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Afognak Lake Sockeye Salmon Stock Monitoring, 2013

by

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and

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January 2014

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

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ABSTRACT

Concerns expressed by local subsistence users over declines in Afognak Lake sockeye salmon *Oncorhynchus nerka* prompted the Alaska Department of Fish and Game to investigate Afognak Lake's rearing environment. Funded through the U.S. Fish and Wildlife Service Office of Subsistence Management, this report provides results from the 2013 season and synthesizes results obtained from 2010–2013.

Based on established mark-recapture techniques, an estimated 305,033 sockeye salmon smolt outmigrated from Afognak Lake in 2013. From 2010–2013, the outmigration averaged 267,994 and ranged from 127,862–329,948. Age-1 smolt comprised 82% of the outmigration in 2013 and averaged 78% of the outmigration from 2010–2013. Although age, weight, and condition data indicate healthy, robust smolt, a life-history based model produced a significantly larger estimate, which could indicate poor survival prior to the outmigration.

Bioenergetic and diet data was collected from juvenile sockeye salmon rearing in Afognak Lake from 2010–2013. Growth trends in the bioenergetics data differed between age classes with age-0 juveniles exhibiting greater variation than age-1 juveniles. Diet data showed annual and seasonal variation in prey selection with a considerable reliance on insects for all age classes. Exploratory stomach content analysis from juvenile coho salmon inhabiting the lake shoals revealed evidence of juvenile sockeye salmon predation.

Limnological sampling was conducted during five monthly events from May to September in 2010–2013. Phosphorus concentrations and zooplankton densities remained low, while chlorophyll-*a* levels maintained average values throughout the study. Nitrogen concentrations, lake temperatures, and phytoplankton biomass rose. Notably, the 2013 phytoplankton biomass reached 200 times that of 2012 and 2,000 times that of 2010.

Afognak Lake sockeye salmon returned in sufficient numbers to meet the escapement goal and support subsistence, sport, and commercial harvest. Escapement was 42,153 in 2013; averaging 46,289 and was predominately comprised of age 1.3 and age 1.2 fish (2010–2013).

Key words: Afognak Lake, Litnik, mark-recapture, age, outmigration, escapement, bioenergetics, Kodiak Island, *Oncorhynchus nerka*, smolt, sockeye salmon, subsistence harvest, inclined-plane trap, zooplankton

INTRODUCTION

The Afognak Lake (also referred to as "Litnik" by local residents) watershed is located on the southeast side of Afognak Island, approximately 45 km northwest of the city of Kodiak (Figure 1). Afognak Lake (58°07′ N, 152°55′ W) lies 21.0 m above sea level, is 8.8 km long, has a maximum width of 0.8 km, and a surface area of 5.3 km^2 (Schrof et al. 2000; White et al. 1990). The lake has a mean depth of 8.6 m, a maximum depth of 23.0 m, a total volume of 46.0 m^3, and an estimated lake-water residence time of 0.4 years (Figure 2). Afognak Lake drains in an easterly direction into the 3.2 km long Afognak River, which in turn flows into Afognak Bay. Afognak Bay is part of the Alaska Maritime National Wildlife Refuge and is where most localized subsistence salmon fishing occurs. The Afognak Native Corporation owns the land surrounding the Afognak Lake watershed down to tidewater.

A counting weir for adult salmon was first established on Afognak River in 1921 just below the lake outlet and was operated intermittently through 1977. From 1978 to the present, the weir has been consistently operated. In 1986, the weir was relocated to its current location, approximately 200 meters upstream of the Afognak River mouth. The Alaska Department of Fish and Game (ADF&G) has conducted annual weir counts in conjunction with sockeye salmon *Oncorhynchus nerka* age, sex, and length (ASL) sampling at the current site. Catch data have been documented through the ADF&G commercial landing fish ticket system, statewide sport fish surveys, and subsistence fishing permits since the late 1970s (Jackson et. al 2013).

In response to declining adult returns, in 1987, ADF&G, in cooperation with the Kodiak Regional Aquaculture Association (KRAA), initiated pre-fertilization fisheries and limnological investigations at Afognak Lake (Honnold and Schrof 2001; Schrof et al. 2000; White et al. 1990). Results of these investigations indicated that sockeye salmon production was limited by rearing capacity (White et al. 1990). Nutrient enrichment was recommended and implemented in 1990 to increase primary and secondary production with the intention to increase sockeye salmon rearing capacity in the lake. The ADF&G and KRAA fertilized Afognak Lake for eleven years (1990–2000).

Afognak Lake sockeye salmon runs substantially declined beginning in 2001 and escapements from 2002 through 2005 were below the established sustainable escapement goal (SEG) range of 40,000 to 60,000 sockeye salmon (Baer 2011; Honnold et al. 2007; Jackson et al. 2013; Nemeth et al. 2010). As a result of these poor runs, the commercial sockeye salmon fishery in the South East Afognak Section (which includes all of Afognak Bay and surrounding waters) was closed from 2001 until 2005, and again in 2007.

In 2004, new sustainable salmon management policies 5 ACC 39.222 and 5 ACC 39.223, provided the framework to a team of ADF&G biologists to re-evaluate the existing Afognak Lake sockeye salmon escapement goal. The team recommended changing the escapement goal from an SEG of 40,000 to 60,000 sockeye salmon to a biological escapement goal (BEG) of 20,000 to 50,000 sockeye salmon (Nelson et al. 2005). The recommendation was based on analysis of a Ricker spawner-recruit model and limnology data, excluding data from years in which the lake was fertilized. In 2007 and 2010, the escapement goal was re-evaluated with additional years of data and was recommended to remain unchanged (Honnold et al. 2007; Nemeth et al. 2010).

Escapements during the last decade have been just below (2002 and 2004) to just above (2001, 2003, 2005–2008) the lower bound of the BEG (Appendix A13). The Afognak River sockeye salmon run has only recently (2010–2013) regained sufficient numbers to meet the escapement goal (20,000–50,000) and support commercial harvest.

In addition to sockeye salmon, other fish species in the Afognak Lake drainage include pink salmon *O. gorbuscha*, coho salmon *O. kisutch*, rainbow trout (anadromous and potamodromous) *O. mykiss*, Dolly Varden *Salvelinus malma*, three spine stickleback *Gasterosteus aculeatus*, and coastrange sculpin *Cottus aleuticus* (White et al. 1990). Chinook *O. tshawytscha* and chum *O. keta* salmon have been observed in the Afognak River on occasion but have not established discernible spawning populations (White et. al 1990).

