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Sockeye Salmon Smolt Investigations on the Chignik River, 2008

by

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and

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March 2009

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)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

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

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ABSTRACT

This report provides the results from the fifteenth year of the Chignik River sockeye salmon *Oncorhynchus nerka* smolt enumeration project operated by the Alaska Department of Fish and Game (ADF&G). Outmigrating juvenile sockeye salmon were captured in a rotary-screw trap array and abundance was estimated using mark-recapture techniques. Sockeye salmon smolts were measured throughout the emigration for age, length, and weight data and genetic samples were collected from these same fish. In 2008, a total of 5,356,455 sockeye salmon smolts were estimated to pass downstream of the traps from May 9 to July 10. Of these, 1,017,498 (19.0%) were age-0., 3,309,894 (61.8%) were age-1., 987,928 (18.4%) were age-2., and 41,136 (0.8%) were age-3. sockeye salmon smolts. Water quality and zooplankton were seasonally assessed in 2008 to describe the physical characteristics, nutrient availability, primary production, and zooplankton forage available to rearing juvenile sockeye salmon in Chignik and Black lakes. Black Lake, a large, shallow nursery lake at the head of the system, was not limited by primary production, however, zooplankton abundance was low (≤17.82 mg dry wt/m^2) from May through July. In Chignik Lake, primary production was not limited, but zooplankton production was low (≤109.36 mg dry wt/m^2) from May until June, which suggested top-down grazing pressure by juvenile sockeye salmon. The watershed sockeye salmon run was formally forecasted using sibling and temperature index relationships. The forecast using smolt information is considered ancillary data. The formal forecast is for a total run of 1.38 million sockeye salmon in 2009 with an expected harvest of 781 thousand fish. Age-2. smolt abundance data, by outmigration year, were regressed against saltwater-age-3 returns from their respective outmigration years to forecast the 2009 sockeye salmon run. It was estimated that approximately 1.62 million sockeye salmon are expected to return in 2009, equating to a harvest of about 1.02 million sockeye salmon. Because only up to eleven years of smolt and corresponding adult return data were used to produce the smolt-based forecast, the confidence in this forecast is fair.

Key words: Sockeye salmon, smolt, Chignik River, forecast, mark-recapture, zooplankton.

INTRODUCTION

Chignik River sockeye salmon *Oncorhynchus nerka* smolt emigration data has been collected and used by the Alaska Department of Fish and Game (ADF&G) to estimate smolt abundance, gauge smolt health, and estimate smolt marine survival annually since 1994. Smolt production data have more recently been used to provide a preseason forecast of the Chignik watershed sockeye salmon run. The interactions, however, between the Black Lake (early run) and Chignik Lake (late run) stocks are not completely understood. The usage of available rearing habitat specific to each stock has not been clearly defined (Bumgarner 1993). The influence of changing physical and environmental factors upon the outmigration of Chignik juvenile sockeye salmon also requires further investigation (Bouwens and Finkle 2003).

The Chignik watershed, which is the primary sockeye salmon producer in the Chignik Management Area (CMA; Bouwens 2004), 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, is an atypical sockeye salmon nursery lake; it is large (41.1 km^2), shallow (mean depth of 1.9 m, maximum depth 4.2 m (Ruggerone et al. 1993), and turbid. The large (24.1 km^2) and deep (mean depth of 26 m) Chignik Lake receives Black Lake effluent via the northern portion of the Chignik River. Both lakes are considered oligotrophic (Kyle 1992) and each maintains its own genetically distinct, but temporally overlapping, runs of sockeye salmon (Templin et al. 1999). The early run (sustainable escapement goal [SEG] range of 350,000 to 400,000 fish through July 4) spawns in Black Lake and its tributaries and enters the watershed from June through mid July. The late run (SEG range of 200,000 to 400,000 fish beginning on July 5 and an additional 50,000 fish inriver run goal [IRRG] apportioned between August and September), returns from late June through the late fall. The late run typically spawns in the tributaries and the shoals of Chignik Lake. Historically, emigrations from the Chignik watershed have been estimated to range between 2 and 26 million sockeye salmon smolts (Finkle and Ruhl 2008). Chignik sockeye salmon smolts generally have been observed to migrate from the watershed beginning in early May, peaking in mid to late May and are predominantly composed of age-1. and -2. fish (Finkle and Ruhl 2008).

Juvenile salmon are known to migrate to sea after certain size thresholds are met, during specific seasons, and under certain physical conditions (Clarke and Hirano 1995). However, it is difficult to directly measure the interactions and impacts of these effects on juvenile fishes. Salmon smolt emigration may be triggered by warmer springtime water temperatures (~ 4 ^{o}C) and increased photoperiod (Clarke and Hirano 1995). Variables affecting growth in juvenile salmon include temperature, competition, food quality and availability, and various water chemistry parameters (Moyle and Cech 1988). Because of these dynamic factors, annual growth of juvenile sockeye salmon often varies among lakes, years, and within individual populations (Bumgarner 1993). If growth rates are not sufficient to achieve the threshold size necessary to emigrate in the spring, juvenile fish may stay in a lake to feed for another year (Burgner 1991), possibly increasing competition among younger age classes in the same rearing area. Within the Chignik watershed, however, small young-of-the-year sockeye salmon have been captured in large numbers in the Chignik River and Chignik Lagoon during the summer months (Finkle and Ruhl 2008). Other past studies have also suggested that a component of juvenile sockeye salmon rear in the Chignik River and Chignik Lagoon in the summer and subsequently return to Chignik Lake in the fall to offset or avoid taxed Chignik Lake rearing conditions (Iverson 1966; Phinney 1968; Roos 1957, 1959). These life history strategies can be assessed via smolt emigration and limnology data.

Smolt emigration data can serve as an indicator of future run strength and overall stock status. These data have been combined into a model used to generate an adult sockeye salmon forecast for the Chignik watershed (Finkle and Ruhl 2008; Volk *in prep*). Forecasts enable harvesters and fish processors to estimate their potential supply and production needs. Current formal forecast methods used to predict the adult runs to the Chignik watershed employ historic age class relationships for the early run and return-per-spawner relationships for the late-run stocks (Volk *in prep*). Smolt emigration estimates by age, and potentially stock, are expected to add accuracy to the forecast models currently used.

The limnology portion of this study seeks to monitor and discern the relationships among the Chignik watershed, its juvenile sockeye salmon, and zooplankton relative to physical conditions such as temperature, turbidity, dissolved oxygen saturation of the water, and available nutrients such as nitrogen, phosphorous, and carbon. With these data, nutrient limitations, physical disturbances, sockeye salmon smolt forage abundance, and intraspecific competition can be identified within the watershed. To date, limnology and smolt data from the Chignik watershed have been used to describe top-down limitations for rearing sockeye salmon and trends in the life history strategies of juvenile sockeye salmon relative to recent physical changes to the watershed (Buffington 2001; Bouwens and Finkle 2003; Finkle 2004).

The 2008 field season was the 15th year of the ADF&G smolt project on the Chignik River, which has been funded since project commencement by the Chignik Regional Aquaculture Association (Finkle and Ruhl 2008). The Chignik River Sockeye Salmon Smolt Enumeration Project has consistently maintained its sampling protocol since the project's inception. This report presents data collected during the 2008 Chignik River Sockeye Salmon Smolt Enumeration Project, comparisons of 2008 smolt data to past smolt data, 2008 limnology data, and adult sockeye salmon forecast estimates for 2009, based on smolt emigration data.

OBJECTIVES

The objectives for the 2008 season were to

1) Estimate the total number of emigrating sockeye salmon smolts, by age, from the Chignik River watershed,
2) Describe emigration timing and growth characteristics (length, weight, and condition factor) of sockeye salmon smolts by age for the Chignik River watershed,
3) Continue to build a smolt forecast model in an effort to estimate marine survival and future runs,
4) Present a stewardship-building sockeye salmon smolt presentation to students at Chignik Lake school,
5) Collect genetic samples from emigrating sockeye salmon smolts for use in a stock separation study,
6) Describe the physical characteristics of Black and Chignik lakes, which include temperature, dissolved oxygen, and light penetration profiles,
7) Describe the nutrient availability and primary production of Black and Chignik lakes, and
8) Describe the zooplankton forage base available to juvenile sockeye salmon in Black and Chignik lakes.

METHODS

STUDY SITE AND TRAP DESCRIPTION

Two rotary-screw traps were operated 8.6 km upstream from Chignik Lagoon (Mensis Point) and 1.9 km downstream from the outlet of Chignik Lake (56° 15’ 26” N. lat., 158° 43’ 49” W. long.; Figure 2). The traps were located near a bend in the river with the highest current and narrowest span.

One large trap and one small trap were operated side by side to capture smolts emigrating from the Chignik watershed. Each trap consisted of a cone constructed of aluminum perforated plate (5 mm holes) mounted on two aluminum pontoons, with the large open end of the cone pointed upstream. The cone mouth diameter was 1.5 m on the small trap (placed nearshore), and 2.4 m on the large trap (placed offshore). Each trap was secured to shore with highly visible polypropylene line. The highly visible line and a strobe light attached to the safety railing of the offshore trap were employed to address safe navigation around the traps and anchor lines for local boat traffic. The strobe was positioned far enough behind the mouth of large trap to minimize trap avoidance by sockeye salmon smolts.

The small trap sampled an area of approximately 0.73 m^2 and the large trap sampled an area of approximately 2.02 m^2 of the river’s profile because only the bottom portion of the cone was submerged. The river current propelled an internal screw welded to the inside of each cone, which rotated the cones at approximately 3-9 revolutions per minute (RPM) during average water flow conditions. Fish were funneled through the cones into live boxes, each approximately 0.7 m^3 in volume. The live boxes sat on the downstream end of each trap. A pair of adjustable aluminum support legs were utilized to maintain and adjust the traps' positions from the shore and their orientation in the current.

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. A floating platform for a 3m x 4m weatherport was tied directly behind the live box work station. The weatherport provided shelter for the crew when processing samples taken from the traps.

During the 2008 field season, both of the traps were operated continuously from 1215 hours on May 9 to 1200 hours on July 10. At the completion of the project, both traps were disassembled and stored.

SMOLT ENUMERATION

Because smolt primarily emigrate at night, sampling days extended 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 at least every six hours each day including checks at 1800 hours and again at the end of the smolt day at 1200 hours.

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), and enumerated. Sockeye salmon fry (< 45 mm FL), coho salmon *O. kisutch* juveniles, Chinook salmon *O. tshawytscha* juveniles, Dolly Varden *Salvelinus malma*, stickleback of the family Gasterosteidae, pond smelt *Hypomesus olidus*, pygmy whitefish *Prosopium coulteri*, starry flounder *Platichthys stellatus*, coastrange sculpin *Cottus aleutus*, and the isopod *Mesidotea entomon* (Merrit and Cummings 1984; Pennak 1989) were also identified and enumerated.

TRAP EFFICIENCY ESTIMATES

Mark-recapture experiments were conducted weekly to determine trap efficiency when a sufficient number of smolts were captured to conduct a marking event. Between approximately 1,000 and 4,000 sockeye salmon smolts for each experiment were collected from the traps and transferred to the live box. Smolts were retained in the live box for no more than three nights if sufficient numbers were not initially captured to perform a mark-recapture experiment. Past mark retention and delayed mortality experiments indicated that most of the captured smolt mortalities occurred during the first three days of capture (Bouwens and Newland 2003). Therefore, all captured smolts were released if the minimum sample size was not met after three nights.

Sockeye salmon smolts were netted from the live box, counted, and transferred into a repository containing an aerated Bismarck Brown Y dye solution (4.6 g of dye to 92.4 L of water) for 15 minutes. Fresh water was then pumped into the container to slowly flush out the dye (90 min). The smolts were allowed to recover in the circulating water. At the end of the marking process, dead and stressed smolts were removed, counted, and disposed of downstream of the traps.

The remaining marked smolts 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 smolts were transported upstream in aerated containers and released evenly across the breadth of the river from the left bank to the right bank. The marking event was performed so that the marked fish were released before midnight. The number of smolts recaptured in the traps was recorded for several days until recoveries ceased. Sockeye salmon smolts recaptured during mark-recapture experiments were recorded separately from unmarked smolts and excluded from daily total catch to prevent double counting.

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 by 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 emigrating smolt by age class for each stratum *h* was determined by first

calculating the proportion of each age class of smolt in the sample population as:

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

where

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

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

with the variance estimated as

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

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

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

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, AND LENGTH SAMPLING

A daily sample of up to 40 sockeye salmon smolts was collected on five days per statistical week for age-weight-length (AWL) data. All smolt sampling data reflected the smolt day in which the fish were captured, and samples were not mixed between days. Smolt were collected throughout the night's migration and held in an instream live box. Forty smolts were then randomly collected from the live box, anesthetized with Tricaine methanesulfonate (MS-222), and sampled for AWL data, and the remaining smolts were released downstream from the traps.

Fork length was measured to the nearest 1 mm, and smolt were weighed to the nearest 0.1 g. Scales were removed from the preferred area (INPFC 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 (Finkle 2007; Appendix A1).

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

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

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

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), and climate observations including air and water temperature (°C), estimated cloud cover (%), and estimated wind velocity (mph) and direction were recorded daily at 1200 hours.

MARINE SURVIVAL ESTIMATES AND FUTURE RUN FORECASTING

Estimates of smolt abundance, by age, were paired with corresponding adult returns from the respective smolt year. The total return to the Chignik River watershed was calculated by adding the total Chignik River sockeye salmon escapement, the total harvest from the CMA, and a portion of the sockeye salmon catch from the Southeastern District Mainland (SEDM) of the Alaska Peninsula Management Area and 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.

Simple linear regression relationships were explored between smolt abundance estimates and the corresponding adult returns, by both emigration and brood years, to investigate the potential of using smolt emigration estimates to forecast future adult sockeye salmon runs. Standard regression diagnostic techniques were used to indicate violations of model assumptions. Regressions were developed between individual freshwater age classes and their corresponding adult returns (by ocean age). It was clear from an impossible marine survival estimate (greater than 100% survival) of emigration year 1996 that the smolt abundance was underestimated in that year. Therefore, data from 1996 were not included in regression analyses for predicting future adult returns.

A statistically significant simple regression relationship was used to forecast the saltwater-age-3 (3-ocean) component (historically, about 85% of the entire run) of the 2009 adult sockeye salmon run from the smolt emigration data. The adult return estimates for the 3-ocean age class were expanded to account for the total run from their historical proportion of the total run.

LIMNOLOGY

One limnology sampling station was set on Black Lake in June 2008 (Figure 3). In May 2008, four sampling stations were established on Chignik Lake (Figure 4). Zooplankton samples and temperature, dissolved oxygen, and light penetration data were gathered at all four Chignik Lake stations but only stations 2 and 4 were dedicated to the collection of water samples (Table 1). Each station's location was logged with a global positioning system (GPS) and marked with a buoy. Sampling was conducted following protocols established by Finkle and Bouwens (2001). Water and zooplankton sampling occurred once every three weeks. Sampling occurred in June and July in Black Lake and from May to August in Chignik Lake (Table 1).

Dissolved Oxygen, Light, and Temperature

Water temperature (°C) and dissolved oxygen (mg/L) levels were measured with a YSI Y-52 meter. Readings were recorded at half-meter intervals to a depth of 5 m, then the intervals increased to one meter. Upon reaching a depth of 20 m, the intervals were increased to every five meters. A mercury thermometer was used to ensure the meter's calibration. Measurements of photosynthetically active wavelengths (kLux) 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 0 kLux light penetration was reached. The mean euphotic zone depth (EZD) was determined (Koenings et al. 1987) for each lake. 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 disc disappeared when lowered into the water column and reappeared when raised in the water column were recorded and averaged.

Water Sampling

Seven to eight liters of water were collected with a Van Dorn bottle from the epilimnion (depth of 1 m) and from the hypolimnion (depth of 29 m) of Chignik Lake stations 2 and 4. Water samples were stored in polyethylene (poly) carboys and refrigerated until processed.

One-liter samples were passed through 4.25-cm diameter 0.7-µm Whatman™ GF/F filters under 15 to 20-psi vacuum pressure for particulate N, P, and C analyses. For chlorophyll-*a* analysis, one liter of lake water from each depth sampled was filtered through a 4.25-cm diameter 0.7-µm Whatman™ GF/F filter, adding approximately 10 ml of $MgCO_3$ solution to the last 50 ml of the sample water during the filtration process. Upon completion of filtration, all filters were placed in individual petri dishes, labeled and frozen. For each sampled depth, 120 ml of sample water and 2 ml of Lugol's acetate were placed in a 125-ml poly bottle for phytoplankton analysis and stored at room temperature until processing.

The water chemistry parameters of pH and alkalinity were assessed with a Eutech Instruments Oakton® pH meter. One hundred milliliters of refrigerated lake water were warmed to 25 °C and titrated with 0.02-N sulfuric acid following the methods of Thomsen et al. (2002).

All filtered and unfiltered water samples were stored and frozen in clean poly bottles. Water analyses were performed at the ADF&G Near Island laboratory for total phosphorous (TP), total ammonia (TA), nitrate + nitrite, chlorophyll *a* and phaeophytin *a*. All laboratory analyses adhered to the methods of Koenings et al. (1987) and Thomsen et al. (2002). Total Kjeldahl nitrogen (TKN) was processed by the Olsen Biochemistry Lab at South Dakota State University.

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. Collected zooplankton were placed in a 125-ml poly bottle containing 12.5 ml of concentrated formalin to yield a 10% buffered formalin solution. Samples were stored for analysis at the ADF&G Near Island laboratory. Subsamples of zooplankton were keyed to family or genus and counted on a Sedgewick-Rafter counting slide. This process was replicated three times per sample then counts were averaged and extrapolated over the entire sample. For each plankton tow, mean length (±0.01 mm) was measured for each family or genus with a sample size derived from a student's t-test to achieve a confidence level of 95% (Edmundson et al. 1994). Biomass was calculated via species-specific linear regression equations using published values of mass for each species and unweighted and weighted length measurements (Koenings et al. 1987).

RESULTS

TRAPPING EFFORT

Both traps were in place for a total of 62 days beginning on the smolt dates of May 9 and ending on July 9 (Appendix B1). The duration of the 2008 trapping season was 1 day longer than the 2007 season. Similar to the 2007 season, large ice sheets covering most of Chignik Lake prevented the installation of the traps prior to May 9.

TRAP CATCH

A total of 61,662 sockeye salmon smolts were captured in the traps in 2008 (Appendix B1). In addition to sockeye salmon smolt, 19,803 sockeye salmon fry, 1,319 juvenile coho salmon, 754 juvenile Chinook salmon, 446 Dolly Varden char, 26,964 stickleback, 65 sculpin, 81 starry flounders, 397 pond smelt, 6 pygmy whitefish, and 4 isopods were captured (Appendix B1). The small screw trap caught approximately 18.0% of the sockeye salmon smolts while the large trap caught roughly 82.0% of the sockeye salmon smolts (Appendix C1).

SOCKEYE SALMON SMOLT EMIGRATION AND TIMING

The estimated number of sockeye salmon smolts that emigrated in 2008 was 5,356,455 (Table 2; Figure 5). The majority of these fish emigrated in late May and early June (Table 3; Figure 6). The 2008 emigration consisted of 1,017,498 age-0., 3,309,894 age-1., and 987,928 age-2., and 41,136 age-3. sockeye salmon smolts (Tables 2 and 3; Figure 7). The majority of age-1. and -2. smolt tended to emigrate from the end of May to the beginning of June (Table 3; Figure 8). Age-0. sockeye salmon smolt were more abundant in trap catches during the beginning of June (Table 3; Figure 8).

TRAP EFFICIENCY ESTIMATES

Mark-recapture experiments were conducted on eight occasions beginning on May 15 and ending on June 29, 2008 (Table 4; Appendix B1). A total of 10,085 smolts, approximately 16%

of the total catch, were marked and released. Ninety-nine smolts were recaptured and trap efficiency estimates ranged from 0.51% to 1.55% (Table 4). The majority of the recaptured marked smolts were caught within two days of being released (Appendix B1).

AGE, WEIGHT, AND LENGTH DATA

A total of 1,717 sockeye salmon smolts were sampled for AWL data in 2008, of which 33.1% were age-0. (BY 07), 49.2% were age-1. (BY 06), 16.8% were age-2. (BY 05), and 1.0% were age-3. (BY 04; Tables 5 and 6). The proportion of age-2. smolts increased in the catch beginning in mid May (Tables 3 and 5). The mean length and weight of age-0. smolts were 53 mm and 1.1 g (Tables 7 and 8). The mean length and weight of age-1. smolts were 65 mm and 2.1 g (Tables 7 and 8; Figure 9). The mean length and weight of age-2. smolts were 79 mm and 3.7 g (Tables 7 and 8; Figure 9). The mean length and weight of age-3. smolts were 91 mm and 6.1 g (Tables 7 and 8). Length frequency histograms indicated that larger smolts (> 65 mm) composed the majority of the catch in May and smaller smolts (< 65 mm) composed the majority of the catch in June and July (Figures 10 through 13). Juvenile sockeye < 45 mm FL were present throughout the trapping season, but were most abundant in the first month of the season (Appendix B1).

PHYSICAL DATA

Daily measurements of river depth and velocity (based on trap RPM), along with the 2008 climate data, are reported in Appendix D1. The absolute water depth at the trap location varied from 99 to 168 cm during the 2008 season (Figure 14). Water temperatures averaged near 3.0 ^{o}C during the first week that traps were installed (May 10 through May 20) and increased steadily throughout the season to a maximum of 9.5 °C (Figure 14; Appendix D1). Relatively stable water levels and calm winds (Figure 14) generally characterized the 2008 season.

