Fishery Data Series No. 18-19

Stock Assessment of Sockeye Salmon in the Buskin River, 2014–2017

Final Report for Study 14-401

USFWS, Office of Subsistence Management

Fishery Information Service Division

by

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May 2018

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

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by
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ABSTRACT

The Alaska Department of Fish and Game, Division of Sport Fish, has assessed the annual run of Buskin River sockeye salmon (*Oncorhynchus nerka*) on Kodiak Island, Alaska since 1990. Buskin River sockeye salmon weir counts were 13,976; 8,718; 11,297; and 7,219 fish for 2014–2017, respectively. Weir counts for Lake Louise were 925, 280, 156, and 141 sockeye salmon for 2014–2017, respectively. Reported annual subsistence harvests for the Buskin River Section were 5,616; 3,920; and 4,767 sockeye salmon for 2014–2016, respectively; harvest is not available for 2017 at this time. Mixed stock analysis of genetic samples from the Buskin River sockeye salmon subsistence fishery showed 91–97% of the 2014–2017 harvests were of Buskin Lake origin sockeye salmon and 0.5–4.1% were of sockeye salmon bound for Lake Louise. In interviews conducted from 2014 through 2017, an average of 89% of subsistence users reported each year that the Buskin River was a traditional fishing location, and an average of 79% reported each year that they subsistence fished in other areas. Enumerated sockeye salmon spawning escapement for the entire drainage was 14,901; 8,998; 11,453; and 7,360 fish for 2014–2017, respectively. Based on a Bayesian spawner-recruitment analysis, estimated spawning escapement for maximum sustained yield is about 6,500 fish (95% credibility interval 5,100–8,400). A sustained yield probability analysis supports the current Buskin Lake system biological escapement goal (BEG) range of 5,000–8,000 sockeye salmon. Age-1.3, -2.2, and -2.3 sockeye salmon composed 90–99% of the subsistence harvests for 2014–2017 and composed 76–96% of the Buskin River and 50–100% of the Lake Louise escapements. Male to female ratios for the Buskin River were between 0.7 and 1.1 to 1 for 2014–2017; they were 1.3–2.5 to 1 for Lake Louise, and 0.8–1.5 to 1 for the subsistence harvest.

Key words: sockeye salmon, *Oncorhynchus nerka*, escapement, escapement goal, Buskin River, Lake Louise, age-sex-length composition, sport harvest, spawner-recruitment, subsistence harvest, stock assessment

INTRODUCTION

The Buskin River drainage, located on the northeast end of Kodiak Island (Figure 1), contains 1 of only 3 native populations of sockeye salmon (*Oncorhynchus nerka*) found on the Kodiak Island road system. The drainage supports one of the largest subsistence salmon fisheries in the Kodiak Archipelago and, historically, the single largest subsistence fishery within the Kodiak–Aleutian Islands Federal Subsistence Region. This subsistence fishery occurs in nearshore marine waters adjacent to the Buskin River mouth and targets several species of salmon, although sockeye salmon typically compose more than 81% of the total harvest for this fishery. Reported subsistence harvests of Buskin River drainage sockeye salmon ranged from 1,514 to 11,151 fish for 2004–2017 (Table 1 and Figure 2). Harvest in this fishery is documented through subsistence permits issued by the Alaska Department of Fish and Game (ADF&G), Division of Commercial Fisheries (CF).

The Buskin River is also the most popular recreational fishing stream on Kodiak Island, recently representing approximately 30% of the total freshwater recreational fishing effort in the Kodiak Management Area (ADF&G Statewide Harvest Survey). Recreational fishing effort on the Buskin River is directed primarily toward sockeye salmon and coho salmon (*O. kisutch*) but also toward steelhead and rainbow trout (*O. mykiss*), pink salmon (*O. gorbuscha*), and Dolly Varden (*Salvelinus malma*). From 2004 through 2017, sport harvests of sockeye salmon from the Buskin River have ranged from 332 to 4,237 fish and averaged 1,767 fish (Table 1 and Figure 2). Sport harvest of sockeye salmon and sport fishing effort on the Buskin River are estimated annually by the ADF&G, Division of Sport Fish (SF), Statewide Harvest Survey (SWHS).

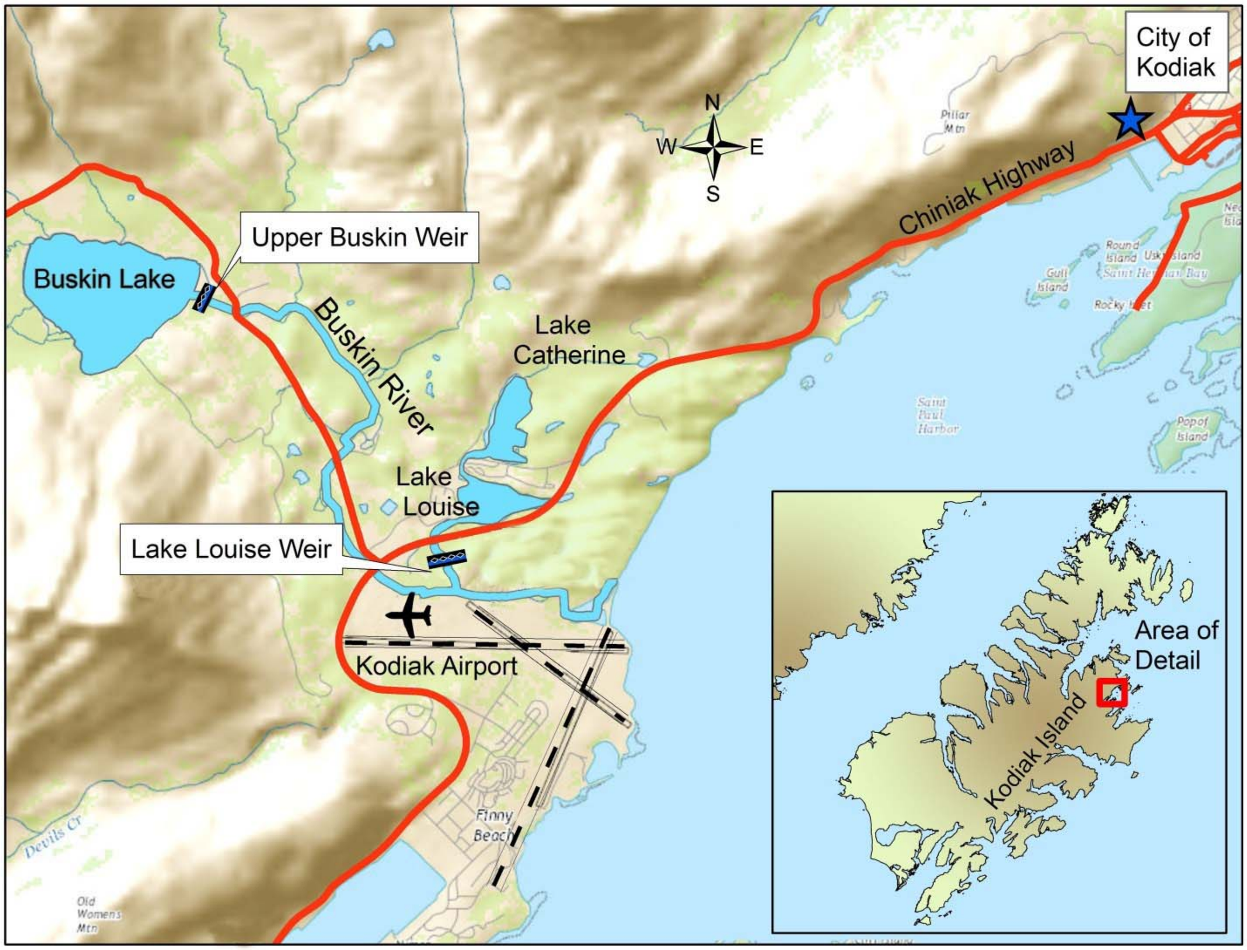

Figure 1.–Buskin River system weir locations, 2014–2017.

Table 1.–Total weir counts and sources of harvest for Buskin River drainage sockeye salmon, 2004-2017.

		Subsistence harvest [b]		Weir count [c]		Estimated sport fishing effort [d]		
Year	Commercial harvest [a]	Sockeye salmon	Other salmon	Buskin Lake	Louise Lake	Harvest	Catch	Angler-days [e]
2004	1,098	9,421	1,766	22,023	2,086	1,379	3,620	17,549
2005	0	8,239	2,801	15,468	2,028	1,540	2,851	17,575
2006	6	7,577	1,732	17,734	4,586	1,577	2,642	19,875
2007	30	11,151	1,422	16,502	1,676	1,509	3,143	17,124
2008	0	2,664	1,255	5,900	833	1,160	1,560	15,180
2009	45	1,883	960	7,757	992	687	1,417	18,695
2010	0	1,514	879	9,800	421	332	699	13,365
2011	38	4,639	380	11,982	360	1,277	2,285	13,879
2012	1	2,631	1,153	8,565	301	1,484	1,938	13,996
2013	17	6,160	775	16,189	903	1,310	2,395	21,497
2014	0	5,616	1,690	13,976	925	4,237	6,165	20,015
2015	12	3,920	1,156	8,718	280	3,978	5,807	12,808
2016	0	4,767	625	11,297	156	2,503	3,247	8,141
2017	0	[f]	[f]	7,219	141	[f]	[f]	[f]
Average	89	5,399	1,276	12,366	1,121	1,767	2,905	16,131

[a] Source: ADF&G, Division of Commercial Fisheries (CF), fish ticket database system. Includes all sockeye salmon harvested annually at the mouth of Buskin River in Womens Bay, statistical areas 259-22 and 259-26.

[b] Source: Subsistence harvest records maintained by CF Westward Region; includes all reported harvest at the Buskin River.

[c] Source: CF Westward Region database.

[d] Source: Statewide Harvest Survey (SWHS) estimates from the Alaska Sport Fishing Survey database [Internet]. 1996–present. Anchorage, AK: Alaska Department of Fish and Game, Division of Sport Fish. Available from: http://www.adfg.alaska.gov/sf/sportfishingsurvey/.

[e] Units are angler-days and include effort directed toward other species.

[f] Not available.

A relatively minor commercial harvest of Buskin River sockeye salmon occurs in the adjacent marine waters of Chiniak Bay. These harvests are small or nonexistent during some years. Fish ticket harvest receipts available from the CF fish ticket database indicate that between 2004 and 2017, the harvest of Buskin River sockeye salmon was less than 50 in every year except 2004, when it reached 1,098 (Table 1). Commercial harvests have averaged less than 5 sockeye salmon annually during the past 6 years.

Inriver runs of sockeye salmon are usually monitored at 2 salmon counting weirs (Figure 1) to ensure the sustainability of the stock (Schmidt et al. 2005; Schmidt 2007; Schmidt and Evans 2010; Polum et al. 2014). One weir, hereafter referred to as the "upper Buskin River weir" (Figure 1) is located about 100 yards (90 m) downstream from the outlet of Buskin Lake and has been operated annually by ADF&G since the mid-1980s. Counts of adult salmon entering Buskin Lake via the Buskin River are usually obtained between late May and late July for this project, with peak daily escapements typically occurring during the third week of June (Figure 3). The second weir used in this project, hereafter named the "Lake Louise weir" (Figure 1), is located on a tributary stream draining both Lake Louise and Lake Genevieve and has been operated annually by ADF&G since 2002. Counts of adult salmon entering this tributary stream are usually obtained between early June and late August, with peak daily escapements typically occurring during August and occasionally into September (Figure 3). The largest daily counts at this weir generally coincide with high water events.

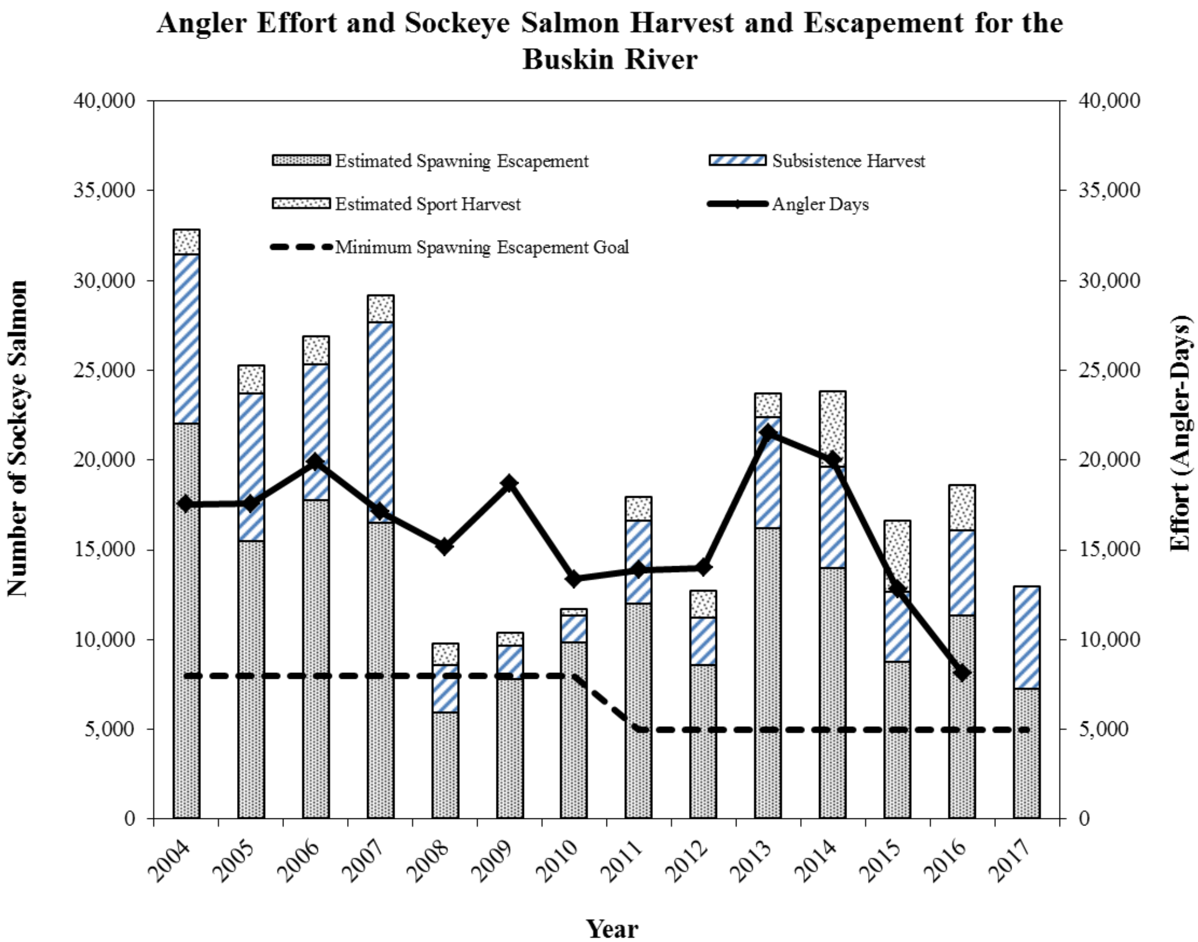

Figure 2.–Buskin Lake sockeye salmon spawning escapement, estimated sport and subsistence harvest of Buskin River sockeye salmon, and sport fishing effort (angler-days) directed toward all fish species in the Buskin River drainage, 2004–2017.

A biological escapement goal (BEG) provides a range of escapements that give the greatest potential for maximum sustained yield based on the best available biological information and is used to guide inseason management of subsistence, sport, and commercial fisheries. For the Buskin River, if inseason weir counts indicate the BEG will not be achieved, harvest restrictions are first enacted for sport and commercial fisheries. If these restrictions are not sufficient to ensure the BEG will be achieved, harvest restrictions may also be placed on the subsistence fishery. The current sockeye salmon BEG for the Buskin River, established in 2010 and beginning with the 2011 season, is 5,000–8,000 fish based on Bayesian analysis of the spawner–recruit relationship (Nemeth et al. 2010). The previous escapement goal of 8,000–13,000 fish was determined in 1996 based on weir counts from 1985 through 1989 (Nelson and Lloyd 2001).

Since the new BEG was established in 2010, the Buskin River sockeye salmon BEG has been met every year (Figure 2).

To improve management of Buskin River sockeye salmon for the benefit of all users, the escapement goal must accurately reflect the production capacity of the stock. Since 2000, ADF&G has obtained funding from the United States Fish and Wildlife Service (USFWS), Office of Subsistence Management, to collect data needed to evaluate the Buskin River sockeye salmon BEG. Escapement data from these efforts, along with harvest data from subsistence permits and commercial fish tickets (ADF&G CF Fish Ticket Database; ADF&G Westward Region Subsistence Database) and statewide sport harvest surveys (SWHS) were used with associated age composition estimates to construct a brood table, conduct a spawner–recruit analysis, and set escapement goals. The BEG is periodically reevaluated as new information becomes available to help ensure that the fisheries can be maintained while the sockeye salmon resource is sustained.

This report presents 2014-2017 study results, including daily sockeye salmon escapement counts; seasonal harvest estimates; stock composition estimates for age, sex, and mean length-at-age by sex; and a spawner-recruit analysis.

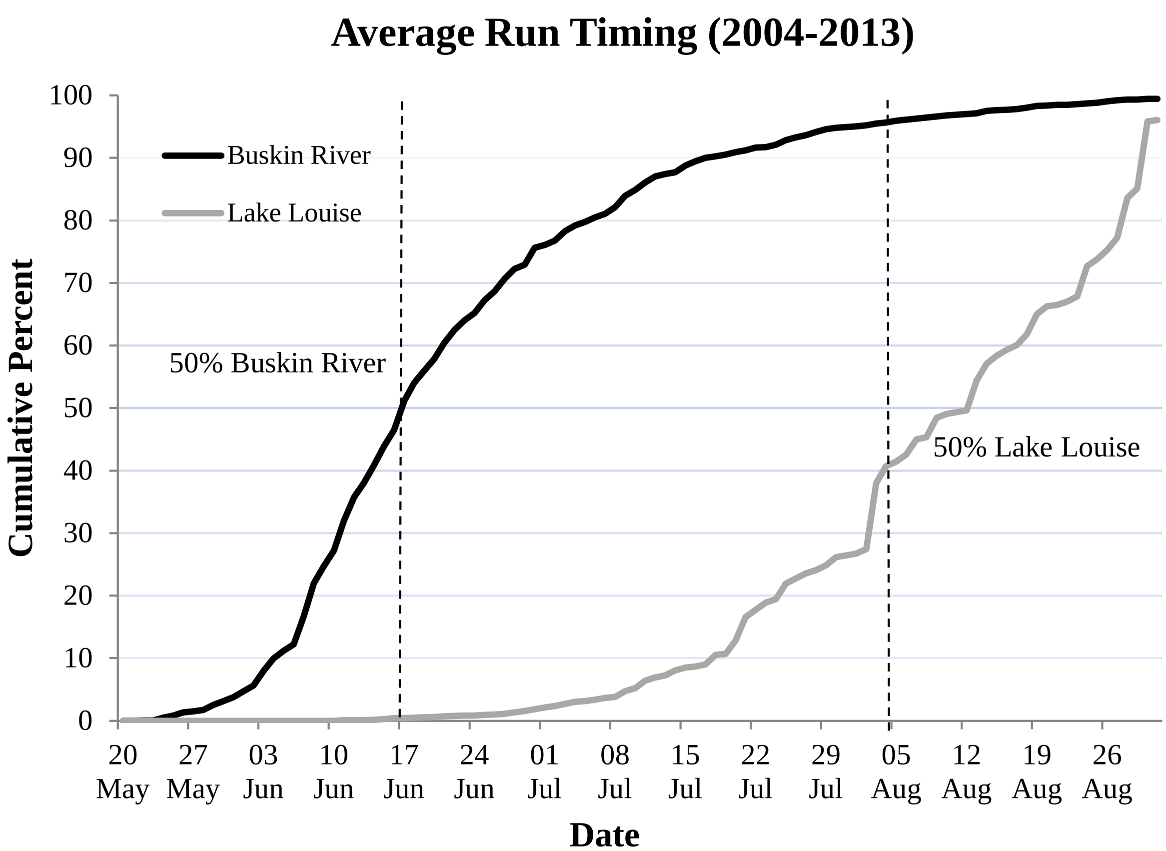

Figure 3.–Historical average run timing of sockeye salmon returning to the Buskin River and Lake Louise, 2004–2013.

Note: Average dates when 50% of the run has passed each weir are shown with dashed lines.

STUDY OBJECTIVES

Objectives for the 2014-2017 stock assessment of Buskin River sockeye salmon were as follows:

1) Census the sockeye salmon escapements into Buskin Lake from approximately mid-May through July 31 and into Louise–Catherine lakes tributary from approximately June 1 through August 31.
2) Estimate the age composition of the sockeye salmon run to Buskin Lake (from combined samples of the subsistence harvest in the Chiniak Bay section and the upper Buskin River weir) such that the estimates are within 5 percentage points of the true value 95% of the time.
3) Estimate the age composition of the sockeye salmon run (escapement) to the Louise–Catherine lakes tributary such that the estimates are within 7.5 percentage points of the true value 95% of the time.
4) Estimate proportions of the sockeye salmon subsistence harvest in the Buskin River Section of Chiniak Bay of Buskin River and Louise–Catherine lakes run components through DNA analysis such that the estimates are within 7 percentage points of the true value 90% of the time in the absence of genetic error.
5) Construct a brood table to evaluate the Buskin River sockeye salmon BEG.
6) Provide education and career development opportunities for federally qualified subsistence users.

METHODS

DATA COLLECTION

Weir Counts

During 2014–2017, 2 weirs were operated each season: the upper Buskin River weir, just downstream from the outlet of Buskin Lake, and the Lake Louise weir, on the tributary stream draining Louise and Genevieve lakes (Figure 1). During each year, the weirs were operated continuously and monitored daily. Fish passage was only allowed when counts were made, and all immigrating and emigrating anadromous fishes passing through the weirs were enumerated and identified by species.

ADF&G operated the upper Buskin River weir about 100 yards (90 m) downstream of the outlet to Buskin Lake (Figure 1). The upper Buskin River weir was constructed with a superstructure framework of wooden tripods weighted with sandbags, aluminum cross stringers, and a boardwalk. Rigid aluminum panels (10 ft high and 2.5 ft wide [3 m × 0.8 m], constructed from 1-inch diameter schedule-40 pipe sections spaced 1 inch [2.5 cm] apart and welded into aluminum T-bars) provided structural continuity and created a barrier about 125 ft (38 m) long to uncontrolled fish passage. Counting gates integrated into the panel array in 2 locations allowed for the controlled passage of fish over a submerged white-colored background to facilitate species identification. A funnel entrance trap constructed of aluminum panels and attached to one of the counting gates was installed to capture immigrating fish for sampling.

The upper Buskin River weir was operated from mid-May to the end of September. Annual sockeye salmon counts obtained from the upper Buskin River weir were considered a close approximation of total spawning escapement because harvests do not typically occur within Buskin Lake or its tributaries.

The Lake Louise weir was operated on a major tributary stream flowing into the Buskin River from Lake Louise (Figure 1). The Lake Louise weir was similar in design to the one used at Buskin Lake. It was approximately 20 feet (6 m) long with a counting gate and funnel entrance trap constructed of aluminum panels. Dates of operation varied somewhat each year. The weir was operated between the first week of June and early September. Escapements to this system vary widely and large proportions of the annual escapement occur on just a few days each season in conjunction with large rainfalls. Annual sockeye salmon counts obtained from the weir provide a close approximation of total spawning escapement into Lake Louise because harvests do not typically occur upstream of the weir site.

Because sport fish harvests or other known removals of sockeye salmon typically do not occur upriver of the weirs at Buskin Lake and Lake Louise, the sum of counts taken at the weirs was considered a census of the spawning escapement (with zero variance). No adjustments were made to the weir counts for the Buskin River system to account for fish migrating before or after weir operation. Adjustments were made occasionally for weir-leakage at the upper Buskin River weir during high flow events based on visual observation of fish escaping, buildup behind the weir before and after the floods, and the duration of the floods. It is expected that very few fish were unaccounted for because there were virtually no high-water estimates made in the 4 years of the study. No adjustments were made to the Lake Louise weir count because of its smaller run size and lack of weir leakage. A Bayesian state-space spawner–recruitment analysis was performed on the Buskin Lake stock but not the Lake Louise stock.

Fishery Harvests

Annual subsistence harvests of Buskin River drainage sockeye salmon were estimated from returns of completed permits received by the CF Kodiak office. From 2004 through 2016 (2017 results are not available), annual return rates of completed permits ranged between 82% and 93% and averaged 88% (Westward Region Subsistence Database). It was not possible to determine the proportion of permit holders who harvested Buskin River sockeye salmon but failed to return permits.

