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The 2013 Chignik River Sockeye Salmon Smolt Outmigration, an Analysis of the Population and Lake Rearing Conditions

by

Adam St. Saviour

and

Kyle Shedd

February 2014

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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by
Adam St. Saviour
Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak

and

Kyle Shedd
Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak

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

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Adam St. Saviour
Alaska Department of Fish and Game, Division of Commercial Fisheries
351 Research Court, Kodiak, AK 99615, USA

and

Kyle Shedd
Alaska Department of Fish and Game, Division of Commercial Fisheries
351 Research Court, Kodiak, AK 99615, USA

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ABSTRACT

This report describes the results of the sockeye salmon *Oncorhynchus nerka* smolt monitoring and enumeration project conducted by the Alaska Department of Fish and Game (ADF&G) in the Chignik River system in 2013. The research was designed to estimate smolt population size and age structure, assess fish body condition, describe limnetic habitat conditions and forage base, collect samples for genetic stock identification, and provide data for the Chignik River preseason adult sockeye salmon forecast. The abundance of sockeye salmon smolt was estimated using a rotary-screw trap array and mark-recapture techniques. In 2013, a total of 19,074,838 sockeye salmon smolt were estimated to have outmigrated from May 9 to July 3. Of these, 117,435 (0.6%) were freshwater age-0; 8,314,053 (43.6%) were freshwater age-1; 10,467,154 (54.9%) were freshwater age-2; and 176,196 (0.9%) were freshwater age-3 smolt. Limnology surveys were conducted in Chignik Lake monthly in May, June, July, and September and in Black Lake June, July, and September 2013 to describe physical characteristics, nutrient availability, primary production, and zooplankton forage available to rearing juvenile sockeye salmon. Smolt were of average body condition and zooplankton levels have rebounded from historic lows in 2012 suggesting a recovery of the food base and a return to more favorable rearing conditions. The smolt-based forecast predicts a total adult run of 2.04 million sockeye salmon in 2014. Findings from this project are key to understanding effects of escapement and environmental changes occurring in the Chignik River system on the sockeye salmon population.

Key words: Sockeye salmon, smolt, *Oncorhynchus nerka,* Chignik River, limnology, mark-recapture, zooplankton, forecast

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) has monitored the sockeye salmon *Oncorhynchus nerka* smolt outmigration in the Chignik River annually since 1994 to gauge the health of smolt leaving the system, estimate marine survival, and estimate age composition of the outmigrating population. In recent years, the data have been used to provide a preseason forecast of the Chignik River adult sockeye salmon run.

The Chignik River system produces the vast majority of the sockeye salmon in the Chignik Management Area (CMA; Bouwens 2004). It consists of a large shallow lagoon, two large lakes, and several tributaries that provide spawning and rearing habitat for sockeye salmon (Figure 1). Black Lake, at the head of the system, has a surface area of approximately 35.7 km^2, is shallow (maximum depth 4.2 m), turbid, and surrounded by low relief. In contrast, Chignik Lake is smaller (22 km^2), deeper (maximum depth 64 m), and surrounded by mountains. Black Lake drains via the Black River into Chignik Lake, which drains via the Chignik River into Chignik Lagoon, and then into the Gulf of Alaska (Narver 1966; Dahlberg 1968; Chasco et al. 2003). Chignik Lagoon is a semi-enclosed estuary with salinities ranging from full marine seawater at the outer spit to nearly freshwater conditions at the head of the lagoon (Simmons et al. 2013b).

Both lakes are considered oligotrophic (Kyle 1992) and each maintains its own genetically distinct, though temporally overlapping, runs of adult sockeye salmon (Templin et al. 1999; Creelman et al. 2011). Early-run sockeye salmon enter the river from June through early July and spawn in Black Lake and its tributaries. Late-run sockeye salmon return from early July through the late fall and spawn in the tributaries and shoals of Chignik Lake. The early run has a biological escapement goal (BEG) range of 350,000 to 450,000 fish through approximately July 4. The late run has a sustainable escapement goal (SEG) range of 200,000 to 400,000 fish beginning on approximately July 5 with an additional 50,000 fish in-river run goal (IRRG) in August and September (Sagalkin et al. 2013).

Typically, juvenile salmon migrate to sea after certain size thresholds are met, during specific seasons, and under certain environmental conditions. Salmon smolt outmigration may be triggered by warming springtime water temperatures (>4 °C), increased photoperiod, (Clarke and Hirano 1995), and smolt size (Rice et al. 1994). Variables affecting growth in juvenile salmon include temperature, competition, 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 (Bumgarner 1993).

Smolt outmigration studies provide information on life history strategies and annual changes in outmigration timing. Combined with limnology investigations, this type of study can provide insight as to how environmental and anthropogenic factors may influence food availability, juvenile outmigration timing, and overwintering habitat selection. Sockeye salmon rearing in Chignik and Black lakes are exposed to different types and levels of environmental stress which may influence their life history strategies. For example, if growth rates are not sufficient to achieve the threshold size necessary to outmigrate in the spring, juvenile fish may stay in a lake to feed for another year (Burgner 1991), possibly increasing competition among age classes. Conversely, stressed smolt may use an entirely different strategy and outmigrate early in order to take advantage of better rearing conditions in the marine environment (Rice et al. 1994). According to Western Regional Climate Center (2012), from 1960 to the 2012 mean annual temperature and precipitation for Cold Bay, Alaska has increased; while Black Lake water levels have decreased since the 1960s. Reported decreases in water surface elevation range from 0.5 to 2.2 meters resulting in volume reductions of 23 to 44%. There is some uncertainty in the measurements due to differences in datums used, but it is widely accepted that a decrease has occurred (Dahlberg 1968; CH2MHILL 1994; Elhakeem and Papanicolaou 2008; Griffiths et al. 2011; US Army Corps of Engineers 2012). Chignik stakeholders have been concerned that the loss of Black Lake volume has led to a reduction in rearing habitat and forage, intensifying competition among stocks.

Competition for food and habitat can influence growth and survival rates as well as migratory behavior of juvenile sockeye salmon (Rice et al. 1994). Several studies indicate Black Lake juveniles move into Chignik Lake to overwinter, with potential deleterious effects on Chignik Lake juveniles (Ruggerone 2003; Finkle 2004; Westley and Hilborn 2006; Simmons et al. 2013a). Top-down pressures have been indicated by decreased zooplankton size of *Bosmina* from Chignik and Black lakes (Kerfoot 1987; Kyle 1992; Bouwens and Finkle 2003). Interactions between the early and late sockeye salmon runs and their habitat use are not completely understood, but these topics have been the focus of numerous studies (Bumgarner 1993; Ruggerone 2003; Westley et al. 2008; Westley et al. 2010; Simmons et al. 2013a; Simmons et al. 2013b; Walsworth et al. *in review*). In particular, the influence of changing physical and environmental factors upon the outmigration of juvenile sockeye salmon merits continued investigation. Other past studies have also suggested that a component of juvenile sockeye salmon rear in the Chignik River and Chignik Lagoon during the summer to avoid overtaxed Chignik Lake rearing habitat and subsequently return to Chignik Lake in the fall of the same year (Roos 1957, 1959; Iverson 1966; Phinney 1968; Walsworth et al. *in review*). Information derived from smolt and lake-assessment monitoring is necessary for understanding changes in the production capacity of the salmon habitat of both Black and Chignik lakes.

Since the inception of the sockeye salmon smolt enumeration project in 1994, estimates of sockeye salmon smolt outmigrations from the Chignik River have ranged from 2 to 40 million sockeye salmon. Chignik sockeye salmon smolt generally have been observed to outmigrate beginning in early May, peak in late May, and are predominantly composed of age-1 and -2 smolt. Smolt outmigration data can serve as an indicator of future run strength and overall stock status (St. Saviour and Hunt 2013). In recent years, abundance and age data from the enumeration project have been used to generate an adult sockeye salmon forecast for the Chignik River. Harvesters use the forecast to make economic decisions including gear purchases, vessel repairs, and their time of arrival to the fishing grounds. Processors use it to estimate their supply and production needs. Forecast methods use historical age class relationships and smolt outmigration estimates to predict adult runs.

The Chignik smolt enumeration project has also supplied samples for genetic analysis since 2006. Genetic analyses have provided valuable information about stock-specific run timing and age composition. One of these studies indicated migration timing of each stock varied by year. In 2006 and 2008, Black Lake juveniles outmigrated in the early part of the season relative to the Chignik Lake juveniles. However in 2007 the opposite pattern occurred, where Chignik Lake smolt made up the majority of the early outmigration and Black Lake smolt dominated the late period (Creelman 2010). Additionally, smolt age was not a consistent indicator of stock origin as previously thought (Narver 1966; Witteveen and Botz 2004). In 2008, smolt ages were similar to those of returning adults, where the vast majority of Black Lake stock were freshwater age-1 and Chignik Lake stock were freshwater age-2. However in 2006 and 2007, the proportions of age-1 and age-2 sockeye salmon smolt were more evenly distributed among stocks (mean 44 to 57%; Creelman 2010). Genetic samples collected between 2009 and 2012 were analyzed this season. Findings are detailed in the *Results* section.

Information on rearing conditions is also needed to determine what factors may affect sockeye salmon production and life-history traits in the Chignik River system. ADF&G has conducted comprehensive limnology studies of Chignik and Black lakes since 2000. In 2008 limnology was formally incorporated into the smolt enumeration project. To date, limnology and smolt data from the Chignik system have been used to describe top-down pressures on the Chignik Lake aquatic community and trends in the life history strategies of juvenile sockeye salmon relative to recent physical changes (Buffington 2001; Bouwens and Finkle 2003; Finkle 2004; US Army Corps of Engineers 2012). The limnology portion of this project is used to identify and understand the relationships among juvenile sockeye salmon and zooplankton relative to physical conditions such as temperature, turbidity, dissolved oxygen, and nutrients.

The 2013 field season was the twentieth year of the ADF&G Chignik River sockeye salmon smolt monitoring and enumeration project. The sampling protocol has been consistent for these 20 years. This report presents data collected in 2013, compares the results of 2013 to previous years, and provides a 2014 adult sockeye salmon forecast based on smolt data.

OBJECTIVES

The objectives for the 2013 season were to:

1. Estimate the total number of outmigrating sockeye salmon smolt, by age class, from the Chignik River system.
2. Describe outmigration timing and growth characteristics (length, weight, and condition factor) of sockeye salmon smolt by age class for the Chignik River system.
3. Describe the physical characteristics of Black and Chignik lakes including: temperature, dissolved oxygen, and light penetration profiles.
4. Describe the nutrient availability and primary productivity of Black and Chignik lakes.

5. Quantify the zooplankton forage base available to juvenile sockeye salmon in Black and Chignik lakes.
6. Estimate Chignik sockeye salmon marine survival and build a smolt-based forecast model to estimate future runs.
7. Collect genetic samples from outmigrating sockeye salmon smolt for use in a stock identification study.

METHODS

STUDY SITE AND TRAP DESCRIPTION

Two rotary-screw traps were operated side by side to capture smolt outmigrating from the Chignik River system. Another trap was modified and used as a live box and work station platform. The live box was placed behind the small trap, which was closest to shore. The trapping site was located 8.6 km upstream from Chignik Lagoon and 1.9 km downstream from the outlet of Chignik Lake (56°15'26" N lat, 158°43'49" W long [NAD 1983]; Figure 2). The traps were located near a bend in the river with relatively high current velocity and narrow span.

Each trap was secured to shore with highly visible polypropylene line. The line and a red photosensitive strobe light attached to the safety railing of the offshore trap were employed to facilitate safe navigation of local boat traffic around the traps and anchor lines. The strobe was positioned far enough behind the mouth of the large trap to minimize trap avoidance by sockeye salmon smolt.

Each trap consisted of a cone constructed of perforated aluminum sheet (5 mm holes) mounted on two aluminum pontoons, with the large open end of the cone pointed upstream. The cone mouth diameter of the small trap was 1.5 m, and 2.4 m for the large trap. The small trap sampled an area of 0.73 m^2, and the large trap sampled an area of 2.0 m^2 of the river's cross-sectional profile because only the bottom half of the cone was submerged. The river current rotated both cones from five to ten revolutions per minute (RPM) during average discharge. Ideal trap RPM is between six and seven; trap distance from shore was adjusted to obtain this speed. Fish were funneled through the cones into live boxes at the downstream end of the traps, each approximately 0.7 m^3 in volume. A pair of adjustable aluminum support legs were used to maintain and adjust the traps' positions from the shore and their orientation to the current. A floating platform supporting a 3 x 4 m weatherport was tied directly behind the live box work station, to provide a sheltered work station while sampling and maintaining the traps.

Both screw traps began fishing at 1530 hours on May 9. Minor periods of fishing interruption occurred throughout the season to clear debris and for trap maintenance. These periods were limited to 3 hours or less and did not occur during primary outmigration hours. The large trap was disassembled for emergency repairs to the trap cone on July 3 and subsequently stored for the winter. The small trap was removed and disassembled for storage on July 4.

SMOLT ENUMERATION

Since smolt primarily outmigrate at night, sampling days occurred for a 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 three times each day beginning at noon, between 2000 and 2200 hours, and no later than 0900 hours the next morning. Traps were checked more frequently throughout the evening during periods of increased smolt outmigration.

Juvenile sockeye salmon greater than 45 mm fork length (FL; measured from tip of snout to fork of tail) were considered smolt (Thedinga et al. 1994). All fish were netted out of the traps' live boxes, identified (McConnell and Snyder 1972; Pollard et al. 1997), enumerated and released, except for those retained for age-weight-length (AWL), genetic samples, and mark-recapture tests. Sockeye salmon fry (<45 mm FL), coho salmon *O. kisutch* juveniles, Chinook salmon *O. tshawytscha* juveniles, pink salmon *O. gorbuscha* juveniles, chum salmon *O. keta* juveniles, Dolly Varden *Salvelinus malma*, stickleback of the family Gasterosteidae, pond smelt *Hypomesus olidus*, pygmy whitefish *Prosopium coulteri*, starry flounder *Platichthys stellatus*, Coast Range sculpin *Cottus aleutus*, Alaska blackfish *Dallia pectoralis,* eulachon *Thaleichthys pacificus,* and isopod *Mesidotea entomon* (Merrit and Cummings 1984; Pennak 1989) were also identified and counted.

TRAP EFFICIENCY AND SMOLT POPULATION ESTIMATES

Mark-recapture experiments were conducted weekly to determine trap efficiency, provided a sufficient number of smolt were captured to conduct a marking event. Between 850 and 4,000 sockeye salmon smolt for each experiment were collected from the traps, counted, and transferred to the live box. If sufficient numbers of smolt were not initially captured to perform a mark-recapture experiment, they were cumulatively retained in the live box for a maximum of three nights. After three nights, all captured live smolt were released downstream of the traps if the minimum sample size was not met. Mortalities that occurred during the holding time were removed and subtracted from the total.

Sockeye salmon smolt were netted from the live box, counted, and transferred into two 24-gal aerated marking containers. After a 30 min resting period, Bismarck Brown-Y dye solution (4.6 g of dye to 92.4 L of water) was mixed into the containers and held for 15 min. Fresh water was then pumped into the containers to slowly flush out the dye for 90 min while smolt recovered. At the end of the marking process, any dead or stressed smolt were removed, counted, and disposed of downstream of the traps.

The remaining marked smolt were taken to the upriver release site (56°15'15" N lat, 158°44'51" W long), approximately 1.3 km upstream of the traps (Figure 2). The smolt were transported upstream in aerated containers and released evenly across the breadth of the river. The marking event was performed so that the marked fish were released before midnight. The number of smolt recaptured in the traps was recorded for several days until recoveries ceased. Sockeye salmon smolt recaptured during mark-recapture experiments were recorded separately from unmarked smolt and excluded from daily total catch to prevent double counting.

Additionally, 100 marked smolt and 100 unmarked smolt were held in instream live boxes for the duration of each mark-recapture stratum to ensure the assumptions of the mark-recapture experiments were validated. Delayed mortality of smolt held for this purpose was incorporated into daily population estimates.

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 recovery period),

M_h = the total number of marked releases in stratum *h*,

and

m_h = the total number of marked recaptures in stratum *h*.

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

$$\hat{U}_h = \frac{u_h(M_h + 1)}{m_h + 1}, \tag{2}$$

where

u_h = the number of unmarked smolt captured in stratum *h*,

Variance was estimated by

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

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

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

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

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

and 95% confidence intervals were estimated from

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

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

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

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

where

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

A_h = the number of smolt sampled in stratum *h* with the variance estimated as

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

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

$$\hat{U}_{jh}=\hat{U}_j\hat{\theta}_{jh} , \tag{9}$$

where $\hat{U}_j$ was the total population size of age *j* smolt, excluding the marked releases (= $\sum U_{jh}$).
The variance for $\hat{U}_{jh}$, ignoring the covariance term, was estimated as

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

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

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

with the variance estimated by

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

AGE, WEIGHT, LENGTH AND GENETICS SAMPLING

Sockeye salmon smolt were collected throughout the night's migration and held in an instream live box. Forty sockeye salmon smolt were randomly collected from the trap's live boxes five days per statistical week, anesthetized with tricaine methanesulfonate (MS-222), and sampled for AWL; the remaining smolt were released downstream.

All AWL sampled smolt were anesthetized with either a non-lethal (smolt > 100 mm) or lethal (smolt ≤ 100 mm) amount of MS-222. Fork length (FL) 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. Fin clips were collected from all AWL-sampled fish for genetic analysis and stored in ethanol following ADF&G protocol. Genetic stock identification of 2009–2012 samples was conducted at the ADF&G Gene Conservation Laboratory in Anchorage using methods described in Creelman (2010) and Dann et al. (2012).

After sampling, live fish were held in aerated water until they completely recovered from the anesthetic and released downstream from the traps. Age was estimated from scales under 60X magnification and described using the European notation (Koo 1962). Condition factor (*K*) (Bagenal and Tesch 1978), which is a quantitative measure of the isometric growth of a fish, was determined for each smolt sampled using

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

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

CLIMATE AND HYDROLOGY

Trap RPM, water depth (cm), air and water temperature (°C), estimated cloud cover (%), and estimated wind velocity (mph) and direction were recorded daily at approximately 1200 hours.

MARINE SURVIVAL ESTIMATES AND RUN FORECASTING

The total sockeye salmon adult run to the Chignik River system was calculated by adding total Chignik River sockeye salmon escapement, total harvest from the CMA, 80% of the pre-July 26 sockeye salmon catch from the Southeastern District Mainland (SEDM) of the Alaska Peninsula Management Area (excluding Northwest Stepovak Section July 1 – July 26), and 90% of the pre-July 26 catch from the Cape Igvak Section of the Kodiak Management Area (5 AAC 09.360(g); 5 AAC 18.360(d)). Marine survival by age and the number of smolt produced per spawner from their respective brood years (BYs) were also calculated.

The total 2014 Chignik early and late adult sockeye salmon run was forecasted using a simple linear regression model of total outmigrating smolt biomass. Data from 1996 and 2008 were excluded due to unrealistic estimates of marine survival and anomalous adult runs. The model was evaluated using standard regression diagnostics and tested for autocorrelation by examining residual plots, and Durbin-Watson statistics. This smolt-based forecast is separate from the formal forecast (Munro et al. *In prep*) which uses adult age-class relationships and escapement data and is stock-specific.

LIMNOLOGY

Limnology data were collected at one sampling station on Black Lake (Figure 3) and at four sampling stations on Chignik Lake (Figure 3). Sampling occurred monthly from May through July with the exception of May for Black Lake. Sampling also occurred in September. Each station's location was logged with a global positioning system (GPS, using NAD 1983 datum) and Chignik Lake stations were marked with a buoy. Zooplankton samples, temperature, dissolved oxygen, and light penetration data were gathered at all sampling stations. Water samples were collected at the Black Lake station and at Chignik Lake stations 2 and 4. Sampling was conducted following protocols established by Finkle and Bouwens (2001).

Dissolved Oxygen, Light, and Temperature

Water temperature (°C) and dissolved oxygen (mg/L) levels were measured with a YSI Pro ODO meter. Readings were recorded at half-meter intervals from 0–5 m, and then intervals increased to one meter. Upon reaching a depth of 25 m, the intervals increased to every five meters up to 50 m (the depth limit of the equipment). A mercury thermometer was used to ensure the meter's calibration. Measurements of photosynthetically active wavelengths ($\mu mol/m^2/sec$) were taken with a Li-Cor LI-250A photometer. Readings began above the surface, at the surface, and proceeded at half-meter intervals until reaching a depth of 5 m. Readings were then recorded at one-meter intervals until the lake bottom or light penetration reached zero. The mean euphotic zone depth (EZD) was calculated for each lake (Koenings et al. 1987; Koenings and Kyle 1997). One-meter temperature and dissolved oxygen measurements were compared to assess the physical conditions in the euphotic zones of each lake. Secchi disc readings were collected from each station to measure water transparency. The depths at which the Secchi disc disappeared when lowered into the water column and reappeared when raised were recorded and averaged.