MARINE SURVIVAL ESTIMATES AND FUTURE RUN FORECASTING

All adult sockeye salmon from BYs 1991 through 2000 and for most of BY 2001 have returned to the Chignik River watershed, and the overall marine survival of smolts ranged from 6% for BY 1999 to 67% for BY 1993 (Table 9). The estimation of the 1993 and 1994 BY marine survival includes a portion of the emigration estimate from 1996, which is considered an outlier (Edwards and Bouwens 2002). When the data were presented by emigration year, however, the marine survivals ranged from 5% for emigration year 2001 to 196% for emigration year 1996, with 1996 being an obvious outlier (Table 10). Therefore, after removing smolt year 1996, the marine survival from smolt years 1994 to 2004 averaged 14 %.

A simple linear regression model displayed a significant relationship ($P=0.009$; $R^2=0.64$) between outmigrating age-2. smolts and 3-ocean adult returns. The smolt regression model forecasted a 2008 total adult run of 1.62 million sockeye salmon while the formal adult forecast predicted a 2008 run of 1.38 million sockeye salmon.

LIMNOLOGY

Temperature and Dissolved Oxygen

Black Lake

On June 20, the 1-m temperature in Black Lake was 11.4 °C and increased to 12.0 °C on July 7 (Table 11; Figure 15). Dissolved oxygen levels at the 1-m depth were 10.9 mg/L over the same time frame (Table 12; Figure 15). During the summer sampling season, temperature, and dissolved oxygen levels generally remained similar throughout the water column. August samples were not collected from Black Lake.

Chignik Lake

One-meter temperatures in June, July, and August were 6.9, 10.2, and 11.5 °C respectively (Table 13; Figure 16). Temperatures in Chignik Lake were fairly homogenous over depth and time (Table 13; Figure 16). Temperature variability did not exceed 2.6 °C over depth during any of the sampling events (Table 13; Figure 16). The 1-m dissolved oxygen level on June 17 was 12.3 mg/L, 11.2 mg/L on July 6, and 11.1 mg/L on August 21 (Table 14; Figure 16). Dissolved oxygen levels showed little variation over depth from July through August (Table 14; Figure 16).

Light Penetration and Water Transparency

Black Lake

Light penetrated the entire water column in Black Lake during the 2008 sampling season (Table 15; Figure 17). The EZD of Black Lake exceeded its maximum depth in June and July, therefore, the mean lake depth (1.9 m) was used to calculate the euphotic volume (EV) of 78.1 x 10^6 m^3 (Table 15; Figure 17). During the 2008 sampling season, water transparency in Black Lake ceased at a mean depth of 1.0 m. August samples were not collected from Black Lake.

Chignik Lake

Light penetration ceased at a depth of 13 m in May, 7 m in June, 10 m in July, and at 12 m in August (Table 16; Figure 17). The EZD was 4.28 m in May, 8.26 m in June, 9.08 m in July, and 11.39 m in August (Table 15). The EV in Chignik Lake averaged 229.7 x 10^6 m^3 for the 2008 sampling season (Table 15; Figure 17). For the 2008 season, water transparency in Chignik Lake ceased at a mean depth of 2.3 m.

Water Quality Parameters, Nutrient Levels, and Photosynthetic Pigments

Black Lake

The pH in Black Lake seasonally averaged 7.64 and alkalinity seasonally averaged 19.0 mg/L $CaCO_3$ (Table 17). For the sampling season TP averaged 22.2 µg/L P and TKN was 263.7 µg/L N (Table 17). Ammonia averaged approximately 3.7 µg/L N and nitrate + nitrite had a seasonal mean of 0.6 µg/L N in 2008 (Table 17). Of the photosynthetic pigments, chlorophyll *a* averaged 6.56 µg/L and phaeophytin *a* had a seasonal mean of 1.42 µg/L (Table 18). Over the season, TKN, ammonia, chlorophyll *a,* and phaeophytin *a* each decreased from the May sampling event to the July sampling event (Table 18).

Chignik Lake

Seasonally, the pH in Chignik Lake averaged 7.47 and alkalinity averaged 21.0 mg/L $CaCO_3$ (Table 17). Total phosphorous averaged 15.6 µg/L P and TKN was 96.3 µg/L N on average for Chignik Lake in 2008 (Table 17). Ammonia averaged 5.9 µg/L N and nitrate + nitrite had a mean of 192.5 µg/L N in 2008 (Table 17). It should be noted that TKN measured 132.0 µg/L N on May 19, 78.0 µg/L N on June 20, and 79.0 µg/L N on July 6 (Table 19). Of the photosynthetic pigments, chlorophyll *a* (seasonal average 2.15 µg/L) was at its lowest concentration in June and phaeophytin *a* (seasonal mean 0.56 µg/L) increased from May to August (Table 19).

Zooplankton

Black Lake

Copepod abundance (seasonal average 29,282/m^2) was greater than cladoceran abundance (seasonal average 3,362/m^2) throughout the sampling season in Black Lake (Table 20; Figure 18). On average, the most prevalent identifiable genera of copepod in Black Lake was *Cyclops* with a seasonal mean of 13,093/m^2 (Table 20; Figure 18). Copepod nauplii (juveniles) were also abundant with a seasonal mean of 16,189/m^2, but could only be identified to class. *Bosmina* were the most prevalent cladocerans in Black Lake in 2008 (Table 20).

Copepod biomass was dominated by *Cyclops*, and was the greatest in June (21.5 mg/m^2; Table 21). The majority of cladoceran biomass, including ovigerous individuals, was comprised of *Bosmina* throughout the 2008 sampling season with a weighted seasonal average of 4.0 mg/m^2 (Table 21). Copepod biomass was greater than cladoceran biomass over the sampling period in 2008 (Table 21; Figure 19;). It should be noted that because zooplankton sampling was absent in August for Black Lake, the 2008 seasonal averages may not truly reflect seasonal zooplankton trends in Black Lake; recent historical August zooplankton data have shown dramatic increases in *Bosmina* biomass.

Average seasonal lengths of the major zooplankton in Black Lake were 0.57 mm for C*yclops*, and 0.31 mm for *Bosmina* (Table 22).

Chignik Lake

The average seasonal copepod density (153,455/m^2) was greater than the average seasonal cladoceran density (62,716/m^2) in 2008 (Table 23). Not including ovigerous zooplankton, *Cyclops* (87,331/m^2*)*, *Diaptomus* (14,265/m^2), and *Epischura* (10,350/m^2) were the densest genera of copepods on average during the 2008 season (Table 23; Figure 20; Appendix E4). *Bosmina* (38,125/m^2) and *Daphnia* (11,968/m^2) were the densest cladocerans (Table 23; Figure 20; Appendix E4). The total average density of copepod and cladoceran zooplankton was less in Black Lake (32,643/m^2) than in Chignik Lake (216,171/m^2) in 2008, however the lack of an August Black Lake sample should be considered when making this comparison (Tables 20 and 23).

Biomass estimates of the copepod *Cyclops* were substantially greater than biomass estimates of other copepod and cladocerans from May through July (Table 24). The copepod *Cyclops* had the greatest biomass of all identified zooplankton in July (248.2 mg/m^2; Table 24). *Bosmina* and *Daphnia* biomass levels generally increased from May to August (Table 24). For the 2008 season, copepods (278.3 mg/m^2) had a greater biomass on average than cladocerans

(44.6 mg/m^2) for a total weighted average of 322.8 mg/m^2 Chignik Lake zooplankton, which was greater than that of Black Lake (Tables 21 and 24; Figures 19 and 21).

Average seasonal lengths of the major non-egg bearing zooplankton in Chignik Lake were 0.93 mm for *Diaptomus*, 0.69 mm for *Cyclops*, 0.63 mm for *Epischura*, 0.33 mm for *Bosmina*, and 0.48 mm for *Daphnia* (Table 25). Ovigerous zooplankton were generally longer than non-egg bearing individuals (Table 25).

DISCUSSION

The point estimate of the 2008 total smolt emigration was the fourth lowest estimated emigration on record since 1994. The confidence in the 2008 estimate is fair considering that the 2008 mark-recapture experiment results were similar to those from past years and sample sizes achieved or exceeded the number required to reduce estimate bias (Carlson et al. 1998). In 2008, a total of 10,085 smolts, which is approximately 16% of the total number of smolts captured in the traps, were marked. Ninety-nine smolts were recaptured in comparison to 1996, the year of the lowest estimated smolt emigration, when, of the 24,695 smolts captured in the traps that season, only 3,180 smolts were marked and 49 smolts were recaptured. The overall 2008 trap efficiency (0.99%) was similar to 1995, 1996, 1997, 2001, and 2002 trap efficiencies. The low trap efficiencies are reasonable considering multiple factors: 1) the cross-sectional area of the Chignik River is roughly 106 m^2 at the trap location and the traps fished approximately 3.0% (2.75 m^2) of the Chignik River, 2) delayed mortality and mark-retention trials did not indicate the need to adjust trap efficiency or population estimates, and 3) the mark-recapture events possessed adequate sample sizes to minimize bias of the population estimate.

Additionally, there has been a concern that a significant portion of the sockeye salmon smolt emigration has been missed prior to the trap being installed in the spring. In 2008, the peak smolt emigration took place on June 5, 28 days after the traps were installed. Since 1996, all peak emigration days have occurred after May 2 and nine out of ten of the peak emigration events have occurred after May 20. These data suggest that installation of the traps during the first week of May is sufficient to capture the majority of the emigration. Similarly, the Chignik River was routinely sampled with a beach seine and a fyke net from May 5th to May 8th to assess if sockeye salmon smolts were outmigrating while waiting for the ice to depart Chignik Lake to ensure safe trap deployment. Few sockeye salmon smolt were captured prior to trap deployment. It should also be noted that water temperature prior to trap deployment was ~3 °C, which was below temperatures observed to coincide with other salmon migrations (Clarke and Hirano 1995). Because cool water temperatures ran later into the spring than usual, it is possible the outmigration timing of sockeye salmon from the watershed was also later and may have extended beyond the project’s budgeted season. Outmigration numbers, however, were low (between 68 and 206 fish captured) during the last week of the project, which suggest that the outmigration was at its end.

Generally, the early run is primarily composed of age-1. sockeye salmon and the late run is primarily composed of age-2. sockeye salmon. Excluding 2005 and 2006, there were decidedly more age-0. sockeye salmon smolt in 2008 than in all past years of the study (Finkle and Ruhl 2008). This may suggest conditions in the watershed are unfavorable for rearing causing the migration of age-0. fish or that there was a relatively substantial number of age-0. fish that were spawned and hatched out in the river and were subsequently captured because of their close proximity to the traps. The low age-1. and -2. smolt abundances in 2008 suggest that subsequent early-run and late-run returns (primarily in 2011) may be poor despite increased zooplankton biomass levels. The sockeye salmon smolts that emigrated in 2008 were comparable to the average size of smolts that emigrated in all past years of the study, except the larger-sized fish from 2007.

Observed marine survivals of Chignik sockeye salmon smolts by fully recruited emigration year (excluding 1996), have ranged from 5 to 26 percent (Table 10). These estimates were well within the ranges observed in other systems (Burgner 1991). This estimated variability in marine survival implies that given constant freshwater production, the resultant adult returns would still fluctuate with annual differences in productivity of the marine environment.

Within each lake, density independent events can affect sockeye salmon production and outmigration. Summer rearing conditions from 2002 to 2005 were generally warmer and more turbid on average in Chignik Lake compared to the past 3 years (Finkle 2007a; Finkle *unpublished data*). Under stressful environmental conditions, such as elevated temperatures (>15°C; Brett et al. 1969) and poor visibility, underyearling sockeye salmon may successfully migrate to sea (Rice at al. 1994). If a portion of these fish emigrated as age-0. fish and survived, it could be expected that a larger-than-average component of age-0. adults would return to the watershed. Historically, there have not been large numbers of freshwater age-0. adult sockeye salmon returning to Chignik in past years (Bouwens and Finkle 2003; Witteveen et al. 2007). In 2005, 2006, and 2008, however, adult returns of age-0. fish increased compared to past years (Finkle *unpublished data*). These age-0. fish would have outmigrated between 2002 and 2006 and reared in the watershed between 2001 and 2005, during which time turbidity increased in Chignik Lake and temperatures increased in Black Lake (Finkle 2007a). In 2008, a total of 19,803 sockeye salmon fry (presmolt) were captured during the field season, which was substantially more than in 2007, but was comparable to other years (Finkle and Ruhl 2008). Although temperatures were cooler from 2006 to 2008, and therefore more metabolically favorable for rearing juvenile sockeye salmon, (Finkle 2007; Finkle *unpublished data*), a flood event in December of 2007 may have affected the increase in the outmigration of age-0. fish from the watershed and the increase in the number sockeye salmon fry captured in the trap.

Nutrient levels during the 2008 sampling season in Black Lake and Chignik Lake were comparable to the past six years, and were comparable to other Alaska lakes (Honnold et al. 1996; Schrof and Honnold 2003). Nutrient data can indicate limitations in aquatic environments. A comparison of total nitrogen (TN) to total phosphorous is a simple indicator of aquatic ecosystem health as both are necessary for primary production (Wetzel 1983; UF 2000). Nitrogen-phosphorous ratios of less than 10:1 indicate nitrogen limitations (USEPA 2000). In Black Lake, the average ratio of total nitrogen to total phosphorous (11.9 TN:1 TP) suggested that nitrogen was not a limiting nutrient (USEPA 2000). Additionally, the phosphorous concentration of Black Lake was greater than that of most oligotrophic lakes (15 µg/L P; U F 2000). A comparison of the photosynthetic pigment, chlorophyll *a,* to its byproduct, phaeophytin *a,* showed that chlorophyll-*a* concentrations were proportionally high (seasonal mean of 4.62 chlorophyll *a* to 1 phaeophytin *a*). This indicated that the potential for rapid algal (phytoplankton) growth existed in Black Lake because chlorophyll *a* was readily available for photosynthesis (COLAP 2001). Thus, even if nutrient limitations existed, as described by the TN/TP ratios, an adequate volume of nitrogen and phosphorous were available for phytoplankton production, and thus had the potential to meet primary (zooplankton) consumption demands. In other words, nitrogen was not a limiting nutrient and phosphorous concentrations were in excess of the levels needed for primary production in Black Lake. In Chignik Lake, the seasonal mean chlorophyll-*a*: phaeophytin-*a* ratio of 3.84:1 suggested that zooplankton were not limited by phytoplankton production. Although photosynthetic pigments in Chignik Lake were less concentrated in 2008 than in all previous years, except 2001, primary nutrients did not appear to be a limiting factor in the watershed in 2008.

The seasonal pH levels in Black and Chignik lakes were slightly higher than pH levels 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 of roughly 4.5 to 9.5 (Wetzel 1983). The recent increased pH levels in Black and Chignik lakes may suggest that juvenile sockeye salmon production has become more competitive as indicated by a decline in zooplankton biomass and the availability of phytoplankton and chlorophyll-*a*. The decreased grazing pressure by zooplankton upon phytoplankton, in turn, allows the phytoplankton biomass to increase and remove greater quantities of carbon dioxide from the water through photosynthesis, increasing the overall level of pH in each lake.

Density estimates for zooplankton have fluctuated in species composition on intra- and interannual time scales in Black and Chignik lakes. Historically in Black Lake, the greatest inseason average zooplankton densities fluctuate between *Cyclops* and *Bosmina*, with a large increase of *Bosmina* in August. This *Bosmina* spike coincides with the migration of Black Lake juvenile sockeye salmon to Chignik Lake, which suggests that the impact and magnitude of top-down pressures (in the form of overgrazing) are greater than bottom-up pressures in Black Lake as biomass increases with a reduction in grazing pressure. Although sampling was not conducted in Black Lake during August, 2008, it appeared that the zooplankton population was behaving consistently with prior years' data based on the results from June and July. Similarly for Chignik Lake, although zooplankton biomass increased over the sampling season, biomass levels were considered low by some indices (Mazumder and Edmundson 2002), suggesting top-down grazing pressure was present as primary nutrients were not limiting.

A formal forecast was prepared which predicted specific age classes based on sibling ocean age class relationships and temperature indices when possible, and median values when sibling relationships did not exist. Using these sibling methods, the 2009 Chignik sockeye salmon forecast is 1.38 million (Volk *in prep*).

For the smolt-based forecast, the emigration during 1996 was excluded from the analysis since adult return and marine survival data indicated that the emigration was likely underestimated. Further discussion on the removal of the 1996 data can be found in Edwards and Bouwens (2002). A simple regression model was developed to forecast the 2008 adult run using smolt emigration data. The regression relationship using outmigrant age-2. smolts and 3-ocean adult returns was statistically significant ($P = 0.003$) and accounted for 84% of the total return. The 2009 smolt-based forecast of 1.62 million sockeye salmon is approximately 236,000 fish more than was forecasted using sibling and temperature regression relationships. The smolt forecast corroborates the sibling and temperature regression relationships. This forecasting method does not have the resolution to forecast by run as we have not yet determined the stock-of-origin of the smolts. However, current genetic analyses may provide a basis for Chignik sockeye salmon smolt stock separation (personal communication, Lisa Creelman, University of Washington graduate student, Seattle, Washington).

A smolt-based forecast was available for the first time in 2002. Since its inception, the smolt-based forecast has overestimated the Chignik total sockeye salmon adult return by as much as 107% (2004 forecast) and underestimated it by as little as 9% (2003 forecast). 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 smolts and temperature against ocean-age class adult returns. The simple linear regression smolt forecast relationship for the 2008 adult return overestimated the adult return by 9%. The simple linear regression employed in the 2008 smolt forecast explained a high percent (59%) of the variability of the dependent variable as explained by the independent variable. Because of the small data set and the past predictive ability of the model, our confidence in the smolt-based forecast is fair.

Genetic samples collected from the outmigrating sockeye salmon smolts will provide a better understanding of ecological events in the watershed. Genetic analyses of the Chignik sockeye salmon smolt outmigration lend themselves to stock-based smolt forecasts in addition to providing information on stock-specific life history traits of rearing and outmigrating juveniles.

A presentation describing the sockeye salmon life cycle and the Chignik Sockeye Salmon Smolt Enumeration project was given to students attending the Chignik Lake School on May 12. The goal of the presentation was to relay the value of the smolt project and develop stewardship in the students for their resource and to help them learn about resource sustainability.

Data from this project are essential for monitoring the health of sockeye salmon in Chignik River watershed. Smolt emigration information may be the only available means to link changes in run strength to freshwater or marine influences. As more outmigration and genetic data become available, the smolt-based forecast should provide a more accurate estimate of adult returns.

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TABLES AND FIGURES

Table 1.–Limnology and zooplankton sampling events, 2008.

Location	Date	Type of sampling
Black Lake	26-May	Water and zooplankton
	20-Jun	Water and zooplankton
	7-Jul	Water and zooplankton
Chignik Lake[a]	19-May	Water and zooplankton
	17-Jun	Water and zooplankton
	6-Jul	Water and zooplankton
	21-Aug	Zooplankton

[a] Only Stations 2 and 4 were dedicated to the collection of water samples.

Table 2.–Chignik River sockeye salmon smolt population estimates, by age class, 1994 to 2008.

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			

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Table 2.–Page 2 of 2.

Year		Number of Smolt							95% C.I.	
		Age-0.	Age-1.	Age-2.	Age-3.	Age-4.	Total	S.E.	Lower	Upper
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			
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	0.6	74.4	25.0	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			

Table 3.–Estimated sockeye salmon smolt emigration from the Chignik River, by age class and statistical week, 2008

Statistical Week	Starting Date	Number of Smolt Age-0.	Age-1.	Age-2.	Age-3.	Total
19	5/3	0	8,579	9,588	1,514	19,681
20	5/10	10,646	134,400	111,778	2,661	259,485
21	5/17	30,079	175,463	260,688	20,053	486,283
22	5/24	103,200	892,374	182,117	12,141	1,189,832
23	5/31	174,023	1,474,079	388,993	0	2,037,095
24	6/7	355,316	430,560	29,261	4,180	819,318
25	6/14	143,194	54,599	4,121	0	201,913
26	6/21	65,667	41,042	586	586	107,881
27	6/28	108,937	48,505	795	0	158,237
28	7/5	26,436	50,293	0	0	76,730
Total		1,017,498	3,309,894	987,928	41,136	5,356,455

Table 4.–Results from mark-recapture tests performed on sockeye salmon smolt migrating through the Chignik River, 2008.

Date	No. Marked	Total Recaptures	Trap Efficiency[a]
5/15	848	10	1.30%
5/21	1,568	12	0.83%
5/27	1,776	8	0.51%
6/2	771	11	1.55%
6/6	1,991	23	1.21%
6/11	1,181	15	1.35%
6/20	977	12	1.33%
6/29	973	8	0.92%
Total	10,085	99	0.99%

[a] Calculated by: = $\{(m_h+1)/(M_h+1)\}*100$ where: m_h = number of marked fish recaptured, and; M_h = number of marked fish (Carlson et al. 1998).

Table 5.–Estimated age composition of Chignik Lake sockeye salmon smolt samples, by week, 2008.

Stat Week	Sample Size		Number of Smolt Age-0.	Age-1.	Age-2.	Age-3.	Total
19	39	Percent	0.0	43.6	48.7	7.7	100.0
		Numbers	0	17	19	3	39
20	195	Percent	4.1	51.8	43.1	1.0	100.0
		Numbers	8	101	84	2	195
21	194	Percent	6.2	36.1	53.6	4.1	100.0
		Numbers	12	70	104	8	194
22	196	Percent	8.7	75.0	15.3	1.0	100.0
		Numbers	17	147	30	2	196
23	199	Percent	8.5	72.4	19.1	0.0	100.0
		Numbers	17	144	38	0	199
24	196	Percent	43.4	52.6	3.6	0.5	100.0
		Numbers	85	103	7	1	196
25	196	Percent	70.9	27.0	2.0	0.0	100.0
		Numbers	139	53	4	0	196
26	184	Percent	60.9	38.0	0.5	0.5	100.0
		Numbers	112	70	1	1	184
27	199	Percent	68.8	30.7	0.5	0.0	100.0
		Numbers	137	61	1	0	199
28	119	Percent	34.5	65.5	0.0	0.0	100.0
		Numbers	41	78	0	0	119
Total	1,717	Percent	33.1	49.2	16.8	1.0	100.0
		Numbers	568	844	288	17	1,717

Table 6.–Estimated age composition of Chignik River sockeye salmon smolt samples, 1994 to 2008.