Afognak Lake sockeye salmon are an important target species for salmon fisheries within the Kodiak region. Residents of Port Lions, Ouzinkie, Afognak Village, and Kodiak have traditionally harvested salmon in Afognak Bay for subsistence uses (Figure 1). Local subsistence users, represented by the Kodiak-Aleutians Regional Advisory Council, Kodiak Fish and Game Advisory Committee, and Kodiak Tribal Council, contended that continued closures of the Afognak system would make it more difficult for local residents to harvest sockeye salmon and would shift fishing effort to small nearby sockeye salmon runs and the Buskin River, constituting an emergency situation. In response to this situation, ADF&G received funding through the Office of Subsistence Management's (OSM) Fishery Resources Monitoring Program to determine the feasibility of estimating sockeye salmon smolt production coming out of Afognak Lake. The 2003 study showed that sockeye salmon smolt could be effectively trapped in Afognak River and their abundance reliably estimated using mark-recapture techniques (Honnold and Schrof 2004).

Continued analysis of Afognak Lake sockeye salmon returns and annual smolt outmigration studies were deemed of high importance for evaluating nutrient food web dynamics and assessing changes in the growth and production of juvenile sockeye salmon. Recognizing the importance of continued studies on Afognak Lake sockeye salmon production, the OSM approved project funding to ADF&G for an additional four years (2010–2013).

In addition to the ongoing research, ADF&G expanded research efforts to investigate the caloric content of juvenile sockeye salmon as a more robust indicator of condition and health than traditional length and weight data (Finkle 2004). Enhanced with concurrent collection of juvenile sockeye salmon diet data, these expanded research efforts should provide valuable insight into growth and production trends.

The goal of this project was to obtain reliable estimates of smolt and adult production over time for Afognak Lake. Data collected from this project has enabled researchers to better identify factors specifically affecting and controlling sockeye salmon production within the freshwater environment. This information continues to help refine the escapement goal and improve pre-season run forecasts. Better management will allow for maximum sustainable yield and prevent unnecessary restrictions of federal and state subsistence fisheries.

This report summarizes the 2013 data collected and combined with data collected in 2010 through 2012, evaluates sockeye salmon production at Afognak Lake as part of a four year study.

PROJECT OBJECTIVES

<u>Smolt</u>

1. Estimate the abundance (*N*), age composition, and average size of outmigrating sockeye salmon smolt within 25% (relative error) of the true value with 95% confidence.
2. Estimate the abundance of outmigrating sockeye salmon smolt using a life-history based model for a comparison estimate with the mark-recapture techniques.
3. Estimate the age composition of outmigrating sockeye salmon smolt within d=0.05 (size of the effect) of the true proportion (for each major age group within each stratum) with 95% confidence.
4. Estimate the average length (mm), weight (g), and condition (Fulton's condition factor; K) by smolt age group and stratum.

<u>Adult salmon</u>

5. Enumerate the escapement of adult sockeye salmon returns through the weir and into Afognak Lake.
6. Estimate the age and sex composition of adult sockeye salmon returns where estimates are within d=0.07 of the true proportion (for each age group within each stratum) with 95% confidence.
7. Estimate the average length (mm) of adult sockeye salmon by age and sex.

Lake Studies and Climate Change

8. Evaluate the condition of juvenile (lake rearing) sockeye salmon relative to diet and energy density.
9. Evaluate the effects of water chemistry, nutrient status, and plankton production of Afognak Lake on smolt production and future adult returns.
10. Assess available historical fisheries and limnological data in relation to climate change effects.

METHODS

SMOLT ASSESSMENT

Trap Deployment and Assembly

Two inclined-plane traps (Ginetz 1977; Todd 1994) were placed in Afognak River to capture outmigrating smolt in 2013. The downstream trap was installed approximately 32 m upstream from the adult salmon weir site and was utilized for smolt enumeration and the recapture of marked fish (Figure 3). The upstream trap was installed approximately 1.2 km upstream from the adult salmon weir site and was utilized solely to capture smolt for dye release testing.

Prior to 2012, a single inclined-plane trap was utilized to capture outmigrating smolt. The single trap system required transportation of smolt from the capture site to the release site, creating unnecessary smolt mortality. Switching to a two trap system reduced smolt mortality and will continue as the preferred estimation method.

Both traps were positioned towards the middle of the river at each location, where water velocity was great enough to make it difficult for smolt to avoid capture and to capture a representative portion of the outmigrating smolt. A live box (1.2 m x 1.2 m x 0.5 m) was attached to the outlet of each trap, and both trapping devices were connected to cables attached to hand-powered cable “come-along” winches fixed to each stream bank. Both traps were secured to an aluminum pipe frame, which allowed the back end of the trap and live box to be adjusted vertically in response to water level fluctuations.

Smolt trapping operations were concluded when daily smolt counts were less than 100 smolt per day for 3 consecutive days. Detailed methods of trap installation, operation, and maintenance are described in the 2013 Afognak Lake Operational Plan (Thomsen 2013).

Smolt Capture and Handling

Smolt trap live boxes were checked every 1 to 2 hours during the night (2200 to 0800 hours), depending on smolt abundance. During the day (0801 to 2159 hours), the live boxes were checked every 3 to 4 hours. All smolt were removed from the live boxes with a dip net, counted, and either released downstream of the trap or transferred to an instream holding box for sampling and marking. The upper trap was only fished until the required numbers of smolt were captured for mark-recapture (dye release) tests and was not fished until the next dye test trial. Species identification was made by visual examination of external characteristics of juvenile salmonids (Pollard et al. 1997). All data, including mortality counts, were entered on a reporting form each time the trap was checked.

Trap Efficiency and Mark-Recapture Abundance Estimation

Total smolt abundance was estimated using mark-recapture procedures to estimate trap efficiency within specific recapture periods (weekly strata). Trap efficiency was then used to estimate the number of smolt outmigrating from the watershed during each stratum.

Releases of sockeye salmon smolt marked with Bismarck Brown Y dye were made once per strata (weekly), as well as when changes were made to the trapping system. As in previous years at Afognak Lake, an effort was made to achieve trap efficiencies from 15% to 20% (Thomsen and Richardson 2013). To estimate total smolt abundance for each strata with a 5% probability of exceeding a relative error (RE) of 25%, a minimum of 330 smolt were marked and released for each experiment (Carlson et al. 1998). To estimate mortality associated with the marking, holding, and transport process, 100 marked and 50 unmarked fish were retained and monitored for four days after the release of dyed fish. Therefore, we targeted a sample size of 700 as the goal for each experiment to account for mortality and testing. Actual numbers of fish marked, released, and retained for mortality testing varied by release event (Tables 1 and 2).

Dyeing Procedure

Smolt captured at the upstream trap (the preferred method) required no transportation and followed steps 3–5. Smolt captured for dye release testing at the downstream trap required treatment prior to transportation to the release site (steps 1–2). If transported, smolt were hauled in a trailer pulled by an all-terrain vehicle to the release site approximately 1.2 km upstream.