Water Sampling

Seven to eight liters of water were collected with a Van Dorn sampler from a depth of 1 m from each lake and also from a depth of 29 m at Chignik Lake. Water sampling and processing techniques have been consistent since 2000 and follow protocols outlined in Finkle (2007). Water analyses were performed at the Chignik field laboratory for pH and alkalinity and at the ADF&G Kodiak Island Laboratory (KIL) for total phosphorous (TP), total ammonia (TA), nitrate + nitrite, total filterable phosphorous (TFP), filterable reactive phosphorous (FRP), chlorophyll *a*, and phaeophytin *a*. Nutrient and photosynthetic pigment analyses were conducted at KIL using a SEAL AutoAnalyser 3 (AA3) HR; methods followed the equipment protocol. Total Kjeldahl nitrogen (TKN) was analyzed at the University of Georgia, Agricultural and Environmental Service Laboratories, Feed and Environmental Water Laboratory in Athens, GA.

Zooplankton

One vertical zooplankton tow was made at each limnology station with a 0.2-m diameter, 153-micron net from one meter above the lake bottom to the surface. Each sample was placed in a 125-ml poly bottle containing 12.5 ml of concentrated formalin and subsequently filled with DI water to yield a 10% buffered formalin solution. Samples were stored for analysis at the ADF&G KIL. Subsamples of zooplankton were keyed to genus or species and counted on a 1 mL Sedgewick-Rafter counting slide. This process was replicated a minimum of three times per sample to ensure the sample was accurately represented. The counts were averaged and extrapolated to the entire sample. For each plankton tow, mean length (±0.01 mm) was measured for each identifiable group with a sample size derived from a student's t-test to achieve a confidence level of 95% (Edmundson et al. 1994). Biomass was calculated via species-specific linear regression equations (Koenings et al. 1987).

RESULTS

TRAPPING EFFORT AND CATCH

The large and small traps were in place for a total of 55 and 56 days, respectively. The traps were operational on May 9. The duration of the 2013 trapping season was slightly shorter than average.

A total of 118,106 sockeye salmon smolt were captured in the traps during the 2013 season (Appendices A1 and B1). In addition to sockeye salmon smolt, 4,120 sockeye salmon fry, 1,788 coho salmon smolt, 10 coho salmon fry, 74 juvenile Chinook salmon, 18 juvenile pink salmon, 13 juvenile chum salmon, 559 Dolly Varden char, 6,715 stickleback, 552 sculpin, 20 starry flounder, 52 pond smelt, 176 pygmy whitefish, 13 Alaska blackfish, 510 isopods, and 4 eulachon were captured (Appendix A1). The small screw trap caught 8.6% of the trapped sockeye salmon smolt, and the large trap 91.4% (Appendix B1).

TRAP EFFICIENCY ESTIMATES

Mark-recapture experiments were conducted on seven occasions beginning May 16 and ending on June 29 (Table 1; Appendix A1). A total of 14,781 smolt, 12.5% of the total catch, were marked and released. One hundred eighteen smolt were recaptured and trap efficiency estimates per stratum ranged from 0.29% to 1.98% (Table 1; Appendix A1). The majority of recaptured marked smolt were caught within the first 24 hours of being released.

SMOLT OUTMIGRATION TIMING AND POPULATION ESTIMATES

An estimated 19,074,838 (95% CI 12,699,069 to 25,450,606) sockeye salmon smolt outmigrated in 2013 (Table 2; Figure 4). The majority of these fish outmigrated from the late May to mid-June; however, there was an early peak on May 17 that may have been related to strong winds blowing down Chignik Lake toward the outlet. (Table 3; Figure 5). The 2013 outmigration estimate comprised 117,435 age-0, 8,314,053 age-1, 10,467,154 age-2, and 176,196 age-3 sockeye salmon smolt (Table 2 and Table 3; Figure 6). Age-1 and age-2 smolt comprised the majority of the outmigration at 43.6% and 54.9% respectively.

AGE, WEIGHT, AND LENGTH DATA

A total of 1,473 usable samples were collected from sockeye salmon smolt for AWL data. The mean length, weight, and *K* of sampled age-0 smolt was 52 mm, 1.2 g, and 0.83 respectively. The mean length, weight, and *K* of sampled age-1 smolt was 72 mm, 3.1 g, and 0.81 respectively. The mean length, weight, and *K* of sampled age-2 smolt was 80 mm, 4.1 g, and 0.78 respectively. The mean length, weight, and *K* of sampled age-3 smolt was 92 mm, 6.3 g, and 0.80 respectively (Tables 4 and 5, Figures 7 and 8). Sockeye salmon fry (<45 mm FL) were captured throughout the trapping season but were most abundant in June (Appendix A).

PRELIMINARY RESULTS 2009-2012 GENETIC STOCK IDENTIFICATION

Genetics results for 2009–2012 genetic stock identification are preliminary. Statistical analyses are ongoing, with a full report with absolute values and credibility intervals is planned for spring of 2014.

To assess run timing, the sockeye salmon smolt outmigration was split into three strata each year based on the outmigration timing for that year. Similar to the findings of Creelman (2010), migration timing of each stock was variable by year from 2009 through 2012. In 2009, Chignik Lake stock dominated the early part of the outmigration (smolt trap catch equaled approximately 20% Black Lake stock in stratum 1). Dominance shifted to Black Lake by the end of the outmigration (approximately 35% Black Lake in stratum 2 and 65% in stratum 3). The only year in which Black Lake dominated the early part of the run was 2010 (approximately 60% Black Lake in strata 1 and 2). By stratum 3, the outmigration comprised approximately 30% Black Lake. In 2011, the proportion of Black Lake remained low throughout the season (approximately 5% in stratum 1, 20% in stratum 2, and 10% in stratum 3). In 2012, the percentage of Black Lake remained at approximately 40% for the entire outmigration.

Stock of origin by age was also variable by year. In 2009, approximately 25% of both age-1 and age-2 smolt sampled at the traps through the entire season were Black Lake. Age-0 and age-3 smolt comprised very small sample sizes and are not presented here. In 2010, approximately 55% of age-1 and 50% of age-2 smolt were Black Lake stock. In 2011, approximately 20% of age-1 and 10% of age-2 smolt were Black Lake stock. In 2012, approximately 70% of age-1 and 15% of age-2 smolt were Black Lake stock.

The Black Lake proportion of all sockeye salmon smolt sampled at the traps by season was approximately 20% in 2009, 60% in 2010, 20% in 2011, and 40% in 2012. In terms of smolt numbers, these proportions equate to approximately 2.0 million Black Lake and 5.0 million Chignik Lake in 2009. In 2010, the estimate of smolt numbers was 16.0 million Black Lake and 12.0 million Chignik Lake. In 2011, the estimate of smolt numbers was 2.3 million Black Lake and 10.0 million Chignik Lake. In 2012, the estimate of smolt numbers was 15.5 million Black Lake and 24.0 million Chignik Lake.

PHYSICAL DATA

The absolute water depth at the trap location ranged from 0 cm to 74 cm. Peak river discharge occurred on June 9, but the river did not start to drop continuously until June 23. Water temperature at the beginning of the season was 2.5 °C. It did not rise above 5.0 °C until June 6; then it increased steadily to a maximum of 9.0 °C on June 29 (Appendix C1 and C2). Relatively warm temperatures, light winds, and overcast skies dominated the 2013 season.

ADULT RUN FORECAST

The smolt-based regression model forecasted a 2014 total adult run of 2.04 million sockeye salmon (80% prediction interval 940,000 to 3.14 million; significance F= 0.02), compared to the formal adult forecast, which predicted a run of 1.70 million sockeye salmon (Munro et al. *In Prep*)

LIMNOLOGY

Sampling was conducted each month when logistically possible in both Black Lake (June 13, July 5, and September 9) and Chignik Lake (May 6, June 17, July 8, and September 5). Comparisons with historical limnology data can be found in Appendices D1 and D2.

Temperature and Dissolved Oxygen

Black Lake

The 1-m temperature in Black Lake in 2013 remained similar throughout sampling dates at 11.9 C on June 13, to 11.7 °C on September 9 (Figure 9). Dissolved oxygen levels at the 1 m depth were also steady, ranging from 10.5 to 10.7 mg/L over the same dates, with a maximum of 11.4 mg/L on July 5 (Figure 9).

Chignik Lake

The average 1 m temperature in Chignik Lake increased from 2.0 °C on May 6, to 12.0 °C on September 5 (Figure 10). Dissolved oxygen levels decreased from 13.5 mg/L to 10.8 mg/L over the same dates (Figure 10). Temperature and dissolved oxygen levels were similar throughout the water column at each sampling date, with no more than 1.2 °C and 1.1 mg/L difference between surface and deeper water.

Light Penetration and Water Transparency

Black Lake

Light penetrated the entire water column in Black Lake during the 2013 sampling season. The EZD (4.18 m) of Black Lake was nearly the same as its maximum depth (4.2 m) throughout the entire sampling season. The mean lake depth (1.9 m) was used to calculate the euphotic volume (EV) of 78.09 x $10^6 m^3$ (Table 6; Figure 11). During the 2013 sampling season, Secchi disc depth readings averaged 1.37 m.

Chignik Lake

EZD was similar on each sampling date and averaged 7.27 m. The EV in Chignik Lake averaged 175.2 x $10^6 m^3$ (Table 6; Figure 11). Mean Secchi disc readings were at a depth of 2.35 m.

Water Quality Parameters, Nutrient Levels, and Photosynthetic Pigments

Black Lake

In 2013, the pH at the Black Lake station averaged 7.9 and alkalinity averaged 29.5 mg/L $CaCO_3$. TP averaged 31.9 µg/L, TFP averaged 4.9 µg/L, and FRP averaged 1.3 µg/L. TKN averaged 980.0 µg/L, ammonia averaged 4.4 µg/L, and nitrate + nitrite averaged 2.9 µg/L. Silicon averaged 1,541.2 µg/L, chlorophyll *a* averaged 5.0 µg/L, and phaeophytin *a* averaged 1.7 µg/L. Nutrients increased over the course of the season, with phosphorus increasing from historic lows in 2012 (Appendix D1). Chlorophyll *a* and phaeophytin *a* concentrations were highest in September (7.0 and 2.6 µg/L respectively; Table 7).

Chignik Lake

In 2013, the pH in Chignik Lake averaged 7.7 and alkalinity averaged 26.2 mg/L $CaCO_3$ across stations and depth. TP averaged 14.4 µg/L, TFP averaged 3.0 µg/L, and FRP averaged 1.9 µg/L. TKN averaged 344.5 µg/L, ammonia averaged 5.8 µg/L, and nitrate + nitrite averaged 133.3 µg/L. Silicon averaged 4,445.0 µg/L, chlorophyll *a* averaged 2.9 µg/L, and phaeophytin *a* averaged 0.7 µg/L. Nitrogen and phosphorus nutrient parameters decreased over the course of the season. Chlorophyll *a* concentration was highest in September (4.7 µg/L), while phaeophytin *a* did not fluctuate throughout the season (Table 8). Photosynthetic pigment levels were comparable to other years (Appendix D2).

ZOOPLANKTON

Black Lake

Copepods were the most abundant zooplankton measured in Black Lake (season average of 109,209 individuals/m^2) followed by cladocerans (season average of 92,587 individuals/m^2). On average, the most prevalent copepod genera in Black Lake was *Cyclops* (48,461 /m^2) (Table 9; Appendix D3). Immature cladocera were the most abundant cladoceran genera with a seasonal average of 36,837 followed by *Chydorinae* and *Bosmina* with a seasonal average of 26,787/m^2 and 25,088/m^2, respectively. Total zooplankton abundance peaked in June (Table 9).

Copepod biomass was greatest in June and was composed predominantly of *Cyclops* (42.6 mg/m^2 weighted season average). Cladoceran biomass was predominantly composed of *Bosmina* throughout the sampling season with a weighted seasonal average of 25.7 mg/m^2 and greatest biomass observed in July. The total weighted seasonal average copepod biomass (108.8 mg/m^2) was greater than cladoceran biomass (45.6 mg/m^2) and resulted in a total weighted seasonal average of 154.4 mg/m^2 for all the Black Lake zooplankton (Table 10; Appendix D4).

Average weighted seasonal lengths of the major non-egg bearing zooplankton in Black Lake were 0.86 mm for *Eurytemora*, 0.52 mm for *Cyclops*, 0.34 mm for *Bosmina*, and 0.26 mm for *Chydorinae* (Table 11).

Chignik Lake

Copepod abundance (season average of 280,708 individuals/m^2) was greater than the average seasonal cladoceran abundance (158,730 /m^2). *Cyclops* (152,987 /m^2) and nauplii (92,054 /m^2) were the most abundant genera of copepods. *Daphnia* (87,279 /m^2) and *Bosmina* (25,832 /m^2) were the most common cladocerans in Chignik Lake (Table 12; Appendix D5).

Copepod biomass was composed predominantly of *Cyclops* May through July (165.9 mg/m^2 weighted season average.) In September, *Eurytemora* had the greatest biomass (242.0 mg/m^2). Cladoceran biomass was composed primarily of *Daphnia* (90.9 mg/m^2 weighted season average) reaching highest biomass in September (319.9 mg/m^2). The total weighted seasonal average copepod biomass (323.2 mg/m^2) was greater than the cladoceran biomass (156.1 mg/m^2) resulting in a weighted average of 479.3 mg/m^2 for all Chignik Lake zooplankton (Table 13; Appendix D6).

Average weighted seasonal lengths of the major non-egg bearing zooplankton in Chignik Lake were 0.57 mm for *Cyclops*, 1.07 mm for *Eurytemora*, and 0.50 mm for *Daphnia* Ovigerous zooplankton were generally longer than non-egg bearing individuals (Table 14).

DISCUSSION

SMOLT POPULATION ESTIMATES AND AGE STRUCTURE

The point estimate of the 2013 total smolt outmigration (19.1 million) was above the 20-year average (14.7 million). Outmigration timing was later than average, with the peak occurring on May 28. There were two large peaks in the 2013 outmigration on May 17 and 28 (Figure 5). The earlier peak coincided with a weather event that included strong winds blowing down Chignik Lake toward the outlet and freezing temperatures.

Outmigration timing and magnitude in 2013 allowed for eight mark-recapture events throughout the season with approximately 14,800 smolt marked and released. Trap efficiency estimates in 2013 were consistent with previous years. Historic efficiencies have generally averaged ~1% annually and individual mark-recapture events often were <1%. Efficiencies are consistent throughout the season and have never been more than 3% in the history of the project (St. Saviour and Hunt 2013). Low trap efficiencies are expected considering the size of the Chignik River and small proportion that the traps cover. Although trap efficiency estimates result in wide confidence intervals around the population point estimate, the interannual trap efficiency consistency provides confidence that the yearly population estimates are comparable among years.

The 2013 smolt population comprised approximately <1% age-0, 44% age-1, 55% age-2 smolt, and 1% age-3. The large proportion of age-2 smolt in the 2013 outmigration was similar to 2012, but atypical for the system (Figure 6). Condition factor among all age classes was average, having rebounded from historic lows in 2012 (Table 5). Condition factor increased among all age classes, with the exception of age-0, over the course of the season (Table 4). These data suggest that the 2013 smolt population has returned to a level within the current carrying capacity of the system. This is encouraging given *K* data from 2012 suggesting that carrying capacity had been exceeded (St. Saviour and Hunt 2013). Two subsequent years of a higher than average proportion of age-2 smolt may indicate that most Chignik sockeye salmon smolt exhibited the life history strategy where they do not outmigrate until a threshold size is met (Burgner 1991). It would take longer to meet this threshold with more intraspecific competition and less food resources available. More fish staying for an extra year in Chignik Lake could perpetuate the problem of high competition and low food resources; however, the rebound in body condition for all age classes of 2013 smolt indicate that the forage base appears to have returned to healthy levels. It is likely that the large proportion of age-2 smolt in 2013 is a result of carryover from the large smolt outmigration and poor rearing conditions in Chignik Lake in 2012 (St. Saviour and Hunt 2013).

Age-0 smolt made up a similar proportion of the population as in recent years (Table 2) and did not indicate anything unusual in 2013. Although age-0 smolt make up a small proportion of the population, fry, less than 45 mm have not been included in the estimate of age-0's. Fry less than 45 mm are not considered smolt (Thedinga et al. 1994) as they are very difficult to remove scales from and age due to their small size. This inherently leads to a biased-high size estimate of the entire age-0 class. Age-0 smolt can reach lengths of over 50 mm in the productive rearing conditions of Black Lake (Finkle 2004). Some of these fish return as adults as evidenced by adult scales (Sagalkin et al. 2013). Some rear in the lagoon or river for the summer (Simmons et al. 2013a; Simmons et al. 2013b) before outmigrating, and others may return to Chignik Lake as juveniles to overwinter. Ongoing otolith microchemistry work should shed light on the frequency of these different life-history strategies (Walsworth et al. *in review*).

ZOOPLANKTON

Black Lake zooplankton density and biomass was higher than recent years, but it has not returned to the highest levels seen in the early 2000's. May and August samples were not collected in 2013, but September samples were collected. Seasonal patterns of zooplankton density and biomass were similar to what has been observed historically. Zooplankton density in Black Lake is usually predominated by copepods early in the season, decreasing from May to June, then peaking in late July or August (Finkle and Ruhl 2008; St. Saviour and Hunt 2013). Cladocerans become the predominant zooplankton in Black Lake late in the summer when phytoplankton levels have increased (chlorophyll *a* 1.5 to 10.4µ/L) and many of the zooplanktivorous fish have left the lake. In 2013, cladoceran biomass peaked in July. The relationship between total smolt and Black Lake zooplankton density is not consistent interannually (Figure 4; Appendix D3). Chignik Lake zooplankton levels are probably equally or more important for Black Lake-stock juvenile sockeye salmon (Finkle 2005).

Chignik Lake zooplankton density and biomass were average in 2013. Of particular note, cladoceran density and biomass were approximately 72% and 62% higher than the ten year average, despite historic lows in 2012 (Appendices D5 and D6). Cladoceran levels in 2013 indicate a recovery from the strong top-down pressure on this aquatic community seen in 2012. Chignik Lake zooplankton seasonal patterns are usually similar to those found in Black Lake, with the exception that copepods remain predominant later into the season when overall zooplankton densities are greatest (Tables 9 and 12). Chignik Lake copepod populations historically are composed primarily of *Cyclops*, while the most abundant cladoceran is *Bosmina*. However, *Daphnia* was the most abundant cladoceran in 2013, although this is largely driven by high density and biomass in September, which is typically not sampled.

When competition is too great or rearing conditions are poor in the freshwater environment, the lagoon may provide important rearing habitat for juvenile sockeye salmon before continuing to the marine environment (Simmons et al. 2013a; Simmons et al. 2013b). Smolt entering the marine environment in good condition (high *K*) have been shown to have higher survival than those with lower *K* (Foerster 1954; Henderson and Cass 1991). Keeping the sockeye salmon smolt population and zooplankton levels, particularly Chignik Lake cladocerans, in balance will help promote productive adult returns in future years. This may be achieved by using zooplankton and smolt *K* data to inform managers of where to aim within the escapement goal range (Sagalkin et al. 2013).

LIMNOLOGY

Nutrient data can indicate limitations in aquatic environments. A ratio of total nitrogen (TN) to total phosphorous (TP) is commonly used to indicate nutrient status, and both are necessary for primary production at specific ratios (Wetzel 1983; University of Florida 2000). Nitrogen-phosphorous ratios of less than 10:1 indicate nitrogen limitations, whereas ratios greater than about 25:1 indicate phosphorus limitation (Wetzel 1983; US Environmental Protection Agency 2000). Water quality data from 2013 indicated nutrient levels in both lakes fell into low to medium production (oligotrophic to mesotrophic) levels as defined by several trophic state indices (Carlson 1977; Forsberg and Ryding 1980; Carlson and Simpson 1996) but were comparable to other Alaskan lakes in the region (Honnold et al. 1996; Schrof and Honnold 2003). The seasonally averaged TN:TP ratio for Black Lake was 30.8:1 this season. Of the two, phosphorus was likely the limiting nutrient in Black Lake during the 2013 season. The seasonal average for Chignik Lake was 33.1:1. The highest ratio by far occurred in May (94.5:1) then dropped to levels between 12 and 20:1 for the remainder of the season. This seasonally averaged ratio is greater than the 10-year average (19.2:1).

The quantity of photosynthetic pigments present in an aquatic system is related to the biomass of primary producers and the potential production level of the system. The ratio of chlorophyll *a* (associated with active cells) to phaeophytin *a* (the byproduct of photosynthesis associated with senescent cells) serves as an indicator of the algal community condition. High chlorophyll *a* to phaeophytin *a* ratios indicate there are adequate nutrients and suitable physical conditions for primary production within the lake. Conversely, low ratios may suggest that primary productivity is taxed. A comparison of photosynthetic pigments chlorophyll *a* to phaeophytin *a* showed that chlorophyll *a* concentrations (ratio 2.9:1) in Black Lake were below the 10-year average (6.6:1). The ratio of chlorophyll *a* was slightly below average in Chignik Lake this season (2013 ratio 4.2:1; 10-year average 5.9:1). These ratios were low despite increases mid-season, primarily attributed to higher phaeophytin *a* levels rather than low chlorophyll *a* levels. Changes in nutrients and forage bases can significantly impact higher trophic levels (Kyle et al. 1988; Milovskaya et al. 1998). Chignik Lake community dynamics are thought to be largely controlled by top-down pressures (Finkle 2004). However, bottom-up controls could become more important in years with fewer juvenile sockeye salmon rearing (Northcote 1988). Continued collection of limnology data is important to understand mechanisms driving resource abundance.