The sport fishery harvest of sockeye salmon was estimated by the SWHS. Commercial harvests were obtained from the CF fish ticket database system.

Age, Sex, and Length Sampling

Sockeye salmon age, sex, and length (ASL) sampling of the Buskin Lake escapement during the 2014–2017 seasons was stratified into 4 temporal intervals: May 15–June 15, June 16–30, July 1–15, and July 16–31. Samples from inriver runs of sockeye salmon to Buskin Lake were obtained from weir traps or beach seines. Typically, sampling was conducted 3 days per week. Whenever possible, all sockeye salmon captured in the weir traps or seines were sampled for ASL. ASL sampling for the Lake Louise escapement was also stratified into 4 temporal intervals: June 1–July 15, July 16–31, August 1–15, and August 16–31. If the Lake Louise run persisted beyond August 31, sampling was extended. Sampling was typically conducted every other day. Whenever possible, all sockeye salmon captured in the weir trap were sampled.

ASL sampling of the subsistence harvests during 2014–2017 was stratified into 2 temporal intervals: May 15–June 15 and June 16–July 15. Sampling was conducted on the fishing grounds during good weather and also dockside at the local boat harbor. Samples were obtained opportunistically within each time interval. No ASL sampling was conducted for either the sport fish or commercial harvests due to the broad distribution of effort in these fisheries over space and time. ASL statistics for these harvests were assumed to be the same as those estimated for escapement counted through the weirs.

Lengths from mid eye to tail fork (METF) were recorded to the nearest millimeter for each sockeye salmon sampled. Sex was determined through external morphology such as head shape and presence of the ovipositor. Whenever possible, 2 scales were removed from the preferred area, left side of the body at a point on a diagonal line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin 2 rows above the lateral line (Welander 1940). Scales not available from the preferred area were taken from the 3rd or 4th row above the lateral line in the same linear plane. Scales not available in either preferred area on the left side were collected from the same region on the right side of the body. Sampled scales were placed on a gummed card for subsequent analysis. Ages of sampled sockeye salmon were determined from scales using criteria described in Mosher (1969). Ages were recorded using European notation (Koo 1962), with a decimal separating the number of winters spent in fresh water (after emergence) from the number of winters spent in salt water.

Subsistence User Survey

In response to a need identified by the Kodiak–Aleutians Region Subsistence Advisory Council, technicians opportunistically surveyed sockeye salmon subsistence users on the fishing grounds adjacent to the Buskin River mouth while concurrently sampling the harvest for ASL. The survey was conducted over the duration of the subsistence fishery each year of the study. Although it probably provided a representative sample of people participating in the fishery, the user survey was not designed to account for bias or estimate precision. The survey provided residency and fishing effort data not currently available from the subsistence permit returns. Following a set of brief introductory remarks, all subsistence users who agreed to be interviewed were asked a short series of questions to determine their residency (Kodiak Island Borough or elsewhere in Alaska) and traditional subsistence fishing location(s) (Buskin River or elsewhere).

GENETIC ANALYSES

Tissue Sampling

Baseline Collections

Baseline samples were collected for genetic analyses from spawning populations of sockeye salmon on islands of the Kodiak archipelago; these are a subset of populations reported in Shedd et al. (2016a) (Appendix A1). Target sample size for baseline collections was 95 individuals to achieve acceptable precision for estimating allele frequencies (Allendorf and Phelps 1981; Waples 1990) and to accommodate the ADF&G’s genotyping platform.

Chiniak Bay Subsistence Harvests

The respective proportions of subsistence harvests originating from 4 reporting groups of interest (described below) were estimated from samples of adult sockeye salmon collected from the subsistence harvest in Chiniak Bay. These samples were collected concurrently with ASL samples taken on the fishing grounds or dockside at the local boat harbor. Occasionally, subsistence harvesters were pressed for time and only genetic samples were taken. The axillary process was clipped from the fish and placed into prelabeled, 1 mL vials filled with ethanol. Labeled samples were shipped to the ADF&G Gene Conservation Laboratory for storage and processing. Sampling periods were concurrent with ASL sampling timelines and attempted to capture the entire fishery, which starts in late May or early June and is over by 4 July.

Laboratory Analyses

Assaying Genotypes

Genomic DNA was extracted from tissue samples using a NucleoSpin[1] 96 Tissue Kit by Macherey-Nagel (Düren, Germany). A total of 96 SNP markers were screened (Shedd et al. 2016a) using Fluidigm 96.96 Dynamic Array Integrated Fluidic Circuits (IFCs), which systematically combine up to 96 assays and 96 samples into 9,216 parallel reactions. The components were pressurized into the IFC using the IFC Controller HX (Fluidigm). Each reaction was conducted in a 7.2 nL volume chamber consisting of a mixture of 20X Fast GT Sample Loading Reagent (Fluidigm), 2X TaqMan GTXpress Master Mix (Applied Biosystems), Custom TaqMan SNP Genotyping Assay (Applied Biosystems), 2X Assay Loading Reagent (Fluidigm), 50X ROX Reference Dye (Invitrogen), and 60–400 ng/µl DNA. Thermal cycling was performed on a Fluidigm FC1 Cycler using a Fast-PCR protocol as follows: a "Thermal-Mix" step of 70°C for 30 min and 25°C for 10 min, an initial "Hot-Start" denaturation of 95°C for 2 min followed by 40 cycles of denaturation at 95°C for 2 s and annealing at 60°C for 20 s, with a final "Cool-Down" at 25°C for 10 s. The Dynamic Array IFCs were read on a Biomark or EP1 System (Fluidigm) after amplification and scored using Fluidigm SNP Genotyping Analysis software.

Assays that failed to amplify on the Fluidigm system were reanalyzed with the QuantStudio 12K Flex Real-Time PCR System (Life Technologies). Each reaction was performed in 384-well plates in a 5 µL volume consisting of 6–40 ng/µl of DNA, 2X TaqMan GTXpress Master Mix (Applied Biosystems), and Custom TaqMan SNP Genotyping Assay (Applied Biosystems). Thermal cycling was performed on a Dual 384-Well GeneAmp PCR System 9700 (Applied Biosystems) as follows: an initial "Hot-Start" denaturation of 95°C for 10 min followed by 40 cycles of denaturation at 92°C for 1 s and annealing at 60°C for 1 min, with a final "Cool-Down" hold at 10°C. The plates were scanned on the system after amplification and scored using the Life Technologies QuantStudio 12K Flex Software.

Genotypes produced on both platforms were imported and archived in the Gene Conservation Lab Oracle database, LOKI.

Laboratory Quality Control

Quality control (QC) analyses were conducted to identify laboratory errors and measure the background discrepancy rate of the genotyping process. The QC analyses were performed as a separate event from the original genotyping, with staff duties altered to reduce the likelihood of repeated human errors. All samples were subject to the following QC protocol: re-extraction of 8% of project fish and genotyping for the same SNPs assayed in the original project. Discrepancy rates were calculated as the number of conflicting genotypes divided by the total number of genotypes compared. These rates describe the difference between original project data and QC data for all SNPs and are capable of identifying extraction, assay plate, and genotyping

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[1] Product names used in this publication are included for completeness but do not constitute product endorsement.

errors. Assuming that the discrepancies are due equally to errors during the original genotyping and errors during QC analysis, error rates in the original genotyping can be estimated as roughly half the rate of discrepancies (Dann et al. 2012). This QC method is the best representation of the error rate in our current genotyping methodology, but it may underestimate error rate if the same error occurs in both genotyping analyses, though this is very unlikely.

Statistical Analysis

We retrieved genotypes from LOKI and imported them into *R* version 3.4.3[2]. All subsequent analyses were performed in *R*, following the methods of Shedd et al. (2016b) using the 89 loci from Shedd et al. (2016a) for the same 4 reporting groups used in Polum et al. (2014): *Buskin Lake*, *Lake Louise*, *Saltery*, and *Other Kodiak*.

DATA ANALYSIS

Age and Sex Composition

Escapement

For each year, the proportion of sockeye salmon of age or sex class *a* in stratum *i* for the escapement of interest (i.e., Buskin Lake, Louise–Catherine lakes) was estimated as a binomial proportion as follows:

$$\hat{p}_{ia} = \frac{n_{ia}}{n_i}, \tag{1}$$

with its variance estimated by

$$\text{var}(\hat{p}_{ia}) = \left[\frac{W_i - n_i}{W_i}\right]\frac{\hat{p}_{ia}(1-\hat{p}_{ia})}{n_i - 1}, \tag{2}$$

where

n_{ia} = the number of sockeye salmon in age or sex class *a* in sample from stratum *i*,

n_i = the total number of sockeye salmon sampled during stratum *i*, and

W_i = the number of sockeye salmon in the weir count during stratum *i*.

The number of fish by age or sex class *a* in stratum *i* was estimated as follows:

$$\hat{W}_{ia} = W_i \hat{p}_{ia}, \tag{3}$$

with its variance estimated by

$$\text{var}(\hat{W}_{ia}) = W_i^2 \,\text{var}(\hat{p}_{ia}). \tag{4}$$

[2] R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

The estimated total number of sockeye salmon ($\hat{W}_a$) of each age or sex class *a* in the escapement and its variance [$\mathrm{var}(\hat{W}_a)$] were calculated as the sum of the individual stratum estimates (from Equations 3 and 4, respectively). The overall proportion of sockeye salmon of age or sex class *a* was calculated as follows:

$$\hat{p}_a = \frac{\hat{W}_a}{W}, \tag{5}$$

with its variance estimated as follows:

$$\mathrm{var}(\hat{p}_a) = \frac{\mathrm{var}(\hat{W}_a)}{W^2}, \tag{6}$$

where W is the sum of the W_i over strata.

Subsistence Harvest

Subsistence harvest estimates could not be stratified because subsistence harvest was only reported seasonally with no reliable method of stratification available. Pooled estimates of age and sex composition of the subsistence harvest were therefore calculated from subsistence harvest ASL samples using Equations 1–4 with deletion of subscript *i*, as was done for any unstratified escapement estimates.

Sport and Commercial Harvest

The number of sockeye salmon in the sport and commercial harvest by age or sex class *a* was estimated as follows:

$$\hat{H}_{SF\_Ca} = (H\hat{S}F + C)\,\hat{p}_a \tag{7}$$

where

$H\hat{S}F$ = SWHS estimate of total sport harvest,

C = commercial harvest, and

$\hat{p}_a$ = proportion of age or sex class *a* derived from escapement sampling (neither sport or commercial harvest was sampled for age or sex).

The variance of the number of fish in the sport and commercial harvest of age or sex class *a* was estimated according to Goodman (1960):

$$\mathrm{var}(\hat{H}_{SF\_Ca}) = (H\hat{S}F + C)^2\,\mathrm{var}(\hat{p}_a) + \hat{p}_a^2\,\mathrm{var}(H\hat{S}F) - \mathrm{var}(\hat{p}_a)\,\mathrm{var}(H\hat{S}F), \tag{8}$$

where

$\mathrm{var}(H\hat{S}F)$ = estimated variance of harvest, estimated from the SWHS.

Note that the commercial harvest (*C*) is obtained from fish tickets, and its variance is therefore considered zero.

Assessment of Age-Sex–Sampling Period Interactions

Log-linear analysis (e.g., Agresti [1990: 143]) on the counts of fish in the 3-way age-sex–sampling period contingency table was used to examine interactions. Models were chosen based on likelihood ratio tests.

Total Run Size Estimation

Sockeye salmon total run size ($\widehat{N}$) was estimated by summing weir counts, harvest from returned subsistence permits ($HSub$), harvest from unreturned subsistence permits ($\widetilde{H}Sub$), estimated sport harvest, and fish ticket tallies of commercial harvests. All components except the sport harvest were treated as censuses (total counts with zero variance). Total harvest, that included an estimate from unreturned subsistence permits, was estimated by assuming a harvest rate that was 65% of the harvest rate for returned permits:

$$\widetilde{H}Sub = HSub + \left[\frac{HSub}{p_r} - HSub\right] \times 0.65 \tag{9}$$

where

$HSub$ = reported subsistence harvest, and

p_r = proportion of issued permits returned.

A value of 0.65 was assumed reasonable based on estimated harvest rates for unreturned permits in other fisheries in the state of Alaska (0.69 for the Kenai River sockeye salmon dip net fishery and 0.66 for the Chitina sockeye salmon dip net fishery [Patricia Hansen, Biometrician, ADF&G, Anchorage, personal communication]). The adjustment is relatively small, and no variance component was calculated.

The number of sockeye salmon of age class *a* in the total run (N_a) to the Buskin River system and its variance were estimated by summing the component estimates from the escapement ($\hat{W}_a$), subsistence harvest ($HSub_a$ + $\widetilde{H}Sub_a$), and sport and commercial harvest ($\hat{H}_{SF\_Ca\ a}$), with variance (var[$\widehat{N}_a$]) calculated by summing the respective variance estimates. A covariance exists between the sport harvest estimate of the age class *a* and the escapement estimate of age class *a* (through $\hat{p}_a$). However, the covariances will be small because the sport harvest is always a relatively small component of the total run.

Exploitation Rate Estimation

Exploitation rates (μ) for the subsistence and sport fisheries were estimated as follows:

$$\hat{\mu} = \frac{H}{\hat{N}} \tag{10}$$

where *H* is either the subsistence harvest (zero variance) or sport harvest estimate and *N* is the total run.

The variance estimate of the subsistence exploitation rate was calculated using the delta method (Seber 1982: p. 8) as follows:

$$\text{var}(\hat{\mu}) = H^2 \frac{1}{\hat{N}^4} \text{var}(\hat{N})\,. \tag{11}$$

The variance of the sport fish exploitation rate was estimated as follows (Seber 1982):

$$\text{var}(\hat{\mu}) = \left(\frac{\hat{H}}{\hat{N}}\right)^2 \left(\frac{\text{var}(\hat{H})}{\hat{H}^2} + \frac{\text{var}(\hat{H})}{\hat{N}^2}\right). \tag{12}$$

Spawner–Recruit Analysis

The spawner–recruit relationship for Buskin River sockeye salmon was estimated using a Bayesian state-space Markov Chain Monte Carlo method with an underlying Ricker-type relationship (Ricker 1975; Fleischman et al. 2013).

The Bayesian state-space method has several advantages over the traditional spawner–recruit model. The method is capable of incorporating into parameter estimation the uncertainty associated with incomplete spawner-recruit datasets (such as missing age composition data), error in spawning escapement measurements (not considered problematic for this analysis), sampling variability in age composition estimation, serial correlation in returns, and other ad hoc sources of variability. These additional sources include errors in sport harvest and subsistence harvest estimation and the notion that the weir count at Buskin Lake represents minimum escapement. The Bayesian method also allows use of incomplete brood year data.

Markov Chain Monte Carlo (MCMC) methods, which are especially well-suited for modeling complex population and sampling processes, were used to obtain the Bayesian estimates. The MCMC algorithms were implemented in R (R Core Team 2017) using the package rjags (Plummer 2016).

The Bayesian MCMC analysis considers all the data simultaneously in the context of the following "full-probability" statistical model. Returns of sockeye salmon originating from spawning escapement in brood years y from 1990 to 2013 are modeled as a Ricker spawner-recruitment function with autoregressive lognormal errors:

$$\ln(R_y) = \ln(S_y) + \ln(\alpha) - \beta S_y + \phi \nu_{y-1} + \varepsilon_y , \qquad (13)$$

where R_y is the total return from brood year y, S_y is the spawning escapement in brood year y, α and β are Ricker parameters, ϕ is the autoregressive coefficient, $\{\nu_y\}$ are the model residuals

$$\nu_y = \ln(R_y) - \ln(S_y) - \ln(\alpha) + \beta S_y , \qquad (14)$$

and the $\{\varepsilon_y\}$ are independently and normally distributed process errors with mean zero and variance σ^2_{SR}.

Age-at-maturity vectors[3] $\underline{\boldsymbol{p}}_y = (p_{y4}, p_{y5}, p_{y6})$ from brood year y returning at ages 4–6 are drawn from a common Dirichlet($\gamma_4, \gamma_5, \gamma_6$) distribution (multivariate analogue of the beta). The Dirichlet parameters can also be expressed in an alternate form where

$$D = \sum_a \gamma_a \qquad (15)$$

is the (inverse) dispersion[4] of the annual age-at-maturity vectors, reflecting consistency of age at maturity among brood years.

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[3] Each vector is made up of age proportions that describe the maturity and survival schedules for a given brood year (cohort) across calendar years.

[4] A low value of D reflects a large amount of variability of age-at-maturity proportions $\underline{\boldsymbol{p}}$ among brood years whereas a high value of D indicates more consistency in $\underline{\boldsymbol{p}}$ over time.

The location parameters

$$\pi_a = \frac{\gamma_a}{D} \qquad (16)$$

are proportions that sum to one, reflecting the age-at-maturity central tendencies.

Age data were obtained from samples of both the escapement and subsistence harvest; the overall age composition sample size used in the Bayesian analysis was calculated as an effective sample size. The effective sample size was calculated as that sample size for which a simple random sample of ages yields variances of the age proportion estimates that are equal or close to the variances achieved under the stratified estimate.

The abundance N of age-a sockeye salmon in calendar year t ($t \in$ 1990–2017) is the product of the age proportion scalar p and the total return R from brood year $y = t-a$:

$$N_{ta} = R_{t-a}\ p_{t-a,a}\ . \qquad (17)$$

Total run during calendar year t is the sum of abundance at age across ages:

$$N_{t\cdot} = \sum_a N_{ta}\ . \qquad (18)$$

Spawning abundance is total abundance minus harvest,

$$S_t = N_{t\cdot} - HSF_t - HSub_t\,, \qquad (19)$$

where HSF_t is in turn the product of the annual exploitation rate μ_t and total run:

$$HSF_t = \mu_t N_t\,, \qquad (20)$$

and $HSub_t$ is

$$HSub_t = HSub_{pt} + \left[\frac{HSub_{pt}}{p_{rt}} - HSub_{pt}\right] p_h\,, \qquad (21)$$

where $HSub_{pt}$ is the (known) harvest from returned permits in year t, p_{rt} is the proportion of issued permits returned, and p_h is a discounting proportion accounting for the reduction in harvest rate associated with unreturned permits. The prior distribution on p_h was set as beta (1.9,1), an informative prior with mean 0.65.

Although spawners were counted at a weir, it was usual for some fish to escape to Buskin Lake either before or after the weir was installed and removed. The spawning escapement available for counting was modeled as follows:

$$W_t = \rho_t S_t \qquad (22)$$

where ρ_t is the proportion of the escapement available for counting in year t; the prior distribution on ρ_t was set as beta (30,1), an informative prior with mean 0.97.

Spawning abundance yielding peak return S_{MAX} is the inverse of the Ricker β parameter. Equilibrium spawning abundance S_{EQ} and spawning abundance leading to maximum sustained yield S_{MSY} are obtained using Equations 23 and 24 (Hilborn 1985):

$$S_{EQ} = \frac{\ln(\alpha)'}{\beta} \tag{23}$$

$$S_{MSY} \approx \frac{\ln(\alpha)'}{\beta}[0.5 - 0.07\ln(\alpha)'] \tag{24}$$

where $\ln(\alpha)'$ is corrected for AR(1) serial correlation as well as lognormal process error:

$$\ln(\alpha)' = \ln(\alpha) + \frac{\sigma_{SR}^2}{2(1-\varphi^2)}. \tag{25}$$

Expected sustained yield at a specified escapement S is calculated by subtracting spawning escapement from the expected return, again incorporating corrections for lognormal process error and AR(1) serial correlation:

$$SY = E[R] - S = Se^{\ln(\alpha') - \beta S} - S. \tag{26}$$

The harvest rate at MSY is calculated as

$$U_{MSY} = \ln(\alpha)'[0.5 - 0.07\ln(\alpha)'] \tag{27}$$

Probability that a given level of escapement would produce average yields exceeding 90% of MSY was obtained by calculating the expected sustained yield (*SY*; Equation 26) at multiple incremental values of *S* (0 to 10,000) for each Monte Carlo sample, then comparing *SY* with 90% of the value of MSY for that sample. The desired probability is the proportion of samples in which *SY* exceeds 0.9 MSY.

Observed data included estimates of spawning abundance (weir counts), estimates of sport harvest, subsistence harvest, and scale age counts. Likelihood functions for the data follow.

Weir counts were modeled as follows:

$$\hat{W}_t = W_t e^{\varepsilon_{Wt}} \tag{28}$$

where the $\{\varepsilon_{Wt}\}$ are normal$(0,\sigma^2_{Wt})$ with measurement error variance σ^2_{Wt}; the weir counts were conservatively assumed to have a coefficient of variation (CV_{Wt}) of 2%, with

$$\sigma_{Wt}^2 = \ln(CV_{Wt}^2 + 1). \tag{29}$$

Estimated sport harvest was modeled as

$$\hat{H}SF_t = HSF_t e^{\varepsilon_{Ht}} \tag{30}$$

Where the ε_{Ht} are normal(0,σ^2_{Ht}) with individual variances σ^2_{Ht} assumed known from the SWHS.

The number of fish sampled for scales (n) that were classified as age-a in calendar year t, x_{ta}, were assumed multinomially (r_{ta},n) distributed, with proportion parameters as follows:

$$r_{ta} = \frac{N_{ta}}{N_{t\cdot}} \tag{31}$$

and where

$$\sum_a r_{ta} = 1. \tag{32}$$

Bayesian analyses require that prior probability distributions be specified for all unknowns in the model. Noninformative priors (chosen to have a minimal effect on the posterior) were used almost exclusively. Initial returns R_{1984}–R_{1989} (those with no linked spawner abundance) were modeled as drawn from a common lognormal distribution with median μ_{LOGR} and variance σ^2_{LOGR}. Normal priors that had mean zero and very large variances, and were constrained to be positive, were used for ln(α) and β (Millar 2002), as well as for μ_{LOGR}. The initial model residual v_0 was given a normal prior with mean zero and variance σ^2_{SR} / ($1-\phi^2$). Diffuse conjugate inverse gamma priors were used for σ^2_{SR} and σ^2_{LOGR}. Annual exploitation rates {μ_t} were given beta(0.1, 0.1) prior distributions.

Markov-chain Monte Carlo samples were drawn from the joint posterior probability distribution of all unknowns in the model. For each of 2 Markov chains initialized, a 200,000-sample burn-in period was discarded. A total of 400,000 samples were then taken over 2 MCMC chains and thinned by 20, yielding a final sample of 20,000 to estimate the marginal posterior means, standard deviations, and percentiles. The Gelman-Rubin convergence diagnostics (Brooks and Gelman 1998), were invoked using the R-coda package functions gelman.diag() and gelman.plot(). Visual inspections of both trace plots of nodes known to converge slowly (e.g., plot of the node consisting of the sum of the Dirchlet parameters [D]) and autocorrelation plots were also used to assess mixing and convergence. Interval estimates were obtained from the percentiles of the posterior distribution. The rjags model code is given in Appendix C1.

RESULTS

2014 SEASON

Upper Buskin River Weir

The upper Buskin River weir was installed on May 17 and operated continuously through July 31. The cumulative weir count through July 31 was 13,198 sockeye salmon with 50% of the run passing the weir by June 15 (Appendix B1). The final sockeye salmon escapement estimate, based on the total weir count, through September 28 was 13,976 fish.

Age was determined for 304 of 352 sockeye salmon sampled for ASL at the upper Buskin River weir (Table 2). Of those with determined ages, 29.7% were age 1.3 and 18.2% were age 2.3, totaling 47.9% that had reared in the ocean for 3 years (Table 2). Most of the remaining escapement (50.7%) reared in the ocean for 2 years. Mean length of males (514 mm, SE 5) was significantly different than that of females (490 mm, SE 2) (2-sample *z*-test; |z| = 4.4, *P-val* < 0.001).

Log-linear modeling of counts in the 3-way age-sex-sampling period ("time") analysis showed that the no-interaction model (χ^2 = 18.56, df = 17, *P-val* = 0.35) was the best fit and indicates that neither age nor sex changed over sampling periods, and that age composition was the same for males and females. The sex ratio was 0.81 (males:females) and was significantly different from 1.0 (large-sample *z*-test; |z| = 1.98, *P-val* = 0.048).

Lake Louise Weir

The Lake Louise weir operated from June 4 to August 31. The cumulative weir count through July 31 was 85 sockeye salmon. The final sockeye salmon escapement estimate, based on the total weir count, was 925 fish, and it was not until August 11 that 50% of the run had passed the weir (Appendix B2).

