060	467,047	240,985	151,549	361,536
1997	335,850	252,474	446,759	243,908	160,532	354,817
1998	198,516	152,957	257,646	98,270	52,711	157,400
1999	182,403	141,887	234,488	104,546	64,030	156,631
2000	141,853	118,329	170,053	70,415	46,891	98,615
2001	238,526	191,716	296,764	160,051	113,241	218,289
2002	244,037	200,238	297,417	162,376	118,577	215,756
2003	265,404	222,600	316,438	197,302	154,498	248,336
2004	385,847	320,871	463,980	284,889	219,913	363,022
2005	358,791	302,444	425,635	267,788	211,441	334,632
2006	334,573	274,950	407,126	240,915	181,292	313,468
2007	277,619	239,140	322,288	179,502	141,023	224,171
2008	231,936	198,986	270,342	123,840	90,890	162,246
2009	207,941	173,422	249,330	121,672	87,153	163,061
2010	124,661	107,907	144,017	55,227	38,473	74,583
2011	131,647	112,125	154,569	67,615	48,093	90,537
2012	98,198	75,714	127,360	74,465	51,981	103,627
2013	87,684	76,532	100,461	40,956	29,804	53,733
2014	135,749	100,836	182,750	123,987	89,074	170,988

Table 2.– Parameter estimates from the 2014 model.

	Parameter Estimate	95% Bound Lower	95% Bound Upper	Overdispersion Parameter (m)
Weir Projects (k)				
Kwethluk Weir	18.33	13.62	24.66	5.86
Tuluksak Weir	165.85	123.90	222.02	4.98
George Weir	39.83	30.72	51.63	12.35
Kogrukluk Weir	14.85	11.64	18.95	8.53
Tatlawiksuk Weir	85.62	67.31	108.92	20.09
Takotna Weir	359.08	271.57	474.79	7.82
Aerial Survey (k)				
Kwethluk River	79.24	53.67	117.00	1.49
Kisaralik River	140.68	93.89	210.80	3.38
Tuluksak River	429.67	293.81	628.33	2.94
Salmon (Aniak River)	207.12	154.38	277.88	4.24
Kipchuk River	160.37	120.99	212.56	8.83
Aniak River	57.80	44.96	74.30	1.73
Holokuk River	415.93	262.88	658.11	2.20
Oskawalik River	573.12	394.88	831.82	4.42
Holitna River	92.83	67.43	127.80	3.27
Cheeneetnuk River	224.70	162.14	311.40	4.27
Gagaryah River	377.28	281.01	506.53	3.65
Pitka Fork	680.65	468.12	989.67	6.71
Bear River	782.07	591.27	1034.44	4.69
Salmon(Pitka Fork)	149.15	113.11	196.68	1.49
Catchability (q)				
Unrestricted	7.46E-05	5.93E-05	9.39E-05	
Restricted (1)	1.40E-05	1.06E-05	1.85E-05	
Restricted (2)	4.04E-05	3.15E-05	5.19E-05	

Appendix I: Run reconstruction methods

Run reconstruction model

Annual drainage-wide Kuskokwim Chinook salmon escapement (E_y) is equal to the drainage-wide 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 commercial, subsistence, sports, and Bethel test fish.

Observation model

Individual escapement counts

Assuming constant proportionality, escapement of *j-th* tributary observed by *i-th* method (weir, aerial) (e_{ijy}) is

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

where k_{ij} is a scaling parameter.

Commercial catch effort

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

$$\hat{f}_{wky} = -\ln(1 - c_{wky} / (p_{wy} N_y)) / q_k \tag{3}$$

where

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

p_{wy}: proportion of Chinook salmon at week *w*

q_k: catchability coefficient of k-th net configurations (i.e., unrestricted, restricted (1), restricted (2)).

