Fishery Data Series No. 20-01

Chinook Salmon Escapement in the Chena and Salcha Rivers and Coho Salmon Escapement in the Delta Clearwater River, 2017

by

Allison N. Matter

and

Matt Tyers

November 2020

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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

FISHERY DATA SERIES NO. 20-01

CHINOOK SALMON ESCAPEMENT IN THE CHENA AND SALCHA RIVERS AND COHO SALMON ESCAPEMENT IN THE DELTA CLEARWATER RIVER, 2017

by
Allison N. Matter
and
Matt Tyers

Alaska Department of Fish and Game, Division of Sport Fish, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

November 2020

Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C.777-777K) under Project F-10-31, Job No. S-3-1(b).

ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.adfg.alaska.gov/sf/publications/. This publication has undergone editorial and peer review.

Allison N. Matter and Matt Tyers
Alaska Department of Fish and Game, Division of Sport Fish
1300 College Road, Fairbanks, AK 99701-1599, USA

This document should be cited as follows:
Matter, A. N., and M. Tyers. 2020. Chinook salmon escapement in the Chena and Salcha Rivers and coho salmon escapement in the Delta Clearwater River, 2017. Alaska Department of Fish and Game, Fishery Data Series No. 20-01, Anchorage.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

During 2017, Alaska Department of Fish and Game conducted salmon enumeration projects on the Chena, Salcha, and Delta Clearwater Rivers in the Tanana River drainage. Chinook salmon *Oncorhynchus tshawytscha* escapements for the Chena and Salcha Rivers were estimated using tower-counting techniques with the addition of sonar (DIDSON and ARIS) methodology as a secondary means of enumeration when events precluded visual counts. A Bayesian mixture model was used to apportion species from the sonar files. The Chena River counting tower and sonars operated from 26 June–3 August and the final escapement estimate was 5,235 (SE = 321) Chinook salmon. The adjusted sex composition was 0.67 (SE = 0.03) male and 0.33 (SE = 0.03) female (*n* = 420). The dominant age class was 1.3 for both males (28% of total sample) and females (46% of total sample). The Salcha River counting tower and sonars operated from 27 June–4 August and the final escapement estimate was 4,195 (SE = 205) Chinook salmon. The adjusted sex composition was 0.65 (SE = 0.07) male and 0.35 (SE = 0.07) female (*n* = 504). Like the Chena River, the dominant age class was 1.3 for both males (49% of total sample) and females (23% of total sample). Incomplete chum salmon *Oncorhynchus keta* escapement for the Chena and Salcha Rivers was estimated to be 21,176 (SE = 994) and 20,093 (SE = 1,220), respectively. Coho salmon *Oncorhynchus kisutch* escapement in the Delta Clearwater River was estimated as 9,617 fish by a visual boat survey at peak escapement on 26 October.

Key words: Chinook salmon, *Oncorhynchus tshawytscha,* chum salmon, *Oncorhynchus keta*, coho salmon, *Oncorhynchus kisutch*, Chena River, Salcha River, Delta Clearwater River, counting tower, escapement, Bayesian mixture model, Bayesian Hierarchical model, DIDSON, ARIS

INTRODUCTION

The Yukon River drainage supports important fisheries resources in Chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), and coho salmon (*O. kisutch*) harvest opportunities. The Chena and Salcha Rivers are tributaries of the Tanana River and support the largest spawning populations of Chinook salmon in the Yukon River drainage, while the Delta Clearwater River (DCR) supports the largest spawning population of coho salmon (Eiler et al. 2006). Historically, Chinook salmon, along with summer and fall chum (*O. keta*) salmon, were targeted in commercial fisheries. During the 10-year historical period of high production (1989–1998), commercial harvests of Chinook salmon in the Yukon River averaged approximately 100,000 fish (Estensen et al. 2017), but due to poor returns, direct commercial fisheries for Chinook salmon have not taken place since 2007. Incidental harvest of Chinook salmon during summer and fall chum directed fisheries has taken place up through 2011 with an average 5-year harvest of 27,497 during 2010–2014 (Estensen et al. 2017). However, the commercial sale of all Chinook salmon, even those that have been captured incidentally, has been prohibited since 2012.

The Chena and Salcha Rivers also support popular sport fisheries in the lower 72 km and 4 km of river, respectively. The sport fisheries in the Chena and Salcha Rivers take place downstream from all spawning areas. The 5-year (2013–2017) average sport catch of Chinook salmon in the Chena River was 30 fish with a corresponding average harvest of 4 fish.[1] A recent 5-year (2013–2017) average sport catch of Chinook salmon in the Salcha River was 1,468 fish with a corresponding average harvest of 20 fish.[2]

Chinook salmon are an important subsistence species throughout the Yukon River drainage. The current amounts necessary for subsistence (ANS) of Chinook salmon in the Alaska portion of the Yukon River drainage was designated by the Alaska Board of Fisheries (BOF) in January 2013 to be 45,500–66,704 Chinook salmon. Since 2008, Chinook salmon harvests have been below the

[1] Alaska Sport Fishing Survey database [Internet]. 1996– . Anchorage, AK: Alaska Department of Fish and Game, Division of Sport Fish (cited December 10, 2018). Available from: http://www.adfg.alaska.gov/sf/sportfishingsurvey/.

[2] Arctic-Yukon-Kuskokwim Database Management System (AYKDBMS). Alaska Department of Fish and Game, Division of Commercial Fisheries (cited December 10, 2018). Available from: https://www.adfg.alaska.gov/CF_R3/external/sites/aykdbms_website/Default.aspx.

ANS. Preliminary 2013–2015 harvests values averaged approximately 13,135, 2,826, and 7,807 fish, respectively (Estensen et al. 2017). Actions by the BOF during 2015 provided flexibility to allow retention of some Chinook salmon caught in salmon gear set for other species to help meet the ANS (e.g., fish wheels, gillnets). Incidental harvest in 2017 was justified based on inseason Chinook salmon run assessment projects (Estensen et al. 2017), including the Chena and Salcha Rivers enumeration projects. However, the 2017 harvest of Chinook salmon in the Tanana River subsistence fisheries was 46% below the recent 5-year average and 63% below the recent 10-year average (Estensen et al. 2017).

Coho salmon are also an important subsistence species in the Yukon River. During 2013–2017, the average annual coho salmon subsistence harvest was 16,632, the average commercial harvest was 90,337, the average personal use harvest was 152, and the average sport harvest was 662 fish (JTC 2017). The 5-year (2009–2013) average sport catch of coho salmon in the Delta Clearwater River was 3,070 fish, and the corresponding average harvest was 147 fish (Jennings et al. 2011a, 2011b, 2015; and Alaska Sport Fishing Survey database[1]).

Alaska Department of Fish and Game (ADF&G) has estimated escapement on the Chena and Salcha Rivers using mark–recapture, counting tower, and sonar techniques; age, sex, and length (ASL) compositions are estimated using carcass surveys. These data have been used to characterize the Chinook salmon abundance estimates for the Chena River since 1986 and for the Salcha River between 1987 and 1998, and 2016 through the present. The Bering Sea Fishermen's Association operated a counting tower and conducted salmon carcass surveys for the Salcha River during 1999–2015.

In 2001, the BOF adopted escapement goals for the Chena, Salcha, and Delta Clearwater Rivers based on analysis of spawner-recruit data from these stocks. Biological escapement goals (BEGs) of 2,800–5,700 Chinook salmon in the Chena River and 3,300–6,500 in the Salcha River were established to provide for maximum sustained yield (Evenson 2002). Long, unbroken data strings of annual Chinook salmon escapements are important for examining the spawner-recruit relationships used to determine meaningful biological escapement goals (Tables 1 and 2). The BEG is evaluated every 3 years by the BOF, incorporating the most recently acquired data. A sustainable escapement goal (SEG) of 5,200–17,000 coho salmon for the Delta Clearwater River was established because the spawner-recruit information required to establish a BEG was not available (Brase and Baker 2015).

Escapement and composition monitoring projects for the Chena and Salcha Rivers are among the longest continuous Chinook salmon escapement data sets in the Yukon River drainage. The monitoring programs provide information on run magnitude and timing, which allows managers to modify fishing regulations to achieve established escapement goals.

Table 1.–Estimates of the Chena River Chinook salmon escapement including standard error and methodology, 1986–2017.

	Escapement		
Year	Estimate	SE	Method
1986	9,065	1,080	Mark–Recapture
1987	6,404	557	Mark–Recapture
1988	3,346	556	Mark–Recapture
1989	2,730	249	Mark–Recapture
1990	5,603	1,164	Mark–Recapture
1991	3,172	282	Mark–Recapture
1992	5,580	478	Mark–Recapture
1993	12,241	387	Counting Tower
1994	11,877	479	Counting Tower
1995	11,394	1,210	Mark–Recapture
1996	7,153	913	Mark–Recapture
1997	13,390	699	Counting Tower
1998	4,745	503	Counting Tower
1999	6,485	427	Counting Tower
2000	4,694	1,184	Mark–Recapture
2001	9,696	565	Counting Tower
2002	6,967	2,466	Mark–Recapture
2003	11,100	653	Counting Tower
2004	9,645	532	Counting Tower
2005	–	–	–
2006	2,936	163	Counting Tower
2007	3,806	226	Counting Tower
2008	3,208	198	Counting Tower
2009	5,253	231	Counting Tower
2010	2,382	152	Counting Tower
2011	–	–	–
2012	2,220	127	Counting Tower
2013	1,859	141	Counting Tower
2014	7,192	73	Sonar
2015	6,291	169	Counting Tower/Sonar
2016	6,665	363	Sonar/Bayesian Hierarchical Model
2017	5,235	321	Counting Tower/Sonar

Note: En dashes represent missing data due to river conditions.

Table 2.–Estimates of the Salcha River Chinook salmon escapement, 1987–2017.

	Escapement		
Year	Estimate	SE	Method[b]
1987	4,771	504	MR
1988	4,322	556	MR
1989	3,294	630	MR
1990	10,728	1,404	MR
1991	5,608	664	MR
1992	7,862	975	MR
1993	10,007	360	CT
1994	18,399	549	CT
1995	13,643	471	CT
1996	7,570	1,238	MR
1997	18,514	1,043	CT
1998	5,027	331	CT
1999	9,198	290	CT
2000	4,595	802	CT
2001	13,328	2,163	CT
2002	9,000[a]	160	CT
2003	15,500[a]	747	CT
2004	15,761	612	CT
2005	5,988	163	CT
2006	10,679	315	CT
2007	6,425	225	CT
2008	5,415[a]	169	CT
2009	12,774	405	CT
2010	6,135	170	CT
2011	7,200[a]	–[c]	CT
2012	7,165	163	CT
2013	5,465	282	CT
2014[d]	–[d]	–[d]	–[d]
2015	6,287	309	CT
2016	2,675	313	CT/S/HM
2017	4,195	205	CT

[a] Estimate was obtained from an expansion of the interrupted tower count.

[b] Escapement estimates were obtained from counting tower (CT), mark–recapture (MR), sonar (S), and/or Bayesian hierarchical model (HM).

[c] Standard error not reported by Bering Sea Fishermen's Association.

[d] Extensive flooding prevented operation of counting tower.

OBJECTIVES

The objectives in 2017 include the following:

1. Estimate the total escapement of Chinook salmon in the Chena and Salcha Rivers using tower-counting techniques such that the estimates were within 15% of the true values 95% of the time.
2. Estimate ASL compositions of the escapement of Chinook salmon in the Chena and Salcha Rivers such that estimated proportions were within 6 percentage points of the true proportions 95% of the time.
3. Count coho salmon in the Delta Clearwater River during peak spawning to estimate minimum escapement.
4. Deploy and maintain sonars in the Chena and Salcha Rivers to enumerate passing salmon during periods of high-water when tower counts could not be completed.
5. Count chum salmon in the Chena and Salcha Rivers throughout the duration of the Chinook salmon run.

METHODS

CHENA AND SALCHA RIVER CHINOOK SALMON

Daily escapements of Chinook and chum salmon were estimated using counting towers on the Chena and Salcha Rivers. White fabric panels were laid on the river bottom on the upstream side of the Moose Creek Dam on the Chena River (Figure 1) and approximately 1 km upriver of the Richardson Highway Bridge (Figure 2) on the Salcha River. Over the course of the salmon run, personnel stood on scaffolding towers and counted all salmon moving upstream and downstream across the white panels for 20-minute intervals beginning at the top of every hour. Lights were suspended over the panels to provide illumination during periods of low ambient light.

The numbers of Chinook and chum salmon passing up- and downstream across the panels were recorded on field forms at the end of each 20-min count. Only counts with an associated water clarity rating of 1–3 were used in the estimate of escapement (Table 3). A count with an associated water clarity rating of 4 or 5 was considered as not counted. Five technicians were assigned to each river to enumerate the salmon escapement. Each day was divided into three 8-hour shifts: Shift I began at 0000 (midnight) and ended at 0759, Shift II began at 0800 and ended at 1559, and Shift III began at 1600 and ended at 2359.

Counting was set to begin on 27 June and continue until there were 3 continuous days with no net upstream passage of Chinook salmon, typically around 5 August. The majority of Chinook salmon spawning occurred upstream of these counting sites and, because no harvest of salmon is allowed on these river sections, final estimates represented total escapement.

In conjunction with the counting towers, 2 sonars were deployed upstream of the white fabric panels on the Salcha and Chena Rivers to estimate the number of migrating salmon during periods of low visibility. One dual-frequency identification sonar (DIDSON) and one adaptive resolution imaging sonar (ARIS) were deployed on opposite sides of the river, upstream of the Chena counting tower and 2 ARIS sonar units were deployed on either side of the river upstream of the Salcha River counting tower. Images were recorded 24 hours a day, 7 days a week for the project duration. Both the DIDSON and ARIS units were mounted to portable aluminum stands that could be moved manually to adjust for changing water depth. Additionally, all units incorporated rotators that enabled remote adjustment and focusing. Weir structures were deployed behind each unit to ensure migrating salmon passed through the sonar beam. When daily visual counts were available and water clarity ratings were greater than 3, the paired estimates were used to evaluate the effectiveness of the sonar.

Inseason and postseason, all fish >450 mm in length in the DIDSON sonar images were measured and recorded using Echotastic, a software program developed to process sonar images (Pfisterer 2010). Historical length distributions of chum and Chinook salmon from the Chena and Salcha Rivers have illustrated that no salmon are less than 450 mm in length. The estimated lengths from the sonar images, along with the associated dates of tower passage, were later used in a Bayesian mixture model that also incorporated historical length and run-timing data to apportion and estimate numbers of Chinook and chum salmon from the total sonar count.

To estimate ASL distributions of the escapement, carcasses of spawned-out Chinook salmon were collected during the last week of July through the first 2 weeks of August. The Chena River was sampled from river km (rkm) 72 to 161 (Figure 1) and on the Salcha River from the Richardson Highway Bridge (rkm 2) to Caribou Creek (88 rkm). Spawned-out chum salmon carcasses were also opportunistically collected and sampled. Two riverboats with 3 people in each boat operated side-by-side to search the entire river width including gravel bars and woody debris where carcasses were likely to deposit. Length measurements were made from mid eye to tail fork (METF) for use in sonar apportionment and length distributions. Sex was determined by looking at primary and secondary sexual characteristics. Scale samples were only taken from Chinook salmon carcasses for aging. Ages were determined from scale patterns as described by Mosher (1969). At least 4 scales were removed from the left side of the fish approximately 2 rows above the lateral line along a diagonal line downward from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Welander 1940). If no scales were present in the preferred area due to decomposition, scales were removed from the same area on the right side of the fish or, if necessary, from any location where scales were still present, other than along the lateral line. Scales were stored in coin envelopes and later mounted on gum cards. After sampling, the carcasses were cut in a distinctive manner down the left side to avoid resampling and returned to the river.

To estimate age compositions with the desired level of precision, a minimum of 417 Chinook salmon carcasses for each river were needed to achieve the objective for describing ASL estimates assuming 15% data loss due to unreadable scales (Thompson 1987).

Delta Clearwater River Coho Salmon

Boat surveys were used to estimate coho salmon escapement on the Delta Clearwater River. The survey was done during peak spawning times over the course of 1 to 2 days along the lower 18 miles of the Delta Clearwater River to within 1.0 mile of the Clearwater Lake outlet (Figure 3). Two persons conducted the survey from a drifting river boat equipped with a 5 ft elevated platform. The total number of coho salmon observed, both dead and alive, was recorded every mile as denoted by mile markers posted on the riverbank and summed for a final minimum count. Previous aerial surveys of the Delta Clearwater River drainage have shown that an average of 20% of the coho escapement is found in areas inaccessible to boat surveys (Parker 2009). Therefore, counts of adult coho salmon were conducted to obtain a minimum estimate of escapement and evaluate whether the SEG was met.

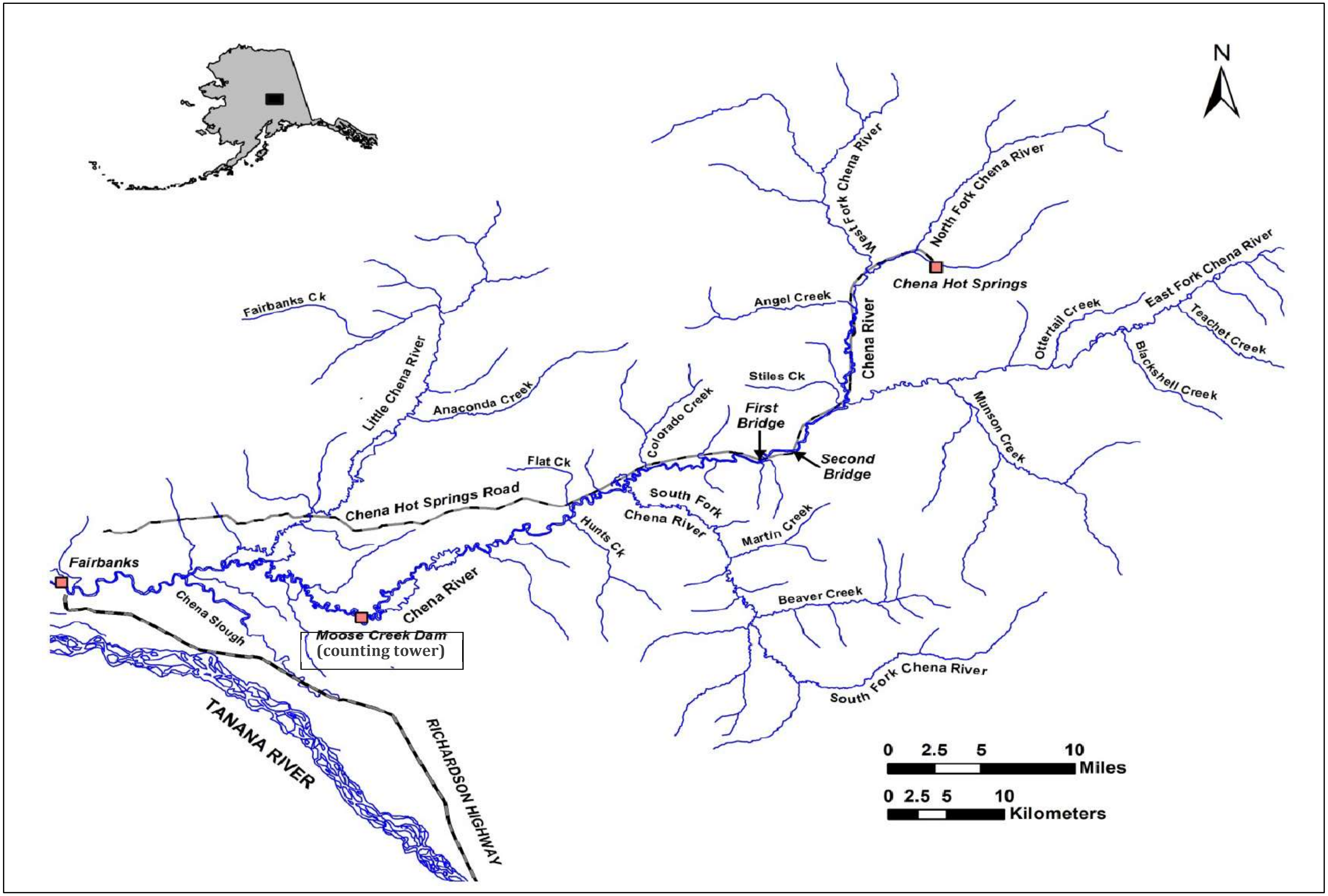

Figure 1.–Map of the Chena River demarcating the Moose Creek Dam (river km 72) and the first bridge on Chena Hot Springs Road (river km 161).

