Fishery Data Series No. 15-36

Karluk Sockeye Salmon Smolt Enumeration, 2014 Season Summary

by

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and

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October 2015

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

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ABSTRACT

The 2014 Karluk Sockeye Salmon Smolt Enumeration project marked the third consecutive year of documenting the smolt outmigration from Karluk Lake since 2006. This report provides the daily and cumulative smolt outmigration estimates as well as biometric, age, and genetic stock composition information. Limnological data collected from Karluk Lake by the Kodiak Regional Aquaculture Association are also presented. The abundance of sockeye salmon smolt was estimated using a Canadian fan trap and mark-recapture techniques. In 2014, a total of 811,255 sockeye salmon smolt were estimated to pass downstream of the trap between May 13 and July 2. The majority of smolt sampled were freshwater-age-2 fish (70%), and average length and weight of each age class were some of the largest in the historical data series. The majority (78%) of outmigrating smolt belonged to the late-run stock, which were mostly freshwater-age-2 fish. The average weighted zooplankton biomass of 2,687 mg/m^2 in 2014 suggests juvenile sockeye salmon in Karluk Lake reared in a healthy nursery environment prior to their outmigration.

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

INTRODUCTION

The Karluk watershed, located on the southwest side of Kodiak Island (Figure 1), supports the largest sockeye salmon *Oncorhynchus nerka* run in the Kodiak Management Area (KMA; Moore 2012). The importance of Karluk sockeye salmon dates back to commercial harvests in the late 1800s (Bean 1891). Overfishing and lack of regulation in the early 1900s, however, helped precipitate run declines that would not improve until the 1970s (Barnaby 1944; Schmidt et al. 1997; Schmidt et al. 1998). Yet, these increased sockeye salmon runs were often overescaped, eventually yielding low returns from 2008 through 2011 that curtailed Karluk subsistence, sport, and commercial salmon fisheries in order to achieve escapement goals. The ensuing public concern motivated the Alaska State Legislature to fund the current Karluk smolt enumeration project to better understand the drivers of Karluk sockeye salmon productivity.

Juvenile salmon are known to migrate to sea under certain environmental conditions, during specific seasons, or after certain size thresholds are met (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 elucidate productivity trends by providing information specific to life history strategies, marine survival rates, and annual changes in outmigration timing. Combined with limnological investigations, smolt outmigration data can offer 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.

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 a maximum depth of over 130 m (Figure 2; Finkle 2013). The lake, which is considered oligotrophic, drains northwest via the Karluk River into Karluk Lagoon located approximately 35 km downstream. It supports 2 distinct runs of sockeye salmon that each maintain biological escapement goals (BEGs): an early run returning between June and early July (BEG of 110,000 to 250,000 fish) and a late run returning between late July through September (BEG of 170,000 to 380,000 fish; Nemeth et al. 2010). Other fish species present in the Karluk watershed 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*.

A variety of methods have been used to assess Karluk smolt abundance, age, weight, and length (AWL), and condition intermittently from 1925 to the present. In 2010 and 2011, "grab sample" studies were conducted at the outlet of Karluk Lake that collected whole fish for stable isotope analyses. In 2013 and 2014, the field seasons were extended and included mark–recapture experiments and collection of tissue samples for genetic stock identification from all AWL sampled smolt. The goal of this project has been to obtain reliable estimates of smolt production over time for Karluk Lake. This report presents data collected in 2014 and compares the results to limnological and previous years' data where possible to identify possible trends in Karluk sockeye salmon productivity.

OBJECTIVES

The objectives for the 2014 season were the following:

1. Estimate the total number of outmigrating sockeye salmon smolt, by age class, from Karluk Lake from May 13 to July 3.
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 isotope 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

One Canadian fan trap captured smolt outmigrating from Karluk Lake (Figure 3) in 2014. Detailed methods of trap installation, operation, and maintenance are described in the 2014 Karluk Lake Operational Plan (Loewen 2014). The trap was installed on May 13 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). A single trap fished at the downstream location was determined to be the most effective due to ineffective capture rates at the upper trap location in 2013. Although the potential for high mortality exists when transporting fish upriver, it was the only viable way to capture adequate numbers of smolt for weekly dye tests.

The trap was positioned in the river's thalweg approximately 16 m from shore. Dimensions of the trap wings on river left were 16.26 m and 15.60 m on river right, with an upstream wing mouth opening of 15.76 m. Water was funneled along the wings towards the trap by perforated aluminum plate supported by additional aluminum Rackmaster pipe frame angled at 45° to 60° to the substrate. This was done to concentrate flow and increase capture efficiency. Fish swimming into the wings were funneled into the trap, which further concentrated the water flow to push the fish into a closed catch box attached the outlet of the trap. The flow rate in the trap was controlled by its position vertically in the water column. Adjustments were made using a hand-powered cable winch (come-along) connected to a steel Rackmaster pipe frame bipod. Captured fishes were held in the live box for species identification, enumeration by species, and sampling of sockeye salmon smolt.

The trap was fished through July 3 and removed for the season on July 4. At the completion of the project, the trap and all other sampling gear were removed from the site.

SMOLT ENUMERATION

Typically sockeye salmon smolt 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 5 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.

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 trap live boxes, identified (McConnell and Snyder 1972; Pollard et al. 1997), enumerated, and released except for those sockeye salmon smolt retained for AWL samples, mark–recapture tests, or stable isotope analysis.

Smolt enumeration concluded a week prior to the scheduled season end date of July 10 to allow time for complete camp extraction: changes to land use agreements made operation of the smolt enumeration project cost prohibitive in its established location.

TRAP EFFICIENCY AND SMOLT POPULATION ESTIMATES

Mark-recapture experiments were scheduled a minimum of once every 5 days to estimate trap efficiency when a sufficient number of sockeye salmon smolt were captured to conduct a marking event (dye test). Sockeye salmon smolt were collected from the trap and transferred to an instream holding box (live box) where they were held for 3 days maximum. If the minimum sample size of 800 sockeye smolt was not collected in that time, all collected smolt were released and collection procedures began anew.

If the minimum sample size of 800 smolt was reached, a maximum of 150 smolt were transferred into each of four 24-gallon plastic containers and moved via raft 0.6 km upriver to the dye site (Figure 5). Retained smolt were moved from the plastic containers into an instream live box to rest for 24 hours prior to the dye test.

Each dye test was performed so that the dyed (marked) smolt were released at approximately 2300 hours to coincide with the start of the evening's outmigration. Smolt were netted from the live box, counted, and transferred back into the 4 aerated plastic containers. Fresh river water was pumped through the plastic containers for 30 minutes to allow the smolt time to acclimate to the new environment. After 30 minutes, the pumps were stopped and 5 grams of Bismarck Brown-Y dye solution were added to each plastic container (5.0 g of dye to 92 L (24 gallons) of water). Aquarium bubblers were used to aerate the water for 20 minutes while the dye set into the smolt.

After the 20 minute dye period, the pumps were started and fresh water was then flushed through the containers for 90 minutes to clear the excess dye and allow the smolt a recovery period. After 90 minutes, all moribund smolt were removed and counted from the containers. The total number of mortalities was subtracted from the total number of marked smolt to determine the exact number of marked smolt remaining to be released. Recovered marked smolt were released across the width of the river at the upper site using a ferry line system and an inflatable raft. The marked mortalities were released downstream of the trap to prevent recapture. Marked smolt were recorded separately from unmarked smolt and excluded from the daily total catch to prevent double counting. All dye and release events took place at the upstream site.

As part of the dye tests, 50 marked and 50 unmarked smolt were removed from the sample population and held in an instream live box to ensure certain assumptions of the mark–recapture experiments were validated (marked smolt retain their marks, and all marked smolt are identifiable). Technicians were tested daily on visual identification of retained marked and unmarked smolt to ensure that marked and unmarked smolt could be distinguished from one another 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

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

and 95% confidence intervals (CI) were estimated from

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

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

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

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

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

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

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

AGE, WEIGHT, AND LENGTH SAMPLING

Sockeye salmon smolt were randomly collected throughout the night's trap checks, anesthetized with Tricaine methanesulfonate (MS-222), and sampled for AWL data. For the first 24 days the trap fished, the sampling goal was 80 fish per smolt day to achieve a total sample size of 750 fish for genetic stock identification. When the smolt genetic sample size was met, the sampling schedule resumed to 40 AWL sockeye specimens per night for 5 consecutive nights, with 2 nights off between collection periods. All smolt sampling data reflects the smolt day in which the fish were captured, and samples were not mixed between days.

AWL sampling times shifted from a daytime to a nighttime event due to personnel loss after June 23. With only 2 technicians available, it was deemed necessary to pull random subsamples from and process samples following each trap check. This method showed no increases in sampling mortality or noticeable changes in population size or age structure.

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 to determine the C/N ratio of marine nutrients from AWL-sampled fish and kept as cold as possible until shipped to town where they were frozen until shipment to Idaho State University for processing. A fin clip from each sampled smolt was preserved in ethanol in labeled vials corresponding to individual fish for genetic identification.

After sampling, AWL fish were held in aerated water until they completely recovered from the anesthetic and released downstream from the trap

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

$$K = \frac{W}{L^3} 10^5 , \quad (13)$$

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

CLIMATE AND HYDROLOGY

Water depth at the trap was recorded in inches from a measuring stick attached to the trap bipod with a garden stake. Air temperature was taken in the shade outside the weatherport, and water temperature was taken from thermometers in the catch box; all measurements were recorded in degrees Celsius. Estimated cloud cover (%), estimated wind velocity (mph), and wind direction were recorded daily at 1200 hours and at midnight.

LIMNOLOGY

Karluk Lake was sampled for limnological data from May through October 2014 by the Kodiak Regional Aquaculture Association following the methods established by Ruhl (2013). Three stations were sampled in Karluk Lake (Figure 2). Water and zooplankton samples and data on temperature, dissolved oxygen, and light penetration were gathered at all stations. Each station's location was logged with a GPS and marked with a buoy.

Physical Data — Temperature, Dissolved Oxygen, and Light Penetration

Water temperature (°C) and dissolved oxygen (mg/L) levels were measured with a YSI ProODO dissolved oxygen and temperature meter. Readings were recorded at 0.5 m intervals to a depth of 5 m and then increased to 1 m intervals. Upon reaching a depth of 25 m, the intervals were increased to every 5 m up to a depth of 50 m. A mercury thermometer was used to ensure the meter functioned properly. Measurements of photosynthetically active radiation (PAR) were taken with a Li-Cor© Li-250A light meter and Li-Cor© Underwater Quantum (UWQ) photometer above the surface, at the surface, and proceeding at 0.5 m intervals until reaching a depth of 5 m. Readings were then continued at 1 m intervals until 0 $\mu mol\ s^{-1}\ m^{-2}$ light penetration was reached. The mean euphotic zone depth (EZD) was determined (Koenings et al. 1987) for the lake. Temperature and dissolved oxygen measurements at 1 m were compared to assess the physical conditions in the euphotic zones of the lake. Secchi disc readings were collected from each station to measure water transparency. The depths at which the disc disappeared when lowered into the water column and reappeared when raised in the water column were recorded and averaged.

Water Sampling — Nutrients, Phytoplankton, pH, and Alkalinity

Using a Van Dorn bottle, 4 to 8 L of water were collected from the epilimnion (depth of 1 m) and hypolimnion (30 m) at each station. Water samples were stored in polyethylene carboys, refrigerated, and initially processed within 12 hours of collection following the methods of Ruhl (2013).

Unfiltered water samples were decanted into labeled, acid-washed, 500 ml polyethylene bottles and frozen for future analysis of particulate nitrogen and phosphorous.

One-liter samples were passed through 4.25 cm diameter 0.7 µm Whatman™ GF/F filters under 15 to 20 psi vacuum pressure for particulate N and P analyses. For chlorophyll-*a* analysis, 1 L of lake water from each depth sampled was filtered through a 4.25 cm diameter 0.7 µm Whatman™ GF/F filter, adding approximately 5 ml of $MgCO_3$ solution to the last 50 ml of the sample water during the filtration process. Upon completion of filtration, all filters were placed in individual Petri dishes, labeled and stored frozen for further processing at the ADF&G Kodiak Island Laboratory (KIL) in Kodiak. Approximately 500 mL of water from each carboy was filtered separately from the chlorophyll-*a* designated sample and stored and frozen in a labeled, acid-washed, 500 mL polyethylene bottle.

Phytoplankton samples were taken from unfiltered lake water collected at 1 m. Exactly 100 mL of the unfiltered lake water was poured into an amber polypropylene bottle with 2.0 mL of Lugol's acetate, sealed, and stored at room temperature. Estimates of biovolume were processed by BSA Environmental Services, Inc. in Beachwood, Ohio.

The water chemistry parameters of pH and alkalinity were assessed with a temperature-compensated pH meter. One hundred milliliters of lake water were titrated with 0.02-N sulfuric acid following the methods of Ruhl (2013).

Water analyses were performed at the ADF&G KIL for total phosphorous (TP), total ammonia (TA), total filterable phosphorous (TFP), filterable reactive phosphorous (FRP), nitrate plus nitrite, and silicon using a SEAL AA3 segmented flow autoanalyzer in accordance with the manufacturer's methodologies. Chlorophyll *a* and phaeophytin *a* were assessed using a Genesis 5 spectrophotometer following the methods outlined by Ruhl (2013). Water samples were sent to the University of Georgia Feed and Environmental Water Laboratory for Total Kjeldahl nitrogen (TKN) analysis. Nutrient data were analyzed via linear regression and compared to published ratio values to indicate trophic level interactions and levels of lake productivity.

Zooplankton - Abundance, Biomass, and Length

One vertical zooplankton tow was made at each limnology station with a 0.2 m diameter, 153-micron net from a 50 m depth to the lake's surface. Each sample was placed in a 125 ml polyethylene bottle containing 12.5 ml of concentrated formalin to yield a 10% buffered formalin solution. Samples were stored for analysis at the ADF&G KIL. Subsamples of zooplankton were keyed to family or genus and counted on a Sedgewick-Rafter counting slide. This process was replicated 3 times per sample then counts were averaged and extrapolated over the entire sample. For each plankton tow, mean length (±0.01 mm) was measured for each family or genus with a sample size derived from a Student's t-test to achieve a confidence level of 95% (Ruhl 2013). Biomass was calculated via species-specific linear regression equations between dry weight and unweighted- and weighted-average length measurements (Koenings et al. 1987). Zooplankton data were compared to physical and nutrient data via linear regression and published values of length and biomass.

GENETIC SAMPLE COLLECTION

Between May 13 and June 5, up to 80 sockeye salmon smolt provided genetic tissue samples per each day within a 5-day sampling week; after June 6 only 40 fish were collected on each sampling day. All genetic tissue samples were paired with AWL data. Sampling protocol followed the well-established methods outlined by Loewen (2014). Outmigrating smolt were split up into 3 temporal strata in order to determine the proportion of each stock: May 13 to May 30, May 31 to June 15, and June 16 to July 2. Samples were sent to the ADF&G Gene Conservation Laboratory for genomic DNA extraction and assay of 96 sockeye salmon single nucleotide polymorphisms (SNPs) for stock identification.

To provide stock-specific outmigration estimates that account for both genetic uncertainty and uncertainty in the population estimate from mark–recapture, the proportional stock composition posteriors (genetic uncertainty) were multiplied by a lognormal distribution of the outmigration numbers based on the mean and CV of the mark–recapture estimates (outmigration estimate uncertainty). Genetic stock composition estimates for age-specific temporal strata were determined where sample sizes permitted, otherwise age classes were considered as 1 strata for the whole year. Stock-specific outmigration estimates for a given age class were determined in a similar manner to stock-specific outmigration estimates with all age classes combined, with the addition that these estimates also needed to account for uncertainty in age composition. Uncertainty in age composition was addressed by taking samples from a Dirichlet distribution parametrized by daily age class counts from scale aging. Where daily age class counts were not available, the proportions were interpolated from the nearest days with age samples and spread over 20 "hypothetical" samples. The Dirichlet distribution of age composition was multiplied by the log normal distribution of daily outmigration to provide a distribution of age-specific daily outmigration that accounts for both the uncertainty in outmigration estimates from mark–recapture and uncertainty in age composition from sampling limited number of fish per day.

Taken together with the age-specific stock composition estimates, both stock and age-specific outmigration estimates could then be determined.

Regarding individual assignments, stock assignments were based on maximum likelihood estimates at 2 different confidence levels: Relaxed (p = 0.80) and Strict (p = 0.95). While proportional stock composition estimates were determined in a Bayesian context using the program BAYES (Pella and Masuda 2001), this method was not ideal for individual assignment. Briefly, the Bayesian protocol assigns individuals to stocks in a baseline using both their genetic likelihood of belonging to a particular stock and the stock proportions in that mixture. Since this method incorporates information regarding the stock proportion estimates in that mixture, this creates an asymmetric ”pull” for dominate stocks in a mixture. This ”pull” effect can cause asymmetric biases in the assignment of ”genetically less certain” individuals when using a statistical threshold to assign individuals (Simmons et al. 2012). To remove potential for this asymmetric bias, solely the genetic likelihood of individuals was considered in a mixture when performing individual assignments. The superiority of the sole use of genetic likelihood method over the GCL’s standard BAYES protocol for individual assignment was confirmed with baseline proof tests using different mixture proportions of Karluk early and late stock individuals taken from the baseline.

