Fishery Data Series No. 14-19

Sockeye Salmon Smolt Enumeration on the Karluk River, 2013

by

Mary Loewen

April 2014

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

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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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April 2014

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This document should be cited as:
Loewen, M. 2014. Sockeye salmon smolt enumeration on the Karluk River, 2013. Alaska Department of Fish and Game, Fishery Data Series No. 14-19, Anchorage.

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TABLE OF CONTENTS

Page

LIST OF TABLES ii
LIST OF FIGURES ii
LIST OF APPENDICES ii
ABSTRACT 1
INTRODUCTION 1
OBJECTIVES 3
METHODS 3
Study Site and Trap Description 3
Smolt Enumeration 4
Trap Efficiency and Smolt Population Estimates 4
Age, Weight, and Length Sampling 6
Climate and Hydrology 7
RESULTS 7
Trapping Effort and Catch 7
Smolt Outmigration Timing and Population Estimates 7
Trap Efficiency Estimates 8
Age, Weight, and Length Data 8
Physical Data 8
DISCUSSION 9
Smolt Outmigration Timing 9
Outmigrating Population Estimates and Trap Avoidance 9
Smolt Age Structure 11
Length and Weight Composition 12
Additional Available Data 13
CONCLUSION 14
ACKNOWLEDGEMENTS 14
REFERENCES CITED 15
TABLES AND FIGURES 17
APPENDIX A. SMOLT TRAP CATCHES BY DAY 33
APPENDIX B. CLIMATOLOGICAL OBSERVATIONS 37
APPENDIX C. SUPPLEMENTAL HISTORICAL DATA 43
APPENDIX D. ZOOPLANKTON DATA 53

LIST OF TABLES

Table **Page**

1. Karluk Lake sockeye salmon smolt population estimates, by freshwater age, 1961 to 2013. 18
2. Estimated sockeye salmon smolt outmigration from Karluk Lake in 2013 by freshwater age and statistical week. 19
3. Results from mark-recapture tests performed on sockeye salmon smolt migrating from Karluk Lake, 2013. 19
4. Length, weight, and condition factor of Karluk Lake sockeye salmon smolt samples from the downstream trap in 2013, by freshwater age and statistical week. 20
5. Length, weight, and condition factor of Karluk Lake sockeye salmon smolt samples from the upstream trap in 2013, by age and statistical week. 21

LIST OF FIGURES

Figure **Page**

1. Map of the Karluk Lake and River, showing local communities and ADF&G project locations. 22
2. Timeline depicting historical smolt investigations on the Karluk River. 23
3. Canadian Fan traps in the Karluk River, Alaska, 2013. 24
4. The Downstream Smolt Trap (Site 1), Karluk River, Alaska, 2013. 24
5. The Upstream Smolt Trap (Site 2), Karluk River, Alaska, 2013. 25
6. Daily counts and cumulative percentage of the sockeye salmon smolt outmigration from Karluk Lake in 2013. 26
7. Reported annual Karluk River sockeye salmon smolt outmigration estimates and corresponding 95% confidence intervals, 1991–1992, 1999–2006, 2012–2013. 27
8. Daily estimates and cumulative outmigration of sockeye salmon smolt from Karluk Lake in 2013. 28
9. A comparison of the estimated age structure of freshwater-age-0 to freshwater-age-4 sockeye salmon smolt outmigrations from the Karluk Lake, 1991–1992, 1999–2006, 2012–2013. 29
10. Average length and weight of sampled freshwater-age-1, -2, and -3 sockeye salmon smolt, by year from 1979 to 2013. 30
11. Length frequency histogram of sockeye salmon smolt outmigration samples from Karluk Lake in 2013 by age class 31

LIST OF APPENDICES

Appendix **Page**

A1. Actual daily counts and trap efficiency data of the Karluk River sockeye salmon smolt project, 2013 34
A2. Results of delayed mortality from marked and unmarked smolt, 2013. 36

B1. Daily climatological observations (noon) for the Karluk Lake sockeye salmon smolt project, 2013. 38
B2. Daily climatological observations (midnight) for the Karluk Lake sockeye salmon smolt project, 2013. 40

C1. Karluk River sockeye salmon escapement, estimated number of smolt by freshwater age, smolt per spawner, adult return by freshwater age, return-per-spawner, and marine survival, by brood year, from 1994 to 2006. 44
C2. Mean length, weight, and condition factor of sockeye salmon smolt samples from the Karluk River by year and freshwater age, 1925–2013. 45
C3. Annual sockeye salmon smolt outmigration estimates by number and biomass (Kg) and corresponding 95% confidence intervals, Karluk River, for years with population estimates, 1991–1992, 1999–2006, 2012–2013. 49
C4. Escapement, harvest and total run for Karluk early-run, late-run and total sockeye salmon run, 1985-2012. 50
C5. Combined sockeye salmon early- and late-run brood table 51

D1. Karluk Lake weighted mean zooplankton biomass (mg/m^3) from 1999 to 2012. 54

ABSTRACT

The 2013 Karluk Sockeye Salmon Smolt Enumeration project marked the second consecutive year of sockeye salmon smolt enumeration on the Karluk River, after a five year hiatus from 2007–2011. This report provides the daily and cumulative smolt outmigration estimates as well as biometric and age composition information, and when possible, comparisons with historical data. The abundance of sockeye salmon smolt was estimated using Canadian fan traps and mark-recapture techniques. In 2013, a total of 269,873 sockeye salmon smolt were estimated to pass downstream of the traps from May 16 to June 24, but significant trap avoidance was observed through visual and sonar investigation. The majority of smolt sampled were freshwater-age-2 fish (76%), and average length and weight of each age class were the largest in the historical data series, suggesting a healthy rearing environment for sockeye salmon in Karluk Lake prior to outmigration.

Key words: Sockeye salmon, smolt, *Oncorhynchus nerka*, Karluk River, mark-recapture.

INTRODUCTION

Karluk Lake is located on the southwest side of Kodiak Island (Figure 1), and supports the largest sockeye salmon *Oncorhynchus nerka* run in the Kodiak Management Area (Moore 2012). Karluk Lake (57.442814°N, 154.112031°W) is approximately 19.5 km long, has a surface area of approximately 38.5 km^2 and maximum depth of over 130 m (Finkle 2013). Karluk Lake drains northwest into the approximately 35 km long Karluk River, which in turn flows into Karluk Lagoon, a semi-enclosed estuary with salinities ranging from full marine seawater at the outer spit to nearly freshwater conditions at the head of the lagoon. In addition to sockeye salmon, other fish species in the Karluk Lake drainage include pink salmon *O. gorbuscha*, Chinook salmon *O. tshawytscha*, chum salmon *O. keta*, coho salmon *O. kisutch*, rainbow trout *O. mykiss*, Dolly Varden *Salvelinus malma*, threespine stickleback *Gasterosteus aculeatus*, and coastrange sculpin *Cottus aleuticus*.

Some of the earliest recorded commercial harvests of sockeye salmon in Alaska are from Karluk Lake, dating from the late 1800s (Bean 1891). In the early 1900s, the sockeye salmon fishery at Karluk Lake was lightly regulated and overfishing is suspected to have occurred. A weir was established on the river in 1912 to enumerate escapement, and one of the provisions of the White Act, implemented in 1924, was to reserve 50% of the run for escapement. Despite these efforts, Karluk Lake sockeye salmon suffered a long-term decline in returns, which did not significantly increase until the late 1970s (Barnaby 1944; Schmidt et al. 1997; Schmidt et al. 1998). There are two runs of sockeye salmon that spawn in the watershed. The majority of the early run enters the Karluk watershed in June and early July while the late run enters the system in late July, continuing through September. The early run has a biological escapement goal (BEG) range of 110,000–250,000 fish, while the late-run BEG is 170,000–380,000 fish (Nemeth et al. 2010). July 16 is used at the cut-off date to distinguish between the two runs.From 1985 through 2007, Karluk sockeye salmon runs were consistently strong, averaging roughly 1.3 million sockeye salmon annually. Established early-run escapement goals were exceeded 16 years in the 22 year period, and late-run escapement goals were exceeded 8 years of the 22 year period.

Sockeye salmon juveniles typically spend up to three years in freshwater before migrating to saltwater. The length of time spent in freshwater can be influenced by food availability, competition for space or food, genetics, lake environmental conditions, and various other factors. Juvenile salmon are known to migrate to sea after certain size thresholds are met, during specific seasons, and under certain environmental conditions (Clarke and Hirano 1995). Salmon smolt outmigration may be triggered by warming springtime water temperatures (>4°C) and increased

photoperiod (Clarke and Hirano 1995). Variables affecting growth in juvenile salmon include temperature, competition for habitat, food quality and availability, and water chemistry characteristics (Moyle and Cech 1988). Because of these dynamic factors, annual growth and survival from egg to smolt of sockeye salmon often varies among lakes, years, and within individual populations. Smolt outmigration studies can provide information on life history strategies, marine survival rates, and annual changes in outmigration timing. Combined with limnological investigations, monitoring smolt outmigration can provide insight as to how environmental factors may influence juvenile growth and population health. Smolt data can also serve as an indicator of future run strength and overall stock status.

Sockeye salmon smolt studies have been conducted sporadically on Karluk Lake since 1925. Previous smolt projects were conducted on Karluk Lake from 1925 to 1936, 1961 to 1968, 1979 to 1992, 1994 to 1995, 1997, and from 1999 to 2006 (Figure 2) by a variety of agencies and employing a range of methodologies. Beach seining at Karluk Lake outlet, sonar estimation, fyke nets, trawling in Karluk Lake, and Canadian fan traps have all been used in the Karluk watershed to assess smolt abundance and condition. Most recently, from 1999 to 2006, Canadian fan traps and mark-recapture techniques were used to estimate smolt outmigration population size and obtain biometric data such as age, length, weight, and body condition factor (a standardized measure of the relationship between the weight and length of the fish to indicate "condition"; Duesterloh and Watchers 2007; Watchers and Duesterloh 2005). In 2006 the average size of outmigrating sockeye salmon smolt was the smallest in the dataset stretching back to 1925. Furthermore, the majority of the fish were freshwater-age-3 (Duesterloh and Watchers 2007); historically, freshwater-age-2 smolt have been the dominant outmigrating age class (Kyle et al. 1988; Rounsefell 1958). While it has been found that lake residence time of Karluk sockeye salmon juveniles is longer than most systems (Koenings and Burkett 1987), increased freshwater age is often associated with poorer rearing conditions that cause juvenile salmon to take longer to reach a minimum size needed for onset of smolting and migration to sea (Foerster 1968).

Poor Karluk River sockeye salmon returns were observed beginning in 2008 (Appendix C4). Annual restrictions on subsistence, sport, and commercial salmon fisheries were necessary from 2008 through 2011 in order to achieve escapement goals. Returns were large enough in 2012 and 2013 to allow for fishing opportunity, though the return-per-spawner ratios of each run were below the replacement value (Appendix C5) and uneven when compared to each other, with early run return-per-spawner lower than late run return-per-spawner.

In 2010 and 2011 "grab sample" studies were conducted at Karluk Lake to estimate age, weight and condition of outmigrating sockeye salmon smolt. Additionally, whole fish were collected for stable isotope analyses. In 2012, ADF&G was allocated funding from the Alaska legislature to reinstitute a comprehensive sockeye salmon smolt enumeration project at Karluk Lake. The 2012 season expanded sampling efforts, and used two traps to conduct mark-recapture experiments for estimating total smolt outmigration (Loewen 2013a). The 2013 field season further extended the sampling duration, and included collection of tissue samples for genetic stock identification from all sampled smolt. The long-term goal of this project is to obtain reliable estimates of smolt production over time for Karluk Lake. This report presents data collected in 2013, compares the results to previous years when possible, and provides guidance for future field seasons based on protocols and outcomes of the 2013 season.

OBJECTIVES

The objectives for the 2013 season were the following:

1. Estimate the total number of outmigrating sockeye salmon smolt, by age class, from Karluk Lake from May 10 to June 25.
2. Describe outmigration timing and growth characteristics (length, weight, and condition factor) by age class for Karluk Lake sockeye salmon smolt. Sample size is constructed such that the estimated mean weight of the major age class per strata will be within 5% and the mean length within 2% of the true value with 95% confidence (Thompson 1992).
3. Collect whole-fish samples for stable isotopic composition ($\delta^{15}N$ and $\delta^{13}C$) investigations
4. Collect tissue samples for future genetic stock identification, corresponding to the sampling in objective 1.
5. Build a smolt outmigration and AWL database to estimate smolt-to-adult survival and to assist in forecasting future runs of Karluk sockeye salmon.

METHODS

STUDY SITE AND TRAP DESCRIPTION

Two Canadian fan traps were operated in an upstream-downstream array to capture smolt outmigrating from Karluk Lake (Figure 3). Detailed methods of trap installation, operation, and maintenance are described in the 2013 Karluk Lake Operational Plan (Loewen 2013b). The The downstream trap was installed approximately 0.6 km downstream from the lake outlet (57.4430°N, 154.1158°W) and was the primary site utilized for smolt enumeration and the recapture of marked fish ("Site 1"; Figure 4). The upstream trap was installed approximately 0.1 km downstream from the lake outlet (57.4413°N, 154.1094°W) and was utilized to capture smolt for dye release testing ("Site 2"; Figure 5). Capturing smolt at the upstream trap for marking and release was intended to reduce possible violations of mark-recovery assumptions through learned trap avoidance, as well as to reduce stressing the fish, as encountered in past project years when only one trap was in operation and transportation of the smolt upstream for release incurred heavy mortality (Duesterloh and Watchers 2005).

Both traps were positioned towards the middle of the river at each location, in the area of greatest apparent water flow. The upstream trap was approximately 6 m from shore, and had wing lengths of 12.9 m (river left) and 14.7 m (river right as looking downstream) and a wing mouth opening of 15.2 m, while the downstream trap was approximately 8 m from shore and had wing lengths of 10.3 m (river left) and 13.1 m (river right) and had a wing mouth opening of 12.8 m. A catch box was attached to the outlet of each trap. Hand-powered cable winches ("come-alongs") attached to the rear of the trap allowed for adjustment of the trap vertically in the water column. Both traps were supported by aluminum Rackmaster pipe frame. Perforated aluminum plate supported by additional Rackmaster pipe frame was installed as wings on either side of the trap improve flow and increase capture efficiency at a 45°-60° degree angle to the substrate. Each trap had a separate live box for holding fish captured during the night.

The downstream trap was installed on May 15 and fished continuously through June 24. The trap was removed for the season on June 25. Detailed methods of trap installation, operation, and maintenance are described in the 2013 Karluk Lake Operational Plan (Loewen 2013b).

The upstream trap was installed on May 19 and was fished to collect smolt for five mark-recapture trials, as well as the two nights following a release of marked fish. At the completion of the project, both traps were disassembled and stored on site.

SMOLT ENUMERATION

Because smolt primarily outmigrate at night, sampling days were defined as the 24-hour period from noon to noon and were identified by the date of the first noon-to-midnight period. The traps were checked a minimum of five times each day beginning at noon, at 1600, between 1900 and 2200 hours, continuously between 0000 to 0400 hours, and no later than 1000 hours the next morning. The upstream trap was fished only when fish were needed for mark-recapture trials, and for the following two nights after a mark-recapture trial to obtain sockeye salmon smolt for age-weight-length (AWL) sampling.

Juvenile sockeye salmon greater than 45 mm fork length (FL; measured from tip of snout to fork of tail) were considered smolt (Thedinga et al. 1994). All fish were netted out of the traps' live boxes, identified (McConnell and Snyder 1972; Pollard et al. 1997), enumerated and released, except for those sockeye salmon retained for AWL samples and smolt to be used for mark-recapture tests, as well as smolt retained for isotope analysis.

Smolt enumeration was scheduled to conclude for the 2013 season when catches were <100 fish per night for three consecutive nights.

TRAP EFFICIENCY AND SMOLT POPULATION ESTIMATES

Mark-recapture experiments were scheduled a minimum of once per week to estimate trap efficiency when a sufficient number of smolt were captured to conduct a marking event. The marking event was performed so that the marked fish were released before midnight to coincide with the start of the evening's outmigration. Sockeye salmon smolt were netted from the live box, counted, and transferred into four aerated repositories containing a Bismarck Brown-Y dye solution (5.0 g of dye to 92 L of water) for 20 minutes. Fresh water was then pumped into the container for 90 minutes to flush out the dye and allow the smolt a recovery period in circulating fresh river water. At the end of the marking process, any dead or stressed smolt were removed, counted, and disposed of downstream of the traps. Fish were released from the dye site by hand across the width of the river. The number of smolt recaptured in downstream trap was recorded each day. Sockeye salmon smolt recaptured during mark-recapture experiments were recorded separately from unmarked smolt and excluded from daily total catch to prevent double counting. All dye and release events took place at the upstream trap.