Age was determined for 121 of 154 sockeye salmon sampled for ASL at the Lake Louise weir (Table 3). Of those with determined ages, about 39% had reared in the ocean for 3 years, and all but 1 were age 1.3. There were 53% age-2.2 and 6% age-1.2 salmon, totaling 59% ocean age-2 salmon in the sample (Table 3). Mean length of males (494 mm, SE 7) was not significantly different than that of females (489 mm, SE 5) (2-sample z-test; |z| = 0.65, *P-val* = 0.52).

Log-linear modeling of counts in the 3-way age-sex-time analysis showed the best-fitting model was one in which age is jointly independent of sex and time (χ^2 = 13.87, df = 9, *P-val* = 0.13). This model is slightly more complex than the no interaction model. The selected model implies age and sex are independent in the marginal table (i.e., collapsed over time), and that age and time are independent when collapsed over sex. The selected model implies that sex composition does, however, change over time. The overall sex ratio was 1.29 (males:females) and was not significantly different from 1.0 (large-sample *z*-test; |z| = 1.5; *P-val* = 0.13).

Age composition of the Lake Louise escapement differed significantly from that of the Buskin Lake escapement (chi-square test of independence; χ^2 = 44.8, df = 4, *P-val* < 0.001), with relatively more ocean-age-3 fish in the Buskin Lake escapement. Sex composition between these run components was also significantly different (large 2-sample *z*-test; |z| = 2.35, *P-val* = 0.02), with relatively more males in the Lake Louise escapement. The mean length of sockeye salmon passing the upper Buskin River weir (501 mm, SE 3) was not significantly different (2-sample *z*-test; |z| = 1.52, *P-val* = 0.13) than those passing the Lake Louise weir (492 mm, SE 5).

Table 2.–Estimated age and sex compositions and mean length-at-age of the sockeye salmon escapement at the upper Buskin River weir, 2014.

	Age												
Run component	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [a]
Females													
Number sampled	0	0	0	36	0	52	60	0	32	0	0	0	198
Proportion	0.00	0.00	0.00	0.12	0.00	0.16	0.19	0.00	0.11	0.00	0.00	0.00	0.55
SE proportion	0.00	0.00	0.00	0.02	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.03
Total escapement	0	0	0	1,682	0	2,303	2,663	0	1,488	0	0	0	7,737
SE escapement	0	0	0	268	0	299	316	0	254	0	0	0	379
Mean length				471		514	468		517				490
SE mean length				3		4	3		4				2
Minimum length				421		424	412		445				412
Maximum length				507		567	542		558				567
Males													
Number sampled	0	1	0	31	4	36	29	0	23	0	0	0	154
Proportion	0.00	0.00	0.00	0.10	0.01	0.13	0.09	0.00	0.08	0.00	0.00	0.00	0.45
SE proportion	0.00	0.00	0.00	0.02	0.01	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.03
Total escapement	0	36	0	1,467	158	1,847	1,270	0	1,061	0	0	0	6,239
SE escapement	0	35	0	253	80	285	231	0	216	0	0	0	379
Mean length		291		470	346	558	502		555				514
SE mean length				7	17	5	7		6				5
Minimum length		291		408	310	495	425		498				291
Maximum length		291		540	380	620	576		608				620
All													
Number sampled	0	1	0	67	4	88	89	0	55	0	0	0	352
Proportion	0.00	0.00	0.00	0.23	0.01	0.30	0.28	0.00	0.18	0.00	0.00	0.00	
SE proportion	0.00	0.00	0.00	0.02	0.01	0.03	0.03	0.00	0.02	0.00	0.00	0.00	
Total escapement	0	36	0	3,150	158	4,151	3,933	0	2,549	0	0	0	13,976
SE escapement	0	35	0	343	80	376	361	0	316	0	0	0	
Mean length		291		470	346	532	479		533				501
SE mean length				4	17	4	3		4				3
Minimum length		291		408	310	424	412		445				291
Maximum length		291		540	380	620	576		608				620

[a] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

Table 3.–Estimated age and sex compositions and mean length-at-age of the sockeye salmon escapement at Lake Louise weir, 2014.

	Age												
Run component	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [a]
Females													
Number sampled	0	0	0	5	0	16	24	0	0	0	0	0	54
Proportion	0.00	0.00	0.00	0.06	0.00	0.17	0.29	0.00	0.00	0.00	0.00	0.00	0.44
SE proportion	0.00	0.00	0.00	0.03	0.00	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.04
Total escapement	0	0	0	51	0	155	264	0	0	0	0	0	403
SE escapement	0	0	0	23	0	38	45	0	0	0	0	0	40
Mean length				477		503	476						489
SE mean length				10		8	6						5
Minimum length				449		442	438						438
Maximum length				501		547	563						563
Males													
Number sampled	0	5	0	3	6	33	27	1	1	0	0	0	100
Proportion	0.00	0.01	0.00	0.01	0.01	0.22	0.24	0.00	0.00	0.00	0.00	0.00	0.56
SE proportion	0.00	0.00	0.00	0.00	0.00	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.04
Total escapement	0	8	0	5	10	203	226	2	2	0	0	0	522
SE escapement	0	2	0	2	2	40	43	1	1	0	0	0	40
Mean length		349		496	336	548	481	500	520	363			494
SE mean length		8		17	8	5	6						7
Minimum length		325		465	317	492	425	500	520	363			317
Maximum length		375		523	360	645	558	500	520	363			645
All													
Number sampled	0	5	0	8	6	49	51	1	1	0	0	0	154
Proportion	0.00	0.01	0.00	0.06	0.01	0.39	0.53	0.00	0.00	0.00	0.00	0.00	
SE proportion	0.00	0.00	0.00	0.03	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00	
Total escapement	0	8	0	56	10	358	490	2	2	0	0	0	925
SE escapement	0	2	0	23	2	48	49	1	1	0	0	0	
Mean length		349		484	336	533	479	500	520	363			492
SE mean length		8		9	8	5	4						5
Minimum length		325		449	317	442	425	500	520	363			317
Maximum length		375		523	360	645	563	500	520	363			645

[a] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

Subsistence Harvest

The reported sockeye salmon subsistence harvest from the marine waters of the Buskin River drainage in 2014 was 5,616 fish (Table 1). About 84% of the permits were returned, resulting in an adjusted harvest of 6,290 fish. Age was determined for 154 of 185 fish sampled for ASL from the harvest (Table 4).

About 72% of sampled sockeye salmon harvested in the subsistence fishery reared in the ocean for 3 years. Ages 1.3 (38.3%) and 2.3 (33.8%) composed the dominant age groups in the subsistence harvest sample (Table 4). About 27% of the sampled sockeye salmon reared in the ocean for 2 years, mostly as age 2.2. Mean length of males (534 mm, SE 4) was significantly different (2-sample *z*-test; $|z| = 2.73$, *P-val* = 0.006) from that of females (519 mm, SE 3).

Log-linear modeling of counts in the 3-way age-sex-time analysis showed that the best fitting model was one in which time is jointly independent of sex and age ($\chi^2 = 13.2$, df = 7, *P-val* = 0.07). The selected model implies time and sex are independent in the marginal table (i.e., collapsed over age), and that age and time are independent when collapsed over sex. The selected model implies that sex composition does, however, change over age. The sex ratio was 1.3 (males:females) and was significantly different from 1.0 (large-sample *z*-test; $|z| = 2.13$; *P-val* = 0.034).

The age composition of the subsistence harvest was significantly different ($\chi^2 = 29.2$, df = 3, *P-val* < 0.001) from that of the Buskin Lake escapement, with relatively more ocean-age-3 fish in the harvest. Sex composition between harvest and run was also significantly different (large 2-sample *z*-test; $|z| = 2.89$, *P-val* = 0.004), with more males in the harvest. Sockeye salmon harvested by the subsistence fishery averaged 527 mm (SE 3) in length compared to fish sampled at the Buskin River weir, which averaged 500 mm (SE 3), and this was significantly different (2-sample *z*-test; $|z| = 7.1$, *P-val* < 0.001).

Sport and Commercial Fisheries

In 2014, anglers fishing the Buskin River drainage caught an estimated 6,165 (SE 1,647) sockeye salmon and harvested 4,237 (SE 1,139) sockeye salmon, expending 20,015 (SE 3,440) angler-days of effort for all species during the entire year (Table 1). For sockeye salmon harvested in the sport fishery, age-sex composition was assumed to be identical to that of the Buskin Lake escapement and harvest by age and sex was calculated according to those proportions (Table 5).

Fish ticket harvest receipts from CF indicate that zero sockeye salmon were harvested at the mouth of the Buskin River in Womens Bay, statistical areas 259-22 and 259-26, during 2014.

Table 4.–Estimated age and sex composition and mean length-at-age of the reported sockeye salmon subsistence harvest for the Buskin River drainage, 2014.

		Age												
Run component		0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [a]
Females														
	Number sampled	0	0	0	0	0	32	10	0	21	0	1	0	80
	Proportion	0.00	0.00	0.00	0.00	0.00	0.21	0.06	0.00	0.14	0.00	0.01	0.00	0.44
	SE proportion	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.03	0.00	0.01	0.00	0.04
	Total escapement	0	0	0	0	0	1,307	408	0	858	0	41	0	2,765
	SE escapement	0	0	0	0	0	204	124	0	172	0	40	0	229
	Mean length						527	483		529		538		519
	SE mean length						4	4		5				3
	Minimum length						470	456		468		538		456
	Maximum length						571	505		561		538		571
Males														
	Number sampled	0	0	0	12	0	27	20	0	31	0	0	0	105
	Proportion	0.00	0.00	0.00	0.08	0.00	0.18	0.13	0.00	0.20	0.00	0.00	0.00	0.58
	SE proportion	0.00	0.00	0.00	0.02	0.00	0.03	0.03	0.00	0.03	0.00	0.00	0.00	0.04
	Total escapement	0	0	0	490	0	1,103	817	0	1,266	0	0	0	3,629
	SE escapement	0	0	0	135	0	191	169	0	201	0	0	0	228
	Mean length				485		556	506		547				534
	SE mean length				10		7	6		5				4.3
	Minimum length				422		500	445		485				347
	Maximum length				526		650	548		608				650
All														
	Number sampled	0	0	0	12	0	59	30	0	52	0	1	0	185
	Proportion	0.00	0.00	0.00	0.08	0.00	0.38	0.19	0.00	0.34	0.00	0.01	0.00	
	SE proportion	0.00	0.00	0.00	0.02	0.00	0.04	0.03	0.00	0.04	0.00	0.01	0.00	
	Total escapement	0	0	0	490	0	2,410	1,225	0	2,124	0	41	0	6,290
	SE escapement	0	0	0	135	0	244	199	0	238	0	40	0	
	Mean length				485		540	498		540		538		527
	SE mean length				10		4	4		4				3
	Minimum length				422		470	445		468		538		347
	Maximum length				526		650	548		608		538		650

[a] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

Table 5.–Estimated age and sex composition and mean length-at-age of the sockeye salmon sport and commercial harvest combined for the Buskin River drainage, 2014.

		Age												
Run component [a]		0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [b]
Females														
	Proportion	0.00	0.00	0.00	0.12	0.00	0.16	0.19	0.00	0.11	0.00	0.00	0.00	0.55
	SE proportion	0.00	0.00	0.00	0.02	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.03
	Harvest	0	0	0	510	0	698	807	0	451	0	0	0	23
	SE harvest	0	0	0	158	0	207	236	0	142	0	0	0	6
Males														
	Proportion	0.00	0.00	0.00	0.10	0.01	0.13	0.09	0.00	0.08	0.00	0.00	0.00	0.45
	SE proportion	0.00	0.00	0.00	0.02	0.01	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.03
	Harvest	0	11	0	445	48	560	385	0	322	0	0	0	19
	SE harvest	0	11	0	141	27	172	123	0	107	0	0	0	5
All														
	Proportion	0.00	0.00	0.00	0.23	0.01	0.30	0.28	0.00	0.18	0.00	0.00	0.00	
	SE proportion	0.00	0.00	0.00	0.02	0.01	0.03	0.03	0.00	0.02	0.00	0.00	0.00	
	Harvest	0	11	0	955	48	1,258	1,192	0	773	0	0	0	4,237
	SE harvest	0	11	0	276	27	356	337	0	227	0	0	0	

[a] There was no commercial harvest of Buskin River drainage sockeye salmon. Sport harvest estimates are calculated using the age-sex proportions of the upper Buskin River weir escapement (Table 2).

[b] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

2015 SEASON

Upper Buskin River Weir

The upper Buskin River weir was installed on May 19 and operated continuously through July 31, 2015. The cumulative weir count through 31 July was 7,814 sockeye salmon, with 50% of the run passing the weir by July 3 (Appendix B1). The final escapement estimate based on the weir count through October 8 was 8,719 fish.

Age was determined for 308 of 367 sockeye salmon sampled for ASL at the Upper Buskin River weir (Table 6). Of those with determined ages, 41.4% were age 1.3 and 32.1% were age 2.3, totaling about 74% that had reared in the ocean for 3 years. There were 8.0% age-1.2 and 15.9% age-2.2 fish, totaling about 24% ocean-age-2 fish in the sample (Table 6). Mean length of males (521 mm, SE 4) was significantly different (2-sample *z*-test; |z| = 3.29, *P-val* = 0.001) from that of females (505 mm, SE 2).

Log-linear modeling of counts in the 3-way age-sex-time analysis showed the best fitting model had time jointly independent of sex and age (χ^2 = 14.64, df = 14, *P-val* = 0.4). The selected model implies time and sex are independent in the marginal table (i.e., collapsed over age), and that age and time are independent when collapsed over sex. The selected model implies that sex composition does, however, change over age. The sex ratio was 1.06 (males:females) and was not significantly different from 1.0 (large-sample *z*-test; |z| = 0.52; *P-val* = 0.60).

Lake Louise Weir

The Lake Louise weir was operated continuously from June 2 to September 23, 2015. The cumulative count through July 31 was 58 sockeye salmon. The final sockeye salmon count at the weir was 280 fish, with 50% of the run passing the weir by August 5 (Appendix B2). Similar to other years, daily peak counts coincided with high water events. More than 37% of the total weir count occurred during August 4 and 5.

Age was determined for 38 of 100 sockeye salmon sampled for ASL at the Lake Louise weir (Table 7). During the late portion of the season, fish were particularly sensitive to sampling during warm, dry weather, so many fish were measured for length and released without taking scale samples. For sockeye salmon with determined ages, about 1.4% were age 1.3 and 15.2% were age 2.3, totaling about 17% that reared in the ocean for 3 years. There were 14.5% age-1.2 fish and 32.4% age-2.2 fish in the sample, totaling about 47% that reared in the ocean for 2 years (Table 7). Mean length of males (437 mm, SE 9) was not significantly different (2-sample *z*-test; *P-val* = 0.06) than that of females (459 mm, SE 8).

Data were too sparse to conduct a loglinear analysis of age-sex-time factors. The sex ratio was 1.93 (males:females) and was significantly different from 1.0 (large-sample *z*-test; |z| = 4.1; *P-val* < 0.001).

Age composition of the Lake Louise escapement differed significantly from that of the Buskin Lake escapement (chi-square test of independence; χ^2 = 85.4, df = 4, *P-val* < 0.001) with relatively more ocean-age-3 fish in the Buskin Lake escapement. Sex composition also differed (large two-sample *z*-test; |z| =2.93, *P-val* = 0.003) with relatively more males in the Lake Louise escapement. Mean length of sockeye salmon passing the Buskin Lake weir (513 mm, SE 2) was significantly different (2-sample *z*-test; |z| = 4.39, *P-val* < 0.001) than that of sockeye salmon passing the Lake Louise weir (445 mm, SE 6).

Table 6.–Estimated age and sex compositions and mean length-at-age of the sockeye salmon escapement at upper Buskin River weir, 2015.

	Age												
Run component	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [a]
Females													
Number sampled	0	0	0	13	0	69	19	0	61	0	0	0	190
Proportion	0.00	0.00	0.00	0.03	0.00	0.21	0.06	0.00	0.20	0.00	0.00	0.00	0.48
SE proportion	0.00	0.00	0.00	0.01	0.00	0.03	0.01	0.00	0.03	0.00	0.00	0.00	0.03
Total escapement	0	0	0	269	0	1,803	502	0	1,759	0	0	0	4,223
SE escapement	0	0	0	75	0	222	127	0	238	0	0	0	261
Mean length				459		511	483		513				505
SE mean length				8		3	9		4				2
Minimum length				414		430	428		436				414
Maximum length				504		565	589		590				590
Males													
Number sampled	0	1	0	18	3	55	34	1	33	0	1	0	177
Proportion	0.00	0.00	0.00	0.05	0.01	0.21	0.10	0.00	0.12	0.00	0.01	0.00	0.52
SE proportion	0.00	0.00	0.00	0.01	0.01	0.03	0.02	0.00	0.02	0.00	0.01	0.00	0.03
Total escapement	0	20	0	430	112	1,809	888	15	1,039	0	72	0	4,495
SE escapement	0	19	0	105	77	250	171	15	202	0	72	0	261
Mean length		335		483	349	553	488	588	546		555		521
SE mean length				9	6	4	6		5				4
Minimum length		335		418	342	434	405	588	496		555		335
Maximum length		335		562	361	616	578	588	604		555		616
All													
Number sampled	0	1	0	31	3	124	53	1	94	0	1	0	367
Proportion	0.00	0.00	0.00	0.08	0.01	0.41	0.16	0.00	0.32	0.00	0.01	0.00	
SE proportion	0.00	0.00	0.00	0.01	0.01	0.03	0.02	0.00	0.03	0.00	0.01	0.00	
Total escapement	0	20	0	699	112	3,612	1,390	15	2,798	0	72	0	8,718
SE escapement	0	19	0	126	77	292	205	15	279	0	72	0	
Mean length		335		473	349	530	486	588	525		555		513
SE mean length				6	6	3	5		3				2
Minimum length		335		414	342	430	405	588	436		555		335
Maximum length		335		562	361	616	589	588	604		555		616

[a] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

Table 7.–Estimated age and sex compositions and mean length-at-age of the sockeye salmon escapement at Lake Louise weir, 2015.

	Age												
Run component	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [a]
Females													
Number sampled	0	0	0	3	1	0	6	0	1	0	0	0	34
Proportion	0.00	0.00	0.00	0.06	0.03	0.00	0.14	0.00	0.03	0.00	0.00	0.00	0.34
SE proportion	0.00	0.00	0.00	0.04	0.03	0.00	0.06	0.00	0.03	0.00	0.00	0.00	0.04
Total escapement	0	0	0	17	10	0	41	0	10	0	0	0	95
SE escapement	0	0	0	10	9	0	16	0	9	0	0	0	11
Mean length				456	388		464		470				459
SE mean length				16			13						8
Minimum length				426	388		440		470				334
Maximum length				482	388		525		470				544
Males													
Number sampled	0	3	0	3	9	1	7	0	4	0	0	0	66
Proportion	0.00	0.04	0.00	0.08	0.29	0.01	0.18	0.00	0.12	0.00	0.00	0.00	0.66
SE proportion	0.00	0.02	0.00	0.05	0.08	0.01	0.06	0.00	0.06	0.00	0.00	0.00	0.04
Total escapement	0	12	0	23	81	4	50	0	33	0	0	0	185
SE escapement	0	5	0	13	22	3	18	0	15	0	0	0	11
Mean length		352		473	352	528	466		512				437
SE mean length		35		19	9		5		8				9
Minimum length		288		438	310	528	452		500				288
Maximum length		410		503	390	528	487		535				556
All													
Number sampled	0	3	0	6	10	1	13	0	5	0	0	0	100
Proportion	0.00	0.04	0.00	0.14	0.32	0.01	0.32	0.00	0.15	0.00	0.00	0.00	
SE proportion	0.00	0.02	0.00	0.06	0.08	0.01	0.08	0.00	0.06	0.00	0.00	0.00	
Total escapement	0	12	0	41	91	4	91	0	42	0	0	0	280
SE escapement	0	5	0	16	22	3	22	0	17	0	0	0	
Mean length		352		464	356	528	465		503				445
SE mean length		35		12	9		6		11				6
Minimum length		288		426	310	528	440		470				288
Maximum length		410		503	390	528	525		535				556

[a] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

Subsistence Harvest

The reported sockeye salmon subsistence harvest from marine waters of the Buskin River system in 2015 was 3,920 fish (Table 1). About 88% of the permits were returned, and the adjusted harvest was 4,281 sockeye salmon. Age was determined for 251 of 271 sockeye salmon sampled for ASL from the harvest, and of these 52.6% were age 1.3 and 32.3% were age 2.3, totaling about 85% that reared in the ocean for 3 years (Table 8). The remaining salmon sampled reared in the ocean for 2 years; 4% were age 1.2 and 10% were age 2.2. Mean length of males (534 mm, SE 3) differed significantly (2-sample *z* test; $|z| = 7.48$, $P\text{-}val < 0.001$) from females (509 mm, SE 20).

Log-linear modeling of counts in the 3-way age-sex-sampling period ("time") analysis showed that the no-interaction model ($\chi^2 = 14.48$, df = 10, $P\text{-}val = 0.15$) was the best fit and indicates that neither age nor sex changed over time, and that age composition is the same for males and females. The sex ratio was1.1 (males:females) and was not significantly different from 1.0 (large-sample *z*-test; $|z| = 0.82$, $P\text{-}val = 0.41$).

Age composition of sockeye salmon harvested in the subsistence fishery was significantly different (chi-square test of independence; $\chi^2 = 16.9$, df = 3, $P\text{-}val < 0.001$) from that of the Buskin Lake escapement, with relatively more ocean-age-3 fish in the harvest. Sex composition between run components was not significantly different (large 2-sample *z*-test; $|z| = 0.20$, $P\text{-}val = 0.84$). The mean length of sockeye salmon harvested by subsistence users (522 mm, SE 2) was significantly different (2-sample *z*-test; $|z| = 3.2$, $P\text{-}val = 0.001$) from that of the Buskin Lake escapement (513 mm, SE 2).

Sport and Commercial Fisheries

In 2015, anglers fishing the Buskin River drainage caught an estimated 5,807 (SE 1,550) sockeye salmon and harvested 3,978 (SE 1,130), expending 12,808 (SE 2,847) angler-days of effort for all species during the year (Table 1).

Fish ticket harvest receipts available from CF indicate that 2 sockeye salmon were harvested adjacent to the Buskin River in Womens Bay, statistical areas 259-22 and 259-26, during 2015.

The age-sex composition of the combined sport and commercial harvests of Buskin River drainage sockeye salmon was assumed to be identical to that of the upper Buskin River weir escapement, and harvest by age and sex was calculated according to those proportions (Table 9).

Table 8.–Estimated age and sex compositions and mean length-at-age of the reported sockeye salmon subsistence harvest for the Buskin River drainage, 2015.

	Age												
Run component	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [a]
Females													
Number sampled	0	0	0	3	0	68	5	0	45	1	0	0	129
Proportion	0.00	0.00	0.00	0.01	0.00	0.27	0.02	0.00	0.18	0.00	0.00	0.00	0.48
SE proportion	0.00	0.00	0.00	0.01	0.00	0.03	0.01	0.00	0.02	0.00	0.00	0.00	0.03
Total escapement	0	0	0	51	0	1,160	85	0	767	17	0	0	2,038
SE escapement	0	0	0	29	0	117	37	0	101	17	0	0	126
Mean length				485		511	473		512	489			510
SE mean length				25		2	18		3				2
Minimum length				454		464	421		466	489			421
Maximum length				534		551	510		558	489			575
Males													
Number sampled	0	0	1	7	0	64	20	1	36	0	0	0	142
Proportion	0.00	0.00	0.00	0.03	0.00	0.25	0.08	0.00	0.14	0.00	0.00	0.00	0.52
SE proportion	0.00	0.00	0.00	0.01	0.00	0.03	0.02	0.00	0.02	0.00	0.00	0.00	0.03
Total escapement	0	0	17	119	0	1,092	341	17	614	0	0	0	2,243
SE escapement	0	0	17	43	0	114	71	17	92	0	0	0	126
Mean length			537	507		536	518	570	543				534
SE mean length				12		3	10		4				3
Minimum length			537	475		446	430	570	502				430
Maximum length			537	568		598	621	570	601				621
All													
Number sampled	0	0	1	10	0	132	25	1	81	1	0	0	271
Proportion	0.00	0.00	0.00	0.04	0.00	0.53	0.10	0.00	0.32	0.00	0.00	0.00	
SE proportion	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	
Total escapement	0	0	17	171	0	2,251	426	17	1,381	17	0	0	4,281
SE escapement	0	0	17	51	0	131	79	17	123	17	0	0	
Mean length			537	500		523	509	570	526	489			522
SE mean length				11		2	9		3				2
Minimum length			537	454		446	421	570	466	489			421
Maximum length			537	568		598	621	570	601	489			621

[a] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

Table 9.–Estimated age and sex compositions and mean length-at-age of the sockeye salmon sport and commercial harvests combined for the Buskin River drainage, 2015.