Year	Dates	Sample Size		Number of Smolt Age-0.	Age-1.	Age-2.	Age-3.	Age-4.	Total
1994	5/6-6/30	2,806	Percent	0.0	61.1	38.9	0.0	0.0	100.0
			Numbers	0	1,715	1,091	0	0	2,806
1995	5/6-6/29	2,557	Percent	10.7	49.8	39.5	0.0	0.0	100.0
			Numbers	273	1,274	1,010	0	0	2,557
1996	5/6-7/28	2,099	Percent	6.0	67.8	26.1	0.1	0.0	100.0
			Numbers	125	1,423	548	3	0	2,099
1997	5/4-7/22	2,657	Percent	7.3	63.1	29.1	0.5	0.0	100.0
			Numbers	195	1,676	774	12	0	2,657
1998	5/2-7/30	2,745	Percent	0.5	28.6	70.1	0.7	0.0	100.0
			Numbers	15	785	1,925	20	0	2,745
1999	5/10-7/3	2,180	Percent	1.8	61.7	36.1	0.3	0.0	100.0
			Numbers	40	1,345	788	7	0	2,180
2000	4/22-7/20	1,915	Percent	11.6	61.4	26.3	0.7	0.0	100.0
			Numbers	223	1,175	503	14	0	1,915
2001	4/29-7/12	2,195	Percent	4.4	75.0	17.7	2.8	0.0	100.0
			Numbers	96	1,647	389	62	1	2,195
2002	5/01-7/8	2,038	Percent	10.6	77.9	11.1	0.3	0.0	100.0
			Numbers	217	1,588	227	6	0	2,038
2003	4/25-7/8	2,098	Percent	7.1	79.6	13.3	0.0	0.0	100.0
			Numbers	149	1,670	279	0	0	2,098
2004	5/6-7/1	1,651	Percent	21.0	62.4	16.6	0.0	0.0	100.0
			Numbers	347	1,030	274	0	0	1,651
2005	4/26-7/8	1,950	Percent	33.5	45.7	20.4	0.4	0.0	100.0
			Numbers	654	892	397	7	0	1,950
2006	4/27-7/9	1,644	Percent	26.2	40.3	31.6	1.9	0.0	100.0
			Numbers	430	663	519	32	0.0	1,644
2007	5/9-7/8	1,087	Percent	0.6	74.4	25.0	0.0	0.0	100.0
			Numbers	6	809	272	0	0	1,087
2008	5/9-7/9	1,717	Percent	33.1	49.2	16.8	1.0	0.0	100.0
			Numbers	568	844	288	17	0	1,717

Table 7.–Length, weight, and condition factor of Chignik River sockeye salmon smolt samples, by age and statistical week, 2008.

				Length (mm)		Weight (g)		Condition Factor	
Age	Stat Week	Starting Date	Sample Size	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
0	20	5/10	8	52	1.05	0.9	0.09	0.67	0.06
0	21	5/17	12	51	0.65	0.9	0.05	0.71	0.04
0	22	5/24	17	56	1.05	1.1	0.09	0.61	0.03
0	23	5/31	17	60	1.19	1.6	0.09	0.72	0.02
0	24	6/7	85	53	0.42	1.0	0.03	0.67	0.01
0	25	6/14	139	52	0.30	1.0	0.02	0.75	0.01
0	26	6/21	112	52	0.35	1.1	0.03	0.81	0.01
0	27	6/28	137	52	0.31	1.2	0.03	0.82	0.01
0	28	7/5	41	54	0.61	1.3	0.06	0.80	0.01
Total			568	53	0.17	1.1	0.01	0.76	0.01
1	19	5/3	17	69	0.90	2.3	0.08	0.70	0.01
1	20	5/10	101	67	0.42	2.1	0.05	0.70	0.01
1	21	5/17	70	67	0.62	2.2	0.06	0.74	0.01
1	22	5/24	147	64	0.35	1.8	0.04	0.68	0.01
1	23	5/31	144	67	0.36	2.2	0.04	0.75	0.01
1	24	6/7	103	64	0.39	1.9	0.04	0.71	0.01
1	25	6/14	53	65	0.77	2.3	0.09	0.79	0.02
1	26	6/21	70	62	0.55	2.1	0.08	0.86	0.02
1	27	6/28	61	62	0.67	2.1	0.07	0.87	0.01
1	28	7/5	78	62	0.57	2.1	0.06	0.85	0.01
Total			844	65	0.17	2.1	0.02	0.76	0.00
2	19	5/3	19	83	1.34	4.3	0.22	0.75	0.01
2	20	5/10	84	79	0.63	3.6	0.09	0.7	0.01
2	21	5/17	104	80	0.57	3.8	0.09	0.75	0.01
2	22	5/24	30	77	1.02	3.2	0.13	0.68	0.01
2	23	5/31	38	80	0.79	3.8	0.14	0.75	0.01
2	24	6/7	7	81	5.03	4.7	1.34	0.76	0.06
2	25	6/14	4	80	1.80	4.3	0.37	0.83	0.02
2	26	6/21	1	69	0.00	2.1	0.00	0.64	0.00
2	27	6/28	1	71	0.00	3.0	0.00	0.84	0.00
Total			288	79	0.35	3.7	0.06	0.73	0.01
3	19	5/3	3	89	4.67	5.3	1.07	0.74	0.04
3	20	5/10	2	86	0.50	4.2	0.40	0.67	0.05
3	21	5/17	8	89	3.72	5.8	0.81	0.79	0.02
3	22	5/24	2	87	5.50	4.6	0.85	0.71	0.00
3	24	6/7	1	110	0.00	12.6	0.00	0.95	0.00
3	26	6/21	1	108	0.00	11.6	0.00	0.92	0.00
Total			17	91	2.54	6.1	0.70	0.77	0.02

Table 8.–Mean length, weight, and condition factor of sockeye salmon smolt samples from the Chignik River, year and age, 1994-2008.

		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
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
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

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Table 8.–Page 2 of 2.

		Length (mm)			Weight (g)			Condition Factor		
Year	Age	Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error
1996	3	3	100	5.55	3	8.4	1.68	3	0.81	0.06
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
2001	4	1	125	-	1	18.8	-	1	0.96	-

Table 9.–Chignik River sockeye salmon escapement, estimated number of smolts by freshwater age, smolts per spawner, adult return by freshwater age, return per spawner, marine survival, by brood year, 1991 to 2008.

Brood Year	Escapement	Smolt Produced Age-0.	Age-1.	Age-2.	Age-3.	Age-4.	Total smolt	Smolt / spawner	Adult Returns[a] Age-0.	Age-1.	Age-2.	Age-3.	Age-4.	Total	Return / spawner	Marine Survival
1991	1,040,098	NA	NA	4,270,636	0	0	4,270,636	4.11	6,868	1,795,467	737,680	11,621	0	2,551,636	2.45	NA
1992	764,436	NA	7,263,054	5,178,450	5,018	0	12,446,522	16.28	152,005	649,920	1,159,871	93,372	0	2,055,168	2.69	17%[b]
1993	697,377	0	2,843,222	731,099	122,289	0	3,696,610	5.30	16,270	457,189	1,998,416	7,265	0	2,479,140	3.55	67%
1994	966,909	735,916	1,200,793	13,738,356	158,056	0	15,833,121	16.37	251	1,818,410	1,483,548	2,467	0	3,304,676	3.42	21%
1995	739,920	80,254	11,172,150	20,374,245	78,798	0	31,705,447	42.85	36,053	2,391,218	942,680	17,366	0	3,387,317	4.58	11%
1996	749,137	528,846	5,790,587	8,221,631	160,017	5,671	14,706,752	19.63	145,189	1,998,842	877,180	13,958	0	3,035,168	4.05	21%
1997	775,618	75,560	12,705,935	4,645,121	516,723	0	17,943,339	23.13	15,852	770,645	956,005	5,627	0	1,748,129	2.25	10%
1998	701,128	73,364	8,047,526	5,024,666	72,184	0	13,217,740	18.85	5,515	1,030,709	350,167	1,052	0	1,387,443	1.98	10%
1999	715,966	1,270,101	18,940,752	2,223,996	0	0	22,434,849	31.34	26,176	913,849	403,536	1,663	0	1,345,224	1.88	6%
2000	805,225	521,546	13,980,423	1,449,494	0	0	15,951,463	19.81	15,176	1,988,373	699,285	2,729	0	2,705,565	3.36	17%
2001	1,136,918	440,947	5,146,278	2,239,716	32,889	0	7,859,830	6.91	79,627	1,031,100	696,415	482	0	1,807,624	1.59	23%
2002[a]	725,220	155,047	6,172,902	1,468,208	119,614	0	7,915,771	10.91								
2003	684,145	244,206	2,075,681	2,847,624	0	0	5,167,511	7.55								
2004	578,259	859,211	2,849,043	1,028,865	41,136											
2005	581,382	1,744,370	1,926,682	987,928												
2006	735,493	9,286	3,309,894													
2007	654,974	1,017,498														
2008	706,058															

[a] Minor age classes are not fully recruited for adult age-2, -3, and -4. returns from brood year 2002.
[b] Age-0. fish not included in marine survival estimate as they outmigrated before the smolt project's first year of operation.

Table 10.–Estimated marine survival of sockeye salmon smolts from the Chignik River by emigration year and ocean age adult returns for each emigration year from 1994 to 2008.

Emigration	Smolt estimates					Adult returns					Marine
Year	Age-0.	Age-1.	Age-2.	Age-3.	Total	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	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			
2006	1,744,370	2,849,043	2,847,624	119,614	7,560,651	771	169,698				
2007	9,286	1,926,682	1,028,865	0	2,964,833	793					
2008	1,017,498	3,309,894	987,928	41,136	5,356,455						
1994-2008 Average (Excluding 1996)											14%

Table 11.–Water temperature, by depth and date, for Black Lake, 2008.

Depth	Temperature (^oC)		
(m)	23-May	20-Jun	7-Jul
0.0	6.5	11.4	12.0
0.5	ND	11.4	12.0
1.0	ND	11.4	12.0
1.5	ND	11.4	12.0
2.0	ND	11.4	12.0
2.5	ND	11.4	12.0

ND= No data.

Table 12.–Dissolved oxygen, by depth and date, for Black Lake, 2008.

Depth	Dissolved oxygen (mg/L)		
(m)	23-May	20-Jun	7-Jul
0.0	ND	10.9	11.3
0.5	ND	10.9	11.0
1.0	ND	10.9	10.9
1.5	ND	10.8	10.9
2.0	ND	10.8	10.8
2.5	ND	10.8	10.8

ND= No data.

Table 13.–Water temperature, averaged over all stations, by depth and date for Chignik Lake, 2008.

Depth	Temperature (°C)			
(m)[a]	19-May[b]	17-Jun	6-Jul	21-Aug
0.0	-	6.9	10.3	11.6
0.5	-	6.9	10.2	11.5
1.0	-	6.9	10.2	11.5
1.5	-	6.9	10.1	11.5
2.0	-	6.9	10.0	11.5
2.5	-	6.9	10.0	11.5
3.0	-	6.9	9.9	11.5
3.5	-	6.8	9.8	11.5
4.0	-	6.8	9.7	11.5
4.5	-	6.8	9.7	11.5
5.0	-	6.8	9.6	11.4
6.0	-	6.8	9.5	11.5
7.0	-	6.8	9.4	11.4
8.0	-	6.8	9.3	11.5
9.0	-	6.7	9.2	11.4
10.0	-	6.7	9.2	11.4
11.0	-	6.7	8.8	11.4
12.0	-	6.7	8.7	11.4
13.0	-	6.6	8.5	11.4
14.0	-	6.6	8.3	11.4
15.0	-	6.6	8.2	11.4
16.0	-	6.6	8.1	11.4
17.0	-	6.5	8.0	11.4
18.0	-	6.5	8.0	11.4
19.0	-	6.5	8.0	11.4
20.0	-	6.5	7.9	11.3
21.0	-	6.5	7.9	11.3
22.0	-	6.4	7.9	11.3
23.0	-	6.4	7.8	11.3
24.0	-	6.4	7.8	11.3
25.0	-	6.4	7.8	11.3
30.0	-	6.4	7.7	11.3

[a] Meter cable was 30 m in length.

[b] Meter not functional.

Table 14.–Dissolved oxygen levels, averaged over all stations, by depth and date for Chignik Lake, 2008.

Depth	Dissolved oxygen (mg/L)			
(m)[a]	19-May[b]	17-Jun	6-Jul	21-Aug
0.0	-	12.2	11.3	11.2
0.5	-	12.3	11.3	11.2
1.0	-	12.3	11.2	11.1
1.5	-	12.3	11.1	11.0
2.0	-	12.3	10.9	10.6
2.5	-	12.3	10.9	10.6
3.0	-	12.2	10.9	10.6
3.5	-	12.3	10.8	10.6
4.0	-	12.2	10.7	10.5
4.5	-	12.3	10.7	10.5
5.0	-	12.3	10.7	10.5
6.0	-	12.3	10.7	10.5
7.0	-	12.3	10.6	10.4
8.0	-	12.3	10.6	10.4
9.0	-	12.3	10.7	10.4
10.0	-	12.3	10.7	10.4
11.0	-	12.3	10.4	10.4
12.0	-	12.3	10.5	10.3
13.0	-	12.3	10.6	10.4
14.0	-	12.3	10.8	10.4
15.0	-	12.3	10.9	10.4
16.0	-	12.3	11.1	10.4
17.0	-	12.3	10.9	10.4
18.0	-	12.3	11.1	10.3
19.0	-	12.3	11.3	10.3
20.0	-	12.3	11.4	10.3
21.0	-	12.3	11.5	10.3
22.0	-	12.3	11.4	10.4
23.0	-	12.3	11.3	10.3
24.0	-	12.3	11.3	10.2
25.0	-	12.3	11.4	9.2
30.0	-	12.3	11.2	9.4

[a] Meter cable was 30 m in length.

[b] Meter not functional.

Table 15.–Euphotic Zone Depth (EZD) and Euphotic Volume (EV) of Black and Chignik Lakes, by month, 2008.

		2008				
Lake		May	June	July	August	Average[a]
Black[b]	EZD	1.70	4.67	5.33	ND	4.23
	Mean EV[c]	70.0	78.1	78.1	ND	78.1
Chignik	EZD	4.28	8.26	9.08	11.39	9.53
	Mean EV[c]	103.2	199.2	218.8	274.5	229.7

[a] Averages calculated from mean light reading (kLux) data.

[b] 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.

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

Table 16.–Average monthly solar illuminance readings by depth and month for Chignik Lake, 2008.

	Solar illuminance (kLux)				
Depth	May	June	July	August	Average
0.0	1,493.3	395.5	325.5	1,010.1	806.1
0.5	1,082.0	269.3	229.3	845.0	606.4
1.0	696.8	198.3	187.3	671.3	438.4
1.5	429.3	147.0	126.3	497.6	300.0
2.0	284.0	112.4	90.5	398.0	221.2
2.5	228.5	84.6	76.5	323.7	178.3
3.0	171.0	66.3	59.3	266.0	140.6
3.5	129.3	49.0	45.0	212.0	108.8
4.0	101.5	38.0	33.9	176.2	87.4
4.5	78.8	29.8	26.1	146.1	70.2
5.0	57.8	21.4	20.3	114.8	53.5
6.0	32.5	13.0	12.0	77.4	33.7
7.0	18.8	9.7	8.6	50.4	21.9
8.0	10.3	-	5.2	33.2	12.2
9.0	6.0	-	3.4	22.9	8.1
10.0	3.4	-	3.4	16.0	5.7
11.0	2.1	-	-	14.7	4.2
12.0	1.2	-	-	11.1	3.1
13.0	0.8	-	-		0.3
14.0	-	-	-		-
15.0	-	-	-		-
16.0	-	-	-		-
17.0	-	-	-		-
18.0	-	-	-		-
19.0	-	-	-		-
20.0	-	-	-		-
21.0	-	-	-		-
22.0	-	-	-		-
23.0	-	-	-		-
24.0	-	-	-		-
25.0	-	-	-		-
26.0	-	-	-		-
27.0	-	-	-		-
28.0	-	-	-		-
29.0	-	-	-		-
30.0	-	-	-		-

Table 17.–Seasonal water quality parameters, nutrient concentrations, and photosynthetic pigments for Chignik Lake (by station) and Black Lake, 2008.

	Chignik Lake			Black Lake
	Station 2	Station 4	Average[a]	Average
pH	7.50	7.45	7.47	7.64
Alkalinity (mg/L)	21.3	20.7	21.0	19.0
Total P (µg/L P)	13.9	17.2	15.6	22.2
TKN (µg/L N)	96.3	ND	96.3	263.7
Ammonia (µg/L N)	5.5	6.3	5.9	3.7
Nitrate + Nitrite (µg/L N)	198.6	186.3	192.5	0.6
Chlorophyll *a* (µg/L)	2.03	2.28	2.15	6.56
Phaeophytin *a* (µg/L)	0.59	0.53	0.56	1.42

[a] Averaged values do not always exactly match the values reported in table 18 and appendices E1& E2 due to rounding.

Table 18.–Water quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Black Lake, 2008.

	2008			
	26-May	20-Jun	7-Jul	Average
pH	7.53	7.67	7.73	7.64
Alkalinity (mg/L)	19.0	18.0	20.0	19.0
Total P (µg/L P)	22.2	22.3	22.2	22.2
TKN (µg/L N)	501.0	152.0	138.0	263.7
Ammonia (µg/L N)	4.8	3.5	2.9	3.7
Nitrate + Nitrite (µg/L N)	0.6	0.6	0.6	0.6
Chlorophyll *a* (µg/L)	13.88	3.66	2.14	6.56
Phaeophytin *a* (µg/L)	2.56	1.14	0.56	1.42

Table 19.–Water quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Chignik Lake, 2008.

	2008			
	19-May	20-Jun	6-Jul	Average[a]
pH	7.34	7.59	7.49	7.47
Alkalinity (mg/L)	23.5	19.5	20.0	21.0
Total P (µg/L P)	13.6	16.5	16.6	15.6
TKN (µg/L N)[b]	132.0	78.0	79.0	96.3
Ammonia (µg/L N)[b]	4.3	6.1	7.4	5.9
Nitrate + Nitrite (µg/L N)	225.9	191.4	160.1	192.5
Chlorophyll *a* (µg/L)	2.24	1.60	2.62	2.15
Phaeophytin *a* (µg/L)	0.34	0.36	0.97	0.56

[a] All stations and depths are averaged for each sample date. Averaged values do not always exactly match the values reported in Table 17 due to rounding.

Table 20.–Average number of zooplankton per m^2 from Black Lake by sample date, 2008.

Taxon	Sample date 5/26	6/20	7/7	Seasonal average
Copepods				
Epischura	-	-	-	-
Ovig. *Epischura*	-	-	-	-
Diaptomus	-	-	-	-
Ovig. *Diaptomus*	-	-	-	-
Cyclops	7,431	19,108	12,739	13,093
Ovig. *Cyclops*	-	-	-	-
Harpaticus	-	-	-	-
Nauplii	31,847	9,554	7,166	16,189
Total copepods	39,278	28,662	19,904	29,282
Cladocerans				
Bosmina	3,185	1,062	796	1,681
Ovig. *Bosmina*	-	1,062	3,981	1,681
Daphnia l.	-	-	-	-
Ovig. *Daphnia l.*	-	-	-	-
Chydorinae	-	-	-	-
Total cladocerans	3,185	2,123	4,777	3,362
Total copepods + cladocerans	42,463	30,786	24,682	32,643

Table 21.–Biomass estimates (mg dry weight/m^2) of the major Black Lake zooplankton taxon by sample date, 2008.

Taxon	Sample date 5/26	6/20	7/7	Seasonal average	Weighted average
Copepods					
Epischura	-	-	-	-	-
Diaptomus	-	-	-	-	-
Cyclops	9.1	21.5	11.0	13.9	13.8
Harpaticus	-	-	-	-	-
Total copepods	9.1	21.5	11.0	13.9	13.8
Cladocerans					
Bosmina	2.8	0.9	0.7	1.5	1.5
Ovigerous *Bosmina*	-	1.9	5.9	2.6	2.6
Daphnia longiremis	-	-	-	-	-
Chydorinae	-	-	-	-	-
Total cladocerans	2.8	2.7	6.6	4.0	4.0
Total Biomass	11.9	24.2	17.6	17.9	17.8

Table 22.–Average length (mm) of zooplankton in Black Lake by sample date, 2008.

Taxon	Sample date 5/26	6/20	7/7	Seasonal average
Copepods				
Epischura	-	-	-	-
Diaptomus	-	-	-	-
Cyclops	0.61	0.58	0.51	0.57
Harpaticus	-	-	-	-
Cladocerans				
Bosmina	0.31	0.30	0.32	0.31
Ovigerous *Bosmina*		0.44	0.40	0.40
Daphnia l.	-	-	-	-
Chydorinae	-	-	-	-

Table 23.–Average number of zooplankton per m^2 from Chignik Lake, by sample date, 2008.