Low capture rates at the upstream trap sometimes necessitated retention of smolt at the downstream trap to achieve the required minimum number of smolt for a trap efficiency test. For the third dye test (June 9) only smolt captured at the downstream trap were used. Between approximately 500 and 1,000 sockeye salmon smolt for each experiment were collected from both traps, except when only fish from the downstream trap were retained, and transferred to an instream holding box. Smolt were collected for a maximum of three consecutive nights to reach desired sample sizes. If desired sample sizes were not achieved fish were released from the live box after the third night,

Additionally, between 50 and 100 marked smolt and the same number of unmarked smolt were held at the upstream trap in an instream live box for five days following the release event to

ensure certain assumptions of the mark-recapture experiments were validated. If significant mortality was observed in the marked, held fish that was not observed in the unmarked, held fish, it is likely that the dyeing process had affected the viability of the smolt released for recapture, and would reduce the number of marked fish available for recapture at the downstream trap. Any mortality observed in the marked, held smolt was incorporated into daily population estimates by reducing the actual number of smolt released by the percentage of mortality observed in the marked, held fish. Furthermore, technicians were tested daily on visual identification of retained marked and unmarked smolts, to ensure that smolt were recognized correctly as dyed or undyed when examined.

The trap efficiency E was calculated by

$$E_h = \frac{m_h + 1}{(M_h + 1)} \tag{1}$$

where

h = stratum or time period index (release event paired with a recapture period),

M_h = the total number of marked smolt released in stratum h, adjusted by the number of marked fish observed dead each day in delayed mortality experiments

and

m_h = the total number of marked smolt recaptured in stratum h.

The population size of outmigrating sockeye salmon smolt was estimated using methods described in Carlson et al. (1998). The approximately unbiased estimator of the total population within each stratum ($\hat{N}_h$) was calculated by

$$\hat{N}_h = \frac{(n_h + 1)(M_h + 1)}{m_h + 1} - 1, \tag{2}$$

where

n_h = the number of unmarked smolt captured in stratum h,

Variance was estimated by

$$v(\hat{N}_h) = \frac{(M_h + 1)(n_h + 1)(M_h + m_h)(n_h - m_h)}{(m_h + 1)^2 (m_h + 2)}. \tag{3}$$

The estimate of $\hat{N}$ for all strata combined was estimated by

$$\hat{N} = \sum_{h=1}^{L} \hat{N}_h , \tag{4}$$

where L was the number of strata. Variance for $\hat{N}$ was estimated by

$$v\left(\hat{N}\right)=\sum_{h=1}^{L} v\left(\hat{N}_h\right), \tag{5}$$

and 95% confidence intervals (CI) were estimated from

$$\hat{N} \pm 1.96\sqrt{v\left(\hat{N}\right)}, \tag{6}$$

which assumed that $\hat{N}$ was asymptotically normally distributed.

The estimate of outmigrating smolt by age class for each stratum *h* was determined by first calculating the proportion of each age class of smolt in the sample population as:

$$\hat{\theta}_{jh}=\frac{A_{jh}}{A_h}, \tag{7}$$

where

A_{jh} = the number of age *j* smolt sampled in stratum *h*, and

A_h = the number of smolt sampled in stratum *h*

with the variance estimated as

$$v\left(\hat{\theta}_{jh}\right)=\frac{\hat{\theta}_{jh}\left(1-\hat{\theta}_{jh}\right)}{A_h} \ . \tag{8}$$

For each stratum, the total population by age class was estimated as

$$\hat{N}_{jh}=N_j\hat{\theta}_{jh}, \tag{9}$$

where $\hat{N}_j$ was the total population size of age *j* smolt, excluding the marked releases (= $\sum N_{jh}$).

The variance for $\hat{N}_{jh}$, ignoring the covariance term, was estimated as

$$v\left(\hat{N}_{jh}\right)=\hat{N}_h^{\,2}v\left(\hat{\theta}_{jh}\right)+\hat{N}_h v\left(\hat{\theta}_{jh}\right)^2 . \tag{10}$$

The total population size of each age class over all strata was estimated as

$$\hat{N}_j=\sum_{h=1}^{L}\hat{N}_{jh}, \tag{11}$$

with the variance estimated by

$$v\left(\hat{N}_j\right)=\sum_{h=1}^{L} v\left(\hat{N}_{jh}\right). \tag{12}$$

AGE, WEIGHT, AND LENGTH SAMPLING

At each trap, smolt sampled for AWL were collected throughout the night's migration and held in an instream live box until sampling the following morning. Five days per statistical week, 40 sockeye salmon smolt were randomly collected from the accumulated fish in the downstream trap live box, anesthetized with Tricaine methanesulfonate (MS-222), and sampled for AWL data. During the two nights immediately following a mark-recapture event, 40 smolt were also

collected on each night from the upstream trap and sampled for AWL data. Paired t-tests were used to test for differences in size and age class of smolt caught in each trap on nights when both traps were fishing. All smolt sampling data reflected the smolt day in which the fish were captured, and samples were not mixed between days.

Fork length (FL, tip of snout to fork of tail) was measured to the nearest 1 mm, and each smolt weighed to the nearest 0.1 g. Scales were removed from the preferred area (International North Pacific Fisheries Commission 1963) and mounted on a microscope slide for age determination. Whole fish were collected for isotopic signature from AWL-sampled fish and frozen until shipped to town. A fin clip for each sampled smolt was preserved in ethanol in labeled vials corresponding to individual fish for genetic identification. One-way ANOVA was used to test for differences in mean length and weight of fish caught in the upstream trap and the downstream trap during the same night.

After sampling, fish were held in aerated water until they completely recovered from the anesthetic, and were released downstream from the traps upon revival. Age was estimated from scales under 60X magnification and described using the European notation (Koo 1962).

Condition factor (Bagenal and Tesch 1978), which is a quantitative measure of the growth of a fish and a relative index of robustness of fish health, was determined for each smolt sampled using

$$K = \frac{W}{L^3} 10^5 , \tag{13}$$

where K is smolt condition factor, W is weight in g, and L is FL in mm.

CLIMATE AND HYDROLOGY

Water depth (cm) from a meter stick attached to the trap, air and water temperature (°C) from thermometers in the catch box and outside the weatherport, estimated cloud cover (%), estimated wind velocity (mph) and wind direction were recorded daily at 1200 hours and at midnight.

RESULTS

TRAPPING EFFORT AND CATCH

Trapping took place for a total of 41 days beginning on May 15 and ending on June 24 (Appendix A1). A total of 24,921 sockeye salmon smolt were captured in the downstream trap (Figure 6). In addition to sockeye salmon smolt, approximately 7,600 sockeye salmon fry, 18,000 juvenile coho salmon, 130 juvenile Chinook salmon, 11,000 Dolly Varden, 3,400 stickleback, and approximately 75,000 sculpin were captured (Appendix A1).

SMOLT OUTMIGRATION TIMING AND POPULATION ESTIMATES

An estimated 269,873 sockeye salmon smolt (95% confidence interval 212,131–327,615 fish) outmigrated in 2013 (Table 1; Figure 7) based upon mark-recapture estimates and trap counts. The outmigration reached 50% on June 5, and the largest night of estimated outmigration occurred May 29 (Figure 8).

TRAP EFFICIENCY ESTIMATES

Mark-recapture experiments were conducted on five occasions beginning on May 29 and ending on June 15. A total of 2,796 smolt were marked and released. Adjusting for delayed mortality resulted in a total seasonal release of 2,081 smolt. Ninety-four smolt were recaptured, and trap efficiency estimates per stratum ranged from 2.3% to 15.0% (Table 3; Appendix A1). The majority of marked smolt were recaptured within two days of being released. Efficiencies from the first test conducted on May 29 were back-applied to smolt counts beginning May 16 (23% of total estimated outmigration).

In 2013, fish from only the upstream trap were used in the first and fifth dye test, while fish from both and upstream and downstream traps were used in the second and fourth dye test, and fish from only the downstream trap were used in the third dye test.

Delayed mortality experiments showed mortality was greatest within the first three days of holding fish. Overall, delayed mortality ranged from 9% for unmarked fish to 24% for marked fish over five days (Appendix A2).

AGE, WEIGHT, AND LENGTH DATA

A total of 998 legible scale samples were collected from sockeye salmon smolt for AWL data. The majority of the outmigration was composed of freshwater-age-2 fish, while older fish (freshwater-age-3) were present in a greater proportion early in the season (May 13–24) and freshwater-age-1 smolt increased as a proportion of the population later in the season (23% after June 14; Table 2). The 2013 outmigration estimate consisted of 44,834 freshwater-age-1 (16.6% of total estimated outmigration), 204,761 freshwater-age-2 (76%), 20,249 freshwater-age-3 (7.5%), and approximately 29 age-4 (<1%) sockeye salmon smolt (Tables 1 and 2; Figure 9).

Of the sampled smolt, the mean length, weight, and condition factor of freshwater-age-1 smolt (n = 197) were 115 mm, 13.9 g, and 0.89. The mean length, weight, and condition factor of freshwater-age-2 smolt (n = 724) were 148 mm, 30.1 g, and 0.90. The mean length, weight and condition factor of freshwater-age-3 smolt (n = 76) were 161 mm, 40.0 g, and 0.92 (Table 4, Figure 10). Length frequency histograms showed that larger smolt (> 120 mm) composed the majority of the catch throughout the season in all age groups (Figure 11).

Additionally, 358 samples were collected from the upstream trap for AWL data. For these samples, the mean length, weight and condition factor of freshwater-age-1 smolt (n = 71) were 114 mm, 12.4 g, and 0.84. The mean length, weight, and condition factor of freshwater-age-2 smolt (n = 279) were 146 mm, 28.5 g, and 0.90. The mean length, weight and condition factor of freshwater-age-3 smolt (n = 8) were 152 mm, 32.4 g, and 0.89 (Table 5).

161 whole fish were retained for isotopic sampling, and frozen for analysis at a later date.

PHYSICAL DATA

The absolute water depth at the trap location varied from 47 cm to 66 cm during the season. Water temperatures averaged near 3.5°C during the first few days the traps were installed (May 18 through May 23) and increased steadily throughout the season to a maximum of 11.5°C on June 18 (Appendix B1 and B2). The season began with low water levels that increased steadily with gradual snow melt throughout the season (Appendix B3). Warm temperatures, little precipitation, and light winds at the trap generally characterized the 2013 season.

DISCUSSION

SMOLT OUTMIGRATION TIMING

The downstream trap was installed on May 15 and appeared to encompass the beginning of the smolt outmigration as 14 sockeye smolt were captured the first two nights of fishing, then no smolt until May 20. Previous project deployment timing had varied from early May to late May, and the timing of trap installment in 2013 was slightly earlier than 2012, and similar to trap deployments in 2000 and 2006, when similar small catches were recorded in the initial few days of trapping (Duesterloh and Watchers 2007). Historically, sockeye salmon smolt leave Karluk Lake in a compressed time frame with the majority of outmigration occurring between May 20 and June 3 in a single peak or with a smaller second peak occurring in the second week of June (Duesterloh and Watchers 2007; Watchers and Duesterloh 2005). This was not observed in 2013. While the greatest single night of estimated outmigration did occur during this period (May 29), only 1,392 smolt were captured that night (estimated total nightly outmigration of 36,025). The largest single night capture occurred late in the season, on June 21, when just over 2,000 fish were captured. This number is extremely small when compared to other years in which over 20,000 smolt might be captured in a single night during the peak of the outmigration.

OUTMIGRATING POPULATION ESTIMATES AND TRAP AVOIDANCE

The 2013 point estimate of 269,873 smolt is lower than any population estimate reported between 1999 and 2006, as well as the 1999–2006 average of 1,872,174 (Loewen 2013a). The total number of smolt caught by the downstream trap (24,921 fish) is also smaller than catches attained during 2000 to 2006 or 2012, although it is similar to the overall catch of 25,042 smolt in 1999 (Duesterloh and Watchers 2007). Trap efficiency estimates in 2013 were less than in 2012, but consistent with or higher than previous years, which historically have ranged between 4.5% and 10.1% (Duesterloh and Watchers 2007).

Low outmigration numbers in 2013 would be expected given the small parent escapements of 2010 and 2011, which were both below 350,000 fish each. However, the 2013 outmigration estimate is considered an underestimate of the true outmigration, and it must be noted that trap avoidance was observed throughout the season. Even with consistent and frequent mark-recapture experiments, smolt population estimates from Karluk River appear to be especially susceptible to underestimation. Population estimates of the Karluk River, especially of 1999, 2005 and 2006, resulted in unrealistic marine survival rates, suggesting an underestimation of the total smolt outmigration (Appendix C2). Historically, sockeye salmon smolt outmigrating from Karluk Lake, are much larger compared to similarly-aged sockeye salmon smolt from other Kodiak Management Area systems. Due to their large size and swimming ability, Karluk smolt may be able to avoid traditional smolt traps better than smolt from other systems, leading to unrealistically small outmigration population estimates.

Despite extremely strong flow into the trap, avoidance was observed. The drop from the trap into the catch box was measured at approximately 4.5 inches, but smolt were observed moving from the catch box back up into the trap and out the mouth of the trap as well as moving into the trap but swimming back upstream before entering the catch box.

To verify suspected avoidance, an underwater camera, a fyke net, and a DIDSON sonar unit were deployed at various times throughout the season. The fyke net was fished for three nights from June 12–June 14, on the river left side of the downstream trap. The fyke net caught less

than 15 sockeye smolt on each of the first two nights, but caught 99 sockeye smolt on June 13, when the trap caught 713 smolt. For several evenings between June 10 and June 22 an underwater camera was placed within the trap and recorded multiple incidents of smolt moving into the trap, then swimming back upstream and out of the trap, despite very strong current. The camera was only operable during daylight hours, so all footage was taken in the evenings between 1900 and 2300. Although species identification cannot be confirmed from the video footage, during this time of the day coho smolt were usually the predominant fish caught in the trap. During each nighttime shift, staff also used headlamps to check areas around the trap for smolt passing downstream outside of the trap, but very few smolt were observed via headlamp.

A DIDSON unit was deployed on two nights, June 21 and June 22, to observe smolt behavior. The first night the DIDSON was deployed to look across the mouth of the trap and numerous clouds of small fish were observed moving into the trap mouth, then moving out again upstream. No attempt was made to verify the species of the fish, or to track their movements once they were out of the sonar beam. On June 22 the DIDSON was placed further upstream to look across the mouth of the wings, and investigate whether smolt were leaving the wings on the river left side of the trap. Fish were observed swimming upstream out of the range of the sonar beam, but could not be visually confirmed to be heading downstream on the outside of the wings. In addition, multiple larger fish, which are suspected to be Dolly Varden, were also observed holding in the space between the wings, and numerous incidents of apparent predatory action on juvenile fish were observed during the DIDSON deployment. The wings apparently provided a productive hunting ground for fish preying upon outmigrating smolt, and an unknown number of sockeye smolt may have been preyed upon as they leave Karluk Lake.

Although the 2013 outmigration estimate is assumed to be an under-estimate of the true number of sockeye smolt that left Karluk Lake, theoretical outmigration estimates using historical data and parent information still suggest 2013 was a small outmigration. Applying the most recent average return-per-spawner ratio (Appendix C5) and a juvenile-adult marine survival rate of 20% (Karluk specific survival rate; Koenings et al. 1993, Honnold and Edmunson 1993) to the 2010 parent escapement (freshwater-age-2. smolt parent escapement) suggests that approximately 892,000 freshwater-age-2 smolt and a total of 1.1 million sockeye smolt could have left Karluk Lake in 2013, if parent spawning conditions and juvenile rearing conditions were favorable in the lake. This estimate indicates that 2013 trap catches would have represented only 2% of the total outmigrating population. However, given the dynamics of trap catches in 2013, an outmigration of even 1.0 million smolt would have resulted in six nights of over 50,000 sockeye smolt leaving the lake, including two nights of over 100,000 smolt. In 2012, one night of an estimated 144,000 sockeye smolt outmigration filled the trap and river, requiring catch weight estimates and the trap to be removed from the water. It is highly unlikely that so many fish could have outmigrated from Karluk Lake and not been detected. Given that the trap was located directly in the thalweg, no modifications to the trap setup due to environmental conditions were required, the trap and wing assembly covered approximately 29% of the wetted width of the river, and that mark-recapture trials returned catch efficiencies averaging 8.5%, 1.1 million smolt represents the uppermost possible outmigration in 2013 under perfect spawning, rearing, and marine survival conditions. Therefore, the number of smolt that outmigrated is likely somewhere between this uppermost possibility and the 2013 outmigration estimate of approximately 300,000 fish.