1. Collected smolt were placed in a 26-gallon lidded cooler, filled with river water and a 0.25% sodium bicarbonate solution to maintain a stable pH. Non-iodized salt was added to the transport water to achieve a 0.75% solution to replicate physiological levels and reduce metabolic stress and electrolyte depletion that can cause post-transport mortality. The transport cooler was continuously supplied with supplemental oxygen at a level of 9 mg/L and within an 80–100% saturation range to maintain conditions similar to ambient river water from which the smolt were collected.
2. Following transport to the release site, smolt were continuously supplied with supplemental oxygen and held for 30 minutes to minimize stress before the dyeing process.
3. Collected smolt were placed into a 26-gallon lidded cooler (unless following steps 1–2). Prior to adding the dye, 50 smolt (undyed) were randomly selected and placed in a separate holding box for four days to estimate holding mortality. The 26-gallon cooler was filled with river water and a 0.25% sodium bicarbonate (unless added during transport) and Bismarck Brown Y dye (30 mg/L) solution. The smolt were continuously oxygenated and submerged in the solution for 30 minutes. Dyed smolt that displayed unusual behavior (labored respiration, flared gills, side swimming, etc.) were removed from the experiment and released downstream of the recapture site.
4. The dye solution was replaced with river water and the smolt were held for 30 minutes before release. Roughly 550 of the dyed smolt were randomly selected from the holding box and placed in 5-gallon buckets for release. Timing of the dyeing process was started so dyed smolt were released across the width of the stream between 2100 and 2300 hours,
5. The remaining dyed smolt (roughly 100) were counted and left in the holding box for four days to estimate delayed mortality resulting from the capture and marking process. The proportion of smolt (dyed minus undyed) that died during the 4-day holding period

was used to estimate the actual number of marked smolt available for recapture in the experiment (M_h). M_h was adjusted by multiplying the delayed mortality ratio (total number of marked and held divided by total number of marked dead) by the number of dyed smolt released.

All dyed smolt recaptured at the downstream trap site were counted and assigned to the strata corresponding to the time period starting the day of their release until the day before the next release and mark-recapture event.

Statistical Formulas

Trap efficiency (E_h) for stratum h was calculated as

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

where

M_h = number of marked smolt released in stratum h

(Note: M_h is adjusted for marking and holding mortality)

m_h = number of marked smolt recaptured in stratum h

A modification of the stratified Petersen estimator (Carlson et al. 1998) was used to estimate the number of unmarked smolt N_h emigrating within each stratum h as

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

where

n_h = number of unmarked smolt recaptured in stratum h.

Variance of the smolt abundance estimate was estimated as

$$\hat{\text{var}}(N_h) = \frac{(M_h + 1)(n_h + 1)(M_h - m_h)(n_h - m_h)}{(m_h + 1)^2 (m_h + 2)}. \tag{3}$$

Total abundance of N of unmarked smolt over all strata was estimated by

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

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

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

and 95% confidence intervals were estimated using

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

which assumes that N is approximately normally distributed.

Within each stratum h, the total population size by age class j was estimated as,

$$\hat{N}_{jh} = \hat{N}_h \hat{\theta}_{jh}, \quad (7)$$

where $\hat{\theta}_{jh}$ is the observed proportion of age class j in stratum h. Variance of $\hat{\theta}_{jh}$ was estimated using the standard variance estimate of a population proportion (Thompson 1987). The variance of $\hat{N}_{jh}$ was then estimated by

$$\hat{\mathrm{var}}\left(\hat{N}_{jh}\right) = \hat{N}_h^2\, v\left(\hat{\theta}_{jh}\right) + \hat{N}_h\, v\left(\hat{\theta}_{jh}\right)^2 . \quad (8)$$

The total number of emigrating smolt within each age class was estimated by summing the individual strata estimates, and its variance was likewise estimated by summation over the individual strata estimates.

Statistical Assumptions

Statistical assumptions were taken from Carlson et al. (1998).

- The population was unchanging (i.e., a closed population with no immigration or outmigration),
- all smolt had the same probability of being marked (i.e., trap is not selective and strata are consistent),
- all smolt had the same probability of capture (i.e., marking fish does not affect their behavior or ability to be captured),
- all marked smolt released can be recovered (i.e., marking mortality was accurate),
- all marked smolt were identifiable (i.e., crew well trained and strata are discrete),
- and marks were not lost after marking (i.e., effectively dyed for external verification).

Life History-Based Abundance Estimation

In addition to a mark-recapture abundance estimate, the predicted number of smolt expected to outmigrate in 2013 was estimated based on a life history model (Table 3). The life-history based estimate utilized sex composition data from parental spawning escapements in 2010 (61% females) and 2011 (61% females), average egg deposition based on the average fecundity assessment of females used in egg-takes by Pillar Creek Hatchery crews in 2010 (2,539 per female) and 2011 (2,697 eggs per female), a 7% egg-to-fry survival (Bradford 1995; Drucker 1970; Koenings and Kyle 1997), a 21% fry-to-smolt survival (Koenings and Kyle 1997) from rates reported from other clear water systems, and a smolt age composition of 77% age-1 and 23% age-2 based on the smolt age composition from 2013. Annual differences between life-history based and mark-recapture estimates were regressed for comparison.

Alternately, the egg-to-fry and fry-to-smolt survival assumptions used in the life history-based estimate were compared to those found at Afognak. Smolt data from Afognak was only used to estimate egg-to-smolt survival. All other parameters and values used were identical to those used in the life history-based estimate.

Age, Weight, and Length Sampling

To ensure proportional abundance sampling, approximately 2% of the daily sockeye salmon smolt catch was sampled to obtain age, weight, and length (AWL) data. For every 100 sockeye salmon smolt counted out of the trap, the field crew retained two smolt for AWL sampling the following morning. Smolt were collected throughout the night and held in an instream live box. The following day, all smolt in the live box were anesthetized using tricaine methanesulfonate (MS-222) prior to being sampled. After being sampled, all smolt were held in aerated buckets of river water until they recovered from the anesthetic, and subsequently released downstream from the trap.

Fork length was recorded to the nearest 1 mm and weight to the nearest 0.1 g. Scales were removed from the preferred area of each fish following procedures outlined by the International North Pacific Fisheries Commission (INPFC 1963) and mounted on a microscope slide for age determination. Age was estimated from scales viewed with a microfiche reader at 60X magnification and recorded in European notation (Koo 1962) following the criteria established by Mosher (1968). In addition, the overall health or condition factor of each sampled smolt was assessed by calculating its body condition factor (*K*; Bagenal and Tesch 1978) as

$$K = \frac{W}{L^3}10^5 , \qquad (9)$$

where

W = weight and L = length.