The seasonal pH levels in Black and Chignik lakes were higher than recent years with slightly higher than historical seasonal averages from the 1960s (1960s Black Lake seasonal average pH = 7.42; 1960s Chignik Lake seasonal average pH = 7.27; Narver 1966). The current levels are well within a safe pH range for aquatic organisms of 4.5 to 9.5. Given average chlorophyll *a* levels and below average chlorophyll *a* to phaeophytin *a* ratios in 2013, pH levels were perhaps driven by higher than usual bacterial respiration and decomposition of algal cells. It could also be driven more by geologic than biological processes, such as higher carbonate flood water washing in from a nearby volcano (Mt. Veniaminof; Wetzel 1983).

OUTMIGRATION TIMING

An estimated 117,435 age-0 sockeye salmon, greater than 45mm in length, outmigrated in 2013 (Table 3). Unlike other systems where smolt leave the freshwater environment and enter directly into entirely marine near-shore feeding areas, the Chignik system has a large lagoon which acts as a transition zone between the freshwater and saltwater ecosystems. This provides a forage base of amphipods, pericardians, and other small crustaceans which may alleviate some of the top-down pressure in Chignik Lake (Bouwens and Finkle 2003). Simmons et al. (2013b) found that sockeye salmon fry were abundant in Chignik Lagoon throughout the summer and that residency time was closely related to sockeye salmon length and age, with smaller fish remaining longer to achieve additional growth in body size before their migration to the marine environment. Under stressful environmental conditions, such as elevated temperatures and poor visibility, underyearling sockeye salmon may migrate to sea (Rice et al. 1994). In 2005, 2006, and 2008 a greater proportion of age-0 smolt were observed outmigrating, possibly using an alternative life history strategy of leaving poor lake rearing conditions in search of more productive lagoon or marine habitat (Simmons 2009). The low proportion of age-0 sockeye salmon that outmigrated in 2013 indicates this did not occur this year.

Temperature also has a strong effect on smolt outmigration. After a 40 year warming period, the average annual temperature on the Alaska Peninsula has been declining for the past 5 to 10 years. This is perhaps as a result of a change in ocean upwelling pattern, and a shift back to colder regime in the Pacific Decadal Oscillation (PDO; Western Regional Climate Center 2012; NOAA Earth System Research Laboratory 2013). A shift in Chignik sockeye salmon smolt peak outmigration timing from about May 23 to June 2 since 1994 indicates recent colder conditions may be delaying the outmigration (Figure 12). Griffiths et al. (2011) showed air temperatures and water temperatures are closely coupled in Black Lake due to the shallow depth of the water body. Air temperatures may play a larger role in the condition and success of sockeye salmon juveniles in Black Lake. In warmer years, thermal stress may cause earlier outmigration of Black Lake juveniles into Chignik Lake (Finkle 2004). In 2013, air and water temperatures at the smolt traps were average. Yet, very few juvenile sockeye salmon were captured in a beach seine at Black Lake after July suggesting water temperature is limiting or something else is controlling early outmigration from Black Lake. Water clarity is one possibility. Black Lake is susceptible to wind-mixing and has more-variable water clarity over the course of a season, whereas Chignik Lake tends to lose clarity over the course of the season due to increased phytoplankton biomass and runoff from the West Fork. Increased water clarity should provide better feeding conditions for both juvenile fishes and zooplankton.

GENETIC STOCK IDENTIFICATION

Similar to Creelman (2010), migration timing by stock was found to be variable between 2009 and 2012. Only in 2010, was smolt outmigration timing consistent with adult returns by stock with Black Lake dominating the early part of the outmigration. Stock composition of age classes in 2009 and 2011 may also have yielded results that contradict conventional wisdom (Narver 1966; Witteveen and Botz 2004; Creelman 2010) with very low proportions of age-1 smolt that were Black Lake stock. It should, however, be noted that at this time, these proportions are not weighted by the strength of each run for a given year. This will require a reanalysis of the data using individual assignment. This work is planned for the winter of 2013/2014.

MARINE SURVIVAL ESTIMATES

All adult sockeye salmon offspring from BYs 1991 through 2005 and most offspring from BY 2006 have returned to the Chignik River; overall marine survival has ranged from 6% for BY 1999 to 67% for BY 1993 (mean survival 28%; Table 15). The estimation of the 1993 and 1994 BY marine survival includes a portion of the outmigration estimate from 1996, which is considered erroneous (Edwards and Bouwens 2002). When presented by outmigration year, marine survivals ranged from 5% for outmigration year 2001 to 84% for outmigration year 2007, with a mean survival rate of 26% (Table 16). The very high marine survival estimate for outmigration year 2007 is likely due to truly high survival and a biased low smolt outmigration estimate. Smolt were much larger than average so they entered the ocean in good condition and likely had higher survival than average (Figure 7). They also may have been stronger swimmers and been able to avoid the traps resulting in biased-low smolt population estimates. Efficiency estimates would not necessarily have accounted for trap avoidance because trap catches were low for much of 2007 and did not allow for consistent mark-recapture experiments. A more realistic marine survival estimate came with the return of the 2009 outmigration year which also had average K (Tables 5 and 16). It should also be noted that marine conditions, which can only be indexed indirectly, strongly influence variability in marine survival.

FORECASTS OF ADULT SALMON RETURNS

A smolt-based sockeye salmon forecast has been developed annually since 2002. Since its inception, the smolt-based forecast has overestimated the actual total sockeye salmon adult run to the Chignik system by as much as 107% (2004 forecast) and underestimated it by as much as 53% (2011 forecast). The 2013 forecast point estimate was -11% of the actual run the ten year forecast average is very close to the true run average, with an error of -5%. Forecast methods have included simple and multiple linear regressions of smolt outmigrants by age class to ocean-age class adult returns and multiple regressions of outmigrant-age class smolt and temperature to ocean-age class adult returns. The 2014 smolt-based forecast used total smolt biomass to predict a total adult run of 2.04 million. This model reflects more of the general trend in smolt to adult returns over time. It is 20% higher than the the formal forecast total of 1.70 million.

The smolt-based forecasting method does not currently have the resolution to forecast by run because stock-specific data series is short. However, if continued, long term genetic stock identification will provide a means for Chignik sockeye salmon smolt stock separation, stock-specific smolt-based forecasts, and smolt production estimates of each stock.

CONCLUSION

The continued collection of smolt outmigration data allows ADF&G to monitor changes in life history strategies of sockeye salmon in the Chignik River system caused by changes in environmental conditions. Reductions in Black Lake water volume and rearing habitat have occurred along with shifts in water temperatures since the 1960s. Timing of Black Lake smolt outmigration to Chignik Lake has shifted earlier in the summer relative to 1970’s timing (Westley et al. 2008) whereas the peak system-wide outmigration has shifted later since 1994. Competition between Black Lake emigrants and Chignik Lake smolt has been demonstrated (Parr 1972; Ruggerone 2003) and is likely stronger in years when Black Lake is warmer. High escapement and recruitment also likely have an effect on competition between stocks as evidenced by top-down pressures on the Chignik Lake zooplankton community. Continued monitoring of smolt outmigration and limnology in the system is the best way to detect changes in early life history strategies that may be deleterious to Chignik sockeye salmon fisheries.

ADF&G has conducted the smolt enumeration project since 1994 and in 2008 formally incorporated the collection of limnology samples from both lakes. This data set is now becoming a long enough time series useful for identifying longer-term changes that may be occurring in the system as well as quantifying long-term natural variation. It has proven instrumental in understanding the mechanisms behind freshwater production and for enhancing management of the system. For example, targeting the lower ends of the escapement goals in response to over escapement and decreased rearing habitat in Black Lake has likely contributed to strong returns in recent years. Data from this project are essential for monitoring the health of sockeye salmon in Chignik system because smolt outmigration information may be the only available means to link changes in run strength to freshwater, marine, or climate influences.

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TABLES AND FIGURES

Table 1.–Results from mark-recapture tests performed on sockeye salmon smolt outmigrating from the Chignik River, 2013.

Date	No. Marked	Total Recaptures	Trap Efficiency[a]
5/9 - 5/21	2,048	5	0.29%
5/22 - 5/26	1,221	6	0.57%
5/27 - 5/31	2,424	17	0.74%
6/1 - 6/5	3,707	45	1.24%
6/6 - 6/10	2,132	13	0.66%
6/11 - 6/17	1,893	16	0.90%
6/18 - 6/28	504	9	1.98%
6/29 - 7/3	852	7	0.94%
Total	14,781	118	0.92%

[a] 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). The number marked accounts for delayed mortality.

Table 2.–Chignik River sockeye salmon smolt population estimates, by age class, 1994 to 2013.

Year		Number of Smolt							95% C.I.	
		Age-0	Age-1	Age-2	Age-3	Age-4	Total	S.E.	Lower	Upper
1994	Numbers	0	7,263,054	4,270,636	0	0	11,533,690	1,332,321	8,922,341	14,145,038
	Percent	0.0	63.0	37.0	0.0	0.0	100.0			
1995	Numbers	735,916	2,843,222	5,178,450	0	0	8,757,588	1,753,022	5,321,664	12,193,512
	Percent	8.4	32.5	59.1	0.0	0.0	100.0			
1996	Numbers	80,245	1,200,793	731,099	5,018	0	2,017,155	318,522	1,392,852	2,641,459
	Percent	4.0	59.5	36.2	0.2	0.0	100.0			
1997	Numbers	528,846	11,172,150	13,738,356	122,289	0	25,561,641	2,962,497	19,755,145	31,368,136
	Percent	2.1	43.7	53.7	0.5	0.0	100.0			
1998	Numbers	75,560	5,790,587	20,374,245	158,056	0	26,398,448	3,834,506	18,882,817	33,914,080
	Percent	0.3	21.9	77.2	0.6	0.0	100.0			
1999	Numbers	73,364	12,705,935	8,221,631	78,798	0	21,079,728	3,070,060	15,062,412	27,097,045
	Percent	0.3	60.3	39.0	0.4	0.0	100.0			
2000	Numbers	1,270,101	8,047,526	4,645,121	160,017	0	14,122,765	1,924,922	10,349,918	17,895,611
	Percent	9.0	57.0	32.9	1.1	0.0	100.0			
2001	Numbers	521,546	18,940,752	5,024,666	516,723	5,671	25,009,358	5,042,604	15,125,854	34,892,862
	Percent	2.1	75.7	20.1	2.1	0.0	100.0			
2002	Numbers	440,947	13,980,423	2,223,996	72,184	0	16,717,551	2,112,220	12,577,007	20,856,909
	Percent	2.6	83.6	13.3	0.4	0.0	100.0			
2003	Numbers	155,047	5,146,278	1,449,494	0	0	6,750,819	527,041	5,717,820	7,783,819
	Percent	2.3	76.2	21.5	0.0	0.0	100.0			
2004	Numbers	244,206	6,172,902	2,239,716	0	0	8,656,824	1,219,278	6,267,039	11,046,609
	Percent	2.8	71.3	25.9	0.0	0.0	100.0			
2005	Numbers	859,211	2,075,681	1,468,208	32,889	0	4,435,988	1,034,892	2,407,600	6,464,376
	Percent	19.4	46.8	33.1	0.7	0.0	100.0			

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Table 2.–Page 2 of 2.

		Number of Smolt							95% C.I.	
Year		Age-0	Age-1	Age-2	Age-3	Age-4	Total	S.E.	Lower	Upper
2006	Numbers	1,744,370	2,849,043	2,847,624	119,614	0	7,560,651	2,280,536	3,090,799	12,030,502
	Percent	23.1	37.7	37.7	1.6	0.0	100.0			
2007	Numbers	9,286	1,926,682	1,028,865	0	0	2,964,833	969,567	1,064,482	4,865,184
	Percent	0.3	65.0	34.7	0.0	0.0	100.0			
2008	Numbers	1,017,498	3,309,894	987,928	41,136	0	5,356,455	605,266	4,170,134	6,542,777
	Percent	19.0	61.8	18.4	0.8	0.0	100.0			
2009	Numbers	110,446	3,777,572	4,288,491	0	0	8,176,509	320,013	7,472,166	8,880,852
	Percent	1.4	46.2	52.4	0.0	0.0	100.0			
2010	Numbers	1,039,131	17,684,165	9,347,999	91,509	0	28,162,803	4,433,289	19,473,557	36,852,050
	Percent	3.7	62.8	33.2	0.3	0.0	100.0			
2011	Numbers	203,380	10,684,120	1,371,044	0	0	12,258,543	1,802,506	8,725,631	15,791,456
	Percent	1.7	87.2	11.2	0.0	0.0	100.0			
2012	Numbers	685,707	16,328,172	22,734,743	196,575	0	39,945,197	4,551,145	31,024,952	48,865,441
	Percent	1.7	40.9	56.9	0.5	0.0	100.0			
2013	Numbers	117,435	8,314,053	10,467,154	176,196	0	19,074,838	3,252,943	12,699,069	25,450,606
	Percent	0.6	43.6	54.9	0.9	0.0	100.0			

Table 3.–Estimated sockeye salmon smolt outmigration from the Chignik River in 2013 by age class and statistical week.

Statistical		Number of Smolt								
Week	Date	age-0	%	age-1	%	age-2	%	age-3	%	Total
19	5/3	0	0.0%	11,396	23.5%	34,430	71.0%	2,667	5.5%	48,493
20	5/10	0	0.0%	395,484	23.5%	1,194,868	71.0%	92,560	5.5%	1,682,912
21	5/17	0	0.0%	1,736,992	29.5%	4,092,235	69.5%	58,881	1.0%	5,888,108
22	5/24	0	0.0%	3,422,522	49.5%	3,491,664	50.5%	0	0.0%	6,914,187
23	5/31	0	0.0%	1,716,001	58.0%	1,227,828	41.5%	14,793	0.5%	2,958,622
24	6/7	112,452	10.5%	685,422	64.0%	267,743	25.0%	5,355	0.5%	1,070,972
25	6/14	0	0.0%	248,255	64.0%	137,704	35.5%	1,939	0.5%	387,899
26	6/21	3,723	4.0%	74,457	80.8%	13,961	15.2%	0	0.0%	92,141
27	6/28	1,260	4.0%	23,523	74.7%	6,721	21.3%	0	0.0%	31,504
Total		117,435	0.6%	8,314,053	43.6%	10,467,154	54.9%	176,196	0.9%	19,074,838

Note: Percentage values may not add up to 100% due to rounding.

Table 4.–Length, weight, and condition factor of Chignik River sockeye salmon smolt samples in 2013, by age and statistical week. Totals weighted by sample size (SS) and by outmigration magnitude (OM).

				Length (mm)		Weight (g)		Condition Factor	
Age	Stat Week	Starting Date	Sample Size	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
0	24	6/7	21	53	0.94	1.3	0.06	0.84	0.03
0	26	6/21	8	52	0.99	1.1	0.06	0.81	0.03
0	27	6/28	3	49	0.33	1.0	0.06	0.83	0.05
Total	Weighted by SS		32	52	0.69	1.2	0.04	0.83	0.02
	Weighted by OM			53		1.3		0.84	
1	20	5/10	47	74	0.92	3.1	0.12	0.74	0.01
1	21	5/17	59	75	0.73	3.2	0.11	0.75	0.01
1	22	5/24	99	74	0.51	3.1	0.07	0.74	0.01
1	23	5/31	116	73	0.59	3.1	0.12	0.78	0.01
1	24	6/7	128	69	0.42	2.7	0.05	0.82	0.01
1	25	6/14	128	73	0.34	3.4	0.04	0.85	0.01
1	26	6/21	160	70	0.74	3.1	0.09	0.86	0.01
1	27	6/28	56	77	1.18	4.0	0.17	0.87	0.01
Total	Weighted by SS		793	72	0.25	3.1	0.03	0.81	0.00
	Weighted by OM			74		3.1		0.76	
2	20	5/10	142	80	0.48	3.9	0.09	0.74	0.00
2	21	5/17	139	78	0.36	3.6	0.05	0.75	0.00
2	22	5/24	101	76	0.43	3.3	0.06	0.76	0.01
2	23	5/31	83	80	1.11	4.3	0.23	0.79	0.01
2	24	6/7	50	79	1.52	4.3	0.30	0.82	0.01
2	25	6/14	71	84	1.35	5.6	0.27	0.88	0.01
2	26	6/21	30	79	1.83	4.6	0.32	0.89	0.02
2	27	6/28	16	98	1.68	8.2	0.45	0.86	0.01
Total	Weighted by SS		632	80	0.33	4.1	0.07	0.78	0.00
	Weighted by OM			78		3.7		0.76	
3	20	5/10	11	91	1.22	5.9	0.27	0.79	0.01
3	21	5/17	2	88	0.50	4.8	0.10	0.72	0.00
3	23	5/31	1	96	0.00	7.9	0.00	0.89	0.00
3	24	6/7	1	103	0.00	9.7	0.00	0.89	0.00
3	25	6/14	1	96	0.00	7.7	0.00	0.87	0.00
Total	Weighted by SS		16	92	1.25	6.3	0.36	0.80	0.01
	Weighted by OM			90		5.8		0.78	

Table 5.–Mean length, weight, and condition factor of sockeye salmon smolt samples from the Chignik River, by year and age, 1994 to 2013.

		Length (mm)			Weight (g)			Condition Factor		
Year	Age	Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error
1995	0	272	46	0.18	272	0.7	0.01	272	0.74	0.01
1996	0	125	49	0.45	113	1.0	0.03	113	0.82	0.01
1997	0	195	46	0.22	195	0.8	0.01	195	0.83	0.01
1998	0	15	45	0.96	15	0.7	0.03	15	0.73	0.03
1999	0	40	52	0.79	40	1.3	0.06	40	0.97	0.03
2000	0	223	60	0.52	223	2.1	0.05	223	0.91	0.01
2001	0	96	56	0.51	96	1.5	0.04	96	0.88	0.01
2002	0	217	49	0.27	217	1.2	0.02	217	0.98	0.01
2003	0	149	56	0.53	149	1.5	0.05	149	0.79	0.01
2004	0	347	56	0.44	347	1.7	0.05	347	0.91	0.01
2005	0	652	56	0.28	649	1.5	0.03	649	0.83	0.01
2006	0	427	52	0.24	427	1.0	0.02	427	0.70	0.01
2007	0	6	64	2.47	6	2.5	0.08	6	1.03	0.16
2008	0	568	53	0.17	566	1.1	0.01	566	0.76	0.01
2009	0	198	53	0.39	196	1.4	0.04	196	0.93	0.01
2010	0	128	54	0.48	128	1.2	0.04	128	0.78	0.01
2011	0	100	49	0.41	100	1.0	0.03	100	0.86	0.01
2012	0	129	52	0.35	129	0.9	0.02	129	0.65	0.01
2013	0	32	52	0.69	32	1.2	0.04	32	0.83	0.02
1994	1	1,715	67	0.16	1,706	2.3	0.02	1,706	0.75	0.00
1995	1	1,272	60	0.34	1,272	2.0	0.04	1,272	0.82	0.00
1996	1	1,423	68	0.29	1,356	2.7	0.04	1,356	0.81	0.00
1997	1	1,673	63	0.35	1,673	2.4	0.04	1,673	0.81	0.00
1998	1	785	69	0.38	780	2.7	0.06	780	0.78	0.01
1999	1	1,344	77	0.17	1,344	4.1	0.03	1,344	0.89	0.00
2000	1	1,175	72	0.22	1,175	3.3	0.04	1,175	0.86	0.00
2001	1	1,647	65	0.13	1,647	2.1	0.02	1,647	0.76	0.00
2002	1	1,588	65	0.18	1,588	2.3	0.02	1,588	0.83	0.00
2003	1	1,665	65	0.11	1,665	2.1	0.01	1,665	0.75	0.00
2004	1	1,030	69	0.20	1,030	2.8	0.03	1,030	0.83	0.00
2005	1	892	69	0.25	892	2.7	0.03	892	0.81	0.00
2006	1	662	68	0.28	662	2.4	0.03	662	0.76	0.00
2007	1	809	82	0.16	809	4.9	0.03	809	0.88	0.00
2008	1	844	65	0.17	817	2.1	0.02	817	0.76	0.00
2009	1	588	79	0.45	571	3.8	0.08	571	0.77	0.00
2010	1	1,205	69	0.17	1,205	2.6	0.02	1,205	0.76	0.00
2011	1	1,401	70	0.22	1,400	2.8	0.03	1,400	0.88	0.01
2012	1	733	68	0.25	733	2.2	0.04	733	0.68	0.00
2013	1	793	72	0.25	792	3.1	0.03	792	0.81	0.00

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Table 5.–Page 2 of 2.