	Age												
Run component [a]	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [b]
Females													
Proportion	0.00	0.00	0.00	0.03	0.00	0.21	0.06	0.00	0.20	0.00	0.00	0.00	0.48
SE proportion	0.00	0.00	0.00	0.01	0.00	0.03	0.01	0.00	0.03	0.00	0.00	0.00	0.03
Harvest	0	0	0	123	0	825	230	0	805	0	0	0	19
SE harvest	0	0	0	48	0	253	86	0	251	0	0	0	6
Males													
Proportion	0.00	0.00	0.00	0.05	0.01	0.21	0.10	0.00	0.12	0.00	0.01	0.00	0.52
SE proportion	0.00	0.00	0.00	0.01	0.01	0.03	0.02	0.00	0.02	0.00	0.01	0.00	0.03
Harvest	0	9	0	197	51	828	406	7	476	0	33	0	21
SE harvest	0	9	0	72	37	259	137	7	161	0	33	0	6
All													
Proportion	0.00	0.00	0.00	0.08	0.01	0.41	0.16	0.00	0.32	0.00	0.01	0.00	
SE proportion	0.00	0.00	0.00	0.01	0.01	0.03	0.02	0.00	0.03	0.00	0.01	0.00	
Harvest	0	9	0	320	51	1,653	636	7	1,281	0	33	0	3,990
SE harvest	0	9	0	106	37	485	201	7	383	0	33	0	

[a] Combined sport and commercial harvest estimates are calculated using the age-sex proportions of the upper Buskin River weir escapement (Table 6).

[b] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

2016 SEASON

Upper Buskin River Weir

The Buskin River weir was installed on May 17 and operated continually through July 31, 2016. The cumulative count at the weir through 31 July was 10,351 sockeye salmon with 50% passing the weir by June 22 (Appendix B1). The final sockeye salmon escapement estimate, based on the total weir count through September 29, was 11,584 fish.

Age was determined for 309 of 361 sockeye salmon sampled for ASL and of these, 23.3% were age 1.3 and 23.2% were age 2.3, totaling about 47% that reared in the ocean for 3 years (Table 10). Most of the remaining sockeye salmon (52.5%) reared in the ocean for 2 years; 15% were age 1.2 and 38% were age 2.2. Mean length of males (510 mm, SE 4) was significantly different from that of females (485 mm, SE 3) (2-sample z test; $|z| = 4.82$, $P\text{-}val < 0.001$).

Log-linear modeling of counts in the 3-way age-sex-time analysis showed that the best fitting model was one in which time is jointly independent of sex and age ($\chi^2 = 15.56$, df = 14, $P\text{-}val = 0.34$). The selected model implies time and sex are independent in the marginal table (i.e., collapsed over age), and that age and time are independent when collapsed over sex. The selected model implies that sex composition does, however, change over age. The sex ratio was 1.1 (males:females) and was not significantly different from 1.0 (large-sample z-test; $|z| = 0.84$; $P\text{-}val = 0.40$).

Table 10.–Estimated age and sex compositions and mean length-at-age of the sockeye salmon escapement at the upper Buskin River weir, 2016.

	Age												
Run component	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [a]
Females													
Number sampled	0	1	0	14	0	33	74	0	29	0	0	0	176
Proportion	0.00	0.00	0.00	0.05	0.00	0.11	0.23	0.00	0.09	0.00	0.00	0.00	0.48
SE proportion	0.00	0.00	0.00	0.01	0.00	0.02	0.03	0.00	0.02	0.00	0.00	0.00	0.03
Total escapement	0	24	0	518	0	1,275	2,596	0	1,037	0	0	0	5,368
SE escapement	0	24	0	153	0	235	308	0	214	0	0	0	333
Mean length		385		457		516	468		512				485
SE mean length				6		4	3		6				3
Minimum length		385		420		473	375		440				375
Maximum length		385		490		570	559		563				570
Males													
Number sampled	0	0	1	27	4	37	49	0	40	0	0	0	185
Proportion	0.00	0.00	0.00	0.10	0.01	0.12	0.15	0.00	0.14	0.00	0.00	0.00	0.52
SE proportion	0.00	0.00	0.00	0.02	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.03
Total escapement	0	0	17	1,123	76	1,357	1,689	0	1,585	0	0	0	5,929
SE escapement	0	0	17	221	37	247	260	0	266	0	0	0	333
Mean length			500	458	351	556	497		540				510
SE mean length				8	21	5	5		7				4
Minimum length			500	398	297	504	405		405				297
Maximum length			500	560	390	650	570		620				650
All													
Number sampled	0	1	1	41	4	70	123	0	69	0	0	0	361
Proportion	0.00	0.00	0.00	0.15	0.01	0.23	0.38	0.00	0.23	0.00	0.00	0.00	
SE proportion	0.00	0.00	0.00	0.02	0.00	0.03	0.03	0.00	0.03	0.00	0.00	0.00	
Total escapement	0	24	17	1,641	76	2,632	4,284	0	2,621	0	0	0	11,297
SE escapement	0	24	17	258	37	318	356	0	318	0	0	0	
Mean length		385	500	457	351	537	479		528				498
SE mean length				6	21	4	3		5				3
Minimum length		385	500	398	297	473	375		405				297
Maximum length		385	500	560	390	650	570		620				650

[a] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

Lake Louise Weir

The Lake Louise weir was operated continuously from June 27 to September 12, 2016. The cumulative count at the weir through July 31 was 31 sockeye salmon. The final sockeye salmon weir count was 156 (Appendix B2), with over 50% passing the weir by August 19.

Age was determined for all 13 sockeye salmon sampled for ASL. Escapement was sporadic and occurred on only a few days with high water levels, making the sampling problematic. Due to the sparse sample size, no age, sex or length estimation was made for Lake Louise sockeye salmon in 2016.

Subsistence Harvest

The reported sockeye salmon subsistence harvest from marine waters of the Buskin River system in 2016 was 4,767 fish (Table 1). About 85% of the permits were returned, resulting in an adjusted harvest of 5,247. Age was determined for 177 of 210 sockeye salmon sampled for ASL from the 2016 harvest (Table 11). Of those with determined ages, 37.9% were age 1.3, and 35.6% were age 2.3 totaling about 73% that reared in the ocean for 3 years (Table 11). Most of the remaining sockeye salmon reared in the ocean for 2 years; 6% were age 1.2 and 20.3% were age 2.2. Mean length of males (526 mm, SE 2) was significantly different (2-sample *z*-test; $|z| = 5.0$, *P-val* < 0.001) from that of females (505 mm, SE 3).

Log-linear modeling of counts in the 3-way age-sex-time analysis showed that the best-fitting model is a no-interaction model ($\chi^2 = 6.68$, df = 10, *P-val* = 0.76) where neither age nor sex change over the sampling period, and age composition is the same for males and females. The sex ratio was 1.53 (males:females) and was not significantly different from 1.0 (large-sample *z*-test; $|z| = 3.2$, *P-val* = 0.002).

The age composition of the subsistence harvest was significantly different (chi-square test of independence; $\chi^2 = 34.6$, df = 3, *P-val* < 0.001) from that of the Buskin Lake escapement, which had relatively fewer ocean-age-3 fish, but sex composition was not significantly different (large 2-sample *z* test; $|z| = 1.8$, *P-val* = 0.07). The mean length of sockeye salmon harvested by subsistence users (517 mm, SE 2) was not significantly different (2-sample *z*-test; $|z| = 1.78$, *P-val* < 0.08) from that of Buskin Lake sockeye salmon (498 mm, SE 11).

Sport and Commercial Fisheries

In 2016, anglers fishing the Buskin River drainage caught an estimated 3,247 sockeye salmon and harvested 2,503 sockeye salmon (SE 1,523), expending 8,141 (SE 1,773) angler-days of effort for all species during the year (Table 1). For sockeye salmon harvested in the sport fishery, age-sex composition was assumed to be identical to that of the Buskin Lake escapement and harvest by age and sex was calculated according to those proportions (Table 12).

Fish ticket harvest receipts available from CF indicate that no sockeye salmon were harvested adjacent to the Buskin River in Womens Bay, statistical areas 259-22 and 259-26, during 2016.

Table 11.–Estimated age and sex compositions, and mean length-at-age of the reported sockeye salmon subsistence harvest for the Buskin River drainage, 2016.

	Age												
Run component	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [a]
Females													
Number sampled	0	0	0	4	0	30	14	0	24	0	0	0	83
Proportion	0.00	0.00	0.00	0.02	0.00	0.17	0.08	0.00	0.14	0.00	0.00	0.00	0.40
SE proportion	0.00	0.00	0.00	0.01	0.00	0.03	0.02	0.00	0.03	0.00	0.00	0.00	0.03
Total escapement	0	.	0	121	0	905	422	0	724	0	0	0	2,074
SE escapement	0	0	0	58	0	147	106	0	134	0	0	0	174
Mean length				460		508	479		522				505
SE mean length				10		4	7		5				3
Minimum length				440		456	418		472				418
Maximum length				480		555	525		575				575
Males													
Number sampled	0	0	0	7	0	37	20	0	38	0	0	0	127
Proportion	0.00	0.00	0.00	0.04	0.00	0.21	0.11	0.00	0.22	0.00	0.00	0.00	0.60
SE proportion	0.00	0.00	0.00	0.01	0.00	0.03	0.02	0.00	0.03	0.00	0.00	0.00	0.03
Total escapement	0	0	0	211	0	1,116	603	0	1,146	0	0	0	3,173
SE escapement	0	0	0	76	0	159	124	0	161	0	0	0	174
Mean length				498		531	505		534				526
SE mean length				7		3	6		4				2
Minimum length				480		495	425		425				425
Maximum length				525		577	549		620				620
All													
Number sampled	0	0	0	11	0	67	36	0	63	0	0	0	210
Proportion	0.00	0.00	0.00	0.06	0.00	0.38	0.20	0.00	0.36	0.00	0.00	0.00	
SE proportion	0.00	0.00	0.00	0.02	0.00	0.04	0.03	0.00	0.04	0.00	0.00	0.00	
Total escapement	0	0	0	326	0	1,986	1,067	0	1,868	0	0	0	5,247
SE escapement	0	0	0	94	0	189	156	0	186	0	0	0	
Mean length				484		521	493		529				517
SE mean length				8		3	5		3				2
Minimum length				440		456	418		425				418
Maximum length				525		577	549		620				620

[a] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

Table 12.–Estimated age and sex compositions and mean length-at-age of the sockeye salmon sport and commercial harvest combined for the Buskin River drainage, 2016.

	Age												
Run component [a]	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [b]
Females													
Proportion	0.00	0.00	0.00	0.05	0.00	0.11	0.23	0.00	0.09	0.00	0.00	0.00	0.48
SE proportion	0.00	0.00	0.00	0.01	0.00	0.02	0.03	0.00	0.02	0.00	0.00	0.00	0.03
Harvest	0	5	0	115	0	283	575	0	230	0	0	0	7
SE harvest	0	5	0	75	0	177	354	0	145	0	0	0	3
Males													
Proportion	0.00	0.00	0.00	0.10	0.01	0.12	0.15	0.00	0.14	0.00	0.00	0.00	0.52
SE proportion	0.00	0.00	0.00	0.02	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.03
Harvest	0	0	4	249	17	301	374	0	351	0	0	0	8
SE harvest	0	0	4	156	12	188	232	0	219	0	0	0	3
All													
Proportion	0.00	0.00	0.00	0.15	0.01	0.23	0.38	0.00	0.23	0.00	0.00	0.00	
SE proportion	0.00	0.00	0.00	0.02	0.00	0.03	0.03	0.00	0.03	0.00	0.00	0.00	
Harvest	0	5	4	364	17	583	949	0	581	0	0	0	1,485
SE harvest	0	5	4	226	12	359	581	0	358	0	0	0	

[a] There was no commercial harvest of Buskin River drainage sockeye salmon. Sport harvest estimates are calculated using the age-sex proportions of the upper Buskin River weir escapement (Table 10).

[b] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

2017 SEASON

Upper Buskin River Weir

The Buskin River weir was installed on May 20 and operated continuously through July 31, 2017. The cumulative count at the weir through July 31 was 7,210 sockeye salmon, with 50% passing the weir by June 7 (Appendix B1). The final sockeye salmon escapement estimate, based on the total weir count through September 27, was 7,222 fish.

Age was determined for 241 of 296 sockeye salmon sampled for ASL, and of these, 27.4 % were age 1.3 and 60.5 % were age 2.3, totaling about 88% that reared in the ocean for 3 years (Table 13). Most of the remaining fish reared in the ocean for 2 years; 1% were age 1.2 and 8% were age 2.2. Mean lengths of males (540 mm, SE 4) and females (514 mm, SE 2) were significantly different (2-sample z-test; $|z| = 5.54$, $P\text{-}val < 0.001$).

Log-linear modeling of counts in the 3-way age-sex-time analysis showed the best-fitting model is one with age conditionally independent of sex. This model indicates that age is independent of sex, within a time stratum. The sex ratio was 0.74 (males:females) and was significantly different from 1.0 (large-sample z-test; $|z| = 2.4$; $P\text{-}val = 0.02$).

Table 13.–Estimated age and sex compositions and mean length-at-age of the sockeye salmon escapement at upper Buskin River weir, 2017.

	Age												
Run component	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [a]
Females													
Number sampled	0	0	0	1	0	30	9	1	74	0	1	0	147
Proportion	0.00	0.00	0.00	0.00	0.00	0.18	0.03	0.01	0.35	0.00	0.01	0.00	0.57
SE proportion	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.04	0.00	0.01	0.00	0.03
Total escapement	0	0	0	7	0	1315	192	52	2524	0	52	0	4146
SE escapement	0	0	0	6	0	224	79	51	265	0	51	0	225
Mean length				475		520	473	528	515		540		514
SE mean length						5	12		3				2
Minimum length				475		460	430	528	463		540		421
Maximum length				475		590	552	528	580		540		590
Males													
Number sampled	0	3	0	2	1	25	16	0	76	0	2	0	149
Proportion	0.00	0.00	0.00	0.01	0.00	0.09	0.05	0.00	0.26	0.00	0.01	0.00	0.43
SE proportion	0.00	0.00	0.00	0.01	0.00	0.02	0.02	0.00	0.03	0.00	0.01	0.00	0.03
Total escapement	0	28	0	66	15	665	391	0	1846	0	67	0	3073
SE escapement	0	17	0	53	15	155	119	0	227	0	53	0	225
Mean length		368		470	320	557	489		554		534		540
SE mean length		61		80		5	10		3		34		4
Minimum length		300		390	320	517	424		420		500		300
Maximum length		490		550	320	605	550		606		567		606
All													
Number sampled	0	3	0	3	1	55	25	1	150	0	3	0	296
Proportion	0.00	0.00	0.00	0.01	0.00	0.27	0.08	0.01	0.61	0.00	0.02	0.00	
SE proportion	0.00	0.00	0.00	0.01	0.00	0.03	0.02	0.01	0.04	0.00	0.01	0.00	
Total escapement	0	28	0	73	15	1980	583	52	4370	0	119	0	7219
SE escapement	0	17	0	53	15	251	141	51	270	0	74	0	
Mean length		368		472	320	537	483	528	535		536		527
SE mean length		61		46		4	8		3		19		2
Minimum length		300		390	320	460	424	528	420		500		300
Maximum length		490		550	320	605	552	528	606		567		606

[a] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

Lake Louise Weir

The Lake Louise weir was operated continuously from June 2 to September 4, 2017. The cumulative count at the weir through July 31 was 70 sockeye salmon. The final sockeye salmon weir count was 141 fish, with over 50% passing the weir by 7 August (Appendix B2).

Age was determined for 63 of 68 sockeye salmon sampled for ASL (Table 14). Of these, 25.3% were age 1.3 and 16.8% were age 2.3, totaling about 42% that reared in the ocean for 3 years. (There were 30.6% age-1.2 and 13.7% were age-2.2 fish in the sample, totaling 44% of sampled salmon that reared in the ocean for 2 years (Table 14). Mean lengths of males (495 mm, SE 12) and females (486 mm, SE 8) were significantly different (2-sample *z*-test; $|z| = 0.64$, *P-val* = 0.52).

Samples size in the second time stratum ($n = 16$) was too small to investigate age-sex-time interactions for data collected in 2017. The sex ratio was 1.40 (males:females) and was not significantly different from 1.0 (large 2-sample *z*-test; $|z| = 1.57$, *P-val* = 0.12).

Age composition of Lake Louise sockeye salmon was significantly different (chi-square test of independence; $\chi^2 = 108$, df = 4, *P-val* < 0.001) from Buskin Lake sockeye salmon. Sex composition differed between the Louise and Buskin rivers escapements (large 2-sample *z*-test; $|z| = 2.57$, *P-val* = 0.01). Mean lengths of Buskin Lake (526 mm, SE 3) and Lake Louise (491 mm, SE 8) salmon were significantly different (2-sample *z*-test; $|z| = 4.4$, *P-val* < 0.001).

Subsistence Harvest

A complete estimate of the sockeye salmon subsistence harvest from the marine waters of the Buskin River system was not yet available for 2017. Final subsistence harvest estimates will be available in the Westward Region CF database in fall 2018 as well as in subsequent reports regarding the subsistence harvest of Buskin River sockeye salmon. At the time of writing, 37% of the permits have been returned, reporting a harvest of 2,634 fish. Expanding this harvest based on the return rate of unreturned permits as indicated in the Methods section, the anticipated expanded 2017 subsistence harvest would be 6,190; this value is used in to calculate the 2017 return by age in the brood table in Table 18. Age was determined for 112 of 126 fish sampled for ASL, and of these 26.8% were age 1.3 and 69.6% were age 2.3, totaling about 96% that reared in the ocean for 3 years (Table 15). Most of the remaining salmon reared in the ocean for 2 years; 2.7% were age 2.2. Mean lengths of males (543 mm, SE 4) and females (519 mm, SE 2) were significantly different (2-sample *z*-test; $|z| = 5.5$, *P-val* < 0.001).

Log-linear modeling of counts in the 3-way age-sex-time analysis showed that the best-fitting model is a no-interaction model ($\chi^2 = 13.06$, df = 10, *P-val* = 0.22) where neither age nor sex change over the sampling period, and age composition is the same for males and females. The sex ratio was 0.75 (males:females) and was not significantly different from 1.0 (large-sample *z*-test; $|z| = 1.63.2$, *P-val* = 0.10).

The age composition of sockeye salmon harvested in the subsistence fishery was significantly different (chi-square test of independence; $\chi^2 = 6.6$, df = 2, *P-val* = 0.03) than that of the Buskin Lake escapement, with relatively more ocean-age-3 fish in fishery. Sex composition between run components was not significantly different (large two-sample *z*-test; $|z| = 0.05$, *P-val* = 0.96). The mean length of sockeye salmon harvested by subsistence users (529 mm, SE 2) was not significantly different (2-sample *z*-test; $|z| = 0.85$, *P-val* = 0.39) from that of Buskin Lake sockeye salmon (527 mm, SE 3).

Table 14.–Estimated age and sex compositions, and mean length-at-age of the sockeye salmon escapement at Lake Louise weir, 2017.

	Age												
Run component	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [a]
Females													
Number sampled	0	0	0	9	0	10	3	0	3	0	0	0	26
Proportion	0.00	0.00	0.00	0.14	0.00	0.16	0.05	0.00	0.05	0.00	0.00	0.00	0.42
SE proportion	0.00	0.00	0.00	0.03	0.00	0.03	0.02	0.00	0.02	0.00	0.00	0.00	0.05
Total escapement	0	0	0	16	0	27	13	0	7	0	0	0	59
SE escapement	0	0	0	4	0	7	6	0	4	0	0	0	7
Mean length				474		511	419		497				486
SE mean length				10		8	6		22				8
Minimum length				430		471	407		468				407
Maximum length				522		550	426		540				550
Males													
Number sampled	0	1	0	16	3	6	4	1	7	0	0	0	42
Proportion	0.00	0.03	0.00	0.19	0.07	0.06	0.04	0.03	0.12	0.00	0.00	0.00	0.58
SE proportion	0.00	0.03	0.00	0.03	0.04	0.01	0.01	0.03	0.04	0.00	0.00	0.00	0.05
Total escapement	0	4	0	27	10	9	6	4	16	0	0	0	82
SE escapement	0	4	0	5	5	2	2	4	6	0	0	0	7
Mean length		305		483	352	538	523	583	537				495
SE mean length				18	9	15	20		8				12
Minimum length		305		300	335	500	470	583	520				300
Maximum length		305		557	366	600	560	583	580				600
All													
Number sampled	0	1	0	25	3	16	7	1	10	0	0	0	68
Proportion	0.00	0.03	0.00	0.31	0.07	0.25	0.14	0.03	0.17	0.00	0.00	0.00	
SE proportion	0.00	0.03	0.00	0.04	0.04	0.05	0.05	0.03	0.05	0.00	0.00	0.00	
Total escapement	0	4	0	43	10	36	19	4	24	0	0	0	141
SE escapement	0	4	0	6	5	7	7	4	7	0	0	0	
Mean length		305		480	352	521	478	583	525				491
SE mean length				12	9	8	24		10				8
Minimum length		305		300	335	471	407	583	468				300
Maximum length		305		557	366	600	560	583	580				600

[a] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

Table 15.–Estimated age and sex compositions and mean length-at-age of the reported sockeye salmon subsistence harvest for the Buskin River drainage, 2017.

		Age												
Run component		0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total [a]
Females														
	Number sampled	0	0	0	0	0	20	0	0	44	0	1	0	72
	Proportion	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.39	0.00	0.01	0.00	0.57
	SE proportion	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.05	0.00	0.01	0.00	0.04
	Total escapement	0	0	0	0	0	1106	0	0	2432	0	55	0	3538
	SE escapement	0	0	0	0	0	223	0	0	284	0	55	0	271
	Mean length						521			520		545		519
	SE mean length						5			3				2
	Minimum length						470			485		545		470
	Maximum length						587			565		545		587
Males														
	Number sampled	0	0	0	0	0	10	3	0	34	0	0	0	54
	Proportion	0.00	0.00	0.00	0.00	0.00	0.09	0.03	0.00	0.30	0.00	0.00	0.00	0.43
	SE proportion	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.04	0.00	0.00	0.00	0.04
	Total escapement	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SE escapement	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mean length						551	527		542				543
	SE mean length						9	13		4				4
	Minimum length						510	505		490				475
	Maximum length						592	551		590				592
All														
	Number sampled	0	0	0	0	0	30	3	0	78	0	1	0	126
	Proportion	0.00	0.00	0.00	0.00	0.00	0.27	0.03	0.00	0.70	0.00	0.01	0.00	
	SE proportion	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.00	0.04	0.00	0.01	0.00	
	Total escapement	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SE escapement	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mean length						531	527		530		545		530
	SE mean length						5	13		3				2
	Minimum length						470	505		485		545		470
	Maximum length						592	551		590		545		592

[a] Sex and age components do not necessarily sum to sex pooled over age or age pooled over sex due to missing sex for age data and missing age for sex data.

Sport and Commercial Fisheries

The 2017 harvest estimate of sockeye salmon from the Buskin River drainage is not yet available from the SWHS. The 2017 run of sockeye salmon to the Buskin River was smaller than in 2016, and the 2017 harvest is anticipated to be less than the 2016 harvest with respect to fishing effort. Harvest is anticipated to be about 1,200 fish, based on the recent average ratio of sport harvest to escapement; this value is used to calculate the 2017 return by age in the brood table in Table 18.

Fish ticket harvest receipts available from CF indicate that no sockeye salmon were harvested near the Buskin River mouth in Womens Bay, statistical areas 259-22 and 259-26, during 2017 (Table 1).

TOTAL RUN, EXPLOITATION RATES, AND BROOD TABLE

The estimated total sockeye salmon runs, were 24,503 in 2014, 16,989 in 2015, and 19,047 in 2016 (Table 16). Neither the subsistence harvest nor the sport harvest is available at this time for 2017. Ocean-age-3 sockeye salmon (ages 2.3 and 1.3) were predominant each year, followed by ocean-age-2 fish (ages 2.2 and 1.2).

Annual subsistence fishery exploitation rates were 25.7% in 2014, 25.2% in 2015, and 27.5% in 2016, whereas annual sport and commercial fishery exploitation rates combined were 17.3% in 2014, 23.4% in 2015, and 13.1% in 2016 (Table 17). Estimates of removals by subsistence and sport users in 2017 are not available at this time. Standard errors of total exploitation rates were low (about 1–5%) and were driven by variability in SWHS harvest estimates.