Likelihood components

Under the assumptions that measurement errors follow distributions of : (1) negative binomial for annual escapement surveys, (2) lognormal for weekly commercial catch efforts, and (3) normal for drainage-wide run, the likelihood function is:

$$L\left(\theta \middle| data\right) = \begin{aligned} & \prod_y \prod_i \prod_j \frac{\Gamma\left(\hat{m}_{ij} + e_{ijy}\right)}{\Gamma\left(\hat{m}_{ij}\right) e_{ijy}!} \left(\frac{\hat{e}_{ijy}}{\hat{m}_{ij} + \hat{e}_{iy}}\right)^{e_{ijy}} \left(\frac{\hat{m}_{ij}}{\hat{m}_{ij} + \hat{e}_{ijy}}\right)^{\hat{m}_{ij}} \\ & \prod_y \prod_w \prod_k \frac{1}{\sigma_\varepsilon \sqrt{2\pi}} \exp\left(-\frac{\left(\ln f_{wky} - \ln \hat{f}_{wky}\right)^2}{2\sigma_\varepsilon^2}\right) \\ & \prod_y \exp\left(-\frac{\left(N_y - \hat{N}_y\right)^2}{2\sigma_{N_y}^2}\right) \end{aligned} \tag{4}$$

The concentrated likelihood function was used to eliminate the need for estimation of variance for commercial efforts. The observed variance was used for the drainage-wide run. Parameter estimation was performed by minimizing the negative log-likelihood of the model using R (R core team 2014) optim with method "L-BFGS-B." (See Appendix II)

Reference

Bue, B.G., K.L. Shaberg, Z.W. Liller, and D.B. Molyeaux. 2012. Estimates of the historic run and escapement for the Chinook salmon stock returning to the Kuskokwim River, 1976-2011. ADF&G Fishery Data Series No. 12-49. Anchorage.

R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Appendix II: 2014 R-code

```
data_file <- '***.csv'
kusko.data <- read.csv(data_file,header=T)

# Extract testfish data and combine week 8, 9 10
testf<-kusko.data[substr(names(kusko.data),1,3)=='rpw']

testf[,8] <- testf[,8]+testf[,9]+testf[,10]
testf <- testf[,-(9:10)]
for (i in 1:dim(testf)[2]) {testf[is.na(testf[i]),i] <- colMeans(testf,na.rm=T)[i]}

ceff <-kusko.data[substr(names(kusko.data),1,3)=='cew']
ceff[,6] <- ceff[,6]+ceff[,7]
ceff <- ceff[,-7]
ceff[ceff == 0] <- NA

ccat <-kusko.data[substr(names(kusko.data),1,3)=='chw']
ccat[,6] <- ccat[,6]+ccat[,7]
ccat <- ccat[,-7]
ccat[ccat == 0] <- NA

creg <-kusko.data[substr(names(kusko.data),1,3)=='cfw']
creg[,6] <- pmax(creg[,6],creg[,7])
creg <- creg[,-7]

# Extract Inriver data
inr <-kusko.data[substr(names(kusko.data),1,3)=='In.']
# Calculate CV
inr$cv <- inr$In.river.sd/inr$In.river

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 run
minrun <- rowSums(cbind(tcatch,esc), na.rm=T, dims = 1)
# Number of years
ny <- length(kusko.data[,1])

# Data for Likelihood calculation
kusko.like.data <- cbind(tcatch,inr,esc,testf[3:8],ccat,ceff,creg)

# Likelihood calculation function
nb.likelihood <- function(theta,likedat,ny){
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])
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])
q1 <- exp(theta[ny+21])
q2 <- exp(theta[ny+22])
q3 <- exp(theta[ny+23])
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])
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])

tfw  <-  rep(0,6)
tfa  <-  rep(0,14)
tft  <-  0
tfc  <-  0
esc  <-  totrun-likedat[,1]

nblike <- function(obs,r,est){lgamma(obs+r)-lgamma(obs+1)-
lgamma(r)+r*log(r/(est+r))+obs*log(est/(est+r))}

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)
```

```
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)

tft  <-  0.5*sum((likedat[,2]-totrun)^2/(likedat[,3])^2,na.rm=T)

# Weekly Catch likelifhood
wk.est <- likedat[,25:30]*totrun
unr <- likedat[,43:48]
unr[unr != 1] <- NA
unr.eff <- likedat[,37:42]*unr
unr.eff <- unr.eff[!is.na(unr.eff)]
unr.h <- likedat[,31:36]*unr
unr.h <- unr.h[!is.na(unr.h)]
unr.wk <- wk.est*unr
unr.wk <- unr.wk[!is.na(unr.wk)]
tf1 <- 0.5*length(unr.eff)*log(sum((log(unr.eff)-log(-log(1-
unr.h/unr.wk)/q1))^2,na.rm=T))


r <- likedat[,43:48]
r[r != 2] <- NA
r[r == 2] <- 1
r.eff <- likedat[,37:42]*r
r.eff <- r.eff[!is.na(r.eff)]
r.h <- likedat[,31:36]*r
r.h <- r.h[!is.na(r.h)]
r.wk <- wk.est*r
r.wk <- r.wk[!is.na(r.wk)]
tf2 <- 0.5*length(r.eff)*log(sum((log(r.eff)-log(-log(1-r.h/r.wk)/q2))^2,na.rm=T))

m <- likedat[,43:48]
m[(m != 3)&(m != 5)] <- NA
m[!is.na(m)] <- 1
m.eff <- likedat[,37:42]*m
m.eff <- m.eff[!is.na(m.eff)]
m.h <- likedat[,31:36]*m
m.h <- m.h[!is.na(m.h)]
m.wk <- wk.est*m
m.wk <- m.wk[!is.na(m.wk)]
tf3 <- 0.5*length(m.eff)*log(sum((log(m.eff)-log(-log(1-m.h/m.wk)/q3))^2,na.rm=T))
tfc <-sum(tf1,tf2,tf3)
```

```
loglink  <- sum(sum(tfw),sum(tfa),tft,tfc,na.rm=T)
return(loglink)}


#Likelihood Calculation
init <- c(rep(log(250000),(ny-5)),rep(log(100000),5),rep(5,6),rep(4,14),rep(-
10,3),rep(2,6),rep(2,14))
lb <-  c(log(minrun),rep(2,6), rep(3,14),rep(-14,3),rep(-3,6),rep(-3,14))
ub <-  c(rep(log(500000),ny),rep(7,6),rep(8,14),rep(-5,3),rep(5,6),rep(5,14))

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)
Rprof()

#Hessian
hessian_obs <- nll$hessian
log_est_obs <- nll$par
est_obs <- exp(log_est_obs)
var_covar_mat_obs <- solve(hessian_obs)
log_var_obs <- diag(var_covar_mat_obs)
log_std_err_obs <- sqrt(log_var_obs)

#Mean and CI output
upper95CI <- exp(log_est_obs + 1.96*log_std_err_obs)
lower95CI <- exp(log_est_obs - 1.96*log_std_err_obs)
output<-data.frame(mean=exp(nll$par),lower95CI=lower95CI,lower95CI=upper95CI)
```