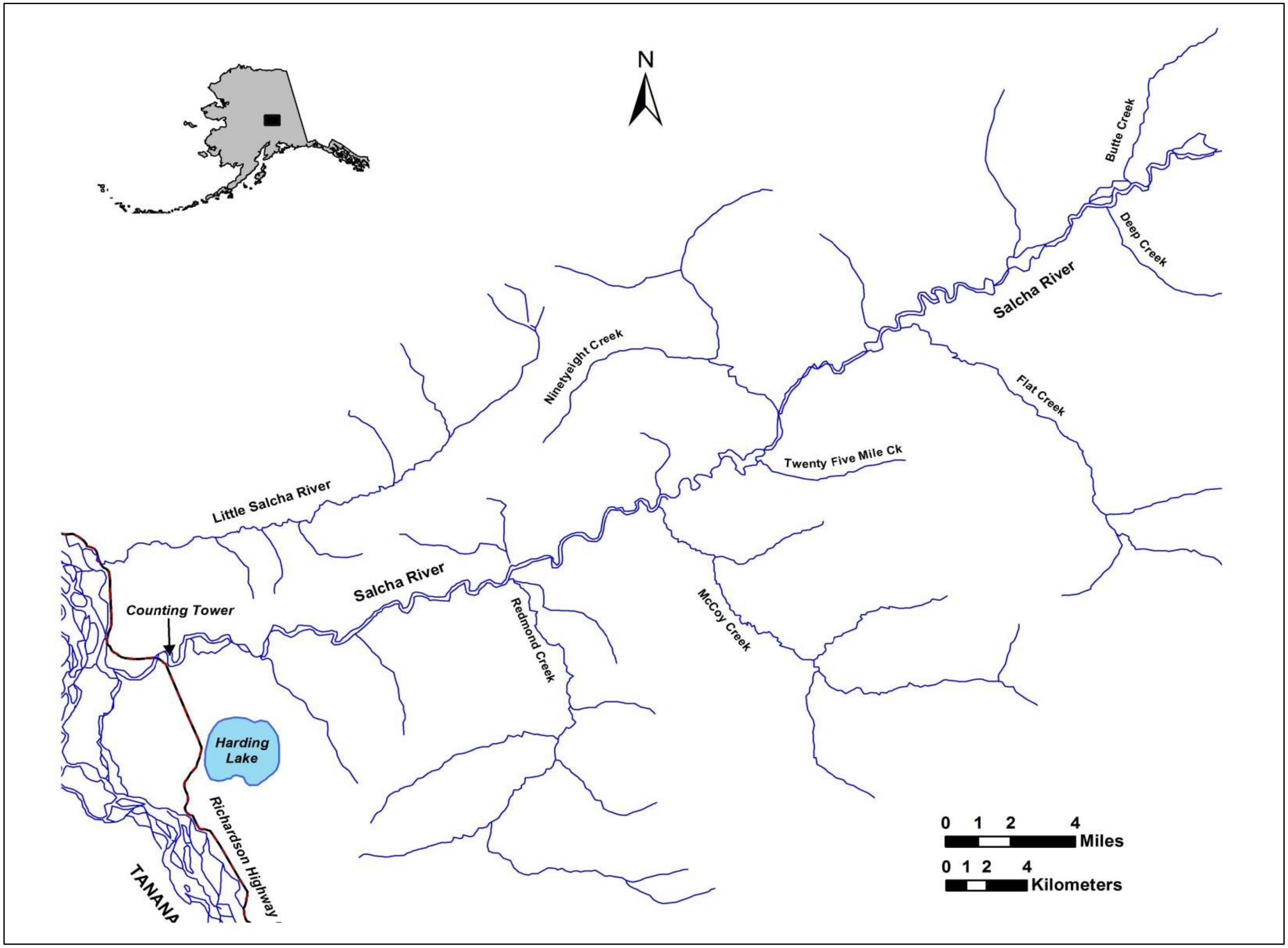

Figure 2.–Map of the Salcha River demarcating the counting tower.

Table 3.–Water clarity ratings.

Rating	Description	Salmon Viewing	Water Condition
1	Excellent	All passing salmon are observable	Virtually no turbidity or glare, “drinking water” clarity; all routes of passage observable
2	Good	All passing salmon are observable	Minimal to moderate levels of turbidity or glare; all routes of passage observable
3	Fair	Possible, but not likely, that some passing salmon may be missed	Moderate to high levels of turbidity or glare; a few likely routes of passage are partially obscured
4	Poor	Likely that some passing salmon may be missed	Moderate to high levels of turbidity or glare; some-many likely routes of passage are obscured
5	Unobservable	Passing fish are not observable	High level of turbidity or glare; ALL routes of passage obscured

DATA ANALYSIS

Chena and Salcha River Chinook Salmon

Counting Towers

Estimates of Chinook salmon escapement were stratified by day and daily estimates were summed to estimate total escapement. Daily escapement was estimated 1 of 5 ways, depending on the frequency of successful counts. The following criteria were used to determine the equations (1–15) used to estimate the daily escapement and its variance:

1. When 2 or more 8-hour shifts per day were considered complete (i.e., a minimum of 4 counting periods per shift were sampled), escapement for that day was estimated using equations 1–3 and variance was estimated using equations 4–8.
2. When only one 8-hour shift per day was considered complete but at least 4 counting periods are sampled, escapement for that day was estimated using equations 1–3 and variance was estimated using equation 13.
3. When no 8-hour shifts were considered complete on a given day, interpolation techniques described in equations 14 and 15 were used to estimate escapement, and equation 13 was used to estimate variance for inseason reporting of escapement estimates. This approach was used when no 8-hour shifts for 1 or 2 consecutive days of counting were considered complete. Postseason escapements for these dates were estimated using the mixture model that apportions the sonar counts of salmon by species (Huang 2012; Stuby and Tyers 2016).
4. When all 8-hour shifts on 3 or more but fewer than 10 consecutive days were considered incomplete, no inseason daily escapement values were reported and postseason daily escapement values were assessed using a mixture model that apportioned the sonar counts of salmon by species (Huang 2012; Stuby and Tyers 2016).
5. When visual counting could not be conducted for an excessive number of days during the run (e.g., more than 10 consecutive days or more than 20 total days), or when neither visual counts nor sonar counts could be conducted for 3 or more consecutive days (i.e., high water and inoperative sonar equipment), a Bayesian hierarchical model was used to estimate escapement for the missed days (if <25% of the total run) using characteristics of the run-timing curve (Hansen et al. 2016).

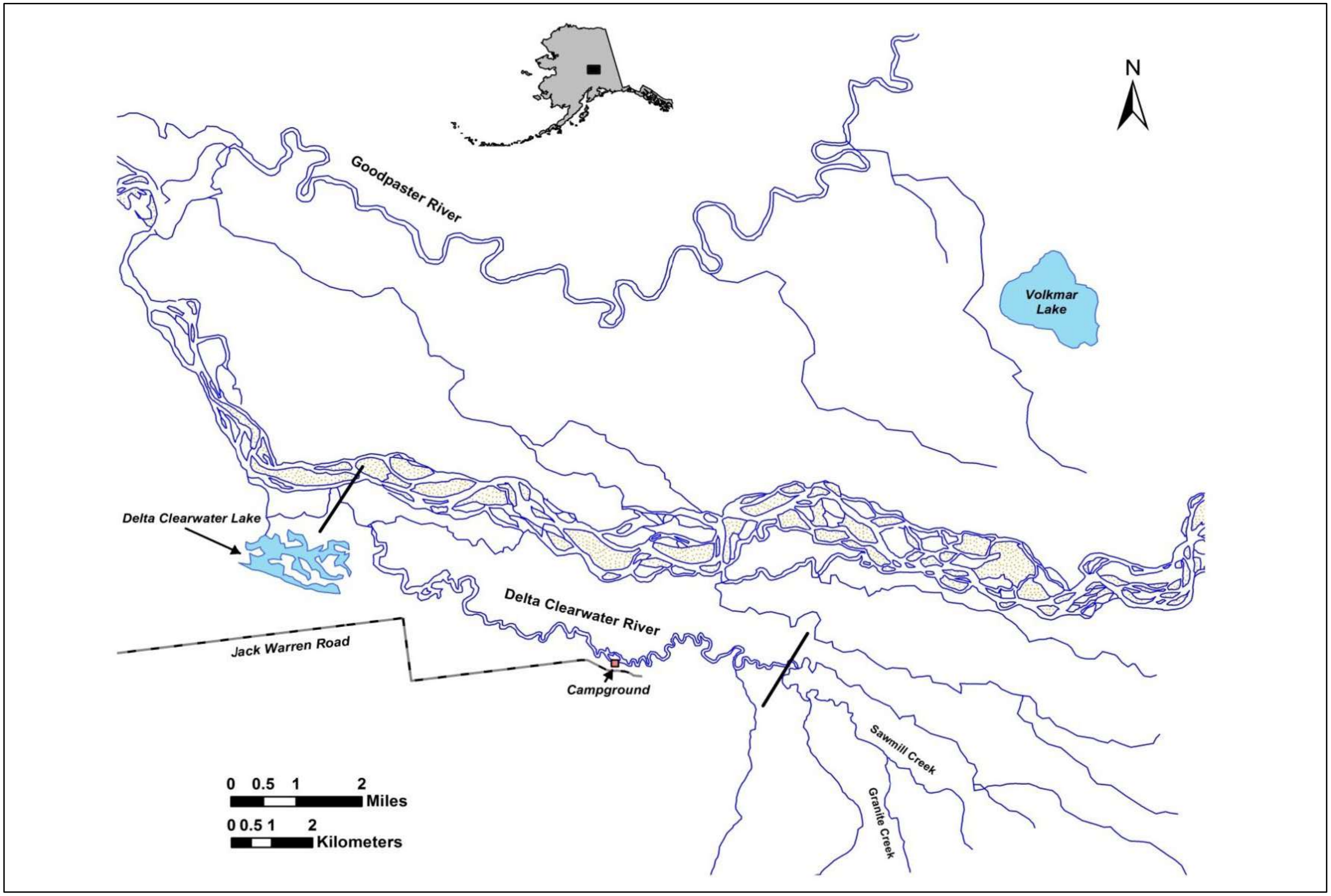

Figure 3.–Map of the Delta Clearwater River demarcating the survey area (bold lines).

Although diel migratory patterns have been noted and statistically accounted for in other systems (Taras and Sarafin 2005), no distinct diel migratory pattern has been documented for Chena or Salcha River Chinook salmon (Stuby 2001; J. Savereide, ADF&G, Fairbanks, unpublished data).

Daily estimates of escapement were considered a two-stage direct expansion where the first stage consisted of the 8 h shifts within a day and the second stage consisted of 20 min counting periods within a shift. The second stage was considered systematic sampling because the 20 min counting periods were not chosen randomly.

The formulas necessary to calculate escapement from counting tower data were taken directly, or modified, from those provided in Cochran (1977). The expanded shift escapement on day *d* and shift *i* were calculated by:

$$\hat{Y}_{di} = \frac{M_{di}}{m_{di}} \sum_{j=1}^{m_{di}} y_{dij} \, . \tag{1}$$

The average shift escapement for day *d* was:

$$\overline{Y}_d = \frac{\sum_{i=1}^{h_d} \hat{Y}_{di}}{h_d} \, . \tag{2}$$

The expanded daily escapement was:

$$\hat{N}_d = \overline{Y}_d H_d \, . \tag{3}$$

The period sampled was systematic because the same period was sampled every hour in a shift. The sample variance associated with periods was approximate using the successive difference approach (Wolter 1985):

$$s_{2di}^2 = \frac{1}{2(m_{di} - 1)} \sum_{j=2}^{m_{di}} \left(y_{dij} - y_{di(j-1)} \right)^2 \, . \tag{4}$$

All shifts were sampled unless water clarity conditions prohibited counts. If 2 or more shifts were not sampled on a given day, then the moving average technique (described below) was used to estimate the daily passage and its variance. If 1 shift was not sampled, then the between-shift sample variance was calculated as:

$$s_{1d}^2 = \frac{1}{h_d - 1} \sum_{i=1}^{h_d} \left(\hat{Y}_{di} - \overline{Y}_d \right)^2 \, . \tag{5}$$

The variance for the expanded daily escapement was estimated by (Cochran 1977, Eq. 11.24):

$$\hat{V}\left(\hat{N}_d\right) = \left[(1 - f_{1d}) H_d^2 \frac{s_{1d}^2}{h_d} \right] + \left[\frac{1}{f_{1d}} \sum_{i=1}^{h_d} \left((1 - f_{2di}) M_{di}^2 \frac{s_{2di}^2}{m_{di}} \right) \right] \tag{6}$$

where

$$f_{1d} = \frac{h_d}{H_d}, \text{ and} \tag{7}$$

$$f_{2di} = \frac{m_{di}}{M_{di}}; \tag{8}$$

and

d	=	day,
i	=	8 h shift,
j	=	20 min counting period,
y_{dij}	=	observed 20 min period count,
$\hat{Y}_{di}$	=	expanded shift escapement estimate,
m_{di}	=	number of 20 min counting periods sampled within a shift,
M_{di}	=	total number of possible 20 min counting periods within a day (24 would indicate a full day),
h_d	=	number of 8 h shifts sampled within a day,
H_d	=	total number of possible 8 h shifts within a day,
D	=	total number of possible days,
f_1	=	fraction of 8 h shifts sampled, and
f_2	=	fraction of 20 min counting periods sampled.

Total escapement and variance estimates were the sum of all daily estimates:

$$\hat{N} = \sum_{d=1}^{D} \hat{N}_d \text{, and} \tag{9}$$

$$\hat{V}\left(\hat{N}\right) = \sum_{d=1}^{D} \hat{V}(\hat{N}_d). \tag{10}$$

Equation 5, the sample variance across shifts, requires data from more than 1 shift per day. In the event that water conditions, personnel constraints, or both did not permit at least 2 shifts during a day, a coefficient of variation (CV) was calculated using all days when more than 1 shift was worked. The average CV was then used to approximate the daily variation for those days when fewer than 2 shifts were worked. The coefficient of variation was used because it is independent of the magnitude of the estimate and is relatively constant throughout the run (Evenson 1995). The daily CV was calculated as:

$$CV_d = SE_d \big/ \hat{N}_d. \tag{11}$$

For all L days of the run where more than one shift was worked, an average CV was calculated as:

$$\overline{CV} = \sum_{l=1}^{L} CV_l \Big/ L. \tag{12}$$

Variance of the escapement for days where one or zero shifts was worked was estimated as:

$$\mathrm{var}\left(\hat{N}_d\right) = (\overline{CV}\hat{N}_d)^2. \tag{13}$$

When k consecutive days were not sampled due to adverse viewing conditions, the moving average estimate for the missing day i was calculated as:

$$\hat{N}_i = \frac{\sum_{j=i-k}^{i+k} I(day\,j\ \ was\,sampled)\hat{N}_j}{\sum_{j=i-k}^{i+k} I(day\ j\,was\,sampled)} \tag{14}$$

where:

$$I(Condition) = \begin{cases} 1 & Condition\,is\,true \\ 0 & otherwise \end{cases} \tag{15}$$

was an indicator function. The moving average procedure was only applied for data gaps less than 3 days for inseason daily estimate reporting (9 consecutive 8-hour shifts). Postseason, all data gaps were assessed using a mixture model (Huang 2012; Stuby and Tyers 2016) applied to the sonar data for final estimates.

Age, Sex, and Length Composition

A comparison of sex composition estimates from mark–recapture methods used in previous years revealed that carcass surveys tended to overestimate the proportions of females in the population and underestimate the proportion of males (Doxey 2004). For years when only a carcass survey was conducted for ASL, adjustment factors were developed based on average ratios of unbiased estimates from past mark–recapture experiments and were applied to sex composition estimates.

The escapement estimate was apportioned by sex prior to apportioning by age categories within each sex. Age compositions were reported using the European notation that includes the number of freshwater and ocean years of residence. For example, age 1.2 symbolizes 1 year of freshwater residence and 2 years in the ocean (4 years total age). The estimated proportions of males and females from carcass surveys were calculated using (Cochran 1977):

$$\hat{p}_{sc} = \frac{y_{sc}}{n_c} \tag{16}$$

with variance:

$$\hat{V}[\hat{p}_{sc}] = \frac{\hat{p}_{sc}(1-\hat{p}_{sc})}{n_c - 1} \tag{17}$$

where y_{sc} is the number of salmon of sex s observed during carcass surveys and n_c is the total number of salmon of either sex observed during carcass surveys for $s = m$ or f.

The adjustment factor necessary to compensate for the sex ratio bias is $\hat{R}_p = 0.708$ with $\hat{V}(\hat{R}_p) = 0.018$ for the Chena River and $\hat{R}_p = 0.867$ with $\hat{V}(\hat{R}_p) = 0.030$ for the Salcha River (Doxey 2004). The bias-corrected estimate and variance (Goodman 1960) of the proportion of females, $\tilde{p}_{fe}$, is:

$$\tilde{p}_{fe} = \hat{p}_{fc}\hat{R}_p \tag{18}$$

with variance:

$$\hat{V}(\tilde{p}_{fe}) = \hat{p}_{fc}^2\hat{V}(\hat{R}_p) + \hat{R}_p^2\hat{V}(\hat{p}_{fc}) - \hat{V}(\hat{R}_p)\hat{V}(\hat{p}_{fc}) \cdot \tag{19}$$

The bias-corrected estimates of the proportion of males is:

$$\tilde{p}_{me} = 1 - \tilde{p}_{fe} \tag{20}$$

with variance:

$$\hat{V}(\tilde{p}_{me}) = \hat{V}(\tilde{p}_{fe}). \tag{21}$$

Escapement of each sex was then estimated by:

$$\hat{N}_s = \tilde{p}_{se}\hat{N}. \tag{22}$$

The variance for $\hat{N}_s$ in this case is (Goodman 1960):

$$\hat{V}(\hat{N}_s) = \hat{V}(\tilde{p}_{se})\hat{N}^2 + \hat{V}(\hat{N})\tilde{p}_{se}^2 - \hat{V}(\tilde{p}_{se})\hat{V}(\hat{N}). \tag{23}$$

The proportion of fish at age k by sex s for samples collected solely for ASL were calculated as:

$$\hat{p}_{sk} = \frac{y_{sk}}{n_s} \tag{24}$$

where $\hat{p}_{sk}$ = the estimated proportion of Chinook salmon that are age k, y_{sk} = the number of Chinook salmon sampled that are age k and sex s, and n_s = the total number of Chinook salmon sampled of sex s. The variance of this proportion was estimated as:

$$\hat{V}[\hat{p}_{sk}] = \frac{\hat{p}_{sk}(1 - \hat{p}_{sk})}{n_s - 1}. \tag{25}$$

Mean lengths and associated variances were calculated for each sex and associated age class using:

$$\bar{l}_j = \frac{\sum_{j\text{-}1}^{n} l_j}{n_s} \text{ and} \tag{26}$$

$$V[\bar{l}_j] = \frac{\sum_{j=1}^{n}(l_j\text{-}\bar{l}_j)}{n(n\text{-}1)}. \tag{27}$$

Escapement at age k for each sex was then estimated by:

$$\hat{N}_{sk} = \hat{p}_{sk}\hat{N}_s. \tag{28}$$

The variance for $\hat{N}_{sk}$ in this case is (Goodman 1960):

$$\hat{V}(\hat{N}_{sk}) = \hat{V}(\hat{p}_{sk})\hat{N}_s^{\ 2} + \hat{V}(\hat{N}_s)\hat{p}_{sk}^2 - \hat{V}(\hat{p}_{sk})\hat{V}(\hat{N}_s). \tag{29}$$

Sonar Mixture Model

The proportions of Chinook and chum salmon in the total sonar counts were estimated using a mixture model with fish length being the discriminating information, weakly informed by run timing. The probability density function (pdf) of fish length i (y_i) was modeled using a weighted mixture model:

$$f(y_i) = p_{c,i}f_c(y_i) + p_{k,i}f_k(y_i) \tag{30}$$

where:

$$0 \le p_{c,i}, p_{k,i} \le 1, \text{ and } p_{c,i} + p_{k,i} = 1 \tag{31}$$

where $f_c(y)$ is the length distribution of chum salmon and $f_k(y)$ is the length distribution of Chinook salmon; weights $p_{c,i}$ and $p_{k,i}$ were the probabilities of fish i being a chum or Chinook salmon, respectively.

There is a moderate difference in length between sexes that is present in both species of salmon. The length distribution of either species can be expressed with a two-component sex mixture model as shown below:

$$f_c(y) = \theta_{c1} f_{c1}(y) + \theta_{c2} f_{c2}(y) \tag{32}$$

and

$$f_k(y) = \theta_{k1} f_{k1}(y) + \theta_{k2} f_{k2}(y) \tag{33}$$

where θ_{c1} and θ_{c2} are the proportions of male and female chum salmon, respectively; and θ_{k1} and θ_{k2} are the proportions of male and female Chinook salmon, respectively. The proportions of males and females add up to 1 for each species. Distributions $f_{cs}(y)$ and $f_{ks}(y)$ were assumed to be normal for both sexes:

$$f_{cs}(y) \sim N(\mu_{cs}, \sigma_{cs}^2) \tag{34}$$

$$f_{ks}(y) \sim N(\mu_{ks}, \sigma_{ks}^2). \tag{35}$$

Prior information about the length means (μ) and variances (σ^2) in equation (34) and (35) were found in other fishery research publications. For this study, prior information for Chinook and chum salmon length distributions were taken from the Arctic-Yukon-Kuskokwim (AYK) Database Management System.[2] In addition, prior information for chum salmon length distribution was provided by Clark (1993).

Individual fish lengths were treated as unobserved variables because lengths were measured from sonar images. A linear relationship was assumed between sonar length ($y_{obs,i}$) and the actual fish length (y_i) for fish i. The sonar fish length ($y_{obs,i}$) was modeled as a normal variable whose mean was a linear function of actual fish length (y_i; Equation 36),

$$y_{obs,i} = \beta_1 + \beta_2 y_i + \varepsilon_i \tag{36}$$

where y_{obs} refers to observed sonar length, which are the fish length measurements obtained from the sonar images; y_i refers to the actual fish length; and the intercept β_1 and slope β_2 are unknown parameters of the linear relationship between $y_{obs,i}$ and y_i. Paired data used to inform the relationship between $y_{obs,i}$ and y_i were obtained from a tethered-fish experiment (Burwen et al. 2010). The relationship between actual length and observed length was not assumed to be the same for the 2 sonar technologies employed (DIDSON and ARIS), so the slope and intercept parameters associated with each technology were allowed to differ.