ADULT SALMON ASSESSMENT

Weir Installation and Adult Salmon Enumeration

A 27 m long weir was installed perpendicular to the stream flow and consisted of 10 wooden tripods (each tripod consisting of three 4″ x 4″ x 8′ spruce timbers and 2″ x 6″ x 6′ horizontal catwalk supports), 33 aluminum pipes (2″ x 10′), 44 picketed aluminum panels (1″ aluminum pipe with 1″ spacing totaling 30″ x 6′), and 2 framed panel gates (Figure 4). All materials were secured with sand bags and lashed together to create a fish tight structure that conformed to the contour of the stream channel.

Two counting gates were placed between panels in the two deepest channels of the river enabling fish to be counted as they pass through the weir. A white flash panel was placed on the substrate beneath each gate to enhance visibility and species identification. Fish were counted by field technicians using hand tally denominators as fish migrated upstream through the gates. The counting gates remained closed until staff were present to count fish through the weir for escapement enumeration or when fish were being collected into the live trap for age, sex, and length sampling (ASL; Thomsen 2013).

Age, Sex, and Length Sampling

An upstream “Scott live trap” (local name for a modified trap capable of capturing steelhead) was installed in front of the east bank gate, which acted as a sampling trap as well as a downstream steelhead trap. The trap consisted of 6 weir panels placed horizontally in the river in the form of a diamond (Thomsen 2013).

Adult sockeye salmon were sampled at the weir site throughout the adult escapement. Details and procedures for adult sampling are outlined in the Kodiak Management Area Sockeye Salmon Catch and Escapement Sampling Operational Plan, 2013 (Moore 2013a). All scales, when possible, were collected from the preferred area of each fish (INPFC 1963). Scales were mounted on scale "gum" cards and returned to the Kodiak ADF&G office where impressions were made on cellulose acetate (Clutter and Whitesel 1956). Fish ages were determined by examining scale impressions for annual growth increments using a microfiche reader fitted with a 60X lens following designation criteria established by Mosher (1968). Ages were recorded using European notation (Koo 1962), where a decimal separates the number of winters spent in fresh water (after emergence) from the number of winters spent in salt water (e.g., 2.3). The total age of the fish includes an additional year representing the time between egg deposition and emergence of fry. Length measurements were taken from mid eye to tail fork to nearest 1 mm and sex was determined from external morphological characteristics.

Age and sex composition of the upstream migrating adult sockeye salmon were estimated daily as a group of proportions (p_{ij}) characterizing a multinomial distribution: $\hat{p}_{ij} = n_{ij} / n$, where n = the number in the sample and n_{ij} = the number in the sample of age i and sex j. On days where escapement occurred but no samples were collected, proportions were estimated by linear interpolation between sampling events. The sample size was selected so that the proportion of each major age group (by stratum) was estimated within at least α=0.07 of its true value 95% of the time (Thompson 1987). Standard error of the age proportions was calculated as the square root of estimated variance of a proportion (Thompson 1987). The six sampling strata were stratum 1 (17 May–30 May), stratum 2 (31 May–6 June), stratum 3 (7 June–13 June), stratum 4 (14 June–27 June), stratum 5 (28 June–25 July), and stratum 6 (26 July–29 August). Average length (unweighted) was calculated by age and sex.

LIMNOLOGICAL ASSESSMENT

Lake Sampling Protocol

Five limnological surveys of Afognak Lake were conducted at approximately four week intervals from May to September, 2013. Two stations, marked with anchored mooring buoys and located with Global Positioning System equipment, were sampled from a float plane during each survey (Figure 2). Zooplankton samples were collected at both stations, but water samples were only collected at Station 1. Data and water samples were returned to the ADF&G Kodiak Island Laboratory (Kodiak, AK) for analyses.

Temperature, Dissolved Oxygen, Light, Water Clarity and Euphotic Volume

Water temperature (°C) and dissolved oxygen (mg/L) levels were measured with a YSI® meter. Surface temperature readings were calibrated against a hand-held mercury thermometer. Temperature and dissolved oxygen readings were recorded at half-meter intervals to a depth of 5 m and then at 1 m intervals to the lake bottom.

In addition, 4 Hobo® water temperature data loggers were deployed in Afognak Lake, next to station 2, and recorded water temperatures every hour at depths of 1 m, 5 m, 10 m, and 13 m continuously.

Water transparency was measured at each station using a Secchi disc as described in Ruhl (2013). Measurements of light in the visible spectrum range (400–700 nm), known as photosynthetic active radiation (PAR), were obtained with a Li-Cor® (Li-250) submersible photometer at the lake sampling stations during the monthly sampling schedule. Readings were taken above the water surface, just below the water's surface (subsurface), and at half-meter intervals below the water surface until reaching a depth of 5 m and then at 1 m intervals to the lake bottom or to a depth at which the reading was less than 1% of the subsurface reading. Measurements were adjusted by linear regression to the Beer-Lambert equation (Wetzel 1983) to estimate an integrated vertical extinction coefficient (K_d m) for PAR within the euphotic zone, the layer of water from the surface down to 1% of subsurface PAR as

$$K_d \text{ m} = (1/z) \ln (I_z / I_o), \tag{10}$$

where

I_o = light intensity just below the water surface, and

I_z = light intensity at water depth z in meters.

Lake primary production potential for rearing juvenile sockeye salmon was assessed through a euphotic volume calculation as the product of the average euphotic zone depth (EZD) for the five monthly sampling periods and lake surface area (Koenings and Burkett 1987).

General Water Chemistry, Phytoplankton and Nutrients

During each survey, water samples were collected at a depth of 1 m below the water's surface using a 4.0 L Van Dorn sampler. Each water sample was emptied into a pre-cleaned polyethylene carboy, which was kept cool and dark, until refrigerated at the Kodiak Island Laboratory. Water samples were processed or frozen within 3 days of arriving at the laboratory. Lake water from the carboy was transferred into a 500 mL bottle, refrigerated, and analyzed for alkalinity and pH. A 250 mL bottle was filled with unfiltered water from the carboy, frozen, and later analyzed for total Kjeldahl nitrogen (TKN), total phosphorus (TP), and reactive silicon (Si). A total of 2.0 L of water was filtered using the following two different methods for assessing different water quality parameters. The first 1.0 L sample of lake water was filtered through a rinsed 4.25 cm diameter Whatman® GF/F cellulose fiber filter under 15 psi vacuum for filtrate collection. The filtrate was then analyzed for total filterable phosphorus (TFP), filterable reactive phosphorus (FRP), nitrate + nitrite (NO_3^- + NO_2^-; N+N), and ammonia (NH_4^+; TA). The second 1.0 L sample of lake water was filtered through another Whatman® fiber filter pad with the addition of approximately 5 mL of magnesium carbonate ($MgCO_3$) added to the final 50 mL of water near the end of the filtration process to act as a preservative. The filtrate was discarded and the fiber filter was retained and frozen on a petri dish for chlorophyll-*a* (chl-*a*) and phaeophytin (pheo-*a*) analysis.