Appendix III: Data Tables.

Appendix IIIA.– 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

Source: Schaberg et al. 2012

Appendix IIIB.– 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	53,504	109,778	394	512
	1991	37,778	74,820	401	117
	1992	46,872	82,654	367	1,380
	1993	8,735	87,674	587	2,483
	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	1,788	332
	1998	17,359	81,213	1,464	210
	1999	4,705	72,775	279	98
	2000	444	70,825	105	64
	2001	90	78,009	290	86
	2002	72	80,982	319	288
	2003	158	67,134	401	409
	2004	2,300	97,110	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	748	62,368	579	337
	2012	306	22,527	579	321
	2013	51	46,476	0	201
	2014	31	11234	0	497

Source: Commercial Harvest: ADF&G Fish Ticket Database. Sport Harvest: 1990-2011 Numbers provided by John Chythlook. 2012 assumed similar to 2011. Subsistence Harvest: 1990-2009 (Hamazaki et al. 2011), 2011and 2012 (Carroll and Hamazaki 2012), 2011 and 2012 (Shelden et al. 2014), 2013 and 2014 (Chris Shelden, ADF&G personnel communication).

Appendix IIIC.– 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	

Note: All historical data were updated in 2014 using Bayesian estimation methods. Years when more than 40% of the historical escapement was missed were not included.