Taxon	Sample date 5/19	6/17	7/6	8/22	Seasonal average
Copepods					
Epischura	-	-	-	41,401	10,350
Ovigerous *Epischura*	-	-	-	-	-
Diaptomus	-	796	-	56,263	14,265
Ovigerous *Diaptomus*	-	-	-	6,369	1,592
Cyclops	104,432	56,728	65,021	123,142	87,331
Ovigerous *Cyclops*	-	-	1,327	9,554	2,720
Harpaticus	-	133	265	-	100
Nauplii	18,976	7,730	11,279	110,403	37,097
Total copepods	123,408	65,386	77,893	347,134	153,455
Cladocerans					
Bosmina	265	630	5,109	146,497	38,125
Ovigerous *Bosmina*	-	133	199	37,155	9,372
Daphnia longiremis	1,327	365	531	45,648	11,968
Ovigerous *Daphnia longiremis*	-	265	1,062	7,431	2,189
Chydorinae	-	-	-	4,246	1,062
Total cladocerans	1,592	1,393	6,900	240,977	62,716
Total Copepods + Cladocerans	125,000	66,779	84,793	588,110	216,171

Table 24.–Biomass estimates (mg dry weight/m^2) of the major zooplankton species in Chignik Lake by sample date, 2008.

Taxon	Sample date 5/19	6/17	7/6	8/22	Seasonal average	Weighted average
Copepods						
Epischura	-	-	-	45.0	11.3	11.3
Ovigerous *Epischura*	-	-	-	-	-	-
Diaptomus	-	2.3	-	438.5	110.2	109.6
Ovigerous *Diaptomus*	-	-	-	-	-	-
Cyclops	106.9	163.5	248.2	134.2	163.2	147.2
Ovigerous *Cyclops*	-	-	7.9	95.8	25.9	10.1
Harpaticus	-	0.3	-	-	0.1	0.1
Total Copepods	106.9	166.1	256.1	713.5	310.7	278.3
Cladocerans						
Bosmina	1.2	1.0	4.4	139.5	36.5	18.9
Ovigerous *Bosmina*	-	1.4	1.7	46.7	12.4	12.0
Daphnia longiremis	1.2	0.5	1.3	50.6	13.4	6.9
Ovigerous *Daphnia longiremis*	-	2.7	5.5	57.6	16.4	6.4
Chydorinae	-	-	-	1.2	0.3	0.3
Total Cladocerans	2.4	5.6	12.8	295.7	79.1	44.6
Total Biomass	109.4	171.7	268.9	1,009.1	389.8	322.8

Table 25.–Average length (mm) of zooplankton from Chignik Lake by sample date, 2008.

Taxon	Sample date 5/19	6/17	7/6	8/22	Seasonal average
Copepods					
Epischura	-	-	-	0.63	0.63
Ovigerous *Epischura*			-		-
Diaptomus	-	0.68	-	1.18	0.93
Ovigerous *Diaptomus*	-	-	-	-	-
Cyclops	0.51	0.76	0.91	0.57	0.69
Ovigerous *Cyclops*	-	-	1.25	1.17	1.21
Harpaticus	0.42	-	-	0.51	0.46
Cladocerans					
Bosmina	0.35	0.36	0.31	0.32	0.33
Ovigerous *Bosmina*	-	0.52	0.47	0.37	0.45
Daphnia longiremis	0.48	0.44	0.48	0.52	0.48
Ovigerous *Daphnia longiremis*	-	0.76	0.78	0.92	0.82
Chydorinae	-	-	-	0.18	0.18

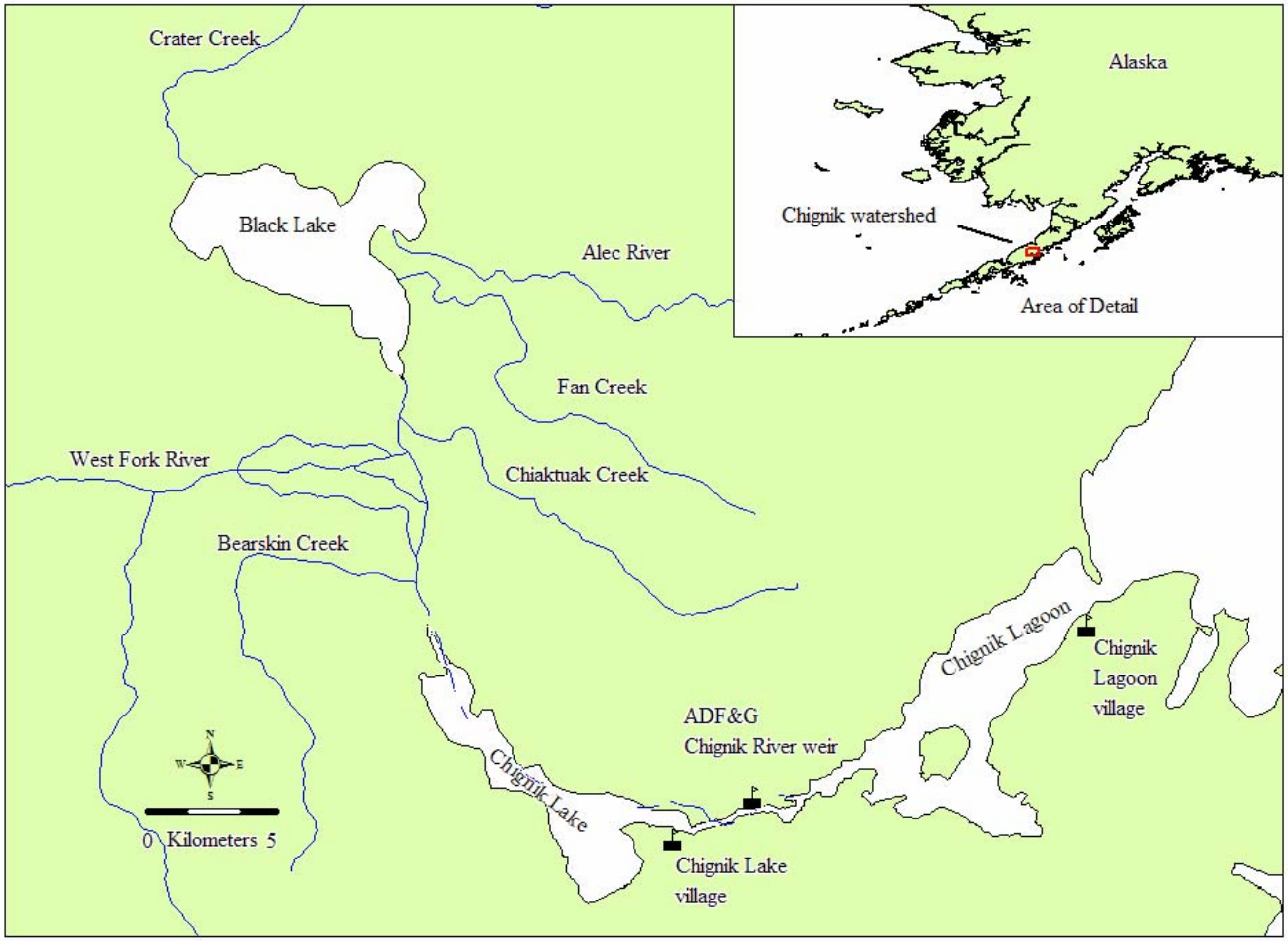


Figure 1.–Map of the Chignik River watershed.

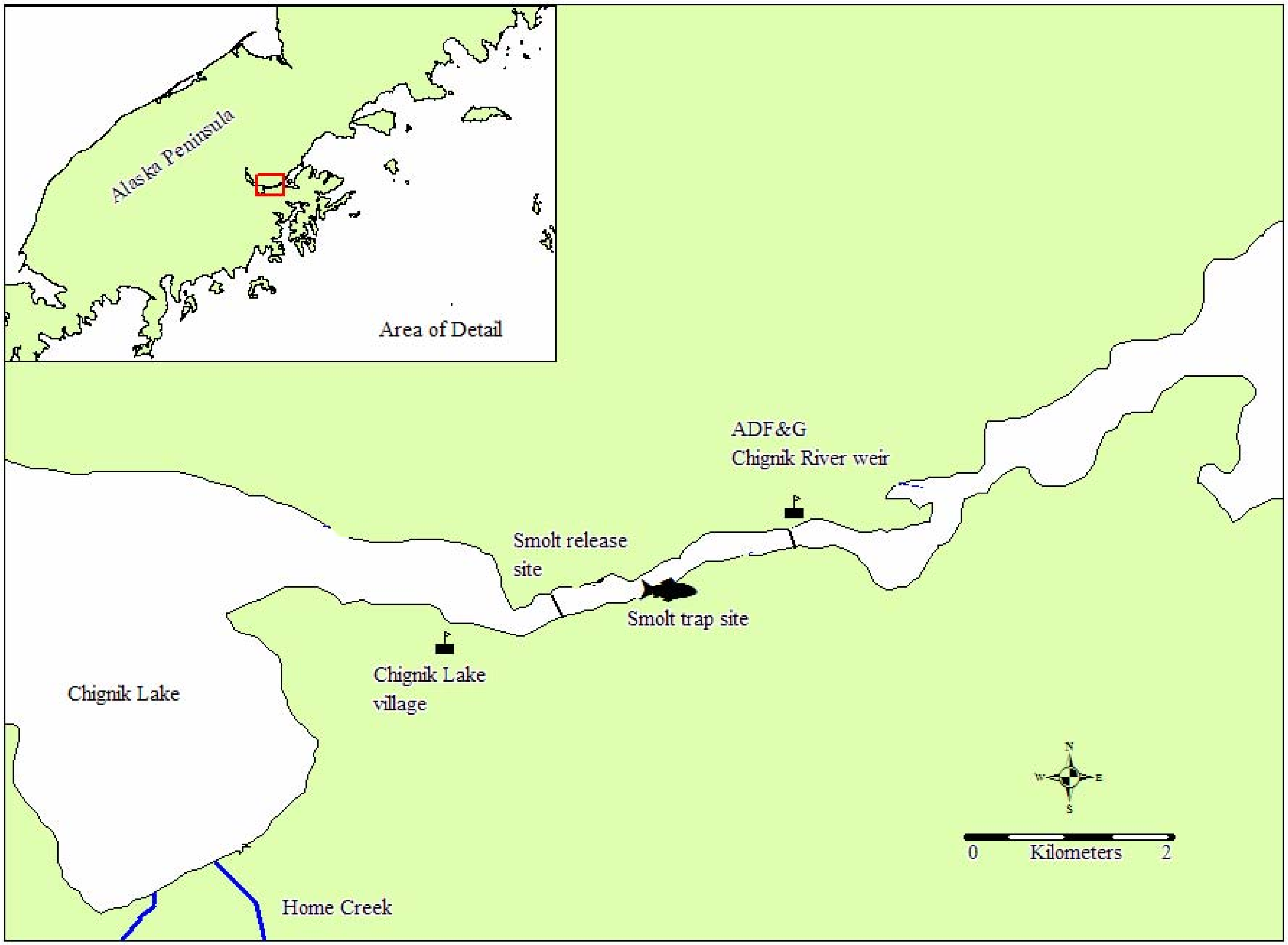


Figure 2.–Location of the traps and the release site of marked smolts in the Chignik River, Alaska, 2008.

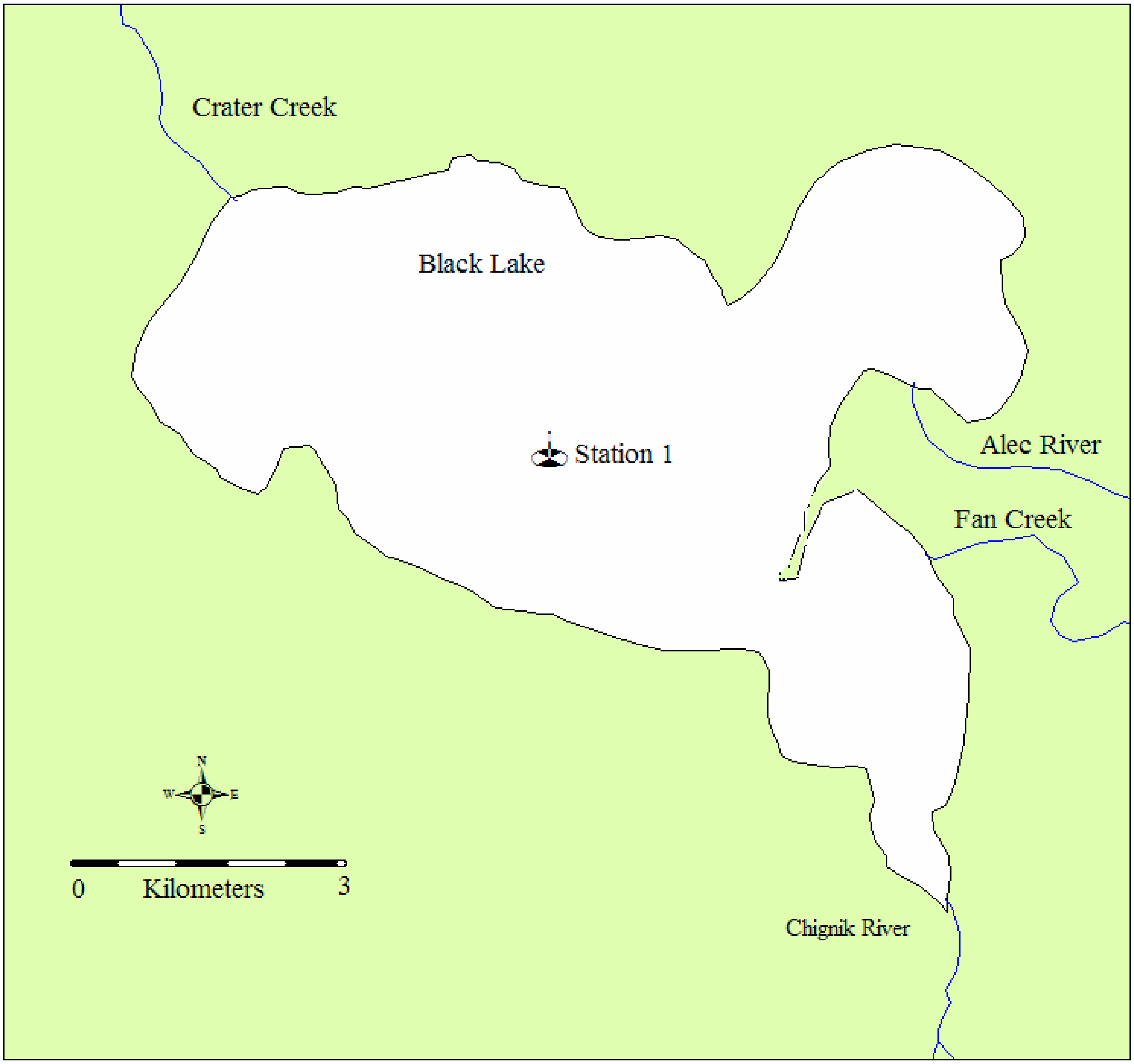


Figure 3.– Location of the Black Lake limnology sampling station.

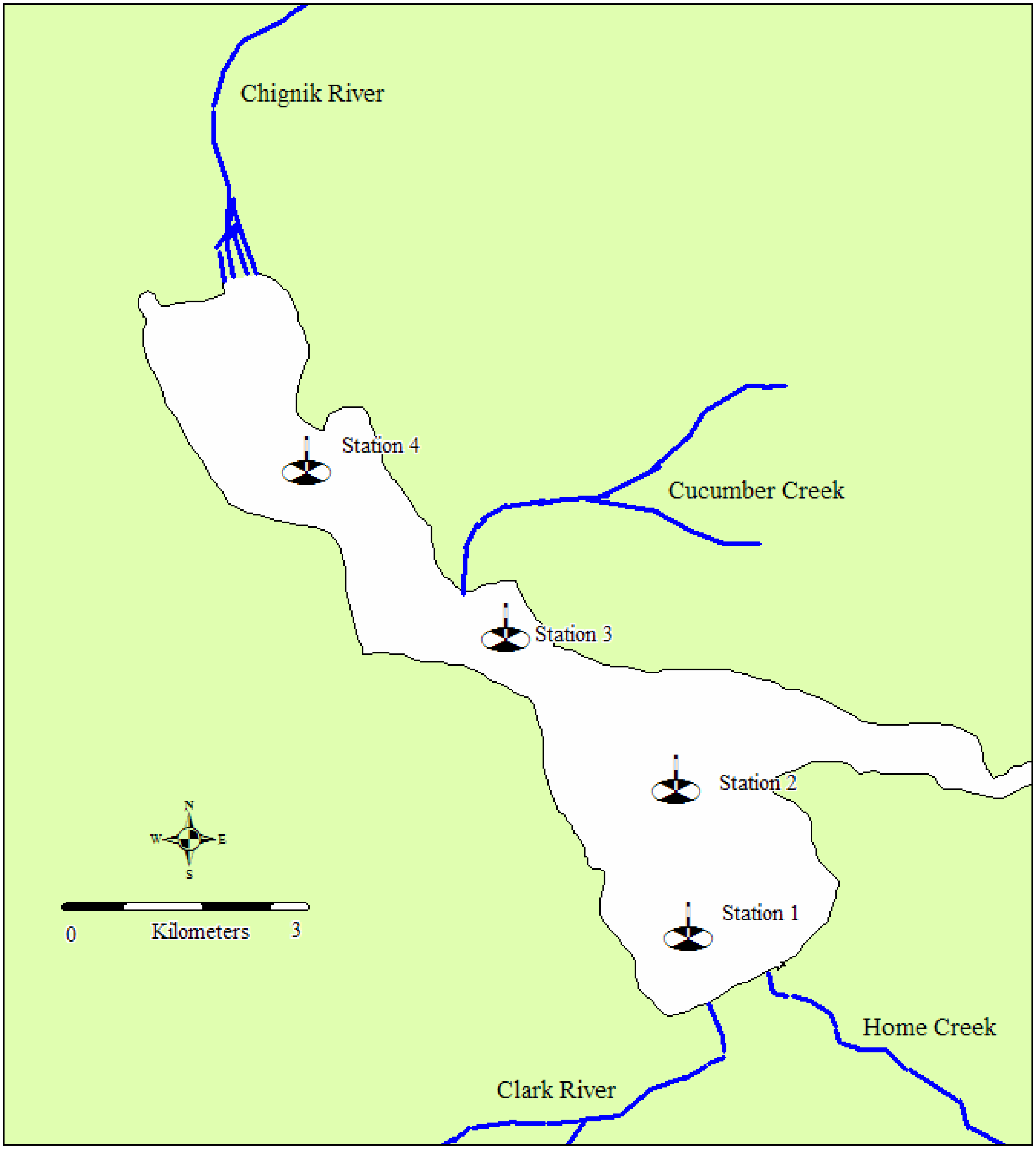


Figure 4.–The locations of the Chignik Lake limnology sampling stations.

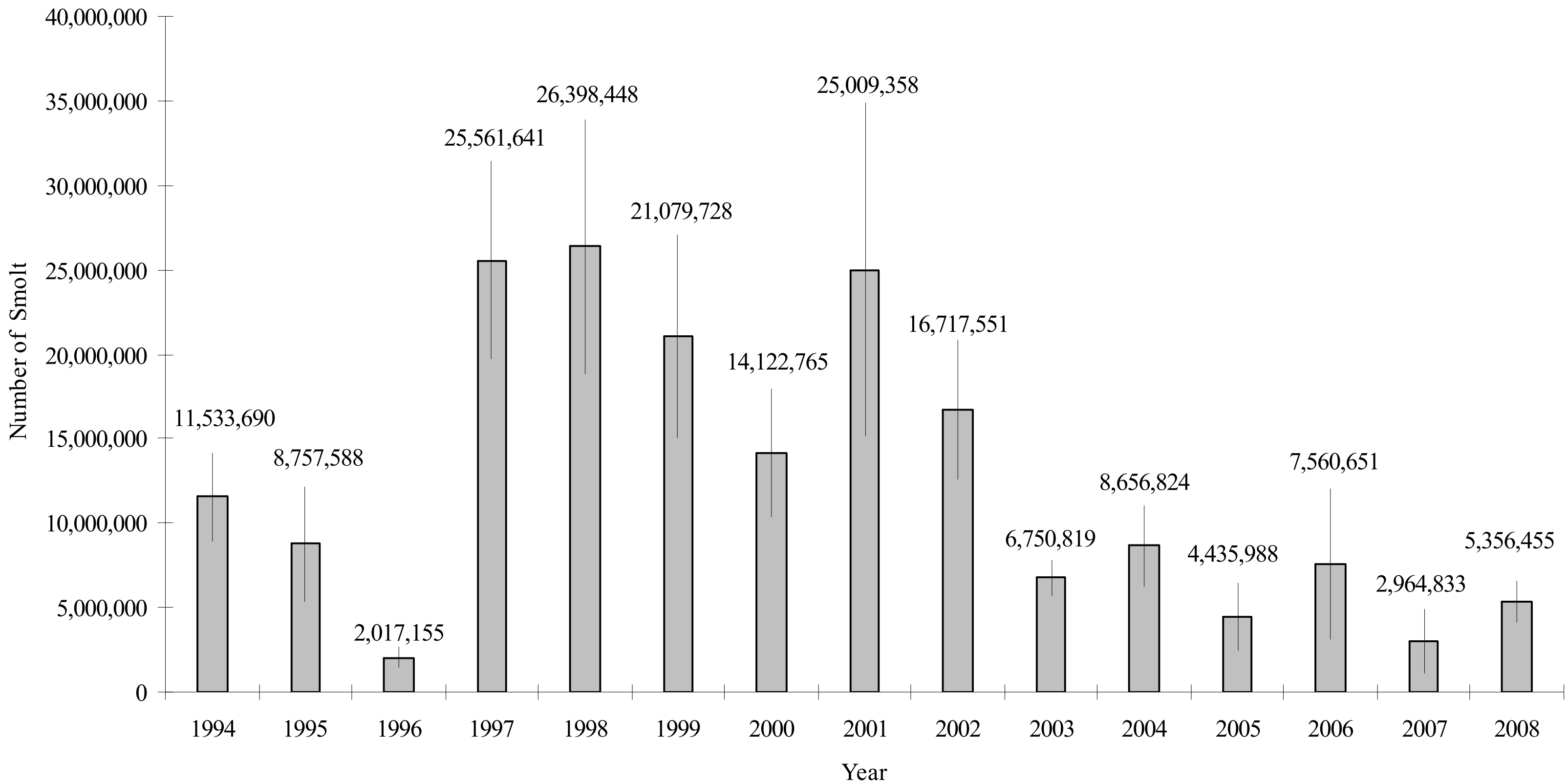


Figure 5.–Annual Chignik River sockeye salmon smolt emigration estimates and corresponding 95% confidence intervals, 1994 to 2008.