The pH of water samples from samples collected at 1 m was measured in situ with a YSI ®pH meter. The pH of water samples collected at depth was measured with an Oakton pHTestr 30® meter. Alkalinity (mg/L as $CaCO_3$) was determined from 100 mL of unfiltered water titrated with 0.02 N H_2SO^4 to a pH of 4.5.

TA, N+N, and Si were analyzed using a SEAL® Analytical AA3 segmented flow autoanalyzer by methods described in the manufacture's chemistry protocols described in Ruhl (2013). TP, TFP, and FRP were analyzed using manual methods described in Ruhl (2013) and Koenings et al. (1987). TKN was determined at the University of Georgia Feed and Environmental Water Laboratory using the 4500-N D conductimetric method of inorganic nitrogen determination.

Total nitrogen (TN), the sum of TKN and N+N, and the ratio of TN to TP were calculated for each sample. Chlorophyll *a* (chl *a*) is the primary photosynthetic pigment in plants and is commonly used as an index of phytoplankton abundance. Samples of chl *a* were prepared for analysis by separately grinding each frozen filter containing the filtrate in 90% buffered acetone using a mortar and pestle, and then refrigerating the resulting slurry from each sample in separate 15 mL glass centrifuge tubes for 2 to 3 hours to ensure maximum pigment extraction. Pigment extracts were centrifuged, decanted, and diluted to 15 mL with 90% acetone. The extracts were analyzed with a SG5 (spectrophotometer) using methods described in Ruhl (2013) and Koenings et al. (1987). Concentrations of phaeophytin *a* (phaeo *a*), a common degradation product of chl *a*, were simultaneously estimated during the spectrophotometer analysis of chl *a*. The ratio of chl *a* to phaeo *a* was calculated to provide an indicator of phytoplankton physiological condition.

Zooplankton

Vertical zooplankton hauls were made at each station using a 0.2 m diameter conical net with 153 μm mesh. The net was pulled manually at a constant speed (~0.5 m/second) from approximately 1 m off the lake bottom to the surface. The contents from each tow were emptied into a 125 mL polyethylene bottle and preserved in 10% buffered formalin. Cladocerans and copepods were identified to genus using taxonomic keys in Edmondson (1959), Thorp and Covich (2001), and Wetzel (1983). Zooplankton lengths were measured in triplicate 1 mL subsamples taken with a Hansen-Stempel pipette and placed in a Sedgewick-Rafter counting chamber. Zooplankton were grouped at the genus level and measured to the nearest 0.01 mm. The standard deviation (SD) of the lengths (L) of up to 15 individuals was estimated. This value was then used to estimate the appropriate sample size (N) by applying it to a *t*-test (t) with a 0.05 significance level and relative to 10% variation from the mean measured length calculated as

$$N=[(t \times SD)/(0.1 \times L)]^2. \tag{11}$$

Biomass was estimated from species-specific linear regression equations of length and dry weight derived by Koenings et al. (1987). For each survey, average density and biomass from the two stations were calculated for each genera.

Phytoplankton

For phytoplankton analysis, 4.0 mL of Lugol's acetate was added to 200 mL of water withdrawn from the contents of the 1 m water sample carboy. Samples were sent to BSA Environmental Services Incorporated (Beachwood, Ohio) for analysis.

JUVENILE (LAKE REARING) ASSESSMENT

Juvenile Collection

Five shoal (littoral) and five mid-lake (pelagic) locations were selected to obtain representative samples of juvenile sockeye salmon rearing in Afognak Lake (Figure 2). The ten sites were sampled on a biweekly basis from May through August in an effort to capture representative fry (age-0) and fingerling (age-1) juvenile sockeye salmon. A 50 m tapered beach seine with 4 mm stretched mesh was utilized for the collection of fish on the five shoal sites. A small mesh pelagic trawl, a small purse seine (30 m), or a 3.5 m cast net were used on the mid-lake sites. All captured fish were identified and enumerated. Juvenile sockeye salmon were separated into three size groups (<45 mm, 46 to 64 mm, and ≥ 65 mm) to ensure proportional representation of each age group. When available, a minimum of five juvenile sockeye salmon representing each size and age group were retained for stomach content and bioenergetic analysis.

The retained juvenile samples were separated by sample location, stored in Whirl-Pak® bags with lake water, and transported to the field lab where individual AWL data was collected as described by Thomsen (2013).

Diet and Bioenergetic Analysis

At the field lab, all fish were sampled for AWL data. Fork length was recorded to the nearest 1 mm and weight to the nearest 0.1 g. Scales were removed from the preferred area of each fish following procedures outlined by the International North Pacific Fisheries Commission (INPFC 1963) and mounted on a microscope slide for age determination. For individuals retained for energy density analysis, samples were frozen in the field before being transported via aircraft to the Kodiak Island Laboratory. The frozen juvenile sockeye salmon samples were stored at or below -20°C prior to shipping to the ADF&G laboratory in Soldotna for further bioenergetic processing. The energy density or calories per gram (cal/g) of each sockeye salmon sample was determined within a precision of 0.1% through the use of a Parr® model 1266 Isoperibol microbomb calorimeter as per the manufactures specifications (Parr Instrument Company 1999).

For fish retained for diet analysis, stomachs were removed and placed in separate 7 mL vials containing isopropyl alcohol to stop digestion and preservation for later analysis. The stomachs of the retained fish, preserved in alcohol, were examined for contents. Because stomach contents were often too small to record accurate weights in the field lab, each prey category was spread to a relatively consistent thickness over a standard grid (0.5 mm squares) and the number of covered grid squares were counted. The grid counts were used as a surrogate measure of prey weight.

A relative index of stomach fullness was created by comparing the total prey weight to the predator weight, or calculating the ratio of the number of prey grids to the predator weight. Diets were analyzed by computing the mean proportional contribution of each prey category by grid counts for each month, location, and age group. When possible the zooplankton and invertebrates were identified by genera through the same methods as described in the limnological assessment and through additional taxonomic key identification (McCafferty 1983; Pennak 1989).

In addition, stomachs from 25 juvenile coho salmon captured at the shoal sites during May were removed, preserved with alcohol, and later examined for contents following identical methods used on juvenile sockeye salmon.

RESULTS

SMOLT ASSESSMENT

Smolt Capture

The trap was fished continuously from 8 May until it was removed for the season on 28 June 2013 (Figures 5 and 6). A total of 36,906 sockeye salmon smolt were captured in the downstream inclined-plane trap (Tables 1 and 2). The outmigration began earlier by 2 days and ended earlier by 4 days than average (2003–2013; Figure 7).

Trapping was conducted continuously in 2010, 2012, and 2013. High water prevented trapping in 2011 from 18 May–27 May. The average number of sockeye salmon smolt captured in the downstream inclined-plane trap from 2010–2013 was 39,017, ranging from 22,092 in 2012 to 54,409 in 2011 (Appendix A1). The outmigration timing for 2010–2013 was earlier than average but ended consistently with previous years (2003–2013; Figure 7).