Timing of outmigration may have also affected the overall population estimate. The annual outmigration is usually determined to have concluded when catches are <100 fish per night for three consecutive nights. Between 1999 and 2006 and in 2012, a decrease in catch each evening was observed after June 18 in all years. In 2013, no decrease in outmigration magnitude was observed and catches over 1,000 smolt per night were still being obtained just prior to the project's end. However, budgetary constraints required the project shut-down. Whether the duration of outmigration this season was unusually long, or what age classes or proportion of the total outmigration may have left Karluk Lake after June 24 is unknown.

Outmigration timing and magnitude in 2013 allowed for five mark-recapture events during the season, with approximately 2,000 smolt marked and released throughout the season. The upstream trap was installed in the river early enough to encompass the entire outmigration, but low catch numbers necessitated moving the trap several times before a suitable location was identified. Low catch numbers continued until May 28, when sufficient smolt for a dye test were captured. Therefore, specific trap efficiencies before this date are unknown. The first mark-recapture test took place on May 29, and the trap efficiency rate from this test applied to catches from the beginning of the season in order to calculate population estimates during the first two weeks of the field season. The downstream trap configuration (perforated plate wings and trap height), as well as water flow and height before May 29 were similar to their configuration during the first mark-recapture test; therefore, applying the trap efficiency rate from the May 29 mark-recapture test to earlier dates through the May 29 mark recapture event is reasonable. In past years, using a one-site mark-recapture design and transporting fish upriver for release had resulted in high mortality (Duesterloh and Watchers 2005). Therefore, the upstream trap was installed to provide fish for mark-recapture experiments without requiring transport of smolt upriver. However, consistently low catch numbers in the upstream trap meant that fish were retained from both traps for mark-recapture experiments throughout the season. In future years, using a single site to trap and recapture the fish and allowing sufficient recovery time at the release site may allow for more mark-recapture tests and therefore more precise estimation of trap efficiencies during the peak of the outmigration. Interannual variation in trap efficiency is expected because the traps were located in different areas of the river in different years, and environmental conditions in certain years (such as high water in 2005) can affect trap efficiencies.

SMOLT AGE STRUCTURE

Freshwater-age-2 fish made up the majority of the 2013 outmigration, with freshwater-age-3 smolt present in larger proportions earlier in the season, and freshwater-age-1 smolt increasing in relative proportion later in the season (Table 2). This is in keeping with Barnaby (1944) in which larger smolt leave the lake first, with smaller fish leaving later in the season, and is also reflected in historical outmigration patterns of age composition throughout the 1999-2006 seasons.

Historically, freshwater-age-2 smolt have been the dominant outmigrating age class followed by freshwater-age-3 smolt (Kyle et al. 1988; Rounsefell 1958, Table 1 and Appendix C2). It is possible that a greater proportion of freshwater-age-1 smolt were captured in the trap than in previous years because their smaller size and relatively weaker swimming ability may have made them more vulnerable to capture in the trap. Given the high condition of even freshwater-age-1 smolt, however, it is also possible that rearing conditions in Karluk Lake were sufficient that more smolt were able to leave the lake at an earlier age than is typical. In 2006, the estimated

proportion of freshwater-age-3 sockeye smolt in the outmigration population was an unprecedented 66%.. Extended residency in freshwater may indicate inadequate forage availability for juvenile salmon. For example, if growth rates are not sufficient to achieve the threshold size necessary to outmigrate in the spring, juvenile fish may stay in a lake to feed for another year (Burgner 1991). Extended freshwater residence for sockeye salmon often also signifies decreased overall lake productivity and subsequent salmon returns (Foerster 1968), such as the returns experienced at Karluk Lake from 2008 to 2011. The return to a predominantly freshwater-age-2 outmigrating smolt population composition suggests that lake rearing conditions have improved compared to those from 2004 to 2009.

However, the effects of several years of escapements in excess of the escapement goal will continue to continue to have ramifications on the overall Karluk system. Large escapements taxed the lake rearing conditions for juvenile sockeye salmon, leading to few, poor condition smolt leaving the system. The adult returns from these years have been observed in the returns of 2007-2011 (Appendix C4). The zooplankton biomass estimated in Karluk Lake in 2009 through 2012 was substantially greater than that from 2005 to 2008, increasing from near-starvation to above satiation levels for rearing salmon (Appendix D; for more on 2012 Karluk limnology see Finkle 2012). While limnological samples suggest that current zooplankton forage and environmental conditions are adequate to support juvenile fish, the low escapements of 2008 to 2011 may have resulted in very few sockeye salmon smolt, continuing the trend of poor returns.

LENGTH AND WEIGHT COMPOSITION

The Karluk sockeye salmon smolt dataset includes age, weight, and length data dating back to the 1920s. On average, freshwater-age-2 and freshwater-age-3 sockeye salmon smolt were larger in 2013 than any in the historical dataset since 1925, while freshwater-age-1 smolt were the third largest average length in the dataset. By weight, all age classes were the heaviest in the dataset (Figure 10; Appendix C3).

The average weight of outmigrating freshwater-age-2 sockeye salmon smolt has a positive correlation with magnitude of returns observed from 1990–2003 (total age-2. returns from an outmigration, $p=.04$, $R^2=0.42$). If the average weight and length for sockeye salmon smolt captured at the downstream trap accurately portrays the characteristics of the total outmigrating population, and the observed positive correlation between size-at-outmigration and returns continues, the returns of smolt enumerated in 2013 should have high marine survival resulting in strong returns compared to recent (2008–2011) returns. However, if smolt differentially avoided the trap (ie. smaller smolt were not captured in the downstream trap and therefore not accurately represented in overall age, weight and length compositions) the reported length and weight of the outmigrating smolt population may be biased towards larger sized fish.

Using one-way ANOVA, statistically significant differences ($p=0.025$) in the mean length of fish were found when the upstream and downstream trap were both fished on the same night (six instances during the season). This is similar to results of 2012, but the difference in mean size was not as pronounced in 2012. These differences in mean length are explained by the fact that larger fish within an age class were more often trapped at the downstream site than the upstream site when the two traps were both fishing. The average size of freshwater-age-3 and freshwater-age-2 fish captured was statistically similar at the upstream and downstream traps (29.0 g and 28.7 g respectively) meaning that it is the difference in small (freshwater-age-1) fish not captured downstream that creates the statistical difference.

It should be noted that the upstream trap was only fished each night until an adequate number of smolt for AWL had been captured, and then was raised out of the water. In contrast, the downstream trap fished continuously, and fish retained for AWL would have represented the entire night's outmigration. Timing of outmigration within a night may vary by age class. If smaller, younger fish leave the lake earlier in the night than older, larger fish, it is possible the upstream trap was not fishing when larger fish would have been passing by, and therefore was not available to catch those larger smolt.

Another possible scenario is that the upstream trap, located only 125 meters from the lake, might capture some juvenile sockeye salmon that were not intending to outmigrate from the lake; a mistake that might not have been corrected in that short distance, but would have resulted in eventually upstream migration prior to traveling the 0.6 km to the downstream trap. Differing rates of active avoidance of the traps by fish size is also a possibility. If large fish avoid the upstream trap at a rate higher than the downstream trap (or conversely, small fish avoid the downstream trap at a rate higher than the upstream trap), this could potentially skew trap efficiency measurements and bias not only population estimates, but also the overall age, weight, and length compositions assumed for the 2013 outmigration. Given that the downstream trap caught larger fish, and that the trap is stationed in the middle of the river, the trap should have been able to effectively catch smaller fish as well. Finally, differences in water velocities between the two sites influencing the behavior of different-sized fish may be a concern, but water velocity was not measured in 2013.

ADDITIONAL AVAILABLE DATA

Data collected from this project enables researchers to better identify what factors are specifically affecting and controlling sockeye salmon production within the freshwater environment which can help refine escapement goals and improve pre-season run forecasts.

In a series of ADF&G memorandums regarding the reduced runs to Karluk Lake, biologists postulated that large escapements from 2000 to 2003, favorable spawning conditions, and favorable rearing conditions produced large numbers of fry for numerous years, which eventually overgrazed and reduced the number of zooplankton available to sockeye salmon fry. Sockeye salmon fry then experienced slow growth and increased mortality, which led to fewer smolt and smolt in poorer condition. Limnological investigations have been conducted in Karluk Lake for many years, and also provide some insight to the rearing habitat and health of sockeye salmon smolt. Estimated Karluk Lake biomass from 2009 through 2012 was substantially greater than that from 2005 to 2008, to above satiation levels for rearing salmon (Appendix D; for more on 2012 Karluk limnology see Finkle 2012).

Stable isotope samples from 2012 and 2013 have not yet been processed, but will help to assess the level of marine-derived nutrients in juvenile sockeye salmon (i.e., Finney et al. 2000). C/N ratios provide an index of lipid content and thus fitness of fish and can be compared to calculated condition factor. The data from these samples will also allow for determination of any trophic level differences between age classes. In addition, the $\delta^{13}C$ ratios, once corrected for lipid contribution, provide a possible index of lake productivity that can supplement ongoing limnological investigations in Karluk Lake.

Genetic tissue samples were collected from each smolt sampled in 2013. While no funds were available to process those samples, it is hoped that identification of the outmigrating smolt by stock (early or late) will provide insight into the dynamics of recovery of each stock. For

example, the early run sockeye salmon stock seems to be recovering less quickly than the late run, and identifying which proportion of the smolt outmigration belongs to each stock might allow managers to prepare for weaker returns of early run fish, and stronger returns of late run fish and manage for effective overall escapement when these smolt return from the sea.

CONCLUSION

The continued collection of smolt outmigration data aids with investigations of changes in life history strategies in the Karluk watershed caused by changes in environmental conditions, such as fluctuating levels of zooplankton forage in Karluk Lake. While smolt investigations have been undertaken at Karluk Lake many times in the past, the sporadic nature and timing of projects makes it difficult to evaluate freshwater production and limits the utility of comparisons through time. Methods employed to enumerate smolt in Karluk waters may not be directly comparable to one another, further making population estimate comparisons difficult. (e.g., beach seining and fin clipping at the lake outlet verses sonar estimation)

In future seasons, improvements to the project including fishing the traps side-by-side, one-site mark-recapture, use of sonar techniques, and quantifying velocity of river flow in addition to height and temperature, will provide further insight to the dynamics of the sockeye salmon smolt outmigration and overall productivity of this important system. For example, the trap and wings can be modified depending on water flow to create a narrower wing mouth opening, increasing the flow into the trap. Additionally, using perforated aluminum sheets to create a longer diversion weir on river left may decrease trap avoidance. A second trap fished alongside and in tandem with the downstream trap would allow for greater trapping area, while maintaining consistent placement of the original trap. A meter to measure flow velocity into the trap relative to the rest of the river is necessary to assess the funneling behavior of the wings, which could be adjusted to increase flow into the trap.

Additional use of the DIDSON unit is also desired to quantify trap avoidance during the outmigration. Methods which do not require trapping of individual fish or provide a census count, such as smolt weirs or sonar enumeration of the total outmigrating population might provide a more robust outmigration estimate. In 2012, a scoping trip on the upper Karluk River located several potential locations suitable for sonar placement.. However, personnel and budget constraints have precluded feasibility studies to this point.

Smolt projects increase in importance and value over the long term, because population estimates can be used as indices. The age, length, and weight data that has been collected over many years is a valuable source of directly comparable interannual data. These data show indications of favorable rearing lake conditions for Karluk Lake sockeye salmon. All age classes of smolt were large, with freshwater-age-2 and freshwater-age-3 smolt larger than any reported since the 1920s, and the condition factor among all age classes was also high. The continued collection of age, length, and weight data when coupled with smolt enumeration, will aid in further understanding the freshwater ecosystem dynamics of Karluk lake and river, and the effects on sockeye salmon run health.

ACKNOWLEDGEMENTS

Julienne Pacheco, Jacob Harding, Ethan Trim and Kelly Krueger were the excellent field staff for the 2013 Karluk Sockeye Salmon Smolt Enumeration project. Trent Dodson and the KRAA staff were quick to provide any assistance requested. Melony Lechner provided incomparable

logistical support. Koniag Inc, provided accommodation for the crew at the field site. Birch Foster, Michelle Moore, Heather Finkle, Nick Sagalkin, and an anonymous colleague reviewed previous versions of this manuscript. References to trade names do not imply endorsement by the Alaska Department of Fish and Game.

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TABLES AND FIGURES

Table 1.–Karluk Lake sockeye salmon smolt population estimates, by freshwater age, 1961 to 2013.

	Number of Smolt						95% C.I.	
Year	Age 0	Age 1	Age 2	Age 3	Age 4	Total	Lower	Upper
1961	6,419	134,811	1,444,399	109,132	0	1,694,761	na	na
1962	0	18,653	1,010,144	406,067	0	1,434,864	na	na
1963	0	3,079	709,755	826,765	0	1,539,599	na	na
1964	0	0	385,593	1,152,095	23,417	1,561,105	na	na
1965	0	0	717,022	733,184	19,101	1,469,307	na	na
1966	0	0	661,593	398,519	20,838	1,080,950	na	na
1967	0	203,736	1,134,127	20,374	0	1,358,237	na	na
1968	0	171,158	2,250,549	1,219,958	0	3,641,665	na	na
1980	0	494,500	1,060,800	131,200	0	1,686,500	na	na
1981	0	219,500	1,561,300	260,900	0	2,041,700	na	na
1982	0	14,000	698,800	108,400	0	821,200	na	na
1983	0	13,000	781,000	147,000	0	941,000	na	na
1984	0	74,000	857,000	143,000	0	1,074,000	na	na
1991	0	108,123	2,392,324	1,640,374	0	4,140,821	2,809,914	5,471,727
1992	0	28,189	2,039,222	1,415,788	10,797	3,493,996	2,780,674	4,207,319
1999	0	35,196	531,134	487,406	12,798	1,066,534	717,152	1,415,915
2000	0	9,441	1,263,785	402,919	0	1,676,502	1,328,451	2,024,553
2001	2,838	238,271	3,062,597	436,469	80	3,740,255	3,136,398	4,344,111
2002	791	11,482	1,072,906	195,323	1,468	1,281,971	1,130,721	1,433,221
2003	0	16,445	1,712,969	501,816	4,205	2,235,435	1,673,898	2,796,972
2004	533	26,479	1,420,076	633,039	186	2,080,339	1,764,223	2,396,454
2005	0	47,834	1,227,246	218,243	2,264	1,494,818	725,956	2,263,680
2006	0	0	393,039	773,173	6,906	1,173,252	965,308	1,381,196
2012	0	26,611	753,793	108,219	35	888,658	730,373	1,046,941
2013	0	44,834	204,760	20,250	29	269,873	212,131	327,615

Table 2.–Estimated sockeye salmon smolt outmigration from Karluk Lake in 2013 by freshwater age and statistical week.

Statistical	Start	Number of Smolt								
Week	Date	Age 1	%	Age 2	%	Age 3	%	Age 4	%	Total
21	5/17	-	-	2,971	73	1,118	27	-	-	4,089
22	5/24	768	2	35,013	73	11,964	25	29	0	47,774
23	5/31	4,469	7	58,896	88	3,587	5	-	-	66,952
24	6/7	3,695	6	58,798	92	1,530	2	-	-	64,023
25	6/14	21,010	35	37,503	63	1,337	2	-	-	59,850
26	6/21	14,892	55	11,580	43	713	3	-	-	27,185
Total		44,834	16.6	204,761	75.9	20,249	8	29	0.0	269,873

Table 3.–Results from mark-recapture tests performed on sockeye salmon smolt migrating from Karluk Lake, 2013.

Date	No. Released[a]	Total Recaptures	Trap efficiency[b]
5/29	206	7	3.9%
6/4	408	39	9.8%
6/9	535	59	11.2%
6/14	503	64	12.9%
6/20	429	90	21.2%

[a] Number of released fish is adjusted for delayed mortality

[b] Calculated by: E = {(R+1)/(M+1)}*100 where: R = number of marked fish recaptured, and; M = number of marked fish (Carlson et al. 1998).

Table 4.–Length, weight, and condition factor of Karluk Lake sockeye salmon smolt samples from the downstream trap in 2013, by freshwater age and statistical week.