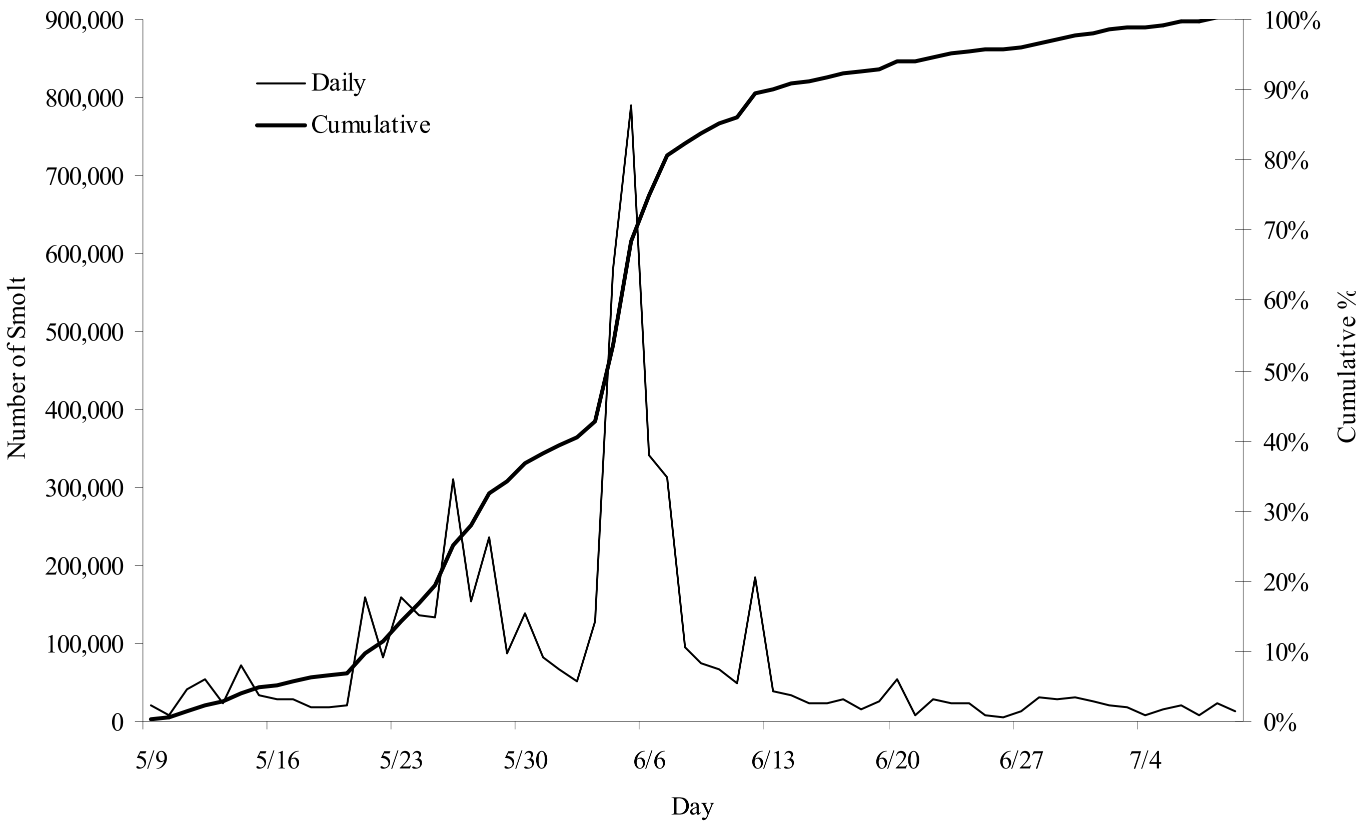


Figure 6.–Estimated daily and corresponding cumulative percentage of the sockeye salmon smolt emigration from the Chignik River, 2008.

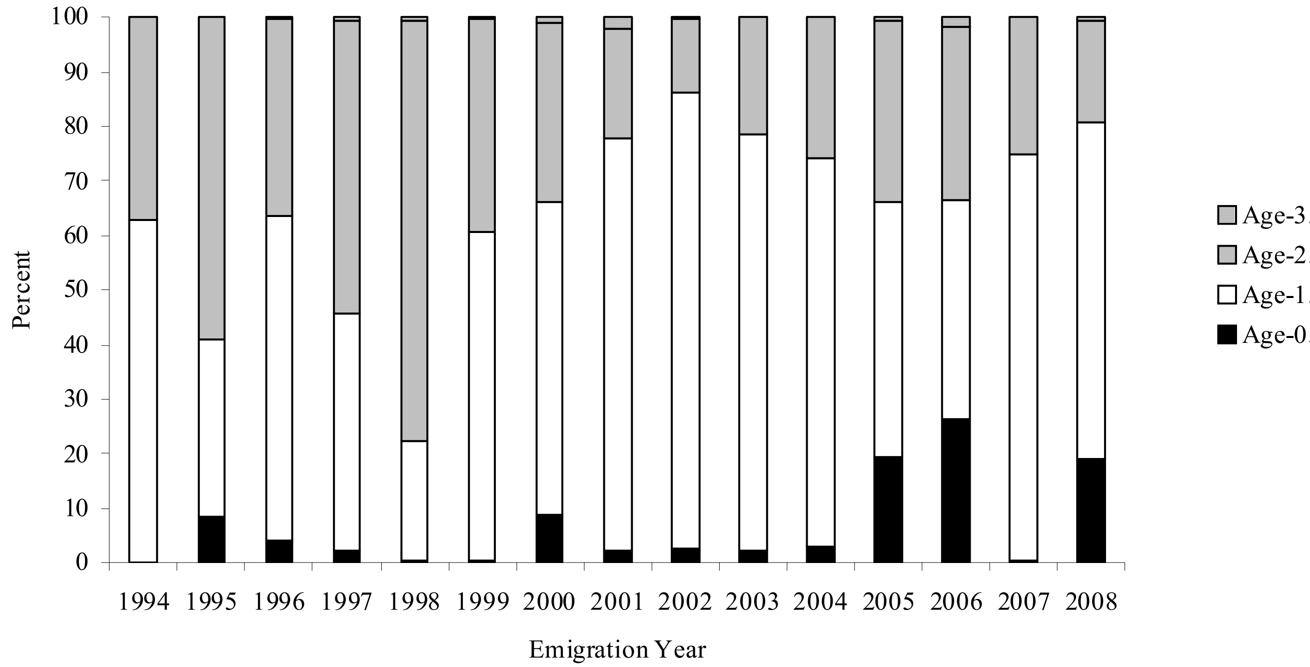


Figure 7.–A comparison of the estimated age structure of sockeye salmon smolt emigrations from the Chignik River, 1994 to 2008.

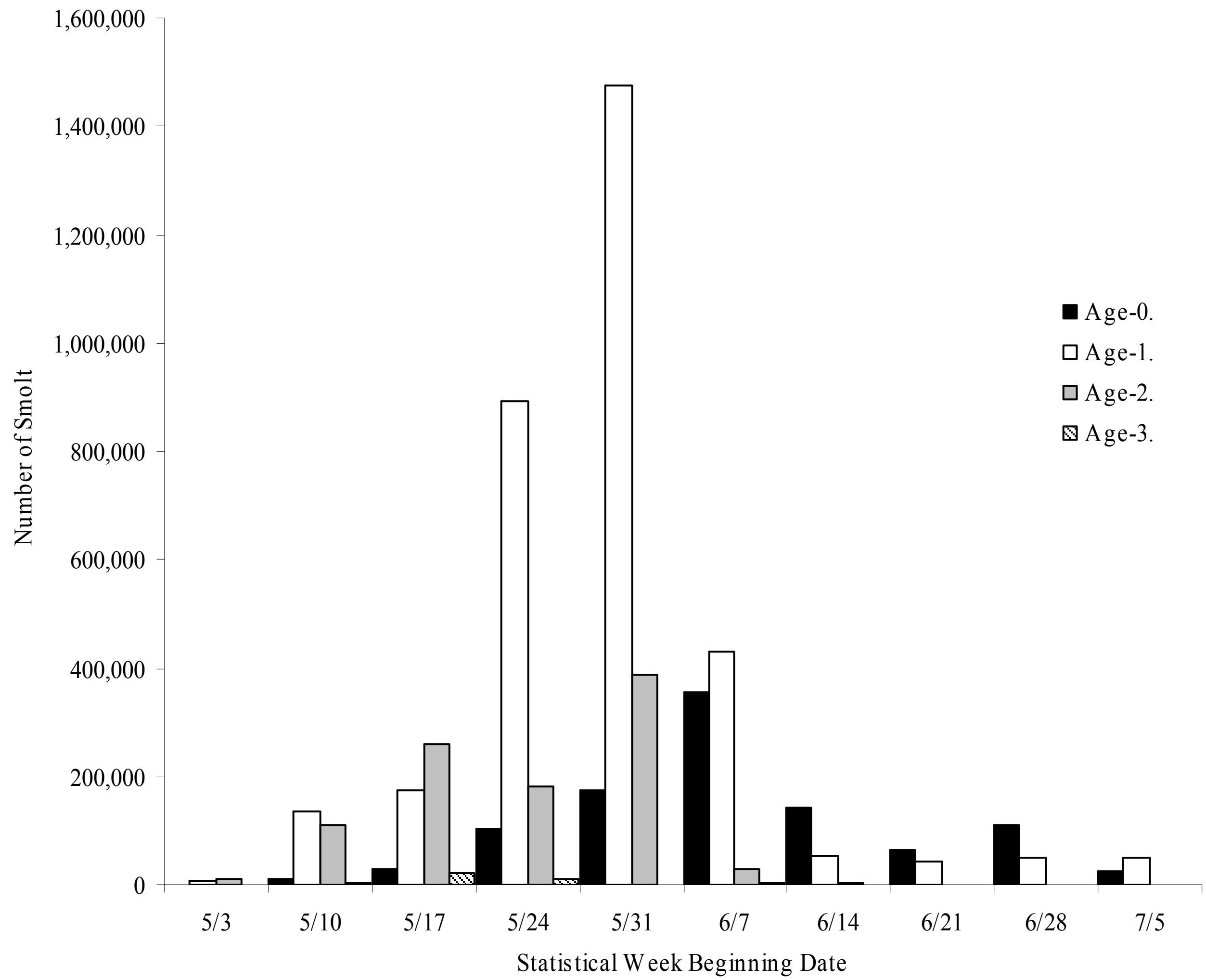


Figure 8.–Estimated emigration of sockeye salmon smolts, by statistical week beginning date, from the Chignik River, 2008.

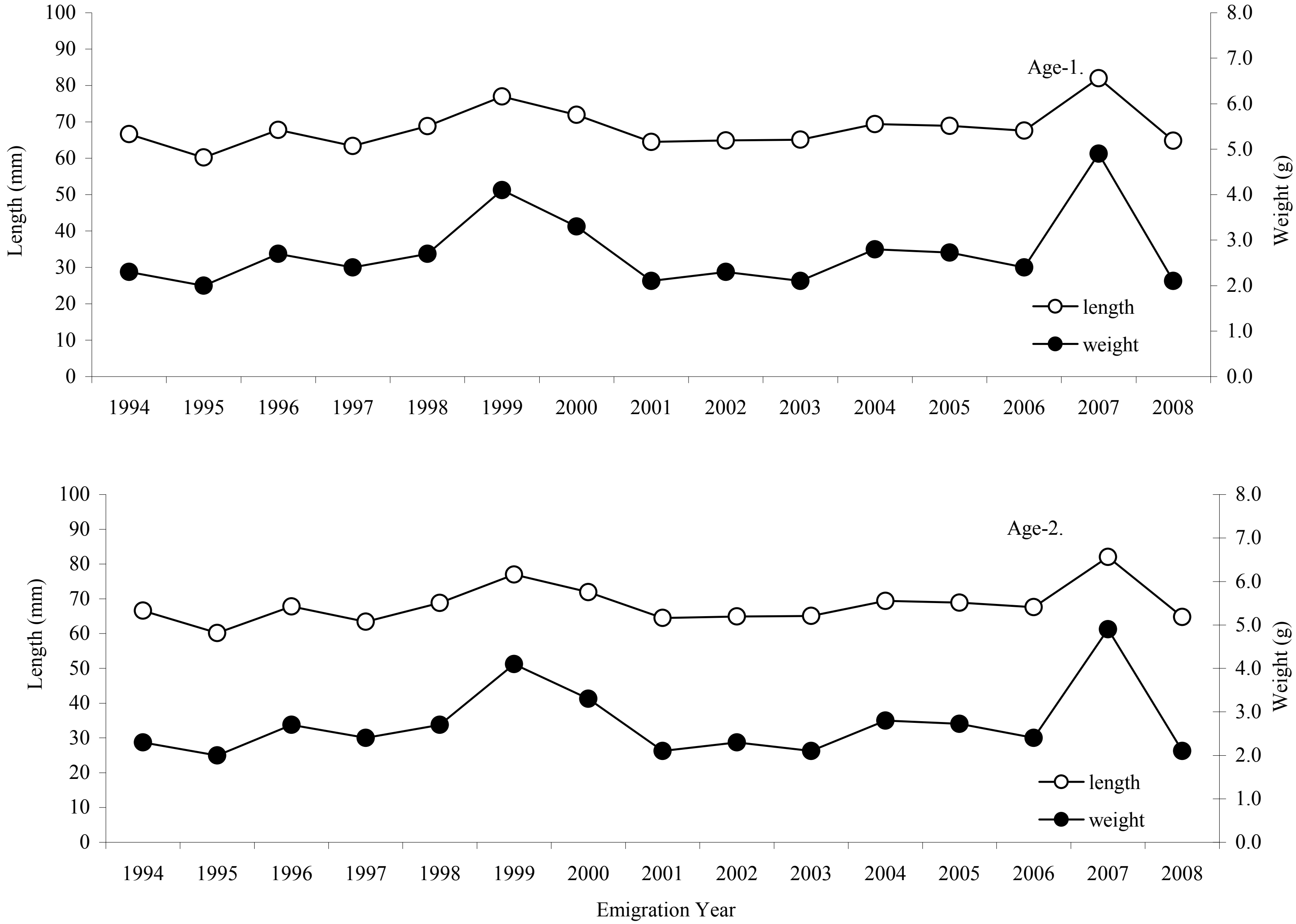


Figure 9.–Average length and weight of age-1. and age-2. sockeye salmon, by year, 1994 through 2008.

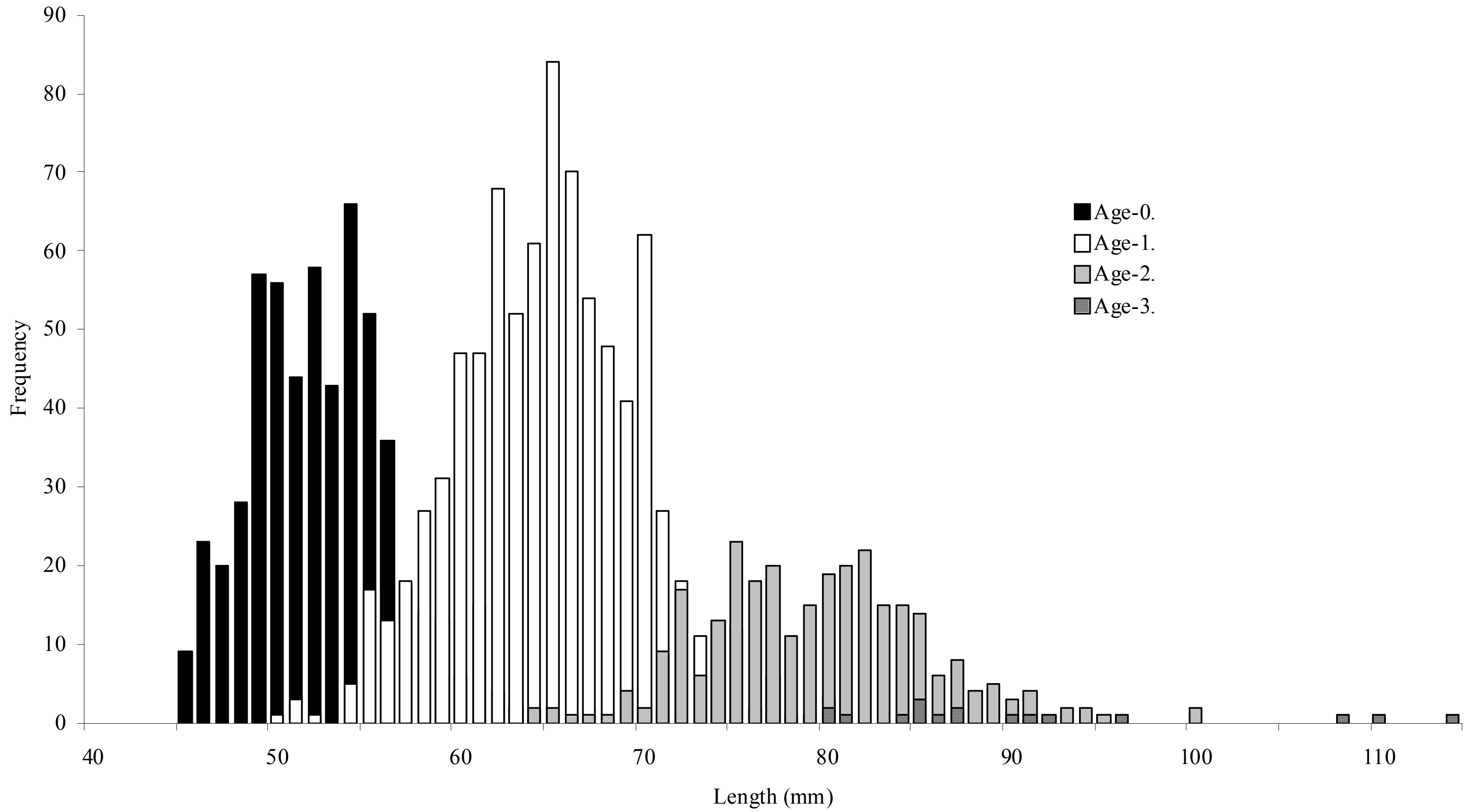


Figure 10.–Length frequency histogram of sockeye salmon smolts, by age sampled from the Chignik River, 2008.

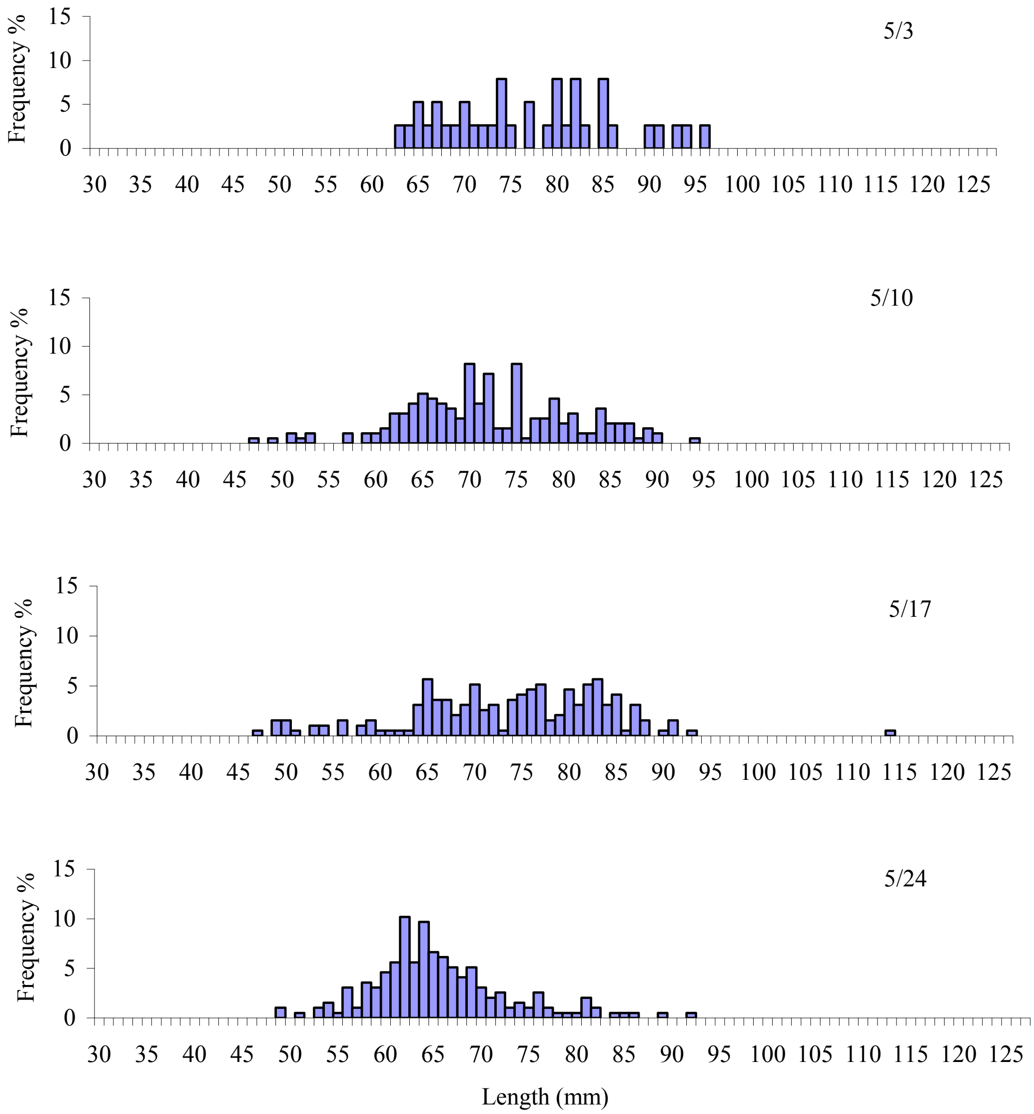


Figure 11.–Length frequency histograms of weekly total sockeye salmon catch samples in the screw traps from May 3 to May 24, 2008.