RESULTS

SMOLT DATA

Trapping Effort and Catch

Trapping took place for a total of 51 smolt days beginning on smolt day May 13 and ending on July 3 (Appendix A1); a total of 74,585 sockeye salmon smolt were captured (Figure 6). In addition to sockeye salmon smolt, there were 33,992 juvenile coho salmon, 6,182 Dolly Varden, 8,448 stickleback, 60,808 sculpin, and 12,108 sockeye salmon fry captured (Appendix A1).

Smolt Outmigration Timing and Population Estimates

An estimated 811,255 sockeye salmon smolt (95% confidence interval 716,651–905,859 fish) outmigrated in 2014 (Table 1; Figures 7 and 8) based upon mark–recapture estimates and trap counts. The outmigration reached 50% on June 4, and the largest night of estimated outmigration occurred May 28 (7,803 fish; Figure 6).

Trap Efficiency Estimates

A total of 6,932 smolt were captured and released for mark–recapture experiments conducted on 7 occasions beginning on May 19 and ending on June 20. A season total of 986 smolt were recaptured for a trap efficiency estimate per stratum ranging from 5.6 to 28.8% (Table 2). The majority of marked smolt recaptures occurred within 2 days of being released. Trap efficiencies from the first and last mark–recapture experiments were applied to the first and last stratum of the project respectively because insufficient numbers of smolt were collected for dye tests during those periods; the results of the first dye test conducted on May 19 were applied to smolt counts from May 13 through May 18, and the results of the last dye test conducted on June 20 were applied to smolt counts from June 25 through July 2.

Age, Weight, and Length Data

A total of 2,467 legible scale samples were collected from sockeye salmon smolt for AWL data. The 2014 outmigration estimate consisted of 252,325 freshwater-age-1 (31.1% of total estimated outmigration), 547,473 freshwater-age-2 (67.5%), and 11,457 freshwater-age-3 (1.4%) sockeye salmon smolt (Tables 3 and 4; Figure 9). Freshwater-age-2 smolt were the predominant age class of the outmigration from May 13 to June 13, while freshwater-age-3 smolt were more abundant at the start of the project and freshwater-age-1 smolt were the most abundant age class after June 14; Table 3).

Of the sampled smolt, the mean length, weight, and condition factor of freshwater-age-1 smolt (n = 651) were 115 mm, 13.3 g, and 0.86. The mean length, weight, and condition factor of freshwater-age-2 smolt (n = 1,725) were 136 mm, 21.4 g, and 0.84. The mean length, weight, and condition factor of freshwater-age-3 smolt (n = 90) were 162 mm, 37.3 g, and 0.85 (Table 4, Figure 10). Length frequency histograms showed that large smolt (> 116 mm) composed the majority of the catch throughout the season in all age groups (Figure 11).

Whole fish (n = 180) were retained for isotopic sampling and frozen for analysis at a later date by Dr. Bruce Finney of Idaho State University.

Stream and Climate Data

The absolute water depth at the trap location varied from 48.3 to 71.1 cm (19 to 28 inches) during the season. Water temperatures averaged near 5.1°C during the first week after the trap was installed (May 12 through May 18) and generally increased throughout the season to a maximum of 11.5°C on July 3 (Appendix B1 and B2). The season began with low water levels that increased in June with heavy rainfall and then decreased in July. Mild temperatures, light precipitation, and gentle winds with occasional squalls characterized the early season. June brought several weeks of saturating rain and strong winds, which dissipated late in the month. Late June and early July had several hot, dry days with corresponding drops in river volume.

LIMNOLOGICAL DATA

Physical Data

The seasonal average 1 m temperature in Karluk Lake was 11.1 °C (Table 2). The warmest temperature occurred in August (15.3 °C) and the coolest was in May (7.3 °C; Table 5 and Figure 12). Dissolved oxygen readings taken at a depth of 1 m were the lowest in August (9.4 mg/L) and the greatest in May (12.4 mg/L), averaging 10.6 mg/L over stations during the sampling season (Table 6; Figure 12). The euphotic zone depth (EZD) was estimated from light penetration data, which was at its deepest in August (26.5 m) and shallowest in October (17.0 m; Tables 7 and 8). The seasonal average of the EZD was 22.1 m (Table 8; Figures 13 and 14).

Water Sampling

All data presented in this section were collected from a 1 m depth.

Water chemistry measurements were variable for Karluk Lake during 2014; pH ranged from 7.76 in May (Station 7) to 8.34 in July (Station 4). The seasonal pH values averaged 8.10 for all stations (Table 9). Seasonal TP averaged between 2.3 µg/L P in August and 3.6 µg/L P in October, with a seasonal mean of 3.1 µg/L P (Table 9). Of the photosynthetic pigments, chlorophyll *a* averaged between 0.59 µg/L in August and 1.39 µg/L in June over the sampling season, with a seasonal average of 0.94 µg/L (Table 9). Seasonal average total nitrogen (TKN plus NO_3+NO_2) concentrations were greatest in October (570.4 µg/L) and lowest in July (107.2 µg/L; Table 9). Silicon concentrations averaged 178.1 µg/L over the sampling season, ranging between 78.9 (May) and 270.3 (September) µg/L (Table 9). Phytoplankton biovolume was greatest in May (1,332,996 mm^3/L) and lowest in August (84,862 mm^3/L; Table 10). Diatoms (Bacillariophyta) were the predominant species on average having the greatest biovolumes in all months sampled except July, which was predominantly chlorophytes (Table 10). In comparison to phytoplankton biovolumes from 2004 to 2006 and 2010 to 2013, 2014 was the greatest recorded biovolume (661,732 mm^3/L; Table 11).

Zooplankton

The 2014 average abundance of Karluk Lake zooplankton was greatest in May (2,507,785 zooplankton/m^2), with the lowest monthly concentration of 873,673 zooplankton/m^2 in October (Table 12). The species composition was composed predominately of the copepod *Cyclops* throughout the season. *Daphnia* were the most abundant cladoceran, reaching their greatest abundance (114,650 zooplankton/m^2) in September (Table 12). Other zooplankton species present in Karluk Lake were *Bosmina*, *Holopedium, Diaptomus, Epischura,* and *Harpaticus*. *Cyclops* had the most ovigerous individuals during a given month (35,563 zooplankton/m^2 in August; Table 12)

The seasonal weighted-average zooplankton biomass for 2014 in Karluk Lake was 2,687 mg/m^2 and ranged from 1,476 mg/m^2 in September to 5,360 mg/m^2 in May (Table 13). Karluk Lake maintained monthly zooplankton biomasses well over 1,000 mg/m^2 during the sampling season (Table 13). *Cyclops* had the greatest biomass (seasonal weighted average of 2,092 mg/m^2) of any species, either egg or non-egg bearing, in Karluk Lake during 2014 (Table 13).

Ovigerous *Diaptomus* were the longest zooplankton (seasonal weighted average of 1.36 mm) collected during 2014 (Table 14). Ovigerous zooplankters were longer than their non-ovigerous counterparts for all identified species except *Daphnia* in June. Non-ovigerous *Cyclops* ranged from 0.69 to 0.84 mm and non-ovigerous *Bosmina* ranged from 0.30 to 0.45 mm (Table 14).

GENETIC DATA

Overall, the 2014 smolt outmigration was approximately 24% early-run and 76% late-run fish, which was similar to the 2013 genetic analysis despite the differing magnitudes of the overall outmigration estimate (376,000 fish in 2013 compared to 811,000 fish in 2014; Table 15). The temporal strata indicated a slight decrease in the proportion of late-run smolt over the course of the outmigration. Age-specific strata indicated that early-run fish predominated the earlier part of the freshwater-age-1 outmigration, while late-run fish were in the majority for the later part of the outmigration (Tables 16 through 18). When considering this in the context of the outmigration numbers, it appears that roughly even numbers of freshwater-age-1 fish belonged to each stock. The freshwater-age-2 outmigration was dominated by late-run fish throughout the outmigration, with almost 90% of all freshwater-age-2 outmigrants belonging to the late-run stock.

Of the 85 fish with sufficient genetic data collected from the Karluk weir area, 76 were from a single day, thus this collection is best thought of as a “grab” sample. For this “grab” sample, about 90% were late-run fish (Table 19).

DISCUSSION

SMOLT OUTMIGRATION TIMING

The trap was installed on May 13 and appeared to encompass the beginning of the smolt outmigration as trap catches were less than 25 fish for each of the first 4 nights. The trap catch sharply increased between May 23 and May 25 when a total of over 11,000 fish were captured, almost tripling the cumulative catch up to that point (3,210 fish). The small catches recorded in the initial few days of trapping were similar to 2000 and 2006 (Duesterloh and Watchers 2007). Historically, the majority of the outmigration has been compressed and unimodal occurring between May 20 and June 3 or bimodal with a second peak occurring in the second week of June (Duesterloh and Watchers 2007; Watchers and Duesterloh 2005). The greatest single night of trapped outmigration (7,803 smolt) occurred during this period (May 28). Captures near or above 4,000 sockeye smolt also occurred throughout the season on 7 other nights. The general trend was several nights of high capture when smolt would enter the traps at a steady rate throughout the night, followed by a period of several nights exhibiting relatively lower numbers. Catches declined after mid-June suggesting the end of the outmigration.

OUTMIGRATION POPULATION ESTIMATE AND TRAP AVOIDANCE

The 2014 point estimate of 811,255 smolt was low compared to historical population estimates (1963–2013 average of 1,759,742 fish). The total number of smolt caught by the trap (74,585 fish) was less than the 1991–2013 average of 105,797 sockeye salmon smolt. With consistent mark–recapture experiments performed throughout the sampling season that met the target release size (> 800 smolt), confidence in the point estimate would appear fair. However, sockeye salmon smolt population estimates from Karluk River may be underestimated. For example, lower outmigration population estimates from 1999, 2005, and 2006 resulted in exceptionally high marine survival rates (> 63%), suggesting underestimation of the total smolt outmigration (Appendix C1).

Historically, sockeye salmon smolt outmigrating from Karluk Lake are much larger compared to similarly-aged sockeye salmon smolt from other systems. Due to their large size and strong swimming ability, Karluk sockeye salmon smolt were efficient at avoiding the Canadian fan trap; underwater video footage from the 2013 field season captured sockeye salmon smolt swimming into and then out of the Canadian fan trap in the Karluk River. Subsequently, being unable to capture a portion of the population violates mark–recapture model assumptions and biases outmigration population estimates. Because the large smolt were unable to be consistently captured, it is likely that the population is underestimated.

Budgetary and logistic constraints required the project cease while smolt were still outmigrating, which may have caused the overall population to be underestimated. The annual outmigration is generally considered over when catches are <100 fish per night for 3 consecutive nights. Between 1999 and 2006 and in 2012, a decrease in catch each evening was observed after June 18 in all years. However, in 2014 catches exceeded 1,000 smolt a night by the project's end on July 2, suggesting the outmigration continued after the traps were removed.

Outmigration timing and magnitude in 2014 allowed for 7 mark–recapture events during the season, with approximately 7,000 smolt marked and released throughout the season. The first mark–recapture test took place on May 19, and the trap efficiency rate from this test was applied to catches from the beginning of the season in order to calculate population estimates during the first week of the field season. Similarly, the results of the dye test conducted on June 20 were applied to the trap catches up to the end of the project. A mark–recapture experiment was conducted on June 25 using 437 fish: this test was deemed invalid because of the low sample size and the subsequent bias and error it would introduce into the population estimate.

Smolt Age Structure

Historically, freshwater-age-2 smolt have been the most abundant age class outmigrating from Karluk Lake, followed by freshwater-age-3 smolt (Foster 2010; Kyle et al. 1988; Rounsefell 1958). In 2014, freshwater-age-2 fish comprised the majority of the outmigration. However, freshwater-age-3 fish were a minimal component of the overall outmigration (< 2%). Extended freshwater residency may indicate poor rearing conditions for juvenile salmon. If growth rates are not sufficient to achieve a threshold size necessary to outmigrate in the spring, juvenile fish may stay in a lake to feed for another year to acquire growth (Burgner 1991). In 2006, the estimated proportion of freshwater-age-3 sockeye smolt in the outmigration population was an unprecedented 66%, which followed years of overescapement and a taxed zooplankton forage base. That all age classes in 2014 had healthy condition factors and few freshwater-age-3 fish outmigrated may suggest that lake rearing conditions have improved compared to those from 2004 to 2009. Because very few smolt were captured during the first week of the project, this also suggested that the beginning of the outmigration was captured and portions of the freshwater-age-3 component were not missed. It should be noted that the relative large size, and subsequent strong swimming ability, of freshwater-age-3 smolt does not preclude trap avoidance as a mechanism for low abundance despite the high recapture rates achieved throughout the season.

In examining outmigration timing by age class, freshwater-age-3 smolt were present in relatively large proportions in the first week of trapping, and freshwater-age-1 smolt increased in proportion midway through the outmigration. This corroborates Barnaby's observations (1944) that larger smolt leave the lake first followed by smaller fish later in the season; this was also reflected in historical outmigration patterns of age composition throughout the 1999–2006 seasons. Again, given the healthy condition of outmigrating smolt, however, favorable rearing conditions in Karluk Lake may have enabled freshwater-age-1 fish to gain sufficient growth to outmigrate in 2014.

Length and Weight Composition

The Karluk sockeye salmon smolt dataset includes age, weight, and length data dating back to 1925. The 2014 sockeye salmon smolt were substantially larger than the historical averages for length and weight for all ages (Figure 10; Appendix C2).

All age classes had significant ($p < 0.03$), negative relationships between length and escapement. This relationship was stronger in freshwater-age-2 and -3 fish ($p < 1.9 \times 10^{-6}$, $R^2 > 0.66$), which exemplifies density dependence on Karluk sockeye salmon. That freshwater-age-1 fish were less affected by density dependence may be more of an indicator of their susceptibility to predation or factors such as temperature or emergence timing. Historical sample sizes for freshwater-age-1 fish were variable, ranging from 1 to 651 fish, suggesting the AWL data may not accurately represent the entire freshwater-age-1 population over time.

There were no significant relationships between size or condition and adult returns. This may be more a result of trap avoidance and biased population estimates. If fish avoided the 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 outmigration. Additionally, Henderson and Cass (1991) found the relationships between smolt size and marine survival was poor among year classes but strong within a year class.

LIMNOLOGICAL DATA

Recent rearing conditions in Karluk Lake have been favorable for juvenile sockeye salmon. May 1-m temperatures were 2.5°C warmer than the historical average and, from July through September, the upper 10 m of the water column hovered near 15°C, considered to be an optimal temperature for sockeye salmon growth (Brett et al. 1969). Beyond optimal growth conditions, it is unknown if the recent warm temperatures in Karluk Lake affect rearing or outmigrating in other ways.

Phosphorous and nitrogen concentrations were generally lower in the epilimnion than in the hypolimnion. This difference may be in part to the consumption of nutrients via strong phytoplankton production in the epilimnion: the 2014 seasonal average biovolume of phytoplankton was more than 6 times greater than the historical average and the largest on record for Karluk Lake. The phytoplankton species composition shifted in July from predominantly diatoms to green algae, which is a common pattern of succession (Reynolds 2006). It is likely this succession occurred as the zooplankton population cropped down the edible diatom community, allowing green algae to thrive without predatory pressure because they are either too large (*Staurastrum* sp.) or too small (*Chlorella minutissima*) to be consumed.

Commensurate with the highest historical monthly phytoplankton biovolume was the highest historical monthly zooplankton biomass. These measurements followed exceptionally high TKN concentrations in 2013 and warm water temperatures in May 2014, supporting further that rearing conditions in Karluk Lake were highly productive. Additionally, the mild 2013–2014 winter may have extended the growing season as no ice formed on the lake, which would impede light penetration and thus algal production.

Zooplankters were generally large in size for their genera with the exception of *Bosmina*. Ovigerous *Bosmina* were typically longer than 0.4 mm, yet non-egg bearing individuals were below the feeding threshold size for juvenile sockeye salmon (Kyle 1992, Schindler 1992). This suggests that grazing pressure by sockeye salmon cropped down the population as evidenced by the seasonally low biomasses and small size. It is also possible that the large abundance of *Cyclops* also contributed to grazing upon smaller individuals of the *Bosmina* population; however, Havel (1980) noted that the capture of cladocera is difficult and energetically taxing for *Cyclops*, suggesting that *Cyclops* predation upon *Bosmina* may be limited in its scope. Furthermore, the rotifer *Asplancha*, which is common in Karluk Lake, is a preferred forage of *Cyclops*.