	Stat	Sample	Length (mm)		Weight (g)		Condition	
Age	Week	Size	Mean	Std. Err	Mean	Std. Err	Mean	Std. Err
1	21	1	110	0.0	12.3	0.0	0.92	0.00
1	22	6	110	5.5	11.8	1.9	0.85	0.04
1	23	12	119	2.8	15.1	1.4	0.87	0.01
1	24	17	117	1.5	14.8	0.5	0.92	0.02
1	25	93	118	1.0	14.7	0.4	0.88	0.01
1	26	68	118	1.2	14.9	0.5	0.88	0.01
Totals		197	115.4	2.0	13.9	0.8	0.89	0.01
2	21	58	159	1.5	37.1	1.1	0.91	0.01
2	22	203	157	0.8	35.1	0.5	0.90	0.00
2	23	141	152	0.9	31.7	0.6	0.89	0.00
2	24	171	146	1.0	28.8	0.6	0.90	0.01
2	25	103	138	1.2	24.3	0.6	0.91	0.01
2	26	48	137	1.9	23.8	0.9	0.90	0.01
Totals		724	148.1	1.2	30.1	0.7	0.90	0.01
3	21	24	182	2.0	55.3	1.4	0.92	0.02
3	22	29	179	1.5	52.6	1.3	0.91	0.01
3	23	10	164	3.6	40.8	3.2	0.91	0.01
3	24	7	155	8.8	38.3	5.6	1.00	0.07
3	25	3	147	4.9	28.2	3.1	0.87	0.02
3	26	3	141	1.9	24.7	0.9	0.89	0.02
Totals		76	161.3	3.8	40.0	2.6	0.92	0.02
4	22	1	150	na	28.6	na	0.85	na
Totals		1	150.0	na	28.6	na	0.85	na

Table 5.–Length, weight, and condition factor of Karluk Lake sockeye salmon smolt samples from the upstream trap in 2013, by age and statistical week.

	Stat	Sample	Length (mm)		Weight (g)		Condition	
Age	Week	Size	Mean	Std. Err	Mean	Std. Err	Mean	Std. Err
1	21	5	113	2.3	12.5	0.6	0.86	0.0
1	22	4	112	4.0	12.1	1.3	0.85	0.0
1	23	2	114	5.5	10.8	0.2	0.74	0.1
1	24	17	113	1.4	12.9	0.5	0.90	0.0
1	25	43	117	1.1	13.8	0.4	0.86	0.0
Totals		71	113.7	2.9	12.4	0.6	0.84	0.0
2	21	33	151	1.4	31.3	0.9	0.91	0.0
2	22	71	150	1.2	30.9	0.7	0.90	0.0
2	23	76	148	1.1	29.4	0.6	0.91	0.0
2	24	63	145	1.5	27.6	0.9	0.89	0.0
2	25	36	137	2.2	23.4	1.1	0.89	0.0
Totals		279	146.0	1.5	28.5	0.9	0.90	0.0
3	21	1	159	0.0	35.4	0.0	0.88	0.0
3	22	5	168	10.8	45.8	7.8	0.92	0.0
3	23	2	143	2.5	22.3	1.2	0.77	0.1
3	25	1	139	0.0	26.1	0.0	0.97	0.0
Totals		9	152.1	3.3	32.4	2.2	0.89	0.0

Note: Samples were collected on two consecutive nights following a mark-recapture trial.

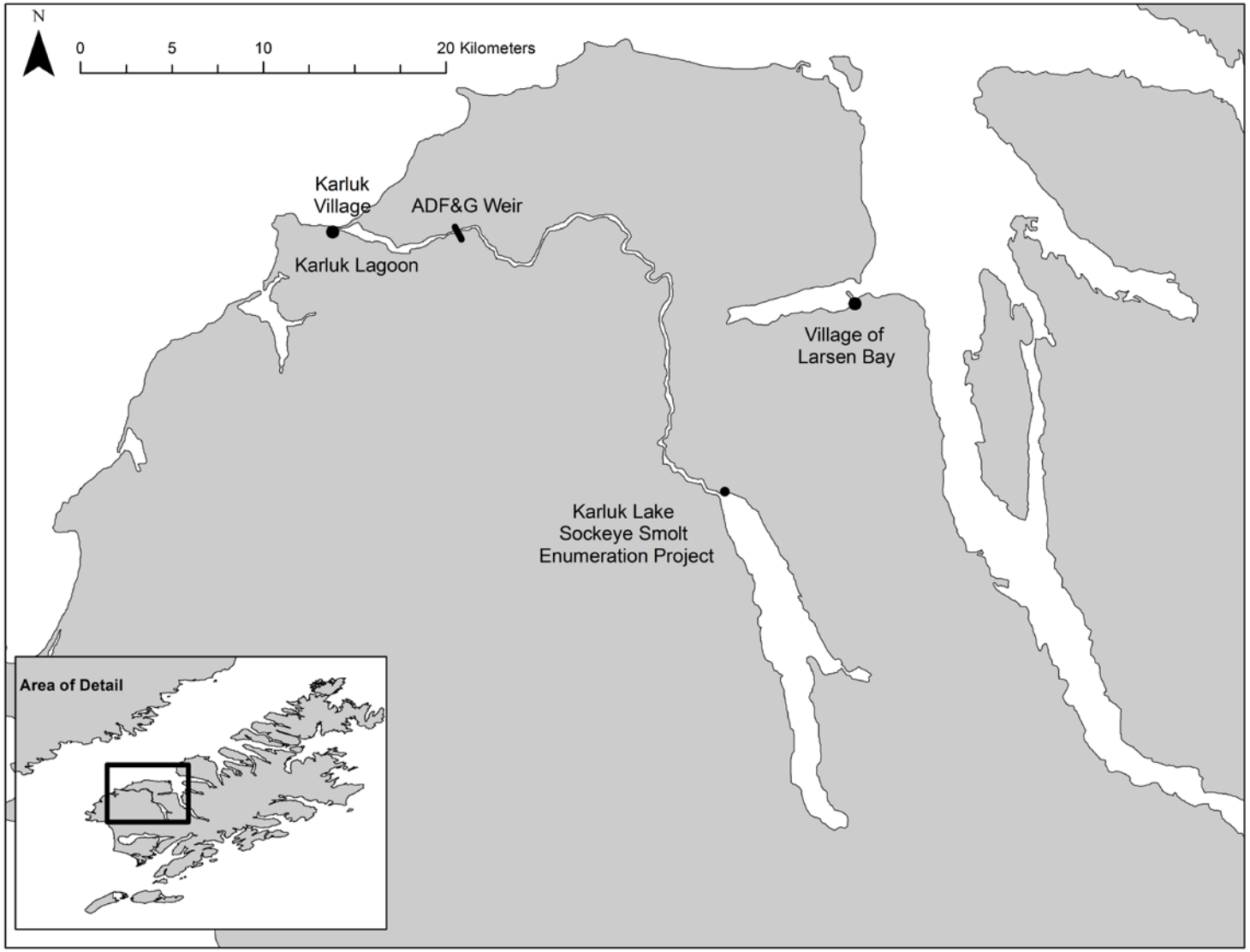

Figure 1.–Map of the Karluk Lake and River, showing local communities and ADF&G project locations.

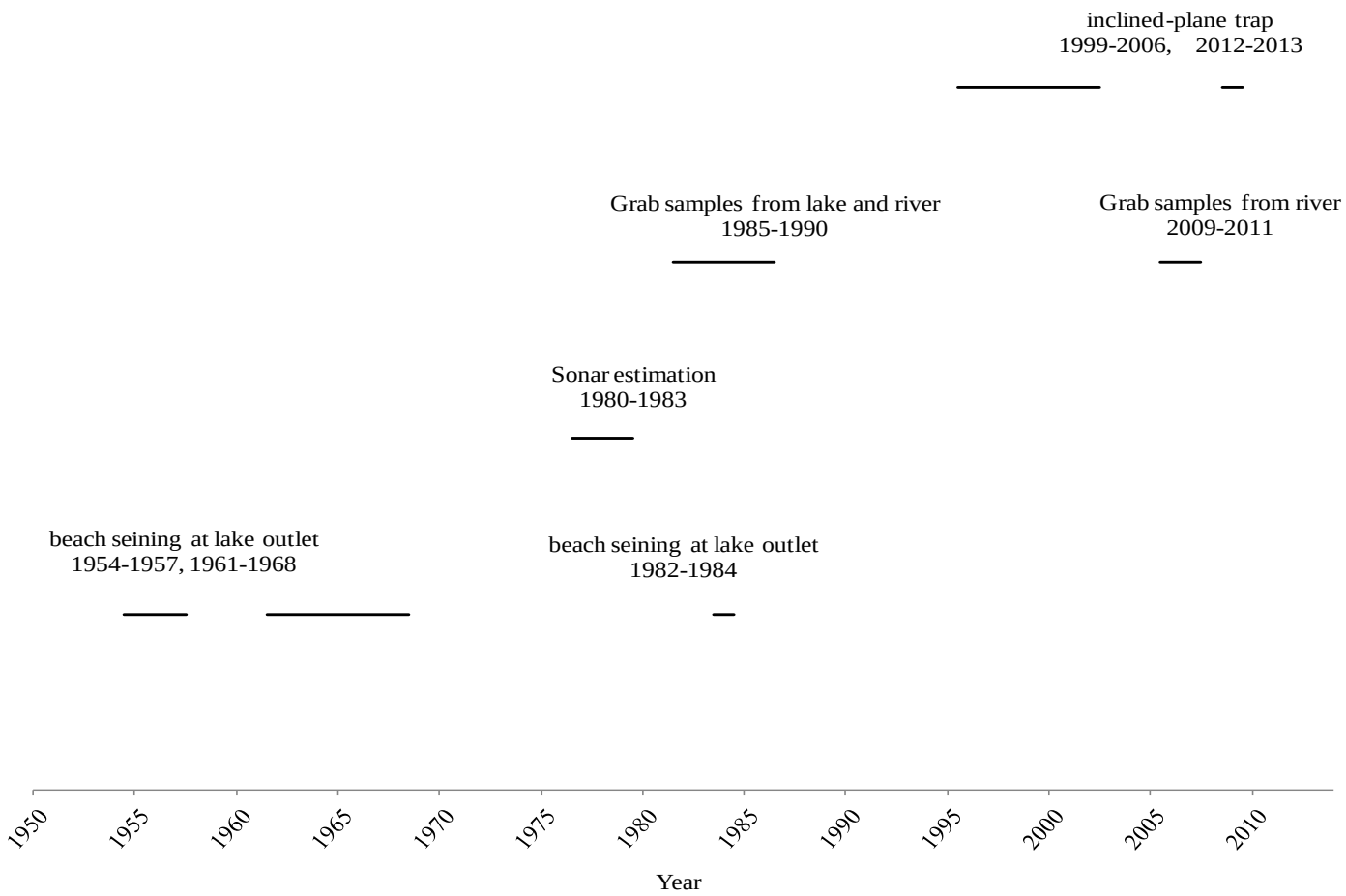

Figure 2.–Timeline depicting historical smolt investigations on the Karluk River.

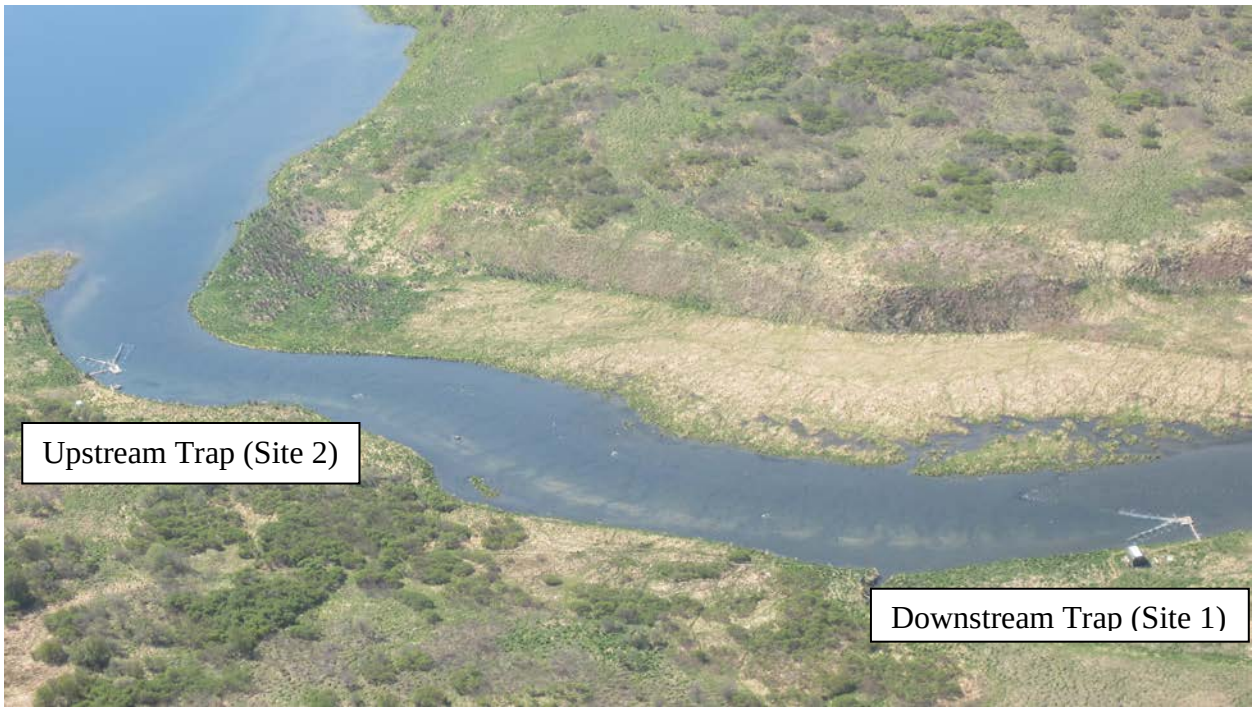

Figure 3.–Canadian Fan traps in the Karluk River, Alaska, 2013.

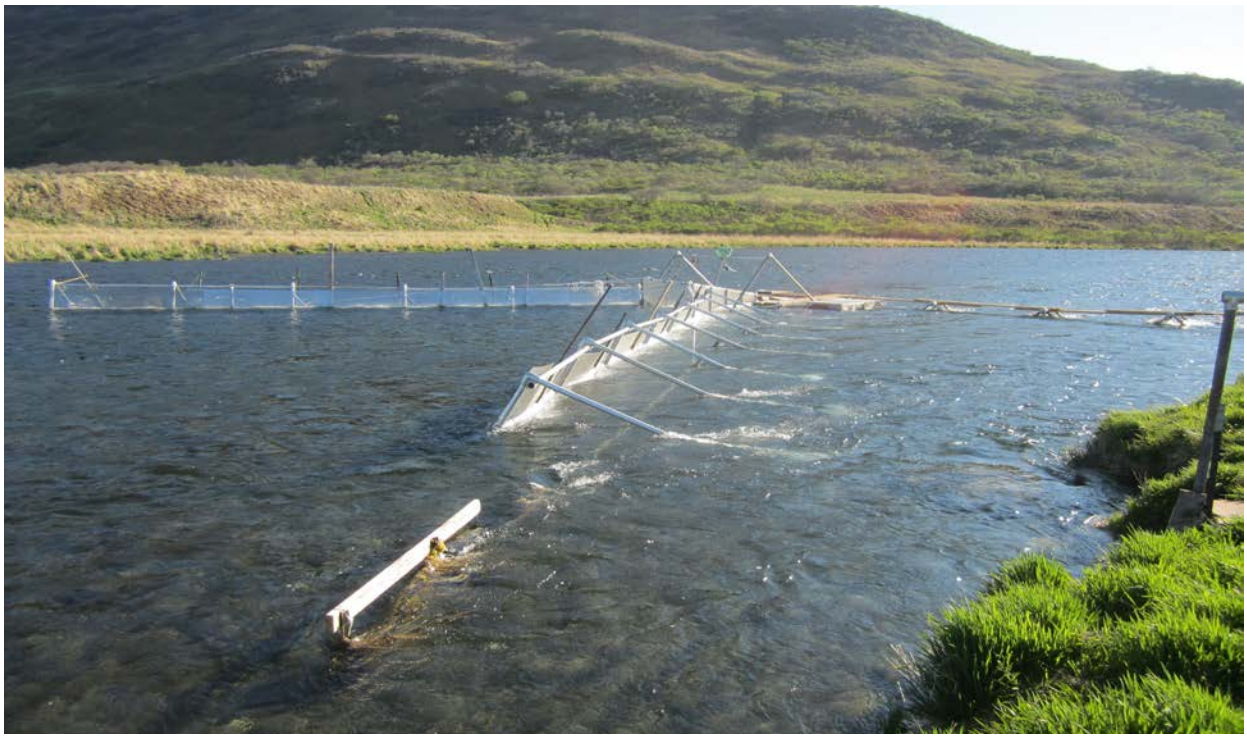

Figure 4.–The Downstream Smolt Trap (Site 1), Karluk River, Alaska, 2013.