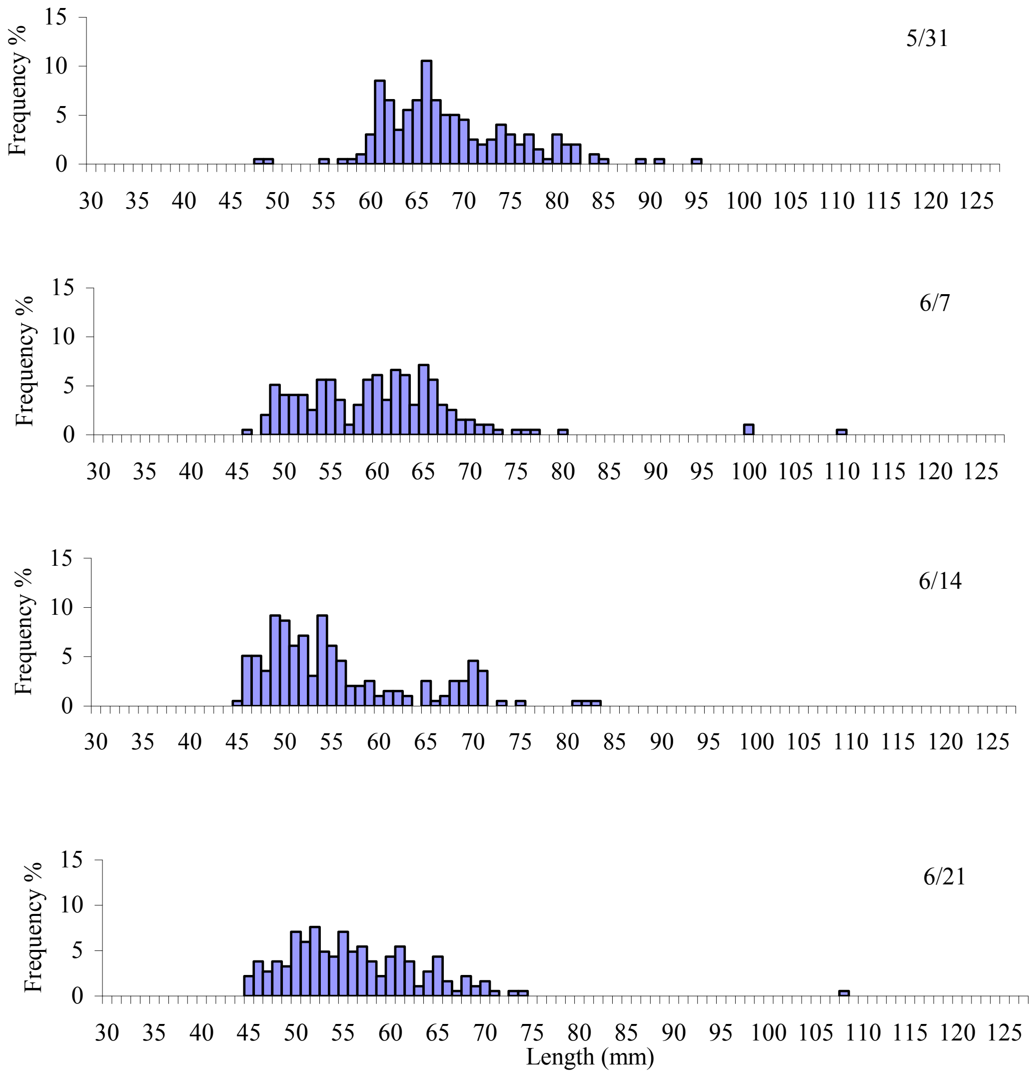


Figure 12.–Length frequency histograms of weekly total sockeye salmon catch samples in the screw traps from May 31 to June 21, 2008.

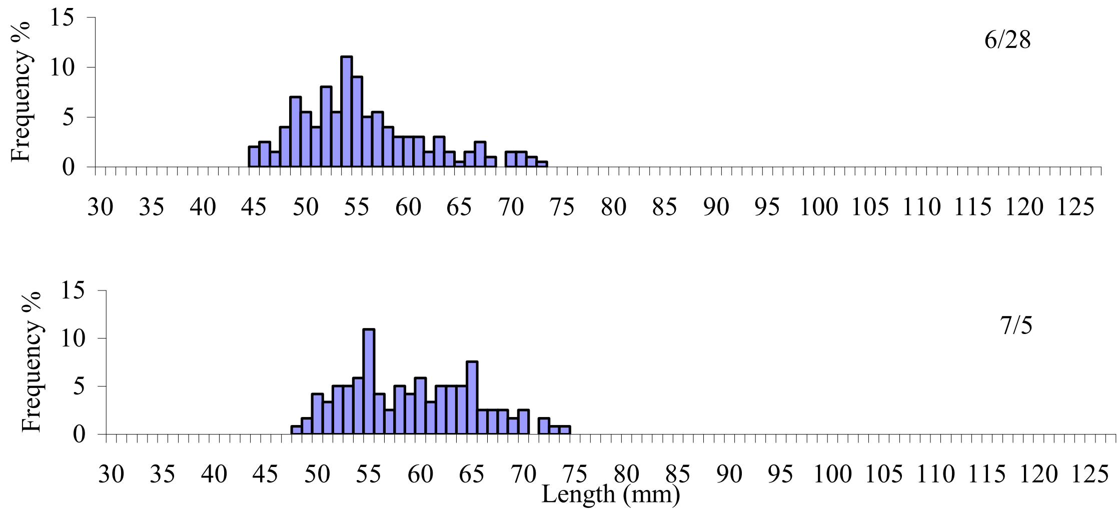
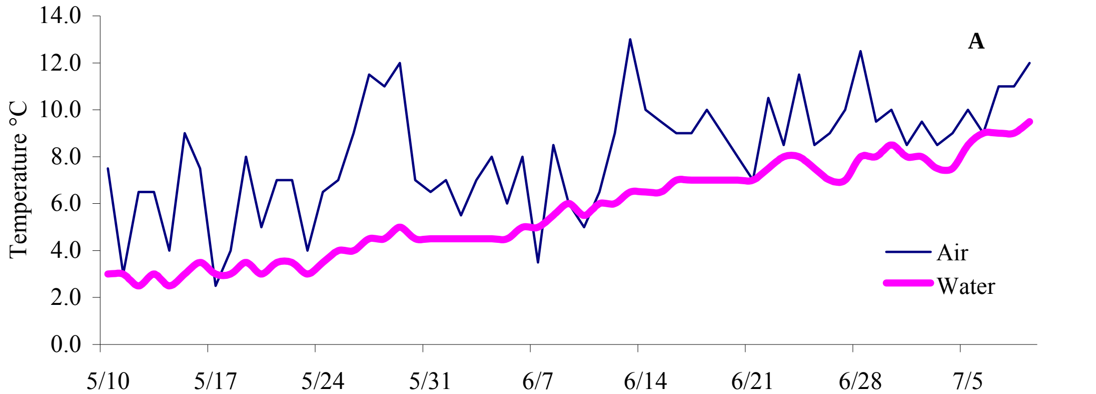
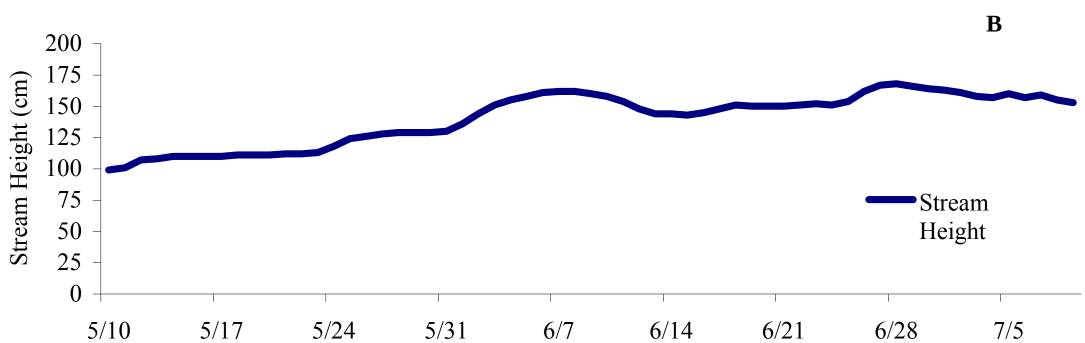


Figure 13.–Length frequency histograms of weekly total sockeye salmon catch samples in the screw traps for June 28 to July 5, 2008.





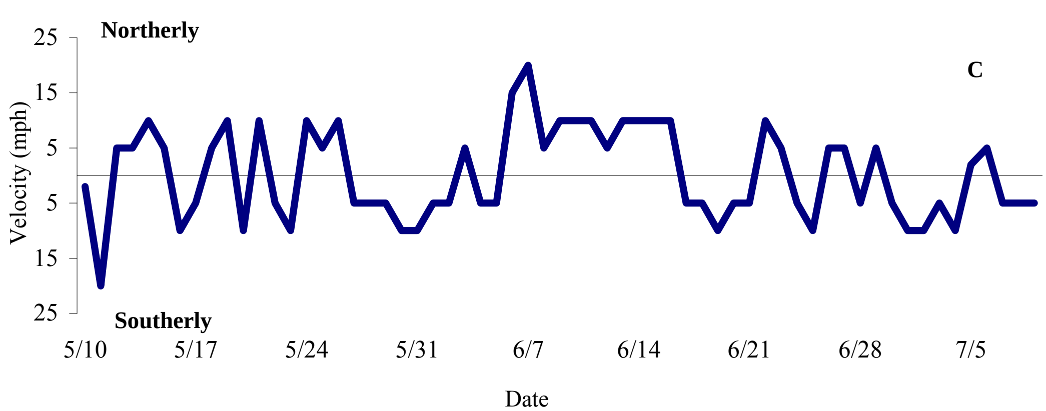


Figure 14.–Air and water temperature (A), stream gauge height (B), and wind velocity and direction data (C) gathered at the Chignik River smolt traps, 2008.

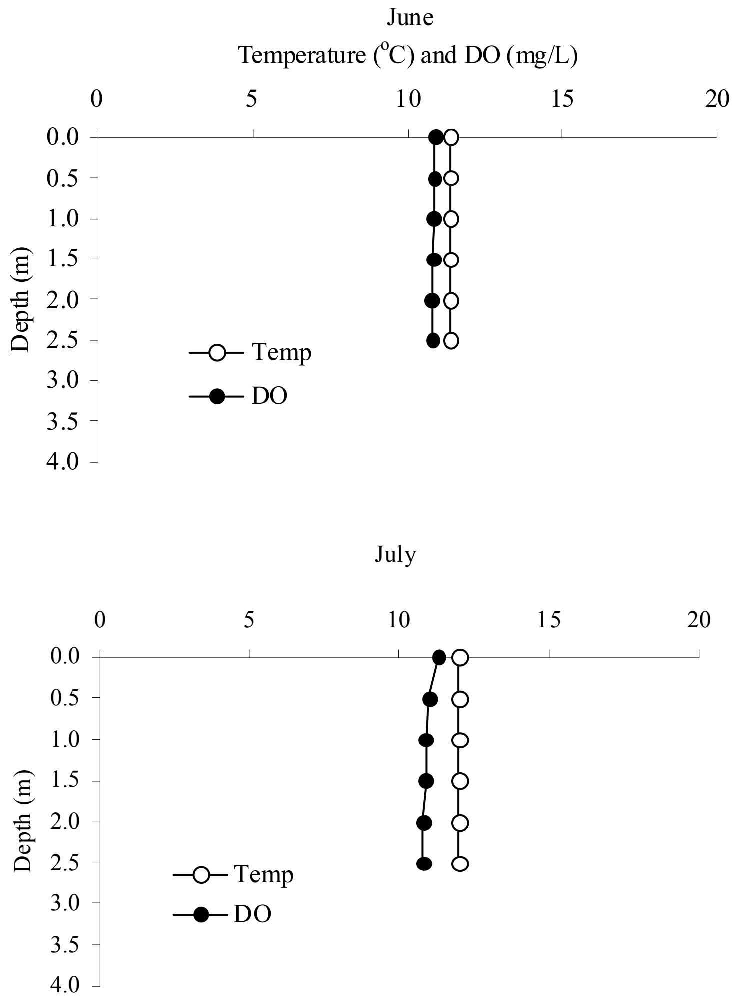
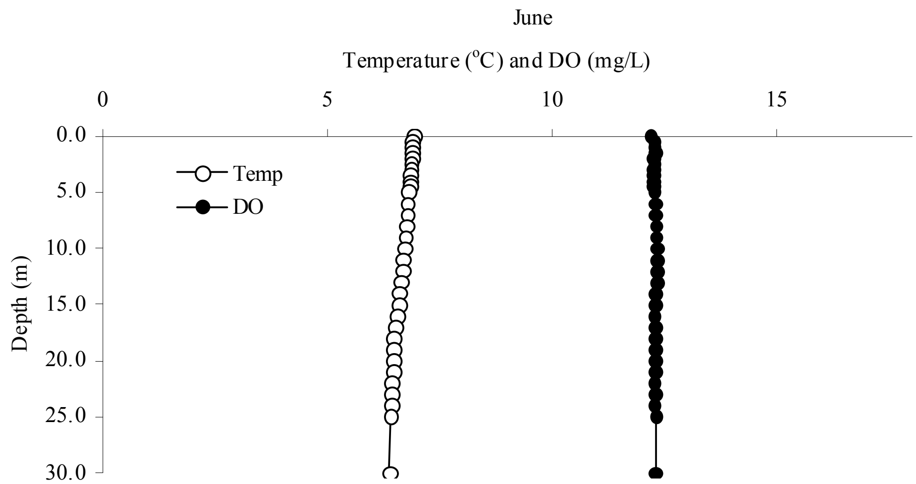
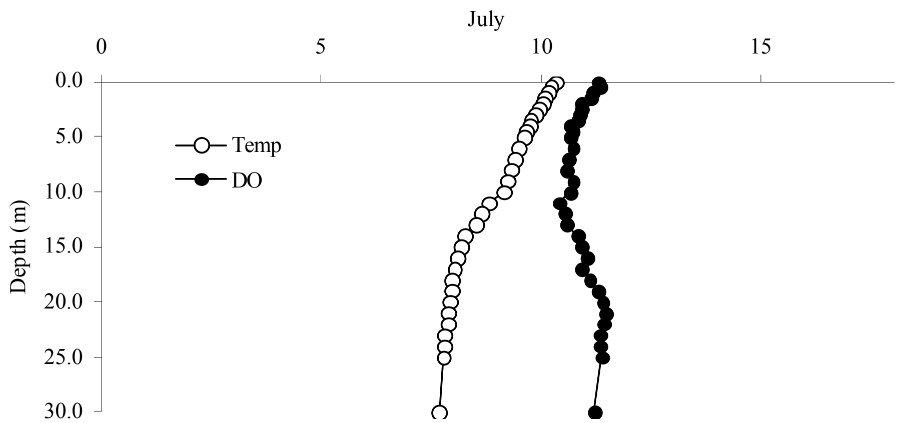


Figure 15.–Mean monthly temperature and dissolved oxygen profiles for Black Lake, 2008.





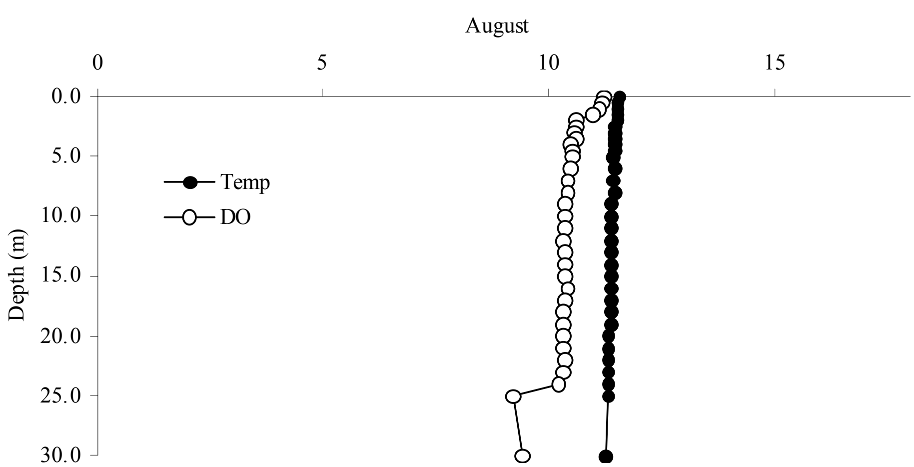


Figure 16.–Mean monthly temperature and dissolved oxygen profiles for Chignik Lake, 2008.

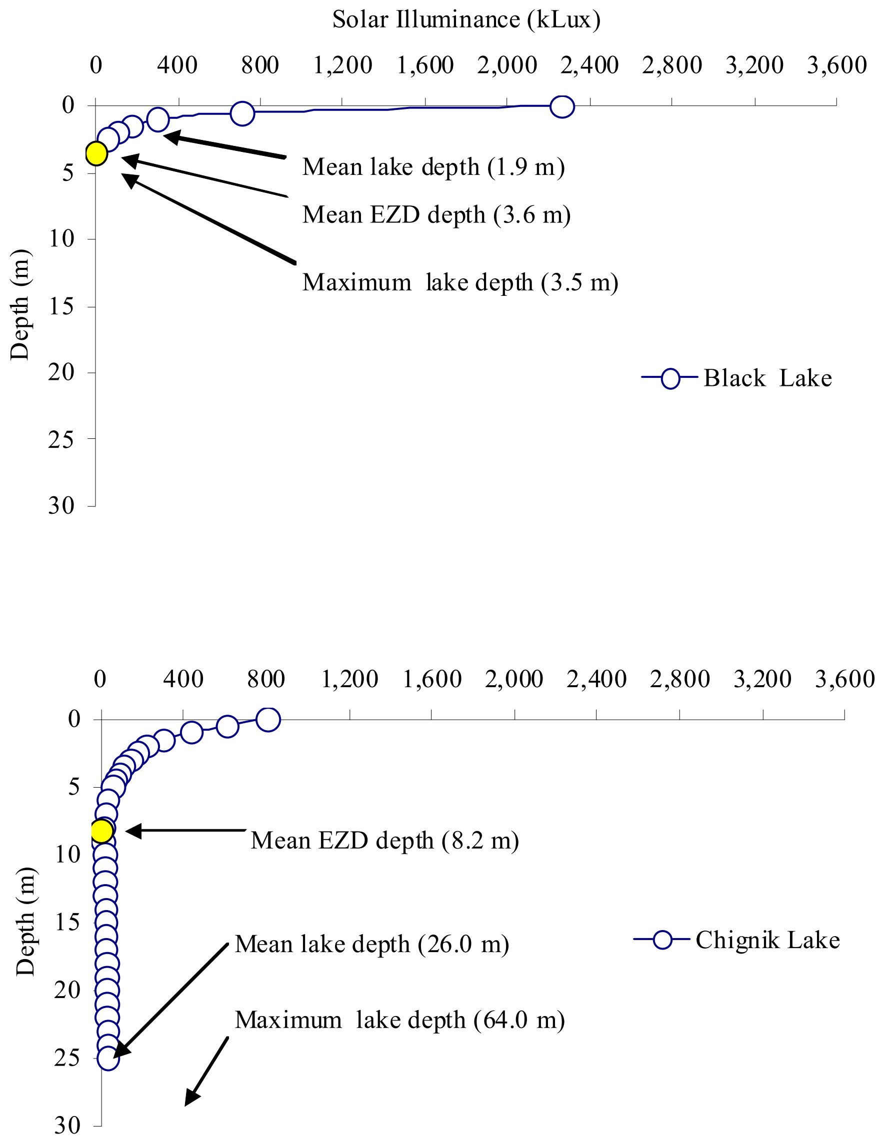


Figure 17.–Light penetration curves relative to mean depth, EZD, and maximum depth for Chignik and Black lakes, 2008.