The mixture model (Equations 30–36) contains unknown parameters including species probability parameters p_c and p_k, sex proportion parameters θs, intercept parameter β_1, and slope parameter

β_2. In order to estimate these unknown parameters, the mixture model was fitted using Markov Chain Monte Carlo (MCMC) as implemented in the statistical software package JAGS (Plummer 2003), called through the statistical software R (R Core Team 2014) using R package R2jags (Su and Yajima 2015; Appendix A).

According to Bayes' theorem, the posterior distributions of the unknown parameters are proportional to the likelihood of the data multiplied by the prior distributions of the parameters. The likelihood of the data collected followed the mixture model density function (Equation 30). The prior distributions of the sex ratio parameters θs were assigned a Dirichlet (α,γ) distribution. The Chinook salmon run starts earlier and will usually peak before or during the early portion of the chum salmon run and that the proportion of the total run comprised of Chinook salmon has followed an approximate logistic trend over the course of the run. Therefore, species proportions parameters $p_{c,d}$ and $p_{k,d}$ for run day x_d were assigned diffuse Dirichlet priors (η_d,ζ_d) that were calculated by run date according to:

$$\log\left(\frac{\eta_d}{\eta_d - 1}\right) = b_0 + b_1 x_d \tag{37}$$

and

$$\zeta_t = 1 - \eta_t . \tag{38}$$

Hyperparameters b_0 and b_1 were estimated using logistic regression to model the relationship between run timing and species in historical data. Because some variability in this relationship exists between years, the values of b_0 and b_1 that were used in the model were estimated in a hierarchical logistic regression model, in which logistic regression parameters for the Chena and Salcha Rivers were treated as multivariate normal. This allowed parameters to vary by year (but modeled as from the same underlying distribution) and river (but modeled as correlated). Chinook and chum salmon lengths were assigned normal priors, using data from the AYK Database Management System (ADF&G 2018b), as well as Clark (1993). The regression parameters β_1 and β_2 were assigned diffuse normal priors. The Bayesian MCMC was conducted using JAGS with 3 chains and 100,000 iterations in each chain. The first 50,000 iterations in each chain were considered as burn-in and discarded.

Species totals were calculated for every iteration of the MCMC procedure, thus giving posterior distributions of the escapement for each species. Escapement estimates and respective standard errors were then obtained by calculating the median and standard deviation of the posterior draws of species totals.

Bayesian Hierarchical Model

In the event visual counting could not be conducted for an excessive number of days during the run (i.e., more than 10 consecutive days or more than 20 total days), or when neither visual counts nor sonar counts could be conducted for 3 or more consecutive days (e.g., high water and inoperative sonar equipment), a Bayesian hierarchical model was used to estimate escapement for the missed days using characteristics of the run-timing curve (Hansen et al. 2016). As a safeguard against reporting spurious results, an estimate was not reported if the Bayesian hierarchical model represented more than 25% of the total estimated run (Toshihide Hamazaki, Division of Commercial Fisheries Biometrician, ADF&G, Anchorage; personal communication).

Estimated daily counts for day d within year k were assumed to be normally distributed around either a lognormal, extreme-value, or log-logistic trends by date:

$$\widehat{N}_{k[d]} \sim N(\theta_{k[d]}, \sigma_\theta^2). \tag{39}$$

The run-timing trends of year k were determined by 3 parameters: a_k describes the amplitude of the run peak, μ_k describes the location by date of the run peak, and b_k describes the width of the run peak. The functional forms are given below for the lognormal, extreme-value, and log-logistic trends, respectively, for run day $x_{k[d]}$:

$$\theta_{k[d]} = a_k e^{\left(-0.5\left(\frac{ln\left(\frac{x_{k[d]}}{\mu_k}\right)}{b_j}\right)^2\right)} \tag{40}$$

$$\theta_{k[d]} = a_k e^{\left(-e^{\left(-\frac{x_{k[d]}-\mu_k}{b_k}\right)} - \left(\frac{x_{k[d]}-\mu_k}{b_k}\right) + 1\right)} \tag{41}$$

$$\theta_{k[d]} = a_k \left(\frac{\left(\frac{b_k}{\mu_k}\right)\left(\frac{x_{k[d]}}{\mu_k}\right)^{(b_k-1)}}{\left(1+\left(\frac{x_{k[d]}}{\mu_k}\right)^{b_k}\right)^2}\right). \tag{42}$$

The lognormal form was used in 2017 because it gave the most biologically reasonable results. Amplitude parameters a_k for each year were considered independent between years, and were each given flat, noninformative priors. However, μ_k and b_k for each year were treated as normally distributed from common distributions, according to:

$$\mu_k \sim N(\mu_0, \sigma_\mu^2) \tag{43}$$

$$b_k \sim N(b_0, \sigma_b^2) \tag{44}$$

with noninformative priors placed on parameters μ_0, σ_μ^2, b_0, and σ_b^2. All available years' data were incorporated into the model in order to fine-tune parameter estimates.

Because Chinook salmon spawning in the Chena and Salcha Rivers have been observed to follow very similar run-timing profiles each year, the mean timing parameters μ_k for each river were not treated as independent, rather one was modeled under the assumption that the difference between the two was normally distributed. This constraint allowed the model to have greater predictive power, particularly if counts were available for one river while a data gap existed for the other.

JAGS code for a current version of this model is provided in Appendix B.

Delta Clearwater River Coho Salmon

The minimum escapement of coho salmon was estimated by:

$$E_{\min} = \sum_{i=1}^{s} C_i \tag{45}$$

where: C_i = count of coho salmon in each mile section and s = number of mile sections.

RESULTS

CHENA RIVER

The Chena River counting tower and sonar site operated from 26 June through 3 August. The estimated escapement of Chinook salmon based primarily on visual counts (34%) and model-apportioned sonar counts (62%; Figure 5) was 5,235 (SE = 321), which falls within the established BEG range (Figure 4). The estimated chum salmon escapement was 21,176 (SE = 994) and was considered a minimum estimate because counts were terminated before the chum run was complete (Table 4).

The 2017 Chinook salmon run-timing pattern was similar to both the recent 5-year average and historical average (Figure 6). The natural variability in run timing can make comparisons among years difficult when calendar day is used (Figure 7). For example, the midpoint of the run (i.e., 50% of the run has passed) on the Chena River has varied from 12 July (2016) to 24 July (1999). To facilitate comparisons among years, run-timing patterns were described by day of the run [i.e., day 1 equals the first Chinook salmon passing upriver during a scheduled count (Figure 6)]. The 2017 midpoint occurred on day 18 of the run while the midpoint for the 5-year average occurred on day 16 and the historic mid-point occurred on day 17.

Salmon carcass surveys took place between 1 August and 10 August. Carcass crews were able to collect 426 Chinook salmon of which 386 were aged. The sex composition of the aged samples was 0.45 (SE = 0.03) female and 0.55 (SE = 0.03) male (Table 5). The sex composition of the estimate adjusted for sex ratio bias was 0.33 (SE = 0.03) female and 0.67 (SE = 0.03) male (Table 5, Figure 8). The mean length for sampled males was 736 mm (SE = 5; Table 6). The mean length for female Chinook salmon was 774 mm (SE = 6; Table 6). For males, the dominant age class was 1.3, which was 46% of the total sample (Tables 6 and 7). For females, the dominant age class was also 1.3, which was 28% of the total sample (Tables 6 and 8). Unadjusted and adjusted age compositions for all Chinook salmon sampled were also calculated (Tables 9 and 10, respectively, and Figure 9). During the carcass survey, body cavities were cut open for most fish to verify sex identification.

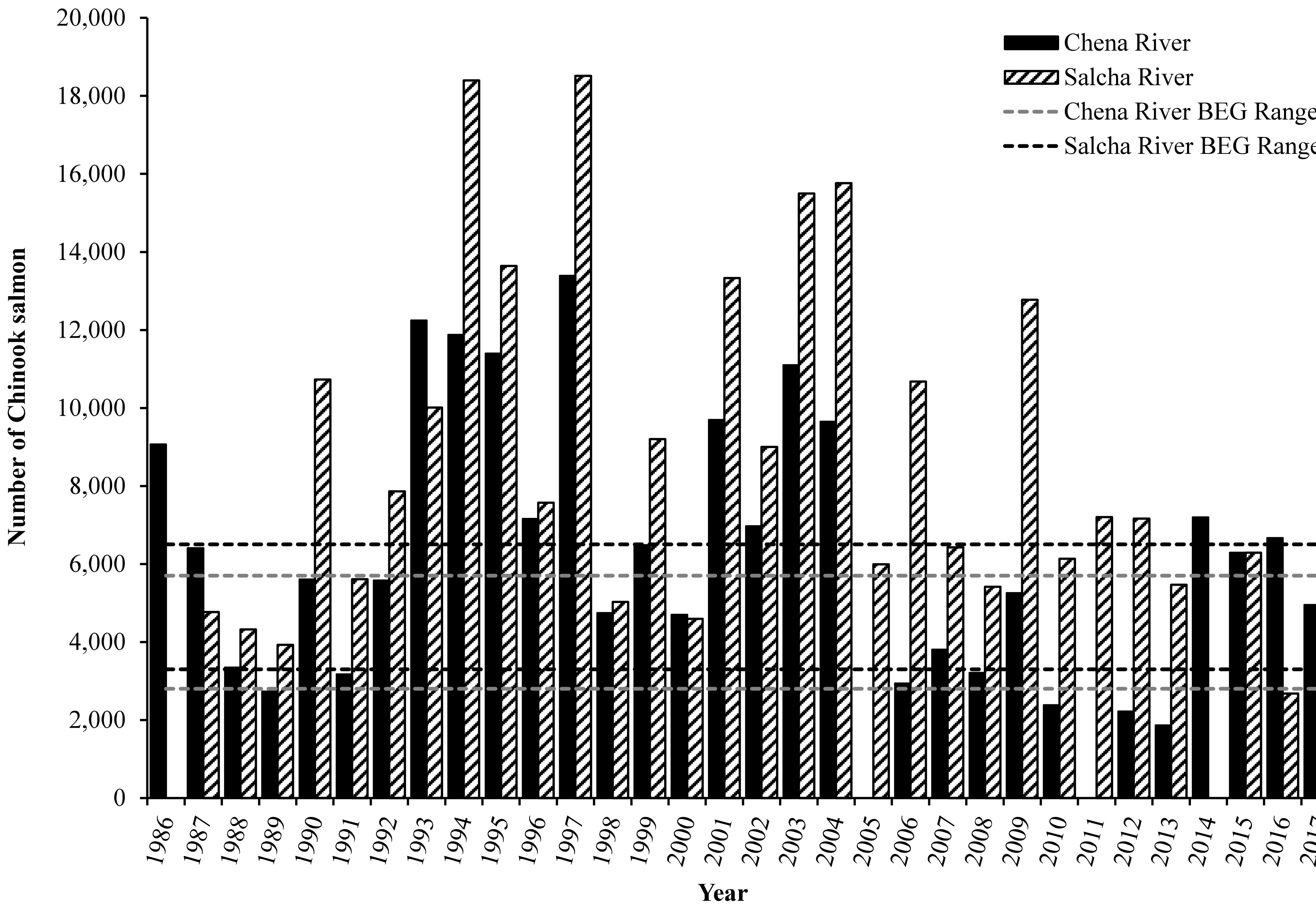

Figure 4.–Estimates of Chinook salmon to the Chena and Salcha Rivers with respective BEG ranges, 1986–2017.

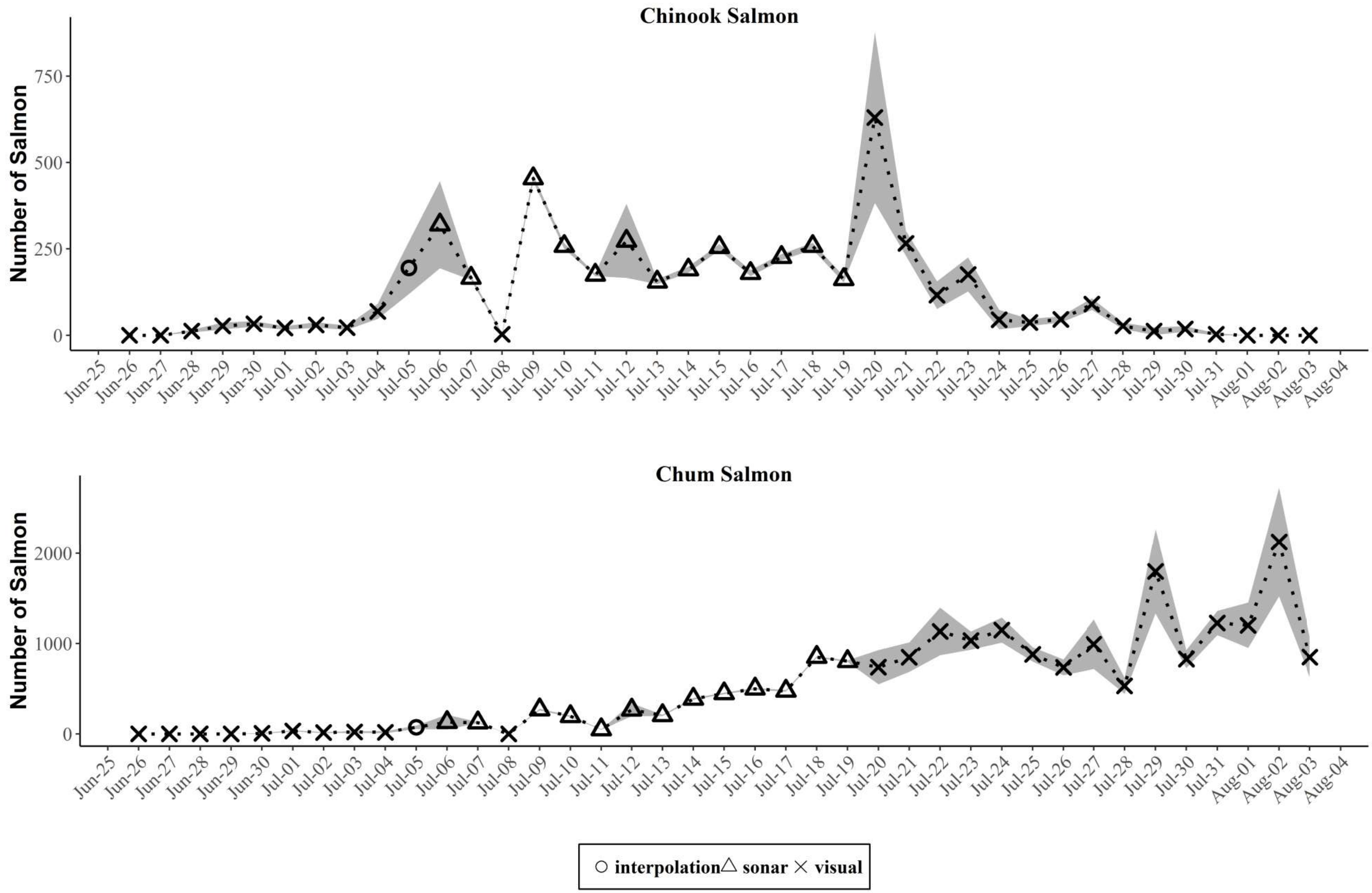

Figure 5.–Daily estimates of Chena River Chinook and chum salmon abundance by visual counts, sonar counts, and interpolation with associated SE (shaded areas), 2017.

Table 4.–Daily estimates of Chena River Chinook and chum salmon escapement in 2017. Shaded cells denote days where counts were estimated from sonar due to high-water events that precluded visual counts.

	Chinook Salmon		Chum Salmon	
Date	Daily Escapement	Daily SE	Daily Escapement	Daily SE
28 June	12	4	0	0
29 June	27	10	0	0
30 June	33	8	6	5
1 Jul	21	5	33	7
2 Jul	30	8	15	5
3 Jul	22	6	22	9
4 Jul	69	22	18	10
5 Jul	195	76	74	19
6 Jul	320	126	130	82
7 Jul	166	6	125	6
8 Jul	289	9	233	8
9 Jul	454	9	269	9
10 Jul	258	8	195	8
11 Jul	175	4	49	4
12 Jul	273	107	267	70
13 Jul	155	7	205	7
14 Jul	190	9	387	9
15 Jul	255	9	448	9
16 Jul	180	9	499	9
17 Jul	226	9	476	9
18 Jul	258	10	850	10
19 Jul	162	9	805	9
20 Jul	630	247	738	190
21 Jul	266	36	849	162
22 Jul	116	40	1,134	263
23 Jul	176	49	1,032	100
24 Jul	45	28	1,148	139
25 Jul	37	10	880	80
26 Jul	46	9	736	88
27 Jul	90	17	992	273
28 Jul	27	9	532	88
29 Jul	12	11	1,798	467
30 Jul	18	8	828	99
31 Jul	3	3	1,227	134
1 Aug	0	0	1,202	251
2 Aug	0	0	2,124	602
3 Aug	0	0	850	218
Total	5,235		21,176	

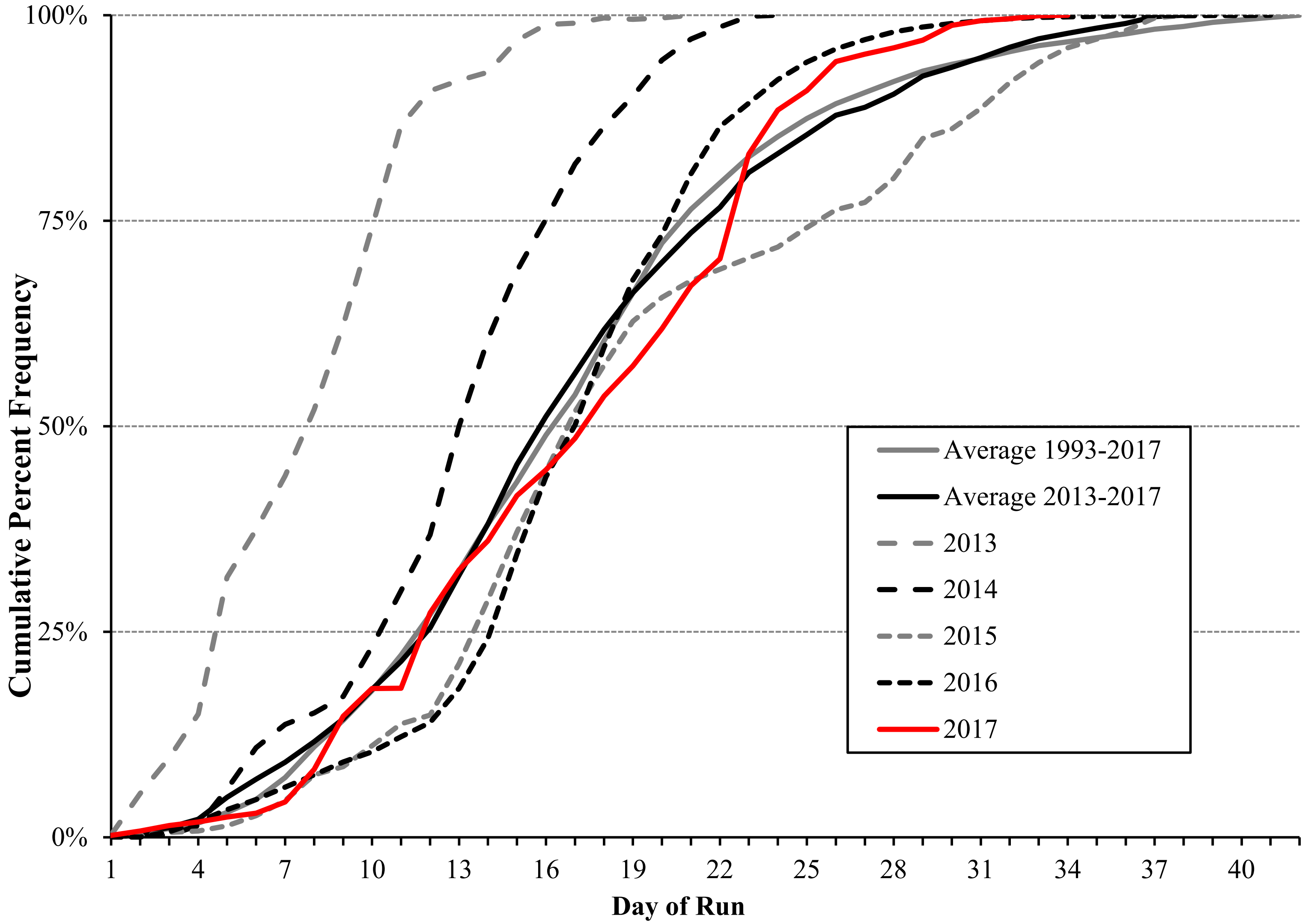

Figure 6.–Average run-timing patterns for Chena River Chinook salmon past the counting tower by the first day of run over all years (1993–1994, 1997–1999, 2001, 2004, 2006–2010, and 2012–2017), recent 5-year average (2013–2017), and compared to 2013–2017.