The brood table for Buskin River sockeye salmon, which was developed using all available upper Buskin River weir data through 2017, showed that the predominant age classes within most brood years were age 5 (averaging 50% of the 1990–2012 brood year returns) and age 6 (averaging 40% of the 1990–2012 brood year returns) (Table 18). Lake Louise data are not included in exploitation rates or the construction of the brood table.

Table 16.–Estimated total run of sockeye salmon to Buskin Lake by age class, 2014-2016.

		Age class												
Year	Statistic	0.2	1.1	0.3	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3	Total
2014														
	Number	0	47	0	4,595	206	7,819	6,350	0	5,446	0	41	0	24,503
	SE	0	37	0	460	84	572	533	0	456	0	40	0	
2015														
	Number	0	29	17	1,190	163	7,516	2,452	40	5,460	17	105	0	16,989
	SE	0	21	17	173	85	581	298	23	489	17	79	0	
2016														
	Number	0	29	21	2,331	93	5,202	6,301	0	5,070	0	0	0	19,047
	SE	0	24	17	355	39	516	699	0	514	0	0	0	

Note: Neither subsistence nor sport harvest are available for 2017 at this time.

Table 17.–Estimated exploitation rates (%) of sockeye salmon migrating to Buskin Lake by fishery, 2014-2016.

Year	Statistic	Subsistence fishery	Sport and commercial fisheries	Total
2014	Exploitation rate	25.7	17.3	16.4
	SE	1.19	3.8	1.1
2015				
	Exploitation rate	25.2	23.4	33.9
	SE	1.7	5.1	2.4
2016				
	Exploitation rate	27.5	13.1	33.2
	SE	2.20	6.95	4.30

Note: Neither subsistence nor sport harvest are available for 2017 at this time.

Table 18.–Brood table for sockeye salmon migrating to Buskin Lake, 1990–2012 brood years.

		Data in sequence top to bottom for each brood year: Return by age, proportion by age, sample year					
Brood year	Escapement	Age 3 (0.2, 1.1)	Age 4 (0.3, 1.2, 2.1)	Age 5 (1.3, 2.2,)	Age 6 (1.4, 2.3, 3.2)	Age 7 (2.4, 3.3)	Total return
1990	10,528	12	2,544	11,674	8,611	204	23,045
		0.00	0.11	0.51	0.37	0.01	
		1993	1994	1995	1996	1997	
1991	9,789	182	2,464	8,512	11,998	468	23,624
		0.0	0.1	0.4	0.5	0.0	1.00
		1994	1995	1996	1997	1998	
1992	9,782	20	611	3,597	5,732	118	10,078
		0.00	0.06	0.36	0.57	0.01	
		1995	1996	1997	1998	1999	
1993	9,526	12	2,820	17,260	9,073	50	29,215
		0.00	0.10	0.59	0.31	0.00	
		1996	1997	1998	1999	2000	
1994	13,146	0	1,586	8,969	6,965	208	17,727
		0.00	0.09	0.51	0.39	0.01	
		1997	1998	1999	2000	2001	
1995	15,520	91	2,889	11,258	6,836	0	21,074
		0.00	0.14	0.53	0.32	0.00	
		1998	1999	2000	2001	2002	
1996	10,277	64	2,407	23,955	12,338	259	39,023
		0.00	0.06	0.61	0.32	0.01	
		1999	2000	2001	2002	2003	
1997	9,840	0	1,850	17,698	9,795	346	29,689
		0.00	0.06	0.60	0.33	0.01	
		2000	2001	2002	2003	2004	
1998	14,767	20	3,475	20,088	12,921	54	36,558
		0.00	0.10	0.55	0.35	0.00	
		2001	2002	2003	2004	2005	
1999	10,812	115	7,892	18,481	10,975	184	37,648
		0.00	0.21	0.49	0.29	0.00	
		2002	2003	2004	2005	2006	

-continued-

Table 18.–Page 2 of 2.

		Data in sequence top to bottom for each brood year: Return by age, proportion by age, sample year					
Brood year	Escapement	Age 3 (0.2, 1.1)	Age 4 (0.3, 1.2, 2.1)	Age 5 (1.3, 2.2,)	Age 6 (1.4, 2.3, 3.2)	Age 7 (2.4, 3.3)	Total return
2000	11,233	238	2,704	12,896	10,812	104	26,754
		0.01	0.10	0.48	0.40	0.00	
		2003	2004	2005	2006	2007	
2001	20,556	0	1,971	8,350	4,196	237	14,754
		0.00	0.13	0.57	0.28	0.02	
		2004	2005	2006	2007	2008	
2002	17,174	275	8,022	24,785	3,375	47	36,504
		0.01	0.22	0.68	0.09	0.00	
		2005	2006	2007	2008	2009	
2003	23,870	0	719	4,087	2,866	0	7,671
		0.00	0.09	0.53	0.37	0.00	
		2006	2007	2008	2009	2010	
2004	22,023	0	2,236	6,474	5,540	0	14,250
		0.00	0.16	0.45	0.39	0.00	
		2007	2008	2009	2010	2011	
2005	15,468	78	1,037	5,476	9,960	91	16,643
		0.00	0.06	0.33	0.60	0.01	
		2008	2009	2010	2011	2012	
2006	17,734	47	700	7,506	8,373	147	16,772
		0.00	0.04	0.45	0.50	0.01	
		2009	2010	2011	2012	2013	
2007	16,502	0	752	2,826	10,180	41	13,798
		0.00	0.05	0.20	0.74	0.00	
		2010	2011	2012	2013	2014	
2008	5,900	56	1,537	8,834	5,446	105	15,977
		0.00	0.09	0.53	0.33	0.01	
		2011	2012	2013	2014	2015	
2009	7,757	91	5,229	14,169	5,517	0	25,006
		0.01	0.31	0.85	0.33	0.00	
		2012	2013	2014	2015	2016	
2010	9,800	190	4,801	9,968	5,070	193	20,222
		0.01	0.29	0.60	0.30	0.01	
		2013	2014	2015	2016	2017	
2011	11,982	47	1,370	11,502	9,458	150	22,527
		0.00	0.08	0.69	0.56	0.00	
		2014	2015	2016	2017	2018	
2012	8,565	29	2,445	4,807	6,027	102	15,419
		0.00	0.15	0.28	0.36	0.01	
		2015	2016	2017	2018	2019	

Note: Shaded values are imputed. Anticipated values for subsistence and sport harvests (see 2017 season sections) were used for calculating the 2017 returns by age

SUBSISTENCE USER SURVEY

The annual number of subsistence users who agreed to be interviewed ranged from 5 to 26 between 2014 and 2017 (Table 19). Most of the subsistence users interviewed on marine waters adjacent to the Buskin River were residents of Kodiak Island and listed the area as their traditional sockeye salmon subsistence fishing location. An average of 79% of those interviewed indicated they also fished for sockeye salmon in other locations, with the 3 most popular locations being Pasagshak, Litnik, and Port Lions-Ouzinkie.

Table 19.–Interview results of Buskin River sockeye salmon subsistence users, 2014–2017.

		Year			
Parameter	Detail	2014	2015	2016	2017
Interview date range		May 26–Jun 25	Jun 6–30	May 26–Jun 24	Jun 1–24
Number of interviews		26	16	12	5
Residency					
	Kodiak	26	15	9	5
	Unknown	0	1	1	0
Location of effort [a]					
	Buskin	20	14	11	5
	Pasagshak	6	1	0	0
	Chiniak	0	0	1	0
	Kenai	0	1	0	0
Subsistence fish elsewhere?					
	Yes	22	12	9	4
	No	4	4	3	1
Other areas fished (not primary location)					
	Pasagshak	9	8	2	3
	Litnik	4	2	1	1
	Port Lions-Ouzinkie	10	3	2	1
	Buskin	5	2	11	5
	Southend	0	1	1	0
	Ouzinki	2	0	0	0
	Larsen Bay	1	0	0	0
	Chignik	0	0	1	0
	Chiniak	1	0	0	0
	Sharatin Bay	0	0	0	0
	Saltery	0	1	3	0
	Kenai	1	0	1	0
Years spent subsistence fishing at Buskin River					
	Mean	18	20	29	20
	Median	17	17	30	17
	Minimum	1	5	3	5
	Maximum	45	41	45	41

[a] Location of traditional subsistence fishing location.

STOCK-RECRUIT MODEL ESTIMATION

The median of the posterior distribution of S_{MSY} for Buskin River sockeye salmon is 6,530 fish (95% credibility interval of 5,137 to 8,435). The value of S_{MSY} lies between 5,137 and 8,435 with 95% certainty (Figure 4 and Table 20). A return vs. spawner plot, along with the fitted model and errors, is presented in Figure 5. Plots of estimated escapement, recruitment, run abundance, model residuals, harvest rates over time are shown in Figure 6. Estimated age at maturity and age composition over time are shown in Figure 7. The relationship between the probability that sustainable yield is within 90% of MSY is given Figure 8.

The Bayesian analysis suggests there may be some positive autocorrelation (ϕ), although the 95% interval extends into the negative (Table 20). No major problems were encountered in assessment of convergence of the MCMC chains. A plot of the node *D*.sum (D in Equation 15), which is typically one of the slowest to converge, is given in Figure 9; the plot shows a classic mixing pattern of the two MCMC chains.

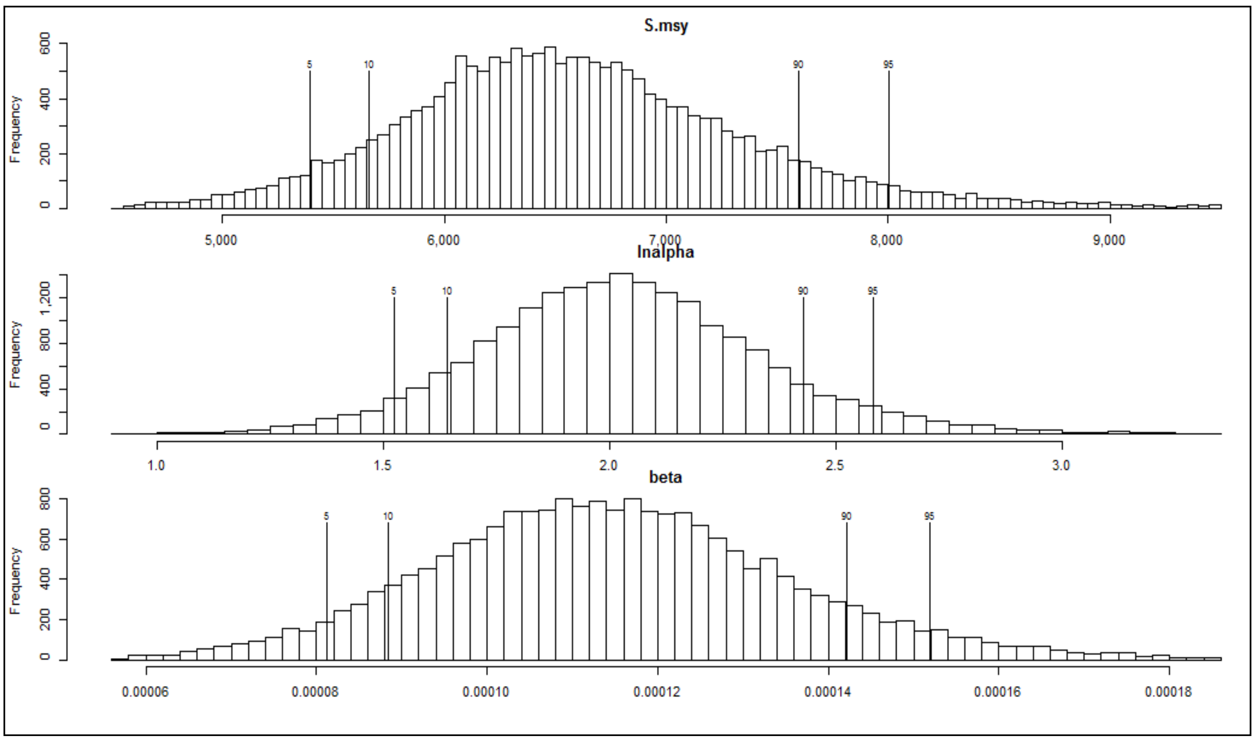

Figure 4.–Posterior distributions of S_{MSY}, ln(α), and β; vertical lines depict 5, 10, 90, and 95th percentiles of the distributions.

Table 20.–Posterior percentiles for important nodes of the Bayesian spawner–recruit analysis

	Percentile		
Parameter	2.5	Median(50)	97.5
$\ln(\alpha)$	1.54	2.11	2.93
β	0.000075	0.000114	0.000161
σ_{RS}	0.29	0.42	0.82
S_{MSY}	5,137	6,530	8,435
π_1	0.09	0.11	0.14
π_2	0.43	0.48	0.52
π_3	0.36	0.41	0.46
φ	−0.31	0.22	0.81

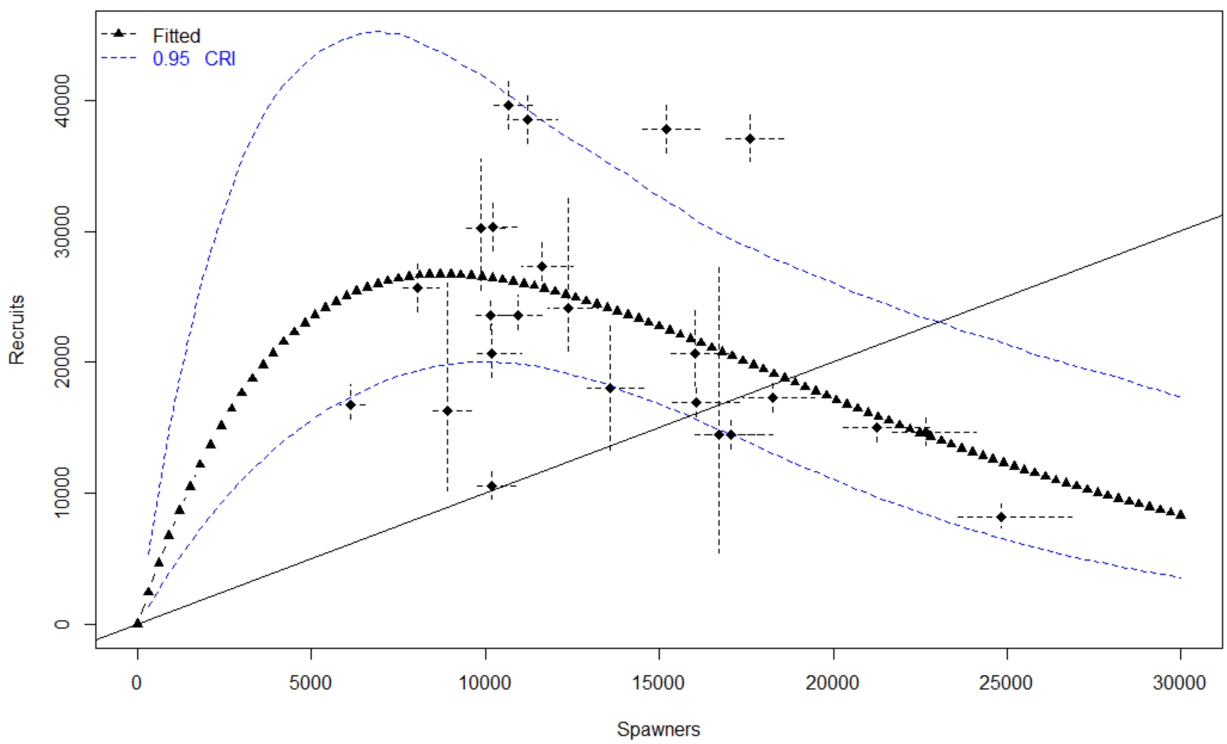

Figure 5.–Fitted R-S (triangles) and $R = S$ (solid line) relationships; error bars are 90% credibility intervals.

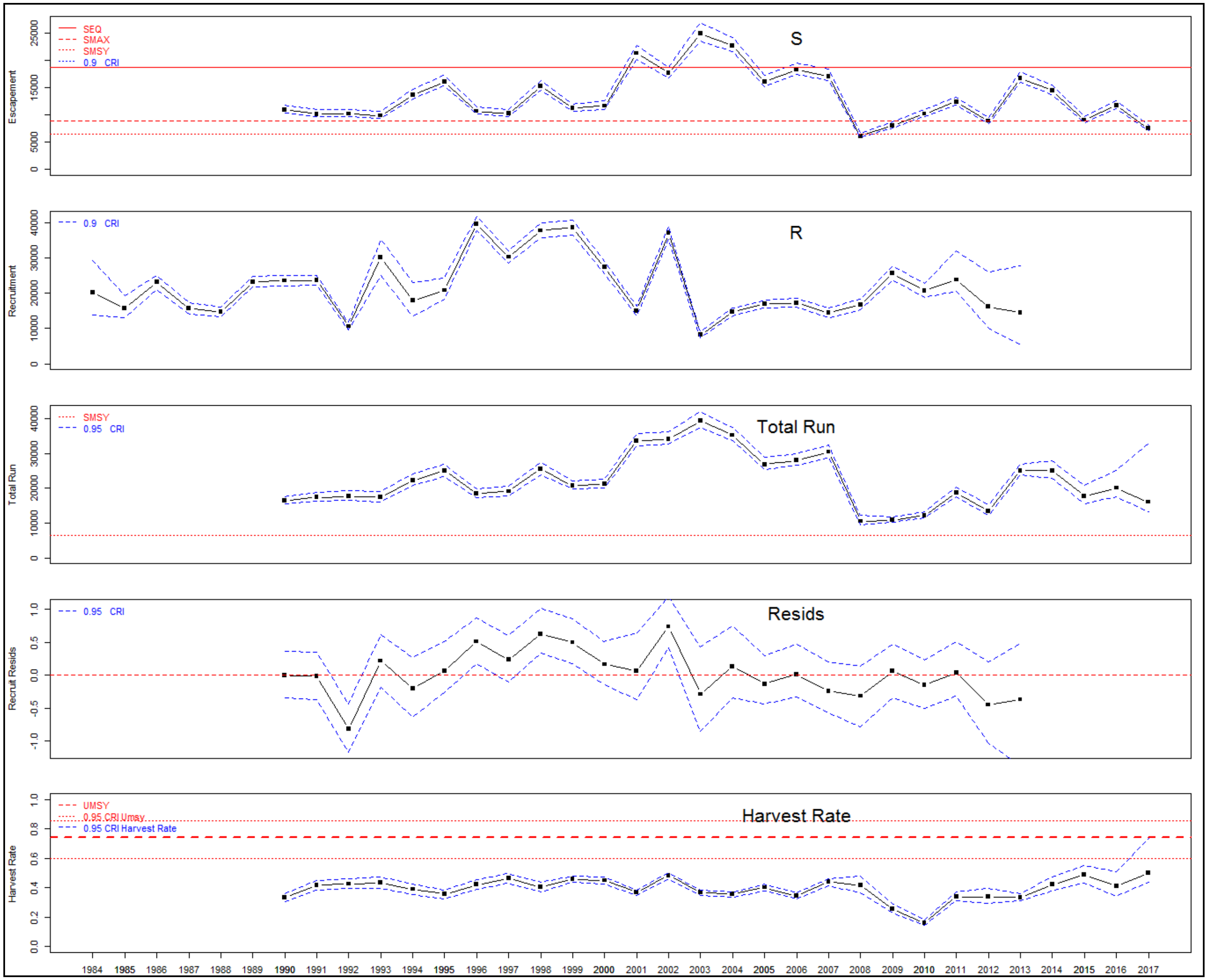

Figure 6.–Point estimates (posterior medians; solid lines) and credibility intervals (CRI; dashed blue lines) of escapement, recruitment, total run, residuals, and harvest rate.

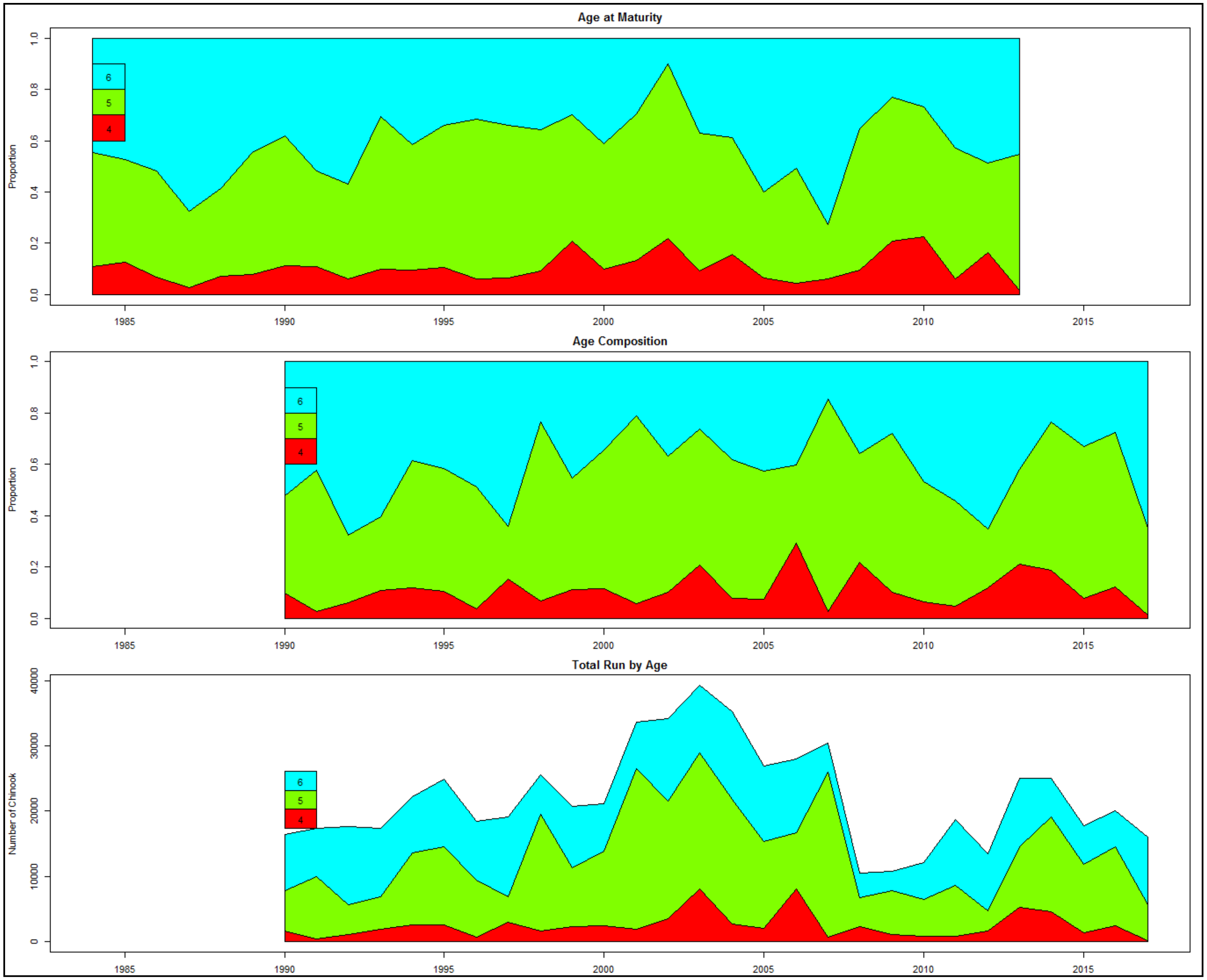

Figure 7.–Point estimates (posterior medians) of age-at-maturity, age composition, and run by age over time.