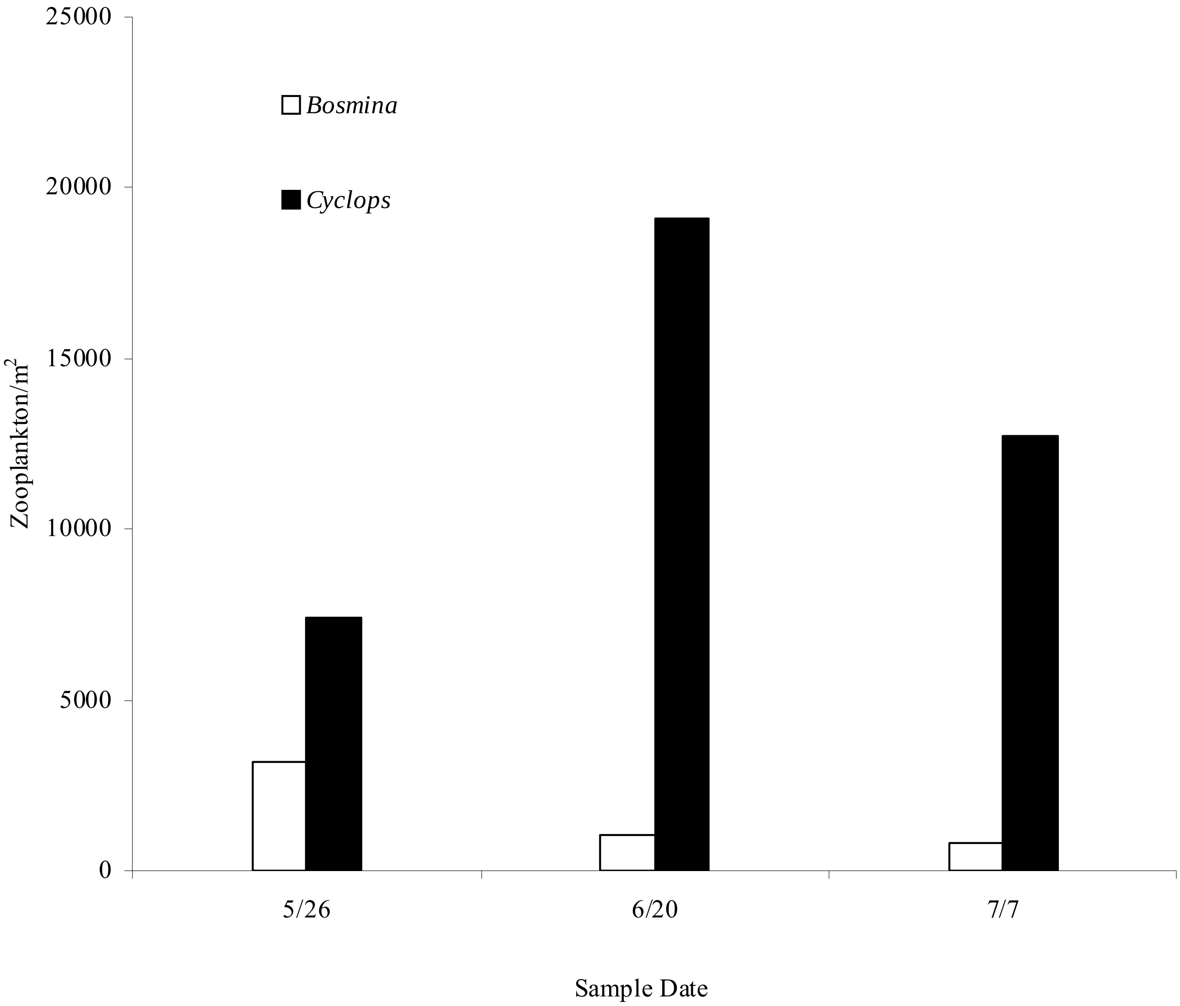


Figure 18.–Number of zooplankton per m^2 of the major copepods (*Cyclops*) and cladocerans (*Bosmina*) in Black Lake, by sample date, 2008.

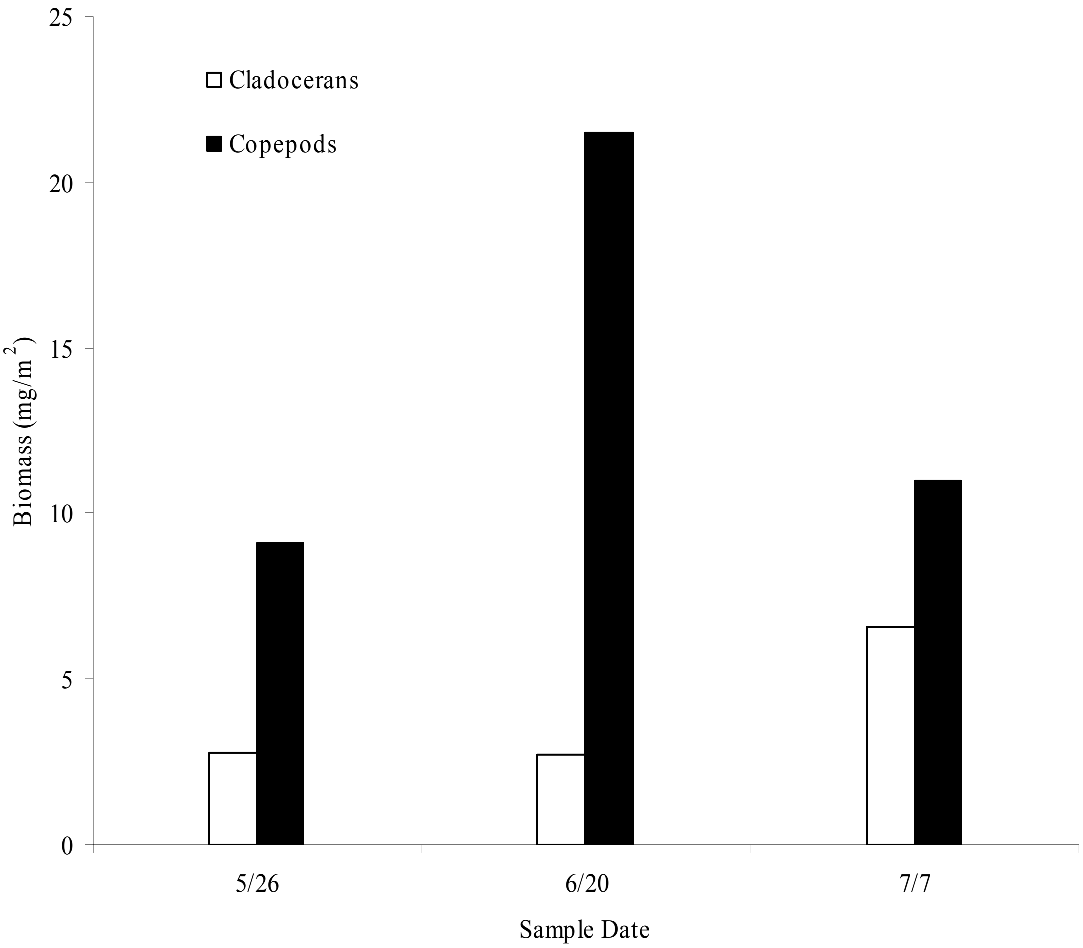


Figure 19.–Mean biomass per m^2 of the major copepods and cladocerans in Black Lake, by sample date, 2008.

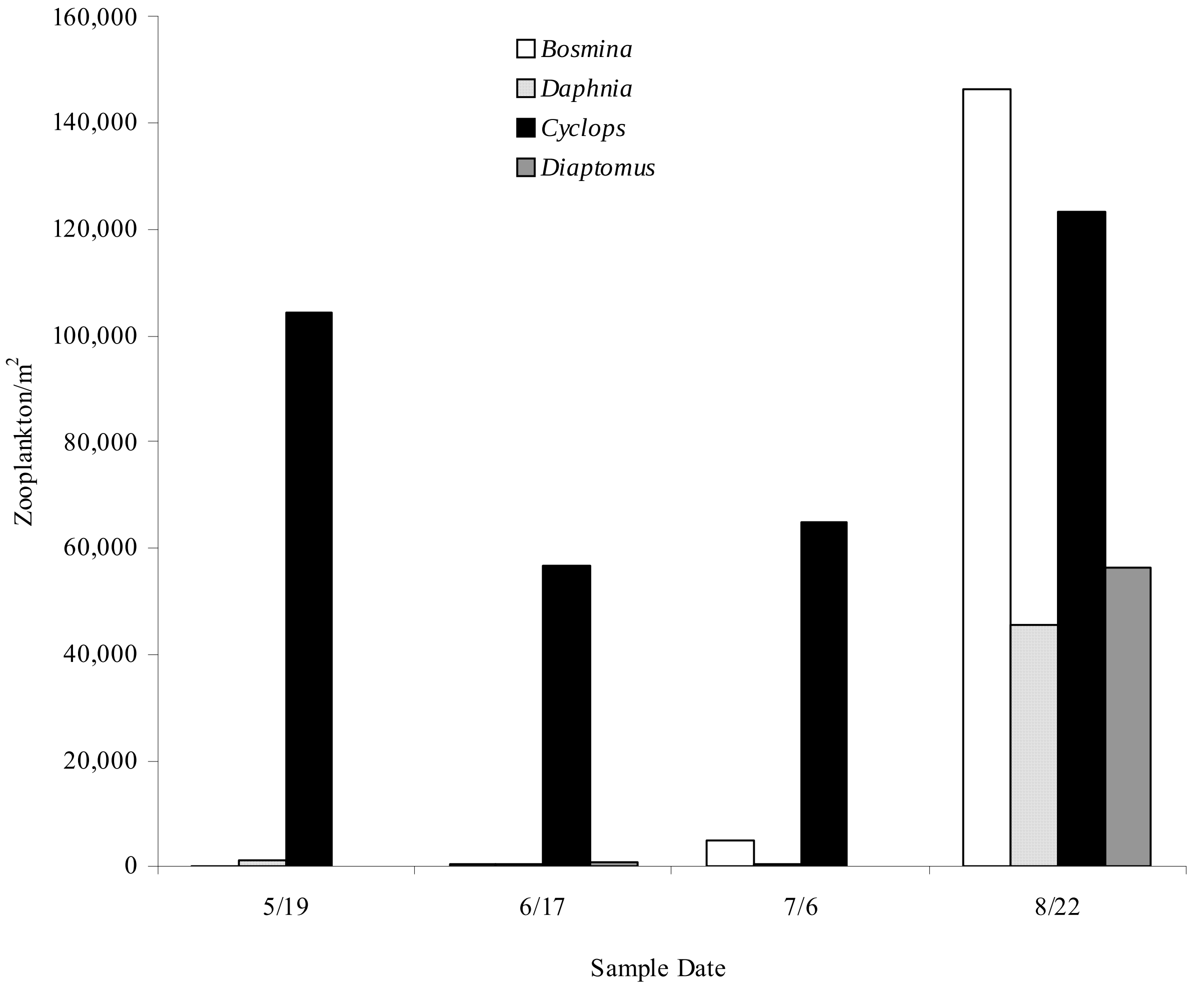


Figure 20.–Number of zooplankton per m^2 of the major copepods (*Cyclops* and *Diaptomus*) and cladocerans (*Bosmina* and *Daphnia*) in Chignik Lake, by sample date, 2008.

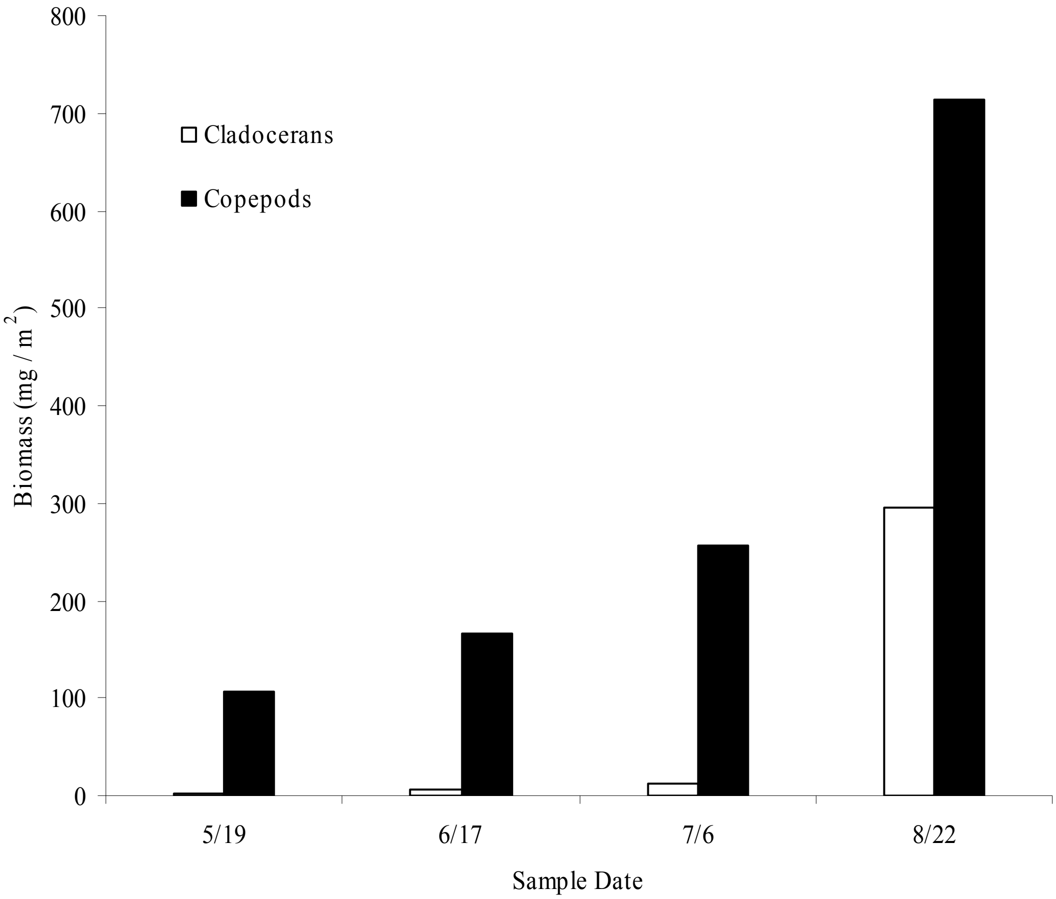


Figure 21.–Mean biomass per m^2 of the major copepods and cladocerans in Chignik Lake, by sample date, 2008.

APPENDIX A. ADF&G PROTOCOL FOR GENETIC SAMPLING

Collection of Axillary Process (AX) Tissue Samples for DNA

ADF&G Gene Conservation Lab, Anchorage

I. General Information

We use axillary processes from individual fish to determine the genetic characteristics and profile of a particular run or stock of fish or to determine the stock composition of fisheries. This is a non-lethal method of collecting genetic data from adult fish. The most important thing to remember in collecting samples is that **only quality samples give quality results**. If sampling from carcasses, fish need to be as freshly dead as possible. DO NOT sample tissue from fungal covered carcasses.

II.Sample procedure:

1. Set-up: Select sampling container that will provide at least 1ml per sampled AX (i.e. if you plan to sample 200 fish use at least a 250ml container). Fill sampling container with alcohol. Fill out adhesive label on container with information requested. Get out paper towels and dognail clipper.
2. Sample from the same side of every fish to avoid double-sampling individuals (only sample one piece of tissue from each fish).
3. Wipe the axillary process with a paper towel. Using dog toenail clipper, remove the entire AX and place the tissue into the sampling container.
4. Repeat process until the container has no more than 1 tissue per ml (ie. if you are sampling into 250ml bottle, stop at 200 samples). Replace lid on container. Invert container several times to distribute alcohol.
5. After 24 hours, “refresh” step - pour out the alcohol from the sampling container and pour in fresh alcohol to assure proper preservation.
6. Store 250ml bulk bottles containing tissues at room temperature, but away from heat and direct sun.

III. Supplies included with sampling kit:

1. – Dog toenail clipper - use to cut off the axillary process
2. 250ml (max: 200 samples) bulk bottles: Nalgene containers
3. Ethanol (ETOH) – bulk in 500 ml Nalgene bottles or 20-liter qubetainers.
4. Paper towels – use to blot excess water or fish slime off fin
5. Printout of sampling instructions
6. Return shipment materials: HAZMAT paperwork, 4-G box, absorbent material, laminated “return address” labels, return shipment instructions.

VI. Shipping: HAZMAT paperwork is required for return shipment of these samples – see shipping instructions.

APPENDIX B. SMOLT TRAP CATCHES BY DAY

Appendix B1.–Actual daily counts and trap efficiency data of the Chignik River sockeye salmon smolt project, 2008.

	Actual Sockeye Smolt		Trap Efficiency Test				Incidental Catch[a]										
Date	Daily	Cum.	Marked	Daily Recoveries	Cum. Recoveries	Efficiency[b]	Soc Fry	Coho	Pink	Chnk	DV	SB	SC	SF	PS	PW	ISO
5/9	255	255	0	0	0		306	9	0	0	3	130	1	0	2	0	0
5/10	113	368	0	0	0		266	10	0	0	0	123	6	5	8	0	0
5/11	536	904	0	0	0		424	21	0	0	9	93	3	0	0	0	0
5/12	685	1,589	0	0	0		448	22	0	0	11	105	0	0	3	0	0
5/13	288	1,877	0	0	0		750	10	0	0	3	114	0	0	3	0	0
5/14	937	2,814	0	0	0		1,756	18	0	0	4	590	3	1	1	0	0
5/15	438	3,252	848	5	5	0.71%	803	8	0	0	5	331	0	0	4	0	1
5/16	365	3,617	0	5	10	1.30%	534	13	0	0	0	117	0	0	10	0	0
5/17	371	3,988	0	0	10	1.30%	424	18	0	0	3	89	0	2	5	0	0
5/18	249	4,237	0	0	10	1.30%	322	17	0	0	3	128	0	0	4	0	0
5/19	238	4,475	0	0	10	1.30%	395	14	0	0	1	101	1	0	2	0	0
5/20	254	4,729	0	0	10	1.30%	321	21	0	0	1	94	0	2	4	0	0
5/21	1,309	6,038	0	0	10	1.30%	390	30	0	0	3	147	0	0	5	0	0
5/22	686	6,724	1,568	8	8	0.57%	529	24	0	1	5	90	2	0	0	1	0
5/23	1,323	8,047	0	4	12	0.83%	778	33	0	0	5	179	0	1	10	0	0
5/24	1,130	9,177	0	0	12	0.83%	489	16	0	0	0	138	0	1	6	0	0
5/25	1,095	10,272	0	0	12	0.83%	469	21	0	0	6	529	2	9	17	0	0
5/26	2,562	12,834	0	0	12	0.83%	365	15	0	1	1	380	0	1	7	0	0
5/27	774	13,608	1,776	5	5	0.34%	315	19	0	3	5	369	1	7	3	0	0
5/28	1,189	14,797	0	2	7	0.45%	235	36	0	9	14	383	1	2	3	1	0
5/29	442	15,239	0	1	8	0.51%	120	34	0	8	12	254	1	6	6	0	1
5/30	695	15,934	0	0	8	0.51%	116	52	0	19	12	487	7	12	12	1	0
5/31	421	16,355	0	0	8	0.51%	154	38	0	10	7	299	4	12	24	0	0
6/1	332	16,687	0	0	8	0.51%	137	10	0	17	2	178	0	2	38	1	0
6/2	815	17,502	771	10	10	1.43%	142	22	0	29	15	416	5	0	14	0	0
6/3	1,974	19,476	0	0	10	1.43%	68	25	0	22	10	933	4	0	9	0	0
6/4	8,995	28,471	0	1	11	1.56%	113	37	0	36	18	2,322	0	0	9	0	0
6/5	12,271	40,742	0	0	11	1.56%	153	125	0	54	29	3,840	6	2	10	0	0
6/6	4,197	44,939	1,991	21	21	1.10%	559	90	0	55	45	3,088	13	7	24	0	1
6/7	3,758	48,697	0	2	23	1.21%	947	61	0	17	30	1,022	3	1	9	0	0

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Appendix B1.–Page 2 of 3.

	Actual Sockeye Smolt		Trap Efficiency Test				Incidental Catch[a]										
Date	Daily	Cum.	Marked	Daily Recoveries	Cum. Recoveries	Efficiency[b]	Soc Fry	Coho	Pink	Chnk	DV	SB	SC	SF	PS	PW	ISO
6/8	281	8,449	0	0	23	1.21%	1,788	81	0	13	13	1,488	0	3	4	0	0
6/9	911	50,751	0	0	23	1.21%	1,026	43	0	20	15	1,032	0	0	8	0	0
6/10	791	51,542	0	0	23	1.21%	674	29	0	15	8	603	0	0	4	0	0
6/11	668	52,210	1,181	14	14	1.27%	735	16	0	3	6	570	0	0	3	0	0
6/12	2,494	54,704	0	0	14	1.27%	669	55	0	12	13	858	0	2	12	0	0
6/13	510	55,214	0	1	15	1.35%	404	16	0	7	7	326	0	1	2	0	0
6/14	459	55,673	0	0	15	1.35%	247	21	0	5	6	390	0	0	6	1	0
6/15	322	55,995	0	0	15	1.35%	284	9	0	4	1	380	0	0	1	0	0
6/16	302	56,297	0	0	15	1.35%	200	10	0	2	1	320	1	0	4	0	0
6/17	375	56,672	0	0	15	1.35%	172	17	0	2	3	240	0	0	4	0	0
6/18	204	56,876	0	0	15	1.35%	151	10	0	3	1	175	0	0	5	0	0
6/19	340	57,216	0	0	15	1.35%	121	16	0	4	2	137	0	0	3	0	0
6/20	718	57,934	977	10	10	1.13%	117	15	0	7	8	136	0	0	11	1	0
6/21	109	58,043	0	2	12	1.33%	19	7	0	7	6	163	0	0	5	0	0
6/22	380	58,423	0	0	12	1.33%	54	5	0	7	3	369	0	0	1	0	0
6/23	317	58,740	0	0	12	1.33%	27	14	0	9	47	178	0	0	0	0	0
6/24	293	59,033	0	0	12	1.33%	53	11	0	6	1	173	0	0	2	0	0
6/25	108	59,141	0	0	12	1.33%	41	4	0	8	3	160	0	1	6	0	0
6/26	58	59,199	0	0	12	1.33%	12	3	0	6	5	125	0	0	3	0	0
6/27	169	59,368	0	0	12	1.33%	22	7	0	12	2	553	0	0	11	0	0
6/28	403	59,771	0	0	12	1.33%	21	3	0	36	8	306	0	1	1	0	0
6/29	252	60,023	973	8	8	0.92%	23	7	0	13	0	145	0	0	1	0	0
6/30	279	60,302	0	0	8	0.92%	15	5	0	16	4	166	0	0	7	0	0
7/1	242	60,544	0	0	8	0.92%	15	6	0	53	2	120	0	0	1	0	0
7/2	180	60,724	0	0	8	0.92%	14	3	0	15	1	108	0	0	8	0	0
7/3	161	60,885	0	0	8	0.92%	8	2	0	33	1	101	0	0	2	0	0
7/4	68	60,953	0	0	8	0.92%	6	5	0	22	5	94	1	0	4	0	1
7/5	143	61,096	0	0	8	0.92%	8	7	0	21	4	81	0	0	2	0	0
7/6	183	61,279	0	0	8	0.92%	5	8	0	39	3	75	0	0	2	0	0

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Appendix B1.–Page 3 of 3.