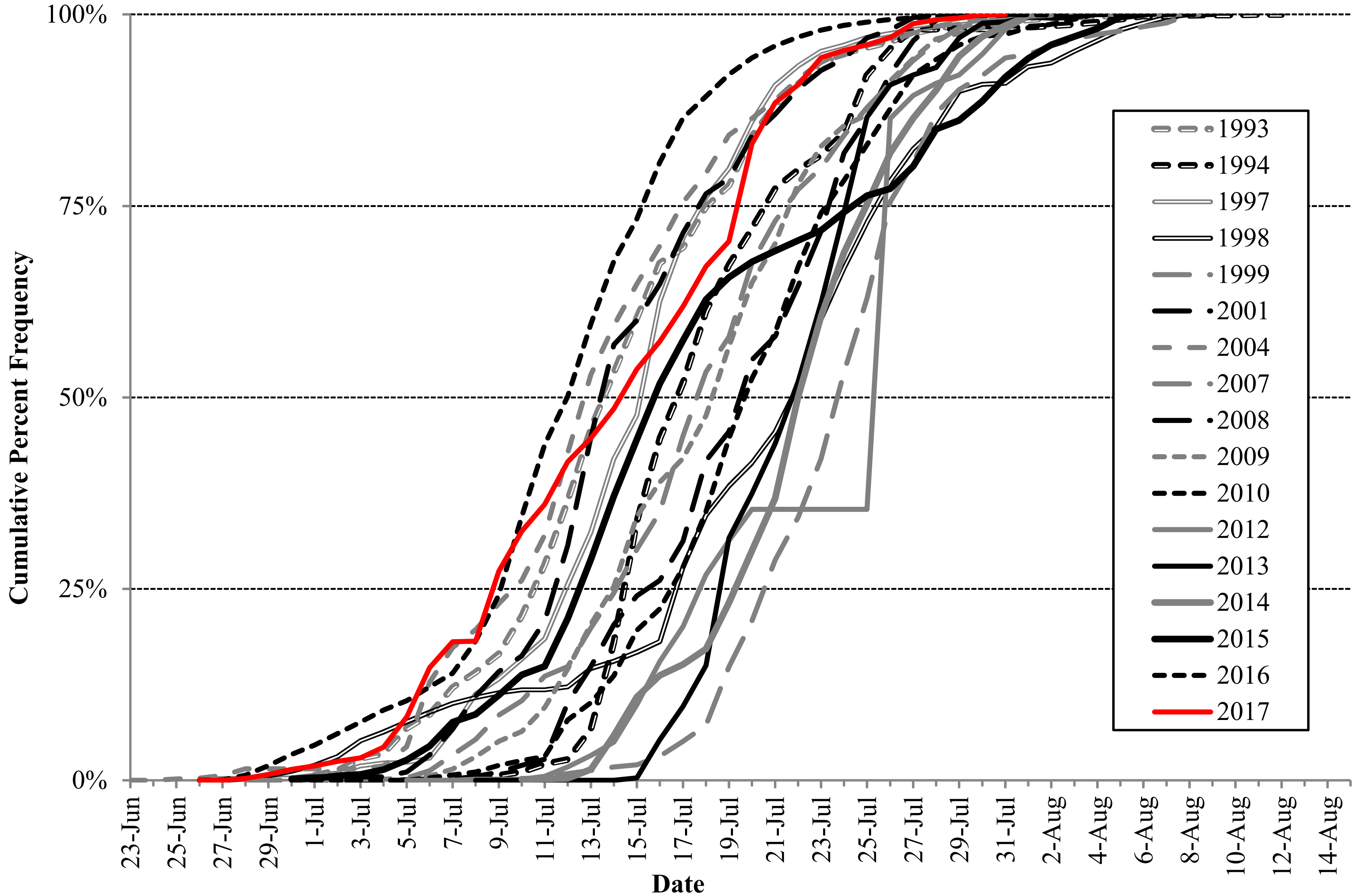

Figure 7.–Cumulative passage of Chena River Chinook salmon for the years when visual or visual/sonar combination counts composed a complete estimate of abundance.

Table 5.–Estimated proportions of male and female Chinook salmon carcasses on the Chena River, 1986–2017.

	Sexed sample size		Sexed sample proportion		Sexed and aged sample size		Sexed and aged sample proportion		Adjusted sample proportion[a]		Total	
Year	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Escapement	Method[b]
1986	987	365	0.73	0.27	538	183	0.75	0.25	0.75	0.25	9,065	MR
1987	438	592	0.43	0.57	235	325	0.42	0.58	0.52	0.48	6,404	MR
1988	347	543	0.39	0.61	183	285	0.39	0.61	0.66	0.34	3,346	MR
1989	119	218	0.35	0.65	101	187	0.35	0.65	0.55	0.45	2,730	MR
1990	412	376	0.52	0.48	291	258	0.53	0.47	0.64	0.36	5,603	MR
1991	684	315	0.68	0.32	231	108	0.68	0.32	0.68	0.32	3,172	MR
1992	368	210	0.64	0.36	289	176	0.62	0.38	0.78	0.22	5,580	MR
1993	205	38	0.84	0.16	156	31	0.83	0.17	0.88	0.12	12,241	CT
1994	326	275	0.54	0.46	281	231	0.55	0.45	0.68	0.32	11,877	CT
1995	305	593	0.34	0.66	267	520	0.34	0.66	0.48	0.52	11,394	MR
1996	346	268	0.56	0.44	286	229	0.56	0.44	0.73	0.27	7,153	MR
1997	524	354	0.60	0.40	424	278	0.60	0.40	0.74	0.26	10,810	MR
1998	160	107	0.60	0.40	134	94	0.59	0.41	0.72	0.28	4,745	CT
1999	74	134	0.36	0.64	61	116	0.34	0.66	0.54	0.46	6,485	CT
2000	113	56	0.67	0.33	99	50	0.66	0.34	0.78	0.22	4,694	MR
2001	342	253	0.57	0.43	292	229	0.56	0.44	0.70	0.30	9,696	CT
2002	277	216	0.56	0.44	207	167	0.55	0.45	0.73	0.27	6,967	MR
2003	253	206	0.55	0.45	204	166	0.55	0.45	0.68	0.32	11,100[c]	CT
2004	98	160	0.38	0.62	88	151	0.37	0.63	0.56	0.44	9,645	CT
2005	352	268	0.57	0.43	319	234	0.58	0.42	0.69	0.31	–	CT
2006	221	183	0.55	0.45	196	166	0.54	0.46	0.68	0.32	2,936	CT
2007	52	31	0.63	0.37	37	25	0.60	0.40	0.74	0.26	3,806	CT
2008	26	18	0.59	0.41	20	16	0.56	0.44	0.71	0.29	3,208	CT
2009	209	272	0.43	0.57	198	244	0.45	0.55	0.60	0.40	5,253	CT
2010	132	54	0.71	0.29	56	25	0.69	0.31	0.79	0.21	2,382	CT
2011	331	156	0.68	0.32	290	135	0.68	0.32	0.77	0.23	–	–
2012	107	132	0.45	0.55	88	110	0.44	0.56	0.61	0.39	2,220	CT/S
2013	127	81	0.61	0.39	105	71	0.60	0.40	0.72	0.28	1,859	CT
2014	244	123	0.66	0.34	190	94	0.67	0.33	0.76	0.24	7,192	S
2015	267	324	0.45	0.55	223	277	0.45	0.55	0.61	0.39	6,291	S/CT
2016	302	86	0.78	0.22	284	84	0.77	0.23	0.84	0.16	6,665	S/HM
2017	227	193	0.54	0.46	211	175	0.55	0.45	0.67	0.33	5,235	S/CT
Average	280	225	0.56	0.44	206	170	0.56	0.44	0.69	0.31	6,291	

Note: En dashes represent missing data due to river conditions.

[a] In years when mark–recapture experiments (MR) were conducted (1986–1992, 1995–1997, 2000, and 2002), males were more likely to be sampled during the first event (electroshocking), and overall, less bias in estimating size and sex was noted from electroshocking than sampling carcasses (second event). As a result, an adjustment factor has been applied to the carcass samples, which have been the primary means of obtaining ASL since 2003.

[b] Escapement estimates were obtained from either a counting tower (CT) assessment, sonar images (S), mark–recapture (MR) experiment, or a Bayesian hierarchical model (HM).

[c] Estimate includes an expansion for missed counting days. Minimum documented abundance with large gaps in counts due to flooding was 8,739 (SE = 653) fish.

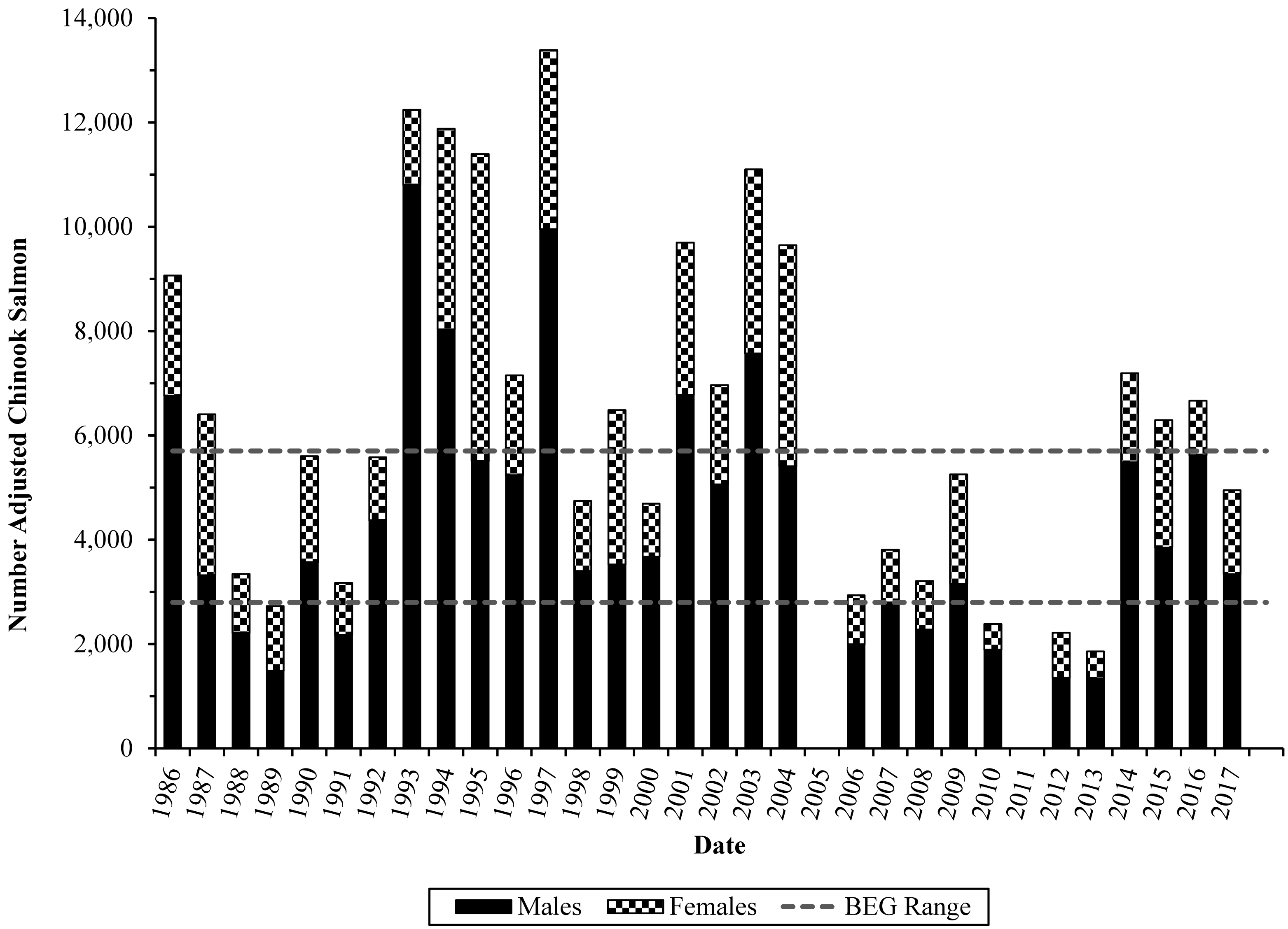

Figure 8.–Estimates of Chinook salmon adjusted sex composition and yearly escapements to the Chena River with the respective BEG range, 1986–2017.

Table 6.–Estimated proportions and mean length by age and sex of Chinook salmon sampled during the Chena River carcass survey, 2017.

	Sample	Sample	Length (mm)			
Age[a]	size	proportion	Mean	SE	Min	Max
Males						
1.2	10	0.03	574	27	430	755
1.3	176	0.46	740	4	540	840
1.4	23	0.06	828	15	710	910
2.3	2	0.01	630	33	475	910
Total aged males	211	0.55	736	5	430	915
Total males[b]	227	0.54	735	5	430	915
Adjusted total[c]		0.67				
Females						
1.2	1	>0.01	665	–	–	–
1.3	110	0.28	756	8	575	845
1.4	64	0.17	805	7	680	935
Total aged females	175	0.45	774	6	575	935
Total females[b]	193	0.46	773	6	575	935
Adjusted total[c]		0.33				
Total						
Total aged	386		753	4	430	935
Total collected	420		753	4	430	935

Note: En dashes (–) mean value could not be calculated.

[a] Age is represented by the number of annuli formed during river residence and ocean residence (i.e., an age of 1.4 represents one annulus formed during river residence and four annuli formed during ocean residence for a total age of 6 years).

[b] Totals include those Chinook salmon that could not be aged.

[c] Estimated proportion of females was adjusted by a factor of 0.708. Adjusted values presented in Table 5.

Table 7.–Age composition and escapement estimates of males for Chena River Chinook salmon, 1986–2017.

Males	Total Age (years)/European Age (freshwater years/ocean years)										Male	Male
	3	4	5		6		7		8		Unadjusted	Adjusted
Year	1.1	1.2	1.3	2.2	1.4	2.3	1.5	2.4	1.6	2.5	Escapement	Escapement
1986	0.002	0.126	0.636	0.000	0.197	0.019	0.020	0.000	0.000	0.000	6,618	6,764
1987	0.000	0.064	0.281	0.000	0.613	0.009	0.034	0.000	0.000	0.000	2,723	3,320
1988	0.016	0.268	0.355	0.000	0.279	0.000	0.082	0.000	0.000	0.000	1,305	2,212
1989	0.010	0.109	0.495	0.020	0.347	0.010	0.010	0.000	0.000	0.000	964	1,492
1990	0.000	0.423	0.309	0.003	0.254	0.000	0.010	0.000	0.000	0.000	2,929	3,569
1991	0.000	0.126	0.489	0.000	0.312	0.000	0.074	0.000	0.000	0.000	2,172	2,172
1992	0.031	0.682	0.208	0.000	0.080	0.000	0.000	0.000	0.000	0.000	3,553	4,373
1993	0.006	0.353	0.442	0.000	0.192	0.000	0.006	0.000	0.000	0.000	10,327	10,804
1994	0.000	0.053	0.644	0.000	0.292	0.004	0.007	0.000	0.000	0.000	6,442	8,029
1995	0.000	0.131	0.360	0.000	0.491	0.000	0.015	0.004	0.000	0.000	3,870	5,509
1996	0.038	0.108	0.629	0.000	0.136	0.000	0.087	0.000	0.000	0.000	4,031	5,239
1997	0.005	0.611	0.184	0.000	0.196	0.000	0.002	0.002	0.000	0.000	6,452	8,038
1998	0.000	0.075	0.858	0.000	0.045	0.000	0.022	0.000	0.000	0.000	2,843	3,399
1999	0.000	0.115	0.377	0.000	0.508	0.000	0.000	0.000	0.000	0.000	2,307	3,527
2000	0.004	0.386	0.458	0.000	0.149	0.000	0.004	0.000	0.000	0.000	3,139	3,675
2001	0.010	0.154	0.462	0.000	0.353	0.000	0.021	0.000	0.000	0.000	5,573	6,777
2002	0.002	0.422	0.364	0.000	0.206	0.000	0.005	0.000	0.000	0.000	3,915	5,063
2003	0.000	0.088	0.623	0.000	0.240	0.000	0.049	0.000	0.000	0.000	6,118	7,573
2004	0.000	0.295	0.318	0.000	0.364	0.000	0.023	0.000	0.000	0.000	3,664	5,410
2005	0.000	0.110	0.571	0.000	0.292	0.000	0.016	0.013	0.000	0.000	–	–
2006	0.000	0.235	0.592	0.005	0.148	0.005	0.015	0.000	0.000	0.000	1,606	1,994
2007	0.054	0.351	0.297	0.000	0.297	0.000	0.000	0.000	0.000	0.000	2,384	2,800
2008	0.000	0.150	0.750	0.000	0.100	0.000	0.000	0.000	0.000	0.000	1,896	2,279
2009	0.000	0.313	0.293	0.000	0.394	0.000	0.000	0.000	0.000	0.000	2,282	3,150
2010	0.000	0.196	0.518	0.018	0.250	0.000	0.018	0.000	0.000	0.000	1,690	1,892
2011	0.003	0.331	0.555	0.003	0.103	0.000	0.000	0.003	0.000	0.000	–	–
2012	0.011	0.114	0.636	0.000	0.239	0.000	0.000	0.000	0.000	0.000	994	1,352
2013	0.019	0.486	0.257	0.000	0.229	0.000	0.010	0.000	0.000	0.000	1,135	1,346
2014	0.021	0.053	0.900	0.000	0.021	0.000	0.000	0.005	0.000	0.000	4,782	5,485
2015	0.013	0.444	0.206	0.000	0.336	0.000	0.000	0.000	0.000	0.000	2,842	3,849
2016	0.000	0.560	0.412	0.000	0.028	0.000	0.000	0.000	0.000	0.000	5,188	5,619
2017	0.000	0.047	0.834	0.000	0.109	0.009	0.000	0.000	0.000	0.000	2,675	3,339
Average	0.008	0.249	0.479	0.002	0.244	0.002	0.017	0.001	0.000	0.000	3,547	4,335

Note: Unadjusted escapement and age composition estimates were derived from the observed sample proportions of males and females from carcass surveys and sum to 1.0. En dashes represent missing data due to river conditions.

Table 8.–Age composition and escapement estimates of females for Chena River Chinook salmon, 1986–2017.

Females	Total Age (years)/European Age (freshwater years/ocean years)										Female	Female
	3	4	5		6		7		8		Unadjusted	Adjusted
Year	1.1	1.2	1.3	2.2	1.4	2.3	1.5	2.4	1.6	2.5	Escapement	Escapement
1986	0.000	0.000	0.131	0.000	0.546	0.000	0.311	0.005	0.000	0.005	2,447	2,301
1987	0.000	0.003	0.022	0.000	0.855	0.000	0.114	0.006	0.000	0.000	3,681	3,084
1988	0.000	0.000	0.060	0.000	0.582	0.000	0.351	0.000	0.000	0.007	2,041	1,134
1989	0.000	0.005	0.187	0.000	0.652	0.000	0.155	0.000	0.000	0.000	1,766	1,238
1990	0.000	0.008	0.194	0.000	0.733	0.000	0.066	0.000	0.000	0.000	2,674	2,034
1991	0.000	0.000	0.120	0.000	0.620	0.000	0.231	0.009	0.009	0.009	1,000	1,000
1992	0.000	0.000	0.284	0.000	0.710	0.000	0.006	0.000	0.000	0.000	2,027	1,207
1993	0.000	0.000	0.258	0.000	0.710	0.000	0.032	0.000	0.000	0.000	1,914	1,437
1994	0.000	0.000	0.182	0.000	0.771	0.004	0.043	0.000	0.000	0.000	5,435	3,848
1995	0.000	0.000	0.131	0.000	0.821	0.000	0.044	0.004	0.000	0.000	7,524	5,885
1996	0.000	0.004	0.210	0.000	0.358	0.000	0.428	0.000	0.000	0.000	3,122	1,914
1997	0.000	0.007	0.058	0.000	0.914	0.000	0.022	0.000	0.000	0.000	4,358	2,772
1998	0.000	0.000	0.532	0.000	0.383	0.000	0.085	0.000	0.000	0.000	1,902	1,346
1999	0.000	0.009	0.181	0.000	0.810	0.000	0.000	0.000	0.000	0.000	4,178	2,958
2000	0.000	0.000	0.145	0.000	0.768	0.000	0.087	0.000	0.000	0.000	1,555	1,019
2001	0.000	0.022	0.175	0.000	0.716	0.000	0.087	0.000	0.000	0.000	4,123	2,919
2002	0.000	0.000	0.137	0.000	0.802	0.000	0.061	0.000	0.000	0.000	3,052	1,904
2003	0.000	0.006	0.271	0.000	0.633	0.000	0.090	0.000	0.000	0.000	4,982	3,527
2004	0.000	0.000	0.086	0.000	0.881	0.000	0.033	0.000	0.000	0.000	5,981	4,235
2005	0.000	0.004	0.402	0.000	0.530	0.004	0.043	0.017	0.000	0.000	–	–
2006	0.000	0.000	0.289	0.000	0.705	0.000	0.006	0.000	0.000	0.000	1,330	942
2007	0.000	0.160	0.440	0.000	0.400	0.000	0.000	0.000	0.000	0.000	1,422	1,006
2008	0.000	0.000	0.438	0.000	0.438	0.000	0.125	0.000	0.000	0.000	1,312	929
2009	0.000	0.008	0.070	0.000	0.910	0.000	0.012	0.000	0.000	0.000	2,971	2,103
2010	0.000	0.000	0.480	0.000	0.480	0.000	0.040	0.000	0.000	0.000	692	490
2011	0.000	0.000	0.274	0.000	0.681	0.000	0.030	0.015	0.000	0.000	–	–
2012	0.000	0.000	0.309	0.000	0.691	0.000	0.000	0.000	0.000	0.000	1,226	868
2013	0.000	0.000	0.169	0.000	0.817	0.014	0.000	0.000	0.000	0.000	724	513
2014	0.000	0.000	0.691	0.000	0.287	0.021	0.000	0.000	0.000	0.000	2,410	1,707
2015	0.000	0.000	0.123	0.000	0.866	0.000	0.011	0.000	0.000	0.000	3,449	2,442
2016	0.000	0.024	0.619	0.000	0.321	0.012	0.024	0.000	0.000	0.000	1,477	1,046
2017	0.000	0.006	0.629	0.000	0.366	0.000	0.000	0.000	0.000	0.000	2,274	1,610
Average	0.000	0.008	0.259	0.000	0.649	0.002	0.079	0.002	0.000	0.001	2,768	1,981

Note: Unadjusted escapement and age composition estimates were derived from the observed sample proportions of males and females from carcass surveys and sum to 1.0.