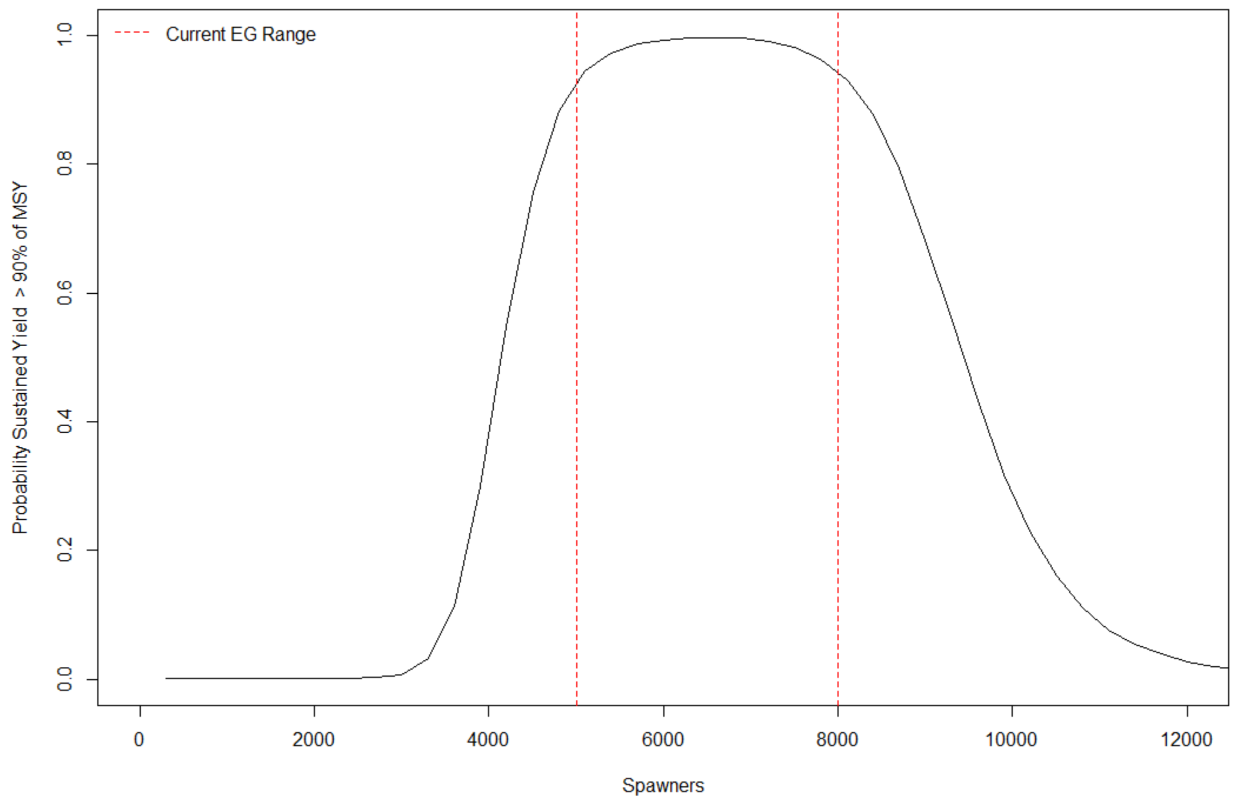

Figure 8.–Probability that sustained yield (SY) is greater than 90% of MSY.

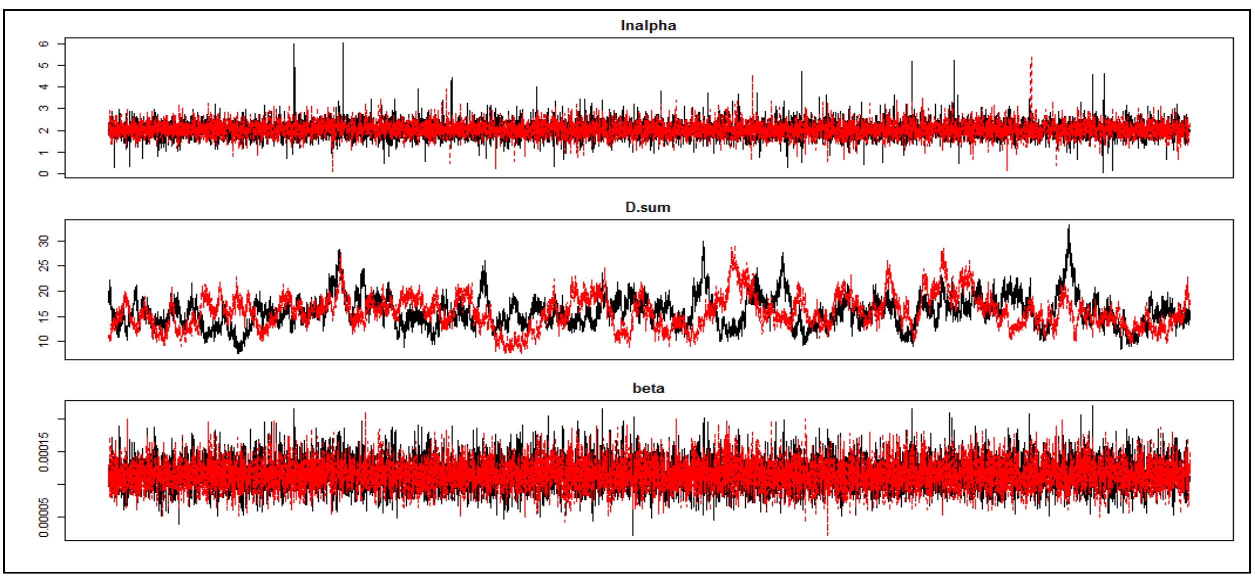

Figure 9.–Trace plots of 3 nodes, including D.sum (D in Equation 15), showing mixing of the two MCMC chains.

GENETICS

Tissue Collections

The number of genetic samples collected annually from the subsistence fishery varied from 126 to 347 samples from 2014 to 2017. Samples were collected concurrently with ASL samples collected from the subsistence fishery and opportunistically at the local boat harbors. Sampling efforts are highly reflective of fishing effort and run strength.

Laboratory Analysis

Assaying Genotypes

We genotyped a random subset of 190 fish or all individuals from each year if less than 190 were available for 96 SNPs (Appendix A1).

Quality Control

Quality control (QC) demonstrated a low overall discrepancy rate of 0.42% for 2014–2017 subsistence harvest samples; all discrepancies, except for 2016, were between homozygotes and heterozygotes (total of 17 out of 5,760 genotypes compared). The 2014–2017 collections of subsistence harvest samples were genotyped with a process that produced genotypes with an error rate of 0.21% if error rates in the original and QC genotyping processes are assumed equal (Table 21).

Table 21.–Quality control (QC) results including the number genotyped in the original sample, the number of individuals included in the QC analysis, failure rates in the original sample, and the number of genotypes compared in the QC for each year.

				QC	Discrepancy rate					
				geno-	Homo-het		Homo-homo			
Year	Original *n*	QC *n*	Failure (%)	types	*n*	%	*n*	%	Overall	Error rate (%)
2014	190	16	0.26%	1536	0	0.00%	0	0.00%	0.00%	0.00%
2015	190	16	0.44%	1536	0	0.00%	0	0.00%	0.00%	0.00%
2016	190	16	6.51%	1536	17	1.11%	9	0.59%	1.69%	0.85%
2017	126	12	0.66%	1152	0	0.00%	0	0.00%	0.00%	0.00%
Total	696	60	1.97%	5760	17	0.28%	9	0.15%	0.42%	0.21%

Note: Discrepancy rates include the rate due to differences of alternate homozygous genotypes (homo-homo), of homozygous and heterozygous genotypes (homo-het), and the overall discrepancy rate. Error rates assume that differences are the result of errors that are equally likely to have occurred in the production and QC genotyping process.

GENETIC STATISTICAL ANALYSIS

Data Retrieval and Quality Control

A total of 28 individuals from subsistence harvest samples were missing genotypes from greater than 20% of the loci and were removed from further analyses, with most individuals from the 2016 sample (Table 22). No individuals were identified as nontarget species or duplicate individuals.

Table 22.–Numbers of sockeye salmon samples from the subsistence harvest of the Buskin River section of Chiniak Bay that were genotyped and were either removed due to missing genotypes (missing), nontarget species (alternate), or duplicate individuals (duplicate); or were used in final mixed stock analyses (final) for each temporal stratum.

Year	Genotyped	Alternate	Missing	Duplicate	Final
2014	190	0	0	0	190
2015	190	0	1	0	189
2016	190	0	26	0	164
2017	126	0	1	0	125
Total	696	0	28	0	668

Subsistence Harvest Stock Composition Estimates

A total of 668 individuals from the subsistence harvests were used in mixed stock analysis (MSA; average per year = 167; Table 23 and Figure 10). Stock composition estimates of the subsistence samples indicated that the majority of harvests originated from the Buskin Lake stock (medians 90.8–97.2%; Table 23). The median estimates for the Lake Louise stock ranged from 0.5% to 4.1%, whereas the Saltery and Other Kodiak reporting groups stocks made up the remainder of all strata.

Table 23.–Stock composition estimates of the sockeye salmon subsistence harvest in the Buskin River Section of Chiniak Bay, 2014–2017.

			Stock composition estimates [a]					
				90% CI				
Year	Sample size	Reporting group	Median	5%	95%	*P* = 0	Mean	SD
2014	190	Buskin Lake	90.8%	86.3%	94.2%	0.00	90.6%	2.4%
		Lake Louise	4.1%	2.1%	7.1%	0.00	4.3%	1.5%
		Saltery	1.2%	0.2%	3.4%	0.00	1.4%	1.0%
		Other Kodiak	3.4%	1.4%	6.9%	0.00	3.7%	1.7%
2015	189	Buskin Lake	92.9%	89.2%	95.8%	0.00	92.8%	2.0%
		Lake Louise	0.5%	0.1%	2.0%	0.00	0.7%	0.6%
		Saltery	0.1%	0.0%	1.5%	0.08	0.3%	0.6%
		Other Kodiak	6.0%	3.4%	9.5%	0.00	6.2%	1.9%
2016	164	Buskin Lake	96.0%	92.7%	98.2%	0.00	95.8%	1.7%
		Lake Louise	1.1%	0.2%	3.1%	0.00	1.3%	0.9%
		Saltery	1.9%	0.4%	4.6%	0.00	2.1%	1.3%
		Other Kodiak	0.6%	0.0%	2.2%	0.00	0.8%	0.7%
2017	125	Buskin Lake	97.2%	93.5%	99.3%	0.00	96.9%	1.8%
		Lake Louise	1.0%	0.0%	3.7%	0.02	1.3%	1.2%
		Saltery	0.1%	0.0%	2.2%	0.07	0.5%	0.8%
		Other Kodiak	1.0%	0.1%	3.5%	0.00	1.3%	1.1%

Note: Stock composition estimates may not sum to 100% due to rounding error.

[a] Estimates include median, 90% credibility interval (CI), the probability that the group estimate is equal to zero (*P-val* = 0), mean, and standard deviation (SD).

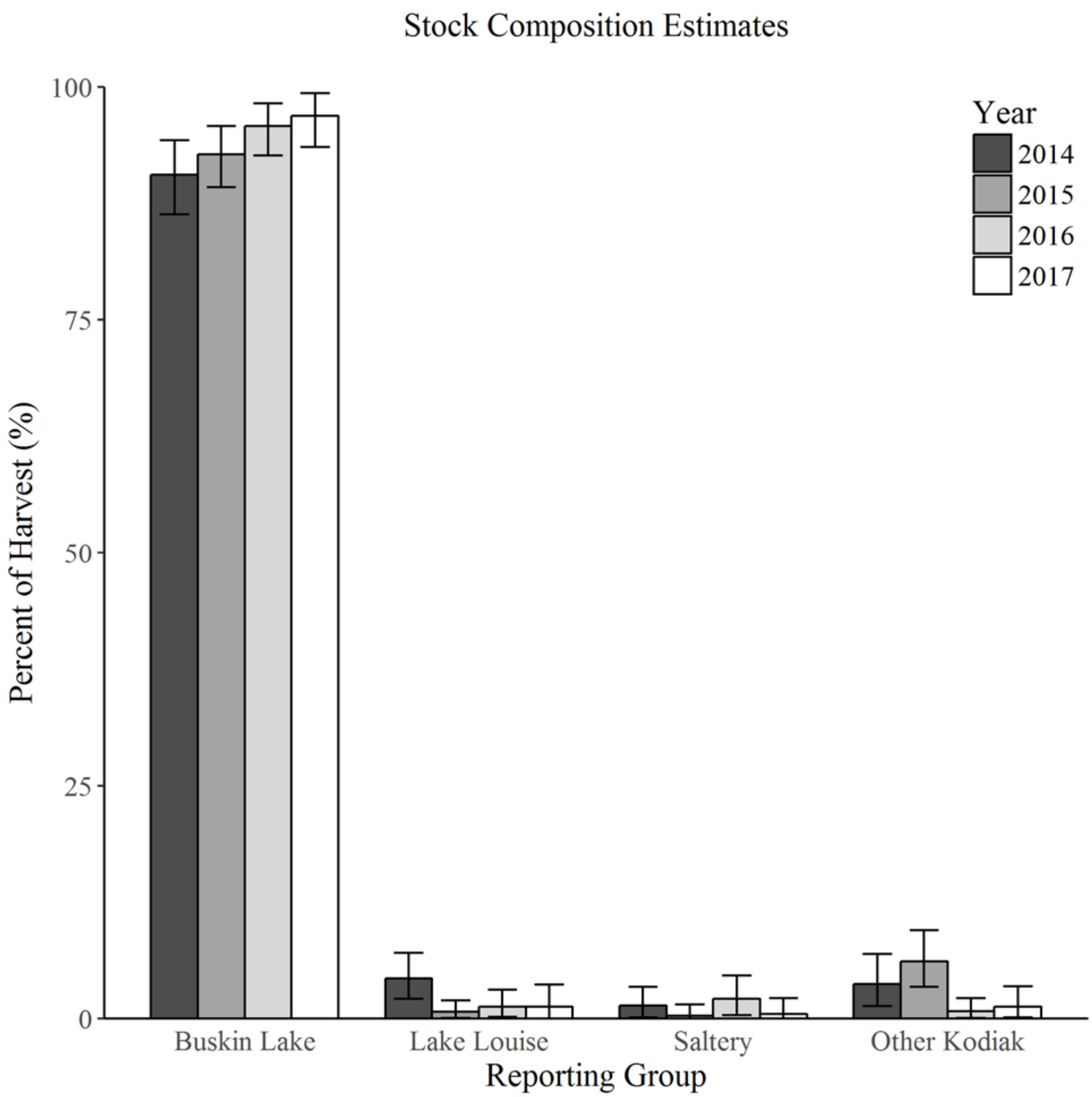

Figure 10.–Median estimate and 90% credibility interval of the contribution of 4 reporting groups to samples of the subsistence harvest in the Buskin River Section of Chiniak Bay, 2014–2017.

DISCUSSION

The Buskin River drainage has consistently productive returns of sockeye salmon that are heavily utilized by subsistence and sport users. Historically, escapements have remained well above the current BEG and are expected to continue to meet or exceed escapement objectives. It is likely that subsistence and sport users can expect a predictable and productive fishery on the Buskin River with few restrictions to fishing effort for sockeye salmon. Since weir operation began, restrictions have been placed on the subsistence or sport fisheries during only 2 years: 2008 and 2009. During 2008–2009, weir counts fell below the lower end of the BEG at the time (8,000 fish), but not below the lower end of the current goal (5,000 fish). It is possible that record high escapements occurring in the brood years of these returns (e.g., brood years 2003–2004) resulted in low productivity due to poor lake rearing conditions. Whatever the cause, the Buskin River sockeye salmon returns have rebounded since then (e.g., brood years 2009–2011) and the runs have been strong enough to warrant liberalization of both the subsistence and sport fisheries in recent years.

The Buskin Lake BEG was lowered from 8,000–13,000 sockeye salmon to 5,000–8,000 sockeye salmon in 2010, and the current spawner-recruit analysis using data collected during the 4 years of this project supports this change. This recent spawner-recruit analysis, illustrated in Figure 5, suggests that the current BEG range of 5,000–8,000 fish will provide for sustained yields within 90% of MSY with 90% or greater probability (Figure 8). Buskin River sockeye salmon fisheries will continue to be managed to achieve this goal, with priority given to the subsistence fishery if restrictions are warranted in the future.

The Buskin River drainage appears to have 2 distinct stocks of sockeye salmon. ADF&G Gene Conservation Laboratory analysis of samples from fish bound for Buskin Lake and Lake Louise showed genetic differences distinct enough to consider these run components as separate populations (C. Habicht, Fisheries Geneticist, ADF&G Gene Conservation Laboratory, Anchorage, personal communication). The allele frequencies are very different between the two populations, and the 100% simulations show that at least 99.8% of the mixtures allocate to the correct populations. These genetic differences have allowed us to examine whether the subsistence fishery harvests Lake Louise fish. Genetic analysis of samples from the 2014–2017 sockeye salmon subsistence harvest near the Buskin River found that Buskin Lake sockeye salmon made up at least 90% of the annual subsistence harvests over this period, whereas harvest of Lake Louise sockeye salmon made up less than 5% of the harvests (Figure 10), supporting a long-held assumption that Lake Louise fish composed a small portion of the harvest. These findings were similar to those in 2010–2013 (Polum et al. 2014); however, the proportion of Buskin Lake stocks was higher in 2014–2017 (average 94%) than during 2010–2013 (average 84%).

The main reason for the low incidence of Lake Louise fish in the subsistence harvest during 2014–2017 is probably that the Lake Louise run during this period has been low, composing an average of 3.1% of the total annual weir counts (Table 1) to the Buskin River drainage. Other possible reasons that Lake Louise fish would not be caught by the subsistence fishery are that the run is consistently 6 weeks later (occurring primarily after the subsistence fishery is over) than that of the main Buskin River run, as suggested by weir count timing at the Lake Louise weir (Figure 3), and that the known difference in size composition of the Lake Louise and Buskin Lake runs (Buskin Lake fish are larger), combined with size selectivity of subsistence fishery gillnets, causes lower harvest rates of Lake Louise fish because many may be small enough to escape the gillnets. There is also anecdotal evidence of greater numbers of net-marked fish at the Buskin River weir than at the Lake Louise weir, indicating greater harvest pressure on Buskin Lake fish. These data support the hypothesis that the Lake Louise run is later than the Buskin Lake run and therefore less subject to harvest.

Sockeye salmon returning to Buskin Lake and Lake Louise have distinct age and size compositions characteristic of their respective runs. The Buskin Lake run is historically dominated by fish rearing in the marine environment for 3 years, mostly age-1.3 and -2.3 fish (Schmidt 2007). We found that the majority of fish sampled at the Buskin Lake weir in the years 2014–2017 were age 1.3 or 2.3 (Tables 2, 6, 10, and 13). Conversely, the Lake Louise run has been historically dominated by fish rearing in the marine environment for 2 years, typically age-1.2 and -2.2 fish (Schmidt 2007). During the period of this study however, we found the dominant age compositions to be variable, albeit with fairly low samples sizes (Tables 3, 7, and 14). From 2014–2017, we found that Buskin Lake sockeye salmon were, on average, 33 mm longer than Lake Louise sockeye salmon. Polum et al. (2014) found a similar size difference during 2011–2013. This is probably due to the age composition of the two runs; the younger fish composing the Lake Louise run are expected to be smaller than older fish composing the Buskin Lake run. However, small runs and subsequently small sample sizes at Lake Louise during 2014–2017 preclude size-at-age examination. Age and size characteristics of Lake Louise salmon may also be linked by adaptation to the physical characteristics of the Lake Louise drainage. The creek flowing out of Lake Louise is shallow and narrow, and smaller sockeye salmon may be able to navigate the creek more easily than larger sockeye salmon, rendering them more fit to spawn in this drainage.

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APPENDIX A: GENETIC BASELINE COLLECTION FOR BUSKIN RIVER SUBSISTENCE HARVEST STOCK OF ORIGIN ANALYSIS

Appendix A1.–Reporting group, ADF&G collection code, location, collection (col no.) and population (pop no.) number, collection date, and the numbers of sockeye salmon used to estimate the stock composition of Chiniak Bay subsistence harvests. The number of individuals includes the number of individuals initially genotyped for the set of 96 SNPs (init'l), fish identified as nontarget species (alt.), the numbers removed because of missing loci (miss.) and duplicate individuals (dup.), and the number of individuals incorporated into the baseline (final).

Reporting group	ADF&G code	Location	Col no.	Pop no.	Date	Init'l	Alt.	Miss.	Dup.	Final	Lat	Long
Other Kodiak	SAKALNE01L	Akalura Lake - Northeast Beach	1	1	9/25/2001	96	0	6	2	88	57.1910	-154.1930
Other Kodiak	SAKALNE11		2	1	9/16/2011	95	0	0	0	95	57.1904	-154.1876
Other Kodiak	SAKAL05L	Akalura Lagoon	3	2	9/2/2005	95	0	0	0	95	57.1629	-154.2274
Other Kodiak	SOLGB01E	Upper Olga Lake - Tributary B	4	3	7/24/2001	96	0	0	0	96	57.0720	-154.1520
Other Kodiak	SOLGA01E	Upper Olga Lake - Tributary A	5	4	7/23/2001	96	0	0	1	95	57.0690	-154.2110
Other Kodiak	SOLGC01E	Upper Olga Lake - Tributary C	6	5	7/23/2001	96	0	1	0	95	57.0460	-154.2410
Other Kodiak	SUPPSW01L	Upper Olga Lake - Southwest Shoal	7	6	9/26/2001	96	0	4	3	89	57.0450	-154.2380
Other Kodiak	SUPS00E	Upper Station Weir - Early	8	7	6/14/2000	95	0	0	0	95	57.0598	-154.2460
Other Kodiak	SUPUP93	Upper Station - Upper Olga Lake	9	8	9/1/1993	95	0	0	0	95	57.0598	-154.2460
Other Kodiak	SLUPS93	Upper Station - Lower Olga Lake	10	9	1993	95	0	1	0	94	57.0599	-154.3345
Other Kodiak	SPINNM08	Frazer Lake - Pinnell Creek	11	10	8/21/2008	78	0	0	0	78	57.3067	-154.2028
Other Kodiak	SSTUM08	Frazer Lake - Stumble Creek	12	10	8/21/2008	95	0	1	0	94	57.3049	-154.2039
Other Kodiak	SCOUR08	Frazer Lake - Courts Beach	13	11	8/21/2008	95	0	7	0	88	57.2897	-154.1636
Other Kodiak	SMIDWS08	Frazer Lake - Midway Beach	14	11	8/21/2008	95	0	4	0	91	57.2534	-154.1268
Other Kodiak	SHOLFS08	Frazer Lake - Hollow Fox Beach	15	11	8/22/2008	95	0	1	0	94	57.2317	-154.1049
Other Kodiak	SMIDWM08	Frazer Lake - Midway Creek	16	12	8/21/2008	93	0	1	0	92	57.2544	-154.1279
Other Kodiak	SLINDM08	Frazer Lake - Linda Creek	17	12	8/22/2008	95	0	5	0	90	57.2332	-154.1259
Other Kodiak	SVALA08	Frazer Lake - Valarian Creek	18	13	8/21/2008	95	0	0	0	95	57.1998	-154.0794
Other Kodiak	SOUTS08	Frazer Lake - Outlet	19	14	8/20/2008	95	0	10	0	85	57.2064	-154.0765
Other Kodiak	SDOGSC08	Dog Salmon Creek	20	15	8/22/2008	95	0	3	0	92	57.1992	-154.0522
Other Kodiak	SCAIDA14	Frazer Lake - Caida Creek	21	16	8/4/2014	95	0	0	3	92	57.2705	-154.1680
Other Kodiak	SREDSS11	Red Lake - South Beach	22	17	9/16/2011	95	0	0	0	95	57.2237	-154.2690
Other Kodiak	SREDSWS11	Red Lake - Southwest Beach	23	17	10/17/2011	95	0	2	0	93	57.2374	-154.2976
Other Kodiak	SREDWS12	Red Lake - West Beach	24	17	9/11/2012	95	0	1	0	94	57.2541	-154.2903
Other Kodiak	SREDNWS11	Red Lake - Northwest Beach	25	17	10/17/2011	95	0	1	0	94	57.2535	-154.3364
Other Kodiak	SREDNES11	Red Lake - Northeast Beach	26	17	9/16/2011	95	0	0	0	95	57.2662	-154.3184
Other Kodiak	SREDCRY11	Red Lake - Crystal Creek	27	18	7/18/2011	95	0	1	0	94	57.2310	-154.2650
Other Kodiak	SREDCON11	Red Lake - Connecticut Creek	28	19	7/18/2011	95	0	0	0	95	57.2640	-154.3158
Other Kodiak	SAYAK00	Ayakulik River Weir - Late	29	20	7/26/2000	96	0	1	2	93	57.1952	-154.5362