Trap Efficiency and Mark-Recapture Abundance Estimation

Daily catches of sockeye salmon smolt in the beginning of the outmigration did not provide adequate trap catches for mark-recapture testing (8 May–19 May; Table 2). As a result, the trap efficiency estimated for 19 May was applied to the first stratum assuming identical trapping conditions. Standard mark-recapture trap efficiency methods were used to generate the total outmigration for the remaining four strata. The five trap efficiency tests ranged from 19.3% in stratum 1 (8 May–26 May) to 7.2% in stratum 5 (19 June–27 June; Table 2; Figure 6). In 2013, mean estimated trap efficiency was below average at 12.6% (2003–2013 at 16.4%; 2010–2013 at 14.5%; Appendix A1).

The estimated total sockeye salmon smolt outmigration from Afognak Lake in 2013 was 305,033 (95% CI 213,849–396,216; Table 1). This is below the ten-year mean outmigration estimate of 349,251 fish but above the four-year mean outmigration estimate of 267,993 fish (Appendices A1 and A2). Peak smolt outmigration occurred in strata 3 and 4 (5 June to 15 June) with the outmigration tapering off in stratum 5 (Table 2).

Life History-Based Abundance Estimation

Using the life history-based abundance method and using the assumptions previously identified, the 2010 escapement of 52,255 adults (brood year 2010) could produce 272,441 age-2 smolt. The 2011 escapement of 49,193 adults (brood year 2011) could produce 917,246 age-1 smolt (Table 3; Figure 8). Combining these two age classes resulted in an outmigration potential of 1,189,687 smolt from Afognak Lake in spring 2013. Life history-based abundance methods tended to overestimate the sockeye salmon smolt outmigration from 2010–2013 (Figure 8).

Age, Weight, Length, and Condition Factor

AWL data were obtained from 755 sockeye salmon smolt collected proportionally throughout the trapping period (Table 4). Summing smolt abundance estimates by age class for all five mark-recapture strata resulted in 249,107 (81.7%) age-1, 55,630 (18.2%) age-2, and 296 (0.1%) age-3 smolt outmigrating to the ocean (Table 5; Figure 9). This was above the 4-year and 10-year averages for age-1 sockeye salmon smolt (2010–2013, 78.0%; 2003–2012, 77.1%) and below the 4-year and 10-year averages for age-2 smolt (2010–2013, 21.9%; 2003–2012, 22.9%, Appendix A2).

Sampled age-1 sockeye salmon smolt had a mean weight of 3.8 g, a mean length of 77 mm, and a mean K of 0.84. Sampled age-2 sockeye salmon smolt had a mean weight of 4.7 g, a mean length of 84 mm, and a mean K of 0.79. Sampled age-3 sockeye salmon smolt had a mean weight of 5.4 g, a mean length of 88.0 mm, and a mean K of 0.79 (Table 4). This was above the 4-year and 10-year average length, weight, and K for age-1 and age-2 smolt (Appendix A3).

ADULT SALMON ASSESSMENT

Enumeration

The first salmon passed through the counting gates on 23 May. Adult salmon were enumerated on a daily basis until 27 August when the weir was removed with 42,153 sockeye, 17,400 pink, 13,090 coho, 1 chum, and 1 Chinook salmon escaping into the Afognak system (Table 6; Figure 10; Appendix A5; Fuerst 2013). Sockeye salmon escapement peaked from 14 June through 20 June when 10,026 fish were enumerated (Table 6). A post-weir estimate of 4,000 pink and 4,000 coho salmon was added to the escapement, using crew observations, after removal of the weir. Additionally, 78 steelhead kelts were passed downstream through the weir. The 2013 sockeye salmon escapement count was below the 4-year and above the 10-year average (Appendix A5). The 2013 coho salmon escapement was the largest since 1998 and above the 4-year and 10-year averages (Appendix A5). Crucially, the amount of coho salmon escapement enumerated is highly dependent on the date the weir is removed, which will be further examined in the Discussion Section.

Age, Sex, and Length Data

A total of 890 adult sockeye salmon were sampled from 23 May through 8 August, resulting in a total of 747 samples where age could be determined from the scales. Distribution of the samples was as follows: stratum 1 (17 May–6 June; n=174), stratum 2 (7 June–13 June; n=176), stratum 3 (14 June–27 June; n=185), stratum 4 (28 June–18 July; n=158), and stratum 5 (19 July–29 August; n=54). The goal of estimating age composition of the escapement within d=0.07 (95%) confidence was achieved for all ages within each strata (Table 7).

The majority (63.9%) of the sockeye salmon escapement was comprised of age-1.3 fish, while 19.6% were age-1.2 fish, 11.1% were age-2.3 fish, and 5.1% were age 2.2 fish (Table 7; Appendix A4). The majority of age-1.2 and age-1.3 fish escaped during June. The estimated sex composition of the escapement was 60% female and 40% male. Overall average length was 516 mm for all sockeye salmon (Table 8).

Age-1.3 sockeye salmon comprise 57.4% of the 4-year and 44.1% of the ten-year averages (Appendix A4). Age-1.2 sockeye salmon comprise 22.8% of the 4-year and 32.6% of the ten-year averages.

Harvest

A total of 6,311 sockeye salmon were harvested from the Southwest Afognak Section (252-34) in 2013 (Table 6). In addition, a total of 28 Chinook, 49 coho, 184 chum, and 8,187 pink salmon were harvested from the Southwest Afognak Section (Jackson et al. 2013). The 4-year average sockeye salmon harvest from the Southwest Afognak Section totaled 8,354 and the 10-year average harvest totaled 3,312 (Table 6).

LIMNOLOGICAL ASSESSMENT

Temperature, Dissolved Oxygen, Light, Water Clarity, and Euphotic Volume

Monthly water temperatures at station 1 taken during limnological sampling ranged from 6.4°C near the lake bottom on 15 May to 18.3°C between 1.0 and 5.0 m on 17 August (Figure 11). Seasonal mean water temperatures at 1 m and near the bottom were at or above the historical average (1989–2012 and 2010–2013; Appendix A6). Mean surface (1 m) temperatures were 10.4°C in the spring, 17.2°C in the summer, and 13.3°C in the fall (Appendix A6).

In 2013, the data logger at 1 m (Station 2) was operated continuously from 13 May to 18 September, recording temperature every hour. For comparison with monthly limnology sampling averages, mean surface (1 m) temperatures were 10.7°C in the spring, 16.8°C in the summer, and 14.4°C in the fall (Table 9). The temperature logger recorded a maximum of 21.8°C in July, a minimum of 7.1°C in May, and an overall mean of 14.4°C. Average monthly temperatures recorded by the data logger were greater in 2013 than previous years (2010–2013; Table 9).