Table 9.–Unadjusted age composition and escapement estimates for all Chena River Chinook salmon, 1986–2017. Escapement estimates were obtained from a counting tower (CT), sonar (S), mark–recapture projects (MR), and/or a hierarchical Bayesian model (HM).

Unadjusted[a]	Total Age (years)/European Age (freshwater years/ocean years)											
All Fish	3	4	5		6		7		8		Total	
Year	1.1	1.2	1.3	2.2	1.4	2.3	1.5	2.4	1.6	2.5	Escapement	Method
1986	0.001	0.094	0.508	0.000	0.287	0.014	0.093	0.001	0.000	0.001	9,065	MR
1987	0.000	0.029	0.130	0.000	0.754	0.004	0.080	0.004	0.000	0.000	6,404	MR
1988	0.006	0.105	0.175	0.000	0.464	0.000	0.246	0.000	0.000	0.004	3,346	MR
1989	0.003	0.042	0.295	0.007	0.545	0.003	0.104	0.000	0.000	0.000	2,730	MR
1990	0.000	0.228	0.255	0.002	0.479	0.000	0.036	0.000	0.000	0.000	5,603	MR
1991	0.000	0.086	0.372	0.000	0.410	0.000	0.124	0.003	0.003	0.003	3,172	MR
1992	0.019	0.424	0.234	0.002	0.316	0.002	0.002	0.000	0.000	0.000	5,580	MR
1993	0.005	0.294	0.412	0.000	0.278	0.000	0.011	0.000	0.000	0.000	12,241	CT
1994	0.000	0.029	0.436	0.000	0.508	0.004	0.023	0.000	0.000	0.000	11,877	CT
1995	0.000	0.044	0.208	0.000	0.709	0.000	0.034	0.004	0.000	0.000	11,394	MR
1996	0.021	0.062	0.443	0.000	0.235	0.000	0.239	0.000	0.000	0.000	7,153	MR
1997	0.003	0.372	0.134	0.000	0.480	0.000	0.010	0.001	0.000	0.000	10,810	MR
1998	0.000	0.044	0.724	0.000	0.184	0.000	0.048	0.000	0.000	0.000	4,745	CT
1999	0.000	0.045	0.249	0.000	0.706	0.000	0.000	0.000	0.000	0.000	6,485	CT
2000	0.003	0.302	0.390	0.000	0.283	0.000	0.022	0.000	0.000	0.000	4,694	MR
2001	0.006	0.096	0.336	0.000	0.512	0.000	0.050	0.000	0.000	0.000	9,696	CT
2002	0.000	0.238	0.278	0.000	0.444	0.000	0.040	0.000	0.000	0.000	6,967	MR
2003	0.000	0.051	0.465	0.000	0.416	0.000	0.068	0.000	0.000	0.000	11,100[b]	CT
2004	0.000	0.109	0.172	0.000	0.690	0.000	0.029	0.000	0.000	0.000	9,645	CT
2005	0.000	0.065	0.499	0.000	0.392	0.002	0.027	0.014	0.000	0.000	4,075	CT
2006	0.000	0.127	0.453	0.003	0.403	0.003	0.011	0.000	0.000	0.000	2,936	CT
2007	0.129	0.194	0.355	0.000	0.323	0.000	0.000	0.000	0.000	0.000	3,806	CT
2008	0.000	0.083	0.611	0.000	0.250	0.000	0.056	0.000	0.000	0.000	3,208	CT
2009	0.000	0.145	0.170	0.000	0.679	0.000	0.007	0.000	0.000	0.000	5,253	CT
2010	0.000	0.136	0.506	0.012	0.321	0.000	0.025	0.000	0.000	0.000	2,382	CT
2011	0.002	0.226	0.466	0.002	0.287	0.000	0.009	0.007	0.000	0.000	–	–
2012	0.005	0.051	0.455	0.000	0.490	0.000	0.000	0.000	0.000	0.000	2,220	CT/S
2013	0.011	0.290	0.222	0.000	0.466	0.006	0.006	0.000	0.000	0.000	1,859	CT
2014	0.014	0.035	0.831	0.000	0.109	0.007	0.000	0.004	0.000	0.000	7,192	S
2015	0.006	0.198	0.160	0.000	0.630	0.000	0.006	0.000	0.000	0.000	6,291	S/CT
2016	0.000	0.438	0.459	0.000	0.095	0.003	0.005	0.000	0.000	0.000	6,665	S/HM
2017	0.000	0.028	0.741	0.000	0.225	0.005	0.000	0.000	0.000	0.000	5,235	S/CT
Average	0.004	0.147	0.378	0.001	0.421	0.002	0.046	0.001	0.000	0.000	6,316	

Note: En dashes indicate that there was no estimate of escapement collected that year and no methodology used.

[a] Unadjusted escapement and age composition estimates were derived from the observed sample proportions of males and females from carcass surveys and sum to 1.0.

[b] Estimate includes an expansion for missed counting days. Minimum documented abundance with large gaps in counts due to flooding was 8,739 (SE = 653) fish.

Table 10.–Adjusted age composition and escapement estimates for all Chena River Chinook salmon, 1986–2017. Escapement estimates were obtained from a counting tower (CT), sonar (S), mark–recapture projects (MR), and/or a hierarchical Bayesian model (HM).

Adjusted	Total Age (years)/European Age (freshwater years/ocean years)											
All Fish	3	4	5		6		7		8		Total	
Year	1.1	1.2	1.3	2.2	1.4	2.3	1.5	2.4	1.6	2.5	Escapement	Method
1986	0.001	0.094	0.508	0.000	0.287	0.014	0.093	0.001	0.000	0.001	9,065	MR
1987	0.000	0.029	0.130	0.000	0.754	0.004	0.080	0.004	0.000	0.000	6,404	MR
1988	0.006	0.105	0.175	0.000	0.464	0.000	0.246	0.000	0.000	0.004	3,346	MR
1989	0.003	0.042	0.295	0.007	0.545	0.003	0.104	0.000	0.000	0.000	2,730	MR
1990	0.000	0.228	0.255	0.002	0.479	0.000	0.036	0.000	0.000	0.000	5,603	MR
1991	0.000	0.086	0.372	0.000	0.410	0.000	0.124	0.003	0.003	0.003	3,172	MR
1992	0.019	0.424	0.234	0.002	0.316	0.002	0.002	0.000	0.000	0.000	5,580	MR
1993	0.005	0.294	0.412	0.000	0.278	0.000	0.011	0.000	0.000	0.000	12,241	CT
1994	0.000	0.029	0.436	0.000	0.508	0.004	0.023	0.000	0.000	0.000	11,877	CT
1995	0.000	0.044	0.208	0.000	0.709	0.000	0.034	0.004	0.000	0.000	11,394	MR
1996	0.021	0.062	0.443	0.000	0.235	0.000	0.239	0.000	0.000	0.000	7,153	MR
1997	0.003	0.372	0.134	0.000	0.480	0.000	0.010	0.001	0.000	0.000	10,810	MR
1998	0.000	0.044	0.724	0.000	0.184	0.000	0.048	0.000	0.000	0.000	4,745	CT
1999	0.000	0.045	0.249	0.000	0.706	0.000	0.000	0.000	0.000	0.000	6,485	CT
2000	0.003	0.302	0.390	0.000	0.283	0.000	0.022	0.000	0.000	0.000	4,694	MR
2001	0.006	0.096	0.336	0.000	0.512	0.000	0.050	0.000	0.000	0.000	9,696	CT
2002	0.000	0.238	0.278	0.000	0.444	0.000	0.040	0.000	0.000	0.000	6,967	MR
2003	0.000	0.051	0.465	0.000	0.416	0.000	0.068	0.000	0.000	0.000	11,100[a]	CT
2004	0.000	0.109	0.172	0.000	0.690	0.000	0.029	0.000	0.000	0.000	9,645	CT
2005	0.000	0.065	0.499	0.000	0.392	0.002	0.027	0.014	0.000	0.000	4,075	CT
2006	0.000	0.127	0.453	0.003	0.403	0.003	0.011	0.000	0.000	0.000	2,936	CT
2007	0.129	0.194	0.355	0.000	0.323	0.000	0.000	0.000	0.000	0.000	3,806	CT
2008	0.000	0.083	0.611	0.000	0.250	0.000	0.056	0.000	0.000	0.000	3,208	CT
2009	0.000	0.145	0.170	0.000	0.679	0.000	0.007	0.000	0.000	0.000	5,253	CT
2010	0.000	0.136	0.506	0.012	0.321	0.000	0.025	0.000	0.000	0.000	2,382	CT
2011	0.002	0.226	0.466	0.002	0.287	0.000	0.009	0.007	0.000	0.000	–	–
2012	0.005	0.051	0.455	0.000	0.490	0.000	0.000	0.000	0.000	0.000	2,220	CT/S
2013	0.011	0.290	0.222	0.000	0.466	0.006	0.006	0.000	0.000	0.000	1,859	CT
2014	0.014	0.035	0.831	0.000	0.109	0.007	0.000	0.004	0.000	0.000	7,192	S
2015	0.006	0.198	0.160	0.000	0.630	0.000	0.006	0.000	0.000	0.000	6,291	S/CT
2016	0.000	0.438	0.459	0.000	0.095	0.003	0.005	0.000	0.000	0.000	6,665	S/HM
2017	0.000	0.034	0.767	0.000	0.193	0.006	0.000	0.000	0.000	0.000	5,235	S/CT
Average	0.006	0.181	0.405	0.001	0.368	0.002	0.036	0.001	0.000	0.000	6,316	

Note: En dashes indicate that there was no estimate of escapement collected that year and no methodology used.

[a] Estimate includes an expansion for missed counting days. Minimum documented abundance with large gaps in counts due to flooding was 8,739 (SE = 653) fish.

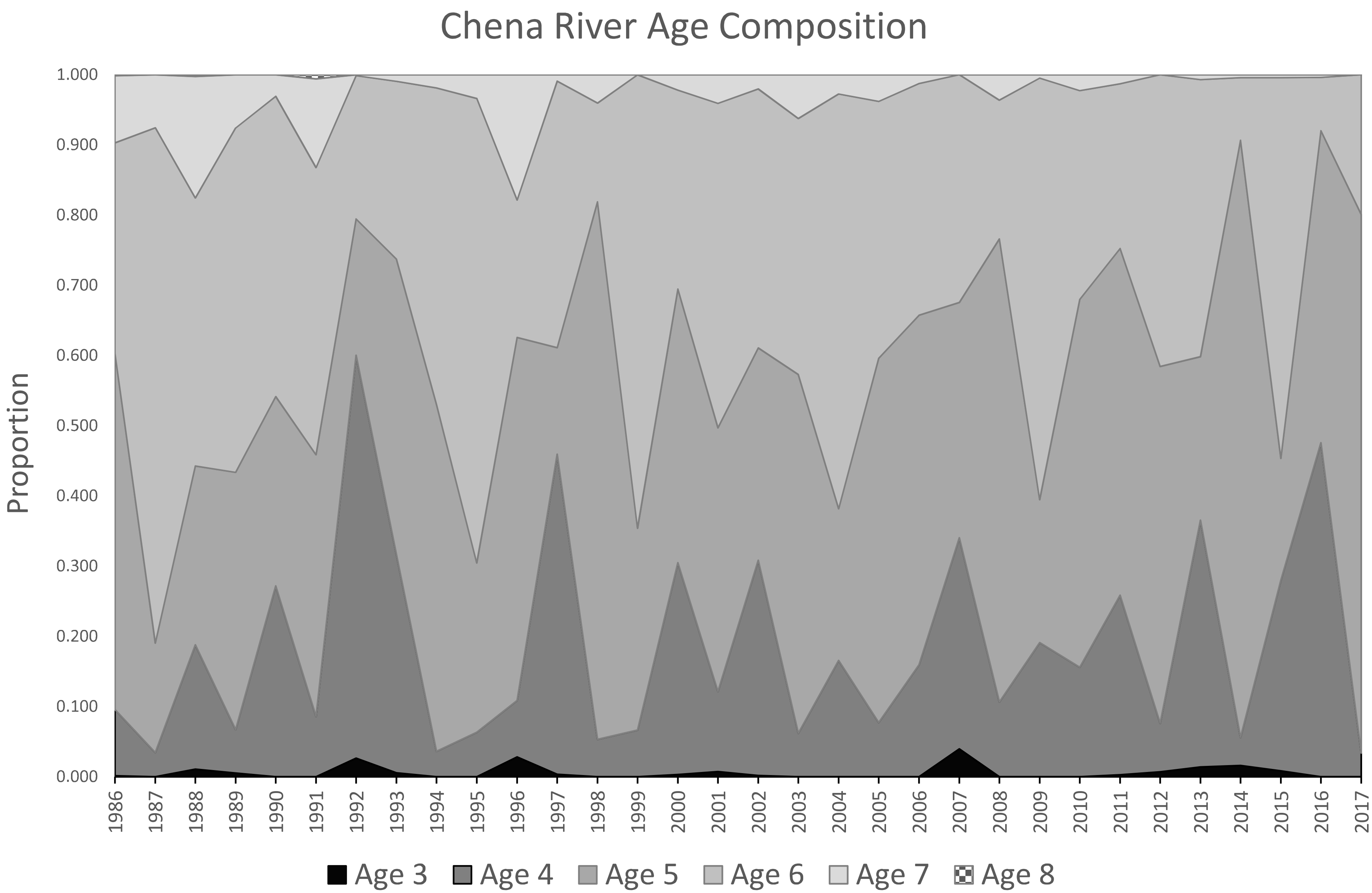

Figure 9.–Age proportions by year for Chinook Salmon sampled on the Chena River, 1986–2017.

Chum salmon were also sampled for sex and length data to inform the mixture model used to apportion sonar targets by species. A total of 173 chum salmon were collected of which 79 were males and 94 were females. Chum salmon lengths averaged 573 mm (SE = 15) for males and 546 mm (SE = 8) for females.

SALCHA RIVER

In 2017, the Salcha River counting tower operated from 26 June–3 July, 6 July–11 July, 14 July–25 July and from 29 July through 4 August when operations ceased for the season. High, muddy water obscured the flash panels during the missing operation days. The estimated escapement of Chinook salmon on the Salcha River was based primarily on visual data (79%) and interpolation based on the methods protocol (21%; Figure 10). The Chinook salmon escapement was estimated to be 4,195 (SE = 205), which falls within the established BEG range (Figure 4). The estimated chum salmon escapement was 29,093 (SE = 1,220) and was considered a minimum estimate because counts were terminated before the chum run was complete (Table 11).

Unlike the Chena River, the 2017 Salcha River midpoint of the run was not similar to the historic or recent 5-year average. The historical and recent 5-year average midpoint of the run was day 17 and day 13, respectively. The 2017 midpoint was day 22, which was 5 days later than the historical average and 9 days later than the 5-year average (Figure 11). By calendar day, Chinook salmon run timing was well within historical ranges (Figure 12).

Similar to the Chena River, salmon carcass surveys were conducted between 1 August and 10 August. Carcass crews were able to collect samples from 504 Chinook salmon carcasses of which 471 were aged. The sex composition of aged samples was 0.59 (SE = 0.02) male and 0.41 (SE = 0.02) female. The sex composition when adjusted for sex ratio bias was 0.65 (SE = 0.07) male and 0.35 (SE = 0.07) female (Table 12, Figure 13). The mean length for males was 705 mm (SE = 5) and for females was 781 mm (SE = 4, Table 13). For males, the dominant age class was 1.3, which was 49% of the total sample (Tables 13 and 14). For females, the dominant age class was also 1.3, which was 23% of the sample (Tables 13 and 15). Unadjusted and adjusted age compositions for all Chinook salmon sampled were also calculated (Tables 16 and 17, respectively, and Figure 14).

Chum salmon were also sampled for sex and length data to add to the mixture model used to apportion sonar targets by species. Of the 223 chum salmon that were collected, 99 were male and 124 were female. Average chum salmon lengths were 574 mm (SE = 7) for males and 548 mm (SE = 5) for females.

DELTA CLEARWATER RIVER COHO SALMON

In 2017, 9,767 coho salmon were counted on the Delta Clearwater River on November 1 (Table 18).

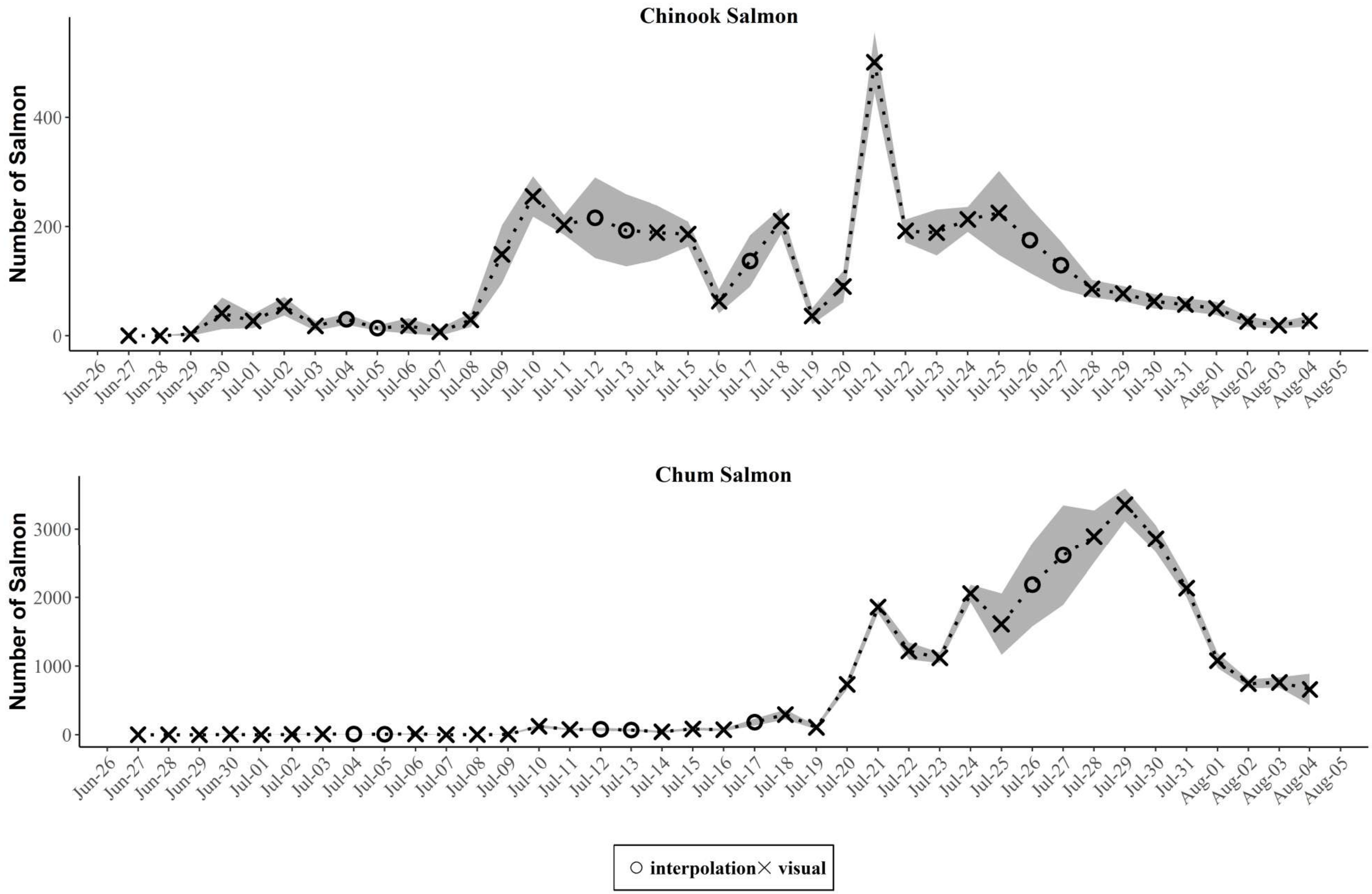

Figure 10.–Daily estimates of Salcha River Chinook and chum salmon abundance by visual counts and interpolation with associated SE (shaded areas), 2017.

Table 11.–Daily estimates of Salcha River Chinook and chum salmon escapement, 2017. Shaded cells denote days where counts were interpolated using moving averages. All non-shaded cells are from visual counts.