-continued-

Reporting group	ADF&G code	Location	Col no.	Pop no.	Date	Init'l	Alt.	Miss.	Dup.	Final	Lat	Long
Other Kodiak	SAYAK08L		30	20	8/14/2008	95	1	2	1	91	57.1950	-154.5289
Other Kodiak	SAYAK11L		31	20	8/8/2011	70	0	0	0	70	57.1950	-154.5289
Other Kodiak	SAYAK12L		32	20	7/26/2012	250	0	0	0	250	57.1950	-154.5289
Other Kodiak	SAYAK12E	Ayakulik River Weir - Early	33	21	6/5/2012	200	0	0	0	200	57.1950	-154.5289
Other Kodiak	SFAL99E	Karluk Lake - Falls Creek	34	22	8/5/1999	66	0	0	0	66	57.2740	-153.9860
Other Kodiak	SCAN99E	Karluk Lake - Canyon Creek	35	22	7/31/1999	96	1	9	1	85	57.2780	-153.9890
Other Kodiak	SOMALL99	Karluk Lake - O'Malley River	36	23	9/28/1999	95	0	1	2	92	57.2773	-153.9955
Other Kodiak	SKARLSE11	Karluk Lake - Southeast Shoal	37	24	9/16/2011	95	0	0	0	95	57.2791	-153.9958
Other Kodiak	SKARLSE99L		38	24	9/28/1999	96	0	0	1	95	57.2830	-153.9960
Other Kodiak	SCAS99E	Karluk Lake - Cascade Creek	39	25	7/28/1999	96	0	6	3	87	57.2770	-154.0080
Other Kodiak	SUTHU99E	Upper Thumb River	40	26	7/29/1999	64	0	3	2	59	57.3500	-153.9720
Other Kodiak	SUTHU00E	Upper Thumb Lake	41	27	7/24/2000	95	0	0	0	95	57.3529	-153.9912
Other Kodiak	SSAL99E	Karluk Lake - Salmon Creek	42	28	7/29/1999	96	0	3	1	92	57.3540	-153.9950
Other Kodiak	SLTHUM99	Lower Thumb River	43	29	9/30/1999	95	0	19	0	76	57.3563	-153.9988
Other Kodiak	STHUS99L	Karluk Lake - Thumb Shoal	44	30	10/1/1999	96	0	1	1	94	57.3580	-153.9990
Other Kodiak	SHAL01E	Karluk Lake - Halfway Creek	45	31	7/19/2001	96	0	0	1	95	57.3580	-154.0630
Other Kodiak	SGRA99E	Karluk Lake - Grassy Point Creek	46	32	7/27/1999	96	0	5	5	86	57.3820	-154.0750
Other Kodiak	SKARLW99L	Karluk Lake - West Shoal	47	33	9/27/1999	96	0	1	1	94	57.3940	-154.0780
Other Kodiak	SKARLE99L	Karluk Lake - East Shoal	48	34	9/27/1999	96	0	0	0	96	57.3990	-154.0410
Other Kodiak	SCOT99E	Karluk Lake - Cottonwood Creek	49	35	7/27/1999	96	0	7	0	89	57.4040	-154.0450
Other Kodiak	SMOR99E	Karluk Lake - Moraine Creek	50	36	7/26/1999	96	0	4	2	90	57.4340	-154.0750
Other Kodiak	SKARL01L	Karluk River	51	37	10/14/2001	62	6	0	0	56	57.4410	-154.1090
Other Kodiak	SUGAN97	Uganik Lake	52	38	7/15/1997	95	0	0	0	95	57.6705	-153.3730
Other Kodiak	SUGAN15	Uganik Lake - Tribuatary	53	39	8/4/2015	190	0	0	0	190	57.6464	-153.3004
Other Kodiak	SBARAB12	Barabara Lake	54	40	8/17/2012	44	0	0	0	44	57.8137	-152.9583
Other Kodiak	SBARAB15		55	40	8/4/2015	51	0	1	0	50	57.8171	-152.9640
Other Kodiak	SLRIV97	Little River Lake	56	41	7/15/1997	96	0	1	0	95	57.7814	-153.6653
Other Kodiak	SMALI93	Malina Lake - Lower	57	42	8/19/1993	80	0	1	1	78	58.1639	-153.1532
Other Kodiak	STHOR06	Thorsheim Lake	58	43	8/23/2006	83	0	0	0	83	58.2354	-152.8861
Other Kodiak	SKAFL08	Kaflia Lake - Mouth Creek	59	44	8/27/2008	95	0	1	0	94	58.2492	-154.2442
Other Kodiak	SAFOG93	Afognak Lake	60	45	8/17/1993	79	0	0	1	78	58.1326	-152.9863
Other Kodiak	SPORT98	Portage Lake	61	46	8/11/1998	96	0	0	0	96	58.2826	-152.4194

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Reporting group	ADF&G code	Location	Col no.	Pop no.	Date	Init'l	Alt.	Miss.	Dup.	Final	Lat	Long
Other Kodiak	SPAUL14	Pauls Lake	62	47	6/25/2014	95	0	0	0	95	58.3758	-152.3256
Buskin Lake	SBUSK05	Buskin Lake	63	48	6/26/2005	95	0	1	0	94	57.7778	-152.5413
Buskin Lake	SBUSKL10		64	48	6/13/2010	95	0	0	1	94	57.7772	-152.5373
Buskin Lake	SBUSKL15		65	48	6/15/2015	190	0	1	0	189	57.7767	-152.5367
Lake Louise	SLKLOU05	Lake Louise - Buskin River	66	49	8/3/2005	95	0	0	0	95	57.7665	-152.4992
Lake Louise	SLKLOU10		67	49	7/19/2010	95	0	0	2	93	57.7585	-152.5090
Lake Louise	SLKLOU14	Lake Louise - Buskin River	68	50	7/2/2014	190	0	1	0	189	57.7585	-152.5090
Other Kodiak	SPASA05	Pasagshak Lake	69	51	7/15/2005	95	0	0	0	95	57.4732	-152.4655
Other Kodiak	SLMIA05	Lake Miam	70	52	9/2/2005	95	0	0	1	94	57.4997	-152.5784
Other Kodiak	SOCEAB06	Ocean Beach	71	53	8/29/2006	95	0	0	0	95	57.1181	-153.1994
Other Kodiak	SHORS05	Horse Marine Lake	72	54	9/2/2005	95	0	0	0	95	57.1258	-153.9143
Saltery	SSALT94	Saltery Lake - Creek	73	55	9/16/1994	95	0	2	0	93	57.5341	-152.7678
Saltery	SSALT99		74	55	8/26/1999	95	0	1	0	94	57.5341	-152.7678
Saltery	SSALT14	Saltery Lake - Weir Early	75	56	6/29/2014	190	0	0	0	190	57.5341	-152.7678
Saltery	SLKIT15	Little Kitoi Hatchery	76	57	9/15/2015	190	0	1	0	189	57.5341	-152.7678
Other Kodiak	SKARLSE11	Karluk Lake - Southeast Shoal	37	24	9/16/2011	95	0	0	0	95	57.279	-153.9958
Other Kodiak	SKARLSE99L		38	24	9/28/1999	96	0	0	1	95	57.283	-153.9960
Other Kodiak	SCAS99E	Karluk Lake - Cascade Creek	39	25	7/28/1999	96	0	6	3	87	57.277	-154.0080
Other Kodiak	SUTHU99E	Upper Thumb River	40	26	7/29/1999	64	0	3	2	59	57.35	-153.9720
Other Kodiak	SUTHU00E	Upper Thumb Lake	41	27	7/24/2000	95	0	0	0	95	57.353	-153.9912
Other Kodiak	SSAL99E	Karluk Lake - Salmon Creek	42	28	7/29/1999	96	0	3	1	92	57.354	-153.9950
Other Kodiak	SLTHUM99	Lower Thumb River	43	29	9/30/1999	95	0	19	0	76	57.356	-153.9988
Other Kodiak	STHUS99L	Karluk Lake - Thumb Shoal	44	30	10/1/1999	96	0	1	1	94	57.358	-153.9990
Other Kodiak	SHAL01E	Karluk Lake - Halfway Creek	45	31	7/19/2001	96	0	0	1	95	57.358	-154.0630
Other Kodiak	SGRA99E	Karluk Lake - Grassy Point Creek	46	32	7/27/1999	96	0	5	5	86	57.382	-154.0750
Other Kodiak	SKARLW99L	Karluk Lake - West Shoal	47	33	9/27/1999	96	0	1	1	94	57.394	-154.0780
Other Kodiak	SKARLE99L	Karluk Lake - East Shoal	48	34	9/27/1999	96	0	0	0	96	57.399	-154.0410
Other Kodiak	SCOT99E	Karluk Lake - Cottonwood Creek	49	35	7/27/1999	96	0	7	0	89	57.404	-154.0450
Other Kodiak	SMOR99E	Karluk Lake - Moraine Creek	50	36	7/26/1999	96	0	4	2	90	57.434	-154.0750
Other Kodiak	SKARL01L	Karluk River	51	37	10/14/2001	62	6	0	0	56	57.441	-154.1090
Other Kodiak	SUGAN97	Uganik Lake	52	38	7/15/1997	95	0	0	0	95	57.671	-153.3730
Other Kodiak	SUGAN15	Uganik Lake - Tribuatary	53	39	8/4/2015	190	0	0	0	190	57.646	-153.3004

-continued-

Appendix A1.–Page 4 of 4.

Reporting group	ADF&G code	Location	Col no.	Pop no.	Date	Init'l	Alt.	Miss.	Dup.	Final	Lat	Long
Other Kodiak	SBARAB12	Barabara Lake	54	40	8/17/2012	44	0	0	0	44	57.814	-152.9583
Other Kodiak	SBARAB15		55	40	8/4/2015	51	0	1	0	50	57.817	-152.9640
Other Kodiak	SLRIV97	Little River Lake	56	41	7/15/1997	96	0	1	0	95	57.781	-153.6653
Other Kodiak	SMALI93	Malina Lake - Lower	57	42	8/19/1993	80	0	1	1	78	58.164	-153.1532
Other Kodiak	STHOR06	Thorsheim Lake	58	43	8/23/2006	83	0	0	0	83	58.235	-152.8861
Other Kodiak	SKAFL08	Kaflia Lake - Mouth Creek	59	44	8/27/2008	95	0	1	0	94	58.249	-154.2442
Other Kodiak	SAFOG93	Afognak Lake	60	45	8/17/1993	79	0	0	1	78	58.133	-152.9863
Other Kodiak	SPORT98	Portage Lake	61	46	8/11/1998	96	0	0	0	96	58.283	-152.4194
Other Kodiak	SPAUL14	Pauls Lake	62	47	6/25/2014	95	0	0	0	95	58.376	-152.3256
Buskin Lake	SBUSK05	Buskin Lake	63	48	6/26/2005	95	0	1	0	94	57.778	-152.5413
Buskin Lake	SBUSKL10		64	48	6/13/2010	95	0	0	1	94	57.777	-152.5373
Buskin Lake	SBUSKL15		65	48	6/15/2015	190	0	1	0	189	57.777	-152.5367
Lake Louise	SLKLOU05	Lake Louise - Buskin River	66	49	8/3/2005	95	0	0	0	95	57.767	-152.4992
Lake Louise	SLKLOU10		67	49	7/19/2010	95	0	0	2	93	57.759	-152.5090
Lake Louise	SLKLOU14	Lake Louise - Buskin River	68	50	7/2/2014	190	0	1	0	189	57.759	-152.5090
Other Kodiak	SPASA05	Pasagshak Lake	69	51	7/15/2005	95	0	0	0	95	57.473	-152.4655
Other Kodiak	SLMIA05	Lake Miam	70	52	9/2/2005	95	0	0	1	94	57.5	-152.5784
Other Kodiak	SOCEAB06	Ocean Beach	71	53	8/29/2006	95	0	0	0	95	57.118	-153.1994
Other Kodiak	SHORS05	Horse Marine Lake	72	54	9/2/2005	95	0	0	0	95	57.126	-153.9143
Saltery	SSALT94	Saltery Lake - Creek	73	55	9/16/1994	95	0	2	0	93	57.534	-152.7678
Saltery	SSALT99		74	55	8/26/1999	95	0	1	0	94	57.534	-152.7678
Saltery	SSALT14	Saltery Lake - Weir Early	75	56	6/29/2014	190	0	0	0	190	57.534	-152.7678
Saltery	SLKIT15	Little Kitoi Hatchery	76	57	9/15/2015	190	0	1	0	189	57.534	-152.7678
					Total	7,699	8	122	38	7,531		

APPENDIX B: SOCKEYE SALMON COUNTS AT THE BUSKIN RIVER AND LAKE LOUISE WEIRS, 2008–2017.

Appendix B1.–Daily cumulative counts (*N*) of sockeye salmon passage through the upper Buskin River weir, mid-May–August 31, 2008–2017.

	2008		2009		2010		2011		2012		2013		2014		2015		2016		2017		2008–2017	
Date [a]	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	Avg %
17 May													0	0			0	0				
18 May													0	0			0	0				
19 May													10	0	0	0	0	0			3	0
20 May													46	0	0	0	12	0	1	0	15	0
21 May	0	0			0	0			0	0	0	0	48	0	4	0	125	1	1	0	22	0
22 May	0	0	2	0	0	0			0	0	0	0	51	0	43	0	130	1	1	0	25	0
23 May	0	0	2	0	0	0			0	0	0	0	53	0	116	1	144	1	1	0	35	0
24 May	0	0	2	0	0	0			7	0	2	0	191	1	117	1	144	1	1	0	52	0
25 May	0	0	2	0	0	0			80	1	2	0	206	1	117	1	144	1	434	6	109	1
26 May	0	0	2	0	0	0			225	3	89	1	208	1	117	1	146	1	563	8	150	2
27 May	0	0	2	0	0	0			311	4	116	1	374	3	117	1	224	2	996	14	238	3
28 May	0	0	2	0	0	0	40	0	313	4	179	1	554	4	141	2	770	7	1,047	14	305	3
29 May	0	0	102	1	288	3	323	3	336	4	251	2	628	4	357	4	776	7	1,119	15	418	4
30 May	0	0	116	1	309	3	495	4	337	4	425	3	1,061	8	424	5	944	8	1,329	18	544	5
31 May	0	0	116	1	332	3	677	6	402	5	676	4	1,202	9	720	8	1,162	10	2,044	28	733	7
1 Jun	4	0	116	1	383	4	835	7	544	6	844	5	1,422	10	816	9	1,316	11	2,624	36	890	9
2 Jun	4	0	116	1	650	7	960	8	870	10	1,004	6	1,455	10	924	11	1,811	16	2,698	37	1,049	11
3 Jun	4	0	183	2	662	7	1,161	10	870	10	1,325	8	1,637	12	1,045	12	2,236	19	2,791	39	1,191	12
4 Jun	13	0	183	2	946	10	1,313	11	983	11	1,612	10	1,738	12	1,047	12	2,557	22	2,945	41	1,334	13
5 Jun	13	0	428	6	974	10	1,479	12	1,014	12	1,827	11	1,877	13	1,272	15	2,785	24	3,257	45	1,493	15
6 Jun	79	1	431	6	976	10	1,541	13	1,179	14	2,050	13	2,565	18	1,322	15	3,091	27	3,507	49	1,674	16
7 Jun	81	1	444	6	1,033	11	2,340	20	1,569	18	2,696	17	2,565	18	1,445	17	3,317	29	3,803	53	1,929	19
8 Jun	106	2	448	6	1,337	14	2,840	24	1,780	21	3,382	21	3,464	25	1,618	19	4,067	35	4,594	64	2,364	23
9 Jun	231	4	458	6	1,531	16	2,982	25	1,870	22	3,836	24	4,260	30	2,113	24	4,397	38	4,629	64	2,631	25
10 Jun	289	5	1,258	16	1,809	18	3,360	28	2,027	24	4,057	25	4,637	33	2,194	25	4,671	40	5,318	74	2,962	29
11 Jun	467	8	1,268	16	1,998	20	3,540	30	2,489	29	4,790	30	4,977	36	2,299	26	4,840	42	5,377	74	3,205	31
12 Jun	680	12	1,268	16	2,129	22	3,895	33	2,592	30	5,379	33	5,930	42	2,387	27	4,874	42	5,377	74	3,451	33
13 Jun	764	13	1,324	17	2,515	26	4,256	36	2,813	33	5,933	37	6,639	48	2,387	27	4,876	42	5,382	75	3,689	35
14 Jun	805	14	1,805	23	2,769	28	4,522	38	2,923	34	6,663	41	6,813	49	2,450	28	4,876	42	5,430	75	3,906	37
15 Jun	964	16	1,835	24	3,054	31	5,310	44	3,080	36	7,450	46	7,172	51	2,593	30	4,882	42	5,479	76	4,182	40

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Date [a]	2008		2009		2010		2011		2012		2013		2014		2015		2016		2017		2008–2017	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	Avg %
16 Jun	1,020	17	1,860	24	3,083	31	5,659	47	3,344	39	7,813	48	7,516	54	2,647	30	4,914	42	5,487	76	4,334	41
17 Jun	1,036	18	2,937	38	3,210	33	6,381	53	4,286	50	9,125	56	7,949	57	2,734	31	4,947	43	5,648	78	4,825	46
18 Jun	1,242	21	3,107	40	3,806	39	6,972	58	4,395	51	9,880	61	8,450	60	2,734	31	5,077	44	5,672	79	5,134	48
19 Jun	1,385	23	3,143	41	3,951	40	7,537	63	4,472	52	10,278	63	8,882	64	2,735	31	5,138	44	5,973	83	5,349	50
20 Jun	1,430	24	3,556	46	4,256	43	7,752	65	4,494	52	10,841	67	9,267	66	2,761	32	5,220	45	6,005	83	5,558	52
21 Jun	1,517	26	3,821	49	4,516	46	8,064	67	4,666	54	10,969	68	9,339	67	2,769	32	5,720	49	6,032	84	5,741	54
22 Jun	1,783	30	4,129	53	4,557	47	8,383	70	5,317	62	11,240	69	9,603	69	2,796	32	5,826	50	6,464	90	6,010	57
23 Jun	1,859	32	4,237	55	4,721	48	8,517	71	5,624	66	11,883	73	9,733	70	3,012	35	6,146	53	6,514	90	6,225	59
24 Jun	1,945	33	4,352	56	4,799	49	8,806	73	5,632	66	12,270	76	9,897	71	3,025	35	6,158	53	6,521	90	6,341	60
25 Jun	2,583	44	4,476	58	5,264	54	9,055	76	5,885	69	12,509	77	10,015	72	3,195	37	6,299	54	6,529	90	6,581	63
26 Jun	2,608	44	4,640	60	5,797	59	9,183	77	5,938	69	12,797	79	10,144	73	3,396	39	6,352	55	6,615	92	6,747	65
27 Jun	2,830	48	4,979	64	6,006	61	9,273	77	6,215	73	13,064	81	10,208	73	3,461	40	6,453	56	6,619	92	6,911	66
28 Jun	3,008	51	5,242	68	6,074	62	9,562	80	6,236	73	13,629	84	10,353	74	3,633	42	6,456	56	6,941	96	7,113	68
29 Jun	3,069	52	5,370	69	6,126	63	9,619	80	6,357	74	13,792	85	10,470	75	3,736	43	6,456	56	6,941	96	7,194	69
30 Jun	3,648	62	5,642	73	6,174	63	9,773	82	6,624	77	13,925	86	10,547	75	4,032	46	6,573	57	6,941	96	7,388	72
1 Jul	3,745	63	5,666	73	6,201	63	9,791	82	6,699	78	14,039	87	10,631	76	4,183	48	6,865	59	6,941	96	7,476	73
2 Jul	3,802	64	5,746	74	6,582	67	9,810	82	6,753	79	14,124	87	10,680	76	4,350	50	6,881	59	6,980	97	7,571	74
3 Jul	4,150	70	5,753	74	7,131	73	9,822	82	6,836	80	14,224	88	10,746	77	4,570	52	6,881	59	7,026	97	7,714	75
4 Jul	4,235	72	5,756	74	7,131	73	10,059	84	6,910	81	14,272	88	10,825	77	4,717	54	6,924	60	7,026	97	7,786	76
5 Jul	4,235	72	5,807	75	7,140	73	10,085	84	6,933	81	14,289	88	10,956	78	5,133	59	7,236	62	7,026	97	7,884	77
6 Jul	4,244	72	5,825	75	7,310	75	10,180	85	6,947	81	14,318	88	11,018	79	5,516	63	7,311	63	7,027	97	7,970	78
7 Jul	4,281	73	5,903	76	7,387	75	10,221	85	6,992	82	14,404	89	11,185	80	5,550	64	7,377	64	7,075	98	8,038	79
8 Jul	4,302	73	6,255	81	7,762	79	10,270	86	7,169	84	14,475	89	12,151	87	5,560	64	7,407	64	7,100	98	8,245	80
9 Jul	4,401	75	6,297	81	8,370	85	10,328	86	7,224	84	14,546	90	12,195	87	5,579	64	8,053	70	7,103	98	8,410	82
10 Jul	4,402	75	6,313	81	8,437	86	10,460	87	7,225	84	14,978	93	12,242	88	5,795	66	8,056	70	7,115	99	8,502	83
11 Jul	4,403	75	6,375	82	8,503	87	10,477	87	7,622	89	15,070	93	12,276	88	5,888	68	8,090	70	7,139	99	8,584	84
12 Jul	4,587	78	6,376	82	8,583	88	10,530	88	7,690	90	15,089	93	12,294	88	5,911	68	8,113	70	7,140	99	8,631	84
13 Jul	4,658	79	6,385	82	8,625	88	10,539	88	7,700	90	15,113	93	12,310	88	5,922	68	8,147	70	7,153	99	8,655	85
14 Jul	4,658	79	6,435	83	8,643	88	10,771	90	7,709	90	15,145	94	12,388	89	5,990	69	8,475	73	7,176	99	8,739	85
15 Jul	4,664	79	6,527	84	9,196	94	10,774	90	7,713	90	15,256	94	12,416	89	6,195	71	8,521	74	7,176	99	8,844	86

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Date [a]	2008		2009		2010		2011		2012		2013		2014		2015		2016		2017		2008–2017	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	Avg %
16 Jul	4,680	79	6,887	89	9,197	94	10,779	90	7,717	90	15,264	94	12,698	91	6,599	76	8,620	74	7,179	99	8,962	88
17 Jul	4,770	81	6,889	89	9,197	94	10,780	90	7,729	90	15,281	94	12,743	91	6,621	76	8,684	75	7,179	99	8,987	88
18 Jul	4,777	81	6,910	89	9,261	95	10,782	90	7,784	91	15,295	94	12,795	92	6,622	76	9,204	79	7,184	99	9,061	89
19 Jul	4,777	81	6,911	89	9,327	95	10,782	90	7,801	91	15,301	95	12,810	92	6,950	80	9,272	80	7,186	100	9,112	89
20 Jul	4,777	81	6,921	89	9,396	96	10,783	90	7,859	92	15,307	95	13,078	94	6,986	80	9,279	80	7,186	100	9,157	90
21 Jul	4,785	81	7,007	90	9,409	96	10,786	90	7,867	92	15,320	95	13,101	94	7,125	82	9,281	80	7,186	100	9,187	90
22 Jul	4,787	81	7,060	91	9,416	96	10,851	91	7,877	92	15,322	95	13,106	94	7,519	86	9,296	80	7,188	100	9,242	91
23 Jul	4,787	81	7,067	91	9,428	96	10,856	91	7,900	92	15,341	95	13,111	94	7,522	86	9,357	81	7,205	100	9,257	91
24 Jul	4,990	85	7,068	91	9,428	96	10,865	91	7,906	92	15,345	95	13,118	94	7,522	86	9,383	81	7,205	100	9,283	91
25 Jul	5,043	85	7,289	94	9,430	96	10,871	91	7,911	92	15,363	95	13,120	94	7,528	86	9,389	81	7,208	100	9,315	91
26 Jul	5,044	85	7,395	95	9,608	98	10,872	91	7,917	92	15,387	95	13,124	94	7,560	87	9,417	81	7,208	100	9,353	92
27 Jul	5,045	86	7,399	95	9,617	98	10,878	91	7,947	93	15,390	95	13,145	94	7,572	87	9,505	82	7,208	100	9,371	92
28 Jul	5,050	86	7,421	96	9,617	98	10,887	91	7,990	93	15,392	95	13,148	94	7,774	89	9,522	82	7,208	100	9,401	92
29 Jul	5,412	92	7,461	96	9,617	98	10,914	91	7,991	93	15,413	95	13,149	94	7,791	89	9,579	83	7,208	100	9,454	93
30 Jul	5,441	92	7,480	96	9,638	98	10,915	91	8,033	94	15,440	95	13,196	94	7,808	90	9,826	85	7,210	100	9,499	94
31 Jul	5,466	93	7,502	97	9,650	98	10,915	91	8,049	94	15,448	95	13,198	94	7,814	90	10,351	89	7,210	100	9,560	94
1 Aug	5,486	93	7,516	97	9,652	98	10,916	91	8,049	94	15,530	96	13,200	94	7,835	90	10,369	90	7,210	100	9,576	94
2 Aug	5,503	93	7,516	97	9,653	99	10,933	91	8,049	94	15,587	96	13,201	94	7,841	90	10,369	90	7,210	100	9,586	94
3 Aug	5,521	94	7,519	97	9,656	99	10,935	91	8,057	94	15,691	97	13,419	96	7,885	90	10,371	90	7,210	100	9,626	95
4 Aug	5,538	94	7,572	98	9,656	99	10,935	91	8,077	94	15,732	97	13,425	96	8,174	94	10,378	90	7,211	100	9,670	95
5 Aug	5,562	94	7,579	98	9,661	99	10,965	92	8,195	96	15,746	97	13,438	96	8,208	94	10,452	90	7,211	100	9,702	96
6 Aug	5,570	94	7,580	98	9,665	99	10,965	92	8,199	96	15,789	98	13,447	96	8,215	94	10,611	92	7,211	100	9,725	96
7 Aug	5,578	95	7,581	98	9,666	99	10,965	92	8,199	96	15,789	98	13,450	96	8,288	95	10,632	92	7,212	100	9,736	96
8 Aug	5,589	95	7,581	98	9,680	99	10,965	92	8,200	96	15,789	98	13,466	96	8,303	95	10,635	92	7,212	100	9,742	96
9 Aug	5,592	95	7,586	98	9,680	99	10,965	92	8,207	96	15,809	98	13,647	98	8,375	96	10,635	92	7,212	100	9,771	96
10 Aug	5,608	95	7,589	98	9,682	99	10,985	92	8,208	96	15,833	98	13,698	98	8,394	96	10,646	92	7,212	100	9,786	96
11 Aug	5,639	96	7,592	98	9,682	99	10,987	92	8,211	96	15,837	98	13,710	98	8,413	96	10,646	92	7,212	100	9,793	96
12 Aug	5,660	96	7,594	98	9,682	99	10,987	92	8,240	96	15,844	98	13,720	98	8,423	97	10,653	92	7,212	100	9,802	96
13 Aug	5,661	96	7,601	98	9,683	99	10,988	92	8,242	96	15,848	98	13,730	98	8,448	97	10,655	92	7,213	100	9,807	97
14 Aug	5,858	99	7,603	98	9,698	99	10,993	92	8,414	98	15,851	98	13,739	98	8,458	97	10,765	93	7,213	100	9,859	97