		Length (mm)			Weight (g)			Condition Factor		
		Sample		Standard	Sample		Standard	Sample		Standard
Year	Age	Size	Mean	Error	Size	Mean	Error	Size	Mean	Error
1994	2	1,091	77	0.22	1,068	3.6	0.04	1,068	0.74	0.00
1995	2	1,008	75	0.23	1,008	3.5	0.04	1,008	0.80	0.00
1996	2	548	80	0.34	533	4.2	0.06	533	0.81	0.00
1997	2	772	83	0.25	772	4.7	0.05	772	0.80	0.00
1998	2	1,925	72	0.13	1,881	3.0	0.03	1,881	0.76	0.00
1999	2	784	81	0.28	784	4.8	0.07	784	0.89	0.00
2000	2	503	76	0.34	503	3.6	0.07	503	0.80	0.00
2001	2	389	75	0.45	387	3.4	0.09	387	0.77	0.01
2002	2	225	80	0.78	225	4.9	0.18	225	0.88	0.01
2003	2	279	76	0.48	279	3.5	0.09	279	0.76	0.01
2004	2	274	77	0.41	274	3.9	0.09	274	0.82	0.00
2005	2	397	76	0.33	397	3.5	0.06	397	0.79	0.00
2006	2	518	78	0.35	518	3.8	0.08	518	0.78	0.00
2007	2	272	90	0.36	272	6.6	0.09	272	0.91	0.00
2008	2	288	79	0.35	287	3.7	0.06	287	0.73	0.01
2009	2	413	80	0.31	411	4.0	0.05	411	0.76	0.00
2010	2	359	81	0.30	359	4.0	0.05	359	0.74	0.00
2011	2	159	78	0.71	158	4.1	0.16	158	0.82	0.01
2012	2	452	78	0.27	452	3.4	0.05	452	0.69	0.00
2013	2	632	80	0.33	630	4.1	0.07	630	0.78	0.00
1997	3	12	87	1.34	12	5.2	0.35	12	0.77	0.02
1998	3	20	84	3.39	19	5.5	0.99	19	0.81	0.02
1999	3	7	90	5.76	7	6.8	1.66	7	0.85	0.03
2000	3	14	86	2.36	14	5.3	0.63	14	0.79	0.01
2001	3	62	90	1.60	61	6.9	0.42	61	0.86	0.01
2002	3	6	110	7.24	6	13.8	2.67	6	1.00	0.03
2005	3	7	108	4.35	7	11.4	1.21	7	0.89	0.02
2006	3	32	99	1.89	32	8.9	0.55	32	0.89	0.02
2008	3	17	91	2.54	17	6.1	0.70	17	0.77	0.02
2010	3	2	92	1.50	2	6.0	0.35	2	0.78	0.01
2012	3	5	87	1.66	5	4.4	0.27	5	0.66	0.02
2013	3	16	92	1.25	16	6.3	0.36	16	0.80	0.01
2001	4	1	125	-	1	18.8	-	1	0.96	-

Table 6.–Euphotic Zone Depth (EZD) and Euphotic Volume (EV) of Chignik and Black lakes, by month, 2013.

		2013				
Lake		May[a]	June	July	September	Average[b]
Chignik	EZD	9.97	7.10	7.02	4.99	7.27
	Mean Ev[d]	240.3	171.1	169.2	120.3	175.2
Black[c]	EZD		4.03	5.16	3.35	4.18
	Mean Ev[d]		78.09	78.09	78.09	78.09

[a] Black Lake was not sampled in May.

[b] EZD calculated per station then averaged for the month (µmol/s/m^2).

[c] The mean depth of Black Lake is 1.9 m; this value was used for the EV calculations instead of the EZD's when the EZD exceeded 1.9 m.

[d] EV units = x 10^6 m^3

Table 7.–Water quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Black Lake, 2013.

	2013[a]			
	13-Jun	5-Jul	9-Sep	Average
pH[b]	ND	7.8	8.0	7.9
Alkalinity (mg/L $CaCO_3$)[b]	ND	25.5	33.5	29.5
Total phosphorous (µg/L P)	28.8	31.4	35.4	31.9
Total filterable phosphorous (µg/L P)	4.8	4.2	5.8	4.9
Filterable reactive phosphorous (µg/L P)	1.1	1.0	1.8	1.3
Total Kjeldhal nitrogen (µg/L N)	833.0	973.0	1,133.0	979.7
Ammonia (µg/L N)	4.1	4.1	4.9	4.4
Nitrate + Nitrite (µg/L N)	2.9	2.6	3.3	2.9
Silicon (µg/L)	2,071.2	1,318.4	1,233.9	1,541.2
Chlorophyll a (µg/L)	4.4	3.5	7.0	5.0
Phaeophytin a (µg/L)	2.1	0.5	2.6	1.7

[a] Limnology sampling did not occur in May or August 2013.

[b] pH and alkalinity were not measured in June 2013.

Table 8.–Water quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Chignik Lake, 2013. All stations and depths are averaged for each sample date.

	2013[a]				
	6-May	17-Jun	8-Jul	5-Sep	Average
pH	7.9	7.8	7.4	7.7	7.7
Alkalinity (mg/L $CaCO_3$)	31.0	26.0	23.3	24.4	26.2
Total phosphorous (µg/L P)	12.3	14.4	12.6	18.5	14.4
Total filterable phosphorous (µg/L P)	3.8	2.8	2.8	2.5	3.0
Filterable reactive phosphorous (µg/L P)	2.7	1.5	1.7	1.8	1.9
Total Kjeldhal nitrogen (µg/L N)[b]	981.0	144.5	118.5	134.0	344.5
Ammonia (µg/L N)	4.6	4.1	9.6	4.9	5.8
Nitrate + Nitrite (µg/L N)	181.2	137.4	120.5	94.0	133.3
Silicon (µg/L)	6,035.7	4,496.6	3,491.0	3,756.9	4,445.0
Chlorophyll a (µg/L)	2.1	2.6	2.3	4.7	2.9
Phaeophytin a (µg/L)	0.8	0.4	0.6	0.9	0.7

[a] Limnology sampling did not occur in August 2013.

[b] TKN values came from 1m samples only.

Table 9.–Average number of zooplankton by taxon per m^2 from Black Lake by sample date, 2013.

Taxon		Sample date[a]			Seasonal
		13-Jun	5-Jul	9-Sep	average
Copepods					
	Cyclops	108,917	24,522	11,943	48,461
	Epischura	9,554	6,423	16,720	10,899
	Ovig. Epischura	0	1,752	0	584
	Eurytemora	7,166	3,503	5,971	5,547
	Ovig. Eurytemora	6,369	1,752	0	2,707
	Nauplii	67,516	35,616	19,904	41,012
Total copepods		199,522	73,567	54,538	109,209
Cladocerans					
	Bosmina	12,739	51,380	11,147	25,088
	Ovig. Bosmina	0	1,752	0	584
	Chydorinae	33,758	33,864	12,739	26,787
	Ovig. Chydorinae	3,185	1,752	0	1,645
	Daphnia L.	3,185	0	0	1,062
	Holopedium	0	1,752	0	584
	Immature Cladocera	36,306	54,299	19,904	36,837
Total cladocerans		89,172	144,798	43,790	92,587
Total copepods + cladocerans		288,694	218,365	98,328	201,796

[a] Zooplankton samples were not collected in May and August 2013.

Table 10.–Biomass estimates (mg dry weight/m^2) of the major Black Lake zooplankton taxa by sample date, 2013.

Taxon		Sample date[a]			Seasonal	Weighted
		13-Jun	5-Jul	9-Sep	average	average
Copepods						
	Cyclops	93.84	26.59	7.74	42.72	42.55
	Epischura	8.38	5.93	10.48	8.26	8.18
	Ovig. Epischura	0.00	19.27	0.00	6.42	6.42
	Eurytemora	27.57	18.39	29.40	25.12	25.04
	Ovig. Eurytemora	63.87	16.08	0.00	26.65	26.64
Total copepods		193.66	86.26	47.62	109.17	108.83
Cladocerans						
	Bosmina	11.13	57.89	8.61	25.87	25.73
	Ovig. Bosmina	0.00	2.65	0.00	0.88	0.88
	Chydorinae	21.73	19.92	6.17	15.94	15.91
	Ovig. Chydorinae	3.03	2.32	0.00	1.78	1.77
	Holopedium	0	3.86	0	1.29	1.29
Total cladocerans		35.89	86.64	14.78	45.76	45.58
Total biomass		229.55	172.90	62.40	154.93	154.41

[a] Zooplankton samples were not collected in May and August 2013.

Table 11.–Weighted average length (mm) of zooplankton from Black Lake by sample date, 2013.

Taxon		Sample date[a]			Weighted average
		13-Jun	5-Jul	9-Sep	
Copepods					
	Cyclops	0.51	0.57	0.45	0.52
	Epischura	0.56	0.57	0.50	0.53
	Ovig. Epischura	0.00	1.37	0.00	1.37
	Eurytemora	0.78	0.94	0.90	0.86
	Ovig. Eurytemora	1.40	1.33	0.00	1.39
Cladocerans					
	Bosmina	0.31	0.35	0.29	0.34
	Ovig. Bosmina	0.00	0.40	0.00	0.41
	Chydorinae	0.27	0.26	0.24	0.26
	Ovig. Chydorinae	0.32	0.38	0.00	0.34
	Holopedium	0.00	0.51	0.00	0.51

[a] Zooplankton samples were not collected in May and August 2013.

Table 12.–Average number of zooplankton by taxon per m^2 from Chignik Lake by sample date, 2013.

Taxon		Sample date[a]			Seasonal
	6-May	17-Jun	8-Jul	5-Sep	Average
Copepods					
Cyclops	281,701	127,282	93,568	109,395	152,987
Ovig. Cyclops	0	0	46,278	3,463	12,435
Epischura	995	4,558	6,486	24,283	9,081
Ovig. Epischura	0	0	0	398	100
Eurytemora	0	4,684	9,156	38,190	13,008
Ovig. Eurytemora	0	0	2,189	1,393	896
Harpacticus	0	597	0	0	149
Nauplii	117582	29,830	91,212	129,591	92,054
Total copepods	400,278	166,952	248,889	306,714	280,708
Cladocerans					
Bosmina	2,030	3,457	28,414	69,427	25,832
Ovig. Bosmina	796	398	1,791	3,463	1,612
Chydorinae	597	3,251	21,497	13,004	9,587
Ovig. Chydorinae	0	0	398	0	100
Daphnia L.	26,964	3,888	9,305	308,957	87,279
Ovig. Daphnia L.	1446.39	677	2,090	43,830	12,011
Immature Cladocera	2,229	12,540	20,701	53,769	22,310
Total cladocerans	34,063	24,210	84,196	492,450	158,730
Total copepods + cladocerans	434,341	191,162	333,084	799,164	439,438

[a] Zooplankton samples were not collected in August 2013.

Table 13.–Biomass estimates (mg dry weight/m^2) of the major Chignik Lake zooplankton taxa by sample date, 2013.

		Sample date[a]				Seasonal	Weighted
Taxon		6-May	17-Jun	8-Jul	5-Sep	Average	average
Copepods							
	Cyclops	256.40	306.03	149.39	58.27	192.52	165.90
	Ovig. Cyclops	0.00	0.00	227.39	16.67	61.01	57.04
	Epischura	1.14	4.68	5.78	14.71	6.58	6.45
	Ovig. Epischura	0.00	0.00	0.00	4.29	1.07	1.07
	Eurytemora	0.00	29.14	62.87	242.01	83.51	84.60
	Ovig. Eurytemora	0.00	0.00	21.19	10.36	7.89	7.84
	Harpacticus	0.00	1.06	0.00	0.00	0.27	0.27
Total copepods		257.54	340.91	466.62	346.31	352.85	323.17
Cladocerans							
	Bosmina	1.32	3.40	30.11	73.45	27.07	27.70
	Ovig. Bosmina	0.89	0.59	3.18	4.88	2.39	2.39
	Chydorinae	0.48	2.60	11.64	7.51	5.56	5.62
	Ovig. Chydorinae	0.00	0.00	0.32	0.00	0.08	0.08
	Daphnia L.	31.39	2.28	9.45	319.85	90.74	90.89
	Ovig. Daphnia L.	5.21	1.38	5.42	108.45	30.12	29.42
Total cladocerans		39.29	10.25	60.12	514.14	155.96	156.10
Total biomass		296.83	351.16	526.74	860.45	508.81	479.27

[a] Zooplankton samples were not collected in August 2013.

Table 14.–Weighted average length (mm) of zooplankton from Chignik Lake by sample date, 2013.

Taxon		Sample date[a]				Weighted
		6-May	17-Jun	8-Jul	5-Sep	average
Copepods						
	Cyclops	0.52	0.76	0.68	0.40	0.57
	Ovig. Cyclops	0.00	0.00	1.12	1.09	1.12
	Epischura	0.62	0.59	0.56	0.50	0.52
	Ovig. Epischura	0.00	0.00	0.00	1.36	1.36
	Eurytemora	0.00	1.10	1.13	1.06	1.07
	Ovig. Eurytemora	0.00	0.00	1.38	1.16	1.29
	Harpacticus	0.00	0.72	0.00	0.00	0.72
Cladocerans						
	Bosmina	0.27	0.34	0.33	0.35	0.34
	Ovig. Bosmina	0.35	0.40	0.43	0.40	0.40
	Chydorinae	0.3	0.31	0.25	0.25	0.26
	Ovig. Chydorinae	0	0.00	0.30	0.00	0.30
	Daphnia L.	0.53	0.38	0.50	0.50	0.50
	Ovig. Daphnia L.	0.89	0.69	0.78	0.74	0.75

[a] Zooplankton samples were not collected in August 2013.

Table 15.–Chignik River sockeye salmon escapement, estimated number of smolt by freshwater age, smolt per spawner, adult return by freshwater age, return per spawner, marine survival, by brood year 1991 through 2006.

Brood		Smolt Produced					Smolt /	Adult Returns					Return /	Marine
Year	Escapement	Age-0.	Age-1.	Age-2.	Age-3.	Total Smolt	Spawner	Age-0.	Age-1.	Age-2.	Age-3.	Total	Spawner	Survival
1991	1,040,098	NA	NA	4,270,636	0	4,270,636	4.11	6,868	1,795,467	737,680	11,621	2,551,636	2.45	NA
1992	764,436	NA	7,263,054	5,178,450	5,018	12,446,522	16.28	152,005	649,920	1,159,871	93,372	2,055,168	2.69	17%
1993	697,377	0	2,843,222	731,099	122,289	3,696,610	5.30	16,270	457,189	1,998,416	7,265	2,479,140	3.55	67%
1994	966,909	735,916	1,200,793	13,738,356	158,056	15,833,121	16.37	251	1,818,410	1,483,548	2,467	3,304,676	3.42	21%
1995	739,920	80,254	11,172,150	20,374,245	78,798	31,705,447	42.85	36,053	2,391,218	942,680	17,366	3,387,317	4.58	11%
1996[a]	749,137	528,846	5,790,587	8,221,631	160,017	14,701,081	19.63	145,189	1,998,842	877,180	13,958	3,035,168	4.05	21%
1997	775,618	75,560	12,705,935	4,645,121	516,723	17,943,339	23.13	15,852	770,645	956,005	5,627	1,748,129	2.25	10%
1998	701,128	73,364	8,047,526	5,024,666	72,184	13,217,740	18.85	5,515	1,030,709	350,167	1,052	1,387,443	1.98	10%
1999	715,966	1,270,101	18,940,752	2,223,996	0	22,434,849	31.34	26,176	913,849	403,536	1,663	1,345,224	1.88	6%
2000	805,225	521,546	13,980,423	1,449,494	0	15,951,463	19.81	15,176	1,988,373	699,285	2,729	2,705,565	3.36	17%
2001	1,136,918	440,947	5,146,278	2,239,716	32,889	7,859,830	6.91	78,019	1,031,100	696,415	482	1,807,624	1.59	23%
2002	725,220	155,047	6,172,902	1,468,208	119,614	7,915,771	10.91	17,633	700,976	412,758	2,079	1,136,292	1.57	14%
2003	684,145	244,206	2,075,681	2,847,624	0	5,167,511	7.55	84,284	875,278	736,979	3,227	1,699,768	2.48	33%
2004	578,259	859,211	2,849,043	1,028,865	41,136	4,778,255	8.26	131,023	1,067,014	987,159	10,222	2,195,418	3.80	46%
2005	581,382	1,744,370	1,926,682	987,928	0	4,658,980	8.01	28,613	1,461,254	935,660	93,748	2,519,275	4.33	54%
2006	735,493	9,286	3,309,894	4,874,340	91,509	8,285,029	11.26	33,123	2,865,182	1,866,513	54,846	4,819,664	6.55	58%
2007	654,974	1,017,498	3,242,862	9,347,999	0	13,608,359	20.78	47,465	520,516	1,278,539				
2008	706,058	59,306	17,684,165	1,371,044	196,575	19,311,090	27.35	17,460	3,040,192					
2009	720,062	1,039,131	10,684,120	22,734,743	176,196	34,634,189	48.10	4,830						
2010	743,911	203,380	16,328,172	10,467,154										
2011	753,817	685,707	8,314,053											
2012	712,389	117,435												
2013	756,101													
1992-2006 Average, excluding 1996													3.15	28%

[a] 1996 data are presented, but considered erroneous due to unrealistic survival estimates and thus not used in subsequent calculations.

Table 16.–Chignik River sockeye salmon smolt estimates, ocean-age-class returns, and marine survival by outmigration years 1994 through 2009.

Emigration	Smolt estimates					Adult returns					Marine
Year	Age-0.	Age-1.	Age-2.	Age-3.	Total Smolt	Age-.1	Age-.2	Age-.3	Age-.4	Total	Survival
1994	0	7,263,054	4,270,636	0	11,533,690	4,063	208,548	1,207,343	9,782	1,429,736	12%
1995	735,916	2,843,222	5,178,450	0	8,757,588	14,186	343,315	1,267,456	3,975	1,628,932	19%
1996[a]	80,245	1,200,793	731,099	5,018	2,017,155	28,209	675,848	3,225,337	16,857	3,946,250	196%
1997	528,846	11,172,150	13,738,356	122,289	25,561,641	11,814	1,232,238	2,767,364	15,622	4,027,038	16%
1998	75,560	5,790,587	20,374,245	158,056	26,398,448	601	170,545	2,756,954	31,741	2,959,840	11%
1999	73,364	12,705,935	8,221,631	78,798	21,079,728	446	136,822	1,524,022	9,416	1,670,706	8%
2000	1,270,101	8,047,526	4,645,121	160,017	14,122,765	5,460	404,961	1,611,191	5,237	2,026,848	14%
2001	521,546	18,940,752	5,024,666	516,723	25,003,687	324	229,693	1,051,600	3,203	1,284,819	5%
2002	440,947	13,980,423	2,223,996	72,184	16,717,551	4,164	432,476	2,013,710	22,238	2,472,588	15%
2003	155,047	5,146,278	1,449,494	0	6,750,819	2,282	158,558	1,540,591	51,097	1,752,528	26%
2004	244,206	6,172,902	2,239,716	0	8,656,824	1,316	178,412	1,285,999	17,447	1,483,173	17%
2005	859,211	2,075,681	1,468,208	32,889	4,435,988	804	204,180	1,205,391	9,166	1,419,541	32%
2006	1,744,370	2,849,043	2,847,624	119,614	7,560,651	771	169,698	1,655,282	8,933	1,834,684	24%
2007	9,286	1,926,682	1,028,865	0	2,964,833	793	429,607	2,041,386	12,977	2,484,763	84%
2008	1,017,498	3,309,894	987,928	41,136	5,356,455	1,734	337,732	3,457,883	61,180	3,858,529	72%
2009	110,446	3,777,572	4,288,491	0	8,176,509	6,022	425,225	2,043,248	23,742	2,484,764	30%
2010	1,039,131	17,684,165	9,347,999	91,509	28,162,803	6,097	856,890	3,515,393			
2011	203,380	10,684,120	1,371,044	0	12,258,543	2,423	131,811				
2012	685,707	16,328,172	22,734,743	196,575	39,945,197	5,249					
2013	117,435	8,314,053	10,467,154	176,196	19,074,838						
1994-2009 Average, Excluding 1996											26%

[a] 1996 data are presented, but considered erroneous due to unrealistic survival estimates and thus not used in subsequent calculations.