Appendix IIID.– 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
Conventional name:	Year	Kwethluk	Kisaralik	Tuluksak	Salmon (Aniak)	Kipchuk	Aniak	Holokuk
	1976							
	1977	2,075		424				
	1978	1,722	2,417		289			
	1979							
	1980			975	1,186			
	1981						9,074	
	1982		81		126			
	1983	471		186	231		1,909	
	1984							
	1985		63	142				
	1986				336		424	
	1987				516	193		
	1988	622	869	195	244		954	
	1989	1,157	152		631	1,598	2,109	
	1990		631	200	596	537	1,255	
	1991		217	358	583	885	1,564	
	1992				335	670	2,284	
	1993				1,082	1,248	2,687	233
	1994		1,243		1,218	1,520		
	1995		1,243		1,446	1,215	3,171	
	1996				985			
	1997		439		980	855	2,187	
	1998		457		425	443	1,930	
	1999							
	2000				238	182	714	
	2001				598			52
	2002	1,795	1,727		1,236	1,615		513
	2003	2,661	654	94	1,242	1,493	3,514	1,096
	2004	6,801	5,157	1,196	2,177	1,868	5,362	539
	2005	5,059	2,206	672	4,097	1,679		510
	2006		4,734			1,618	5,639	705
	2007		692	173	1,458	2,147	3,984	
	2008	487	1,074		589	1,061	3,222	418
	2009							565
	2010		235					229
	2011				79	116		61
	2012		588		49	193		36
	2013	1,165	599	83	154	261	754	
	2014				497	1,220	3,201	80

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

Var name:	Year	a.osk	a.hlt	a.che	a.gag	a.pit	a.ber	a.slp
Conventional name:	Year	Oskawalik	Holitna	heeneetnu	Gagaryah	Pitka	Bear	almon(Pitk
	1976		2,571				182	
	1977			2,407	897			1,930
	1978		2,766	268	504		227	1,100
	1979							682
	1980							
	1981						93	
	1982		521				127	413
	1983		1,069	173				572
	1984			1,177				545
	1985			1,002				620
	1986		650					
	1987	193		317				
	1988	80						474
	1989							452
	1990	113						
	1991							
	1992	91	2,022	1,050	328			2,536
	1993	103	1,573	678	419			1,010
	1994			1,206	807			1,010
	1995	326	1,887	1,565	1,193			1,911
	1996							
	1997	1,470	2,093	345	364			
	1998							
	1999	98	741					
	2000		301					362
	2001		4,156		143	151	175	1,033
	2002	295	733	730			211	
	2003	844		810	1,093	165	176	
	2004	293	4,051	918	670	197	206	1,138
	2005	582	1,760			290	367	1,801
	2006	386	1,866	1,015	531	744	347	862
	2007				1,035	170	165	943
	2008	213		290	177	131	245	1,033
	2009	379		323	303	248	209	632
	2010				62	187	75	135
	2011	26		249	96	67	145	767
	2012	51		229	178	85		670
	2013	38	532	138	74		64	469
	2014	200		340	359			1,865

Note: All aerial surveys were reviewed in 2014 by ADF&G staff and updated based on standardized criteria. 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 IIIE.– Proportion of total annual Chinook salmon run in District W-1 by week, as estimated by Bethel Test Fishery.

						Week of R
		1	2	3	4	5
Var name:	Year	rpw.1	rpw.2	rpw.3	rpw.4	rpw.5
Conventional name:	Year	5/27 - 6/2	6/3 - 6/9	6/10 - 6/16	6/17 - 6/23	6/24 - 6/30
	1976					
	1977					
	1978					
	1979					
	1980					
	1981					
	1982					
	1983					
	1984	0.0042	0.0396	0.2243	0.2903	0.1488
	1985	0.0000	0.0000	0.0000	0.0930	0.2427
	1986	0.0000	0.0577	0.1503	0.4039	0.1656
	1987	0.0000	0.0659	0.1988	0.3070	0.2368
	1988	0.0082	0.1140	0.2080	0.3086	0.1786
	1989	0.0000	0.0320	0.1769	0.2780	0.3474
	1990	0.0047	0.0339	0.1434	0.2095	0.3325
	1991	0.0000	0.0738	0.0593	0.2965	0.2942
	1992	0.0000	0.0313	0.3466	0.1791	0.2132
	1993	0.0143	0.1568	0.2148	0.4172	0.1270
	1994	0.0133	0.1161	0.2883	0.3098	0.1396
	1995	0.0135	0.0743	0.1566	0.3066	0.3005
	1996	0.0284	0.2007	0.4007	0.2138	0.0963
	1997	0.0000	0.0449	0.1913	0.5295	0.1196
	1998	0.0000	0.0707	0.1166	0.2199	0.3866
	1999	0.0000	0.0110	0.1360	0.1349	0.2469
	2000	0.0000	0.1226	0.2089	0.3896	0.1530
	2001	0.0000	0.0456	0.0791	0.4157	0.2510
	2002	0.0036	0.0842	0.3547	0.2245	0.1601
	2003	0.0195	0.1439	0.2764	0.2748	0.1433
	2004	0.0039	0.0576	0.2130	0.2927	0.2513
	2005	0.0000	0.0339	0.2335	0.2851	0.1876
	2006	0.0000	0.0140	0.1299	0.3054	0.2935
	2007	0.0000	0.0222	0.0996	0.2000	0.3114
	2008	0.0046	0.0272	0.1524	0.2931	0.3057
	2009	0.0000	0.0466	0.1955	0.2830	0.3460
	2010	0.0061	0.0185	0.2190	0.3755	0.1517
	2011	0.0083	0.1082	0.1188	0.2976	0.1996
	2012	0.0000	0.0062	0.0508	0.2964	0.3308
	2013	0.0000	0.0144	0.1681	0.3708	0.2654
	2014	0.0224	0.2261	0.2834	0.2370	0.1217