GENETIC DATA

Empirical evidence supports the hypothesis that the opportunities for growth in the productive northern oceans are vastly superior to freshwater (Gross et al. 1988), but the risk of mortality at sea is also higher than if individuals had not outmigrated (Quinn and Myers 2004). This decision to go to seas is thought to reflect a balance between the benefits of growth in freshwater versus marine ecosystems and the probability of survival or mortality in each habitat (Hendry et al. 2004). More freshwater-age-1 fish were present in the the early-run stock than the late-run stock, which were predominantly freshwater-age-2 outmigrants. Interestingly, this begs the question of what drives a Karluk juvenile sockeye salmon to migrate to sea or spend an additional year in freshwater. Factors such as fry emergence timing and climatic conditions may play a greater role in determining life history decisions as available forage has been abundant.

ADDITIONAL DATA

Data collected from this project enable 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.

Stable isotope samples from 2012 to 2014 have been processed but are awaiting analysis by Dr. Bruce Finney of Idaho State University. These data will help to assess the level of marine-derived nutrients in juvenile sockeye salmon (e.g., Finney et al. 2000). Carbon-Nitrogen 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.

CONCLUSION

Many past smolt investigations conducted at Karluk Lake were sporadic in nature and timing, limiting the evaluation of freshwater production over time. Despite these limitations, the collection of smolt outmigration data has increased our understanding of juvenile sockeye salmon life history strategies in the Karluk watershed.

Through the course of this project, it is apparent that Karluk juvenile sockeye salmon are affected by density dependence. However, the timing of fry emergence, zooplankton blooms, and climatic change may also influence their life history strategies. Koenings and Burkett (1987) indicated that zooplankton biomass peaked twice, once each in May and September. Asynchrony between the peak blooms and fry emergence was hypothesized to have negatively affected juvenile condition and survival leading to poor adult returns (Koenings and Burkett 1987). Review of historical data has shown that between 1981 and 1996, zooplankton biomasses were at their greatest in September for 6, and in May for 2, of those 16 years; from 1999 to 2013, the peak biomass has occurred between mid-June and August for 11 of those 15 years. Although the 2014 zooplankton biomass was greatest in May, June through August biomass levels were comparable to 1999–2013 biomasses and well in excess of satiation levels. With the exceptions of 2004 to 2006 and 2008, zooplankton production has been healthy in Karluk Lake. The causes of the shift in the timing of the zooplankton bloom are uncertain but may be related to climate via warmer winters and thus extended growing seasons. Similarly, lower seasonal biomasses may indicate hatch-bloom synchrony in the spring or grazing pressure from rearing juveniles in the late summer and fall.

With the addition of smolt stock identification data, it is not surprising that the majority of the 2014 outmigration was composed of late-run fish as this mirrored proportions of early- and late-run fish in the parent escapement. The overwhelming proportion of late-run fish in the freshwater-age-2 component of the outmigration, however, is noteworthy. Late-run adult sockeye salmon are known to spawn as late as October, and possibly into November, which hypothetically would cause a substantial portion of late-run alevin to hatch later than those whose parents, from either stock, spawned in August or September. This delay in the emergence timing of late-run alevin would force them to compete with fish from within their own cohort that had more time to rear and acquire growth. In turn, this may cause the later emerging fish to choose a life history strategy to overwinter an additional year to gain more growth before outmigration.

Ultimately, the lack of strong seasonal relationships between variables in Karluk Lake is also of relevance because it highlights the intricacy among factors that can influence productivity and the inherent need for continued study. As primary production is the base of a food web, any changes in it may significantly impact higher trophic levels, such as secondary or tertiary consumers (Milovskaya et al. 1998). In some lake systems, a negative change in rearing conditions at these levels can cause migratory behavior or decreased juvenile sockeye salmon freshwater survival (Parr 1972; Ruggerone 1994; Bouwens and Finkle 2003). Thus, it is important to know and understand patterns of resource abundance and habitat usage to effectively manage a system and conserve its resources. Continued study of Karluk Lake is necessary for identifying if its rearing habitat may have deleterious effects upon its rearing salmonids.

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TABLES AND FIGURES

Table 1.–Karluk Lake sockeye salmon smolt population estimates, by freshwater age, 1961 to 2014.

	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	64,021	282,860	29,147	43	376,071	291,720	460,422
2014	0	252,325	547,473	11,457	0	811,255	716,651	905,859

Table 2.–Results from mark-recapture tests performed on sockeye salmon smolt migrating from Karluk Lake, 2014.

Date	No. released[a]	Total recaptures	Trap efficiency[b]
5/19	798	62	7.8%
5/25	1,292	137	10.6%
5/30	1,046	300	28.7%
6/4	1,209	164	13.6%
6/9	871	52	6.0%
6/14	888	226	25.5%
6/20	828	49	5.9%
6/25	437	12	2.8%

[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 3.–Estimated sockeye salmon smolt outmigration from Karluk Lake in 2014 by freshwater age and statistical week.

Stat week	Sample size		Freshwater age composition 0	1	2	3	Total
20	33	Percent	0.0	7.3	56.9	35.9	100.0
		Numbers	0	57	447	282	786
21	512	Percent	0.0	0.0	92.1	7.9	100.0
		Numbers	0	0	82,814	7,068	89,881
22	535	Percent	0.0	7.7	90.8	1.5	100.0
		Numbers	0	13,669	161,586	2,675	177,929
23	505	Percent	0.0	15.7	84.2	0.1	100.0
		Numbers	0	11,296	60,637	85	72,018
24	216	Percent	0.0	30.9	68.3	0.8	100.0
		Numbers	0	54,385	120,285	1,347	176,018
25	216	Percent	0.0	50.1	49.9	0.0	100.0
		Numbers	0	57,197	56,865	0	114,062
26	250	Percent	0.0	58.3	41.7	0.0	100.0
		Numbers	0	79,969	57,230	0	137,200
27	200	Percent	0.0	82.5	17.5	0.0	100.0
		Numbers	0	35,751	7,609	0	43,360
Total	2,467	Percent	0.0	31.1	67.5	1.4	100.0
		Numbers	0	252,325	547,472	11,457	811,255

Table 4.–Length, weight, and condition factor of Karluk Lake sockeye salmon smolt samples from the downstream trap in 2014, by freshwater age and statistical week.

Age	Stat week	Sample size	Length (mm)		Weight (g)		Condition (K)	
			Mean	SE	Mean	SE	Mean	SE
1	20	-	-	-	-	-	-	-
1	21	-	-	-	-	-	-	-
1	22	71	108	0.7	10.6	0.2	0.83	0.01
1	23	112	110	0.5	11.5	0.2	0.85	0.00
1	24	45	115	0.8	13.0	0.3	0.84	0.00
1	25	126	118	0.6	14.2	0.2	0.86	0.00
1	26	134	119	0.5	14.5	0.2	0.86	0.00
1	27	163	117	0.5	14.1	0.2	0.87	0.00
Totals		651	115	0.3	13.3	0.1	0.86	0.00
2	20	19	146	1.4	26.7	0.9	0.85	0.01
2	21	443	143	0.4	24.5	0.2	0.83	0.00
2	22	460	133	0.5	20.1	0.2	0.83	0.00
2	23	392	134	0.5	20.6	0.2	0.85	0.00
2	24	168	134	0.6	21.0	0.3	0.86	0.00
2	25	90	134	0.8	21.0	0.4	0.87	0.00
2	26	116	130	0.8	19.4	0.3	0.87	0.00
2	27	37	127	1.3	18.1	0.6	0.87	0.01
Totals		1,725	136	0.2	21.4	0.1	0.84	0.00
3	20	14	168	4.0	41.8	2.6	0.86	0.02
3	21	68	163	1.4	37.9	0.9	0.85	0.01
3	22	4	147	4.7	25.9	3.4	0.81	0.04
3	23	1	145	0.0	27.2	0.0	0.89	0.00
3	24	3	132	8.2	21.0	4.3	0.88	0.04
3	25	-	-	-	-	-	-	-
3	26	-	-	-	-	-	-	-
3	27	-	-	-	-	-	-	-
Totals		90	162	1.5	37.3	0.9	0.85	0.01

Table 5.–Karluk Lake seasonal water temperature profiles (°C), 2014.

	Month						Seasonal
Depth (m)	May	June	July	August	Sept	Oct	average
0.1	7.6	8.6	13.8	15.2	13.4	8.2	11.1
0.5	7.4	8.6	13.8	15.3	13.4	8.2	11.1
1	7.3	8.5	13.8	15.3	13.4	8.2	11.1
1.5	7.3	8.5	13.8	15.3	13.4	8.2	11.1
2	7.2	8.5	13.7	15.3	13.4	8.2	11.1
2.5	7.2	8.5	13.7	15.3	13.4	8.2	11.0
3	7.0	8.5	13.7	15.3	13.4	8.2	11.0
3.5	6.9	8.5	13.7	15.3	13.4	8.2	11.0
4	6.8	8.5	13.7	15.3	13.4	8.2	11.0
4.5	6.7	8.5	13.6	15.3	13.4	8.2	10.9
5	6.7	8.5	13.5	15.3	13.4	8.2	10.9
6	6.6	8.4	13.3	15.3	13.4	8.2	10.9
7	6.6	8.4	13.2	15.2	13.4	8.2	10.8
8	6.5	8.4	12.9	15.1	13.4	8.2	10.8
9	6.5	8.4	12.7	15.0	13.4	8.2	10.7
10	6.4	8.4	12.5	14.8	13.4	8.1	10.6
11	6.4	8.3	12.2	14.7	13.4	8.1	10.5
12	6.4	8.3	11.6	14.2	13.3	8.1	10.3
13	6.3	8.2	10.5	13.0	13.1	8.1	9.9
14	6.3	8.2	9.4	12.4	12.5	8.1	9.5
15	6.3	8.2	8.8	10.6	12.3	8.1	9.1
16	6.3	8.1	8.3	9.7	11.9	8.1	8.7
17	6.2	8.1	7.9	8.6	11.2	8.0	8.4
18	6.2	7.9	7.6	8.0	10.2	8.0	8.0
19	6.2	7.8	7.4	7.6	8.0	8.0	7.5
20	6.2	7.7	7.1	7.3	7.6	8.0	7.3
21	6.1	7.7	7.0	7.1	7.4	8.0	7.2
22	6.1	7.2	6.8	6.9	7.2	8.0	7.0
23	6.0	6.6	6.7	6.7	7.0	8.0	6.8
24	6.0	6.5	6.5	6.6	6.9	8.0	6.8
25	5.9	6.4	6.4	6.6	6.7	8.0	6.7
30	5.5	6.1	6.1	6.3	6.4	7.7	6.4
35	5.0	5.8	5.9	6.1	6.2	7.4	6.1
40	4.7	5.6	5.7	5.9	6.0	7.0	5.8
45	4.6	5.5	5.5	5.7	5.8	6.7	5.6
50	4.4	5.3	5.2	5.5	5.6	6.5	5.4

Table 6.–Karluk Lake seasonal dissolved oxygen profiles (mg/L), 2014.

	Month						Seasonal
Depth (m)	May	June	July	August	Sept	Oct	average
0.1	12.3	11.4	10.3	9.4	9.7	10.4	10.6
0.5	12.4	11.4	10.3	9.4	9.7	10.4	10.6
1	12.4	11.4	10.3	9.4	9.7	10.3	10.6
1.5	12.4	11.4	10.3	9.4	9.6	10.3	10.6
2	12.4	11.4	10.3	9.4	9.6	10.3	10.6
2.5	12.4	11.4	10.3	9.4	9.6	10.3	10.6
3	12.5	11.4	10.3	9.4	9.6	10.3	10.6
3.5	12.5	11.4	10.3	9.4	9.6	10.3	10.6
4	12.5	11.4	10.3	9.4	9.6	10.3	10.6
4.5	12.5	11.4	10.3	9.4	9.6	10.3	10.6
5	12.5	11.4	10.4	9.4	9.6	10.3	10.6
6	12.6	11.4	10.5	9.4	9.6	10.3	10.6
7	12.5	11.4	10.6	9.4	9.6	10.2	10.6
8	12.5	11.4	10.6	9.4	9.5	10.2	10.6
9	12.5	11.4	10.7	9.4	9.5	10.2	10.6
10	12.5	11.3	10.8	9.5	9.5	10.2	10.6
11	12.5	11.3	10.8	9.5	9.5	10.2	10.6
12	12.5	11.3	11.0	9.6	9.5	10.2	10.7
13	12.5	11.3	11.3	10.0	9.5	10.1	10.8
14	12.5	11.3	11.5	10.1	9.6	10.1	10.9
15	12.5	11.3	11.6	10.7	9.6	10.1	11.0
16	12.5	11.3	11.6	10.9	9.7	10.1	11.0
17	12.4	11.3	11.6	11.2	9.8	10.1	11.1
18	12.4	11.3	11.6	11.2	9.9	10.0	11.1
19	12.4	11.3	11.6	11.2	10.4	10.0	11.2
20	12.4	11.3	11.5	11.1	10.5	10.0	11.1
21	12.4	11.3	11.5	11.0	10.4	10.0	11.1
22	12.4	11.4	11.4	11.0	10.4	9.9	11.1
23	12.4	11.5	11.4	10.9	10.3	9.9	11.1
24	12.4	11.5	11.3	10.9	10.3	9.9	11.1
25	12.4	11.6	11.3	10.8	10.3	9.9	11.0
30	12.3	11.5	11.1	10.6	10.1	9.7	10.9
35	12.2	11.4	11.0	10.5	10.0	9.6	10.8
40	12.0	11.4	10.9	10.3	9.8	9.4	10.6
45	11.9	11.3	10.8	10.0	9.6	9.2	10.4
50	11.7	11.2	10.1	9.6	9.1	9.0	10.1

Table 7.–Karluk Lake seasonal light penetration profiles (µmol s^{-1} m^{-2}), 2014.

	Month						Seasonal
Depth (m)	May	June	July	August	Sept	Oct	average
0.1	760.0	458.3	532.3	122.3	232.5	512.0	447.4
0.5	697.7	378.3	435.3	95.2	199.5	453.7	385.9
1	594.7	242.3	362.0	77.9	176.5	375.0	312.7
1.5	534.7	204.3	336.7	69.6	149.5	261.0	265.9
2	415.7	181.0	316.3	64.0	136.0	227.0	229.5
2.5	366.3	160.7	278.0	59.6	120.5	191.7	201.1
3	328.7	152.7	239.7	55.6	112.8	159.3	178.5
3.5	302.0	140.7	205.3	51.6	105.8	132.7	158.9
4	275.0	117.0	182.0	47.9	96.1	118.7	141.6
4.5	247.7	104.7	164.0	41.0	89.3	107.0	127.3
5	221.7	94.3	152.8	41.7	82.5	94.0	115.8
6	192.0	78.7	133.7	36.5	70.1	70.8	98.0
7	147.3	65.0	108.7	32.0	58.7	56.1	78.7
8	117.0	54.7	88.8	27.6	49.4	42.4	63.7
9	92.3	46.0	72.6	24.1	40.3	34.4	51.9
10	77.3	39.3	58.4	21.0	33.6	27.5	43.0
11	64.8	30.3	46.2	18.1	25.9	22.1	34.8
12	52.7	24.0	37.7	15.5	22.0	17.6	28.4
13	43.9	20.0	29.9	13.6	18.3	14.3	23.5
14	37.8	16.4	23.6	11.6	15.4	11.5	19.5
15	29.6	13.6	18.9	9.9	12.7	9.4	15.8
16	25.0	11.8	15.1	8.3	11.1	7.7	13.2
17	22.7	10.7	12.0	6.8	9.3	6.3	11.4
18	18.0	11.1	9.1	5.6	7.7	5.2	9.5
19	14.9	9.2	6.8	4.7	6.5	4.3	7.7
20	12.2	7.4	5.3	3.9	5.4	3.5	6.3
21	10.5	5.2	4.1	3.1	4.8	2.9	5.1
22	8.9	5.2	3.1	2.6	3.8	2.4	4.3
23	7.4	4.2	2.5	2.1	3.3	2.0	3.6
24	6.1	3.0	1.9	1.8	2.8	1.6	2.9
25	5.1	2.0	1.5	1.5	2.4	1.4	2.3
26	4.3	1.6	1.3	1.5	2.0	1.1	2.0
27	3.6	1.3	1.4	1.7	1.7	1.0	1.9
28	3.1	1.1	0.9	1.4	1.5	0.8	1.5
29	2.6		0.7	1.1	1.3	0.7	1.5
30	2.2		0.6	0.9	1.1		1.7

Table 8.–Karluk Lake seasonal euphotic zone depths, 2014.

Month	May	June	July	August	Sept	Oct	Seasonal mean
Depth (m)	22.18	21.73	20.83	26.47	24.66	16.96	22.14

Table 9.–Karluk Lake seasonal average water chemistry, algal pigment, and nutrient concentrations by depth, 2014.