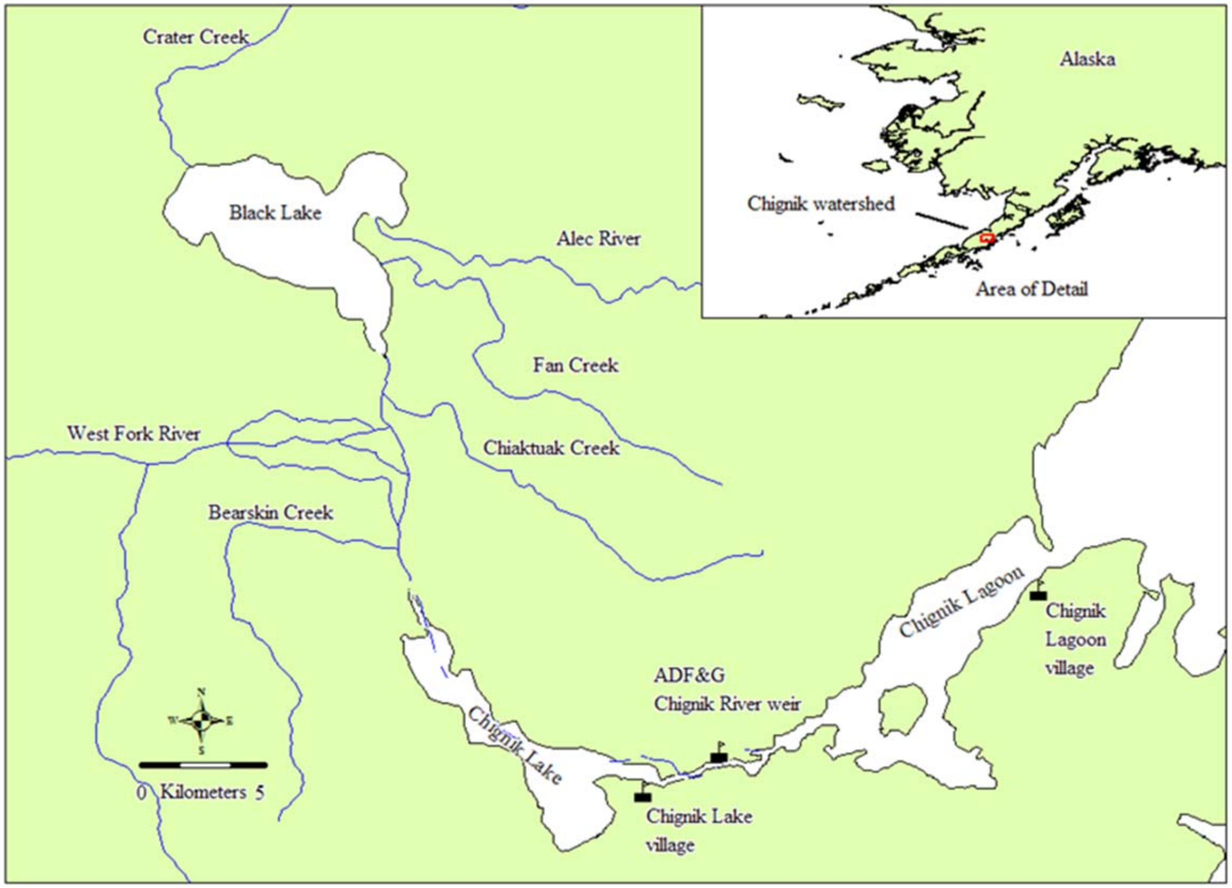

Figure 1.–Map of the Chignik River Basin.

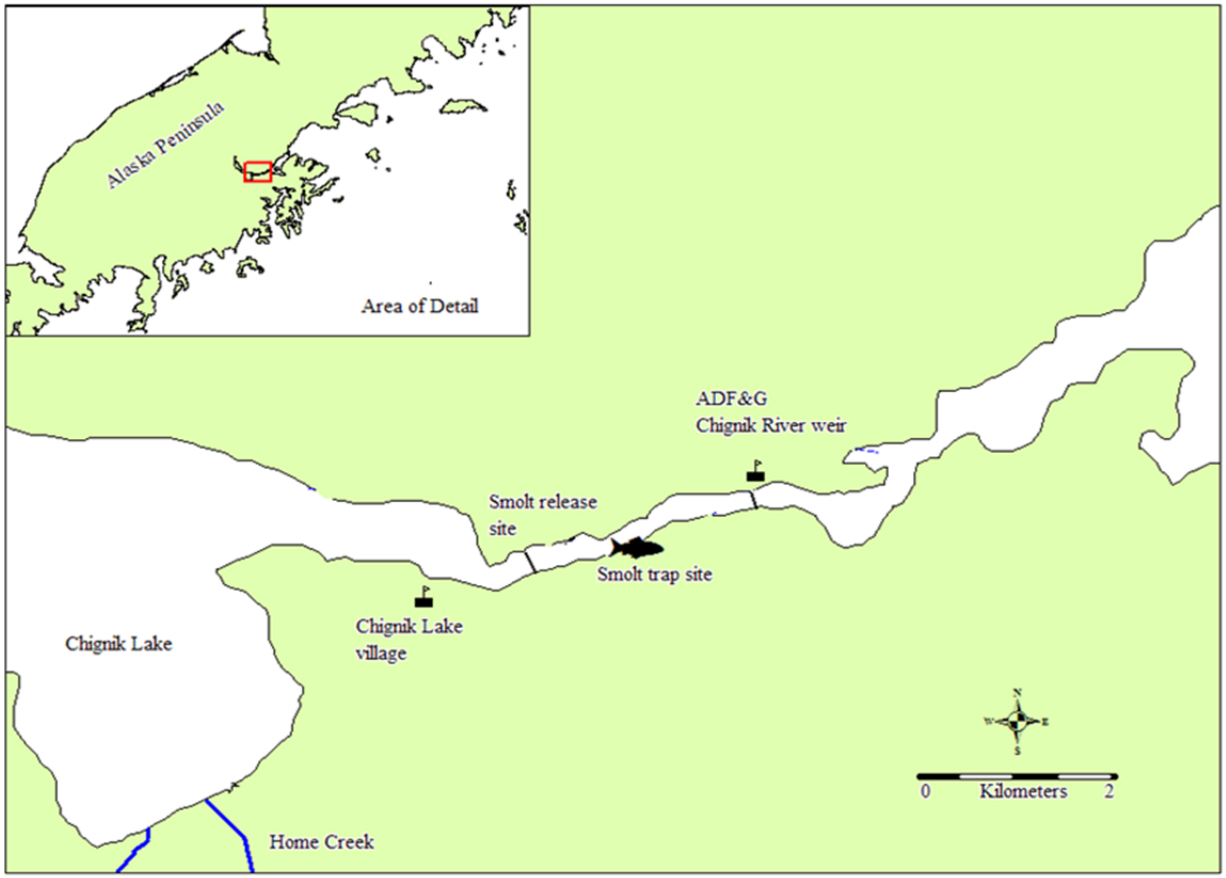

Figure 2.–Location of the traps and the release site of marked smolt in the Chignik River, Alaska, 2013.

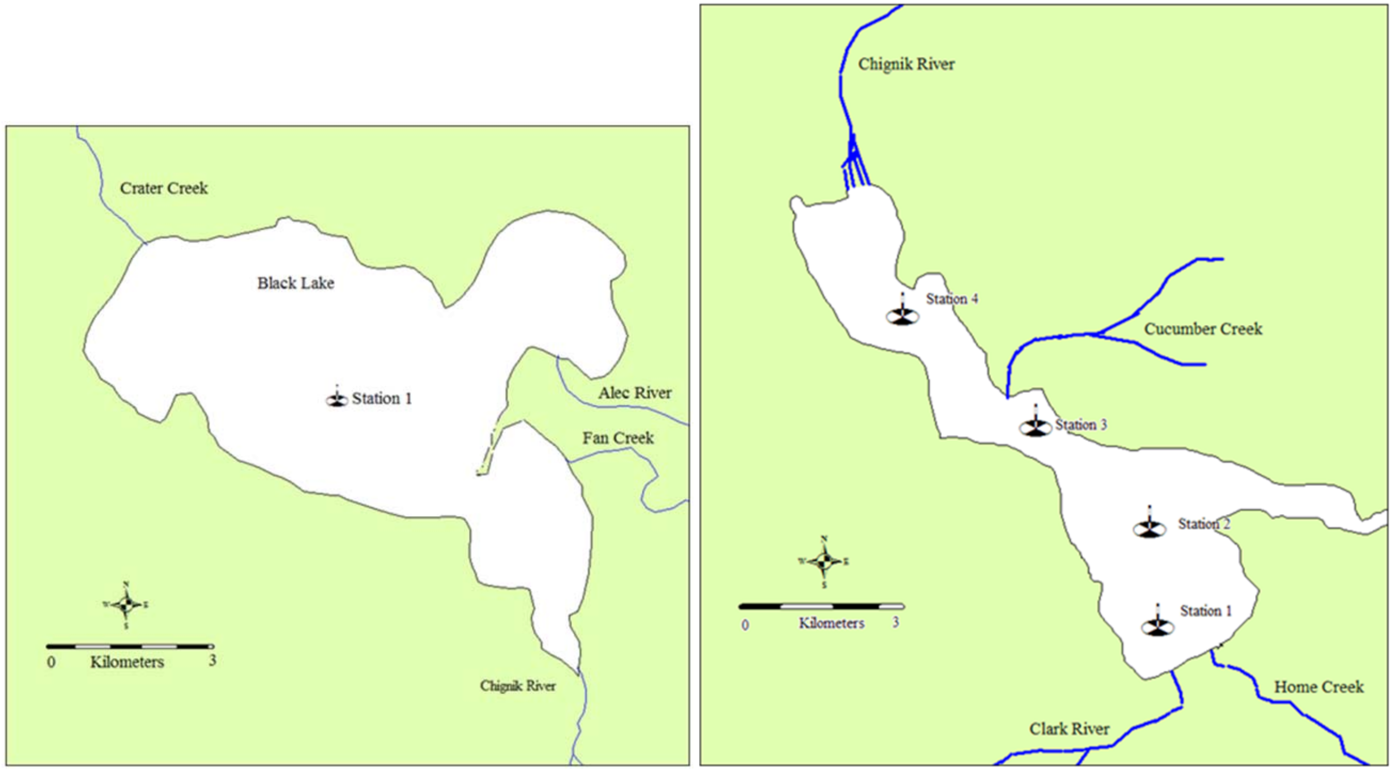

Figure 3.–Location of the Black Lake and Chignik Lake limnology sampling stations, 2013.

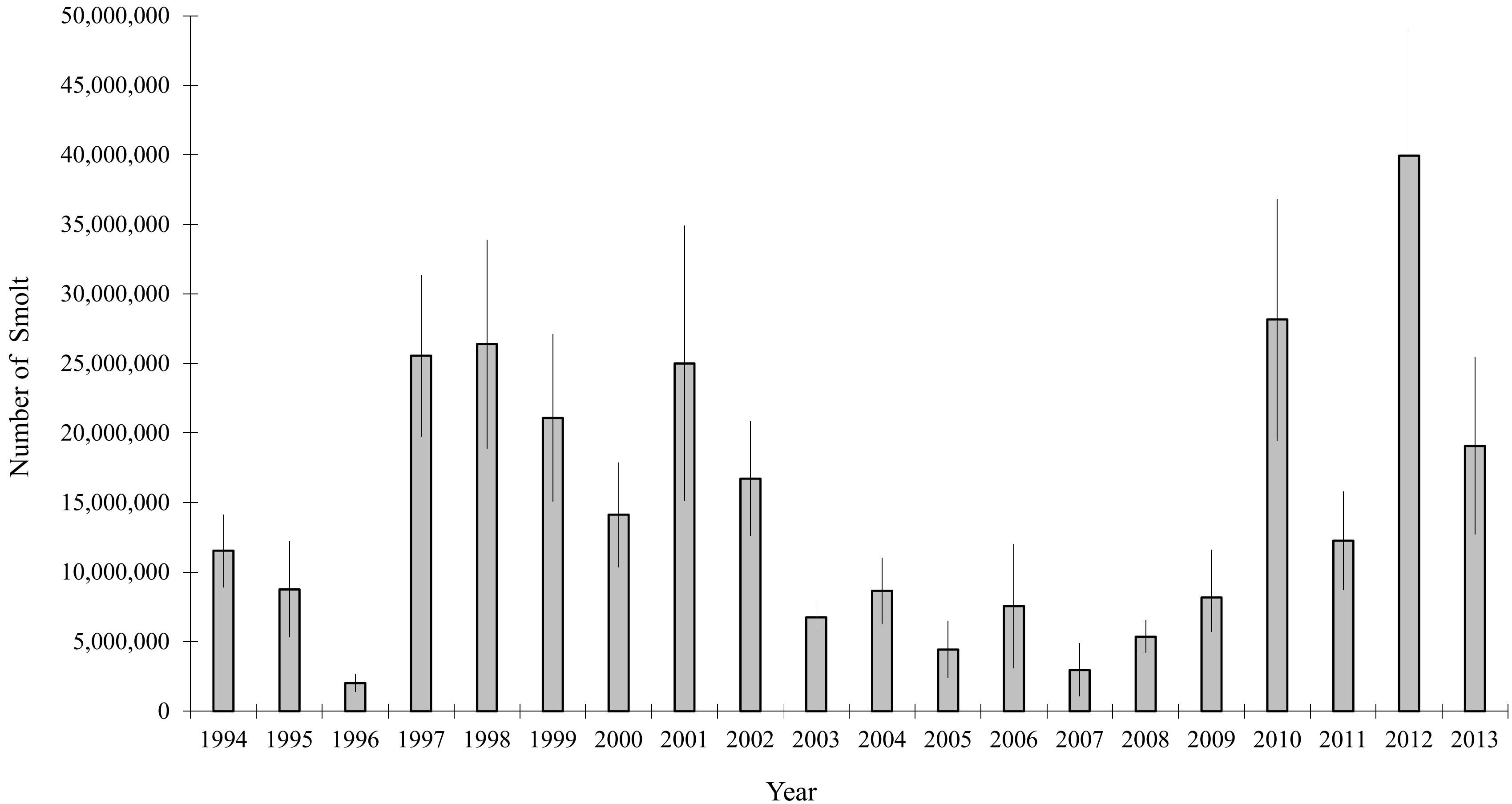

Figure 4.–Annual sockeye salmon smolt outmigration estimates and corresponding 95% confidence intervals, Chignik River, 1994–2013. Outmigration estimates from 1996 were underestimated.

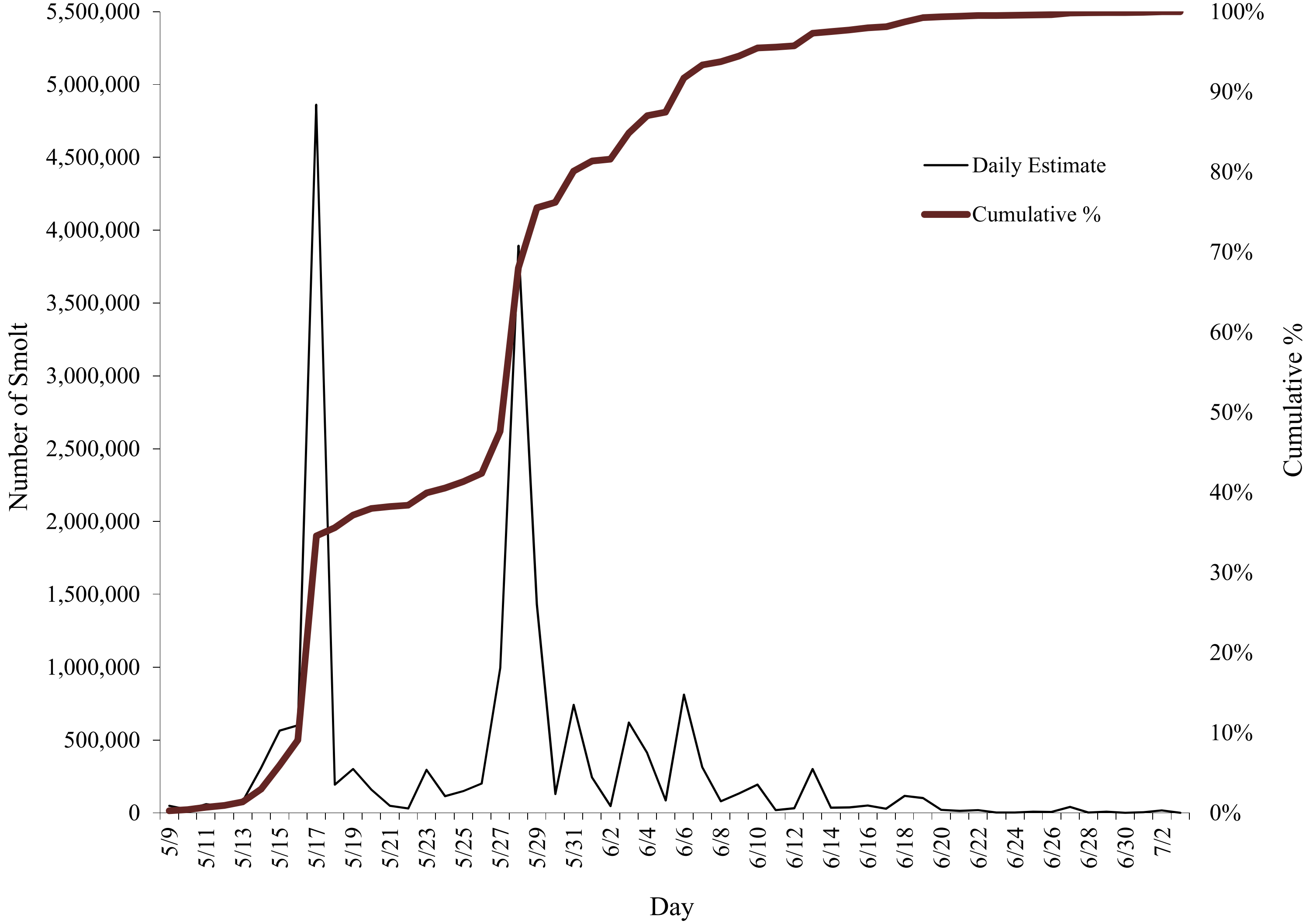

Figure 5.–Daily estimate and cumulative percentage of the sockeye salmon smolt outmigration from the Chignik River in 2013.

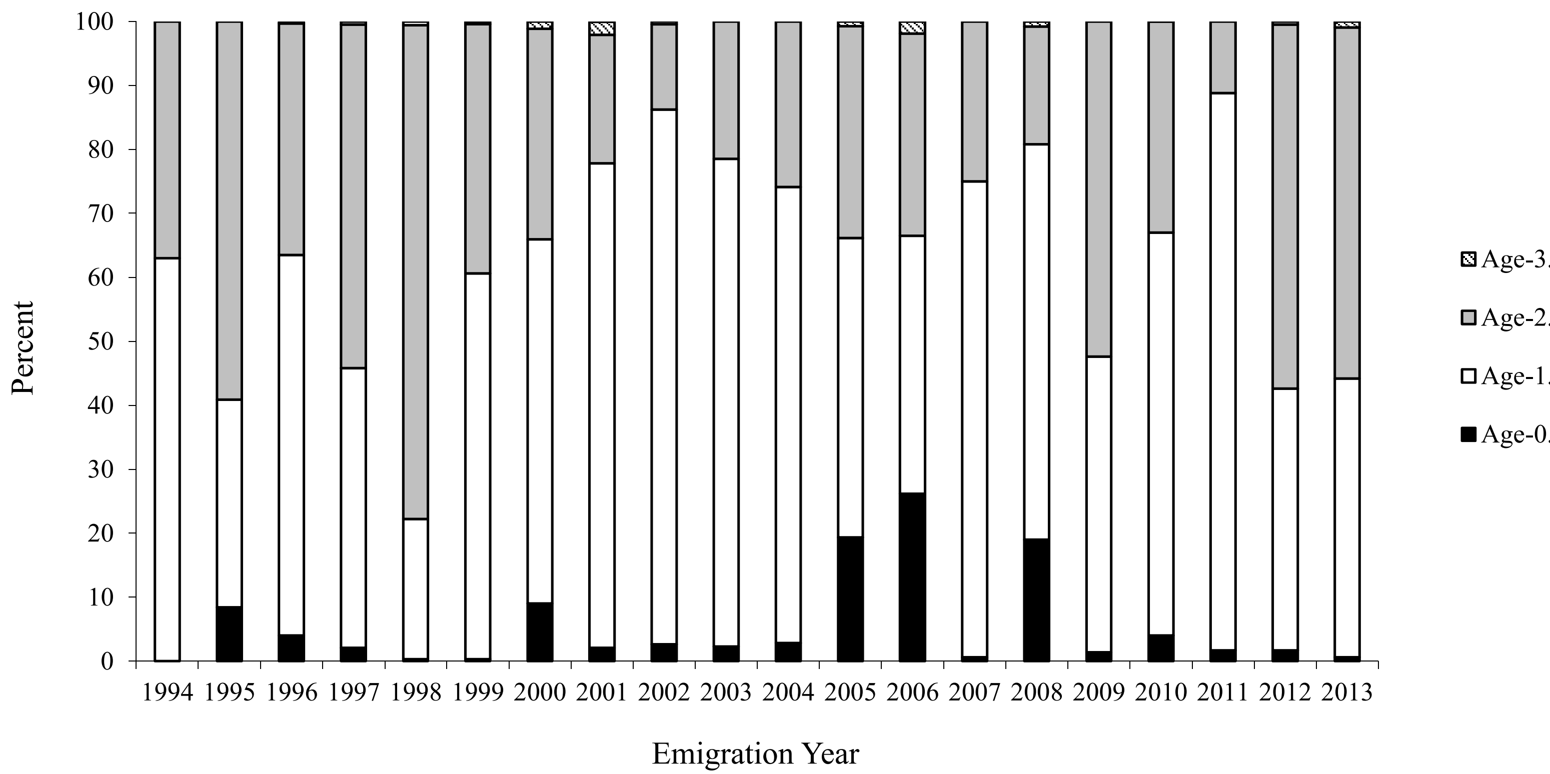

Figure 6.–A comparison of the estimated age structure of age-0. to age-3. sockeye salmon smolt outmigrations from the Chignik River, 1994–2013.