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	2008		2009		2010		2011		2012		2013		2014		2015		2016		2017		2008–2017	
Date [a]	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	Avg %
15 Aug	5,862	99	7,604	98	9,709	99	10,993	92	8,452	99	15,858	98	13,749	98	8,465	97	10,775	93	7,213	100	9,868	97
16 Aug	5,875	100	7,605	98	9,710	99	10,994	92	8,453	99	15,859	98	13,751	98	8,470	97	10,789	93	7,213	100	9,872	97
17 Aug	5,878	100	7,612	98	9,720	99	10,995	92	8,453	99	15,893	98	13,753	98	8,512	98	10,926	94	7,213	100	9,896	98
18 Aug	5,882	100	7,613	98	9,739	99	11,024	92	8,454	99	15,936	98	13,754	98	8,526	98	10,961	95	7,213	100	9,910	98
19 Aug	5,882	100	7,615	98	9,751	100	11,251	94	8,455	99	15,947	99	13,761	98	8,536	98	11,010	95	7,213	100	9,942	98
20 Aug	5,882	100	7,620	98	9,755	100	11,254	94	8,455	99	15,955	99	13,763	98	8,550	98	11,024	95	7,213	100	9,947	98
21 Aug	5,883	100	7,620	98	9,761	100	11,263	94	8,460	99	15,957	99	13,764	98	8,553	98	11,044	95	7,213	100	9,952	98
22 Aug	5,883	100	7,620	98	9,761	100	11,274	94	8,460	99	15,962	99	13,772	99	8,554	98	11,053	95	7,213	100	9,955	98
23 Aug	5,886	100	7,622	98	9,764	100	11,290	94	8,464	99	15,972	99	13,776	99	8,556	98	11,062	95	7,213	100	9,961	98
24 Aug	5,887	100	7,622	98	9,766	100	11,292	94	8,465	99	15,998	99	13,791	99	8,559	98	11,068	96	7,213	100	9,966	98
25 Aug	5,889	100	7,623	98	9,766	100	11,369	95	8,465	99	16,001	99	13,801	99	8,560	98	11,069	96	7,214	100	9,976	98
26 Aug	5,889	100	7,623	98	9,769	100	11,561	96	8,465	99	16,003	99	13,813	99	8,563	98	11,075	96	7,214	100	9,998	98
27 Aug	5,890	100	7,625	98	9,769	100	11,684	98	8,466	99	16,013	99	13,817	99	8,578	98	11,085	96	7,214	100	10,014	99
28 Aug	5,890	100	7,698	99	9,771	100	11,795	98	8,466	99	16,013	99	13,838	99	8,584	98	11,099	96	7,214	100	10,037	99
29 Aug	5,890	100	7,728	100	9,771	100	11,801	98	8,466	99	16,023	99	13,842	99	8,586	98	11,125	96	7,214	100	10,045	99
30 Aug	5,890	100	7,731	100	9,771	100	11,806	99	8,466	99	16,024	99	13,845	99	8,587	98	11,130	96	7,214	100	10,046	99
31 Aug	5,892	100	7,731	100	9,772	100	11,816	99	8,467	99	16,024	99	13,845	99	8,588	98	11,137	96	7,214	100	10,049	99
Total [b]	5,900		7,757		9,800		11,982		8,565		16,189		13,976		8,719		11,584		7,222		10,169	

[a] Sockeye salmon escapement after July 31 was estimated through a weir located lower in the drainage operated through a different project focused on counting coho salmon. Counts after July 31 were usually small and sporadic; therefore, run timing was estimated based on the July 31 total.

[b] Total includes counts until weir was removed each year.

Appendix B2.–Daily cumulative counts (*N*) of sockeye salmon passage through the Lake Louise weir, late May–August 31, 2004-2013.

	2008		2009		2010		2011		2012		2013		2014		2015		2016		2017		2008–2017	
Date	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	Avg %
25 May									0	0												
26 May									0	0												
27 May									0	0												
28 May									0	0												
29 May									0	0												
30 May			0	0					0	0												
31 May			0	0					0	0												
1 Jun			0	0					0	0	0	0									0	0
2 Jun			0	0					0	0	0	0			0	0			0	0	0	0
3 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
4 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
5 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
6 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
7 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
8 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
9 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
10 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
11 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
12 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
13 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
14 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
15 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
16 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
17 Jun			0	0					0	0	0	0	0	0	0	0			0	0	0	0
18 Jun	1	0	0	0					0	0	0	0	0	0	0	0			0	0	0	0
19 Jun	1	0	0	0					0	0	0	0	0	0	0	0			0	0	0	0
20 Jun	1	0	0	0			3	1	0	0	0	0	0	0	0	0			1	1	1	0
21 Jun	1	0	0	0			5	1	0	0	0	0	0	0	0	0			2	1	1	0
22 Jun	1	0	0	0			8	2	0	0	0	0	0	0	0	0			2	1	1	0
23 Jun	1	0	0	0			8	2	0	0	0	0	0	0	0	0			2	1	1	0
24 Jun	1	0	0	0			8	2	0	0	0	0	0	0	0	0			2	1	1	0

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	2008		2009		2010		2011		2012		2013		2014		2015		2016		2017		2008–2017	
Date	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	Avg %
25 Jun	1	0	0	0			8	2	0	0	0	0	0	0	0	0			2	1	1	0
26 Jun	1	0	0	0			8	2	0	0	0	0	0	0	0	0	4	3	2	1	2	1
27 Jun	1	0	0	0			8	2	0	0	0	0	0	0	0	0	5	3	2	1	2	1
28 Jun	5	1	0	0			8	2	0	0	0	0	0	0	0	0	6	4	11	8	3	2
29 Jun	13	2	0	0			8	2	0	0	0	0	0	0	0	0	6	4	11	8	4	2
30 Jun	13	2	0	0	0	0	10	3	0	0	0	0	0	0	0	0	8	5	11	8	4	2
1 Jul	13	2	0	0	0	0	10	3	0	0	0	0	0	0	0	0	8	5	11	8	4	2
2 Jul	13	2	0	0	0	0	10	3	0	0	1	0	2	0	0	0	8	5	11	8	5	2
3 Jul	32	4	0	0	0	0	10	3	0	0	3	0	4	0	0	0	8	5	11	8	7	2
4 Jul	51	6	0	0	0	0	10	3	0	0	3	0	4	0	0	0	8	5	11	8	9	2
5 Jul	51	6	0	0	0	0	10	3	0	0	3	0	13	1	7	3	8	5	11	8	10	3
6 Jul	51	6	0	0	0	0	10	3	0	0	3	0	14	2	29	10	8	5	11	8	13	3
7 Jul	52	6	0	0	0	0	10	3	0	0	3	0	17	2	44	16	14	9	12	9	15	4
8 Jul	56	7	0	0	0	0	10	3	0	0	3	0	42	5	45	16	14	9	12	9	18	5
9 Jul	56	7	0	0	75	18	10	3	0	0	3	0	45	5	45	16	14	9	12	9	26	7
10 Jul	56	7	0	0	76	18	10	3	0	0	3	0	47	5	45	16	14	9	12	9	26	7
11 Jul	56	7	0	0	76	18	10	3	0	0	5	1	51	6	45	16	14	9	12	9	27	7
12 Jul	56	7	0	0	78	19	10	3	5	2	5	1	51	6	45	16	14	9	12	9	28	7
13 Jul	56	7	0	0	78	19	10	3	5	2	5	1	58	6	45	16	14	9	12	9	28	7
14 Jul	56	7	0	0	78	19	10	3	5	2	6	1	67	7	45	16	14	9	12	9	29	7
15 Jul	56	7	0	0	78	19	10	3	5	2	6	1	69	7	46	16	14	9	25	18	31	8
16 Jul	56	7	0	0	78	19	10	3	5	2	6	1	70	8	46	16	14	9	27	19	31	8
17 Jul	56	7	0	0	78	19	10	3	5	2	6	1	70	8	50	18	14	9	27	19	32	8
18 Jul	56	7	0	0	78	19	10	3	5	2	6	1	70	8	50	18	14	9	27	19	32	8
19 Jul	56	7	0	0	78	19	10	3	5	2	8	1	70	8	50	18	14	9	27	19	32	8
20 Jul	56	7	9	1	78	19	10	3	5	2	8	1	70	8	50	18	14	9	67	48	37	11
21 Jul	56	7	188	19	78	19	10	3	5	2	8	1	70	8	50	18	14	9	67	48	55	13
22 Jul	56	7	190	19	78	19	10	3	5	2	8	1	73	8	50	18	14	9	67	48	55	13
23 Jul	56	7	190	19	78	19	10	3	5	2	8	1	77	8	56	20	15	10	70	50	57	14
24 Jul	56	7	190	19	78	19	10	3	5	2	8	1	77	8	56	20	15	10	70	50	57	14
25 Jul	90	11	314	32	78	19	10	3	5	2	9	1	77	8	56	20	15	10	70	50	72	15

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Date	2008		2009		2010		2011		2012		2013		2014		2015		2016		2017		2008–2017	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	Avg %
26 Jul	90	11	337	34	78	19	10	3	5	2	9	1	77	8	56	20	15	10	70	50	75	16
27 Jul	90	11	350	35	78	19	10	3	5	2	9	1	77	8	56	20	15	10	70	50	76	16
28 Jul	90	11	350	35	78	19	10	3	5	2	9	1	77	8	56	20	25	16	70	50	77	16
29 Jul	90	11	368	37	78	19	10	3	5	2	9	1	84	9	58	21	25	16	70	50	80	17
30 Jul	90	11	401	40	128	30	10	3	5	2	9	1	85	9	58	21	28	18	70	50	88	18
31 Jul	90	11	404	41	139	33	10	3	5	2	9	1	85	9	58	21	31	20	70	50	90	19
1 Aug	90	11	404	41	139	33	10	3	5	2	9	1	85	9	58	21	35	22	70	50	91	19
2 Aug	90	11	404	41	139	33	10	3	5	2	9	1	85	9	58	21	35	22	70	50	91	19
3 Aug	90	11	405	41	139	33	10	3	5	2	100	11	211	23	59	21	35	22	70	50	112	22
4 Aug	90	11	405	41	139	33	10	3	5	2	102	11	235	25	113	40	35	22	70	50	120	24
5 Aug	90	11	577	58	139	33	10	3	37	12	102	11	243	26	164	59	35	22	70	50	147	29
6 Aug	90	11	600	60	139	33	10	3	37	12	219	24	243	26	164	59	37	24	70	50	161	30
7 Aug	90	11	600	60	139	33	10	3	37	12	538	60	265	29	164	59	37	24	141	100	202	39
8 Aug	90	11	600	60	139	33	10	3	37	12	561	62	269	29	164	59	37	24	141	100	205	39
9 Aug	90	11	600	60	140	33	10	3	37	12	561	62	336	36	164	59	37	24	141	100	212	40
10 Aug	90	11	600	60	140	33	10	3	37	12	562	62	430	46	172	61	37	24	141	100	222	41
11 Aug	90	11	600	60	140	33	10	3	37	12	562	62	598	65	172	61	37	24	141	100	239	43
12 Aug	99	12	600	60	140	33	10	3	37	12	562	62	686	74	172	61	37	24	141	100	248	44
13 Aug	743	89	600	60	140	33	10	3	37	12	562	62	755	82	172	61	37	24	141	100	320	53
14 Aug	761	91	600	60	184	44	10	3	55	18	562	62	792	86	172	61	76	49	141	100	335	57
15 Aug	762	91	600	60	269	64	10	3	72	24	562	62	793	86	172	61	76	49	141	100	346	60
16 Aug	762	91	600	60	269	64	10	3	75	25	677	75	797	86	172	61	76	49	141	100	358	61
17 Aug	762	91	600	60	273	65	10	3	75	25	701	78	797	86	196	70	76	49	141	100	363	63
18 Aug	766	92	600	60	273	65	15	4	75	25	772	86	797	86	196	70	76	49	141	100	371	64
19 Aug	787	94	600	60	273	65	65	18	75	25	796	88	797	86	196	70	80	51	141	100	381	66
20 Aug	789	95	600	60	273	65	87	24	75	25	798	88	797	86	196	70	80	51	141	100	384	66
21 Aug	791	95	601	61	275	65	88	24	75	25	801	89	797	86	196	70	80	51	141	100	385	67
22 Aug	794	95	601	61	284	68	89	25	80	27	815	90	797	86	196	70	80	51	141	100	388	67
23 Aug	797	96	601	61	285	68	90	25	80	27	821	91	920	99	196	70	80	51	141	100	401	69
24 Aug	797	96	602	61	285	68	90	25	80	27	824	91	923	100	196	70	81	52	141	100	402	69
25 Aug	798	96	603	61	286	68	132	37	80	27	827	92	923	100	196	70	81	52	141	100	407	70

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	2008		2009		2010		2011		2012		2013		2014		2015		2016		2017		2008–2017	
Date	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	Avg %
26 Aug	798	96	604	61	286	68	204	57	80	27	827	92	923	100	198	71	81	52	141	100	414	72
27 Aug	798	96	624	63	286	68	287	80	82	27	827	92	925	100	198	71	81	52	141	100	425	75
28 Aug	798	96	898	91	286	68	334	93	82	27	829	92	925	100	198	71	81	52	141	100	457	79
29 Aug	798	96	955	96	288	68	338	94	82	27	829	92	925	100	198	71	81	52	141	100	464	80
30 Aug	798	96	987	99	288	68	338	94	82	27	903	100	925	100	198	71	81	52	141	100	474	81
31 Aug	806	97	990	100	289	69	338	94	83	28	903	100	925	100	198	71	81	52	141	100	475	81
Total [a]	833		992		421		360		301		903		925		280		156		141		531	

[a] Total includes counts until the weir was removed each year.

APPENDIX C: CODE USED IN STOCK–RECRUIT ANALYSIS

Appendix C1.–rjags code used in stock–recruit analysis for the Buskin River sockeye salmon stock.

```
#Spawner Recruit analysis for Buskin River sockeye salmon
#1990-2017 data
# T=28 calendar years for which we have escapement and possibly age data-1990-2017
# A=3 return ages (4, 5, 6) (Total age===> 4=0.3+1.2+2.1; 5= 1.3+2.2; 6=1.4+2.3+3.2)
# Age Data matrix is a T=28 By A=3 structure.
# BY Returns w/Ricker S-R Link with AR1 Errors
# R[y] = Total Return from BY y
# T+A-1 =28+3-1=30 BYs Represented in the age Data (=(T-a.min)+A+(a.min-1) ); BYs=1984 (=1990-6) -2013 (=2017-4)
# Oldest Age of Returning Fish     =6=a.max;
# Youngest Age of Returnung Fish   =4=a.min.
# We DO NOT Have Spawning Abundances for the First     A+a.min -1 = 3+4-1   = 6 BYs (1984-1989)   (this was 5 for Buskin Coho)
# We DO     Have Spawning Abundances for the Remaining T-a.min    = 28-4    =24 (BYs 7-30; 1990-2013)
#                                        T      = 28
#                                        a.min  =  4
#                                        a.max  =  6
#                                        A      =  3
# Note: R corresponds to BY 1984 through BY 2013 (length=30);  6 yr olds in run for 1990 correspond to 1984; 4 yr olds in 2017 run corresponds to BY 2013
# Note  S corresponds to 1990 through 2017 (length= 28) ;
model  {
  #  AR Set-Up
   for (y in (A+a.min):(T+A-1)) {                          #  y in 7:30;  Through BY's for which we have spawning abundances
       log.R[y] ~ dt(log.R.mean2[y],tau.white,500)
       R[y]<-exp(log.R[y])
       log.R.mean1[y] <- log(S[y-a.max]) + lnalpha - beta * S[y-a.max]
       log.resid[y] <- log(R[y]) - log.R.mean1[y]
   }

  log.resid.vec <- log.resid[(A+a.min):(T+A-1)] # Anchor code section

  log.R.mean2[A+a.min] <- log.R.mean1[A+a.min] + phi * log.resid.0  # [7]; Establish AR log.R mean for first BY having sp ab

  for (y in (A+a.min+1):(T+A-1)) {                          # y in 8:30; Est AR log.R means for remBYs having sp ab.
        log.R.mean2[y] <- log.R.mean1[y] + phi * log.resid[y-1]
                                        }
  lnalpha ~ dnorm(0,1.0E-6)I(0,)
  beta ~ dnorm(0,1.0E-1)I(0,)
  phi ~ dnorm(0,1.0E-4)I(-1,1)
  tau.white ~ dgamma(0.01,0.01)
  log.resid.0 ~ dnorm(0,tau.red)T(-3,3)
  alpha <- exp(lnalpha)
  tau.red <- tau.white * (1-phi*phi)
  sigma.white <- 1 / sqrt(tau.white)
  sigma.red <- 1 / sqrt(tau.red)
  lnalpha.c <- lnalpha + (sigma.white * sigma.white / 2 / (1-phi*phi) )
  S.max<-1/beta
  S.eq<-lnalpha.c*S.max
  S.msy <- S.eq*(0.5 - 0.07*lnalpha.c)
  U.msy <- lnalpha.c * (0.5 - 0.07*lnalpha.c)

#  BROOD YEAR RETURNS W/O SR LINK DRAWN FROM COMMON LOGNORMAL DISTN---Anchor
    mean.log.R ~ dnorm(0,1.0E-4)I(0,)
    tau.R ~ dgamma(0.1,0.1)
    R.0 <- exp(mean.log.R)
    sigma.R0 <- 1 / sqrt(tau.R)
    for (y in 1:a.max) {
    log.R[y] ~ dt(mean.log.R,tau.R,500)
    R[y] <- exp(log.R[y])
    }
```

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```
#  Dirichlet Generation of Returns at Age
#  Generate all T+A-1 = 22 Maturity Schedules, Use Only Those Necessary
   D.scale ~ dunif(0,1)
   D.sum <- 1 / (D.scale * D.scale)
   pi[1] ~ dbeta(1,1)
   pi.2p ~ dbeta(1,1)
   # pi.3p ~ dbeta(1,1)
   pi[2] <- pi.2p * (1 - pi[1])
   #pi[3] <- pi.3p * (1 - pi[1] - pi[2])
   pi[3] <- 1 - pi[1] - pi[2]
   for (a in 1:A) {
   gamma[a] <- D.sum * pi[a]
   for (y in 1:(T+A-1)) {
   g[y,a] ~ dgamma(gamma[a],1)
   p[y,a] <- g[y,a]/sum(g[y,])
   }
   }
# Assign Product of P and R to All Cells in N Matrix (T by A Matrix)
# y Subscript Indexes BY
# y=1 corresponds to the BY of the Oldest Fish (single upper right cell-bold: BY 1984)
# y=30 corresponds to the BY of the Youngest Fish (single lower left cell-bold: BY 2013)

# First Do Initial Cells WITHOUT SR Link (x's in Matrix below)-There are 6 BYs Like This
# Fill first column of x's then second then third, referencing approp cells in p1 and approp Rlag[y]

# T      S                      4 5 6   (Ages)
# 1990   s                       x x x <-y=1 (1990-6: BY 1984)
# 1991   s                       x x x
# 1992   s                       x x x
# 1993   s                       x x x
# 1994   s                       z x x
# 1995   s                       z z x
# 1996   s                       z z z
# 1997   s                       z z z
#        s                      .
# 2015   s                       z z z
# 2016   s                       z z z
# 2017   s y=30(2017-4:BY 2013)->    z z z

# ASSIGN PRODUCT OF P AND R TO ALL CELLS IN N MATRIX
      for (a in 1:A) {
      for (y in a:(T + (a - 1))) {
         N.ta[y - (a - 1), (A + 1 - a)] <- p[y, (A + 1 - a)] * R[y]
      }
      }
# Multinomial Scale Sampling on Total Annual Return N
# Index t is Calendar Year
for (t in 1:T) {
        N[t] <- sum(N.ta[t,1:A])                      # Annual return in year t
for (a in 1:A) {
        p2[t,a] <- N.ta[t,a] / N[t]                  # Multinomial proportions in Calendar year t
              }    # a
       # n[t] <- sum(x[t,1:A])                      # Multinomial sample size in Calendar year t
       # x[t,1:A] ~ dmulti(p2[t,],n[t])               # Count Data
       x[t,1:A] ~ dmulti(p2[t,],n.tot[t])             # Count Data
        }    # t
```

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```
# From 1990 on (this code) Escapement  Measured at Buskin Lake Weir
# Model Sport harvest as lognormal(), with var=SWHS estimate
# Model Prop of Unreported Permits Having Same Harvest Rate as Reported Permits as dbeta()
# Model proportion of true esc covered by weir operation as w~ beta -then obs esc ~lognorm()
# Weir Counting Error:  2% cv

for(y in 1:T) {

# Sport Harvest
p.HSF[y]~dbeta(0.1,0.1)                        # Uninformative beta (alpha + beta is small)
HSF[y]<-p.HSF[y]*N[y]
log.HSF[y]<-log(HSF[y])
tau.log.HSF[y]<-1/cv.HSF[y]/cv.HSF[y]
HSF.hat[y]~dlnorm(log.HSF[y], tau.log.HSF[y])

# Subsistence Harvest
 #padjSub[y]~dbeta(5,1)                        # Prop unreported permits having same harv rate as reported permits
 padjSub[y]~dbeta(5.6,3)                       # Prop unreported permits having harv rate as 0.65 reported permits
 HSub[y]<-Sub[y]+ (Sub[y]/pret[y] - Sub[y])*padjSub[y] # Rep Subs harv plus (Max harvest minus Reported harvest)*padjSub

SubSF[y]<-HSub[y]+HSF[y]
mu[y]<-SubSF[y]/N[y]

# Escapement
 S[y] <-max(N[y] - HSF[y]-HSub[y], 10)
 w[y]~dbeta(30,1)
 Sadj[y]<-w[y]*S[y]
 log.Sadj[y]<-log(Sadj[y])
 tau.log.Sadj[y]<-1/cv.Sadj[y]/cv.Sadj[y]
 Shat[y]~dlnorm(log.Sadj[y],tau.log.Sadj[y])

# Inriver run
IR[y]<-max(N[y]-HSub[y],10)
                }  # y

# Generate Fitted Values of R Every 1000 Spawning Fish-For Graphics
for (i in 1:20) {  Rfit1[i] <- 1000*i * exp(lnalpha - beta * 1000*i)  }

# Calculate Sustained Yield at Regular INtervals of S
# Find the Probability that Each Value of S Will Result in Yileds wWithin 10% of MSY

R.msy <- S.msy * exp(lnalpha - beta * S.msy)*exp(sigma.red*sigma.red/2)
MSY <- R.msy - S.msy

for (i in 1:S.ninc)  {
  S.star[i] <- S.byinc*i
  R.fit[i] <- S.star[i] * exp(lnalpha - beta * S.star[i])*exp(sigma.red*sigma.red/2)
  SY[i] <- R.fit[i] - S.star[i]
  I90[i] <- step(SY[i] - 0.9 * MSY)
  I80[i] <- step(SY[i] - 0.8 * MSY)
  I70[i] <- step(SY[i] - 0.7 * MSY)
}
  }
```