Figure 5.–The Upstream Smolt Trap (Site 2), Karluk River, Alaska, 2013.

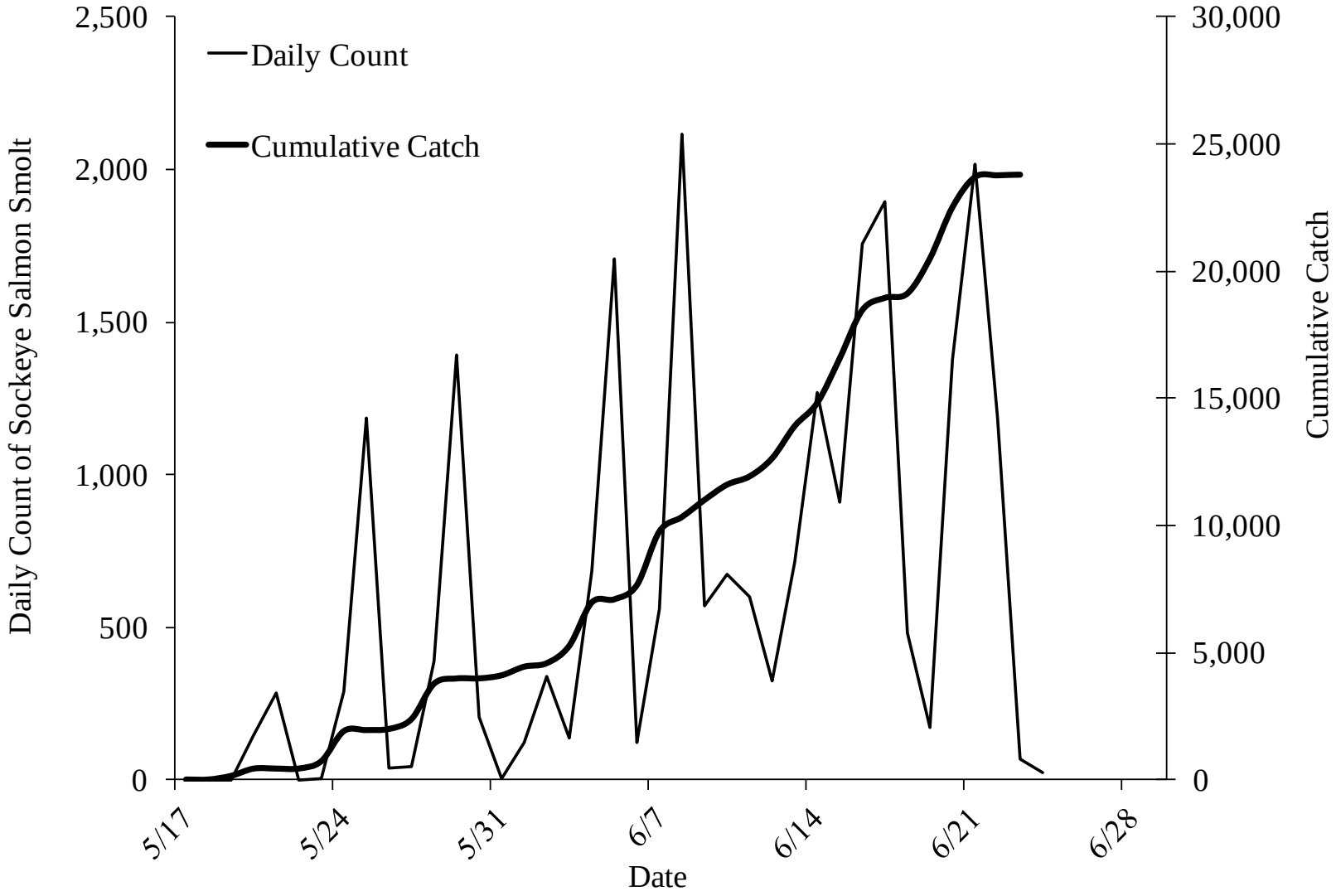

Figure 6.–Daily counts and cumulative percentage of the sockeye salmon smolt outmigration from Karluk Lake in 2013.

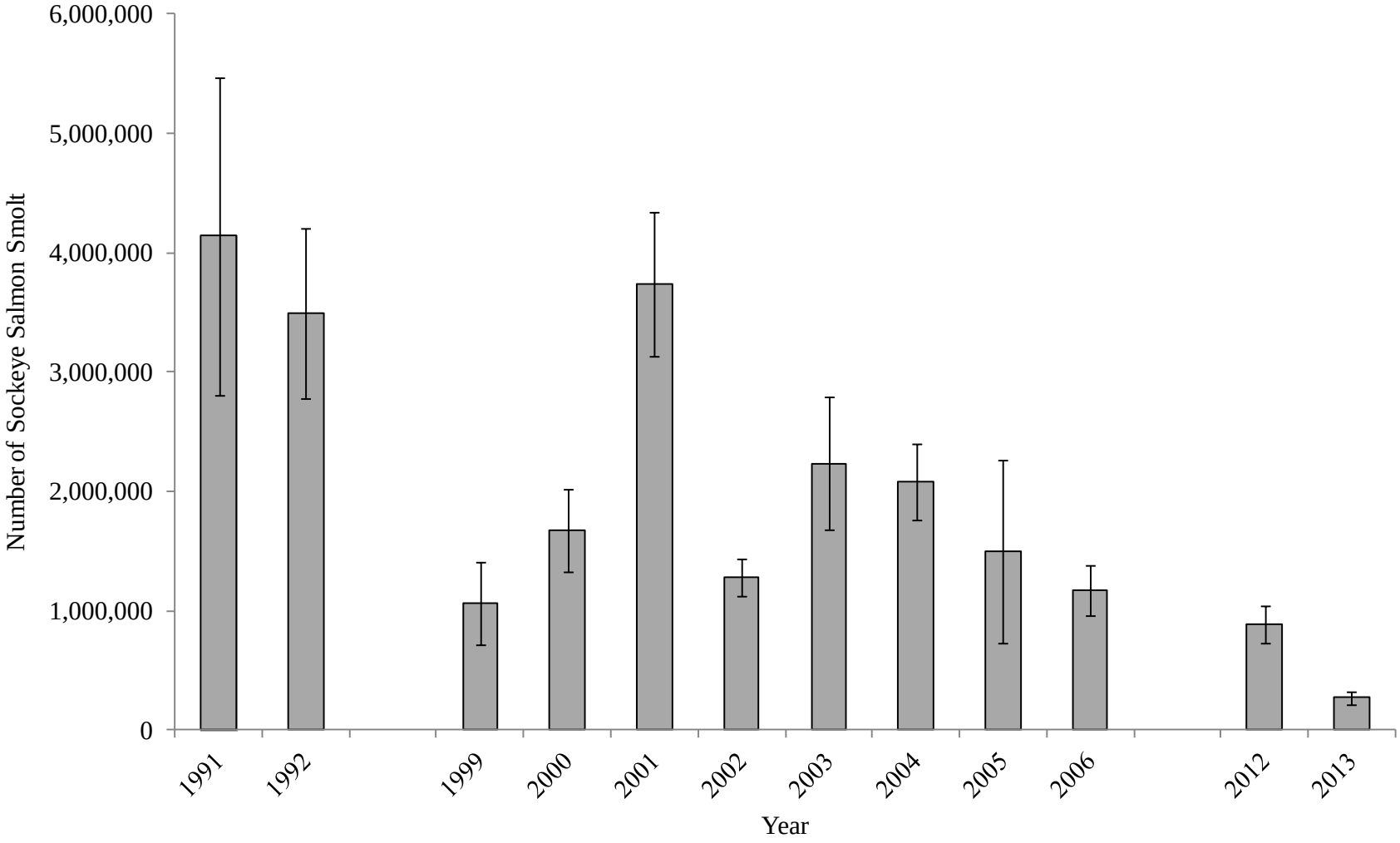

Figure 7.–Reported annual Karluk River sockeye salmon smolt outmigration estimates and corresponding 95% confidence intervals, 1991–1992, 1999–2006, 2012–2013.

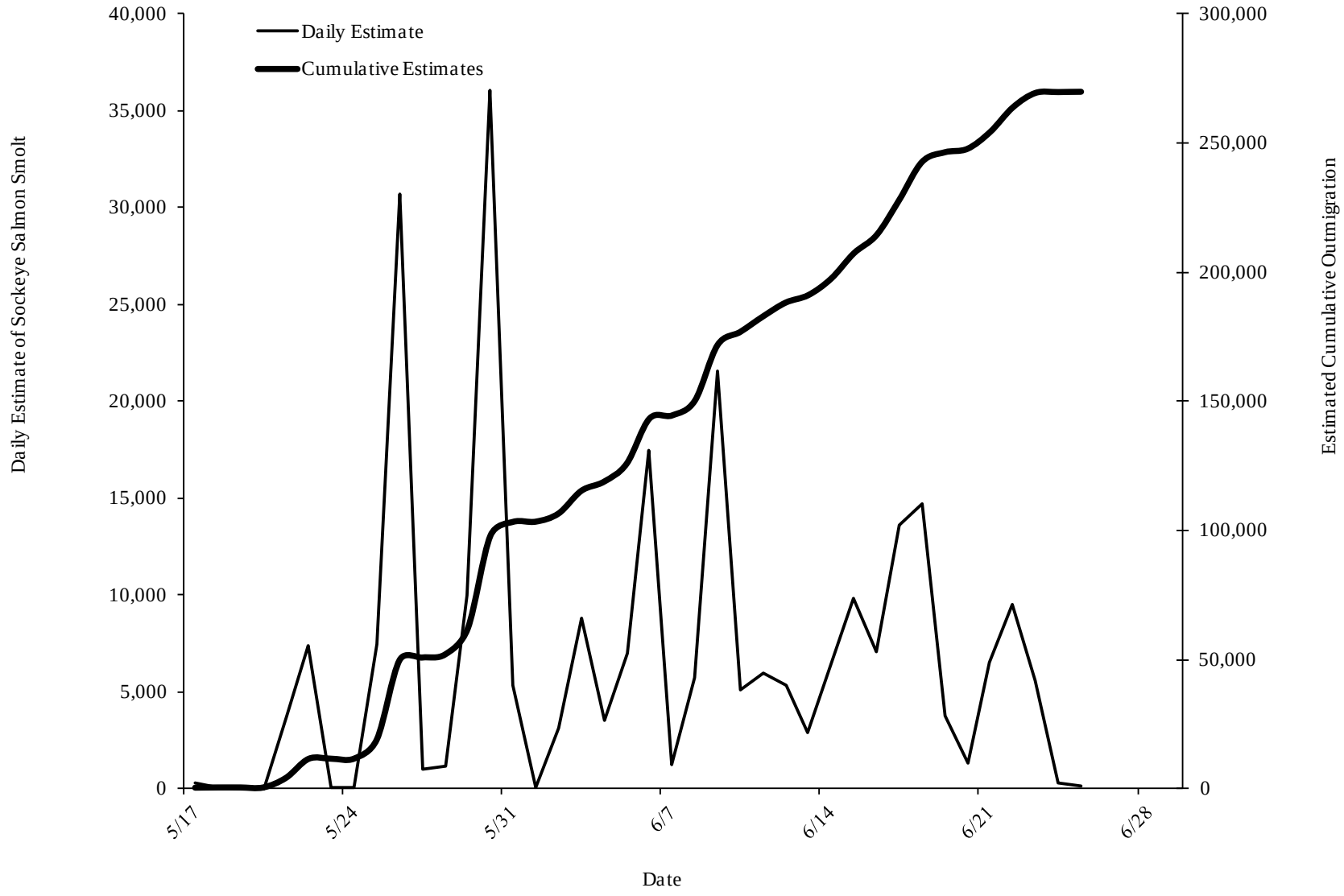

Figure 8.–Daily estimates and cumulative outmigration of sockeye salmon smolt from Karluk Lake in 2013.

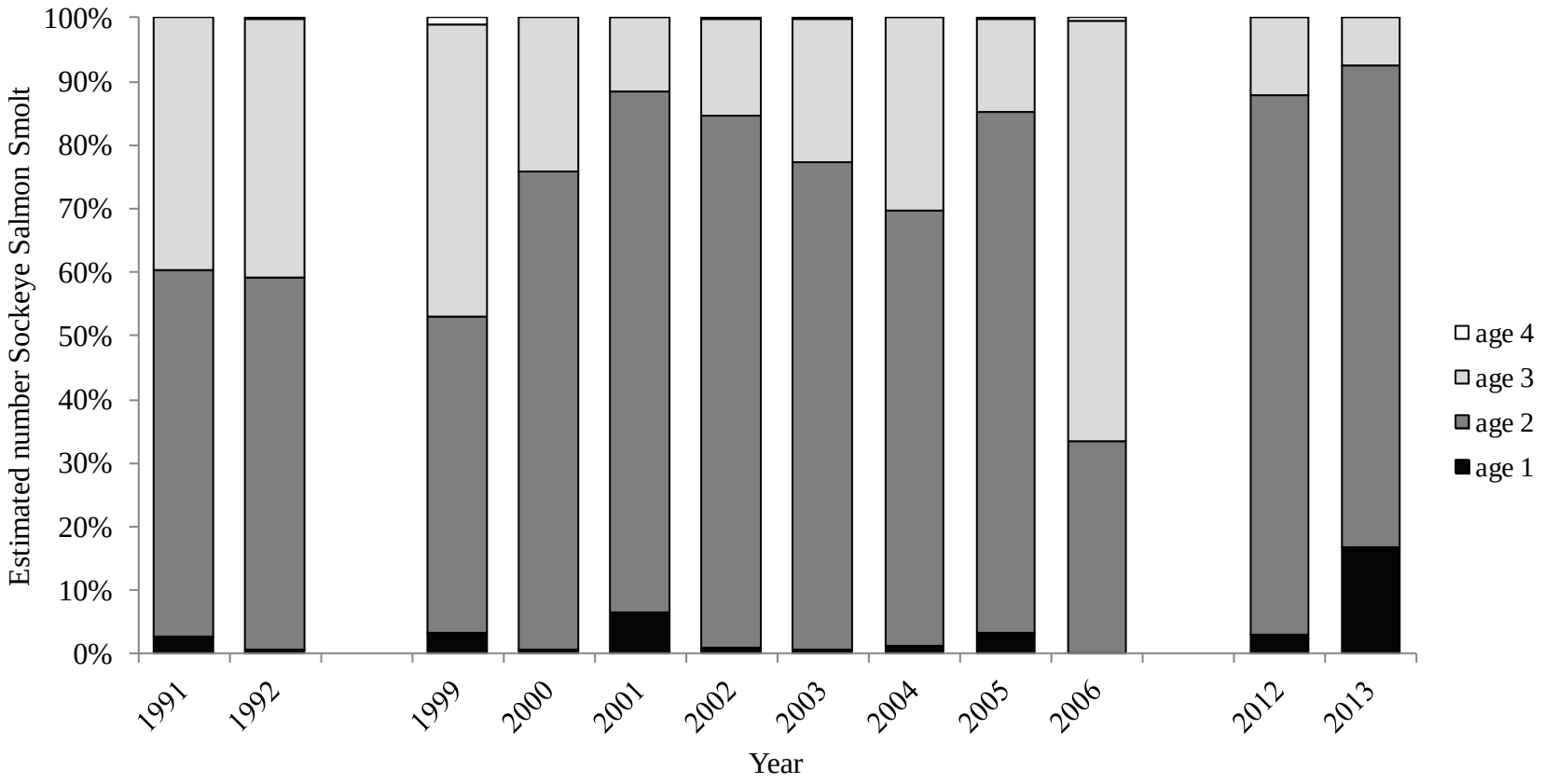

Figure 9.–A comparison of the estimated age structure of freshwater-age-0 to freshwater-age-4 sockeye salmon smolt outmigrations from the Karluk Lake, 1991–1992, 1999–2006, 2012–2013.