Afognak Lake was stratified from June through July with turnover occurring in August (Figure 11). Monthly dissolved oxygen (DO) concentrations at station 1 taken during limnology sampling ranged from 12.2 mg/L at the surface in the spring to 7.6 mg/L near the lake bottom in the summer (Appendix A7). Mean vertical light extinction coefficient was -0.52 m, mean EZD depth was 8.75 m, and mean Secchi disk reading was 4.65 meters (Appendix A8). The estimated euphotic volume (EV) for Afognak Lake was 46.37×10^6 m^3 (Appendix A8). Using the EV model and 800–900 spawners per EV unit resulted in a spawning capacity estimate of 39,941 to 44,933 adults (Koenings and Kyle 1997; Appendix A8).

EZD values recorded in 2013 indicated that, on average, the first 9 m of the water column at the sampling stations were photosynthetically active (Appendix A8). Historic mean EZD values were comparable, with 9 m of the water column being photosynthetically active (1987–2011 and 2010–2013; Appendix A8).

General Water Chemistry and Nutrients

Afognak Lake mean pH was 7.42 and ranged from 7.28 in September to 7.58 in June (Station 1; Table 10; Appendix A9). Mean alkalinity level was 11.9 mg/L and ranged from 11.5 mg/L in June and July to 12.5 mg/L in September (Table 10). Mean chl-*a* concentration was 1.31 µg/L and ranged from 10.96 µg/L in June, July, and September to 2.08 µg/L in August (Table 10). Mean pheo-*a* concentration was 0.38 µg/L and ranged from 0.16 µg/L in July to 0.61 µg/L in September. Mean reactive silicon concentration was 2,801.3 µg/L and ranged from 2,561.8 µg/L in August to 3,201.5 µg/L in May (Table 11).

Mean TP concentration was 4.3 µg/L and ranged from 3.7 µg/L in May to 5.3 µg/L in September (Table 11; Appendix A10). Mean TFP concentration was 1.9 µg/L and ranged from 1.6 µg/L in July to 2.3 µg/L in August. Mean FRP concentration was 1.5µg/L and ranged from 0.8 µg/L in September to 2.3 µg/L in May.

Mean TKN concentration was 374.8 µg/L and ranged from 303.0 µg/L in May to 435.0 µg/L in June (Table 11; Appendix A10). Mean NH_4^+ concentration was 13.4 µg/L and ranged from 5.0 µg/L in June to 23.7 µg/L in August. Mean NO_2 + NO_3 concentration was 20.7 µg/L and ranged from 1.8 µg/L in July to 53.0 µg/L in May. Mean TN concentration was 395.5 µg/L and ranged from 340.0 µg/L in August to 463.4 µg/L in June. The overall mean TN to TP ratio, by weight, was 206.1:1 and ranged from 164.7:1 in September to 256.5:1 in June.

Zooplankton

In 2013, overall (stations 1 and 2 averaged) mean zooplankton density was 84,873 no/m^2 (Table 12). All zooplankton were cladocerans (*Order* Anomopoda and Ctenopoda) or copepods (*Order* Calanoida, Cyclopoida, and Harpacticoida). Cladocerans were more abundant (72.6% of mean density) than copepods (27.4%). Among the cladocerans, the two most abundant groups were *Bosmina* (74.5% of cladocerans; 54.1% of total density) and a pooled category called "other cladocerans" (15.4% of cladocerans; 11.2% of total), which consisted of various unidentified immature cladocerans. Other observed cladoceran genera were *Daphnia* (6.8%; 5.0% of total) and *Holopedium* (3.3%; 2.4% of total). Among the copepods, the two most abundant groups were the *Epischura* (44.6% of copepods; 12.2% of total) and the pooled category of "other copepods" (40.7% of copepods; 11.1% of total) which was made up mostly of the genus *Harpaticus* and various unidentified nauplii (larvae) or immature copepods. The other copepod genera included *Cyclops*, usually an important component of the zooplankton community in sockeye salmon rearing lakes (14.5% of copepods; 4.0% of total), and *Diaptomus* (0.2% of copepods; 0.1% of total).

In 2013, the seasonal mean weighted zooplankton biomass was 73.4 mg/m^2, and was mostly comprised (57.9% of mean total biomass) of cladocerans (Table 12). The cladoceran genus *Bosmina* represented 46% of the biomass, followed by the copepod genus *Epischura* representing 35.5%. The remaining biomass was composed of *Holopedium* (4.7%), *Daphnia* (7.1%), *Cyclops* (6.4%), *Diaptomus* (0.2%), and "other copepods and cladocerans," which consisted of larvae too small to weigh.

The copepod *Diaptomus* were the largest zooplankton genus/species measured, with a weighted mean length of 0.91 mm (Table 12; Appendices A11 and A12). Mean lengths of the remaining zooplankton measured, in decreasing size, were 0.79 mm for the copepod *Epischura*, 0.65 mm for the copepod *Cyclops*, 0.56 mm for the cladoceran *Daphnia*, 0.47 mm for the cladoceran *Holopedium*, and 0.28 mm for the cladoceran *Bosmina*. All mean weighted lengths include ovigerous individuals.

For historical comparison, using only the predominant crustaceans at station one, the post fertilization (2001–2012) average weighted mean zooplankton density was 95,043 no/m^2 (Appendices A11 and A12). This compares with the 2013 average weighted mean zooplankton density at station one of 76,932 no/m^2 and a 4-year average of 80,014 no/m^2. The post fertilization average zooplankton biomass was 124 mg/m^2. This compares with the 2013 mean total zooplankton biomass at station one of 91 mg/m^2 and a 4-year average of 108 mg/m^2.

Phytoplankton

In 2013, the seasonal mean phytoplankton biomass was 236,527 mg/m^3. Phytoplankton species composition was predominately composed of Bacillariophyta (Diatoms; 117,046 mg/m^3) and Chrysophyta (85,184 mg/m^3; Table 13). From 2010–2013 total biomass has fluctuated tremendously, ranging from 127 mg/m^3 in 2010 to 236,527 mg/m^3 in 2013 (Appendix A15).

JUVENILE (LAKE REARING) ASSESSMENT

Juvenile Collection

A total of 333 lake rearing juvenile sockeye salmon were captured in Afognak Lake from May to September, 2013, (Table 14). The five shoal collection sites (Figure 2; stations 1–5) provided a total of 317 specimens while 16 juvenile sockeye salmon were collected from the mid-lake collection sites (Figure 2; stations 6–10).

Of the 317 shoal samples, 162 were age-0, 145 were age-1, and 10 were age-2. Of the 16 mid-lake samples, 13 were age-0 and 3 were age-1 (Table 14).

A total of 1,055 lake rearing juvenile sockeye salmon were captured in Afognak Lake from 2010–2013. Of those, 785 were collected from shoal sites and 270 were collected from mid-lake sites. The majority (657) of the lake rearing juvenile sockeye salmon collected were age-0, while 377 were age-1 and 21 were age-2 juveniles.