Sample Depth (m)	Nutrient	May	June	July	August	Sept	Oct	Seasonal mean
1	pH	7.99	8.20	8.34	8.10	8.08	7.86	8.10
1	Alkalinity (mg/L $CaCO_3$)	23.58	23.83	23.00	27.00	25.17	26.08	24.78
1	Total phosphorous (µg/L P)	3.2	3.3	2.6	2.3	3.3	3.6	3.1
1	Total filterable phosphorous (µg/L P)	1.8	1.3	0.5	0.9	1.3	1.4	1.2
1	Filterable reactive phosphorous (µg/L P)	0.1	0.4	0.6	1.1	0.5	0.3	0.5
1	Total Kjeldahl nitrogen (µg/L N)	106.7	140.7	107.0	278.3	543.0	543.7	286.6
1	Ammonia (µg/L N)	17.2	9.5	1.7	2.3	1.0	1.4	5.5
1	Nitrate + nitrite (µg/L N)	35.9	17.6	0.2	1.5	1.2	26.7	13.9
1	Organic silicon (µg/L)	78.9	114.3	201.4	202.6	270.3	201.2	178.1
1	Chlorophyll *a* (µg/L)	0.91	1.39	0.64	0.59	1.01	1.12	0.94
1	Phaeophytin *a* (µg/L)	0.18	0.78	0.33	0.12	0.18	0.37	0.33
30	pH	7.97	8.26	8.25	7.90	7.95	7.84	8.03
30	Alkalinity (mg/L $CaCO_3$)	23.42	23.67	23.00	28.00	26.33	26.25	25.11
30	Total phosphorous (µg/L P)	4.0	3.1	3.8	3.6	3.6	4.0	3.7
30	Total filterable phosphorous (µg/L P)	1.5	1.2	0.8	0.8	1.5	1.2	1.2
30	Filterable reactive phosphorous (µg/L P)	0.2	0.4	0.3	0.6	0.7	0.4	0.5
30	Total Kjeldahl nitrogen (µg/L N)	1,231.7	69.3	45.3	428.7	354.0	495.7	437.4
30	Ammonia (µg/L N)	13.3	21.4	5.9	3.6	1.2	1.9	7.9
30	Nitrate + nitrite (µg/L N)	38.7	30.9	46.7	58.0	63.2	48.1	47.6
30	Organic silicon (µg/L)	48.3	189.8	108.0	139.6	137.7	175.6	133.2
30	Chlorophyll *a* (µg/L)	1.39	1.97	2.24	1.39	0.96	0.85	1.41
30	Phaeophytin *a* (µg/L)	0.40	0.64	0.23	0.18	0.39	0.49	0.40

Table 10.–Karluk Lake monthly phytoplankton biovolume by phyla, 2014.

Phyla	Seasonal average (mm^3/L)						
	May	June	July	Aug	Sep	Oct	Seasonal mean
Bacillariophyta	1,240,473	396,489	71,118	54,768	470,682	865,501	516,505
Chlorophyta	22,892	277,472	157,868	2,888	28,053	16,076	84,208
Chrysophyta	11,912	3,701	2,158	15,359	22,106	24,285	13,254
Cryptophyta	1,175	277	0	2,463	14,305	4,585	3,801
Cyanobacteria	765	403	455	232	7,733	4,213	2,300
Euglenophyta	1,012	0	2,882	7,616	0	3,155	2,444
Pyrrophyta	54,768	0	94	1,536	178,925	0	39,220
Total	1,332,996	678,343	234,575	84,862	721,804	917,815	661,732

Table 11.–Karluk Lake annual average phytoplankton biovolumes by phyla, 2004–2006 and 2010–2014.

Phyla	Biovolume (mm^3/L)								
	2004	2005	2006	2010	2011	2012	2013	2014	Historical average
Bacillariophyta	40,933	42,630	12,480	7,697	4,365	108,971	58,065	516,505	98,956
Chlorophyta	961	2,373	235	670	5	17,547	15,820	84,208	15,227
Chrysophyta	5,498	5,575	7,629	806	60	-	5,531	13,254	4,794
Cryptophyta	3,538	4,490	2,380	305	18	94,561	2,348	3,801	13,930
Cyanobacteria	54	19	3	5	45	2,331	1,427	2,300	773
Dinophyta	-	-	-	-	103	-	-	-	13
Euglenophyta	-	236	1,129	-	3	60,150	2,204	2,444	8,271
Haptophyta	6,915	6,600	5,608	-	-	-	-	-	2,390
Pyrrhophyta	9,347	12,925	12,550	4,299	-	134,159	24,310	39,220	29,601
Total	67,246	74,847	42,013	13,783	4,600	417,719	109,705	661,732	173,956

Table 12.–Karluk Lake zooplankton abundance (no/m^2), 2014.

Taxon	Date 20-May	18-Jun	16-Jul	13-Aug	16-Sep	15-Oct	Seasonal average
Copepods:							
Cyclops	2,296,532	1,518,909	639,862	574,310	620,488	531,847	1,030,325
Ovig. *Cyclops*	35,386	4,7776,90	-	35,563	5,839	531	14,833
Diaptomus	91,295	68,073	44,321	67,056	48,301	119,427	73,079
Ovig. *Diaptomus*	-	597	-	5,485	1,592	-	1,279
Epischura	-	-	-	531	-	-	88
Harpaticus	-	-	-	885	-	-	147
Nauplii	64,402	44,586	41,136	46,709	51,486	23,355	45,279
Total copepods:	2,487,615	1,636,943	732,219	730,538	727,707	675,159	1,165,030
Cladocerans:							
Bosmina	708	11,545	10,350	13,624	26,539	30,255	15,503
Ovig. *Bosmina*	1,062	796	796	5,839	19,108	30,786	9,731
Daphnia longiremis	9,200	25,876	106,688	113,942	114,650	102,972	78,888
Ovig. *Daphnia longiremis*	3,185	-	796	41,401	14,331	10,085	11,633
Holopedium	-	3,583	8,758	-	-	-	2,057
Immature cladocerans	6,016	3,583	17,516	37,509	29,193	24,416	19,705
Total cladocerans:	20,170	45,382	144,904	212,314	203,822	198,514	137,518
Total copepods + cladocerans	2,507,785	1,682,325	877,123	942,852	931,529	873,673	1,302,548

Table 13.–Karluk Lake weighted zooplankton biomass (mg/m^2), 2014.

Taxon	Date 20-May	18-Jun	16-Jul	13-Aug	16-Sep	15-Oct		Seasonal average	Seasonal weighted average
Copepods:									
Cyclops	4,751	3,026	1,664	1,179	1,038	877		2,089	2,092
Ovig. *Cyclops*	204	25	43	196	32	3		84	84
Diaptomus	376	349	283	259	141	491		316	309
Ovig. *Diaptomus*	-	6	-	58	14	-		13	13
Epischura	-	-	-	1	-	-		0.1	0.1
Harpaticus	-	-	-	1	-	-		0.1	0.1
Total copepods:	5,330	3,406	1,989	1,693	1,226	1,371		2,503	2,499
Cladocerans:									
Bosmina	1	14	18	11	22	29		16	16
Ovig. *Bosmina*	1	2	2	10	35	52		17	17
Daphnia L.	17	43	160	166	153	141		113	112
Ovig. *Daphnia L.*	11	-	1	133	39	28		35	36
Holopedium	-	12	27	-	-	-		7	7
Total cladocerans:	30	72	209	320	250	250	-	188	188
Total copepods + cladocerans	5,360	3,477	2,198	2,013	1,476	1,621	-	2,691	2,687

Table 14.–Karluk Lake seasonal weighted zooplankton length (mm), 2014.

Taxon	Date						Seasonal average length	Weighted average length
	20-May	18-Jun	16-Jul	13-Aug	16-Sep	15-Oct		
Copepods:								
Cyclops	0.77	0.77	0.84	0.77	0.70	0.69	0.76	0.77
Ovig. *Cyclops*	1.23	1.18	1.28	1.23	1.22	1.23	1.23	1.23
Diaptomus	1.01	1.02	1.15	0.98	0.87	0.97	1.00	0.99
Ovig. *Diaptomus*	-	1.36	-	1.38	1.30	-	1.35	1.36
Epischura	-	-	-	0.67	-	-	0.67	0.67
Harpaticus	-	-	-	0.54	-	-	0.54	0.54
Cladocerans:								
Bosmina	0.30	0.39	0.45	0.30	0.30	0.32	0.34	0.34
Ovig. *Bosmina*	0.38	0.57	0.51	0.43	0.44	0.43	0.46	0.43
Daphnia L.	0.70	0.60	0.60	0.59	0.56	0.57	0.60	0.58
Ovig. *Daphnia L.*	0.87	-	0.57	0.87	0.77	0.80	0.77	0.83
Holopedium	-	0.63	0.61	-	-	-	0.62	0.61

Table 15.–Estimates of stock composition and stock-specific outmigration for Karluk River sockeye salmon smolt by stratum, 2014.

Stratum			Composition (%)						Outmigration (number of fish)				
				90% CI						90% CI			
Period dates	Sample size CV	Reporting group	Median	5%	95%	P=0	Mean	SD	Median	5%	95%	Mean	SD
Early	*n*=252	Early	15.6	10.7	21.2	0.00	15.7	3.2	41,604	27,964	58,188	42,145	9,233
5/13-30	CV=7.9%	Late	84.4	78.8	89.3	0.00	84.3	3.2	225,594	195,387	260,072	226,406	19,731
											Early Total	268,597	
Middle	*n*=252	Early	27.9	22.2	34.1	0.00	28.0	3.6	75,244	57,644	96,048	75,837	11,705
5/31-6/15	CV=8.4%	Late	72.1	65.9	77.8	0.00	72.0	3.6	194,234	164,994	227,706	195,025	19,124
											Middle Total	270,853	
Late	*n*=252	Early	28.8	22.4	35.7	0.00	28.9	4.1	77,424	55,462	105,823	78,584	15,404
6/16-7/2	CV=13.6%	Late	71.2	64.3	77.6	0.00	71.1	4.1	191,163	149,898	243,456	193,158	28,533
											Late Total	271,806	
2014	*n*=756	Early	24.2	20.7	27.8	0.00	22.2	2.0	196,367	168,278	225,778	196,566	17,465
5/13-7/2		Late	75.8	72.2	79.3	0.00	75.8	2.0	614,889	585,478	642,978	614,69.	17,465
											2014 Total	811,256	

Note: Stock composition estimates may not sum to 100% and stock-specific outmigration estimates may not sum to the total outmigration due to rounding error.

Table 16.–Estimates of stock composition and stock-specific outmigration for Karluk River sockeye salmon smolt by age, 2014.

Stratum			Composition (%)						Outmigration (number of fish)				
Age	Sample size	Reporting		90% CI						90% CI			
dates	CV	group	Median	5%	95%	P=0	Mean	SD	Median	5%	95%	Mean	SD
Age 1	*n*=250	Early	53.0	45.6	60.2	0.00	53.0	4.5	132,528	105,715	165,410	133,664	18,194
5/13-7/2	CV=10.6%	Late	47.0	39.8	54.4	0.00	47.0	4.5	117,677	92,923	148,181	118,754	16,966
											Age 1 Total	252,325	
Age 2	*n*=494	Early	12.3	9.1	15.9	0.00	12.4	2.1	67,183	49,154	88,522	67,784	11,960
5/13-7/2	CV=5.9%	Late	87.7	84.1	90.9	0.00	87.6	2.1	478,701	431,532	531,687	479,759	30,577
											Age 2 Total	547,473	
											2014 Total	799,798	

Note: Stock composition estimates may not sum to 100% and stock-specific outmigration estimates may not sum to the total outmigration due to rounding error.

Table 17.–Estimates of stock composition and stock-specific outmigration for Karluk River freshwater-age-1 sockeye salmon by stratum, 2014.

Stratum			Composition (%)						Outmigration (number of fish)				
				90% CI						90% CI			
Period dates	Sample size CV	Reporting group	Median	5%	95%	P=0	Mean	SD	Median	5%	95%	Mean	SD
Early	*n*=87	Early	82.2	71.8	90.6	0.00	81.8	5.7	75,925	61,072	94,317	76,597	10,206
5/13-6/15	CV=11.3%	Late	17.8	9.4	28.2	0.00	18.2	5.7	16,447	8,523	27,209	16,990	5,751
											Early Total	93,619	
Late	*n*=163	Early	35.6	27.2	44.5	0.00	35.7	5.3	57,763	40,350	80,856	58,840	12,455
6/16-7/2	CV=15.6%	Late	64.4	55.5	72.8	0.00	64.3	5.3	104,325	78,785	137,922	105,797	18,159
											Late Total	158,706	
2014	*n*=250	Early	52.9	46.4	59.3	0.00	52.8	3.9	132,528	105,715	165,410	133,664	18,194
5/13-7/2		Late	47.1	40.7	53.6	0.00	47.2	3.9	117,677	92,923	148,181	118,754	16,966
											2014 Total	252,325	

Note: Stock composition estimates may not sum to 100% and stock-specific outmigration estimates may not sum to the total outmigration due to rounding error.

Table 18.–Estimates of stock composition and stock-specific outmigration for Karluk River freshwater-age-2 sockeye salmon by stratum, 2014.

Stratum			Composition (%)						Outmigration (number of fish)				
Period	Sample size	Reporting		90% CI						90% CI			
dates	CV	group	Median	5%	95%	P=0	Mean	SD	Median	5%	95%	Mean	SD
Early	*n*=229	Early	12.7	8.3	18.1	0.00	12.9	3.0	31,078	19,790	45,373	31,605	7,832
5/13-30	CV=8.1%	Late	87.3	81.9	91.7	0.00	87.1	3.0	212,454	183,718	245,391	213,252	18,843
											Early Total	244,846	
Middle	*n*=177	Early	8.3	4.2	13.6	0.00	8.5	2.9	15,635	7,837	26,194	16,158	5,650
5/31-6/15	CV=9.0%	Late	91.7	86.4	95.8	0.00	91.5	2.9	172,337	148,139	202,209	173,389	16,479
											Middle Total	189,527	
Late	*n*=88	Early	17.4	9.1	27.5	0.00	17.7	5.6	19,742	9,936	33,913	20,540	7,381
6/16-7/2	CV=17.0%	Late	82.6	72.5	90.9	0.00	82.3	5.6	93,897	69,987	125,931	95,410	17,170
											Late Total	113,099	
2014	*n*=494	Early	12.3	9.2	15.8	0.00	12.4	2.0	67,183	49,154	88,522	67,784	11,960
5/13-7/2		Late	87.7	84.2	90.8	0.00	87.6	2.0	478,701	431,532	531,687	479,759	30,577
											2014 Total	547,472	

Note: Stock composition estimates may not sum to 100% and stock-specific outmigration estimates may not sum to the total outmigration due to rounding error.

Table 19.–Estimates of stock composition for Karluk River sockeye salmon smolt collected at the Weir, 2014.