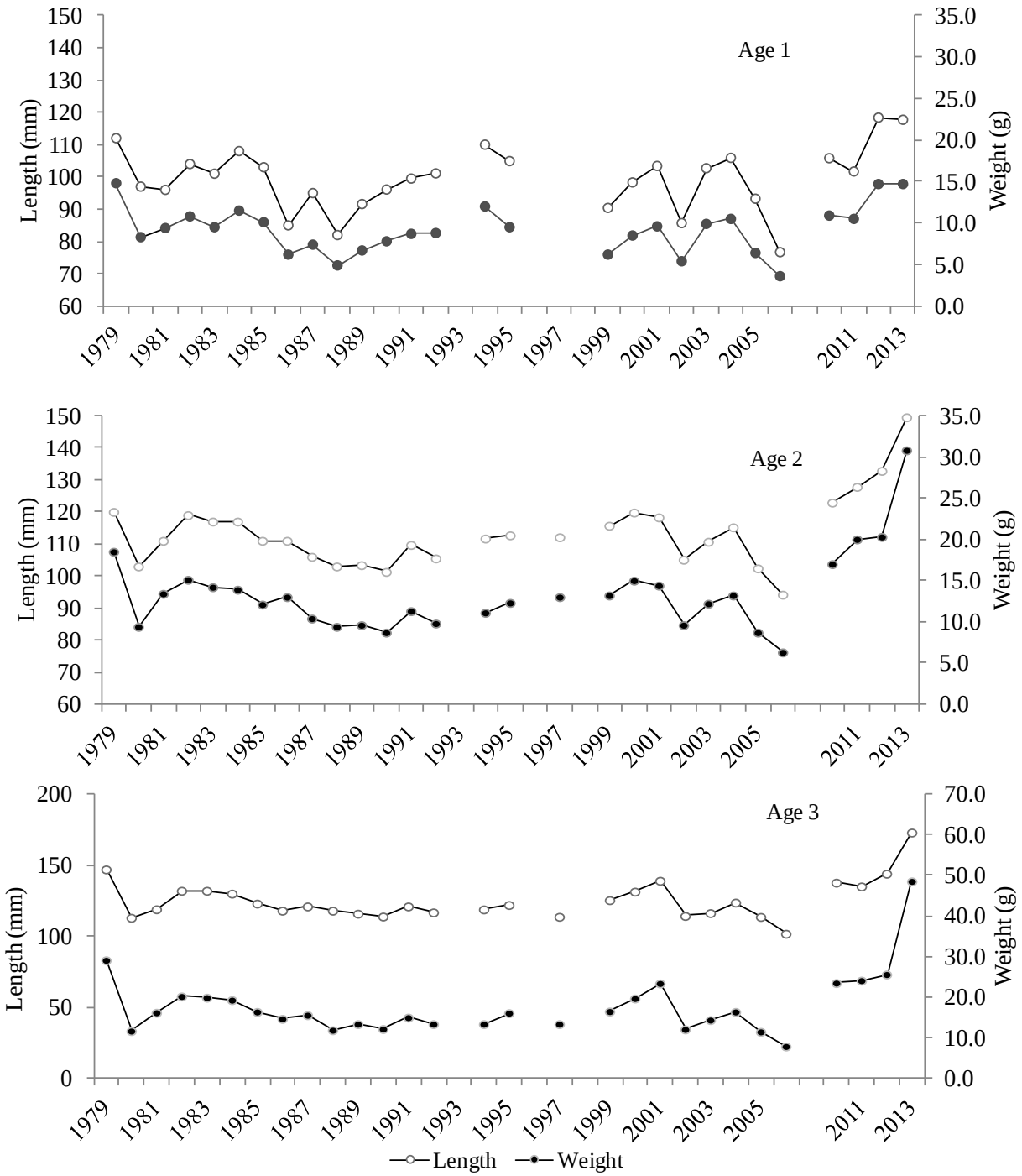

Figure 10.–Average length and weight of sampled freshwater-age-1, -2, and -3 sockeye salmon smolt, by year from 1979 to 2013.

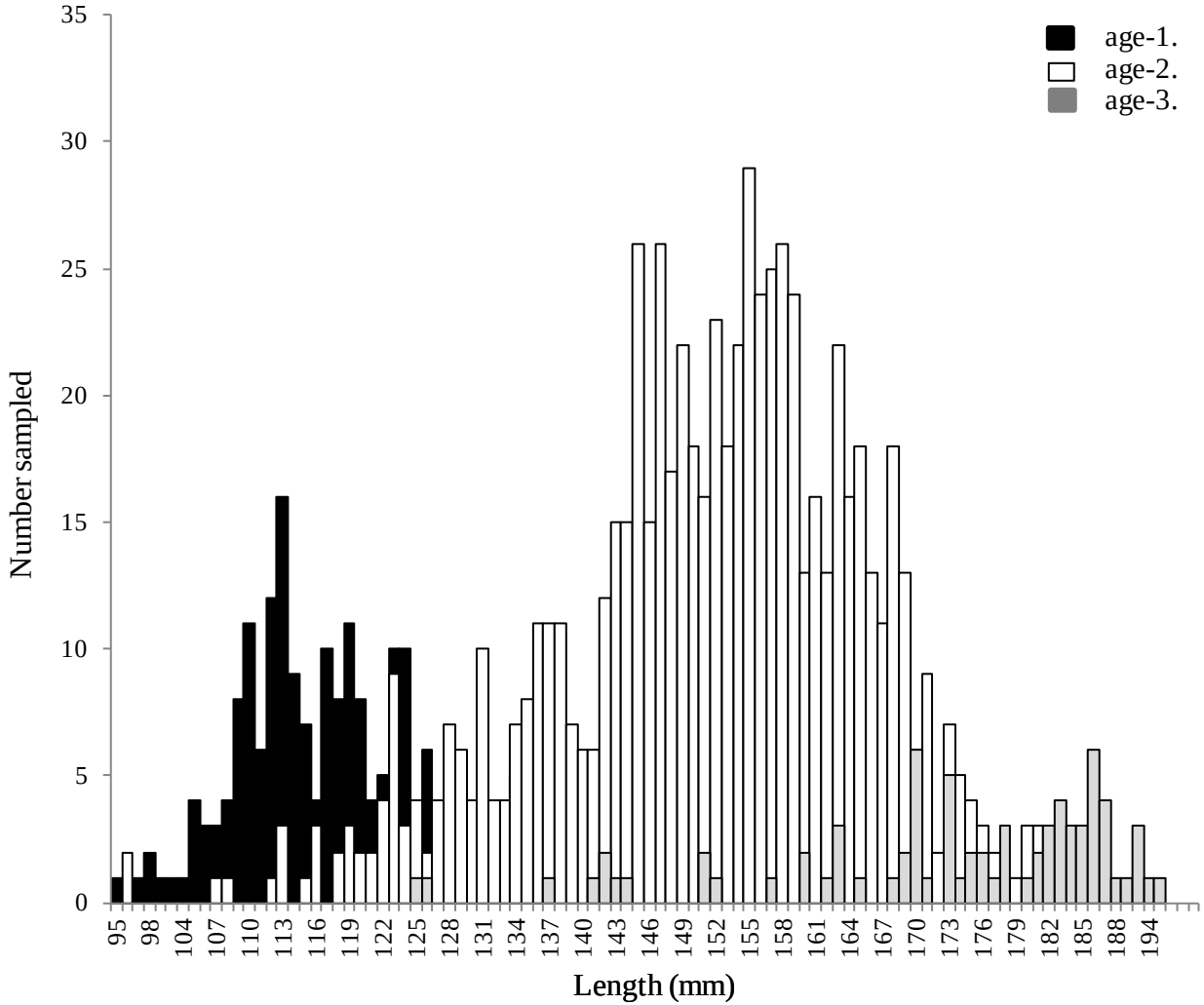

Figure 11.–Length frequency histogram of sockeye salmon smolt outmigration samples from Karluk Lake in 2013 by age class.

APPENDIX A. SMOLT TRAP CATCHES BY DAY

Appendix A1.–Actual daily counts and trap efficiency data of the Karluk River sockeye salmon smolt project, 2013.

	Sockeye Smolt			Trap efficiency tests				Incidental catch[a]					
Date	Daily	Cum.	Daily Mortality	Marked[b]	Daily recoveries	Cum. recoveries	Efficiency[c]	Sock fry	Coho	Chnk	Dolly Varden	SB	SC
15-May	0	0	0					143	-	-	347	9	4,416
16-May	11	11	0					131	116	-	219	23	8,460
17-May	3	14	0					123	44	1	244	27	2,833
18-May	-	14	0					262	105	5	243	33	2,877
19-May	-	14	0					102	16	5	177	28	1,495
20-May	144	158	0					234	78	2	606	25	2,345
21-May	285	443	2					178	36	11	519	26	1,669
22-May	1	444	1					192	31	3	312	39	2,616
23-May	2	446	0					193	23	5	197	66	1,273
24-May	287	733	5					402	27	-	459	127	700
25-May	1,187	1,920	1					446	70	3	687	192	960
26-May	39	1,959	0					673	38	1	423	66	8,950
27-May	45	2,004	0					437	34	-	263	44	3,795
28-May	387	2,391	0					380	58	4	266	71	2,941
29-May	1,392	3,783	4	303	4	4	2.31%	766	331	3	557	97	1,371
30-May	207	3,990	6	303	1	5	2.31%	596	152	-	468	361	4,321
31-May	3	3,993	1	303	1	6	2.31%	270	133	-	193	207	5,343
1-Jun	122	4,115	1	303	0	6	2.31%	110	899	1	248	86	1,207
2-Jun	339	4,454	0	303	0	6	2.31%	138	548	-	380	129	1,935
3-Jun	137	4,591	2	303	1	7	2.31%	145	135	-	261	81	1,521
4-Jun	684	5,138	4	499	25	25	7.82%	74	127	-	245	74	578
5-Jun	1,709	6,847	12	499	10	35	7.82%	249	487	1	308	126	412

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Appendix A1.–Page 2 of 2.

	Sockeye Smolt			Trap efficiency tests				Incidental catch[a]					
Date	Daily	Cum.	Daily Mortality	Marked[b]	Daily recoveries	Cum. recoveries	Efficiency[c]	Sock fry	Coho	Chnk	Dolly Varden	SB	SC
6-Jun	121	8,211	2	499	3	38	7.82%	240	188	1	374	76	1,217
7-Jun	559	8,770	6	499	0	38	7.82%	104	1,205	2	305	146	913
8-Jun	2,113	10,883	10	499	1	39	7.82%	64	1,327	2	227	94	675
9-Jun	568	11,451	1	644	19	19	9.16%	40	754	-	210	133	808
10-Jun	671	12,122	7	644	30	49	9.16%	145	1,021	-	360	45	385
11-Jun	601	12,723	8	644	6	55	9.16%	116	1,398	-	438	210	453
12-Jun	326	13,049	5	644	2	57	9.16%	101	1,289	-	279	178	641
13-Jun	713	13,762	1	644	2	59	9.16%	221	1,524	30	220	131	318
14-Jun	1,267	15,029	3	751	42	42	8.52%	32	2,047	7	158	44	318
15-Jun	911	15,940	7	751	17	59	8.52%	42	704	7	118	102	345
16-Jun	1,757	17,697	4	751	1	60	8.52%	37	955	7	115	55	265
17-Jun	1,894	19,591	6	751	4	64	8.52%	76	973	13	132	95	172
18-Jun	483	20,074	0	751	0	64	8.52%	41	292	3	64	58	194
19-Jun	172	20,246	1	751	0	64	8.52%	43	310	5	31	10	590
20-Jun	1,379	21,625	10	599	68	68	15.03%	4	179	-	83	15	513
21-Jun	2,018	23,643	6	599	19	87	15.03%	20	222	3	75	26	505
22-Jun	1,186	24,829	4	599	3	90	15.03%	10	106	1	99	12	2,675
23-Jun	67	24,896	0	599	0	90	15.03%	8	43	2	67	16	766
24-Jun	25	24,921	0	599	0	90	15.03%	2	26	-	76	45	759
Total		24,921		15,034	259	1226	8.56%[d]	7,590	18,051	128	11,053	3,428	74,530

[a] Soc Fry = sockeye salmon fry, Coho = juvenile coho salmon, Chnk = juvenile Chinook salmon, DV = Dolly Varden, SB = stickleback, SC = sculpin.

[b] Number marked has been adjusted from actual released to account for delayed mortality.

[c] Calculated by: E = {(R+1)/(M+1)}*100 where: R = number of marked fish recaptured, and M = number of marked fish (Carlson et al. 1998).

[d] Average of trap efficiency trials throughout the season.

Appendix A2.–Results of delayed mortality from marked and unmarked smolt, 2013.

Date	Dye Test	Marked fish retained	Unmarked fish retained	Marked mortalities	Unmarked mortalities	Total marked mortalities	Total unmarked mortalities
29-May	1	50	50	0	0		
30-May	1	50	50	1	0		
31-May	1	50	50	9	1		
1-Jun	1	50	50	3	4		
2-Jun	1	50	50	3	4		
3-Jun	1	50	50	0	0	16	9
5-Jun	2	60	60	6	1		
6-Jun	2	60	60	3	3		
7-Jun	2	60	60	0	1		
8-Jun	2	60	60	2	1		
9-Jun	2	60	60	0	1	12	8
10-Jun	3	100	100	12	10		
11-Jun	3	100	100	3	5		
12-Jun	3	100	100	2	3		
13-Jun	3	100	100	0	2		
14-Jun	3	100	100	0	0	17	20
14-Jun	4	100	100	18	4		
15-Jun	4	100	100	8	1		
16-Jun	4	100	100	6	0		
17-Jun	4	100	100	1	0		
18-Jun	4	100	100	0	0		
19-Jun	4	100	100	0	0	33	5
22-Jun	5	60	60	14	14		
23-Jun	5	60	60	2	2		
24-Jun	5	60	60	1	1		
25-Jun	5	60	60	0	0		
26-Jun	5	60	60	0	0	17	17

APPENDIX B. CLIMATOLOGICAL OBSERVATIONS

Appendix B1.–Daily climatological observations (noon) for the Karluk Lake sockeye salmon smolt project, 2013.

Date[a]	Time	Air (°C)	Water (°C)	Cloud cover[b]	Wind direction[b]	Velocity (mph)[b]	Stream depth	Comments
16-May	12:10	5.5	–	100%	NE	0-5	45	light drizzle
17-May	12:00	2.0	3.5	100%	W	5-10	56	light snow, high fog, H2O level up
18-May	11:46	1.0	3.5	10%	NW	10-15	55	clear day
19-May	12:00	6.0	4	0%	E	5-10	54	clear day, sunny
20-May	12:00	6.0	3.5	100%	N	0-5	53	downriver wind all night, pushed didymo into trap
21-May	11:56	6.0	4	100%	E	5-10	54	ooccasional gusts, sprinkling, low ceiling, strong onshore breeze all day
22-May	12:45	6.0	4	100%	S	5-10	54	still windy and cool
23-May	12:00	7.0	3.5	100%	–	0	54	overcast, mist on lake
24-May	11:43	13.5	4	60%	W	5	56	sun, clouds at variable height
25-May	12:03	8.0	5.5	1%	E	0-5	57	clam, warm and sunny, early fog
26-May	11:54	12.0	6	25%	E	5-10	58	onshore winds with gusts, clouds rollign in from east
27-May	11:30	7.0	5	100%	Variable	5-15	58	drizzle, wind picking up
28-May	12:15	10.5	5	20%	–	0-5	60	mostly clear, sunny
29-May	11:39	12.0	5	0%	E	0-5	60	calm and sunny, no bugs!
30-May	11:36	12.5	6	20%	NE	0-5	60	sunny and slight breezer
31-May	12:07	13.0	5.5	90%	SE	0-5	64	slight breeze, high clouds
1-Jun	12:01	11.0	5	100%	S	0-5	63	overcast, ceiling lowered from overnight
2-Jun	12:15	12.0	6	100%	NE	5-10	64	overcast, high winds, sprinkling
3-Jun	12:15	9.0	6	100%	N	5-10	64	light rain on and off, varying wind from N, overcast
4-Jun	12:05	10.5	N/A	100%	N	5-10	64	
5-Jun	12:13	12.5	N/A	30%	E	5-10	65	high clouds, sunny, breezy

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Appendix B1.–Page 2 of 2.