	Actual Sockeye Smolt		Trap Efficiency Test				Incidental Catch[a]										
Date	Daily	Cum.	Marked	Daily Recoveries	Cum. Recoveries	Efficiency[b]	Soc Fry	Coho	Pink	Chnk	DV	SB	SC	SF	PS	PW	ISO
7/7	68	61,347	0	0	8	0.92%	15	5	0	41	0	94	0	0	9	0	0
7/8	206	61,553	0	0	8	0.92%	17	5	0	14	2	131	0	0	7	0	0
7/9	109	61,662	0	0	8	0.92%	12	5	0	18	3	98	0	0	6	0	0
Total		61,662	10,085	99	99	1.13%	19,803	1,319	0	754	446	26,964	65	81	397	6	4

[a] Soc Fry = sockeye salmon fry, coho = juvenile coho salmon, pink = juvenile pink salmon, chnk = juvenile chinook salmon, DV = Dolly Varden, SB = stickleback, SC = sculpin, SF = starry flounder, PS = pond smelt, PW = pygmy whitefish, ISO = isopods.

[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).

APPENDIX C. SMOLT TRAP CATCHES BY TRAP

Appendix C1.–Number of sockeye salmon smolt caught by trap, by day, from the Chignik River, May 9 through July 9, 2008.

	Small Trap		Large Trap		Combined		Percent Total	
Date	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Small	Large
5/9	107	107	148	148	255	255	42.0%	58.0%
5/10	44	151	69	217	113	368	38.9%	61.1%
5/11	208	359	328	545	536	904	38.8%	61.2%
5/12	285	644	400	945	685	1,589	41.6%	58.4%
5/13	92	736	196	1,141	288	1,877	31.9%	68.1%
5/14	222	958	715	1,856	937	2,814	23.7%	76.3%
5/15	173	1,131	265	2,121	438	3,252	39.5%	60.5%
5/16	108	1,239	257	2,378	365	3,617	29.6%	70.4%
5/17	110	1,349	261	2,639	371	3,988	29.6%	70.4%
5/18	96	1,445	153	2,792	249	4,237	38.6%	61.4%
5/19	110	1,555	128	2,920	238	4,475	46.2%	53.8%
5/20	54	1,609	200	3,120	254	4,729	21.3%	78.7%
5/21	377	1,986	932	4,052	1,309	6,038	28.8%	71.2%
5/22	164	2,150	522	4,574	686	6,724	23.9%	76.1%
5/23	136	2,286	1,187	5,761	1,323	8,047	10.3%	89.7%
5/24	171	2,457	959	6,720	1,130	9,177	15.1%	84.9%
5/25	101	2,558	994	7,714	1,095	10,272	9.2%	90.8%
5/26	461	3,019	2,101	9,815	2,562	12,834	18.0%	82.0%
5/27	131	3,150	643	10,458	774	13,608	16.9%	83.1%
5/28	96	3,246	1,093	11,551	1,189	14,797	8.1%	91.9%
5/29	103	3,349	339	11,890	442	15,239	23.3%	76.7%
5/30	105	3,454	590	12,480	695	15,934	15.1%	84.9%
5/31	82	3,536	339	12,819	421	16,355	19.5%	80.5%
6/1	56	3,592	276	13,095	332	16,687	16.9%	83.1%
6/2	68	3,660	747	13,842	815	17,502	8.3%	91.7%
6/3	73	3,733	1,901	15,743	1,974	19,476	3.7%	96.3%
6/4	450	4,183	8,545	24,288	8,995	28,471	5.0%	95.0%
6/5	2,392	6,575	9,879	34,167	12,271	40,742	19.5%	80.5%
6/6	747	7,322	3,450	37,617	4,197	44,939	17.8%	82.2%
6/7	846	8,168	2,912	40,529	3,758	48,697	22.5%	77.5%
6/8	281	8,449	862	41,391	1,143	49,840	24.6%	75.4%
6/9	150	8,599	761	42,152	911	50,751	16.5%	83.5%
6/10	142	8,741	649	42,801	791	51,542	18.0%	82.0%
6/11	130	8,871	538	43,339	668	52,210	19.5%	80.5%
6/12	306	9,177	2,188	45,527	2,494	54,704	12.3%	87.7%
6/13	142	9,319	368	45,895	510	55,214	27.8%	72.2%
6/14	114	9,433	345	46,240	459	55,673	24.8%	75.2%
6/15	63	9,496	259	46,499	322	55,995	19.6%	80.4%
6/16	127	9,623	175	46,674	302	56,297	42.1%	57.9%
6/17	93	9,716	282	46,956	375	56,672	24.8%	75.2%
6/18	105	9,821	99	47,055	204	56,876	51.5%	48.5%
6/19	99	9,920	241	47,296	340	57,216	29.1%	70.9%
6/20	75	9,995	643	47,939	718	57,934	10.4%	89.6%
6/21	39	10,034	70	48,009	109	58,043	35.8%	64.2%
6/22	51	10,085	329	48,338	380	58,423	13.4%	86.6%
6/23	74	10,159	243	48,581	317	58,740	23.3%	76.7%

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Date	Small Trap		Large Trap		Combined		Percent Total	
	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Small	Large
6/24	102	10,261	191	48,772	293	59,033	34.8%	65.2%
6/25	59	10,320	49	48,821	108	59,141	54.6%	45.4%
6/26	19	10,339	39	48,860	58	59,199	32.8%	67.2%
6/27	37	10,376	132	48,992	169	59,368	21.9%	78.1%
6/28	105	10,481	298	49,290	403	59,771	26.1%	73.9%
6/29	96	10,577	156	49,446	252	60,023	38.1%	61.9%
6/30	71	10,648	208	49,654	279	60,302	25.4%	74.6%
7/1	134	10,782	108	49,762	242	60,544	55.4%	44.6%
7/2	81	10,863	99	49,861	180	60,724	45.0%	55.0%
7/3	81	10,944	80	49,941	161	60,885	50.3%	49.7%
7/4	17	10,961	51	49,992	68	60,953	25.0%	75.0%
7/5	26	10,987	117	50,109	143	61,096	18.2%	81.8%
7/6	43	11,030	140	50,249	183	61,279	23.5%	76.5%
7/7	15	11,045	53	50,302	68	61,347	22.1%	77.9%
7/8	31	11,076	175	50,477	206	61,553	15.0%	85.0%
7/9	26	11,102	83	50,560	109	61,662	23.9%	76.1%
Total		11,102		50,560		61,662	18.0%	82.0%

APPENDIX D. PHYSICAL OBSERVATIONS

Appendix D1.–Daily climatological observations for the Chignik River sockeye salmon smolt project, 2008.

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
5/10	11:59	7.5	3.0	30%	SE	0-5	4.3	4.5	99	Traps fishing @ 1215 (5/9)
5/11	12:02	3.0	3.0	100%	SE	15-20	4.3	5.3	101	Steady rain/sleet
5/12	11:53	6.5	2.5	100%	NW	0-5	4.8	5.0	107	
5/13	11:58	6.5	3.0	80%	NW	0-5	4.8	5.0	108	
5/14	11:56	4.0	2.5	90%	NW	5-10	4.8	5.0	110	
5/15	12:09	9.0	3.0	60%	NW	0-5	4.8	5.0	110	Dye test release @ 2346
5/16	11:42	7.5	3.5	60%	SE	5-10	4.8	4.8	110	
5/17	11:48	2.5	3.0	100%	SE	0-5	4.8	5.0	110	Steady rain
5/18	11:58	4.0	3.0	100%	NW	0-5	4.8	5.3	111	Steady rain
5/19	12:11	8.0	3.5	75%	NW	5-10	5.0	5.3	111	
5/20	11:58	5.0	3.0	100%	SE	5-10	5.0	5.3	111	Steady light rain
5/21	11:53	7.0	3.5	90%	NW	5-10	5.0	5.0	112	
5/22	11:54	7.0	3.5	95%	SE	0-5	5.0	5.0	112	Dye test release @ 2338
5/23	11:54	4.0	3.0	100%	SE	5-10	5.3	5.5	113	Gusts of 20-25, steady rain
5/24	11:53	6.5	3.5	100%	NW	5-10	6.3	5.8	118	
5/25	11:57	7.0	4.0	70%	NW	0-5	6.5	6.0	124	
5/26	12:25	9.0	4.0	55%	NW	5-10	6.5	5.8	126	
5/27	11:56	11.5	4.5	0%	SE	0-5	6.3	6.0	128	Dye test release @ 2325
5/28	11:53	11.0	4.5	100%	SE	0-5	7.0	6.3	129	
5/29	11:59	12.0	5.0	75%	SE	0-5	7.0	6.3	129	
5/30	11:58	7.0	4.5	100%	SE	5-10	6.8	6.3	129	
5/31	11:49	6.5	4.5	100%	SE	5-10	6.8	6.3	130	
6/1	12:03	7.0	4.5	100%	SE	0-5	7.5	6.5	136	
6/2	11:39	5.5	4.5	100%	SE	0-5	0.0	6.5	144	Dye test release @ 2316
6/3	11:51	7.0	4.5	100%	NW	0-5	9.0	7.5	151	
6/4	11:59	8.0	4.5	100%	SE	0-5	9.0	7.8	155	
6/5	11:54	6.0	4.5	95%	SE	0-5	9.3	8.3	158	
6/6	12:07	8.0	5.0	60%	NW	10-15	9.5	8.3	161	Dye test release @ 2341
6/7	11:48	3.5	5.0	25%	NW	15-20	9.5	8.5	162	Strong NW winds

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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
6/8	11:59	8.5	5.5	25%	NW	0-5	8.8	8.0	162	
6/9	12:30	6.0	6.0	100%	NW	5-10	9.0	7.5	160	
6/10	11:53	5.0	5.5	65%	NW	5-10	8.0	7.5	158	
6/11	12:11	6.5	6.0	100%	NW	5-10	8.0	7.8	154	Dye test release @ 2319
6/12	11:51	9.0	6.0	90%	NW	0-5	7.3	6.3	148	
6/13	12:01	13.0	6.5	40%	NW	5-10	7.5	7.3	144	
6/14	11:52	10.0	6.5	75%	NW	5-10	7.5	7.3	144	
6/15	11:57	9.5	6.5	90%	NW	5-10	7.5	7.5	143	
6/16	11:51	9.0	7.0	100%	NW	5-10	7.8	7.5	145	
6/17	12:09	9.0	7.0	100%	SE	0-5	7.8	7.5	148	
6/18	11:50	10.0	7.0	95%	SE	0-5	7.8	7.5	151	
6/19	12:04	9.0	7.0	100%	SE	5-10	7.8	7.5	150	
6/20	12:07	8.0	7.0	100%	SE	0-5	7.8	7.5	150	Dye test release @ 2325
6/21	12:14	7.0	7.0	100%	SE	0-5	7.8	7.5	150	
6/22	12:09	10.5	7.5	30%	NW	5-10	7.8	7.5	151	
6/23	12:01	8.5	8.0	100%	NW	0-5	7.5	7.3	152	
6/24	12:00	11.5	8.0	100%	SE	0-5	7.3	7.0	151	
6/25	11:56	8.5	7.5	100%	SE	5-10	8.0	7.8	154	Steady rain
6/26	11:58	9.0	7.0	100%	NW	0-5	8.5	8.0	162	
6/27	12:00	10.0	7.0	95%	NW	0-5	8.5	8.3	167	
6/28	12:02	12.5	8.0	70%	SE	0-5	8.5	8.3	168	
6/29	12:00	9.5	8.0	100%	NW	0-5	9.0	8.3	166	Dye test release @ 2326
6/30	11:53	10.0	8.5	95%	SE	0-5	8.5	7.8	164	
7/1	11:57	8.5	8.0	100%	SE	5-10	8.0	7.8	163	
7/2	12:04	9.5	8.0	95%	SE	5-10	8.3	7.8	161	
7/3	12:07	8.5	7.5	100%	SE	0-5	8.3	7.8	158	
7/4	11:54	9.0	7.5	100%	SE	5-10	8.0	7.5	157	
7/5	11:45	10.0	8.5	100%	SE	0-5	8.0	7.5	160	
7/6	11:45	9.0	9.0	100%	SE	0-5	8.3	7.5	157	

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Date[a]	Time	Air (°C)	Water (°C)	Cloud[b] Cover (%)	Wind[b] Dir	Vel.[b] (Mph)	Trap Revolutions (rpm) Small	Trap Revolutions (rpm) Large	Stream Gauge (cm)	Comments
7/7	12:40	11.0	9.0	90%	SE	0-5	8.0	7.8	159	
7/8	11:53	11.0	9.0	100%	SE	0-5	8.3	8.0	155	
7/9	11:51	12.0	9.5	25%	SE	0-5	8.3	7.5	153	

[a] Actual calendar dates.

[b] Based on observer estimates.

APPENDIX E. HISTORICAL LIMNOLOGY DATA

Appendix E1.–Seasonal averages of water quality parameters, nutrient concentrations, and photosynthetic pigments by year for Black Lake, 2004-2008.

	2004	2005	2006	2007	2008
	Average	Average	Average	Average	Average
pH	7.81	7.62	8.01	7.64	7.64
Alkalinity (mg/L)	30.2	25.0	20.5	19.7	19.0
Total P (µg/L P)	22.2	27.9	20.4	24.4	22.2
TKN (µg/L N)	188.8	324.5	216.0	124.3	263.7
Ammonia (µg/L N)	9.7	3.9	11.0	130.1	3.7
Nitrate + Nitrite (µg/L N)	3.7	1.9	0.9	1.6	0.6
Chlorophyll *a* (µg/L)	3.60	4.97	4.44	3.28	6.56
Phaeophytin *a* (µg/L)	0.15	0.98	0.76	0.93	1.42

Appendix E2.–Seasonal averages of water quality parameters, nutrient concentrations, and photosynthetic pigments by year for Chignik Lake, 2004-2008.

	2004	2005	2006	2007	2008
	Average	Average	Average	Average	Average
pH	7.62	7.57	7.70	7.46	7.47
Alkalinity (mg/L)	22.4	23.8	24.8	18.2	21.0
Total P (µg/L P)	18.5	15.8	16.0	14.2	15.6
TKN (µg/L N)	146.5	199.5	86.0	148.3	96.3
Ammonia (µg/L N)	9.1	6.2	14.1	7.9	4.7
Nitrate + Nitrite (µg/L N)	128.0	110.9	129.9	194.0	192.5
Chlorophyll *a* (µg/L)	4.02	3.27	6.60	2.19	2.15
Phaeophytin *a* (µg/L)	0.32	0.65	0.90	0.37	0.56

Appendix E3.–Seasonal average number of zooplankton per m^2 from Black Lake, by year, 2004-2008.

Taxon	2004 Seasonal average	2005 Seasonal average	2006 Seasonal average	2007 Seasonal average	2008 Seasonal average
Copepods					
Epischura	37,649	18,113	-	5,750	-
Ovig. *Epischura*	-	-	-	-	-
Diaptomus	25,000	3,716	796	3,185	-
Ovig. *Diaptomus*	149	266	-	-	-
Cyclops	46,198	46,842	31,582	5,662	13,093
Ovig. *Cyclops*	-	-	-	-	-
Harpaticus	531	-	266	-	-
Napulii	40,509	38,150	7,564	9,996	16,189
Total copepods	150,036	107,086	40,207	24,593	29,282
Cladocerans					
Bosmina	398,855	203,755	2,323	1,858	1,681
Ovig. *Bosmina*	90,147	29,990	796	-	1,681
Daphnia l.	199	-	-	-	-
Ovig. *Daphnia l.*	-	-	-	-	-
Chydorinae	78,954	12,407	3,052	2,919	-
Total cladocerans	568,156	246,152	6,171	4,777	3,362
Total copepods + cladocerans	718,192	353,238	46,378	29,370	32,643

Appendix E4.–Seasonal average number of zooplankton per m^2 from Chignik Lake, by year, 2004-2008.

Taxon	2004 Seasonal average	2005 Seasonal average	2006 Seasonal average	2007 Seasonal average	2008 Seasonal average
Copepods					
Epischura	67,163	51,946	6,842	3,981	10,350
Ovig. *Epischura*	-	-	-	-	-
Diaptomus	45,467	49,367	17,350	4,305	14,265
Ovig. *Diaptomus*	3,605	2,816	1,393	619	1,592
Cyclops	140,871	120,322	175,889	327,406	87,331
Ovig. *Cyclops*	4,532	10,388	24,648	1,150	2,720
Harpaticus	1,078	348	1,335	1,062	100
Napulii	73,733	115,371	87,024	23,664	37,097
Total copepods	336,447	350,559	314,482	362,187	153,455
Cladocerans					
Bosmina	59,929	88,990	74,459	4,453	38,125
Ovig. *Bosmina*	8,944	24,968	16,956	575	9,372
Daphnia longiremis	29,824	15,787	22,805	8,139	11,968
Ovig. *Daphnia longiremis*	7,501	6,336	6,919	2,861	2,189
Chydorinae	8,373	6,179	-	3,340	1,062
Total cladocerans	114,570	142,259	121,139	19,367	62,716
Total copepods + cladocerans	451,017	492,818	435,621	381,554	216,171

Appendix E5.–Average weighted biomass estimates (mg dry weight/m^2) of the major Black Lake zooplankton taxon by year, 2004-2008.

	2004	2005	2006	2007	2008
Taxon	Weighted average	Weighted average	Weighted average	Weighted average	Weighted average
Copepods:					
Epischura	21.2	14.3	-	28.3	-
Diaptomus	31.5	8.3	1.1	8.7	-
Cyclops	35.7	44.3	22.1	10.4	13.8
Harpaticus	-	-	0.2	-	-
Total copepods	88.5	66.8	23.4	47.4	13.8
Cladocerans:					
Bosmina	365.6	180.7	2.1	1.0	1.5
Ovigerous *Bosmina*	125.8	43.0	0.8	-	2.6
Daphnia longiremis	0.1	-	-	-	-
Chydorinae	40.5	8.7	1.8	6.2	-
Total cladocerans	531.9	232.4	4.8	7.2	4.0
Total Biomass	620.4	299.2	28.2	54.6	17.8

Appendix E6.–Average weighted biomass estimates (mg dry weight/m^2) of the major Chignik Lake zooplankton taxon by year, 2004-2008.

Taxon	2004 Weighted average	2005 Weighted average	2006 Weighted average	2007 Weighted average	2008 Weighted average
Copepods					
Epischura	49.5	43.4	5.5	8.1	11.3
Ovigerous *Epischura*	-	-	-	-	-
Diaptomus	92.1	121.3	37.7	53.2	109.6
Ovigerous *Diaptomus*	22.2	23.1	28.4	89.0	-
Cyclops	155.5	153.9	300.7	557.8	147.2
Ovigerous *Cyclops*	20.4	49.3	138.7	69.0	10.1
Harpaticus	0.6	0.2	1.0	4.3	0.1
Total Copepods:	340.2	391.2	463.1	781.5	278.3
Cladocerans					
Bosmina	49.5	79.4	36.8	11.2	18.9
Ovigerous *Bosmina*	11.4	31.0	12.2	12.0	12.0
Daphnia longiremis	37.2	19.2	10.2	31.0	6.9
Ovigerous *Daphnia longiremis*	23.6	19.2	2.8	32.5	6.4
Chydorinae	6.0	4.0	6.6	4.6	0.3
Total Cladocerans:	127.7	152.8	68.6	91.3	44.6
Total Biomass	467.9	544.0	586.1	872.8	322.8

APPENDIX F. DISTRIBUTION LIST

Appendix F1.–Distribution List

Individual	Organization	Address	# of copies
Chuck McCallum	Chignik Regional Aquaculture Assn.	2731 Meridian #B Bellingham WA 98225	10
Chuck McCallum	Lake and Peninsula Borough	1577 C St. Suite 330 Anchorage AK 99501	1
Heather Finkle	ADF&G	Kodiak ADF&G Office	1
Todd Anderson	ADF&G	Kodiak ADF&G Office	1
Rob Baer	ADF&G	Kodiak ADF&G Office	1
Lisa Creelman	ADF&G	Kodiak ADF&G Office	1
Birch Foster	ADF&G	Kodiak ADF&G Office	1
Steve Honnold	ADF&G	Kodiak ADF&G Office	1
James Jackson	ADF&G	Kodiak ADF&G Office	1
Mary Loewen	ADF&G	Kodiak ADF&G Office	2
Jim McCullough	ADF&G	Kodiak ADF&G Office	1
Dave Sterritt	ADF&G	Kodiak ADF&G Office	1
Steve Schrof	ADF&G	Kodiak ADF&G Office	1
Steve Thomsen	ADF&G	Kodiak ADF&G Office	1
Greg Watchers	ADF&G	Kodiak ADF&G Office	1
Mark Witteveen	ADF&G	Kodiak ADF&G Office	1