Strata			Composition (%)					
Period	Sample	Reporting		90% CI				
dates	size	group	Median	5%	95%	P=0	Mean	SD
Early	*n*=85	Early	11.8	5.3	20.5	0.00	12.2	4.7
5/16-6/4		Late	88.2	79.5	94.7	0.00	87.8	4.7

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

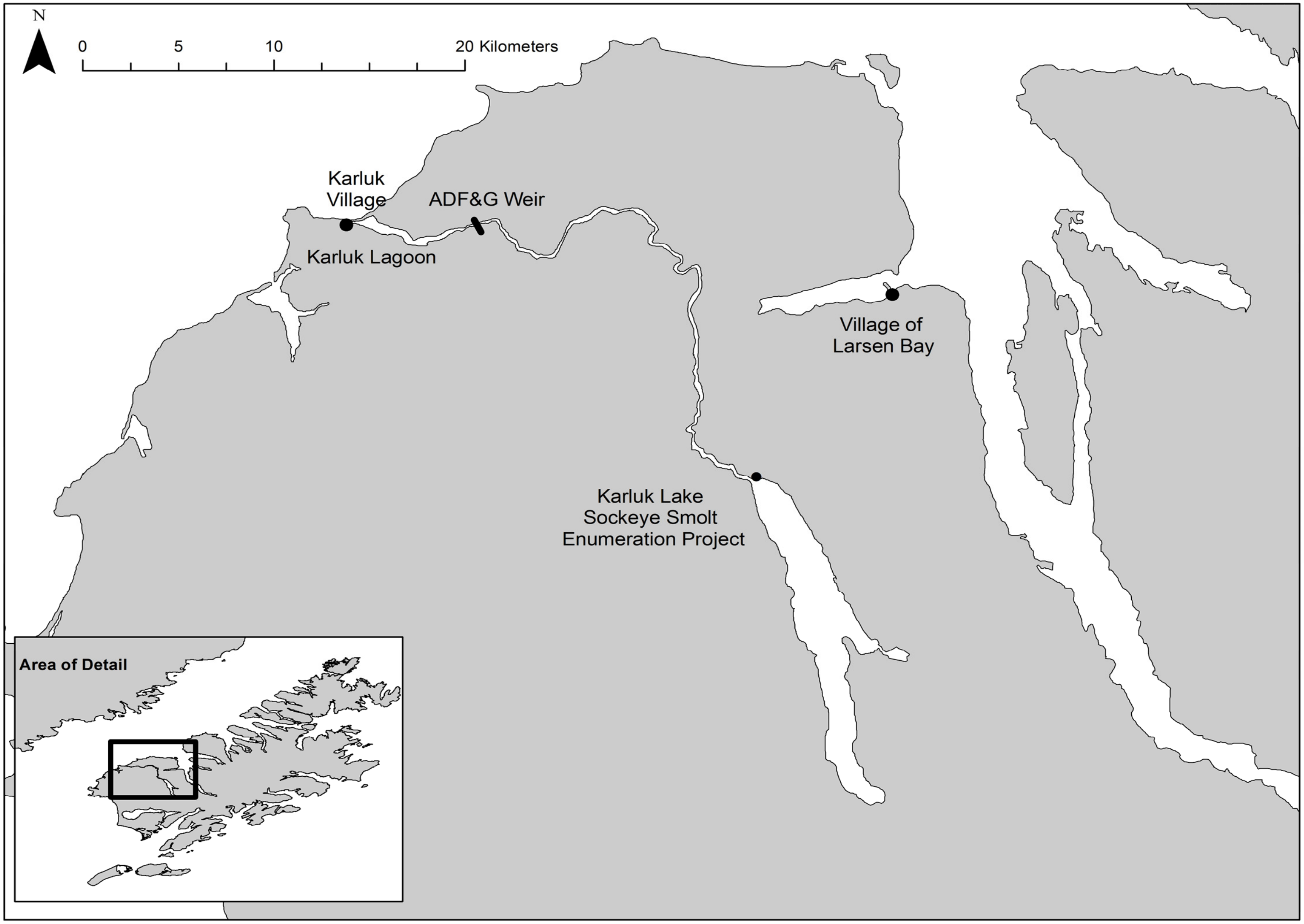

Figure 1.–Map of the Karluk Lake and River, showing local communities and ADF&G project locations.

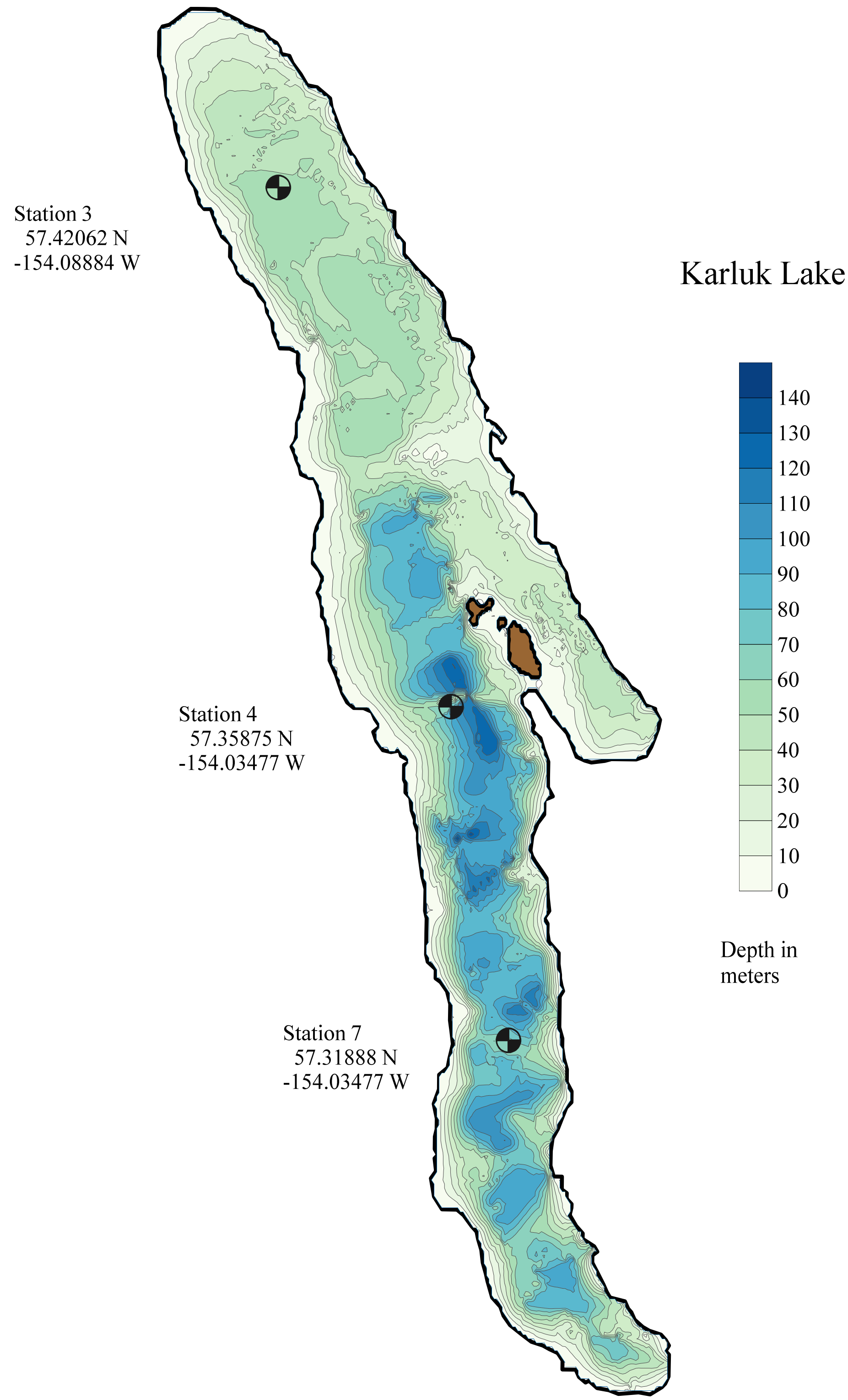

Figure 2.–Bathymetric map of Karluk Lake showing the limnological sampling stations, 2014.

Figure 3.–Aerial view of the upstream dye test platform location (former upper trap Site 2) and downstream trap (Site 1), 2014.

Figure 4.–View of the trap (Site 1), 2014.

Figure 5.–Dye test platform.

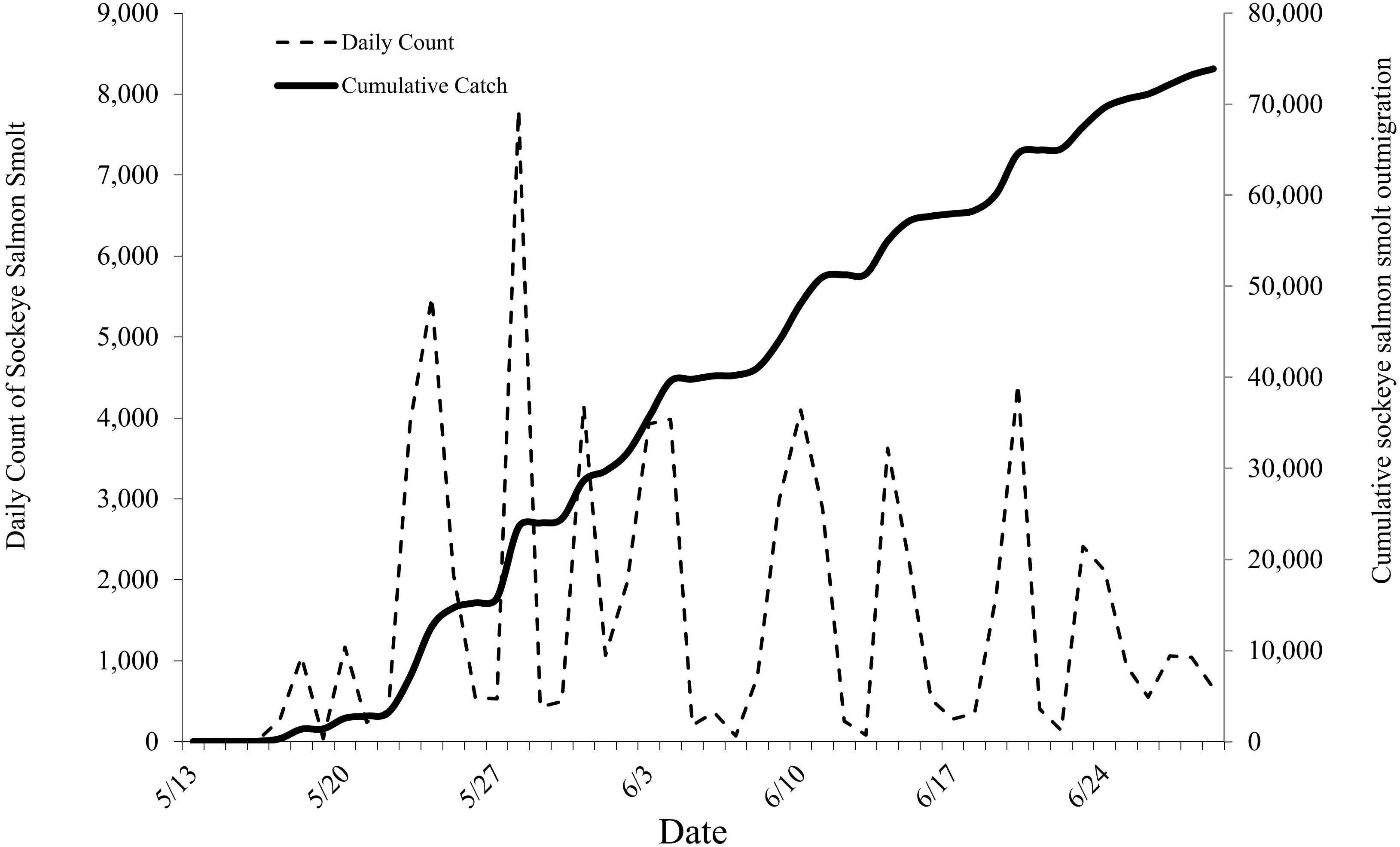

Figure 6.–Daily counts and cumulative catch of the sockeye salmon smolt outmigration from Karluk Lake in 2014.

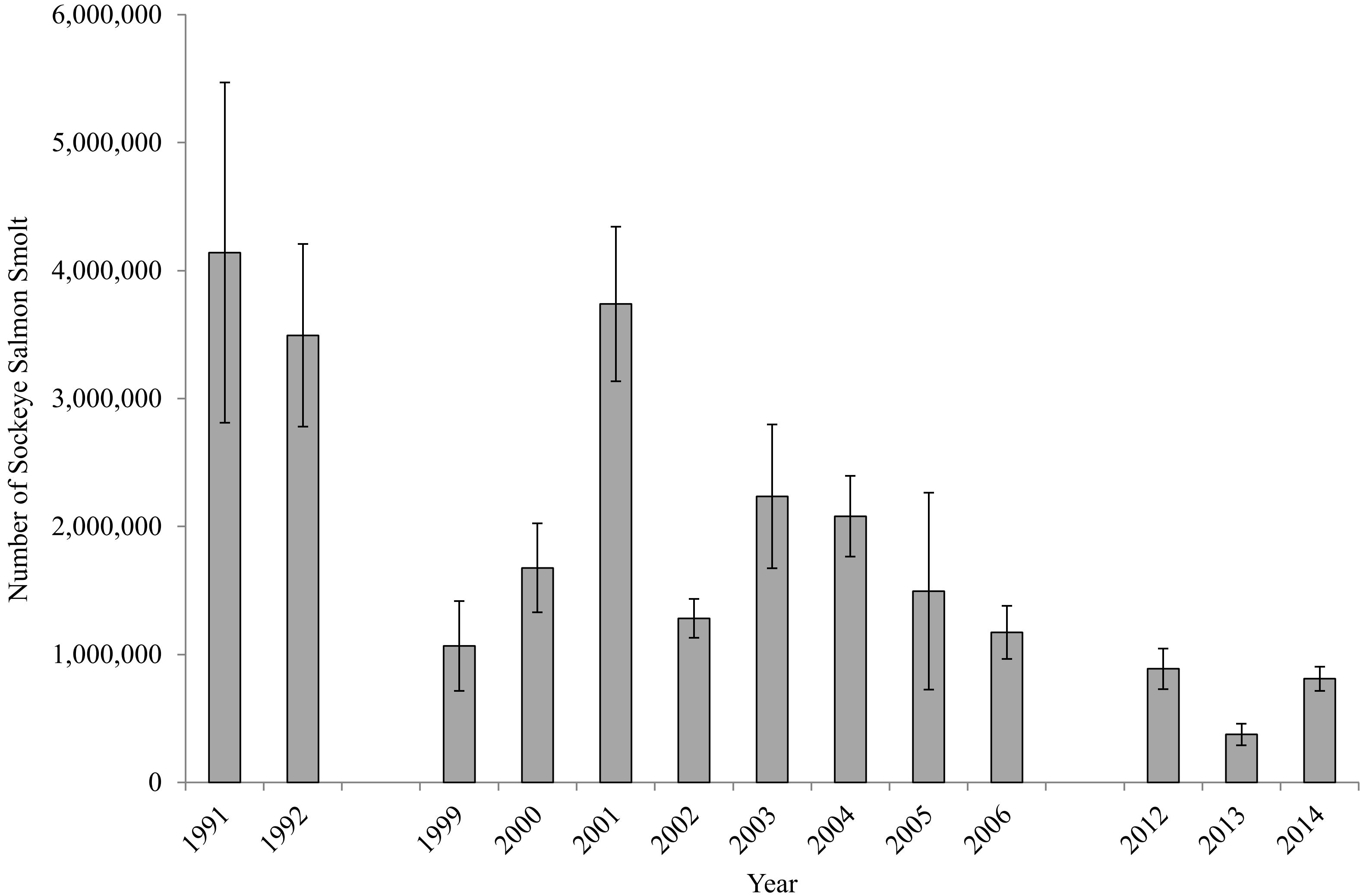

Figure 7.–Reported annual sockeye salmon smolt emigration estimates and corresponding 95% confidence intervals, Karluk River, for years 1991–1992, 1999–2006, and 2012–2014.

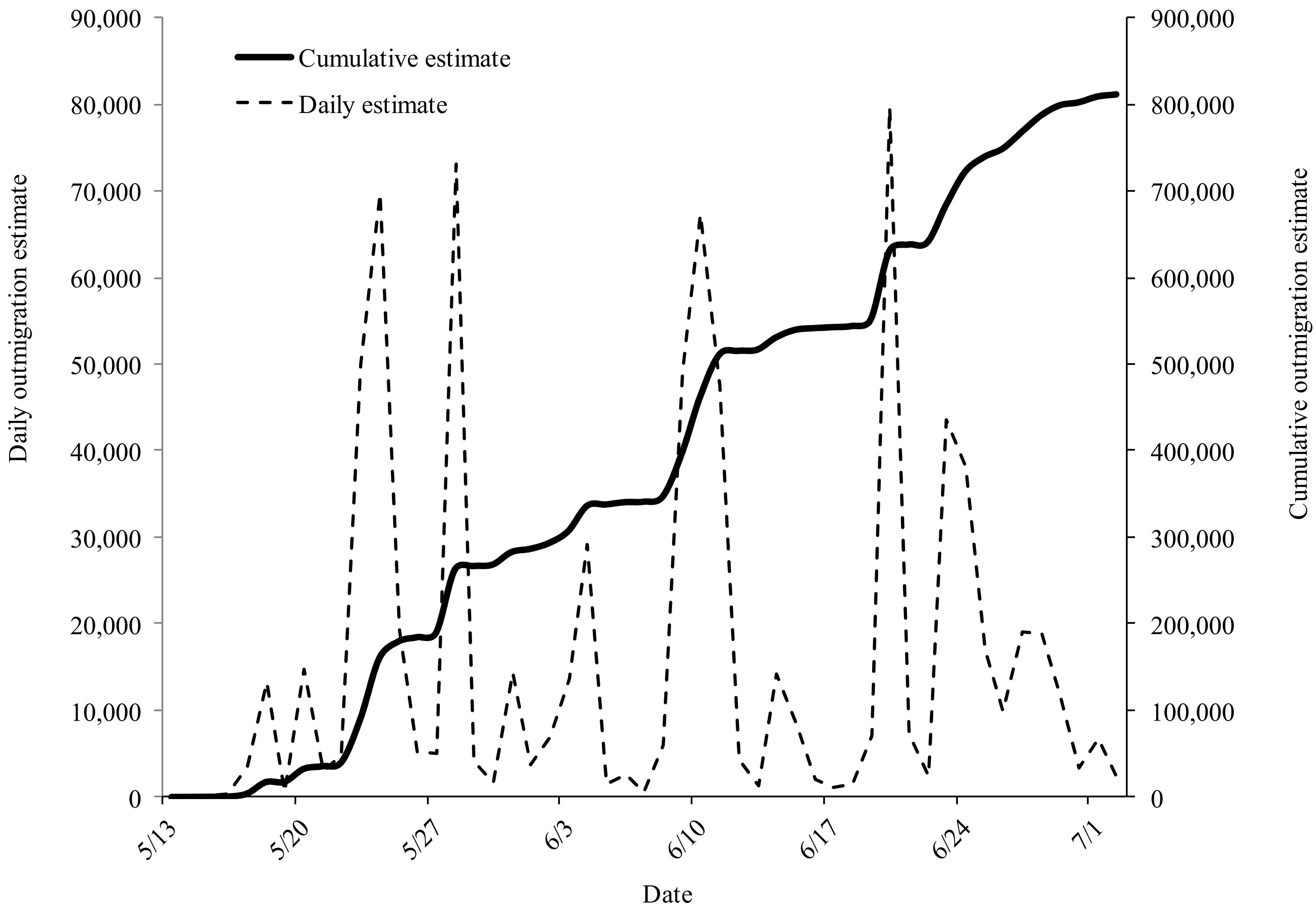

Figure 8.–Daily estimates and cumulative outmigration of sockeye salmon smolt from Karluk Lake in 2014.