Date[a]	Time	Air (°C)	Water (°C)	Cloud cover[b]	Wind direction[b]	Velocity (mph)[b]	Stream depth	Comments
6-Jun	12:01	13.0	4	90%	NNW	5-10	66	
7-Jun	12:08	12.0	4	100%	E	0-5	66	high ceiling, cool breeze, lake calm
8-Jun	12:00	21.0	7	40%	NE	0	66	breezy, sunny, calm lake surface
9-Jun	11:55	14.0	6	0%	SW	0	66	upstream breezy, sun, calm overnight
10-Jun	12:43	16.5	5.5	0%	SE	0	65	breeze has been pickign up throughout day
11-Jun	12:30	15.0	6	0%	E	0-5	65	calm clear day, light breeze
12-Jun	12:01	11.0	7	20%	E	0-5	66	variable breeze, high stratus clouds
13-Jun	12:08	17.0	N/A	50%	NW	0-5	67	
14-Jun	12:22	12.0	7	10%	S	0-5	66	
15-Jun	12:19	13.0	11	0%	E	0-5	65	clear day, light breeze
16-Jun	12:01	15.0	10.5	5%	E	0-5	65	sunny, light breeze, whispy clouds
17-Jun	11:45	11.5	10	0%	NE	0-5	64	clear day, light breeze, river seems to have dropped a little
18-Jun	12:19	19.5	13	30%	NE	0-5	65	clear day, warm and low breeze
19-Jun	12:06	13.0	11	100%	NE	5-10	65	cloudy, many bugs
20-Jun	13:25	12.0	11	65%	SE	0-5	64	occasional strong gusts
21-Jun	12:00	11.0	11	100%	S	5-10	65	light breeze, off and on rain this morning
22-Jun	12:15	11.0	10.5	100%	SE	10-20	64	winds gusting, lots of swell into the river mouth, much didymo
23-Jun	12:09	16.0	11	100%	SE	0-5	64	breezy, cool, high ceiling
24-Jun	12:00	13.0	11	100%	Variable	0-5	63	

[a] Actual calendar dates.

[b] Based on observer estimates.

Appendix B2.–Daily climatological observations (midnight) for the Karluk Lake sockeye salmon smolt project, 2013.

Date[a]	Time	Air (°C)	Water (°C)	Cloud cover[b]	Wind direction[b]	Velocity (mph)[b]	Stream depth	Comments
19-May	0:35	0.5	3	5%	WNW	5-10	54	chilly, ice on deck
20-May	2:10	-2.0	3	2%	N	0-5	53	
22-May	0:04	6.0	3.5	100%	S	5-10	53	still a persistent onshore wind
23-May	0:04	6.0	3.5	100%	–	0	54	foggy, light mis, no didymo
24-May	0:59	7.0	3.5	100%	–	0	56	calm
27-May	0:12	7.0	5	100%	N	0-5	58	light rain, overcast, calm winds
28-May	0:00	6.0	4.5	80%	–	0-5	59	clearing skies
29-May	0:22	7.0	4	95%	E	0-5	60	occasional breeze, calm
30-May	0:00	7.0	5	100%	NE	0-5	63	calm at Wxport, 5-10 offshore breeze at cabin, light sprinkles
2-Jun	0:15	4.0	6	95%	S	0-5	63	overcast, winds blowing waves 1' high at lake mouth
3-Jun	0:25	8.0	5.5	100%	E	0-5	64	overcast, very light breeze
4-Jun	0:15	6.5	N/A	100%	NW	5-10	64	inversion, thick low clouds rolling down the valleys
5-Jun	0:20	6.5	N/A	100%	N	0-5	65	low celing at 16:00,
6-Jun	0:23	10.5	N/A	50%	N	5-10	65	
7-Jun	0:29	6.5	4	95%	NW	0-5	65	
8-Jun	0:45	2.5	4	10%	–	0-10	66	clear, onshore winds beginning approx 22:30
9-Jun	0:30	6.0	5	10%	–	5-10	66	
10-Jun	1:40	-2.0	5	0%	–	0-5	65	Fog is forming downriver
11-Jun	1:05	2.5	5.5	0%	–	0-5	66	calm, still somewhat bright out
12-Jun	0:20	5.0	5.5	0%	NW	0-10	65	lots of coho in trap
13-Jun	0:30	7.0	7	100%	NW	0-5	66	beginning to rain
13-Jun	1:27	9.0	7	100%	N	0-10	66	dead calm, overcast
15-Jun	0:18	7.0	10	100%	S	0-5	66	

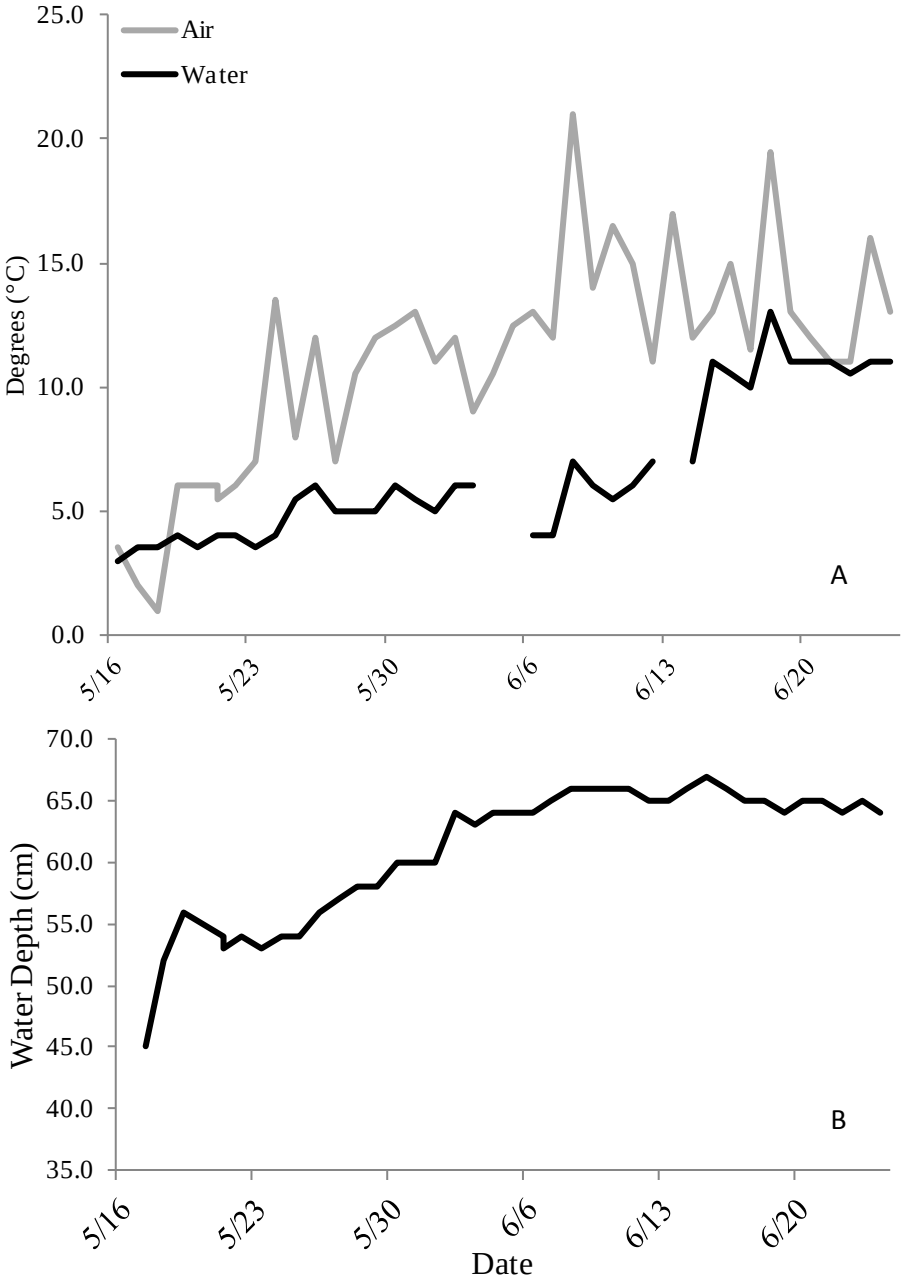
-continued-

Appendix B2.–Page 2 of 2.

Date[a]	Time	Air (°C)	Water (°C)	Cloud cover[b]	Wind direction[b]	Velocity (mph)[b]	Stream depth	Comments
16-Jun	0:20	6.5	9	0%	NW	0-5	64	foggy, came upriver
17-Jun	0:25	5.0	10	0%	NE	0-5	65	clear evening
18-Jun	1:11	6.5	11	0%	–	0	65	clear warm night, no breeze
19-Jun	0:06	7.0	11	10%	NE	0-5	65	calm, light breeze, very bright
20-Jun	0:27	9.0	11	100%	SE	0-5	62	cloudy, strong onshore winds
21-Jun	1:30	7.0	11.5	100%	–	0	65	solstice, strong onshore breeze at lake most of day
22-Jun	0:05	8.5	11	60%	Variable	0-5	65	high haze, some cloud cover, calm at Wxport, 15-20 NE at lake
23-Jun	0:16	9.0	10.5	100%	Variable	0-5	64	
24-Jun	0:14	9.0	11	100%	NW	0-5	63	cool, sprinkle, light breeze
25-Jun	0:20	6.5	6.5	90%	–	0	63	calm, chilly

[a] Actual calendar dates.
[b] Based on observer estimates.

Appendix B3.–Air and water temperature (A), stream gauge height (B) data gathered at the Karluk River smolt trap, 2013.



APPENDIX C. SUPPLEMENTAL HISTORICAL DATA

Appendix C1.–Karluk River sockeye salmon escapement, estimated number of smolt by freshwater age, smolt per spawner, adult return by freshwater age, return-per-spawner, and marine survival, by brood year, from 1994 to 2006.

Brood		Smolt Produced					Total	Smolt/	Adult Returns							Marine
Year	Esc	Age 0	Age 1	Age 2	Age 3	Age 4	Smolt	Spawner	fw-age 0	fw-age 1	fw-age 2	fw-age 3	fw-age 4	Run Total	R/S	Survival
1994						12,798										
1995	743,056	NA	NA	NA	487,406	0										
1996	574,326	NA	NA	531,134	402,919	80	934,133	1.6								
1997	564,761	NA	35,196	1,263,785	436,469	1,468	1,736,918	3.1	3,210	33,519	465,318	319,931	4,377	826,355	1.5	48%
1998	637,146	0	9,441	3,062,597	195,323	4,205	3,271,567	5.1	2,348	53,150	770,870	226,219	3,199	1,055,785	1.7	32%
1999	981,538	0	238,271	1,072,906	501,816	186	1,813,179	1.8	3,759	131,143	1,265,274	178,577	247	1,579,000	1.6	87%
2000	736,744	2,838	11,482	1,712,969	633,039	2,264	2,362,591	3.2	0	40,710	934,711	238,917	437	1,214,775	1.6	51%
2001	863,538	791	16,445	1,420,076	218,243	6,906	1,662,462	1.9	1,838	8,798	1,208,387	293,366	2,602	1,514,991	1.8	91%
2002	865,576	0	26,479	1,227,246	773,173	NA	2,026,898	2.3	155	12,724	1,148,082	327,698	1,240	1,489,899	1.7	74%
2003	1,078,710	533	47,834	393,039	NA	NA	NA									
2004	719,934	0	0	NA	NA	NA										
2005	781,962	0														
2006	490,373															

Appendix C2.–Mean length, weight, and condition factor of sockeye salmon smolt samples from the Karluk River by year and freshwater age, 1925–2013.

	Age 1					Age 1			
Year	n	Length (mm)	Wt. (g)	Cond. (K)	Year	n	Length (mm)	Wt. (g)	Cond. (K)
1925	3	113	na	na	1993	-	-	-	-
1926	5	100	na	na	1994	1	110	12.0	0.9
1927	5	116	na	na	1995	7	105	9.5	0.8
1928	6	111	na	na	-				
1929	0	na	na	na	1997	0	na	na	na
1930	24	110	na	na	-				
1931	16	111	na	na	1999	40	90	6.2	0.8
1932	16	105	na	na	2000	16	98	8.5	0.9
1933	43	114	na	na	2001	459	103	9.6	0.9
1934	7	123	na	na	2002	33	86	5.4	0.8
1935	16	113	na	na	2003	17	103	9.9	0.9
1936	60	111	na	na	2004	30	106	10.5	0.9
-					2005	4	93	6.4	0.8
1961	na	110	13.1	1.0	2006	3	77	3.6	0.8
1962	na	108	11.3	0.9	-				
1963	na	110	14.5	1.1	2010	46	106	10.9	0.9
1964	0	na	na	na	2011	29	102	10.5	0.9
1965	0	na	na	na	2012	185	118	14.7	0.9
1966	0	na	na	na	2013	197	115	13.9	0.9
1967	na	102	10.7	1.0					
1968	na	104	9.9	0.9					
-									
1979	66	112	14.8	1.1					
1980	300	97	8.3	0.9					
1981	77	96	9.4	1.1					
1982	8	104	10.8	1.0					
1983	17	101	9.5	0.9					
1984	165	108	11.5	0.9					
1985	227	103	10.1	0.9					
1986	426	85	6.2	1.0					
1987	43	95	7.4	0.8					
1988	8	82	4.9	0.8					
1989	5	92	6.7	0.8					
1990	30	96	7.8	0.9					
1991	166	100	8.7	0.8					
1992	59	101	8.8	0.8					

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Appendix C2.–Page 2 of 4

	Age 2					Age 2			
Year	n	Length (mm)	Wt. (g)	Cond. (K)	Year	n	Length (mm)	Wt. (g)	Cond. (K)
1925	563	136	22.8	0.9	1993	-	-	-	-
1926	445	136	22.9	0.9	1994	167	112	11.1	0.8
1927	212	134	21.2	0.9	1995	79	113	12.3	0.8
1928	494	128	19.9	0.9	-				
1929	418	130	20.0	0.9	1997	157	112	13.0	0.9
1930	1,145	127	18.5	0.9	-				
1931	1,795	130	20.0	0.9	1999	598	116	13.2	0.8
1932	1,358	133	20.9	0.9	2000	963	120	15.0	0.9
1933	685	136	23.9	1.0	2001	1,565	118	14.4	0.9
1934	822	140	24.8	0.9	2002	1,610	105	9.6	0.8
1935	1,520	142	26.3	0.9	2003	1,130	111	12.2	0.9
1936	744	133	21.3	0.9	2004	1,082	115	13.2	0.9
-					2005	941	102	8.7	0.8
1961	na	115	13.7	0.9	2006	439	94	6.3	0.8
1962	na	113	12.4	0.9	-				
1963	na	119	14.6	0.9	2010	306	123	17.0	0.9
1964	na	128	21.0	1.0	2011	138	128	20.0	0.9
1965	na	127	19.1	0.9	2012	1,117	133	20.3	0.9
1966	na	115	13.2	0.9	2013	721	148	30.1	0.9
1967	na	113	13.8	1.0					
1968	na	113	12.4	0.9					
-									
1979	201	120	18.5	1.1					
1980	496	103	9.4	0.9					
1981	600	111	13.4	1.0					
1982	413	119	15.1	0.9					
1983	1,014	117	14.2	0.9					
1984	670	117	13.9	0.9					
1985	541	111	12.1	0.9					
1986	1,184	111	13.0	1.0					
1987	1,776	106	10.4	0.9					
1988	800	103	9.4	0.9					
1989	828	103	9.6	0.9					
1990	270	101	8.7	0.8					
1991	1,584	110	11.3	0.8					
1992	1,340	106	9.8	0.8					

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Appendix C2.–Page 3 of 4.