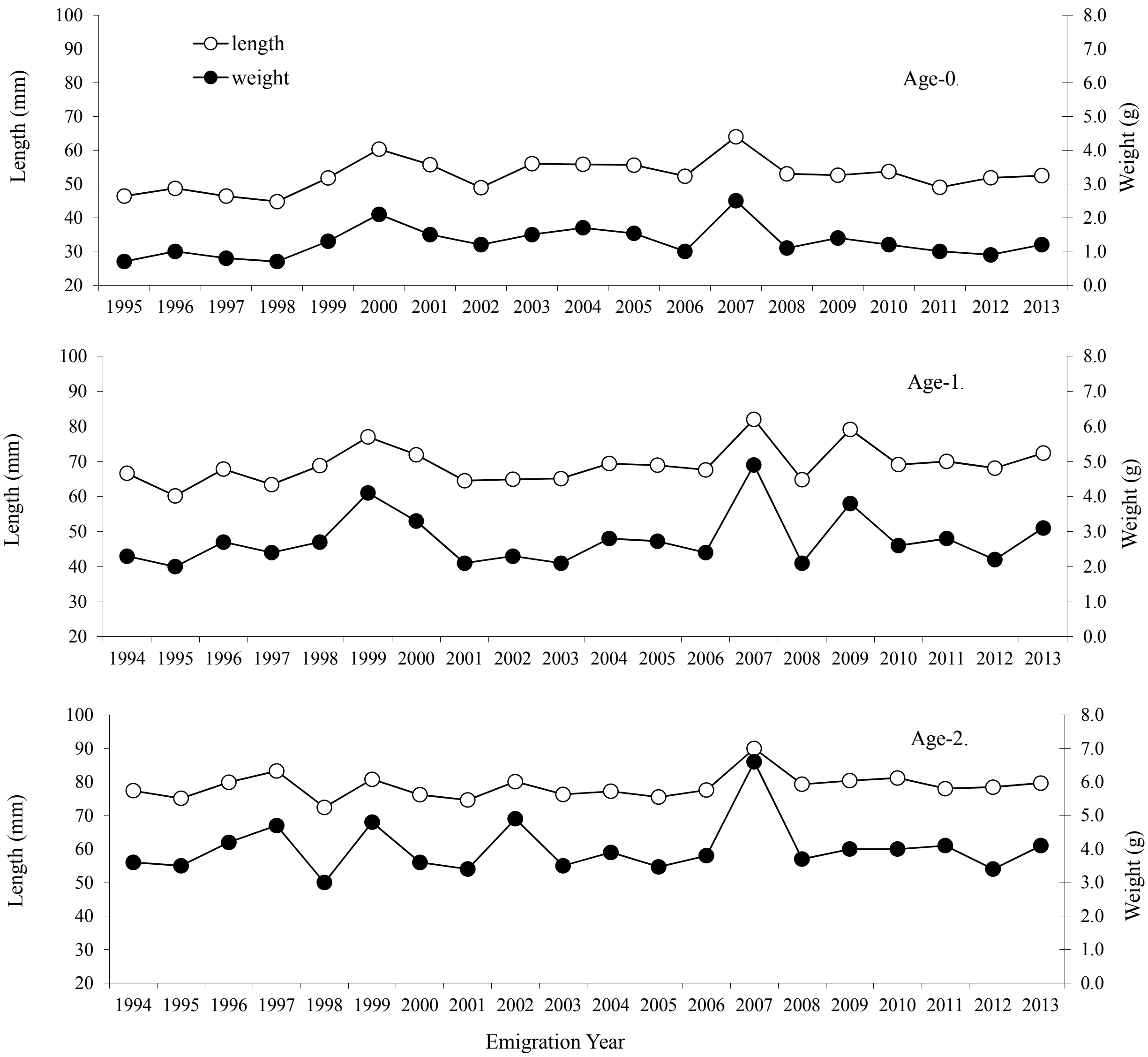

Figure 7.–Average length and weight of sampled age-0., age-1. and age-2. sockeye salmon smolt, by year from 1994 to 2013. Age-3. smolt comprise such a small percentage of the yearly population as to be negligible.

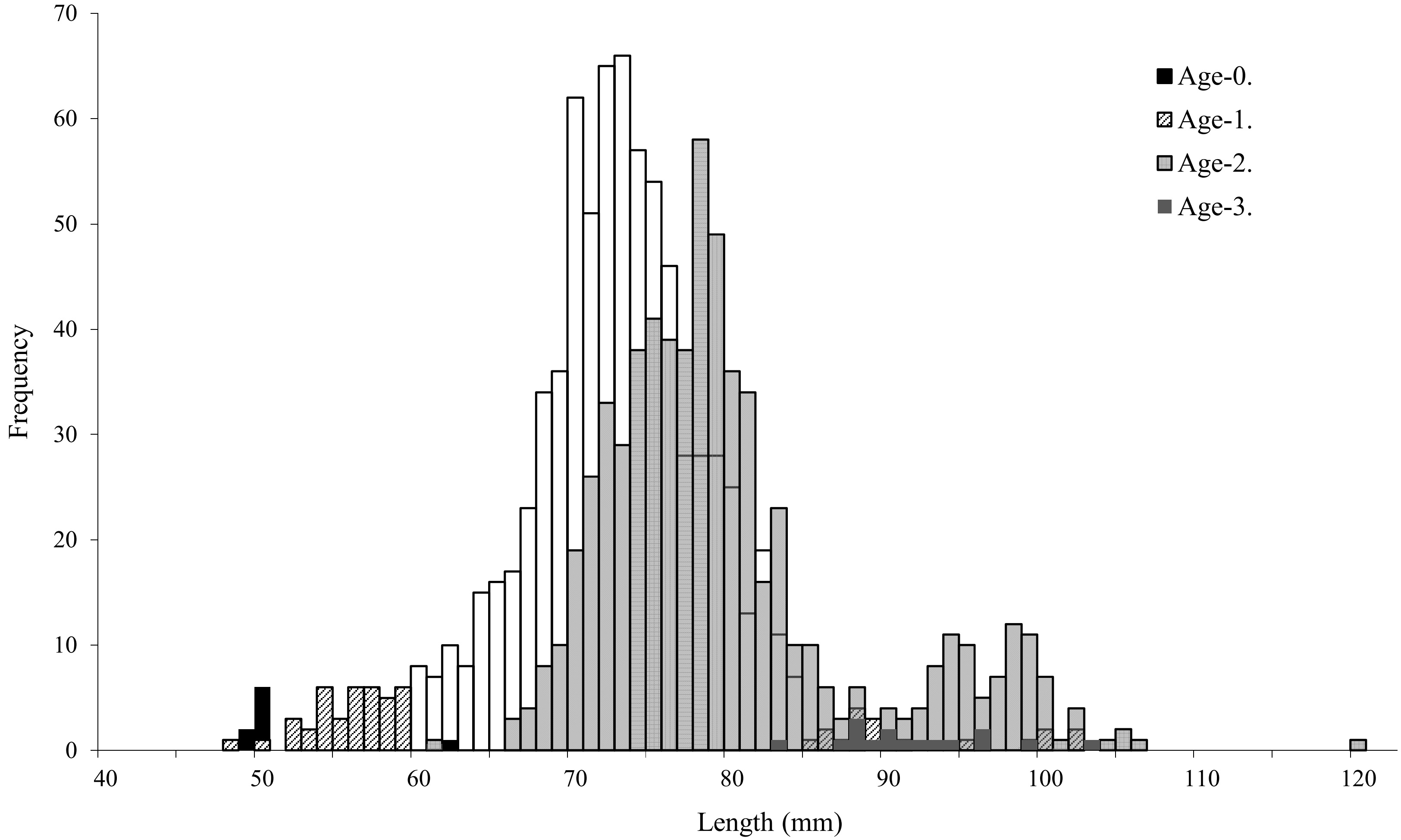

Figure 8.–Length frequency histogram of sockeye salmon smolt from the Chignik River in 2013 by age.

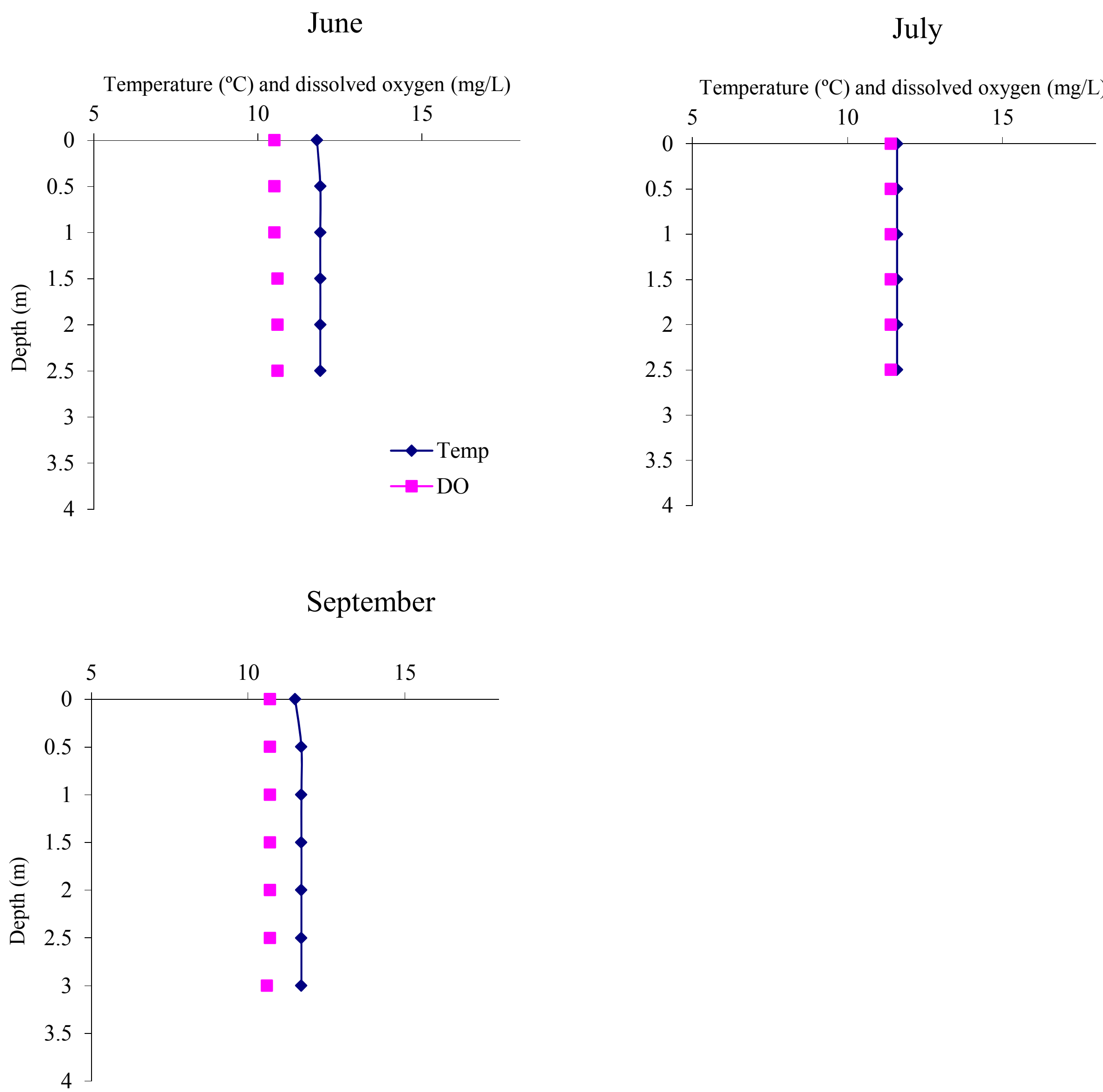

Figure 9.–Mean monthly temperature and dissolved oxygen profiles in Black Lake in 2013.

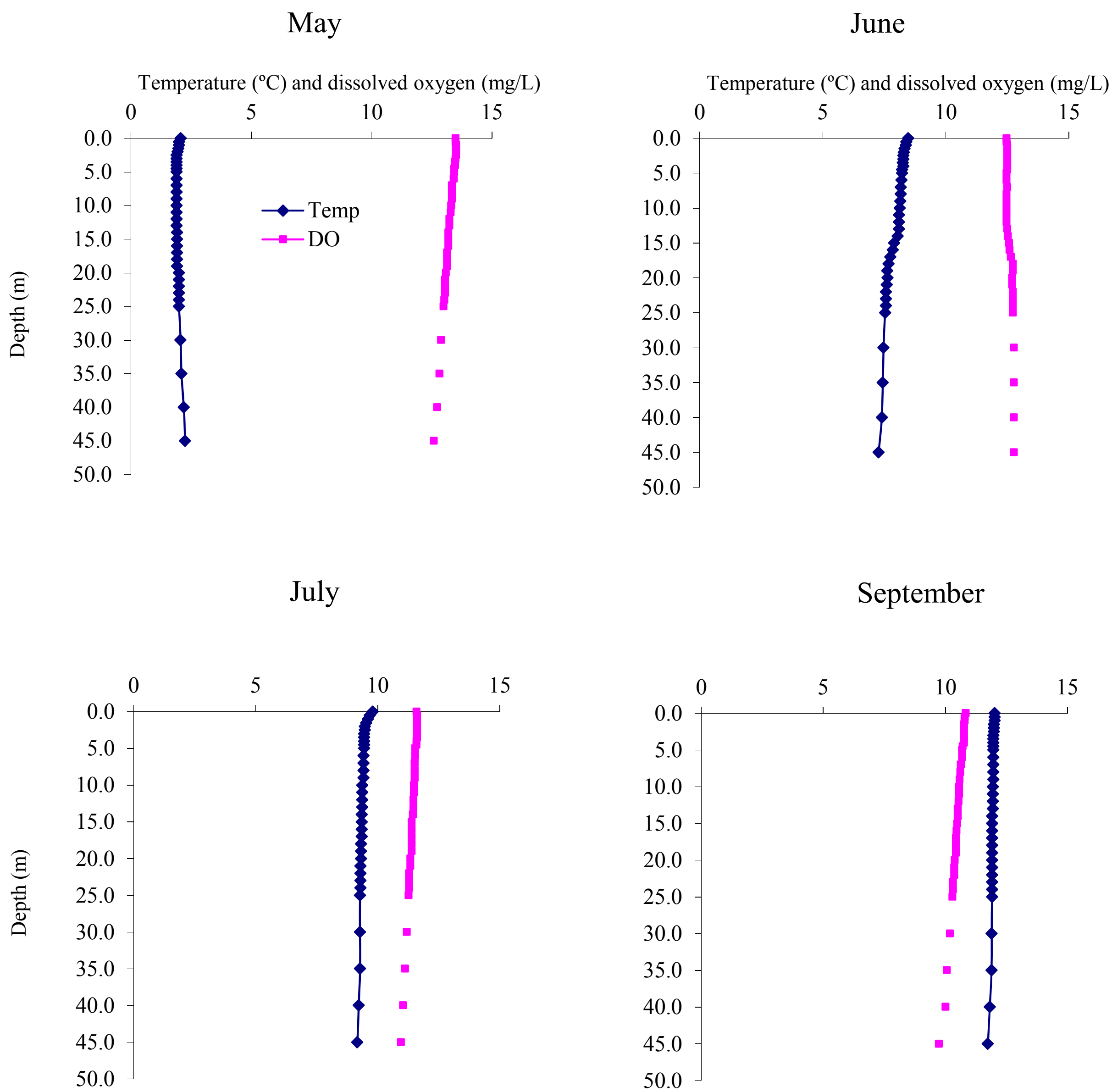

Figure 10.–Mean monthly temperature and dissolved oxygen profiles in Chignik Lake in 2013.

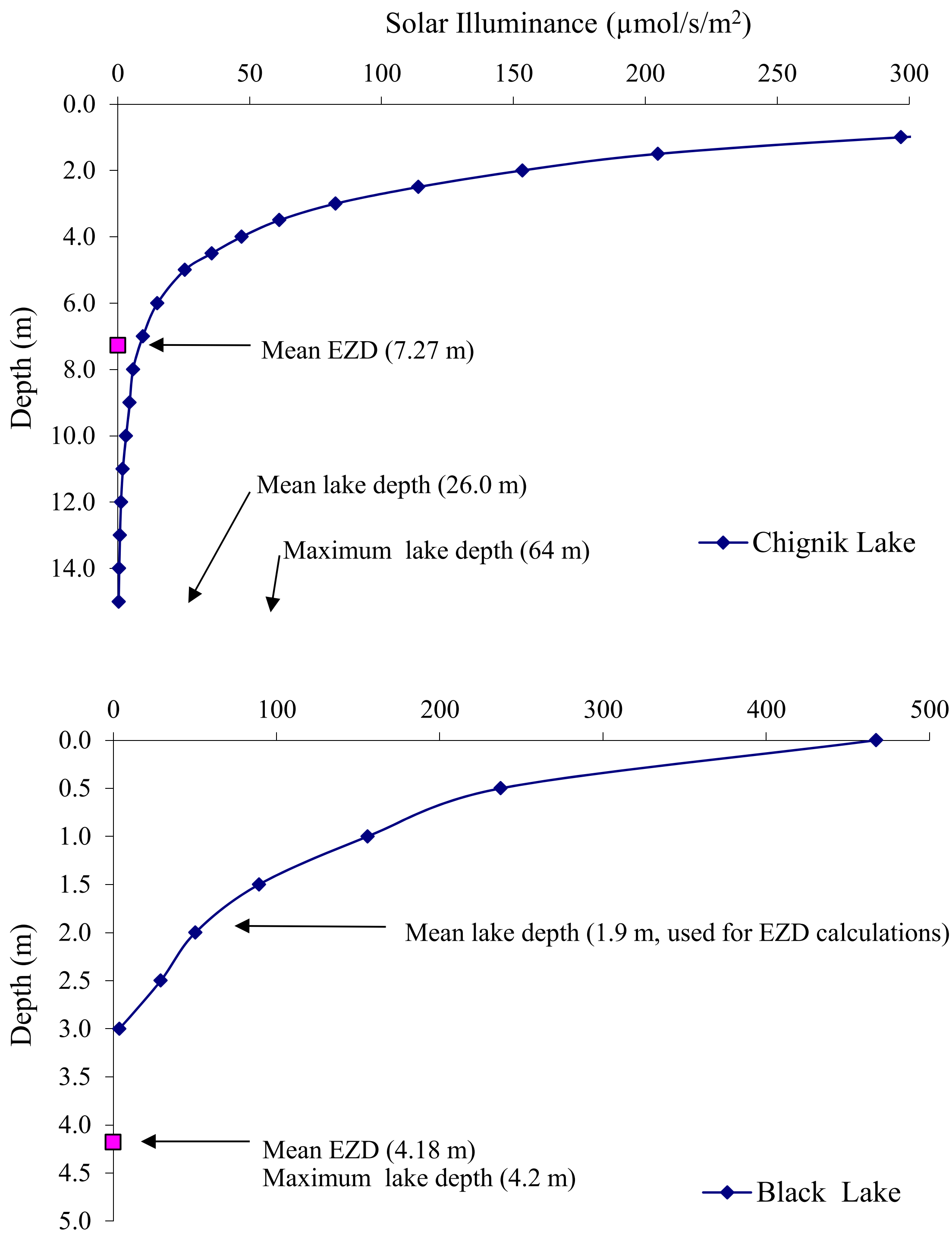

Figure 11.–Light penetration curves relative to mean depth, euphotic zone depth (EZD), and maximum depth in Chignik and Black lakes in 2013. Note differences in the axes.

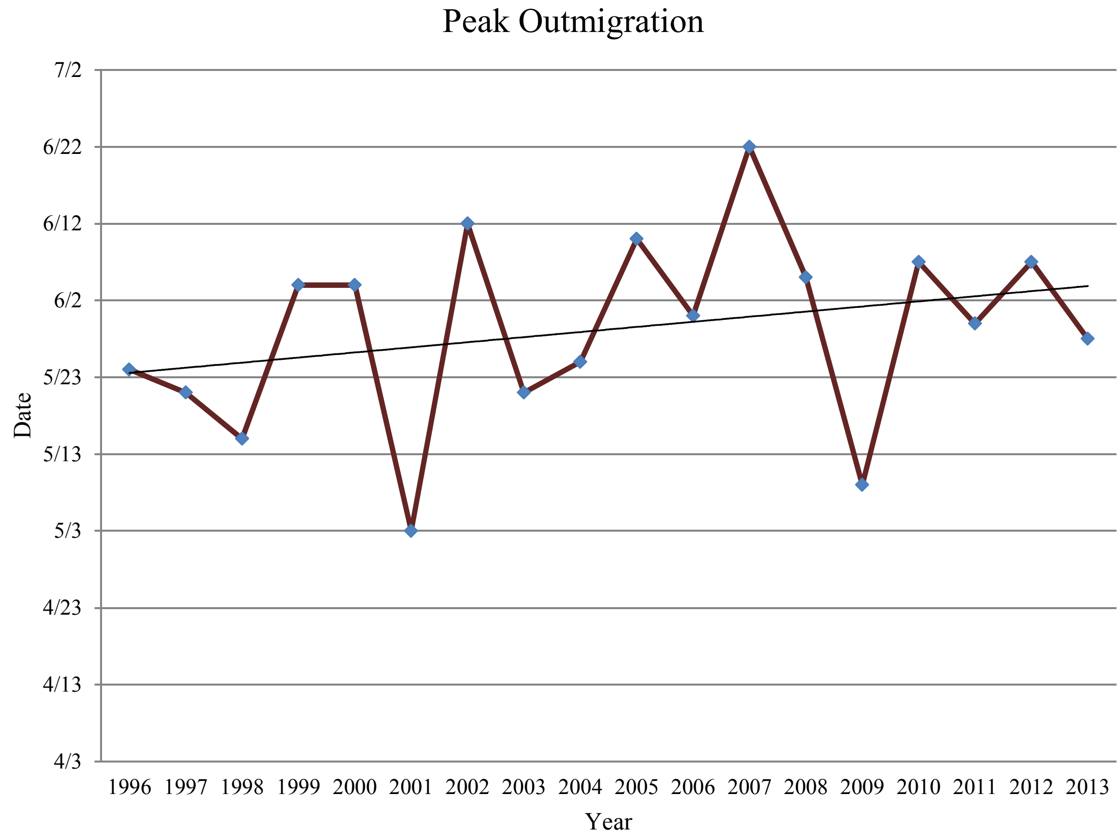

Figure 12.–Peak sockeye salmon smolt outmigration date by year 1996 – 2013.