	Chinook salmon		Chum salmon	
Date	Daily escapement	Daily SE	Daily escapement	Daily SE
27 June	0	0	0	0
28 June	0	0	0	0
29 June	3	3	0	0
30 June	41	29	5	4
1 Jul	27	13	0	0
2 Jul	54	17	6	5
3 Jul	18	9	9	4
4 Jul	30	10	9	2
5 Jul	14	5	7	2
6 Jul	18	14	12	9
7 Jul	7	7	0	0
8 Jul	29	13	3	2
9 Jul	149	53	6	3
10 Jul	255	37	123	23
11 Jul	203	18	77	12
12 Jul	216	74	81	22
13 Jul	193	66	68	19
14 Jul	189	50	43	16
15 Jul	186	23	85	19
16 Jul	63	22	72	20
17 Jul	137	47	183	51
18 Jul	210	24	294	72
19 Jul	36	15	108	27
20 Jul	90	29	735	72
21 Jul	501	55	1,860	87
22 Jul	192	21	1,221	124
23 Jul	189	42	1,121	77
24 Jul	213	23	2,058	127
25 Jul	225	77	1,611	447
26 Jul	175	60	2,187	607
27 Jul	129	44	2,620	727
28 Jul	86	16	2,892	381
29 Jul	77	14	3,356	239
30 Jul	63	13	2,859	195
31 Jul	57	12	2,136	132
1 Aug	50	12	1,080	109
2 Aug	26	10	744	65
3 Aug	19	6	762	76
4 Aug	27	10	662	229
Total	4,195		29,093	

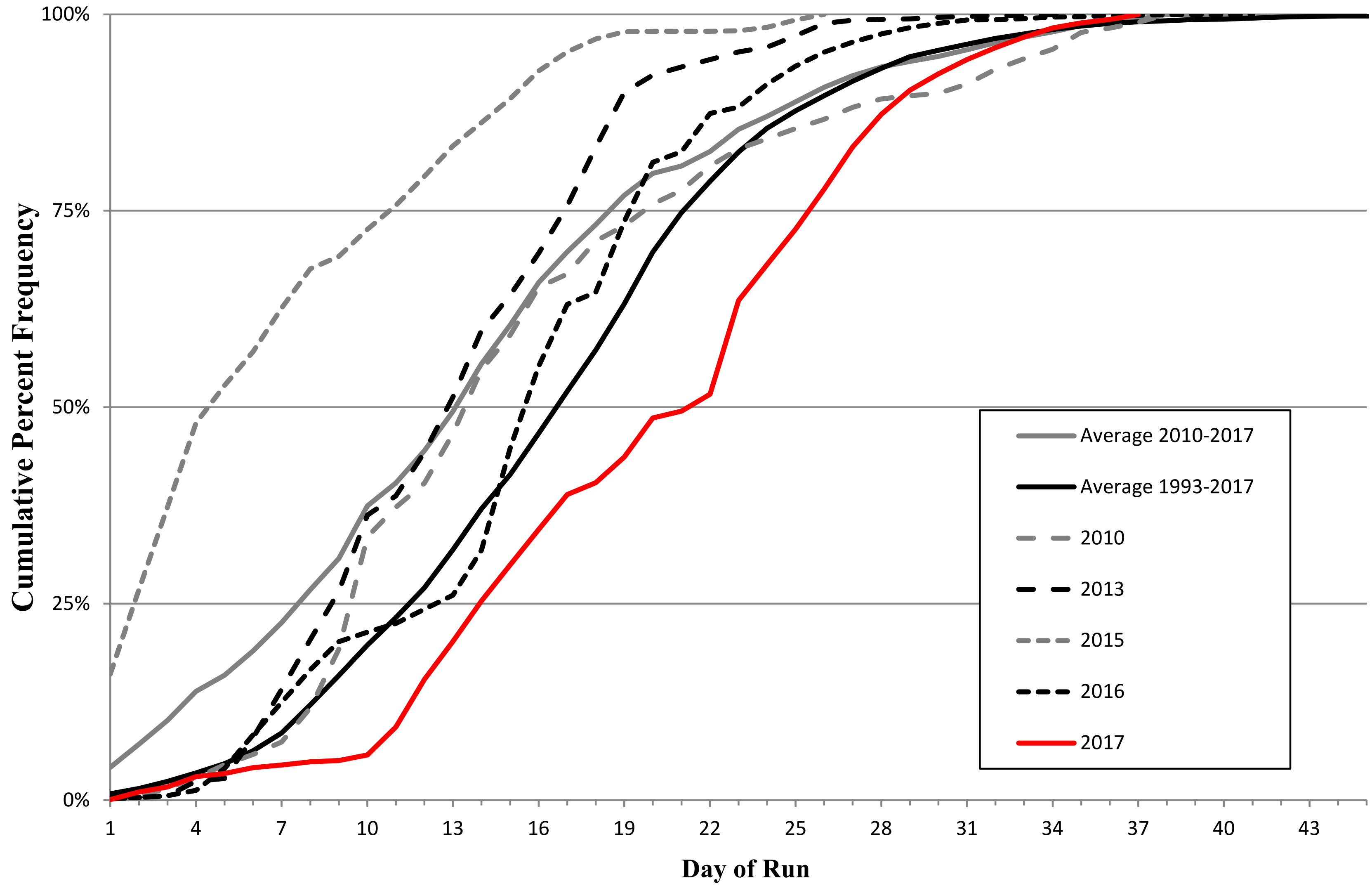

Figure 11.–Average run-timing patterns for Salcha River Chinook salmon past the counting tower by the first day of run over all years (1993–1995, 1997–1999, 2004–2007, 2009–2010, 2012–2013, and 2015–2017), a recent 5 year average (2010, 2013, 2015–2017), and compared to 2010, 2013, and 2015–2017. Included are years when visual and/or visual and sonar combination counts composed a complete estimate of abundance.

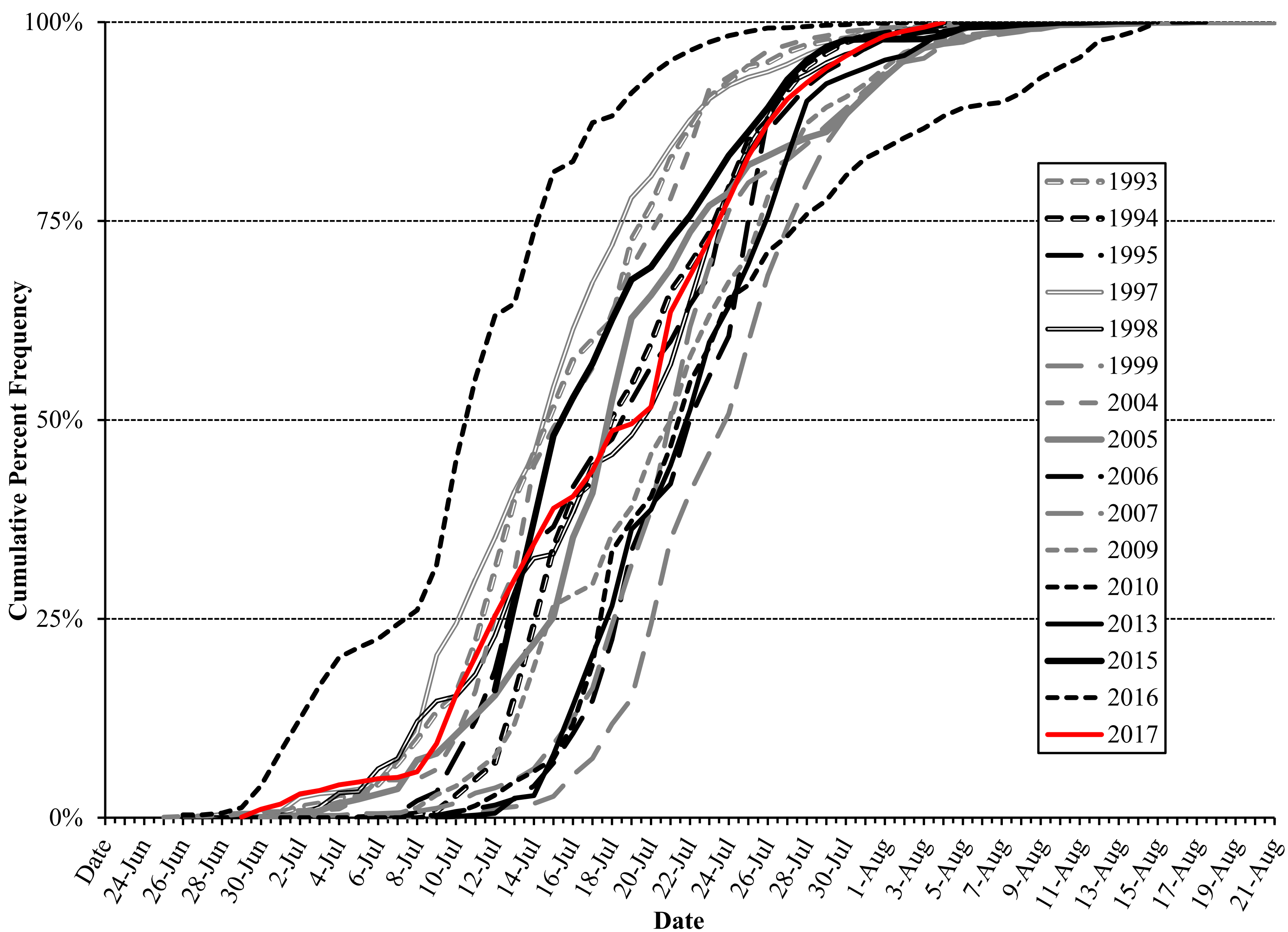

Figure 12.–Cumulative passage of Salcha River Chinook salmon for the years when visual or visual/sonar combination counts composed a complete estimate of abundance.

Table 12.–Estimated proportions of male and female Chinook salmon sampled from carcass surveys on the Salcha River, 1987–2017.

	Sexed Sample Size		Sexed Sample Proportion		Sexed and Aged Sample Size		Sexed and Aged Sample Proportion		Adjusted Sample Proportion[a]		Total	
Year	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Escapement	Method[b]
1987	315	536	0.37	0.63	204	345	0.37	0.63	0.48	0.52	4,771	MR
1988	448	423	0.51	0.49	300	197	0.6	0.4	0.55	0.45	4,322	MR
1989	139	171	0.45	0.55	84	137	0.38	0.62	0.56	0.44	3,294	MR
1990	716	601	0.54	0.46	261	265	0.5	0.5	0.64	0.36	10,728	MR
1991	388	318	0.55	0.45	272	241	0.53	0.47	0.59	0.41	5,608	MR
1992	606	343	0.64	0.36	429	220	0.66	0.34	0.64	0.36	7,862	MR
1993	418	150	0.74	0.26	328	125	0.72	0.28	0.76	0.24	10,007	CT
1994	330	288	0.53	0.47	287	233	0.55	0.45	0.61	0.39	18,399	CT
1995	290	368	0.44	0.56	240	305	0.44	0.56	0.51	0.49	13,643	CT
1996	235	236	0.5	0.5	203	210	0.49	0.51	0.74	0.26	7,570	MR
1997	113	105	0.52	0.48	90	90	0.5	0.5	0.57	0.43	18,514	CT
1998	104	44	0.7	0.3	86	37	0.7	0.3	0.74	0.26	5,027	CT
1999	175	185	0.49	0.51	139	168	0.45	0.55	0.53	0.47	9,198	CT
2000	29	19	0.6	0.4	23	18	0.56	0.44	0.62	0.38s	4,595	CT
2001	194	114	0.63	0.37	120	72	0.63	0.38	0.67	0.33	13,328	CT
2002	212	111	0.66	0.34	184	98	0.65	0.35	0.7	0.3	9,000	CT
2003	96	70	0.58	0.42	87	57	0.6	0.4	0.66	0.34	15,500	CT
2004	90	150	0.38	0.63	85	144	0.37	0.63	0.45	0.55	15,761	CT
2005	295	357	0.45	0.55	275	327	0.46	0.54	0.53	0.47	5,988	CT
2006	318	249	0.56	0.44	288	221	0.57	0.43	0.62	0.38	10,679	CT
2007	198	110	0.64	0.36	198	110	0.64	0.36	0.69	0.31	6,425	CT
2008	215	137	0.61	0.39	184	119	0.61	0.39	0.66	0.34	5,415	CT
2009	311	200	0.61	0.39	279	179	0.61	0.39	0.66	0.34	12,774	CT
2010	318	141	0.69	0.31	287	125	0.7	0.3	0.73	0.27	6,135	CT
2011	349	251	0.58	0.42	305	222	0.58	0.42	0.64	0.36	7,200	CT
2012	208	296	0.41	0.59	169	251	0.4	0.6	0.49	0.51	7,165	CT
2013	99	101	0.5	0.51	89	90	0.5	0.5	0.56	0.44	5,465	CT
2014[c]	274	129	0.68	0.32	309	142	0.69	0.31	No value	No value	No value	CT
2015	307	226	0.58	0.42	266	201	0.57	0.43	0.63	0.37	6,287	CT
2016	313	190	0.62	0.38	290	184	0.61	0.39	0.67	0.33	2,675	S/CT/HM
2017	299	205	0.59	0.41	277	194	0.59	0.41	0.65	0.35	4,195	CT
Average	271	220	0.56	0.44	214	172	0.56	0.44	0.62	0.38	8,584	

[a] In years when mark–recapture experiments (MR) were conducted (1986–1992, 1995–1997, 2000, and 2002), males were more likely to be sampled during the first event (electroshocking), and overall, less bias in estimating size and sex was noted from electroshocking than sampling carcasses (second event). As a result, an adjustment factor has been applied to the carcass samples, which have been the primary means of obtaining age, sex, and length since 2003.

[b] Escapement estimates were obtained from either a counting tower (CT) assessment, sonar images (S), mark–recapture (MR) experiment, or a Bayesian hierarchical model (HM).

[c] No estimate due to flooding.

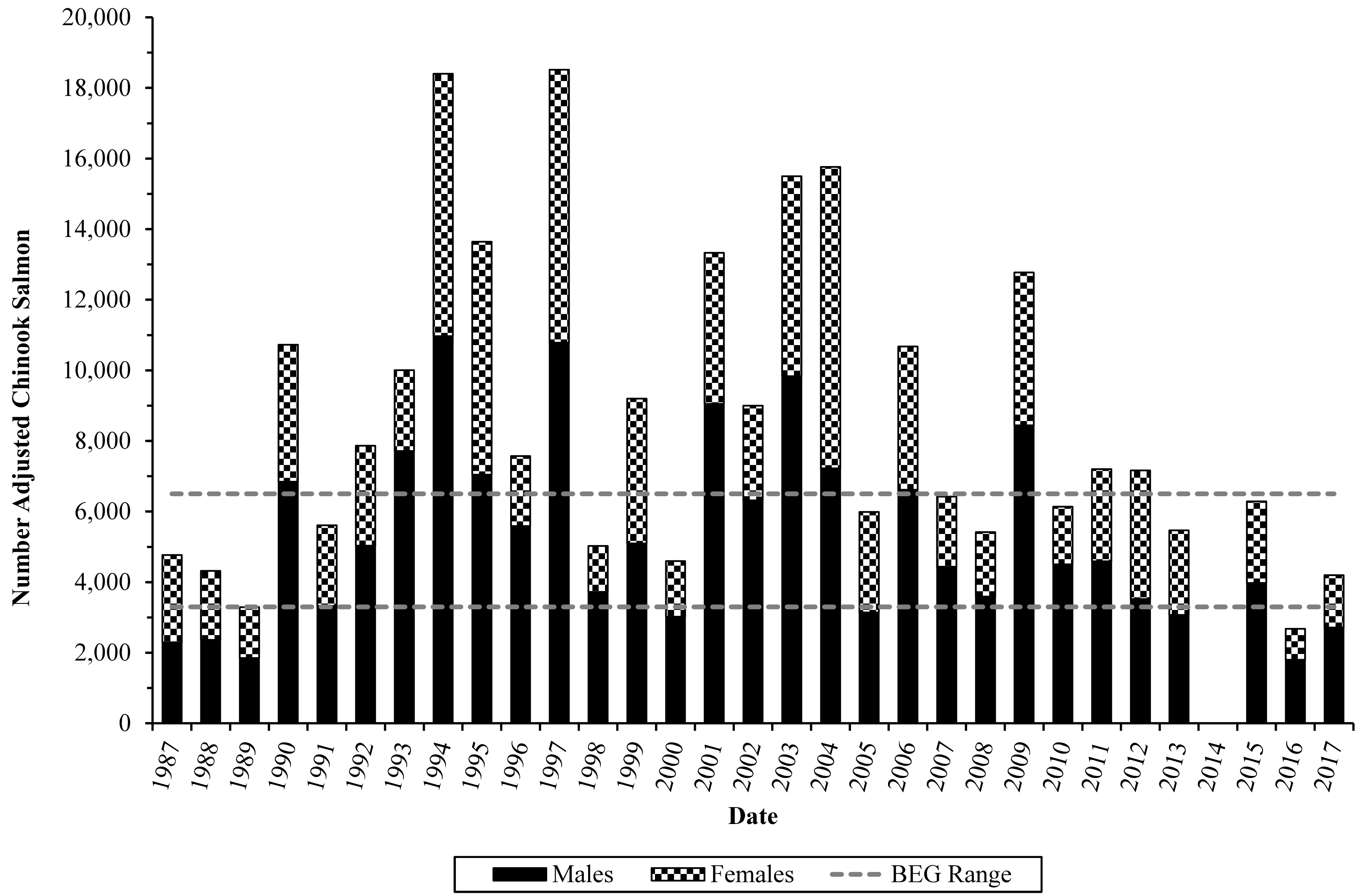

Figure 13.–Estimates of Chinook salmon adjusted sex composition and yearly escapements to the Salcha River with the respective BEG range, 1986–2017.

Table 13.–Estimated proportions and mean length by age and sex of Chinook salmon sampled during the Salcha River carcass survey, 2017.

	Sample	Sample	Length (mm)			
Age[a]	size	proportion	Mean	SE	Min	Max
Males						
1.2	26	0.06	554	9	475	645
1.3	230	0.49	717	4	430	850
2.2	1	<0.01	585	–	–	–
1.4	20	0.04	772	18	615	905
Total aged males	277	0.59	705	5	430	905
Total males[b]	299	0.59	705	5	430	905
Adjusted total[c]		0.65				
Females						
1.3	109	0.23	758	4	645	855
1.4	84	0.18	810	5	690	910
2.3	1	<0.01	775	–	–	–
Total aged females	194	0.41	781	4	645	910
Total females[b]	205	0.41	782	4	645	910
Adjusted total[c]		0.35				
Total						
Total Aged	471		753	4	430	935
Total Collected	504		753	4	430	935

Note: En dashes (–) mean value could not be calculated.

[a] Age is represented by the number of annuli formed during river residence and ocean residence (e.g., an age of 1.4 represents 1 annulus formed during river residence and 4 annuli formed during ocean residence plus 1 year for year of spawning for a total age of 6 years).

[b] Totals include those Chinook salmon that could not be aged.

[c] Estimated proportion of females after applying a correction factor of 0.867. Adjusted values presented in Table 12.

Table 14.–Age composition and escapement estimates for Salcha River Chinook salmon males, 1987–2017.

Males	Total Age (years)/European Age (freshwater years/ocean years)										Male	Male
	3	4	5		6		7		8		Unadjusted[a]	Adjusted[b]
Year	1.1	1.2	1.3	2.2	1.4	2.3	1.5	2.4	1.6	2.5	Escapement	Escapement
1987	0.005	0.152	0.275	0.000	0.544	0.000	0.025	0.000	0.000	0.000	1,766	2,290
1988	0.007	0.333	0.330	0.000	0.243	0.000	0.083	0.003	0.000	0.000	2,223	2,363
1989	0.012	0.107	0.548	0.000	0.333	0.000	0.000	0.000	0.000	0.000	1,477	1,853
1990	0.004	0.333	0.352	0.000	0.268	0.000	0.042	0.000	0.000	0.000	5,832	6,845
1991	0.004	0.143	0.489	0.000	0.309	0.000	0.051	0.000	0.004	0.000	3,082	3,325
1992	0.019	0.543	0.338	0.007	0.084	0.005	0.005	0.000	0.000	0.000	5,020	5,031
1993	0.012	0.384	0.454	0.000	0.146	0.003	0.000	0.000	0.000	0.000	7,364	7,613
1994	0.010	0.035	0.561	0.000	0.366	0.000	0.028	0.000	0.000	0.000	9,825	11,251
1995	0.000	0.296	0.292	0.000	0.388	0.000	0.021	0.004	0.000	0.000	6,013	7,023
1996	0.054	0.118	0.567	0.000	0.177	0.000	0.084	0.000	0.000	0.000	3,777	5,588
1997	0.000	0.256	0.244	0.000	0.489	0.000	0.011	0.000	0.000	0.000	9,597	10,488
1998	0.035	0.070	0.756	0.000	0.128	0.000	0.012	0.000	0.000	0.000	3,532	3,716
1999	0.000	0.201	0.374	0.000	0.424	0.000	0.000	0.000	0.000	0.000	4,471	4,834
2000	0.000	0.304	0.565	0.000	0.130	0.000	0.000	0.000	0.000	0.000	2,776	2,846
2001	0.008	0.167	0.425	0.000	0.400	0.000	0.000	0.000	0.000	0.000	8,395	8,995
2002	0.000	0.554	0.190	0.000	0.179	0.000	0.076	0.000	0.000	0.000	5,907	6,288
2003	0.011	0.126	0.598	0.000	0.241	0.000	0.023	0.000	0.000	0.000	8,964	10,181
2004	0.000	0.247	0.176	0.000	0.576	0.000	0.000	0.000	0.000	0.000	5,910	7,168
2005	0.000	0.204	0.516	0.000	0.265	0.000	0.011	0.004	0.000	0.000	2,709	3,168
2006	0.000	0.101	0.715	0.000	0.174	0.000	0.010	0.000	0.000	0.000	5,989	6,659
2007	0.000	0.343	0.364	0.000	0.293	0.000	0.000	0.000	0.000	0.000	4,130	4,436
2008	0.011	0.163	0.658	0.000	0.168	0.000	0.000	0.000	0.000	0.000	3,307	3,571
2009	0.000	0.520	0.315	0.000	0.165	0.000	0.000	0.000	0.000	0.000	7,774	8,446
2010	0.007	0.352	0.571	0.007	0.052	0.010	0.000	0.000	0.000	0.000	4,250	4,501
2011	0.003	0.252	0.574	0.000	0.157	0.010	0.003	0.000	0.000	0.000	4,188	4,589
2012	0.006	0.148	0.509	0.000	0.337	0.000	0.000	0.000	0.000	0.000	2,957	3,517
2013	0.022	0.225	0.202	0.000	0.539	0.000	0.011	0.000	0.000	0.000	2,705	3,072
2014[c]	0.022	0.215	0.701	0.004	0.055	0.000	0.004	0.000	0.000	0.000	–[c]	–[c]
2015	0.011	0.402	0.391	0.008	0.180	0.008	0.000	0.000	0.000	0.000	3,621	3,976
2016	0.000	0.597	0.383	0.000	0.021	0.000	0.000	0.000	0.000	0.000	1,664	1,799
2017	0.000	0.094	0.830	0.004	0.072	0.000	0.000	0.000	0.000	0.000	2,489	2,716
Average	0.009	0.258	0.460	0.001	0.255	0.001	0.016	0.000	0.000	0.000	4,758	5,323

[a] Unadjusted escapement and composition estimates were derived from the observed sample proportions of males and females from carcass surveys and sum to 1.0.