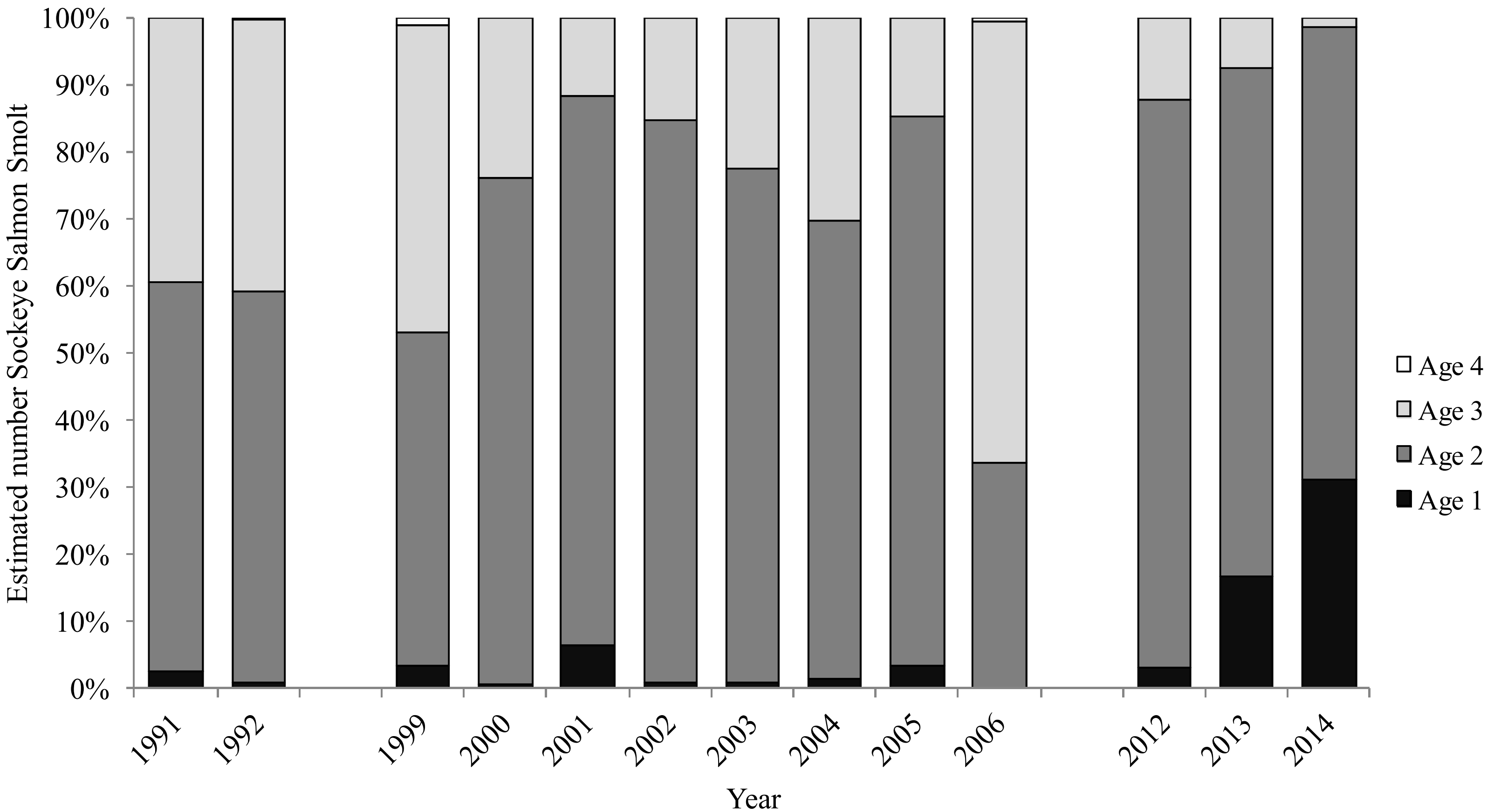

Figure 9.–A comparison of the estimated age structure of freshwater-age-1 to freshwater-age-4 sockeye salmon smolt outmigrations from Karluk Lake, 1991–1992, 1999–2006, and 2012–2014.

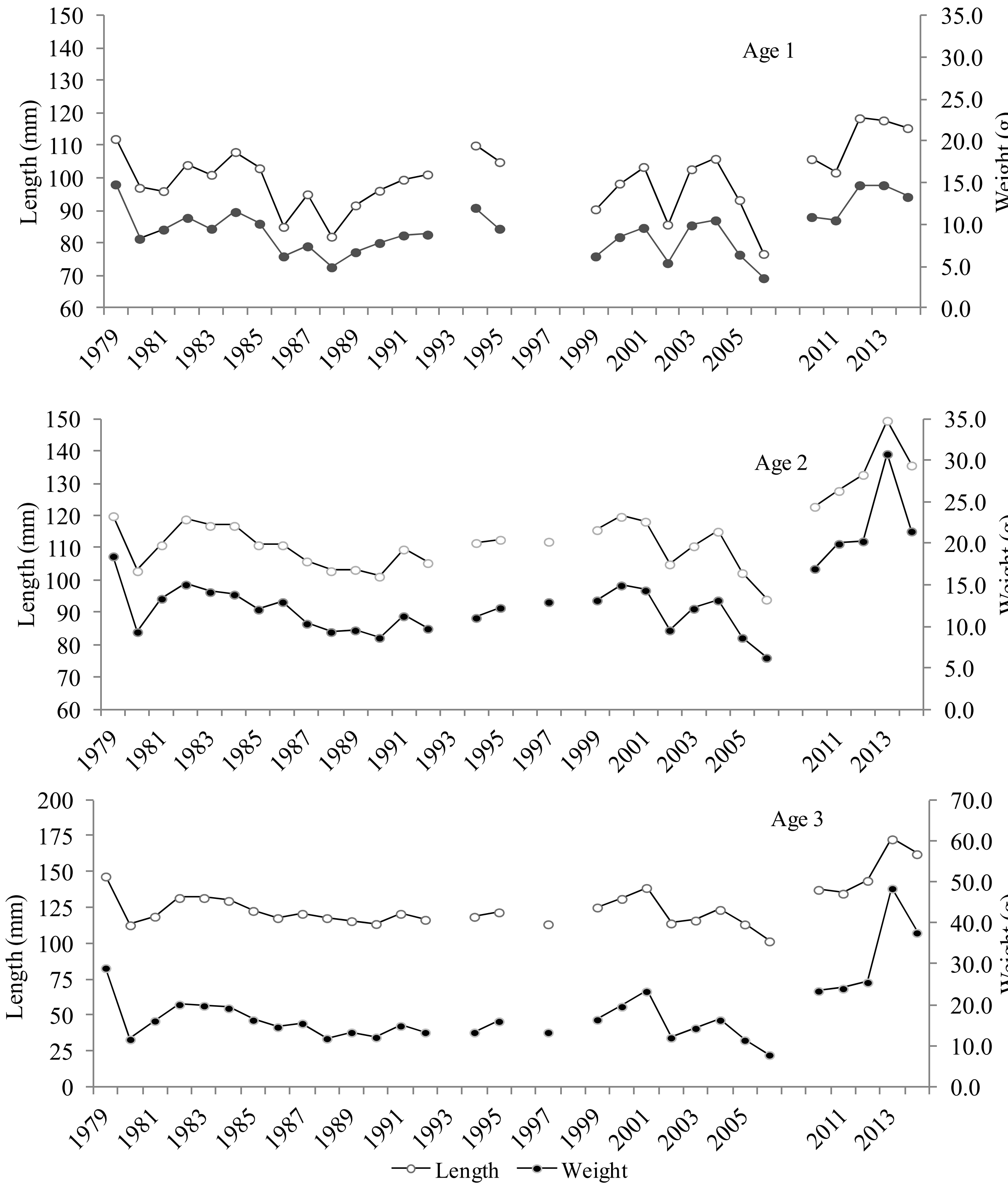

Figure 10.–Average length and weight of sampled freshwater-age-1, -age-2, and -age-3 sockeye salmon smolt, by year, from 1979 to 2014.

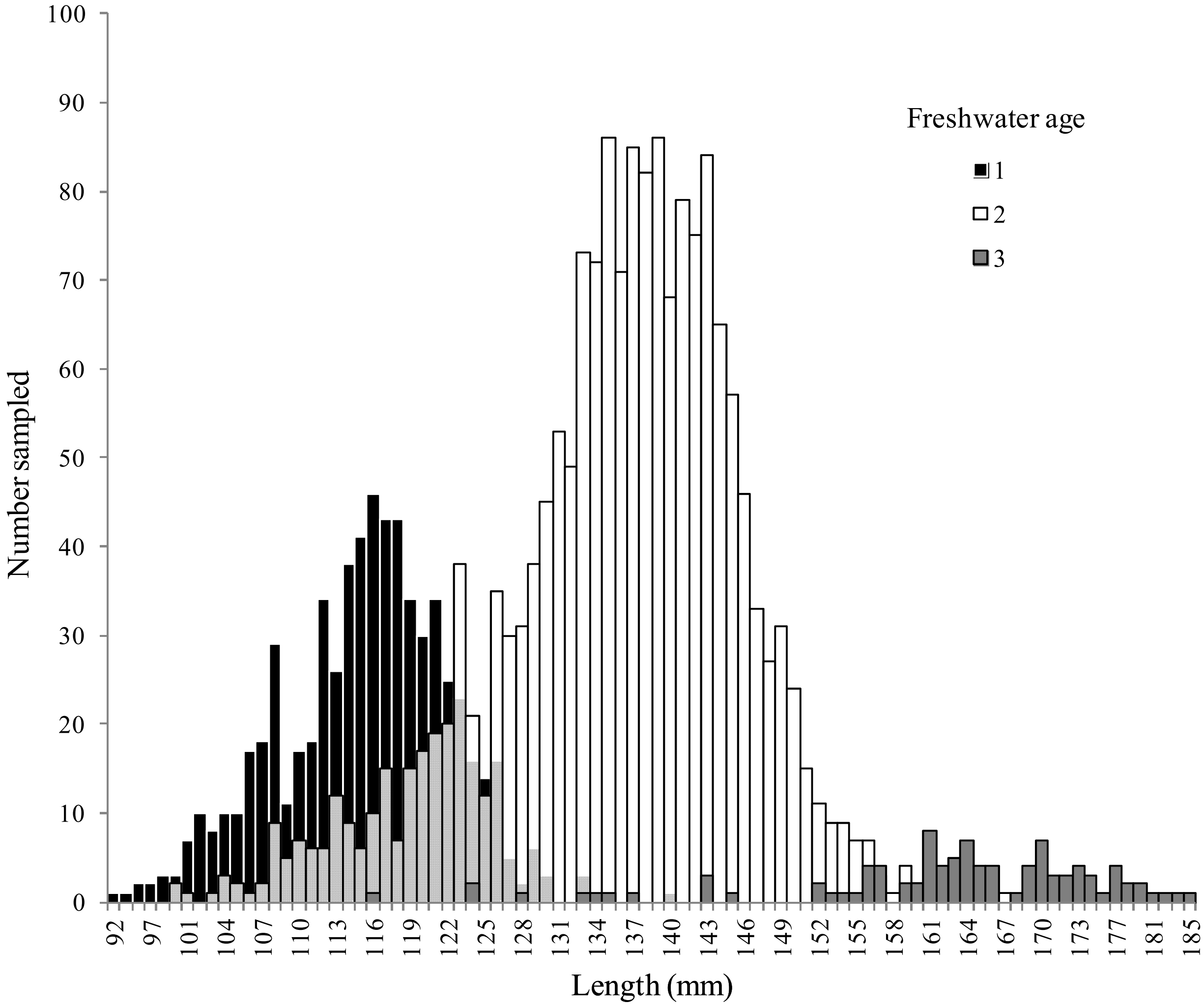

Figure 11.–Length frequency histogram of sockeye salmon smolt outmigration samples from Karluk Lake in 2014 by age class.

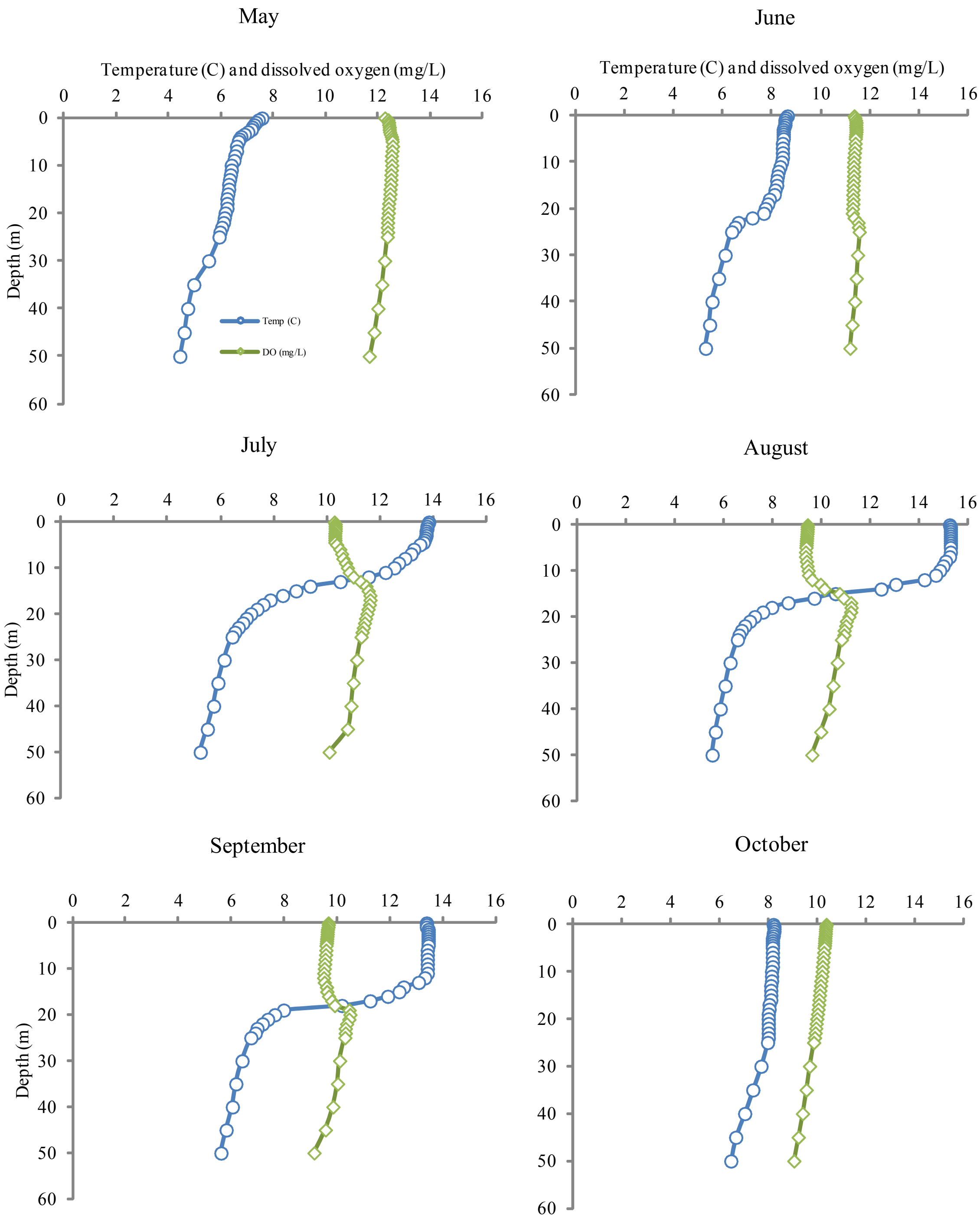

Figure 12.–Karluk Lake monthly temperature and dissolved oxygen depth profiles, 2014.