APPENDIX A. SMOLT TRAP CATCHES BY DAY

Appendix A1.–Daily trap catch and efficiency from the Chignik River, May 9 through July 3, 2013.

	Actual Sockeye Smolt		Trap Efficiency Test				Incidental Catch[c]														
Date[a]	Daily	Cum.	Marked	Daily Recoveries	Cum. Recoveries	Efficiency[b]	Fry Sockeye	Coho	Fry Coho	Pink	Chnk	Chum	DV	SB	SC	SF	PS	PW	AB	ISO	EU
9-May	142	142	0	0	0	0.29%	5	0	0	0	0	0	4	63	14	0	0	0	0	1	0
10-May	66	208	0	0	0	0.29%	13	5	0	0	0	0	6	106	18	0	2	0	1	4	0
11-May	172	380	0	0	0	0.29%	9	20	0	0	0	0	7	72	12	0	1	0	1	7	0
12-May	135	515	0	0	0	0.29%	18	4	0	0	1	0	3	71	18	0	0	0	1	7	0
13-May	239	754	0	0	0	0.29%	8	2	0	0	1	0	2	61	9	0	0	0	0	3	0
14-May	903	1,657	0	0	0	0.29%	10	1	0	0	0	0	1	61	5	0	2	0	0	6	0
15-May	1,654	3,311	0	0	0	0.29%	18	2	0	0	0	0	1	111	4	0	1	0	0	5	0
16-May	1,759	5,070	2,048	4	4	0.29%	32	19	0	1	1	0	2	181	10	0	3	0	0	1	0
17-May	14,235	19,305	0	0	4	0.29%	35	13	0	1	0	0	4	82	12	0	2	0	3	4	0
18-May	569	19,874	0	0	4	0.29%	41	2	0	0	0	0	2	102	6	0	0	0	0	0	0
19-May	880	20,754	0	0	4	0.29%	62	1	2	0	0	0	1	120	6	0	0	0	0	0	0
20-May	464	21,218	0	0	4	0.29%	18	0	0	0	0	0	0	87	11	0	0	0	0	2	0
21-May	142	21,360	0	1	5	0.29%	23	2	0	0	0	0	3	87	4	0	0	0	0	0	0
22-May	175	21,535	1,221	1	1	0.57%	32	6	0	0	1	0	4	118	8	1	0	0	0	1	0
23-May	1,687	23,222	0	1	2	0.57%	14	18	0	0	0	0	5	136	4	1	0	0	0	1	0
24-May	657	23,879	0	3	5	0.57%	31	36	0	0	5	0	5	135	6	0	1	0	1	4	0
25-May	861	24,740	0	1	6	0.57%	33	37	0	0	5	0	4	221	5	0	1	0	0	1	0
26-May	1,148	25,888	0	0	6	0.57%	28	29	0	0	0	0	10	208	14	0	0	1	0	2	1
27-May	7,388	33,276	2,424	15	15	0.74%	21	26	0	0	1	0	10	204	24	2	0	0	0	6	0
28-May	28,896	62,172	0	0	15	0.74%	7	58	0	0	0	0	6	101	4	0	1	0	0	4	0
29-May	10,627	72,799	0	2	17	0.74%	33	19	0	2	1	3	10	126	17	0	1	0	0	5	1
30-May	956	73,755	0	0	17	0.74%	4	11	0	0	5	0	7	76	10	0	0	0	0	3	0
31-May	5,505	79,260	0	0	17	0.74%	6	33	0	0	2	0	16	69	11	0	2	0	1	6	0
1-Jun	3,031	82,291	3,707	41	41	1.24%	46	17	0	0	2	1	13	188	28	1	0	0	0	23	1
2-Jun	568	82,859	0	1	42	1.24%	66	19	2	0	2	0	18	214	10	2	1	2	0	2	0
3-Jun	7,679	90,538	0	3	45	1.24%	21	24	0	0	0	0	9	61	10	0	0	1	0	2	0
4-Jun	5,111	95,649	0	0	45	1.24%	13	18	0	0	2	0	11	31	10	0	0	0	0	13	0
5-Jun	1,058	96,707	0	0	45	1.24%	58	14	0	0	3	0	5	135	9	2	1	1	0	3	0
6-Jun	5,319	102,026	2,132	8	8	0.66%	20	18	0	0	2	0	9	120	18	1	2	2	0	5	0
7-Jun	2,060	104,086	0	5	13	0.66%	50	42	0	3	1	0	16	157	19	2	0	5	0	3	0
8-Jun	523	104,609	0	0	13	0.66%	29	49	1	0	0	0	19	98	3	2	2	0	0	6	0
9-Jun	869	105,478	0	0	13	0.66%	60	94	2	0	1	2	53	223	15	1	0	7	0	72	0
10-Jun	1,273	106,751	0	0	13	0.66%	147	93	0	0	1	1	32	244	19	2	1	4	0	38	0
11-Jun	166	106,917	1,893	11	11	0.90%	317	19	0	0	1	0	9	168	3	0	0	0	0	19	0
12-Jun	285	107,202	0	1	12	0.90%	201	11	0	0	0	0	9	111	1	0	0	1	0	11	0
13-Jun	2,699	109,901	0	3	15	0.90%	159	45	0	1	1	0	12	107	5	0	4	3	0	21	0
14-Jun	321	110,222	0	1	16	0.90%	243	24	0	0	0	0	10	192	9	0	1	2	0	10	0
15-Jun	337	110,559	0	0	16	0.90%	33	46	0	0	0	0	8	131	7	0	4	2	0	10	0
16-Jun	447	111,006	0	0	16	0.90%	6	45	1	0	1	1	11	118	5	3	2	8	0	28	1
17-Jun	242	111,248	0	0	16	0.90%	10	44	0	0	1	0	12	137	7	0	3	4	0	7	0
18-Jun	2,301	113,549	504	4	4	1.98%	15	42	0	0	3	1	7	184	7	0	1	6	0	3	0
19-Jun	2,019	115,568	0	3	7	1.98%	35	71	0	0	3	0	9	126	9	0	1	10	0	8	0
20-Jun	390	115,958	0	1	8	1.98%	56	86	0	1	1	1	4	81	4	0	0	11	0	7	0
21-Jun	271	116,229	0	1	9	1.98%	70	28	0	0	3	0	8	87	5	0	0	5	0	4	0
22-Jun	371	116,600	0	0	9	1.98%	609	39	0	0	3	1	3	111	2	0	0	8	0	2	0

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	Actual Sockeye Smolt		Trap Efficiency Test				Incidental Catch[c]														
Date[a]	Daily	Cum.	Marked	Daily Recoveries	Cum. Recoveries	Efficiency[b]	Fry Sockeye	Coho	Fry Coho	Pink	Chnk	Chum	DV	SB	SC	SF	PS	PW	AB	ISO	EU
23-Jun	51	116,651	0	0	9	1.98%	150	29	0	1	0	0	2	79	3	0	0	11	0	6	0
24-Jun	51	116,702	0	0	9	1.98%	21	61	0	0	0	0	1	91	6	0	1	5	0	8	0
25-Jun	134	116,836	0	0	9	1.98%	78	110	0	7	2	0	20	224	20	0	0	15	0	12	0
26-Jun	123	116,959	0	0	9	1.98%	37	84	1	0	2	0	39	254	7	0	1	18	0	6	0
27-Jun	824	117,783	0	0	9	1.98%	181	64	0	1	5	2	27	139	7	0	4	11	1	19	0
28-Jun	52	117,835	0	0	9	1.98%	204	28	0	0	2	0	23	90	13	0	0	8	0	6	0
29-Jun	74	117,909	852	6	6	0.94%	139	44	0	0	1	0	27	65	18	0	0	9	2	30	0
30-Jun	7	117,916	0	1	7	0.94%	178	35	0	0	5	0	10	35	11	0	1	5	0	21	0
1-Jul	34	117,950	0	0	7	0.94%	200	22	0	0	1	0	3	48	8	0	3	1	1	17	0
2-Jul	151	118,101	0	0	7	0.94%	69	77	0	0	2	0	7	51	20	0	2	10	1	13	0
3-Jul	5	118,106	0	0	7	0.94%	98	2	1	0	0	0	0	17	2	0	0	0	0	2	0
Total		118,106	14,781	118		0.92%	4,120	1,788	10	18	74	13	559	6,715	552	20	52	176	13	510	4

[a] Large trap was removed at the end of smolt day July 2nd and small trap was removed at the end of smolt day July 3rd.

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

[c] Coho = juvenile coho salmon, Pink = juvenile pink salmon, Chnk = juvenile Chinook salmon, Chum = juvenile chum salmon, DV = Dolly Varden, SB = stickleback, SC = sculpin, SF = starry flounder, PS = pond smelt, PW = pygmy whitefish, and AB = Alaskan blackfish, ISO = isopods, and EU = eulachon.

APPENDIX B. SMOLT CATCHES BY TRAP

Appendix B1.–Number of sockeye salmon smolt caught by trap, by day from the Chignik River, May 9 through July 3, 2013.

	Small Trap		Large Trap		Combined		Daily Proportion	
Date[a]	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Small	Large
5/9	14	14	128	128	142	142	9.9%	90.1%
5/10	8	22	58	186	66	208	12.1%	87.9%
5/11	54	76	118	304	172	380	31.4%	68.6%
5/12	18	94	117	421	135	515	13.3%	86.7%
5/13	30	124	209	630	239	754	12.6%	87.4%
5/14	111	235	792	1,422	903	1,657	12.3%	87.7%
5/15	252	487	1,402	2,824	1,654	3,311	15.2%	84.8%
5/16	644	1,131	1,115	3,939	1,759	5,070	36.6%	63.4%
5/17	1,266	2,397	12,969	16,908	14,235	19,305	8.9%	91.1%
5/18	123	2,520	446	17,354	569	19,874	21.6%	78.4%
5/19	43	2,563	837	18,191	880	20,754	4.9%	95.1%
5/20	38	2,601	426	18,617	464	21,218	8.2%	91.8%
5/21	26	2,627	116	18,733	142	21,360	18.3%	81.7%
5/22	36	2,663	139	18,872	175	21,535	20.6%	79.4%
5/23	282	2,945	1,405	20,277	1,687	23,222	16.7%	83.3%
5/24	99	3,044	558	20,835	657	23,879	15.1%	84.9%
5/25	235	3,279	626	21,461	861	24,740	27.3%	72.7%
5/26	271	3,550	877	22,338	1,148	25,888	23.6%	76.4%
5/27	499	4,049	6,889	29,227	7,388	33,276	6.8%	93.2%
5/28	2,051	6,100	26,845	56,072	28,896	62,172	7.1%	92.9%
5/29	1,107	7,207	9,520	65,592	10,627	72,799	10.4%	89.6%
5/30	119	7,326	837	66,429	956	73,755	12.4%	87.6%
5/31	244	7,570	5,261	71,690	5,505	79,260	4.4%	95.6%
6/1	495	8,065	2,536	74,226	3,031	82,291	16.3%	83.7%
6/2	183	8,248	385	74,611	568	82,859	32.2%	67.8%
6/3	91	8,339	7,588	82,199	7,679	90,538	1.2%	98.8%
6/4	53	8,392	5,058	87,257	5,111	95,649	1.0%	99.0%
6/5	139	8,531	919	88,176	1,058	96,707	13.1%	86.9%
6/6	122	8,653	5,197	93,373	5,319	102,026	2.3%	97.7%
6/7	62	8,715	1,998	95,371	2,060	104,086	3.0%	97.0%
6/8	50	8,765	473	95,844	523	104,609	9.6%	90.4%
6/9	179	8,944	690	96,534	869	105,478	20.6%	79.4%
6/10	157	9,101	1,116	97,650	1,273	106,751	12.3%	87.7%
6/11	69	9,170	97	97,747	166	106,917	41.6%	58.4%
6/12	12	9,182	273	98,020	285	107,202	4.2%	95.8%
6/13	79	9,261	2,620	100,640	2,699	109,901	2.9%	97.1%
6/14	174	9,435	147	100,787	321	110,222	54.2%	45.8%
6/15	37	9,472	300	101,087	337	110,559	11.0%	89.0%
6/16	55	9,527	392	101,479	447	111,006	12.3%	87.7%
6/17	28	9,555	214	101,693	242	111,248	11.6%	88.4%
6/18	116	9,671	2,185	103,878	2,301	113,549	5.0%	95.0%
6/19	111	9,782	1,908	105,786	2,019	115,568	5.5%	94.5%
6/20	83	9,865	307	106,093	390	115,958	21.3%	78.7%

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Appendix B1.–Page 2 of 2.

Date[a]	Small Trap		Large Trap		Combined		Daily Proportion	
	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Small	Large
6/21	42	9,907	229	106,322	271	116,229	15.5%	84.5%
6/22	63	9,970	308	106,630	371	116,600	17.0%	83.0%
6/23	19	9,989	32	106,662	51	116,651	37.3%	62.7%
6/24	13	10,002	38	106,700	51	116,702	25.5%	74.5%
6/25	28	10,030	106	106,806	134	116,836	20.9%	79.1%
6/26	22	10,052	101	106,907	123	116,959	17.9%	82.1%
6/27	57	10,109	767	107,674	824	117,783	6.9%	93.1%
6/28	20	10,129	32	107,706	52	117,835	38.5%	61.5%
6/29	16	10,145	58	107,764	74	117,909	21.6%	78.4%
6/30	3	10,148	4	107,768	7	117,916	42.9%	57.1%
7/1	11	10,159	23	107,791	34	117,950	32.4%	67.6%
7/2	7	10,166	144	107,935	151	118,101	4.6%	95.4%
7/3	5	10,171	0	107,935	5	118,106	100.0%	0.0%
Total		10,171		107,935		118,106	8.6%	91.4%

[a] Large trap was removed at the end of smolt day July 2nd and small trap was removed at the end of smolt day July 3rd.

APPENDIX C. CLIMATE OBSERVATIONS

Appendix C1.– Daily climate observations at the Chignik River smolt traps in 2013.

Date[a]	Time	Air (°C)	Water (°C)	Cloud[b] Cover (%)	Wind[b] Dir	Vel.[b] (mph)	Trap Revolutions (rpm) Small	Large	Stream Gauge (cm)	Comments
5/9	21:10	-	2.5	100%	E	10	3.00	3.50	-	
5/10	14:30	-	2.5	30%	W	5	2.00	3.50	-	sunny
5/11	12:30	1.3	2.5	100%	W	10	3.25	3.25	-	
5/12	12:00	6.5	2.5	10%	W	8	3.50	3.50	0	sunny
5/13	11:35	5.0	2.8	10%	NW	10	3.75	3.75	2	
5/14	11:40	7.0	3.0	10%	NW	5	4.00	3.75	3	sunny
5/15	11:55	5.5	3.0	100%	E	calm	3.75	3.50	3	
5/16	12:00	4.0	3.0	30%	NW	18	4.25	4.00	4	
5/17	13:00	-2.0	2.5	100%	NW	23	4.25	4.00	6	cold, ice on traps
5/18	11:30	1.0	2.0	60%	W	13	4.00	4.00	6	snowed 1-2"
5/19	12:00	7.0	3.8	5%	calm	calm	4.00	4.00	3	calm and sunny
5/20	12:30	8.0	3.5	100%	calm	calm	4.00	3.50	1	
5/21	12:20	8.0	3.5	100%	NE	8	4.00	3.50	0	
5/22	12:30	14.0	4.0	60%	variable	3	4.60	4.60	9	
5/23	12:00	9.5	4.5	70%	W	5	5.50	5.00	20	
5/24	12:10	13.0	4.5	30%	calm	calm	5.75	5.25	25	
5/25	12:05	8.0	4.0	100%	E	13	6.50	5.80	26	
5/26	12:05	5.5	3.8	100%	E	10	7.00	6.00	33	drizzle
5/27	11:10	6.0	3.8	100%	E	5	7.30	7.00	40	drizzle
5/28	12:20	8.0	4.0	90%	W	calm	7.75	7.00	47	
5/29	12:20	12.0	4.5	95%	W	10	8.00	6.00	51	
5/30	12:20	8.4	4.5	95%	E	5	8.00	7.25	54	
5/31	12:30	10.0	4.5	100%	SE	3	8.00	6.50	58	
6/1	11:55	8.5	5.0	95%	SE	3	8.50	7.50	60	
6/2	12:30	8.5	4.5	100%	calm	calm	8.20	7.00	59	rain
6/3	12:20	8.5	4.8	100%	E	5	9.00	7.75	65	rain/drizzle
6/4	12:00	8.5	5.0	100%	calm	calm	9.00	8.00	70	
6/5	12:20	7.0	4.8	100%	E	8	9.20	8.00	72	
6/6	12:40	12.0	5.5	5%	E	5	9.25	8.00	70	sunny