[b] In years when mark–recapture experiments (MR) were conducted, males were more likely to be sampled during the first event (electroshocking) and, overall, less bias in estimating size and sex was noted from electroshocking than sampling carcasses (second event). As a result, an adjustment factor has been applied to the carcass samples, which have been the primary means of obtaining ASL since 1997.

[c] Extensive flooding prevented operation of counting tower.

Table 15.–Age composition and escapement estimates for Salcha River Chinook salmon females, 1987–2017.

Females	Total Age (years)/European Age (freshwater years/ocean years)										Female Unadjusted[a] Escapement	Female Adjusted[b] Escapement
	3	4	5		6		7		8			
Year	1.1	1.2	1.3	2.2	1.4	2.3	1.5	2.4	1.6	2.5		
1987	0.000	0.003	0.038	0.000	0.849	0.000	0.110	0.000	0.000	0.000	3,005	2,481
1988	0.000	0.005	0.066	0.000	0.690	0.000	0.239	0.000	0.000	0.000	2,099	1,959
1989	0.000	0.000	0.131	0.000	0.730	0.000	0.139	0.000	0.000	0.000	1,817	1,441
1990	0.000	0.008	0.147	0.000	0.713	0.000	0.132	0.000	0.000	0.000	4,896	3,883
1991	0.000	0.000	0.133	0.000	0.680	0.000	0.183	0.000	0.004	0.000	2,526	2,283
1992	0.000	0.005	0.327	0.000	0.650	0.000	0.014	0.005	0.000	0.000	2,842	2,831
1993	0.000	0.008	0.224	0.000	0.736	0.000	0.032	0.000	0.000	0.000	2,643	2,394
1994	0.000	0.017	0.185	0.000	0.721	0.004	0.073	0.000	0.000	0.000	8,574	7,148
1995	0.000	0.010	0.138	0.000	0.816	0.000	0.030	0.007	0.000	0.000	7,630	6,620
1996	0.000	0.005	0.205	0.000	0.390	0.000	0.400	0.000	0.000	0.000	3,793	1,982
1997	0.000	0.033	0.044	0.000	0.900	0.000	0.022	0.000	0.000	0.000	8,917	8,026
1998	0.000	0.000	0.649	0.000	0.297	0.000	0.054	0.000	0.000	0.000	1,495	1,311
1999	0.000	0.000	0.131	0.000	0.863	0.000	0.006	0.000	0.000	0.000	4,727	4,364
2000	0.000	0.111	0.389	0.000	0.389	0.000	0.111	0.000	0.000	0.000	1,819	1,749
2001	0.000	0.000	0.194	0.000	0.722	0.000	0.083	0.000	0.000	0.000	4,933	4,333
2002	0.000	0.000	0.041	0.000	0.776	0.000	0.184	0.000	0.000	0.000	3,093	2,712
2003	0.000	0.000	0.211	0.000	0.754	0.000	0.035	0.000	0.000	0.000	6,536	5,319
2004	0.000	0.000	0.028	0.000	0.958	0.000	0.014	0.000	0.000	0.000	9,851	8,593
2005	0.000	0.000	0.330	0.000	0.627	0.000	0.043	0.000	0.000	0.000	3,279	2,820
2006	0.000	0.000	0.204	0.000	0.760	0.005	0.032	0.000	0.000	0.000	4,690	4,020
2007	0.000	0.009	0.100	0.000	0.882	0.000	0.009	0.000	0.000	0.000	2,295	1,989
2008	0.000	0.000	0.303	0.000	0.655	0.000	0.042	0.000	0.000	0.000	2,108	1,844
2009	0.000	0.000	0.056	0.000	0.939	0.000	0.006	0.000	0.000	0.000	5,000	4,328
2010	0.000	0.032	0.584	0.000	0.344	0.000	0.016	0.024	0.000	0.000	1,885	1,634
2011	0.000	0.000	0.054	0.000	0.914	0.000	0.032	0.000	0.000	0.000	3,012	2,611
2012	0.000	0.000	0.207	0.000	0.765	0.000	0.028	0.000	0.000	0.000	4,208	3,648
2013	0.000	0.000	0.111	0.000	0.844	0.000	0.044	0.000	0.000	0.000	2,760	2,393
2014[c]	0.000	0.000	0.372	0.000	0.589	0.000	0.039	0.000	0.000	0.000	–[c]	–[c]
2015	0.000	0.000	0.299	0.000	0.701	0.000	0.000	0.000	0.000	0.000	2,666	2,311
2016	0.000	0.152	0.446	0.000	0.397	0.000	0.005	0.000	0.000	0.000	1,010	876
2017	0.000	0.000	0.562	0.000	0.433	0.005	0.000	0.000	0.000	0.000	1,706	1,479
Average	0.000	0.013	0.223	0.000	0.693	0.000	0.070	0.001	0.000	0.000	3,859	3,239

[a] Unadjusted escapement and composition estimates were derived from the observed sample proportions of males and females from carcass surveys and sum to 1.0.

[b] In years when mark–recapture experiments (MR) were conducted, males were more likely to be sampled during the first event (electroshocking) and, overall, less bias in estimating size and sex was noted from electroshocking than sampling carcasses (second event). As a result, an adjustment factor has been applied to the carcass samples, which have been the primary means of obtaining ASL since 1997.

[c] Extensive flooding prevented operation of counting tower.

Table 16.–Unadjusted age composition and escapement estimates for all fish of Salcha River Chinook salmon, 1986–2017. Escapement estimates were obtained from a counting tower (CT), sonar (S), mark–recapture projects (MR), and/or a hierarchical Bayesian model (HM).

Unadjusted[a]	Total Age (years)/European Age (freshwater years/ocean years)											
All Fish	3	4	5		6		7		8		Total	
Year	1.1	1.2	1.3	2.2	1.4	2.3	1.5	2.4	1.6	2.5	Escapement	Method
1987	0.002	0.058	0.126	0.000	0.736	0.000	0.078	0.000	0.000	0.000	4,771	MR
1988	0.004	0.203	0.225	0.000	0.421	0.000	0.145	0.002	0.000	0.000	4,322	MR
1989	0.005	0.041	0.290	0.000	0.579	0.000	0.086	0.000	0.000	0.000	3,294	MR
1990	0.002	0.169	0.249	0.000	0.492	0.000	0.087	0.000	0.000	0.000	10,728	MR
1991	0.002	0.076	0.322	0.000	0.483	0.000	0.113	0.000	0.004	0.000	5,608	MR
1992	0.012	0.361	0.334	0.005	0.276	0.003	0.008	0.002	0.000	0.000	7,862	MR
1993	0.009	0.280	0.391	0.000	0.309	0.002	0.009	0.000	0.000	0.000	10,007	CT
1994	0.006	0.027	0.392	0.000	0.525	0.002	0.048	0.000	0.000	0.000	18,399	CT
1995	0.000	0.136	0.206	0.000	0.628	0.000	0.026	0.006	0.000	0.000	13,643	MR
1996	0.027	0.061	0.383	0.000	0.286	0.000	0.245	0.000	0.000	0.000	7,570	MR
1997	0.000	0.144	0.144	0.000	0.694	0.000	0.017	0.000	0.000	0.000	18,514	MR
1998	0.024	0.049	0.724	0.000	0.179	0.000	0.024	0.000	0.000	0.000	5,027	CT
1999	0.000	0.091	0.241	0.000	0.664	0.000	0.003	0.000	0.000	0.000	9,198	CT
2000	0.000	0.220	0.488	0.000	0.244	0.000	0.049	0.000	0.000	0.000	4,595	MR
2001	0.005	0.104	0.339	0.000	0.521	0.000	0.031	0.000	0.000	0.000	13,328	CT
2002	0.000	0.362	0.138	0.000	0.387	0.000	0.113	0.000	0.000	0.000	9,000	MR
2003	0.007	0.076	0.444	0.000	0.444	0.000	0.028	0.000	0.000	0.000	15,500	CT
2004	0.000	0.092	0.083	0.000	0.817	0.000	0.009	0.000	0.000	0.000	15,761	CT
2005	0.000	0.093	0.415	0.000	0.462	0.000	0.028	0.002	0.000	0.000	5,988	CT
2006	0.000	0.057	0.493	0.000	0.428	0.002	0.020	0.000	0.000	0.000	10,679	CT
2007	0.000	0.224	0.269	0.000	0.503	0.000	0.003	0.000	0.000	0.000	6,425	CT
2008	0.007	0.099	0.518	0.000	0.360	0.000	0.017	0.000	0.000	0.000	5,415	CT
2009	0.000	0.317	0.214	0.000	0.467	0.000	0.002	0.000	0.000	0.000	12,774	CT
2010	0.005	0.255	0.575	0.005	0.141	0.007	0.005	0.007	0.000	0.000	6,135	CT
2011	0.002	0.146	0.355	0.000	0.476	0.006	0.015	0.000	0.000	0.000	7,200	CT
2012	0.002	0.060	0.329	0.000	0.593	0.000	0.017	0.000	0.000	0.000	7,165	CT/S
2013	0.011	0.112	0.156	0.000	0.693	0.000	0.028	0.000	0.000	0.000	5,465	CT
2014	0.015	0.146	0.596	0.002	0.226	0.000	0.015	0.000	0.000	0.000	–[b]	–[b]
2015	0.006	0.235	0.342	0.006	0.406	0.004	0.000	0.000	0.000	0.000	6,879	S/CT
2016	0.000	0.424	0.407	0.000	0.167	0.000	0.002	0.000	0.000	0.000	2,675	S/HM
2017	0.000	0.055	0.720	0.002	0.221	0.002	0.000	0.000	0.000	0.000	4,195	CT
Average	0.005	0.154	0.352	0.001	0.446	0.001	0.041	0.001	0.000	0.000	8,604	

[a] Unadjusted escapement and composition estimates were derived from the observed sample proportions of males and females from carcass surveys and sum to 1.0.

[b] Extensive flooding prevented operation of counting tower.

Table 17.–Adjusted age composition and escapement estimates for all fish of Salcha River Chinook salmon, 1986–2017. Escapement estimates were obtained from a counting tower (CT), sonar (S), mark–recapture projects (MR), and/or a hierarchical Bayesian model (HM).

Adjusted	Total Age (years)/European Age (freshwater years/ocean years)											
All Fish	3	4	5		6		7		8		Total	
Year	1.1	1.2	1.3	2.2	1.4	2.3	1.5	2.4	1.6	2.5	Escapement	Method
1987	0.002	0.074	0.151	0.000	0.703	0.000	0.069	0.000	0.000	0.000	4,771	MR
1988	0.004	0.185	0.210	0.000	0.446	0.000	0.154	0.002	0.000	0.000	4,322	MR
1989	0.007	0.060	0.366	0.000	0.507	0.000	0.061	0.000	0.000	0.000	3,294	MR
1990	0.002	0.215	0.278	0.000	0.429	0.000	0.075	0.000	0.000	0.000	10,728	MR
1991	0.002	0.085	0.344	0.000	0.460	0.000	0.105	0.000	0.004	0.000	5,608	MR
1992	0.012	0.349	0.334	0.004	0.288	0.003	0.008	0.002	0.000	0.000	7,862	MR
1993	0.009	0.298	0.402	0.000	0.281	0.002	0.007	0.000	0.000	0.000	10,007	CT
1994	0.006	0.028	0.409	0.000	0.509	0.002	0.046	0.000	0.000	0.000	18,399	CT
1995	0.000	0.158	0.217	0.000	0.595	0.000	0.025	0.005	0.000	0.000	13,643	CT
1996	0.040	0.089	0.472	0.000	0.233	0.000	0.167	0.000	0.000	0.000	7,570	MR
1997	0.000	0.163	0.161	0.000	0.661	0.000	0.016	0.000	0.000	0.000	18,514	CT
1998	0.026	0.052	0.728	0.000	0.172	0.000	0.023	0.000	0.000	0.000	5,027	CT
1999	0.000	0.112	0.266	0.000	0.620	0.000	0.003	0.000	0.000	0.000	9,198	CT
2000	0.000	0.238	0.505	0.000	0.219	0.000	0.038	0.000	0.000	0.000	4,595	CT
2001	0.006	0.113	0.351	0.000	0.503	0.000	0.027	0.000	0.000	0.000	13,328	CT
2002	0.000	0.389	0.146	0.000	0.357	0.000	0.108	0.000	0.000	0.000	9,000[a]	CT
2003	0.007	0.080	0.456	0.000	0.429	0.000	0.027	0.000	0.000	0.000	15,500[a]	CT
2004	0.000	0.113	0.096	0.000	0.783	0.000	0.008	0.000	0.000	0.000	15,761	CT
2005	0.000	0.107	0.428	0.000	0.437	0.000	0.026	0.002	0.000	0.000	5,988	CT
2006	0.000	0.062	0.520	0.000	0.397	0.002	0.019	0.000	0.000	0.000	10,679	CT
2007	0.000	0.240	0.282	0.000	0.475	0.000	0.003	0.000	0.000	0.000	6,425	CT
2008	0.007	0.108	0.538	0.000	0.333	0.000	0.014	0.000	0.000	0.000	5,415[a]	CT
2009	0.000	0.343	0.227	0.000	0.427	0.000	0.002	0.000	0.000	0.000	12,774	CT
2010	0.005	0.267	0.575	0.005	0.130	0.008	0.004	0.006	0.000	0.000	6,135	CT
2011	0.002	0.161	0.385	0.000	0.432	0.006	0.014	0.000	0.000	0.000	7,200[a]	CT
2012	0.003	0.073	0.355	0.000	0.555	0.000	0.014	0.000	0.000	0.000	7,165	CT
2013	0.013	0.126	0.162	0.000	0.673	0.000	0.026	0.000	0.000	0.000	5,465	CT
2014[b]	–	–	–	–	–	–	–	–	–	–	–	–
2015	0.007	0.254	0.357	0.005	0.372	0.005	0.000	0.000	0.000	0.000	6,287	CT
2016	0.000	0.451	0.403	0.000	0.144	0.000	0.002	0.000	0.000	0.000	2,675	CT/S/HM
2017	0.000	0.061	0.736	0.002	0.199	0.002	0.000	0.000	0.000	0.000	4,195	CT
Average	0.006	0.168	0.370	0.001	0.419	0.001	0.036	0.001	0.000	0.000	8,604	

[a] Estimate includes an expansion for missed counting days.

[b] Extensive flooding prevented operation of counting tower.

Table 18.–Minimum estimates of escapement for Delta Clearwater River coho salmon, 1980–2017.

Year	Survey Date	Minimum Escapement
1980	28 Oct	3,946
1981	21 Oct	8,563
1982	3 Nov	8,365
1983	25 Oct	8,019
1984	6 Nov	11,061
1985	13 Nov	6,842
1986	21 Oct	10,857
1987	27 Oct	22,300
1988	28 Oct	21,600
1989	25 Oct	12,600
1990	26 Oct	8,325
1991	23 Oct	23,900
1992	26 Oct	3,963
1993	21 Oct	10,875
1994	24 Oct	62,675
1995	23 Oct	20,100
1996	29 Oct	14,075
1997	24 Oct	11,525
1998	20 Oct	11,100
1999	28 Oct	10,975
2000	24 Oct	9,225
2001	19 Oct	46,875
2002	31 Oct	38,625
2003	21 Oct	105,850
2004	27 Oct	37,950
2005	25 Oct	34,293
2006	24 Oct	16,748
2007	31 Oct–1 Nov	14,650
2008	30 Oct	7,500
2009	26 Oct	16,850
2010	30 Oct	5,867
2011	28 Oct	16,544
2012	19 Oct	5,230
2013	24 Oct	6,222
2014	4 Nov	4,285
2015	22 Oct	19,553
2016	26 Oct	6,767
2017	1 Nov	9,617
Average	5 Nov	18,272

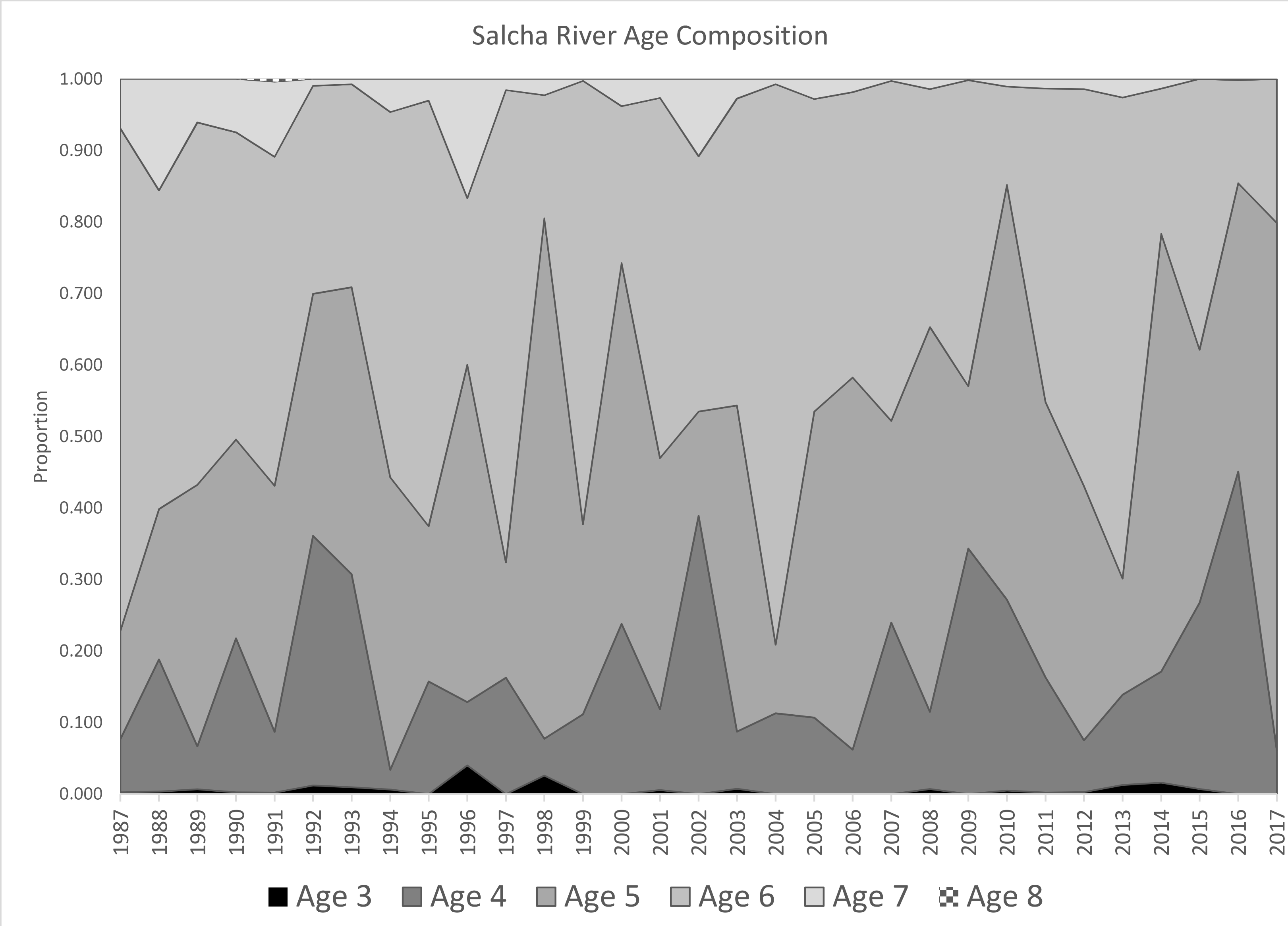

Figure 14.–Age proportions by year for Chinook Salmon sampled on the Salcha River, 1987–2017.

DISCUSSION

During the 2017 season, 5,235 (SE = 321) Chinook salmon and 21,176 (SE = 994, incomplete estimate) chum salmon were enumerated on the Chena River via visual counts (64%), sonar target apportionment (33%) and moving average interpolation (3%; Figure 5). High water events caused an extended period of poor visibility that required the use of sonar technology to estimate fish passage. Postseason, a length-based mixture model was used to apportion sonar targets during the low visibility period and the total was added to expanded visual counts and single days of interpolated data (Huang 2012).