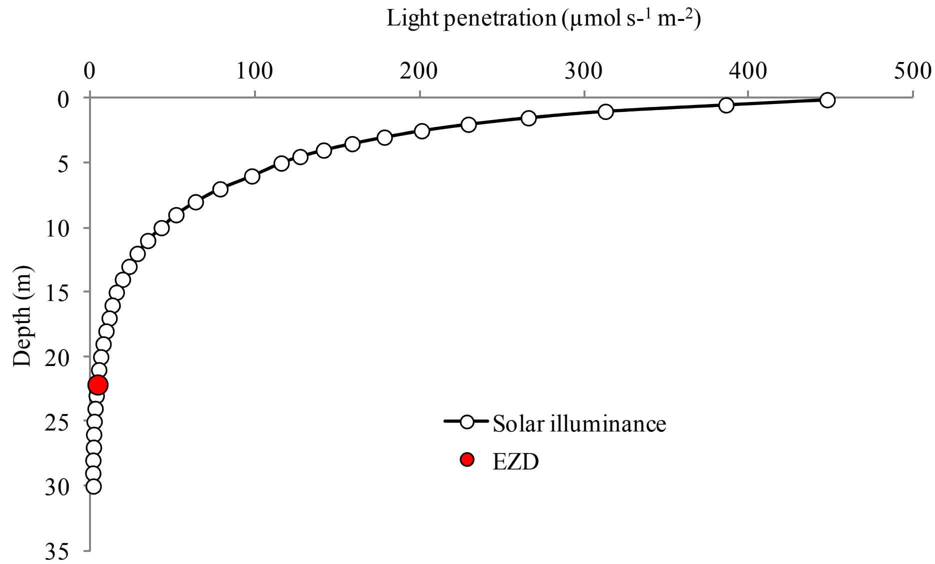

Figure 13.–Karluk Lake seasonal average light penetration depth profile, 2014.

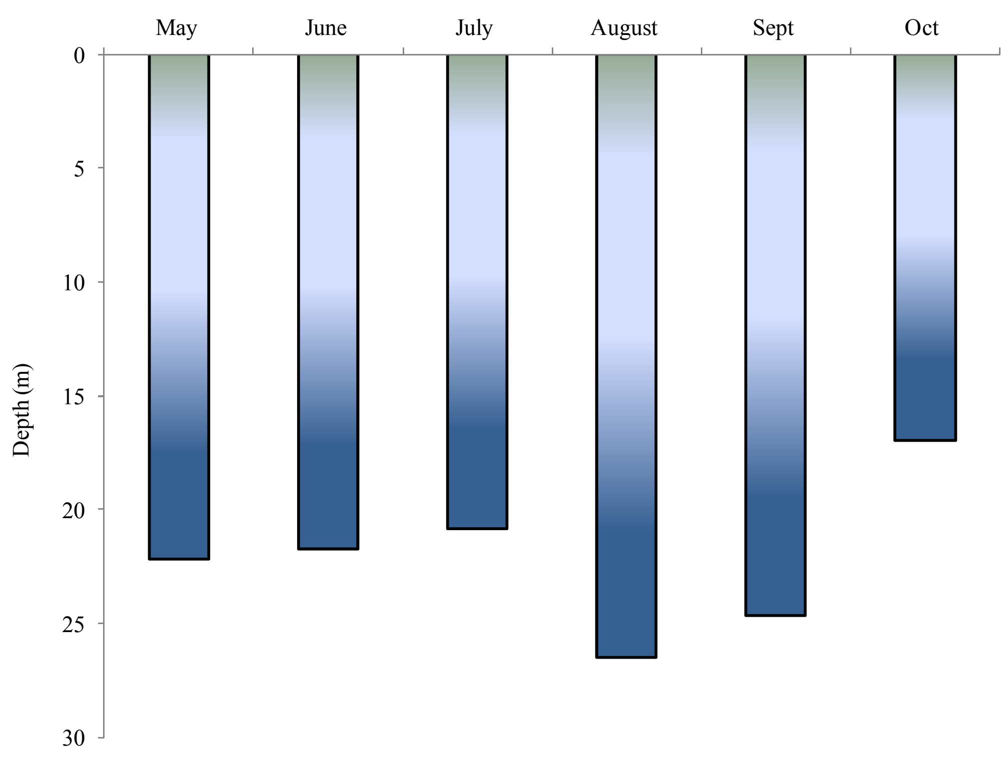

Figure 14.–Karluk Lake monthly average euphotic zone depth, 2014.

APPENDIX A. SMOLT TRAP CATCHES BY DAY

Appendix A1.–Actual daily counts and trap efficiency data of the Karluk River sockeye salmon smolt project, 2014.

	Sockeye Smolt			Trap efficiency tests				Incidental catch[a]				
Date	Daily	Cum.	Daily Mortality	Marked[b]	Daily recoveries	Cum. recoveries	Efficiency[c]	Sock fry	Coho	Dolly Varden	SB	SC
13-May	12	12	0					480	15	191	76	333
14-May	15	27	0					1,133	18	266	37	208
15-May	11	38	0					1,185	35	273	70	1,377
16-May	24	62	0					1,594	99	534	164	1,330
17-May	271	333	1					1,684	155	362	213	987
18-May	1,048	1,381	1					477	99	256	166	2,022
19-May	37	1,418	0	798	23	26	3.3%	236	57	277	56	3,188
20-May	1,166	2,584	0	798	12	38	4.8%	347	341	293	414	359
21-May	240	2,824	0	798	18	57	7.1%	773	816	285	1,210	3,633
22-May	386	3,210	2	798	4	61	7.6%	514	884	237	338	1,107
23-May	3,939	7,149	3	798	1	62	7.8%	584	2,480	212	436	1,218
24-May	5,494	12,643	0	798	0	62	7.8%	65	2,289	153	308	1,597
25-May	2,061	14,704	4	1,292	122	123	9.5%	311	2,067	275	178	956
26-May	547	15,251	1	1,292	2	127	9.8%	78	1,844	138	129	1,078
27-May	529	15,780	5	1,292	0	131	10.1%	16	919	87	68	487
28-May	7,803	23,583	5	1,292	4	135	10.4%	16	1,532	163	141	5,057
29-May	429	24,012	2	1,292	2	137	10.6%	17	450	110	121	1,681
30-May	497	24,509	13	1,046	284	286	27.3%	48	491	98	149	1,634
31-May	4,153	28,662	1	1,046	12	298	28.5%	5	1,678	75	129	2,079
1-Jun	1,068	29,730	0	1,046	0	298	28.5%	47	708	93	160	77
2-Jun	1,966	31,696	1	1,046	0	298	28.5%	29	1,007	63	106	1,365
3-Jun	3,927	35,623	3	1,046	2	300	28.7%	58	913	119	175	2,275

-continued-

	Sockeye Smolt			Trap efficiency tests				Incidental catch[a]				
Date	Daily	Cum.	Daily mortality	Marked[b]	Daily recoveries	Cum. recoveries	Efficiency[c]	Sock fry	Coho	Dolly Varden	SB	SC
4-Jun	3,983	39,606	8	1,209	135	135	11.2%	30	521	83	118	1,281
5-Jun	203	39,809	0	1,209	18	154	12.7%	9	391	89	66	4,998
6-Jun	363	40,172	1	1,209	10	164	13.6%	61	304	79	46	1,902
7-Jun	71	40,243	0	1,209	0	164	13.6%	10	877	91	41	1,515
8-Jun	807	41,050	5	1,209	0	164	13.6%	7	1,397	58	34	926
9-Jun	2,986	44,036	5	871	35	40	4.6%	14	2,313	66	37	284
10-Jun	4,096	48,132	6	871	5	48	5.5%	27	1,820	111	74	1,059
11-Jun	2,888	51,020	0	871	4	52	6.0%	35	1,040	89	47	1,064
12-Jun	254	51,274	0	871	0	52	6.0%	107	416	107	437	4,720
13-Jun	83	51,357	2	871	0	52	6.0%	38	181	47	91	795
14-Jun	3,624	54,981	2	888	213	214	24.1%	49	1,041	22	45	255
15-Jun	2,202	57,183	3	888	7	221	24.9%	36	495	27	52	348
16-Jun	522	57,705	1	888	4	225	25.3%	104	203	68	61	307
17-Jun	279	57,984	2	888	1	226	25.5%	35	227	58	45	1,273
18-Jun	351	58,335	0	888	0	226	25.5%	196	698	58	45	269
19-Jun	1,812	60,147	2	888	0	226	25.5%	109	434	39	64	157
20-Jun	4,419	64,566	2	828	32	36	4.3%	45	640	38	57	279
21-Jun	403	64,969	2	828	7	46	5.6%	204	475	50	31	289
22-Jun	138	65,107	1	828	2	48	5.8%	200	145	49	17	495
23-Jun	2,412	67,519	1	828	1	49	5.9%	30	295	19	18	115
24-Jun	2,112	69,631	1	828	0	49	5.9%	55	297	38	146	720
25-Jun	939	70,570	2	437	9	9	2.1%	177	97	24	64	79
26-Jun	549	71,119	2	437	2	11	2.5%	290	119	24	70	1,011
27-Jun	1,060	72,179	2	437	0	11	2.5%	85	18	187	332	45

-continued-

Appendix A1.–Page 3 of 3.

	Sockeye Smolt			Trap efficiency tests				Incidental catch[a]				
Date	Daily	Cum.	Daily mortality	Marked[b]	Daily recoveries	Cum. recoveries	Efficiency[c]	Sock fry	Coho	Dolly Varden	SB	SC
28-Jun	1,042	73,221	2	437	0	11	2.5%	141	178	25	100	103
29-Jun	663	73,884	0	437	0	11	2.5%	105	144	18	507	95
30-Jun	190	74,074	1	437	0	11	2.5%	145	173	21	88	405
1-Jul	373	74,447	1	437	1	12	2.8%	51	108	19	450	206
2-Jul	138	74,585	0	437	0	12	2.8%	16	48	18	421	65
Totals	74,585	74,581	96	7,369	972	1,002	11.6%d	12,108	33,992	6,182	8,448	60,808

[a] Sock Fry = sockeye salmon fry, Coho = juvenile coho salmon, SB = stickleback, SC = sculpin.

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

[c] Calculated by: = {(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 B. CLIMATOLOGICAL OBSERVATIONS

Appendix B1.–Daily climatic observations for the Karluk Lake sockeye salmon smolt project, 2014.

Date[a]	Time	Air (°C)	Water (°C)	Cloud cover[b]	Wind direction[b]	Velocity (mph)[b]	Stream depth (in)	Comments
12-May	15:40	18	5	5%	W	0-5	NA	First day, no flowmeter or gauge yet.
13-May	23:55	NA	4.6	0%	0	NA	NA	Depth gauge not installed yet.
13-May	-	-	-	-	-	-	-	No noon entry made.
14-May	0:19	7.5	0	1%	NW	0-5	NA	
14-May	12:00	20	4.8	0%	NA	variable	NA	
15-May	0:04	4	5	0%	NA	NA	NA	No flowmeter yet.
15-May	11:40	14.5	4.9	0%	NA	variable	20	No flowmeter yet
16-May	0:01	2.5	4.1	5%	NA	0	20	
16-May	11:56	17	4.8	0%	N	5-10	22	
17-May	0:01	8	6.4	0%	NA	0	21	
17-May	12:00	15	8	0%	S	0-5	22	
18-May	0:11	9.5	6.2	90%	N	5-10	21	
18-May	12:00	14	7.2	50%	N	10-15	22	
19-May	0:21	5	4.4	0%	W	0-5	22	
19-May	12:00	11.6	4.7	0%	N	10-15	22	
20-May	0:03	4.5	4.5	0%	W	5-10	22	
20-May	12:08	11	5.2	1%	N	0-5	23	
21-May	0:11	0	4.8	5%	NA	NA	23.5	
21-May	12:28	17.5	5.6	50%	S	5-10	23	
22-May	0:08	3.5	5.7	20%	W	0-5	22	
22-May	12:23	15.7	6.3	5%	NA	0	24	
23-May	0:01	5	6.4	1%	NA	0	23	
23-May	11:58	15.5	7	0%	NA	0	22	
24-May	0:22	5	7.2	0%	W	0-5	23	
24-May	11:57	15	7.9	40%	E	0-5	22	

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Date[a]	Time	Air (°C)	Water (°C)	Cloud cover[b]	Wind direction[b]	Velocity (mph)[b]	Stream depth (in)	Comments
25-May	0:01	5.5	8.8	5%	NA	0	22	
25-May	11:53	11	9.5	30%	NA	0	22	
26-May	1:15	7	9.4	90%	SW	10-15	21	
26-May	11:55	9	9.1	100%	E	5-10	21	
27-May	1:27	9	8.9	100%	S	0-5	21	
27-May	12:04	10	8.9	100%	E	5-10	21	
28-May	0:00	8	8.9	98%	S	0-5	20	Raining
28-May	11:59	14	8.8	100%	E	0-5	21	
29-May	0:01	10.5	9	60%	S	5-10	21	
29-May	12:13	13	8.9	100%	SW	15	22	Light rain
30-May	0:01	8	9.3	40%	NA	0	22	Light rain
30-May	12:00	10	8.9	100%	N	5-10	21	Light rain
31-May	0:07	5.5	8.1	100%	SSW	0-5	22	Winds gusting
31-May	12:01	7	8.2	95%	E	10-15	23	Light rain
1-Jun	0:04	7.5	8.5	100%	SE	0-5	22	
1-Jun	12:01	14	8.8	60%	NW	0-5	22	Sunshine!
2-Jun	0:04	7	8.2	80%	NA	0	22	
2-Jun	11:58	18	9	80%	W	0-5	23	
3-Jun	0:01	5.5	8.3	1%	E	0-5	21.5	
3-Jun	12:08	11	9.2	1%	E	0-5	22	
4-Jun	0:33	3.8	8.6	0%	NA	0	21.5	
4-Jun	12:00	15	9.7	0%	N	0-5	22	
5-Jun	0:05	4	7.7	0%	N	0-5	21	
5-Jun	12:00	16	8.3	80%	NE	5-10	22	
6-Jun	0:20	10	8.7	95%	NW	5-10	21	

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Date[a]	Time	Air (°C)	Water (°C)	Cloud cover[b]	Wind direction[b]	Velocity (mph)[b]	Stream depth (in)	Comments
6-Jun	11:59	14	8.3	100%	SE	5-10	21	
7-Jun	0:02	8	5.6	80%	NA	0	21	
7-Jun	11:52	11	5.9	100%	NW	5-10	21.5	Raining lightly, lake calm
8-Jun	0:08	9	4.8	100%	NA	0	21	
8-Jun	11:58	10.5	6.7	100%	E	5-10	21	Winds gusting to 10 mph plus
9-Jun	0:03	5	5.9	30%	NA	0	21	
9-Jun	12:04	11	6.6	60%	E	5-10	20	Winds gusting to 10 mph plus
10-Jun	0:01	5	7.6	20%	N	0-5	21	
10-Jun	12:10	11	8.7	40%	W	5-10	20	
11-Jun	0:06	6	8.1	15%	NA	0	20	
11-Jun	12:00	10.5	9.1	100%	W	0-5	20	
12-Jun	0:09	9	9.4	100%	S	0-5	19	Light rain/mist/ Full moon is hidden.
12-Jun	12:10	9	9.3	100%	S	0-5	19	
13-Jun	0:19	7.5	9.7	100%	NA	0	19	Bursts of rain.
13-Jun	12:10	9.5	9.7	100%	N	10-20	19	
14-Jun	0:05	9.5	6.1	100%	W	10-20	20	
14-Jun	12:00	10.5	6.1	100%	N	0-5	19	
15-Jun	0:20	8	6.1	40%	W	0-5	20	Bright moon, clear sky!
15-Jun	11:59	13.5	9.4	1%	W	0-5	20	
16-Jun	0:09	9	8.5	100%	NA	0	19	
16-Jun	12:00	8.5	8.6	100%	N	0-5	19	
17-Jun	0:24	5	8.6	100%	W	0-5	20	Rainy, foggy
17-Jun	12:03	9.5	4.9	100%	W	5-10	21	
18-Jun	0:02	7	5.3	100%	W	0-5	21	Raining in bursts, foggy
18-Jun	12:11	9.5	6.7	100%	S	0-5	23	

-continued-

Appendix B1.–Page 4 of 5.