-continued-

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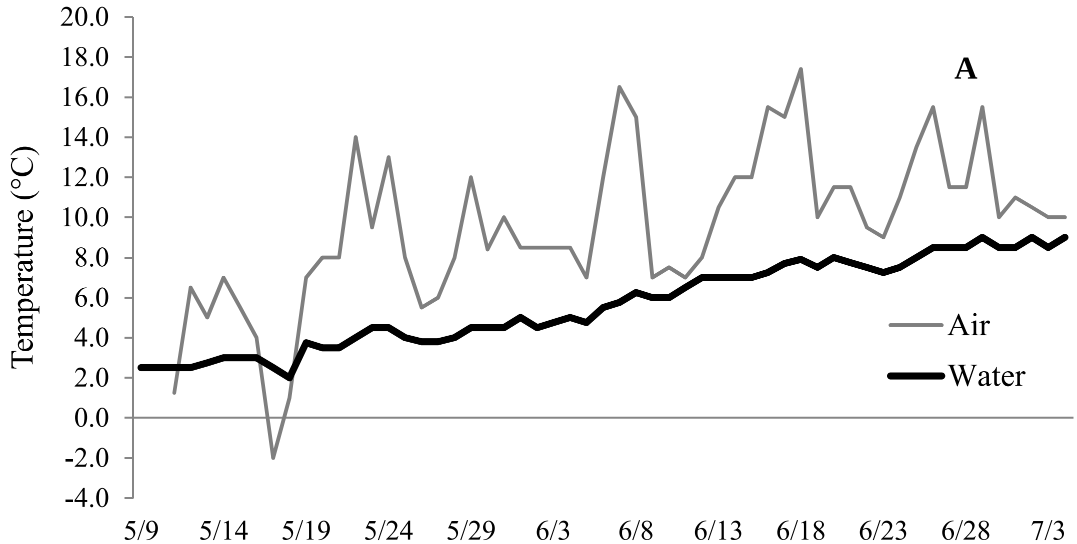
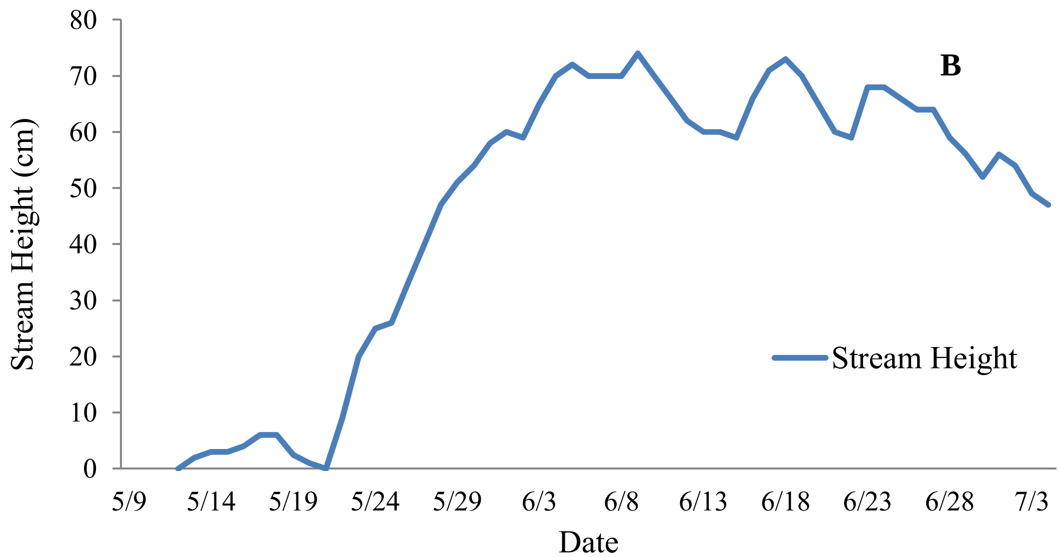
Date[a]	Time	Air (°C)	Water (°C)	Cloud[b] Cover (%)	Wind[b] Dir	Vel.[b] (mph)	Trap Revolutions (rpm) Small	Large	Stream Gauge (cm)	Comments
6/7	12:30	16.5	5.8	35%	W	8	9.25	8.00	70	sunny
6/8	12:30	15.0	6.3	5%	W	8	9.50	8.00	70	sunny
6/9	13:30	7.0	6.0	45%	W	10	9.50	7.80	74	windy
6/10	12:50	7.5	6.0	60%	NW	15	9.25	8.00	70	windy
6/11	12:30	7.0	6.5	1%	NW	8	8.50	8.00	66	clear sky
6/12	12:15	8.0	7.0	100%	S	8	8.50	8.00	62	
6/13	12:30	10.5	7.0	100%	S	3	9.00	7.50	60	overcast
6/14	12:15	12.0	7.0	80%	S	3	8.50	7.50	60	
6/15	12:15	12.0	7.0	60%	S	8	8.25	7.50	59	
6/16	11:50	15.5	7.3	70%	SW	3	9.00	8.00	66	
6/17	13:30	15.0	7.7	1%	SE	8	8.50	8.00	71	clear and sunny
6/18	12:50	17.4	7.9	0%	W	8	9.50	8.20	73	sunny and hot
6/19	12:45	10.0	7.5	100%	W	3	8.50	8.00	70	overcast
6/20	12:30	11.5	8.0	100%	W	3	8.25	8.00	65	overcast
6/21	12:30	11.5	7.8	100%	W	5	8.20	7.50	60	overcast
6/22	12:30	9.5	7.5	100%	W	10	8.00	7.30	59	overcast, rained overnight
6/23	12:30	9.0	7.3	100%	E	13	8.75	7.75	68	drizzle
6/24	12:00	11.0	7.5	100%	E	8	9.00	8.75	68	overcast
6/25	12:00	13.5	8.0	55%	E	10	8.50	7.75	66	
6/26	12:00	15.5	8.5	50%	E	20	8.50	8.00	64	windy
6/27	12:10	11.5	8.5	70%	E	15	8.50	8.00	64	windy
6/28	12:45	11.5	8.5	100%	E	5	8.00	7.50	59	overcast
6/29	12:10	15.5	9.0	80%	variable	3	8.00	7.50	56	
6/30	12:15	10.0	8.5	100%	E	3	7.75	7.00	52	rain
7/1	12:00	11.0	8.5	98%	E	3	7.75	7.00	56	
7/2	12:30	10.5	9.0	100%	E	3	7.75	7.00	54	
7/3	12:30	10.0	8.5	100%	E	3	7.75	-	49	large trap pulled; cone damage
7/4	12:45	10.0	9.0	100%	W	3	7.75	-	47	only small trap fishing

[a] Actual calendar dates.

[b] Based on observer estimates.

Appendix C2.–Air and water temperature gathered at the Chignik River smolt traps in 2013.





APPENDIX D. HISTORICAL LIMNOLOGY DATA

Appendix D1.–Seasonal averages of water quality parameters, nutrient concentrations, and photosynthetic pigments by year for Black Lake, 2000–2013.

	2000[a]	2001[b]	2002	2003	2004	2005	2006[b,c]	2007[b]	2008[b]	2009	2010	2011	2012[c]	2013[b,c,d]
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average
pH	7.43	7.53	7.45	7.45	7.81	7.57	8.01	7.64	7.64	7.67	7.78	7.69	7.69	7.89
Alkalinity (mg/L $CaCO_3$)	13.3	32.5	32.3	32.3	30.2	24.3	20.5	19.7	19.0	29.4	22.0	26.6	26.7	29.5
Total phosphorous (µg/L P)	56.8	35.2	37.1	41.6	22.2	27.9	20.4	24.4	22.2	41.1	29.8	34.3	11.0	31.9
Total filterable phosphorous (µg/L P)	10.7	9.8	98.0	10.1	5.1	8.6	11.0	ND	ND	6.9	8.0	4.3	3.2	4.9
Filterable reactive phosphorous (µg/L P)	4.0	7.4	24.7	5.4	2.6	7.2	9.1	ND	ND	ND	3.3	3.2	1.5	1.3
Total kjedhal nitrogen (µg/L N)	ND	320.6	323.5	256.8	188.8	324.5	216.0	124.3	263.7	233.5	210.8	426.5	ND	979.7
Ammonia (µg/L N)	36.6	3.3	4.1	4.5	9.7	3.9	11.0	130.1	3.7	2.6	6.4	3.3	6.0	4.4
Nitrate + Nitrite (µg/L N)	38.9	15.5	8.3	25.2	3.7	1.9	0.9	1.6	0.6	1.9	1.0	1.1	2.4	2.9
Silicon (µg/L)	ND	ND	ND	ND	3382.8	ND	ND	ND	ND	ND	ND	2925.7	1618.6	1541.2
Chlorophyll a (µg/L)	18.1	4.3	2.6	5.1	3.6	5.0	4.4	3.3	6.6	3.0	2.8	4.6	5.8	5.0
Phaeophytin a (µg/L)	10.0	11.9	1.4	1.8	0.2	1.0	0.8	0.9	1.4	1.4	1.5	0.5	0.8	1.7

[a] Seasonal average includes a surface water sample in August.

[b] Limnology samples were not collected in August.

[c] Limnology samples were not collected in May.

[d] Season average includes limnology samples collected in September.

Appendix D2.–Seasonal averages of water quality parameters, nutrient concentrations, and photosynthetic pigments for Chignik Lake, 2000–2013.

	2000	2001	2002	2003	2004	2005	2006[a]	2007[a]	2008[a]	2009	2010	2011[a,b]	2012[c]	2013[a,b]
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average
pH	7.81	7.47	7.45	7.38	7.62	7.57	7.70	7.46	7.48	7.50	7.22	7.52	7.36	7.71
Alkalinity (mg/L $CaCO_3$)	15.0	24.8	24.6	23.5	22.4	23.8	24.8	18.2	21.0	23.8	20.1	22.9	24.1	26.2
Total phosphorous (µg/L P)	14.5	27.6	19.7	16.7	18.6	15.8	20.1	14.2	15.6	22.3	13.6	12.4	10.2	14.5
Total filterable phosphorous (µg/L P)	5.9	12.3	8.5	7.5	6.5	6.5	8.3	ND	ND	ND	5.4	3.3	3.5	3.0
Filterable reactive phosphorous (µg/L P)	5.2	8.3	4.6	5.6	4.1	5.7	8.9	ND	ND	ND	4.5	5.1	2.4	1.9
Total kjedhal nitrogen (µg/L N)[d]	230.0	101.8	119.7	99.0	146.5	199.5	86.0	148.3	96.3	79.8	44.5	151.0	ND	344.5
Ammonia (µg/L N)	28.2	10.3	10.5	9.8	9.1	6.4	10.7	7.9	5.9	5.8	6.7	8.3	11.0	5.8
Nitrate + Nitrite (µg/L N)	162.6	191.6	117.4	166.7	128.0	103.3	129.9	194.0	192.5	152.3	154.4	187.1	171.7	133.3
Silicon (µg/L)	ND	ND	ND	ND	4128.8	ND	ND	ND	ND	ND	5986.1	2966.0	5289.8	4445.1
Chlorophyll a (µg/L)	9.1	4.7	2.3	2.3	4.0	3.0	6.6	2.2	2.2	2.3	1.5	2.2	2.9	2.9
Phaeophytin a (µg/L)	1.6	1.3	1.3	0.5	0.3	0.6	0.9	0.4	0.6	0.6	0.8	0.5	0.3	0.7

[a] Limnology samples were not collected in August

[b] Season average includes limnology samples collected in September.

[c] Limnology samples were not collected in May

[d] TKN values came from 1m samples only.

Appendix D3.–Seasonal average number of zooplankton per m^2 from Black Lake by year, 2000–2013.

Taxon	2000 Seasonal average	2001[a] Seasonal average	2002[b] Seasonal average	2003 Seasonal average	2004 Seasonal average	2005 Seasonal average	2006[a,c] Seasonal average	2007[a] Seasonal average	2008[a] Seasonal average	2009 Seasonal average	2010 Seasonal average	2011 Seasonal average	2012[c] Seasonal average	2013[a,b,c] Seasonal average
Copepods														
Cyclops	39,819	3,668	50,573	19,042	46,198	46,842	31,582	5,131	13,093	24,031	18,312	8,519	15,906	48,461
Ovig. Cyclops	-	-	-	265	-	-	-	-	-	-	66	1,354	-	-
Diaptomus	3,747	1,533	3,153	11,080	23,010	3,716	796	1,062	-	2,489	2,787	-	-	-
Ovig. Diaptomus	-	-	-	1,327	-	265	-	-	-	-	149	-	-	-
Epischura	9,166	1,946	6,805	6,303	37,649	18,113	-	5,750	-	3,729	4,263	2,389	5,166	10,899
Ovig. Epischura	159	-	-	-	-	-	-	-	-	-	-	318	-	584
Eurytemora	-	-	-	-	-	-	-	-	-	-	199	2,309	3,769	5,547
Ovig. Eurytemora	-	-	-	-	-	-	-	-	-	-	-	2,866	-	2,707
Harpacticus	-	1,062	-	531	531	-	265	-	-	-	149	-	177	-
Ovig. Harpaticus	-	-	-	-	-	-	-	-	-	-	-	-	177	-
Nauplii	24,298	3,716	24,023	24,350	40,509	38,150	8,758	9,996	16,189	28,938	12,971	18,869	10,209	41,012
Total copepods	77,189	11,925	84,554	62,898	147,897	107,086	41,401	21,939	29,282	59,188	38,897	36,624	35,403	109,209
Cladocerans														
Bosmina	46,900	38,417	86,316	285,496	398,855	203,755	2,322	619	1,681	49,209	28,646	3,424	27,955	25,088
Ovig. Bosmina	13,008	9,802	35,159	39,809	90,147	29,989	796	-	1,681	11,545	7,431	52,787	2,300	584
Chydorinae	14,441	369,840	30,127	3,516	78,716	12,407	3,052	2,919	-	-	-	318	1,203	26,787
Ovig. Chydorinae	-	-	446	-	398	-	-	-	-	-	-	8,121	-	1,645
Daphnia L.	861	248	-	1,526	199	-	-	-	-	66	-	80	531	1,062
Holopedium	-	-	-	-	-	-	-	-	-	-	66	-	531	584
Immature Cladocera	1,115	-	-	21,895	7,083	17,914	2,588	-	-	8,824	4,943	16,162	7,006	36,837
Total cladocerans	76,324	418,306	152,049	352,243	575,398	264,066	8,758	3,539	3,362	69,644	41,086	80,892	39,526	92,587
Total copepods + cladocerans	153,513	430,231	236,603	415,141	723,295	371,152	50,159	25,478	32,643	128,832	79,983	117,516	74,929	201,796

[a] Zooplankton samples were not collected in August.
[b] Season average includes zooplankton samples collected in September.
[c] Zooplankton samples were not collected in May.

Appendix D4.–Average weighted biomass estimates (mg dry weight/m^2) of the major Black Lake zooplankton taxon by year, 2000–2013.

	2000	2001[a]	2002[b]	2003	2004	2005	2006[a,c]	2007[a]	2008[a]	2009	2010	2011	2012[c]	2013[a,b,c]
Taxon	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average
Copepods														
Cyclops	45.36	4.36	35.79	18.34	35.15	44.39	22.04	4.47	14.02	23.90	12.46	8.26	15.05	42.55
Ovig. Cyclops	-	-	-	0.80	-	-	-	-	-	-	0.38	3.36	-	-
Diaptomus	13.70	3.29	15.71	42.68	29.55	8.20	1.11	2.89	-	5.58	7.05	-	-	-
Ovig. Diaptomus	-	-	-	8.88	-	2.24	-	-	-	-	1.16	-	-	-
Epischura	10.40	9.16	3.58	3.57	65.64	14.02	-	10.04	-	3.19	2.89	1.64	4.52	8.18
Ovig. Epischura	1.68	-	-	-	-	-	-	-	-	-	-	0.60	-	6.42
Eurytemora	-	-	-	-	-	-	-	-	-	-	1.26	9.52	20.36	25.04
Ovig. Eurytemora	-	-	-	-	-	-	-	-	-	-	-	24.04	-	26.64
Harpacticus	-	1.78	-	0.35	-	-	0.17	-	-	-	0.09	-	0.18	-
Total copepods	71.14	18.59	55.08	74.62	130.34	68.85	23.32	17.40	14.02	32.67	25.29	47.42	40.11	108.83
Cladocerans														
Bosmina	43.23	40.64	66.42	294.29	372.52	180.80	2.07	0.34	1.45	49.59	25.02	2.31	22.47	25.73
Ovig. Bosmina	17.10	10.48	44.36	78.67	128.39	43.31	0.81	-	2.58	18.07	12.28	70.25	2.99	0.88
Chydorinae	8.16	1685.43	15.52	2.35	38.91	8.58	1.84	2.08	-	-	-	-	0.45	15.91
Ovig. Chydorinae	-	-	0.41	-	0.42	-	-	-	-	-	-	4.53	-	1.77
Daphnia L.	0.73	0.07	-	2.31	0.05	-	-	-	-	0.16	-	0.17	0.55	-
Holopedium	-	-	-	-	-	-	-	-	-	-	0.77	-	0.40	1.29
Total cladocerans	69.22	1736.62	126.71	377.62	540.29	232.69	4.72	2.42	4.03	67.82	38.07	77.26	26.86	45.58
Total biomass	140.36	1755.21	181.79	452.24	670.63	301.54	28.04	19.82	18.05	100.49	63.36	124.68	66.97	154.41

[a] Zooplankton samples were not collected in August.

[b] Season average includes zooplankton samples collected in September.

[c] Zooplankton samples were not collected in May.

Appendix D5.–Seasonal average number of zooplankton per m^2 from Chignik Lake by year, 2000–2013.

Taxon	2000 Seasonal average	2001 Seasonal average	2002 Seasonal average	2003[a] Seasonal average	2004 Seasonal average	2005 Seasonal average	2006 Seasonal average	2007 Seasonal average	2008 Seasonal average	2009 Seasonal average	2010 Seasonal average	2011 Seasonal average	2012[b] Seasonal average	2013[a,c] Seasonal average
Copepods														
Cyclops	193,005	43,363	170,001	37,726	140,995	120,322	175,889	292,645	82,109	130,339	92,755	142,259	72,426	152,987
Ovig. Cyclops	2,119	3,507	14,580	916	4,547	10,388	24,648	10,898	2,637	3,767	3,679	6,844	1,920	12,435
Diaptomus	11,072	12,869	35,347	62,274	44,994	49,367	17,350	8,741	14,099	34,562	32,866	-	-	-
Ovig. Diaptomus	765	48	4,777	1,393	2,704	2,816	1,169	1,443	1,858	1,368	1,302	-	-	-
Epischura	33,615	13,400	49,645	70,621	66,980	51,946	6,842	3,168	10,350	5,180	10,039	17,411	15,822	9,081
Ovig. Epischura	149	48	-	-	-	-	-	-	-	-	-	265	-	100
Eurytemora	-	-	-	-	-	-	-	-	-	-	2,223	18,063	8,740	13,008
Ovig. Eurytemora	-	-	-	-	-	-	-	-	-	-	-	12,029	164	896
Harpacticus	178	528	1,244	398	979	348	1,335	265	100	604	559	-	332	149
Ovig. Harpaticus	-	-	-	-	-	-	-	133	-	-	66	-	62	-
Nauplii	41,723	14,969	92,473	55,573	73,434	115,371	87,024	47,605	36,148	48,066	35,065	63,923	47,607	92,054
Total copepods	282,626	88,733	368,067	228,901	334,632	350,559	314,258	364,898	147,301	223,885	178,554	260,795	147,072	280,708
Cladocerans														
Bosmina	46,646	30,213	70,113	73,447	59,531	88,990	37,553	13,021	38,112	22,030	39,442	10,735	50,495	25,832
Ovig. Bosmina	12,137	4,622	19,622	14,358	8,919	24,968	8,393	2,604	9,372	1,592	3,581	20,674	1,132	1,612
Chydorinae	4,000	1,516,382	11,462	1,115	8,207	6,179	13,311	6,137	531	43,676	7,844	2,057	2,066	9,587
Ovig. Chydorinae	-	-	133	-	166	-	-	-	-	13,854	1,555	3,299	88	100
Daphnia L.	8,251	1,462	20,750	68,073	30,072	15,787	8,053	38,681	11,901	-	-	10,707	1,407	87,279
Ovig. Daphnia L.	909	33	10,516	7,086	7,501	6,336	1,120	16,073	2,189	-	-	7,912	212	12,011
Holopedium	40	-	-	-	-	-	-	-	-	-	-	-	102	-
Immature Cladocera	1,411	5,862	5,955	5,679	4,082	12,415	9,554	-	-	6,251	7,593	10,646	5,281	22,310
Total cladocerans	73,393	1,558,574	138,552	169,759	118,478	154,674	77,984	76,516	62,105	87,402	60,015	66,030	60,784	158,730
Total copepods + cladocerans	356,019	1,647,307	506,618	398,660	453,110	505,233	392,242	441,415	209,407	311,287	238,570	326,825	207,856	439,438

[a] Season average includes zooplankton samples collected in September.

[b] Zooplankton samples were not collected in May.

[c] Zooplankton samples were not collected in August.

Appendix D6.–Average weighted biomass estimates (mg dry weight/m^2) of the major Chignik Lake zooplankton taxon by year, 2000–2013.

	2000	2001	2002	2003[a]	2004	2005	2006	2007	2008	2009	2010	2011	2012[b]	2013[a,c]
Taxon	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average
Copepods														
Cyclops	356.85	333.52	200.10	36.40	137.55	138.37	376.50	467.14	131.58	220.36	112.79	171.18	91.04	165.90
Ovig. Cyclops	15.31	135.69	58.16	3.71	20.39	40.33	153.67	58.86	13.40	25.27	15.51	32.21	9.58	57.04
Diaptomus	252.75	423.33	129.24	136.41	97.45	125.38	37.81	40.58	76.05	72.87	100.40	-	-	-
Ovig. Diaptomus	18.42	0.07	28.74	7.18	16.54	23.24	12.34	13.43	6.40	13.19	12.13	-	-	-
Epischura	146.70	405.59	34.33	37.86	50.36	43.47	4.90	4.17	13.16	4.21	7.98	16.17	15.38	6.45
Ovig. Epischura	1.03	0.08	-	-	-	-	-	-	-	-	-	0.29	-	1.07
Eurytemora	-	-	-	-	-	-	-	-	-	-	11.76	95.90	48.65	84.60
Ovig. Eurytemora	-	-	-	-	-	-	-	-	-	-	-	95.53	1.58	7.84
Harpacticus	0.12	1.45	0.76	0.26	0.60	0.27	1.09	0.39	0.05	0.43	0.34	-	0.21	0.27
Total copepods	791.18	1299.73	451.33	221.82	322.89	371.06	586.31	584.57	240.64	336.33	260.91	411.28	166.44	323.17
Cladocerans														
Bosmina	182.98	141.13	57.52	77.57	47.50	77.73	30.74	12.37	35.48	23.33	35.80	9.01	45.93	27.70
Ovig. Bosmina	66.93	29.81	27.30	24.83	11.32	31.43	9.86	5.66	11.87	2.60	5.72	27.26	1.48	2.39
Chydorinae	5.16	15.48	7.47	0.75	5.80	3.90	9.25	3.52	0.15	-	-	1.20	1.32	5.62
Ovig. Chydorinae	-	-	0.09	-	0.23	-	-	-	-	-	-	2.28	0.09	0.08
Daphnia L.	23.20	15.17	23.94	77.20	34.64	19.22	8.90	47.63	13.33	52.15	9.19	8.09	1.44	90.89
Ovig. Daphnia L.	6.03	0.09	33.57	19.31	24.07	19.21	2.66	45.04	8.05	34.75	5.69	18.01	0.60	29.42
Holopedium	0.22	-	-	-	-	-	-	-	-	-	-	-	0.04	-
Total cladocerans	284.52	201.68	149.89	199.66	123.56	151.49	61.41	114.22	68.88	112.83	56.40	65.85	50.90	156.10
Total biomass	1075.70	1501.41	601.22	421.48	446.45	522.55	647.72	698.79	309.52	449.16	317.31	477.13	217.34	479.27

[a] Season average includes zooplankton samples collected in September.

[b] Zooplankton samples were not collected in May.

[c] Zooplankton samples were not collected in August.