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Appendix IIIE.– 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

Appendix IIIF.– 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

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Appendix IIIF.– Chinook Salmon Catch and Effort (permit-hours) by week for Kuskokwim River District W-1.

		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

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Appendix IIIF.– Chinook Salmon Catch and Effort (permit-hours) by week for Kuskokwim River District W-1.

		Week 7 7/8 - 7/14			Week 8 7/15 - 7/21		
Var name:	Year	chw.7	cew.7	cfw.7	chw.8	cew.8	cfw.8
Conventional name:	Year	Catch	Effort	Net	Catch	Effort	Net
	1976	1,238	4,548	2	236	1,590	2
	1977	153	2,310	2	0	0	0
	1978	987	7,668	2	0	0	0
	1979	470	3,120	2	0	0	0
	1980	445	2,586	2	0	0	0
	1981	941	2,640	2	0	0	0
	1982	1,055	4,734	2	0	0	0
	1983	633	2,796	2	0	0	0
	1984	2,069	5,592	2	744	2,238	2
	1985	0	0	0	0	0	0
	1986	1,156	3,192	3	0	0	0
	1987	1,910	3,582	3	2,758	6,720	3
	1988	5,270	10,794	3	1,728	6,636	3
	1989	6,043	10,962	3	868	2,622	3
	1990	4,931	8,534	3	0	0	0
	1991	904	3,426	3	452	3,408	3
	1992	0	0	0	0	0	0
	1993	0	0	0	0	0	0
	1994	578	1,984	3	441	3,000	3
	1995	1,452	3,716	3	568	3,488	3
	1996	408	896	3	251	1,195	3
	1997	0	0	0	0	0	0
	1998	1,127	1,668	3	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	1	6	3	0	6	0
	2009	113	436	3	83	672	3
	2010	271	686	3	186	958	3
	2011	227	996	5	129	1,226	5
	2012	45	604	5	195	1,616	5
	2013	16	2,402	5	16	2,402	5
	2014	23	568	5	6	1,878	5

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		Week 9 7/22-8/26		
Var name:	Year	chw.9	cew.9	cfw.9
Conventional name:	Year	Catch	Effort	Net
	1976	0	0	0
	1977	0	0	0
	1978	0	0	0
	1979	0	0	0
	1980	0	0	0
	1981	0	0	0
	1982	0	0	0
	1983	0	0	0
	1984	0	0	0
	1985	0	0	0
	1986	0	0	0
	1987	0	0	0
	1988	662	6,276	3
	1989	210	3,372	3
	1990	0	0	0
	1991	419	7,522	3
	1992	0	0	0
	1993	0	0	0
	1994	538	6,348	3
	1995	0	0	0
	1996	307	6,398	3
	1997	0	0	0
	1998	816	4,296	3
	1999	0	0	0
	2000	0	0	0
	2001	0	0	0
	2002	0	0	0
	2003	0	0	0
	2004	127	360	3
	2005	0	0	0
	2006	0	0	0
	2007	0	0	0
	2008	0	12	0
	2009	58	752	3
	2010	176	1,632	3
	2011	24	1,668	5
	2012	39	1,464	5
	2013	21	1,802	5
	2014	2	5,718	5

Key to column Net: 1= unrestricted mesh size, 2 = restricted to 6” or less (old twine type), 3 = restricted to 6” or less (new twine type), 4 = unrestricted and restricted mesh size periods in the same week, and 5 = restricted to 6” or less and personal use harvest was also included in the catch and effort calculation.