Date[a]	Time	Air (°C)	Water (°C)	Cloud cover[b]	Wind direction[b]	Velocity (mph)[b]	Stream depth (in)	Comments
19-Jun	0:06	8.5	7.6	100%	NA	0	22	Calm, not raining
19-Jun		8	7.8	100%	W	0-5	22	
20-Jun	12:03 0:12	9	7.7		W	0-5	24	
20-Jun	12:01	15	8.6	95% 20%	E	0-5	24	
21-Jun	0:18	8	8.1	40%	NA	0	24	Calm and warmish
21-Jun	12:07	15	9.5	90%	E	0-5	23	
22-Jun	0:00	9	10	100%	NA	0	25	Raining, overcast
22-Jun	12:01	13	9.9	100%	NA	0	25	
23-Jun	0:01	8	9.8	100%	NA	0	25	Drizzle
23-Jun	12:00	16	10	100%	S	0-5	27	
24-Jun	0:05	11.5	10.1	100%	S	0-5	27	Drizzle, heavy fog in t mountain valleys
24-Jun	11:50	19	10.6	5%	W	5-10	28	
25-Jun	0:50	5.5	10.1	80%	NA	0	28	Fog
25-Jun	12:10	11.5	10.9	40%	S	10-20	28	
26-Jun	0:00	9.5	11.4	5%	S	0-5	28	
26-Jun	12:31	16	10.8	95%	NA	0	28	
27-Jun	0:01	14	10.5	100%	NA	0	26	Ceiling high above mountains
27-Jun	12:00	18	9.6	95%	NA	0	26	
28-Jun	0:01	9	9.2	1%	NA	0	26	
28-Jun	12:04	21.5	10.5	0%	W	0-5	26	
29-Jun	0:01	12.5	10.9	0%	NA	0	26	Clear skies
29-Jun	12:05	19	11.6	10%	S	0-5	25	
30-Jun	0:00	11	11	70%	W	5-10	25	
30-Jun	12:05	16	10.5	100%	W	0-5	25	
1-Jul	0:00	9	9.5	70%	NA	0	25	

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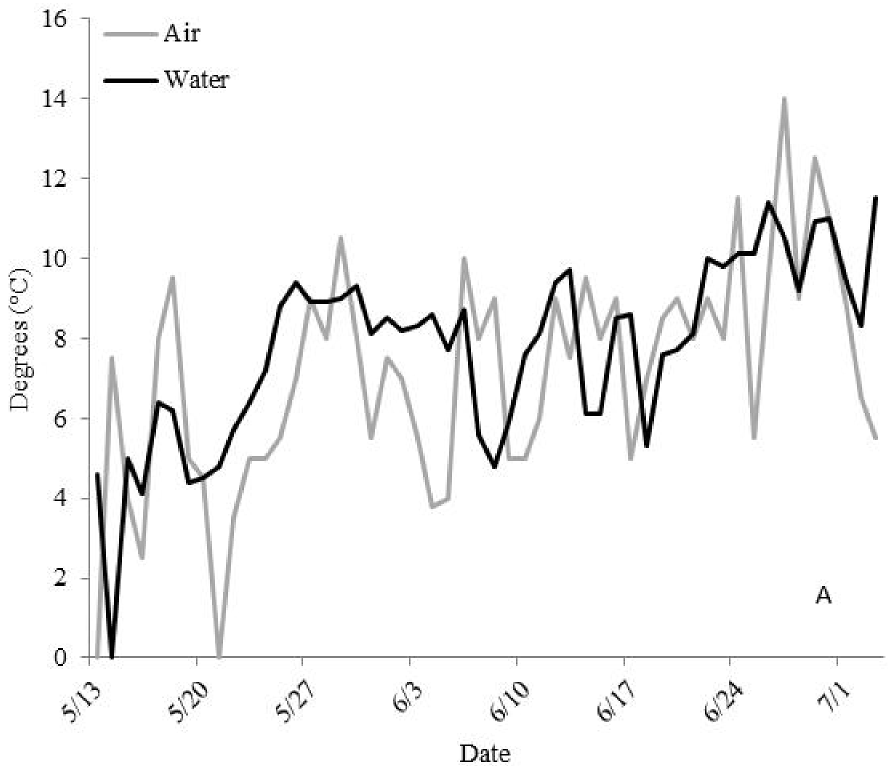
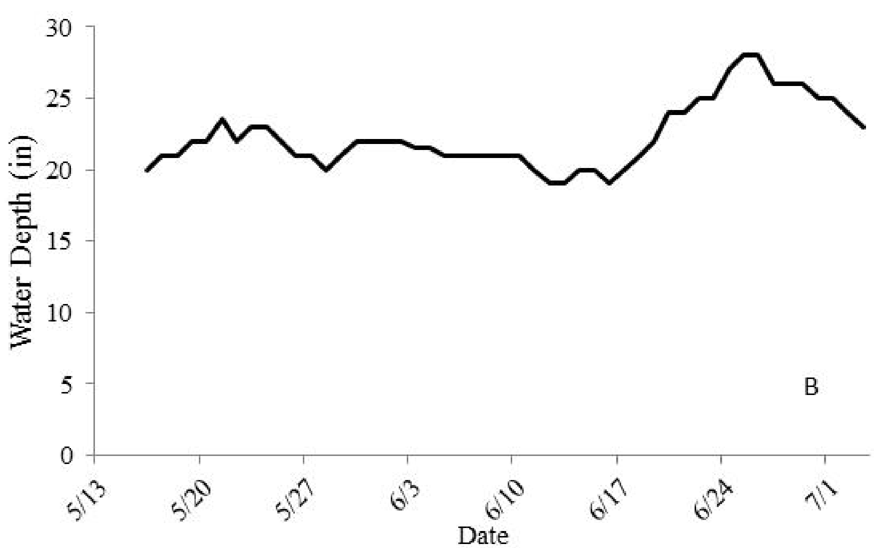
Date[a]	Time	Air (°C)	Water (°C)	Cloud cover[b]	Wind direction[b]	Velocity (mph)[b]	Stream depth (in)	Comments
1-Jul	12:00	19	10	10%	NA	0	24	
2-Jul	0:44	6.5	8.3	0%	NA	0	24	
2-Jul	12:02	18	12.3	1%	SE	0-5	24	
3-Jul	0:01	5.5	11.5	0%	NA	0	23	

[a]Actual calendar dates.

[b]Based on observer estimates.

Appendix B2.–Air and water temperature (A) and stream gauge height (B) data gathered at the Karluk River smolt trap, 2014.





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 by freshwater age						Smolt/	Adult returns by freshwater age							Marine
year	Esc	Age 0	Age 1	Age 2	Age 3	Age 4	Total smolt	spawner	Age 0	Age 1	Age 2	Age 3	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	540	8,352	907,619	355,919	1,048	1,273,479	2.2	136%
1997	564,761	NA	35,196	1,263,785	436,469	1,468	1,736,918	3.1	1,838	12,793	1,162,035	358,228	0	1,534,893	2.7	88%
1998	637,146	0	9,441	3,062,597	195,323	4,205	3,271,567	5.1	1,399	14,210	1,754,106	288,044	999	2,058,758	3.2	63%
1999	981,538	0	238,271	1,072,906	501,816	186	1,813,179	1.8	0	82,823	1,252,869	418,946	94	1,754,732	1.8	97%
2000	736,744	2,838	11,482	1,712,969	633,039	2,264	2,362,591	3.2	4,200	21,298	1,163,990	323,123	1,569	1,514,180	2.1	64%
2001	863,538	791	16,445	1,420,076	218,243	6,906	1,662,462	1.9	0	9,479	957,258	256,542	500	1,223,779	1.4	74%
2002	865,576	0	26,479	1,227,246	773,173	NA	2,026,898	2.3	2,790	23,249	497,853	59,667	627	584,186	0.7	29%
2003	1,078,710	533	47,834	393,039	NA	NA	NA									
2004	719,934	0	0	NA	NA	NA	NA									
2005	781,962	0	NA	NA	NA	NA	NA									
2006	490,373	NA	NA	NA	NA	NA	NA									
2007	546,575	NA	NA	NA	NA	35	NA									
2008	246,490	NA	NA	NA	108,218	29	NA									
2009	330,078	NA	NA	757,745	20,250		NA									
2010	348,102	NA	26,659	204,706	11,457											
2011	317,322		44,834	547,473												
2012	502,690		252,325													
2013	571,359															
2014	640,566															

Appendix C2.–Mean length, weight, and condition factor of sockeye salmon smolt samples from the Karluk River by year and freshwater age, 1925–2014.

	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	0.90
1927	5	116	na	na	1995	7	105	9.5	0.82
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	0.78
1932	16	105	na	na	2000	16	98	8.5	0.87
1933	43	114	na	na	2001	459	103	9.6	0.86
1934	7	123	na	na	2002	33	86	5.4	0.78
1935	16	113	na	na	2003	17	103	9.9	0.89
1936	60	111	na	na	2004	30	106	10.5	0.87
-					2005	4	93	6.4	0.79
1961	na	110	13.1	1.0	2006	3	77	3.6	0.80
1962	na	108	11.3	0.9	-				
1963	na	110	14.5	1.1	2010	46	106	10.9	0.91
1964	0	na	na	na	2011	29	102	10.5	0.93
1965	0	na	na	na	2012	185	118	14.7	0.90
1966	0	na	na	na	2013	197	115	13.9	0.88
1967	na	102	10.7	1.0	2014	651	115	13.3	0.86
1968	na	104	9.9	0.9					
-									
1979	66	112	14.8	1.07					
1980	300	97	8.3	0.90					
1981	77	96	9.4	1.05					
1982	8	104	10.8	0.96					
1983	17	101	9.5	0.92					
1984	165	108	11.5	0.91					
1985	227	103	10.1	0.92					
1986	426	85	6.2	1.01					
1987	43	95	7.4	0.82					
1988	8	82	4.9	0.84					
1989	5	92	6.7	0.84					
1990	30	96	7.8	0.85					
1991	166	100	8.7	0.84					
1992	59	101	8.8	0.83					

-continued-

	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	0.91	1993	-	-	-	-
1926	445	136	22.9	0.91	1994	167	112	11.1	0.79
1927	212	134	21.2	0.88	1995	79	113	12.3	0.83
1928	494	128	19.9	0.95	-				
1929	418	130	20.0	0.91	1997	157	112	13.0	0.92
1930	1,145	127	18.5	0.90	-				
1931	1,795	130	20.0	0.91	1999	598	116	13.2	0.84
1932	1,358	133	20.9	0.89	2000	963	120	15.0	0.86
1933	685	136	23.9	0.95	2001	1,565	118	14.4	0.86
1934	822	140	24.8	0.90	2002	1,610	105	9.6	0.82
1935	1,520	142	26.3	0.92	2003	1,130	111	12.2	0.90
1936	744	133	21.3	0.91	2004	1,082	115	13.2	0.85
-					2005	941	102	8.7	0.81
1961	na	115	13.7	0.90	2006	439	94	6.3	0.80
1962	na	113	12.4	0.86	-				
1963	na	119	14.6	0.87	2010	306	123	17.0	0.90
1964	na	128	21.0	1.00	2011	138	128	20.0	0.94
1965	na	127	19.1	0.93	2012	1,117	133	20.3	0.86
1966	na	115	13.2	0.87	2013	721	148	30.1	0.90
1967	na	113	13.8	0.96	2014	1,742	136	21.5	0.84
1968	na	113	12.4	0.86					
-									
1979	201	120	18.5	1.07					
1980	496	103	9.4	0.87					
1981	600	111	13.4	0.97					
1982	413	119	15.1	0.90					
1983	1,014	117	14.2	0.89					
1984	670	117	13.9	0.87					
1985	541	111	12.1	0.87					
1986	1,184	111	13.0	0.95					
1987	1,776	106	10.4	0.86					
1988	800	103	9.4	0.86					
1989	828	103	9.6	0.86					
1990	270	101	8.7	0.82					
1991	1,584	110	11.3	0.84					
1992	1,340	106	9.8	0.82					

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	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	0.93		1993	-	-	-	-
1926	156	144	28.5	0.95		1994	129	119	13.4	0.79
1927	144	147	27.3	0.86		1995	2	122	16.1	0.89
1928	225	141	28.4	1.01		-				
1929	603	143	25.2	0.86		1997	83	114	13.4	0.91
1930	625	137	25.0	0.97		-				
1931	247	138	26.8	1.02		1999	549	125	16.5	0.83
1932	634	139	29.5	1.10		2000	268	131	19.7	0.86
1933	521	144	29.6	0.99		2001	313	139	23.4	0.87
1934	75	148	33.3	1.03		2002	262	114	12.1	0.80
1935	286	152	26.6	0.76		2003	271	116	14.4	0.91
1936	233	143	18.2	0.62		2004	616	124	16.4	0.86
-						2005	207	114	11.5	0.78
1961	na	124	16.6	0.87		2006	565	102	7.9	0.74
1962	na	123	15.8	0.85		-				
1963	na	129	18.5	0.86		2010	43	138	23.5	0.89
1964	na	136	24.1	0.96		2011	33	135	24.1	0.97
1965	na	142	26.7	0.93		2012	116	144	25.6	0.90
1966	na	131	18.9	0.84		2013	76	161	40.0	0.92
1967	na	133	23.1	0.98		2014	99	162.5	37.7	0.86
1968	na	124	15.3	0.80						
-										
1979	11	147	29.1	0.91						
1980	80	113	11.7	0.80						
1981	83	119	16.2	0.95						
1982	64	132	20.2	0.88						
1983	149	132	19.9	0.87						
1984	63	130	19.3	0.88						
1985	37	123	16.4	0.87						
1986	28	118	14.7	0.90						
1987	316	121	15.6	0.86						
1988	10	118	11.9	0.82						
1989	149	116	13.4	0.85						
1990	709	114	12.2	0.82						
1991	654	121	15.0	0.84						
1992	565	117	13.4	0.83						

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	Age 4			
Year	*n*	Length (mm)	Wt. (g)	Cond. (K)
1925	0	na	na	na
1926	3	164	na	na
1927	0	na	na	na
1928	4	151	na	na
1929	12	155	na	na
1930	20	143	na	na
1931	14	145	na	na
1932	20	146	na	na
1933	23	147	na	na
1934	6	161	na	na
1935	2	146	na	na
1936	9	151	na	na
-				
1961	0	na	na	na
1962	0	na	na	na
1963	0	na	na	na
1964	na	149	33.7	1.02
1965	na	145	28.7	0.94
1966	na	137	21.4	0.83
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	0.81
1991	0	na	na	na
1992	4	127	18.0	0.87

	Age 4			
Year	*n*	Length (mm)	Wt. (g)	Cond. (K)
1993	-	-	-	-
1994	0	na	na	na
1995	0	na	na	na
-				
1997	1	109	12.3	1.0
-				
1999	15	132	18.9	0.8
2000	0	na	na	na
2001	1	140	23.7	0.9
2002	2	105	10.2	0.9
2003	4	113	12.5	0.9
2004	2	134	21.3	0.9
2005	1	120	11.9	0.7
2006	6	104	8.2	0.7
-				
2010	2	151	31.6	0.9
2011	1	164	38.4	0.9
2012	1	168	33.8	0.7
2013	1	150	28.6	0.9
2014	0	na	na	na

Appendix C3.–Escapement, harvest, and total run for Karluk early-run, late-run and total sockeye salmon run, 1985–2014.

	Early run			Late run			Total run		
Year	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
2013	175,000	107,786	282,786	336,479	416,935	753,414	511,479	524,721	1,036,200
2014	252,097	177,598	429,695	538,469	738,981	1,277,450	790,566	916,579	1,707,145
10 yr avg (2003-2013)	159,727	108,322	268,149	293,059	236,344	529,403	452,786	344,666	797,552

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

Appendix C4.–Combined sockeye salmon early- and late-run brood table.

		Ages																				Total	Return/
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	4.4	Return	Spawner
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	0	2,114,121	2.1
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	0	2,215,407	2.5
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	0	1,275,984	1.7
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	0	947,433	1.6
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	0	1,210,493	1.1
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	0	1,160,579	1.6
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	0	1,357,833	1.3
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	0	574,152	0.7
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	0	1,220,845	1.9
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	0	1,605,867	1.9
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	0	1,663,181	2.2
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	0	1,273,479	2.2
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	0	1,534,893	2.7
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	0	2,058,758	3.2
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	0	1,754,732	1.8
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	0	1,514,180	2.1
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	0	1,223,779	1.4
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	0	584,186	0.7
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	0	434,170	0.4
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	0	343,242	0.5
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	0	0	0	0	222,276	0.3
490,373	0	0	15	23	16,901	7,236	0	5,609	151,008	18,497	34	51,706	81,816	0	59	8,640	0	0	0	0			
546,575	0	0	840	2,256	7,039	34,540	0	16,203	627,538	1,805	22	341,459	74,021	0	1,577	15,113	0						
246,490	0	0	339	34	23,839	16,798	103	50,734	649,030	2,689	298	361,266	69,883	0									
330,078	0	501	589	15	34,826	33,736	0	14,462	1,099,776	7,663													
348,102	0	203	3,308	0	62,511	70,414																	
317,322	148	185	3,998																				
502,690	0																						
571,359																							
790,566																							
																					5-year average (2001-2005)	561,531	0.7
																					10-year average (1996-2005)	1,094,370	1.5

APPENDIX D. LIMNOLOGICAL DATA

Appendix D1.–Karluk Lake weighted mean zooplankton biomass (mg/m^2) from 1999 to 2014.