	Age 3					Age 3			
Year	n	Length (mm)	Wt. (g)	Cond. (K)	Year	n	Length (mm)	Wt. (g)	Cond. (K)
1925	84	145	28.5	0.9	1993	-	-	-	-
1926	156	144	28.5	1.0	1994	129	119	13.4	0.8
1927	144	147	27.3	0.9	1995	2	122	16.1	0.9
1928	225	141	28.4	1.0	-				
1929	603	143	25.2	0.9	1997	83	114	13.4	0.9
1930	625	137	25.0	1.0	-				
1931	247	138	26.8	1.0	1999	549	125	16.5	0.8
1932	634	139	29.5	1.1	2000	268	131	19.7	0.9
1933	521	144	29.6	1.0	2001	313	139	23.4	0.9
1934	75	148	33.3	1.0	2002	262	114	12.1	0.8
1935	286	152	26.6	0.8	2003	271	116	14.4	0.9
1936	233	143	18.2	0.6	2004	616	124	16.4	0.9
-					2005	207	114	11.5	0.8
1961	na	124	16.6	0.9	2006	565	102	7.9	0.7
1962	na	123	15.8	0.8	-				
1963	na	129	18.5	0.9	2010	43	138	23.5	0.9
1964	na	136	24.1	1.0	2011	33	135	24.1	1.0
1965	na	142	26.7	0.9	2012	116	144	25.6	0.9
1966	na	131	18.9	0.8	2013	76	161	40.0	0.9
1967	na	133	23.1	1.0					
1968	na	124	15.3	0.8					
-									
1979	11	147	29.1	0.9					
1980	80	113	11.7	0.8					
1981	83	119	16.2	1.0					
1982	64	132	20.2	0.9					
1983	149	132	19.9	0.9					
1984	63	130	19.3	0.9					
1985	37	123	16.4	0.9					
1986	28	118	14.7	0.9					
1987	316	121	15.6	0.9					
1988	10	118	11.9	0.8					
1989	149	116	13.4	0.9					
1990	709	114	12.2	0.8					
1991	654	121	15.0	0.8					
1992	565	117	13.4	0.8					

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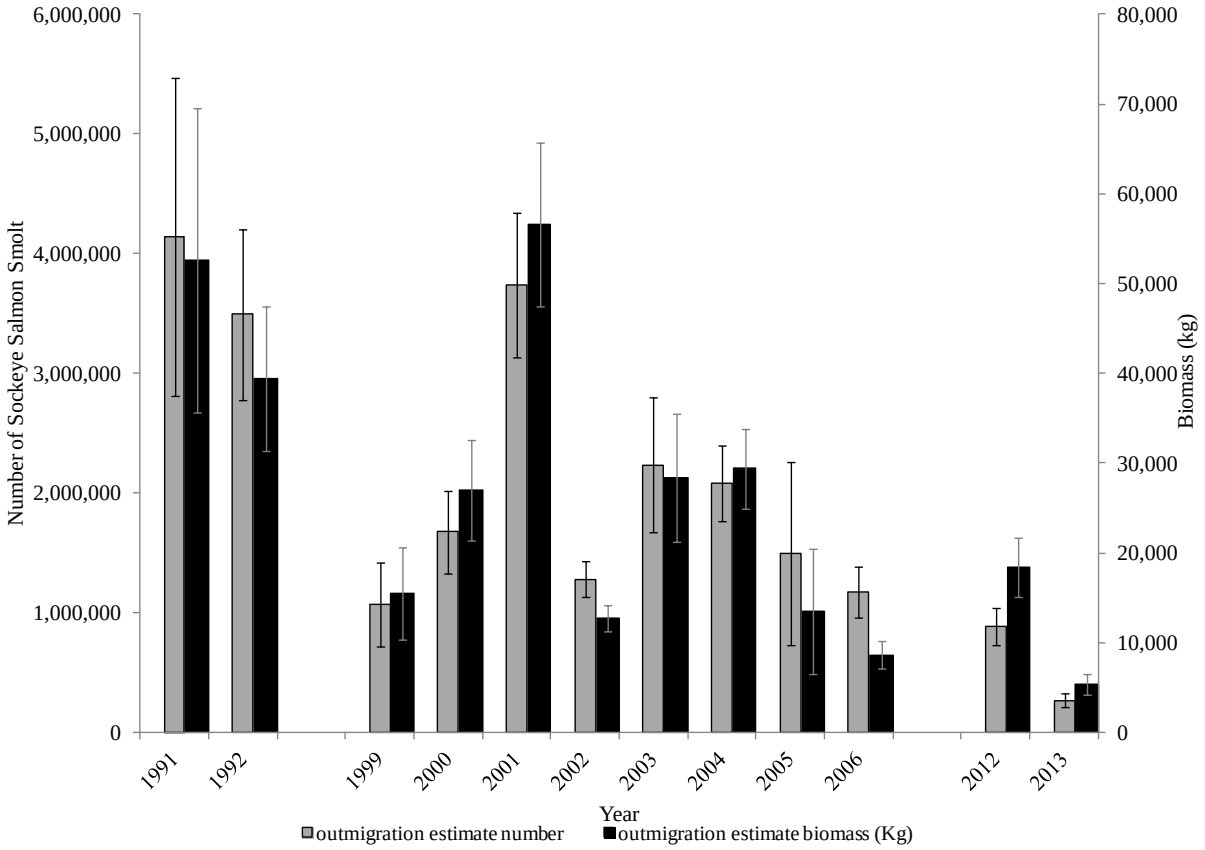
Appendix C2.–Page 4 of 4.

	Age 4					Age 4			
Year	n	Length (mm)	Wt. (g)	Cond. (K)	Year	n	Length (mm)	Wt. (g)	Cond. (K)
1925	0	na	na	na	1993	-	-	-	-
1926	3	164	na	na	1994	0	na	na	na
1927	0	na	na	na	1995	0	na	na	na
1928	4	151	na	na	-				
1929	12	155	na	na	1997	1	109	12.3	1.0
1930	20	143	na	na	-				
1931	14	145	na	na	1999	15	132	18.9	0.8
1932	20	146	na	na	2000	0	na	na	na
1933	23	147	na	na	2001	1	140	23.7	0.9
1934	6	161	na	na	2002	2	105	10.2	0.9
1935	2	146	na	na	2003	4	113	12.5	0.9
1936	9	151	na	na	2004	2	134	21.3	0.9
-					2005	1	120	11.9	0.7
1961	0	na	na	na	2006	6	104	8.2	0.7
1962	0	na	na	na	-				
1963	0	na	na	na	2010	2	151	31.6	0.9
1964	na	149	33.7	1.0	2011	1	164	38.4	0.9
1965	na	145	28.7	0.9	2012	1	168	33.8	0.7
1966	na	137	21.4	0.8	2013	1	150	28.6	0.9
1967	0	na	na	na					
1968	0	na	na	na					
-									
1979	0	na	na	na					
1980	0	na	na	na					
1981	0	na	na	na					
1982	0	na	na	na					
1983	0	na	na	na					
1984	0	na	na	na					
1985	0	na	na	na					
1986	0	na	na	na					
1987	0	na	na	na					
1988	0	na	na	na					
1989	0	na	na	na					
1990	1	121	14.4	0.8					
1991	0	na	na	na					
1992	4	127	18.0	0.9					

Appendix C3.–Annual sockeye salmon smolt outmigration estimates by number and biomass (Kg) and corresponding 95% confidence intervals, Karluk River, for years with population estimates, 1991–1992, 1999–2006, 2012–2013.



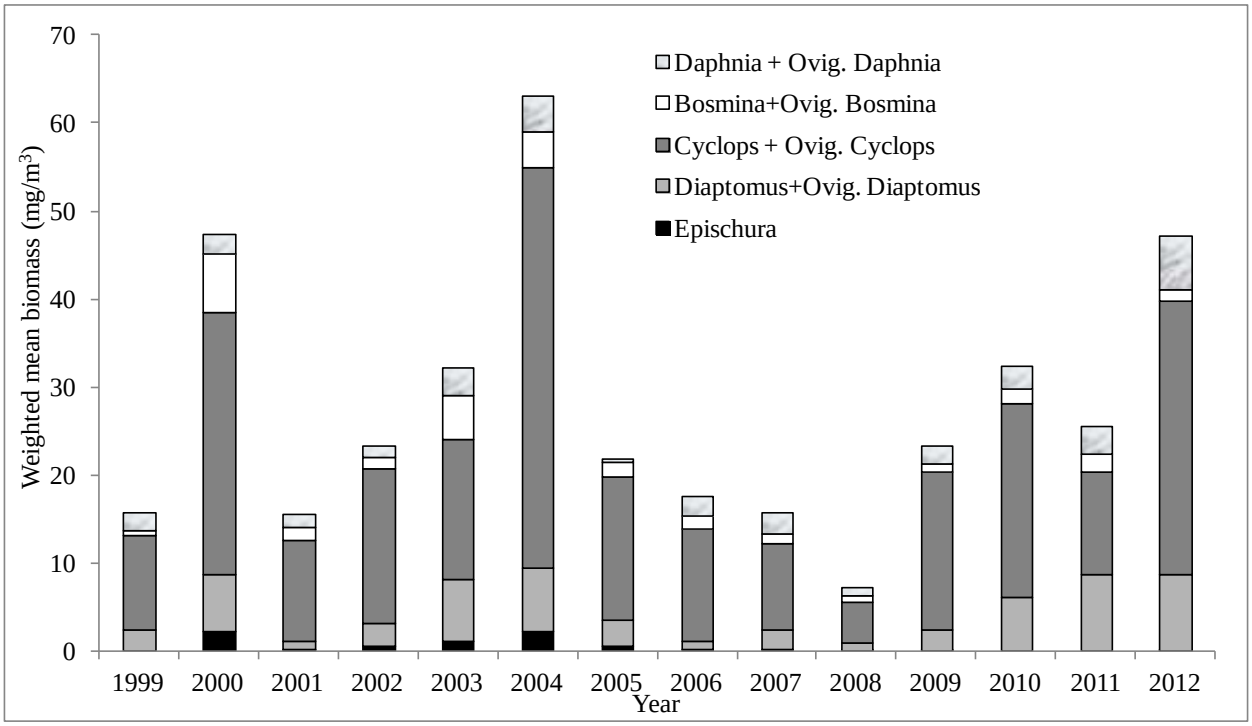
Appendix C4.–Escapement, harvest and total run for Karluk early-run, late-run and total sockeye salmon run, 1985-2012.

Year	Early Run Sockeye Salmon			Late Run Sockeye Salmon			Total Run Sockeye Salmon		
	Escapement	Harvest	Run	Escapement	Harvest	Run	Escapement	Harvest	Run
1985	316,688	28,326	345,014	679,260	168,328	847,588	995,948	196,654	1,192,602
1986	358,756	116,191	474,947	528,415	297,042	825,457	887,171	413,233	1,300,404
1987	354,094	77,156	431,250	412,157	170,019	582,176	766,251	247,175	1,013,426
1988	296,510	35,236	331,746	282,306	127,721	410,027	578,816	162,956	741,772
1989[a]	349,753	2[a]	349,755	758,893	3,476	762,369	1,108,646	3,478	1,112,124
1990	196,197	32,021	228,218	541,891	990,660	1,532,551	738,088	1,022,681	1,760,769
1991	243,069	28,135	271,204	831,970	1,097,830	1,929,800	1,075,039	1,125,965	2,201,004
1992	217,152	245,012	462,164	614,262	442,692	1,056,954	831,414	687,704	1,519,118
1993	261,169	308,579	569,748	396,288	235,361	631,649	657,457	543,940	1,201,397
1994	260,771	188,452	449,223	587,258	106,325	693,583	848,029	294,778	1,142,807
1995	238,079	283,333	521,412	504,977	361,535	866,512	743,056	644,868	1,387,924
1996	250,357	509,874	760,231	323,969	187,717	511,686	574,326	697,591	1,271,917
1997	252,859	134,480	387,339	311,902	127,114	439,016	564,761	261,594	826,355
1998	252,298	116,473	368,771	384,848	302,166	687,014	637,146	418,639	1,055,785
1999	392,419	182,579	574,998	589,119	414,885	1,004,004	981,538	597,464	1,579,002
2000	291,351	266,481	557,832	445,393	211,546	656,524	736,744	478,027	1,214,356
2001	338,799	303,664	642,463	524,739	347,790	872,527	863,538	651,453	1,514,989
2002	456,842	167,038	623,880	408,734	457,285	866,019	865,576	624,323	1,489,899
2003	451,856	372,761	824,617	626,854	965,484	1,592,340	1,078,710	1,338,245	2,416,957
2004	393,468	396,287	789,755	326,466	332,464	658,930	719,934	728,751	1,448,685
2005	283,860	245,800	529,660	498,102	423,571	921,675	781,962	669,371	1,451,334
2006	202,366	272,537	474,903	288,007	282,441	570,450	490,373	554,978	1,045,353
2007	294,740	198,354	493,094	251,835	469,775	721,610	546,575	668,129	1,214,704
2008	82,191	70,751	152,942	164,299	130,587	294,886	246,490	201,338	447,828
2009	52,798	16,054	68,852	277,280	52,504	329,784	330,078	68,558	398,636
2010	71,453	9,008	81,361	276,649	39,348	315,997	348,102	48,356	397,358
2011	87,049	6,805	93,854	230,273	36,741	267,014	317,322	43,546	360,868
2012	188,085	47,801	235,886	314,605	275,192	589,797	502,690	322,993	825,683
10 yr avg (2003-2012)	210,787	163,616	374,492	325,437	300,811	626,248	536,224	464,426	1,000,741

[a] harvest in 1989 was curtailed due to the *Exxon Valdez* oil spill

Appendix C5.–Combined sockeye salmon early- and late-run brood table.

Brood		Ages																				Total	Return/
Year	Escap.	0.1	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	4.1	2.4	3.3	4.2	2.5	3.4	4.3	Return	Spawner
1985	995,948	169	0	0	1,108	34,423	3,054	189	64,204	857,770	3,504	595	582,343	479,906	0	2,417	84,329	0	0	80	30	2,114,121	2.1
1986	887,171	0	917	0	15,855	45,260	3,179	451	64,417	922,905	5,193	94	244,243	786,438	0	1,042	121,463	1,833	0	382	1,736	2,215,407	2.5
1987	766,251	106	6,403	201	18,523	25,661	4,621	0	9,053	341,056	22,249	416	67,440	658,628	0	364	114,695	3,909	0	690	1,969	1,275,984	1.7
1988	578,816	0	2,531	111	2,424	13,032	7,809	0	12,835	273,518	21,019	0	108,174	415,378	0	320	87,097	231	0	39	2,915	947,433	1.6
1989	1,108,646	0	3,555	2,420	3,717	14,401	20,231	0	17,281	413,003	11,750	0	318,963	315,406	0	1	81,739	6,312	0	0	1,713	1,210,493	1.1
1990	738,088	0	3,591	1,152	6,292	35,144	6,021	0	60,959	526,527	7,671	670	199,230	177,289	0	860	133,255	1,855	0	0	64	1,160,579	1.6
1991	1,075,039	0	7,113	1,564	3,941	42,953	15,038	0	91,998	666,957	11,818	52	319,120	166,698	809	1,058	25,220	3,135	0	111	247	1,357,833	1.3
1992	831,414	0	1,567	4,592	4	13,507	16,401	0	25,393	109,918	19,978	0	119,087	197,361	0	1,282	64,982	0	0	79	0	574,152	0.7
1993	657,457	0	2	3,035	3,210	6,859	35,420	0	19,259	639,135	3,637	36	331,071	110,620	0	1,752	66,085	437	0	288	0	1,220,845	1.9
1994	848,029	0	0	1,215	1,192	33,674	11,589	0	58,440	911,130	2,865	427	341,227	164,038	0	1,138	75,161	2,602	0	1,170	0	1,605,867	1.9
1995	743,056	0	1,156	218	3,219	72,034	21,791	0	34,842	585,666	8,715	0	636,813	212,775	0	1,829	80,723	1,240	0	776	1,384	1,663,181	2.2
1996	574,326	0	540	633	0	5,033	6,066	0	2,686	536,918	5,143	0	364,573	223,849	0	61	125,466	0	0	1,461	1,048	1,273,479	2.2
1997	564,761	0	0	407	1,838	5,403	33,517	0	6,982	728,007	21,956	0	400,510	299,455	0	0	36,396	0	0	421	0	1,534,893	2.7
1998	637,146	0	0	709	0	4,843	53,672	1,399	8,126	1,454,347	12,924	532	246,087	247,984	715	0	27,136	0	0	0	284	2,058,758	3.2
1999	981,538	0	0	898	0	40,499	70,349	0	41,265	835,603	13,803	161	346,917	290,912	0	0	113,907	0	0	324	94	1,754,732	1.8
2000	736,744	155	669	990	3,376	15,660	4,556	0	4,519	754,444	8,968	129	401,632	133,107	0	3,358	175,473	1,569	0	5,575	0	1,514,180	2.1
2001	863,538	0	0	0	0	5,766	11,948	0	3,713	348,367	9,430	0	580,345	165,301	0	16,518	80,809	425	80	1,002	75	1,223,779	1.4
2002	865,576	0	0	140	2,790	8,213	23,571	0	14,436	253,126	1,923	460	220,449	37,981	0	707	19,763	99	0	0	528	584,186	0.7
2003	1,078,710	0	0	208	2,036	4,731	10,947	0	3,037	72,321	2,885	49	31,487	285,279	969	1	7,201	11,146	0	0	1,873	434,170	0.4
2004	719,934	0	1,037	5	400	2,194	900	0	1,489	32,206	15,673	0	12,204	255,611	0	0	19,317	2,185	0	21	0	343,242	0.5
2005	781,962	0	3,532	342	0	6,452	3,279	0	3,050	77,602	5,013	0	28,297	89,734	176	0	4,800	0					
2006	490,373	0	0	15	23	16,901	7,236	0	5,609	151,008	18,497	34	51,706	81,816	0								
2007	546,575	0	0	840	2,256	7,039	34,540	0	16,203	627,538	1,805												
2008	246,490	0	0	339	34	23,839	16,798																
2009	330,078	0	501	589																			
2010	348,102	0																					
2011	317,322																						
2012	502,690																						
																					10 year average (1995-2004):	1,238,460	1.7
																					5 year average (2000-2004):	819,911	1.0

APPENDIX D. ZOOPLANKTON DATA

Appendix D1.–Karluk Lake weighted mean zooplankton biomass (mg/m^3) from 1999 to 2012.