On the Salcha River, 4,195 (SE = 205) Chinook salmon and 20,093 chum salmon (SE = 1,220, incomplete estimate) were enumerated using visual counts (82%) and moving average interpolation (18%; Figure 10). High water events caused poor visibility during three 2-day events, so the use of sonar technology was not required to estimate escapement. The respective estimates of Chinook salmon fell within the BEG range for both the Chena (2,800–5,700) and Salcha Rivers (3,300–6,500).

Chinook salmon run timing for the Chena and Salcha Rivers have shown similarities over the years (Figures 7 and 12). In fact, the historical midpoint of the run for both the Chena and Salcha Rivers is day 17. This is not surprising given both are Tanana River tributaries that originate from the West Point Summit area and are in relative proximity to each other. For 2017, there was just a 4-day delay in run timing from the midpoint on the Chena River to the midpoint on the Salcha River. However, over the years it has been observed that no matter when Chinook salmon arrive on their spawning grounds, sampling for post-spawning carcasses has always occurred during the same time period of late July to mid-August.

Sex, size, and age composition data of Yukon River Chinook salmon stocks are often collected as a monitoring tool and can be used as an indicator of run quality. Abundance estimates of escapement by themselves do not fully describe the fecundity of any single years' returns given the variability in fish size, age, and sex. Reproduction is generally limited by the abundance of females in the population—specifically large females, which have greater fecundity than smaller females. Large eggs will probably produce large juveniles (due to yolk quantity), which tend to have higher survival rates (Quinn 2005). Age composition also plays an important role because older fish tend to be larger. Thus, a run dominated by 4-year-old males (such as we saw in 2016) is probably less productive (i.e., of lower quality) than one dominated by 6-year-old females when escapement estimates are held constant. Because size and age-at-maturity are heritable (Ferrari 2004), selection for smaller fish may lead to a negative feedback loop where younger and smaller adults produce offspring that mature earlier, thus perpetuating the occurrence of low-quality (and less productive) escapements (Lewis et al. 2015). In other words, escapements of larger, older females have a higher probability of producing returns with older and larger fish.

To address escapement quality concerns, fisheries managers have instituted several regulatory changes on the Yukon River regarding gillnet mesh size because of the correlation between mesh size and the size of fish caught. Mesh size restrictions have been used by managers to allow more large Chinook salmon (typically females) to reach the spawning grounds (Howard and Evenson 2010). Gear and fishing restrictions have been in place on the Yukon River since 2014; however, sex compositions and dominant age class trends have continued to fluctuate. This suggests that other, non-anthropogenic reasons are also driving trends in sex composition and size-at-maturity.

In 2017, the Chena and Salcha Rivers had adjusted sex composition estimates that were similar to their respective historical averages. The 2017 adjusted sex composition for the Chena River was 0.67 males and 0.33 females, which was similar to the historical average of 0.68 males and 0.32 females. Like the Chena River, the 2017 Salcha River sex composition (0.65 males and 0.35 females) was similar to the historic average of 0.61 males and 0.39 females. In the Yukon River Chinook salmon enumeration projects downriver from the Tanana River, females typically account for 45% to 50% of the escapement (JTC 2017), but in the Chena and Salcha Rivers, females range from 11% to 51% and from 23% to 52% of the escapement, respectively.

In 2017, returning Chinook salmon were, on average, older than returning Chinook salmon from the previous year. In 2016, the dominant age class for both the Chena and Salcha Rivers was 4-year-olds. Typically, on both the Chena and Salcha Rivers, age-1.3 and age-1.4 Chinook salmon make up the greatest proportion of the escapement estimates. The 2017 age composition data indicate that the age composition of spawners followed historical trends as age-1.3 Chinook salmon were the dominant age class on the Chena (77%) and Salcha (74%) Rivers.

The Delta Clearwater River boat count was conducted in 2017 during 1 day in good conditions and produced minimum estimates of escapement above the established SEG. Previous studies have expanded the boat count to account for the escapement to inaccessible tributaries in the Delta Clearwater River drainage. This expansion was done to conduct a spawner-recruit analysis and was not used to evaluate whether the SEG was met. For this reason, the minimum escapement estimate used to evaluate the SEG is the only one reported. The Delta Clearwater River sport fishery was not restricted because the run was projected to meet the SEG.

CONCLUSION

Continued assessment of the Chena, Salcha, and Delta Clearwater Rivers is required to determine whether the established escapement goals for the largest Chinook and coho salmon stocks in the Alaska portion of the Yukon River drainage are met. The fact that the Chena and Salcha Rivers made escapement during 2017 is promising for the future of the Chinook salmon runs.

ACKNOWLEDGEMENTS

The author would like to thank the following ADF&G Sport Fish technician staff who made the 2017 Chena and Salcha River counting towers/sonar sites a success: Loren St. Amand, Chad Bear, Virgil Davis, Brett George, Eric Nakalsky, Matt Stoller, Laura Gutierrez, Mary Webb, and Melissa Spaulding. A special thanks to ADF&G Sport Fish permanent staff who helped with carcass surveys: Phil Joy, Klaus Wuttig, Rick Queen, and former project biologist Lisa Stuby. The author processed all Chinook salmon scales, and Anchorage Commercial Fisheries staff aged the Chinook salmon scale samples. James Savereide helped with counting tower and sonar setup and project design, gave valuable advice, and (along with Rachael Kvapil) edited and prepared the final report. Thanks to the assistant area manager Brandy Baker, and field technician Ellie Mason, for performing the annual Delta Clearwater River coho salmon counts. The U.S. Army Corps of Engineers provided access to the Moose Creek Dam. The Alaska Sustainable Salmon Fund (AKSSF) is funding the Chena River counting tower through 2018 and the Salcha River counting tower through 2019. The coho salmon counts are annually funded through ADF&G base funds.

REFERENCES CITED

Brase, A. L., and B. Baker. 2015. Fishery management report for recreational fisheries in the Tanana River management area, 2014. Alaska Department of Fish and Game, Fishery Management Report, No. 15-49, Anchorage.

Burwen, D. L., S. J. Fleischman, and J. D. Miller. 2010. Accuracy and precision of salmon length estimates taken from DIDSON sonar images. Transactions of the American Fisheries Society 139:1306–1314.

Clark, R. A. 1993. Abundance and age-sex-size composition of chum salmon escapements in the Chena and Salcha Rivers, 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-13, Anchorage, Alaska, USA.

Cochran, W. G. 1977. Sampling Techniques. 3rd edition, John Wiley, New York.

Doxey, Mike 2004. Salmon studies in the Chena, Chatanika, Delta Clearwater, and Salcha Rivers, 2001. Alaska Department of Fish and Game, Fishery Data Series No. 04-01, Anchorage.

Eiler, J. H., T. T. Spencer, J. J. Pella, and M. M. Masuda. 2006. Stock composition, run timing, and movement patterns of Chinook salmon returning to the Yukon River basin in 2004. U. S. Department of Commerce, NOAA Technical Memo NMFS-AFSC-165.

Estensen, J. L., S. N. Schmidt, S. Garcia, C. M. Gleason, B. M. Borba, D. M. Jallen, A. J. Padilla, and K. M. Hilton. 2017. Annual management report Yukon Area, 2015. Alaska Department of Fish and Game, Fishery Management Report No. 17-12, Anchorage.

Evenson, M. J. 1995. Salmon studies in Interior Alaska, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-5, Anchorage.

Evenson, M. J. 2002. Optimal production of Chinook salmon from the Chena and Salcha rivers. Alaska Department of Fish and Game, Fishery Manuscript No. 02-1, Anchorage.

Ferrari, S., and F. Cibari-Neto. 2004. Beta regression for modelling rates and proportions. Journal of Applied Statistics 31:799-815.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Hansen, T. R., B. J. Blain, D. V. Taylor, and Z. W. Liller. 2016. Salmon escapement monitoring in the Kuskokwim Area, 2014. Alaska Department of Fish and Game, Fishery Data Series No. 16-03, Anchorage.

Howard, K. G., and D. F. Evenson. 2010. Yukon River Chinook salmon comparative mesh size study. Alaska Department of Fish and Game, Fishery Data Series No. 10-92, Anchorage.

Huang, J. 2012. Sonar-based Chena River salmon assessment 2008. Alaska Department of Fish and Game, Fishery Data Series No. 12-39, Anchorage.

JTC (Joint Technical Committee of the Yukon River US/Canada Panel). 2017. Yukon River salmon 2016 season summary and 2017 season outlook. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A17-01, Anchorage.

Jennings, G. B., K. Sundet, and A. E. Bingham. 2011a. Estimates of participation, catch and harvest in Alaska sport fisheries during 2009. Alaska Department of Fish and Game, Fishery Data Series No. 11-45, Anchorage.

Jennings, G. B., K. Sundet, and A. E. Bingham. 2011b. Estimates of participation, catch and harvest in Alaska sport fisheries during 2010. Alaska Department of Fish and Game, Fishery Data Series No. 11-60, Anchorage.

Jennings, G. B., K. Sundet, and A. E. Bingham. 2015. Estimates of participation, catch and harvest in Alaska sport fisheries during 2011. Alaska Department of Fish and Game, Fishery Data Series No. 15-04, Anchorage.

Lewis B., Grant W. S., Brenner R. E., Hamazaki T. 2015. Changes in size and age of Chinook Salmon *Oncorhynchus tshawytscha* returning to Alaska. PLoS ONE 10(6):e0130184. https://doi.org/10.1371/journal.pone.0130184.

Mosher, K. H. 1969. Identification of Pacific salmon and steelhead trout by scale characteristics. United States Department of the Interior, U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Washington, D.C., Circular 317.

Parker, J. F. 2009. Fishery management report for sport fisheries in the Upper Tanana River drainage in 2008. Alaska Department of Fish and Game, Fishery Management Report No. 09-47, Anchorage.

Pfisterer, C. 2010. Echotastic 2.0 User Manual. Alaska Department of Fish and Game, Fairbanks Alaska.

Plummer, M. 2003 JAGS: A program for analysis of Bayesian graphical models using Gibbs Sampling

Quinn, T. P. 2005. The behavior and ecology of Pacific salmon & trout. American Fisheries Society, University of Washington Press.

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

Stuby, L., and M. Tyers. 2018. Chinook salmon escapement in the Chena and Salcha rivers and coho salmon escapement in the Delta Clearwater River, 2016. Alaska Department of Fish and Game, Fishery Data Series No. 18-13, Anchorage.

Stuby, L. 2001. Salmon studies in interior Alaska, 2000. Alaska Department of Fish and Game, Fishery Data Series No. 01-24, Anchorage.

Su, Y., and Yajima, M. 2015. R2jags: A package for running jags from R. R package version 0.05-0.01. http://CRAN.R-project.org/package=R2jags.

Taras, B. D., and D. R. Sarafin. 2005. Chinook salmon escapement in the Gulkana River, 2002. Alaska Department of Fish and Game, Fishery Data Series No. 05-02, Anchorage.

Thompson, S. K. 1987. Sample size for estimating multinomial proportions. The American Statistician, 41:42-46.

Welander, A. D. 1940. A study of the development of the scale of the Chinook salmon (*Oncorhynchus tshawytscha*). Master's thesis, University of Washington, Seattle.

Wolter, K. M. 1985. Introduction to variance estimation. Springer-Verlag, New York.

APPENDIX A:
JAGS CODE OF MIXTURE MODEL

Appendix A1.–JAGS code of mixture model.

```
model { for(i in 1:n.fish) {
        L.mm.D[i] ~ dnorm(muL[i],precL)
        muL[i] <- betaD0[sonar[i]] + betaD1[sonar[i]]*L.mm.act[i]
        L.mm.act[i] ~ dnorm(mu[i],tau[i])
        mu[i] <- lambda[species[i],sex[i],river[i]]
        tau[i] <- prec[species[i],sex[i],river[i]]

        species[i] ~ dcat(ps[i,1:2])
        sex[i] ~ dcat(psex[species[i],1:2])

        logit(pi[i]) <- b0[river[i]]+b1[river[i]]*day[i]
        alpha.inf[i,1] <- pi[i]
        alpha.inf[i,2] <- (1-pi[i])
        ps[i,1:2] ~ ddirch(alpha.inf[i,1:2])
 }

 ## priors for sonar/actual length regression
 # informed from Burwen tethered-fish experiment results
 betaD0[1] ~ dnorm(44.81988,precbD0)
 betaD1[1] ~ dnorm(0.87156,precbD1)
 betaD0[2] ~ dnorm(44.81988,precbD0)
 betaD1[2] ~ dnorm(0.87156,precbD1)
 precbD0 <- 1/63.36818/63.36818
 precbD1 <- 1/0.07835/0.07835
 precL <- 1/(54.59*54.59)

 ## length composition priors
 # means - indices are [species, sex, river]
 lambda[1,1,1] ~ dnorm(chena_chin_m_mn,t1)
```

-continued-

```
lambda[1,2,1] ~ dnorm(chena_chin_f_mn,t2)
lambda[2,1,1] ~ dnorm(chena_chum_m_mn,t3)
lambda[2,2,1] ~ dnorm(chena_chum_f_mn,t4)
lambda[1,1,2] ~ dnorm(salcha_chin_m_mn,t5)
lambda[1,2,2] ~ dnorm(salcha_chin_f_mn,t6)
lambda[2,1,2] ~ dnorm(salcha_chum_m_mn,t7)
lambda[2,2,2] ~ dnorm(salcha_chum_f_mn,t8)

# precision from standard error (supplied as data)
t1 <- pow(chena_chin_m_se,-2)
t2 <- pow(chena_chin_f_se,-2)
t3 <- pow(chena_chum_m_se,-2)
t4 <- pow(chena_chum_f_se,-2)
t5 <- pow(salcha_chin_m_se,-2)
t6 <- pow(salcha_chin_f_se,-2)
t7 <- pow(salcha_chum_m_se,-2)
t8 <- pow(salcha_chum_f_se,-2)

# precision from standard deviation
prec[1,1,1] <- pow(chena_chin_m_sd,-2)
prec[1,2,1] <- pow(chena_chin_f_sd,-2)
prec[2,1,1] <- pow(chena_chum_m_sd,-2)
prec[2,2,1] <- pow(chena_chum_f_sd,-2)
prec[1,1,2] <- pow(salcha_chin_m_sd,-2)
prec[1,2,2] <- pow(salcha_chin_f_sd,-2)
prec[2,1,2] <- pow(salcha_chum_m_sd,-2)
prec[2,2,2] <- pow(salcha_chum_f_sd,-2)

# priors for standard deviation (supplied as data)
```

-continued-

```
chena_chin_m_sd ~ dnorm(chena_chin_m_sd_mn, chena_chin_m_sd_prec)
chena_chin_f_sd ~ dnorm(chena_chin_f_sd_mn, chena_chin_f_sd_prec)
chena_chum_m_sd ~ dnorm(chena_chum_m_sd_mn, chena_chum_m_sd_prec)
chena_chum_f_sd ~ dnorm(chena_chum_f_sd_mn, chena_chum_f_sd_prec)
salcha_chin_m_sd ~ dnorm(salcha_chin_m_sd_mn, salcha_chin_m_sd_prec)
salcha_chin_f_sd ~ dnorm(salcha_chin_f_sd_mn, salcha_chin_f_sd_prec)
salcha_chum_m_sd ~ dnorm(salcha_chum_m_sd_mn, salcha_chum_m_sd_prec)
salcha_chum_f_sd ~ dnorm(salcha_chum_f_sd_mn, salcha_chum_f_sd_prec)

chena_chin_m_sd_prec <- pow(chena_chin_m_sd_sd,-2)
chena_chin_f_sd_prec <- pow(chena_chin_f_sd_sd,-2)
chena_chum_m_sd_prec <- pow(chena_chum_m_sd_sd,-2)
chena_chum_f_sd_prec <- pow(chena_chum_f_sd_sd,-2)
salcha_chin_m_sd_prec <- pow(salcha_chin_m_sd_sd,-2)
salcha_chin_f_sd_prec <- pow(salcha_chin_f_sd_sd,-2)
salcha_chum_m_sd_prec <- pow(salcha_chum_m_sd_sd,-2)
salcha_chum_f_sd_prec <- pow(salcha_chum_f_sd_sd,-2)

## parameters for run-timing logistic relationship
b0 <- mu.b0
b1 <- mu.b1
prec.b0 <- 1/0.6543603
prec.b1 <- 1/0.003060084

## priors for sex (supplied as data)
psex[1,1:2] ~ ddirch(alpha.sex.chin[])
psex[2,1:2] ~ ddirch(alpha.sex.chum[])

## posterior distributions of the totals for each species
```

-continued-

```
N.chum <- sum(species[]) - n.fish
N.chin <- (2*n.fish) - sum(species[])

# some calculated subtotals - certain data regions needed to be expanded
Nchum_chena <- sum(species[1:9042]) - nchena
Nchin_chena <- (2*nchena) - sum(species[1:9042])
Nchum_salcha <- sum(species[9043:12361]) - nsalcha
Nchin_salcha <- (2*nsalcha) - sum(species[9043:12361])
for(k in 1:ndays) {
 N.chum.day[k] <- sum(species[ifirst[k]:ilast[k]]) - nfishday[k]
 N.chin.day[k] <- 2*nfishday[k] - sum(species[ifirst[k]:ilast[k]])
}
N.chum.before <- sum(species[9693:9704]) + sum(species[9712:9717]) - 18
N.chin.before <- 2*18 - sum(species[9693:9704]) - sum(species[9712:9717])
N.chum.after <- sum(species[9705:9711]) + sum(species[9718:9719]) - 9
N.chin.after <- 2*9 - sum(species[9705:9711]) - sum(species[9718:9719])  }
```

APPENDIX B:
JAGS CODE OF BAYESIAN HIERARCHICAL MODEL

Appendix B1.–JAGS code of Bayesian hierarchical model.

```
model {
 for(j in 1:nyrs) {
 for(i in 1:ndays){
  y1[i,j] ~ dnorm(theta1[i,j], tausq1[j])
 #  y1[i,j] ~ dpois(theta1[i,j])
 # Assume that run timing distribution takes log normal distribution
 theta1[i,j] <- a1[j]*exp(-0.5*pow(log(x[i]/mu1[j])/b1[j],2))
 # Assume that run timing distribution takes Extreme value distribution
 #  theta1[i,j] <- a1[j]*exp(-exp(-(x[i]-mu1[j])/b1[j])-(x[i]-mu1[j])/b1[j]+1)
 # Assume that run timing distribution takes log-logistic distribution
 #                    theta1[i,j]           <-          (a1[j]*(b1[j]/mu1[j])*pow((x[i]/mu1[j]),b1[j]-
1))/pow(1+pow((x[i]/mu1[j]),b1[j]),2)

  y2[i,j] ~ dnorm(theta2[i,j], tausq2[j])
  #  y2[i,j] ~ dpois(theta2[i,j])
  # Assume that run timing distribution takes log normal distribution
  theta2[i,j] <- a2[j]*exp(-0.5*pow(log(x[i]/mu2[j])/b2[j],2))
  # Assume that run timing distribution takes Extreme value distribution
  #  theta2[i,j] <- a2[j]*exp(-exp(-(x[i]-mu2[j])/b2[j])-(x[i]-mu2[j])/b2[j]+1)
  # Assume that run timing distribution takes log-logistic distribution
  #                    theta2[i,j]           <-          (a2[j]*(b2[j]/mu2[j])*pow((x[i]/mu2[j]),b2[j]-
1))/pow(1+pow((x[i]/mu2[j]),b2[j]),2)
 }
 }
# a[] indicates the maximum height (amplitude) of the function a>0
# mu[] indicates the function peaks when x = mu mu>0 : Peak timing
# b[] indicates peak width of the function b>0 standard deviation

# Priors
```

-continued-

```
for(i in 1:nyrs) {
 # Normal distribution Positive only
 # a: is independent not hierarchical
 a1[i] ~ dnorm(0,0.00001)T(0,)
 b1[i] ~ dnorm(b01,b01.prec)T(0.16,)

 mu1[i] <- mu2[i] + eps

 a2[i] ~ dnorm(0,0.00001)T(0,)
 b2[i] ~ dnorm(b02,b02.prec)T(0.16,)
 mu2[i] ~ dnorm(mu02,mu02.prec)T(0,)
}
eps ~ dnorm(0,0.01)
prec.mu <- pow(sig.mu,-2)
sig.mu ~ dunif(0,2)

b01 ~ dnorm(0.5,0.001)T(0.16,)
mu01 ~ dnorm(25,0.001)T(0,)
b01.prec <-1/b01.ssq
b01.ssq <- b01.sigma*b01.sigma
b01.sigma ~ dunif(0,100)
mu01.prec <-1/mu01.ssq
mu01.ssq <- mu01.sigma*mu01.sigma
mu01.sigma ~ dunif(0,100)

b02 ~ dnorm(0.5,0.001)T(0.16,)
mu02 ~ dnorm(25,0.001)T(0,)
b02.prec <-1/b02.ssq
b02.ssq <- b02.sigma*b02.sigma
```

-continued-

```
b02.sigma ~ dunif(0,100)
mu02.prec <-1/mu02.ssq
mu02.ssq <- mu02.sigma*mu02.sigma
mu02.sigma ~ dunif(0,100)


## This assumes that variance of each year is independent.
for(i in 1:nyrs) {
 tausq1[i] <- pow(sigma1[i],-2)
 sigma1[i] ~ dunif(0,100)

 tausq2[i] <- pow(sigma2[i],-2)
 sigma2[i] ~ dunif(0,100)
}

# Backestimate escapement
for(j in 1:nyrs){
 for(i in 1:ndays){
  y1est[i,j] <- y1[i,j]
  y2est[i,j] <- y2[i,j]
 }
}
}
```