Diet and Bioenergetic Analysis

Lake rearing juvenile sockeye salmon (*n*=108) were examined for calorimetric analysis; of those, 55 were age-0, 50 were age-1, and 3 were age-2 (Table 15). Of the 55 age-0 juvenile sockeye salmon, 42 were from shoal sites and 13 were from mid-lake sites. Of the 50 age-1 juvenile sockeye salmon, 47 were from shoal sites and 3 were from mid-lake sites. All age-2 juvenile sockeye salmon were from shoal sites.

Age-0 juvenile sockeye salmon from the shoals averaged 5,866 cal/g and those from mid-lake averaged 5,761 cal/g (Table 15; Figures 12 and 13). Age-1 juvenile sockeye salmon from the shoals averaged 5,498 cal/g and those from mid lake averaged 5,757 cal/g. Age-2 juvenile sockeye salmon from the shoals and averaged 4,895 cal/g. The average energy content (cal/g) increased over time for age-1 juvenile sockeye salmon, but for age-0 juveniles, energy content declined after June then remained fairly steady throughout the summer. Age-1 juvenile sockeye salmon had the greatest average cal/g in August. In contrast, the condition of juvenile sockeye salmon increased steadily throughout the season for all age classes (Figure 14).

Stomach contents of 227 lake rearing juvenile sockeye salmon were analyzed; of those, 122 were age-0, 98 were age-1, and 7 were age-2 fish (Table 16). Because of difficulties in obtaining mid water samples, only a couple fish were obtained for stomach content analysis and the remaining fish were used for energy density analysis. In view of the restricted number of mid-lake individuals, diet analysis is limited to shoal inhabitants. Although there were slight variations, there was no significant difference in the stomach fullness index values among shoal locations, months or different age classes (Figures 15 and 16).

For age-0 juvenile sockeye salmon the proportion of zooplankton in the diet decreased over the season (Figure 17). Zooplankton comprised 42% of the diets in June, 14% of the diet in July and 6% of the diet in August. Dipteran insects comprised 47% of the diets in June, 76% of the diets in July, and 67% of the diets in August (Table 16). Subsamples of the zooplankton species showed *Bosmina* to be the most abundant zooplankton followed by *Epischura* and the cladocera *Chydoridae*. Of the dipteran insects, emergent Chironomidae (pupae and subadult midges; approximately 70%) and Ceratapagonidae (biting midges) were the predominant taxa. Some prey items did not contribute significantly to the total composition but were important items as displayed by their frequency of occurrence. These prey items include Arachnids (water mites), Collembola (springtails) and terrestrial Hymenoptera insects.

For age-1 juvenile sockeye salmon, diet composition remained fairly constant throughout the season and zooplankton comprised only a small percentage of diets (Figure 18). The percent of the diet comprised of zooplankton was only 1.5% in May, 0% in June, 5.5% in July, and 2.8% in August (Table 16). Observed zooplankton in age-1 juvenile diets were generally larger individuals and included *Chydoridae*, *Epischura*, and *Cyclops*. Dipteran insects contributed the most to the diets with 88% in May, 95% in June, 54% in July, and 63% in August. Similar to age-0 juvenile sockeye salmon diet composition, emergent Chrionomidae were the most abundant Dipterans with other significant contributors including Ceratapagonidae, Simuliidae, and terrestrial Hymenoptera. Arachnids and Collembola did not contribute significantly to the total composition, but were important prey items as they occurred in most of the diets.

Age-2 juvenile sockeye salmon diet samples were limited to samples collected in May. The diet of age-2 juvenile sockeye salmon was composed of 89% Dipeteran insects, 6% other insects, 2% zooplankton, 1% dipteran larvae, and 1% vegetation (Table 16).

DISCUSSION

SMOLT ASSESSMENT

This was the third year using two-site mark-recapture methods at the Afognak site (Thomsen and Richardson 2013). The previous eight years employed one-site mark-recapture methods (Baer 2011). Despite changes in field personnel, project biologists, trapping methods, and varying environmental conditions, a mean trap efficiency of 16.4% (2003–2013) has been within the targeted range of 15% to 20% and ranged from 11.4% to 19.9% annually (Appendix A1).

The summer of 2013 was dryer and warmer than normal with low water levels. The lower water levels likely led to decreased trap efficiency in the last half of the season (mean of 12.6%; Table 1). However, trap efficiencies by strata in 2013 were comparable to previous years, suggesting consistency in mark-recapture estimates (Appendix A1).

The Afognak Lake sockeye salmon smolt outmigration followed a more typical pattern since the mark-recapture project was initiated in 2003. The outmigration estimate of 305,033 was above the most recent five-year average (291,376) and below the ten-year average (349,251; Appendices A1 and A2). The trap catch of 36,906 was below average but was within the mean standard deviation for an estimate at this site (5 and 10-year; Appendix A1).

Timing of the outmigration began and ended earlier than average with older smolt, as expected, migrating earlier (Figures 7 and 9). Age composition was predominately composed of age-1 smolt (81.7%) with age-2 smolt composing 18.2% of the outmigration (Table 5). In the previous three years (2010–2012) of this study, the average age composition of sockeye salmon smolt was composed of 78.0% age-1, 21.9% age-2, and 0.01% age-3 smolt (Appendix A2). The ten-year (2003–2012) average age composition of sockeye salmon smolt is composed of 77.1% age-1, 22.9% age-2, and 0.0% age-3 smolt. The dominance of age-1 smolt typically indicates favorable freshwater rearing conditions (Koenings and Kyle 1997).

In 2013, age-1 and age-2 outmigrating smolt had the greatest average length, weight, and K observed in the last four years (2010–2013; Table 4; Appendix A3). Since 2010, outmigrating smolt length, weight, and K have steadily increased (Figure 19; Appendix A3). The robustness of age-1 and age-2 sockeye salmon smolt indicates favorable freshwater rearing conditions.

The sockeye salmon smolt outmigration was fairly typical in numbers and timing and the age composition and condition of the smolt indicate favorable rearing conditions. However, the life history-based estimate for 2013 may indicate poor egg to smolt survival. As in previous reports, life history-based population estimates were calculated as a comparison to the mark-recapture estimates. Life history-based abundance estimates have been greater than mark-recapture abundance estimates in eight years (2003, 2006–2008, and 2010–2013) and less than mark-recapture abundance estimates in three years (2004, 2005, and 2009). In 2012 and 2013, life history-based estimates have been far greater than mark-recaptures estimates (88% and 74% respectively; Table 3; Figure 8; Appendices A1 and A2).

Values used to calculate the life history-based estimate were derived from a variety of lakes with some of the lakes being larger and more productive with rearing conditions that are not similar to morphometric features of Afognak Lake. With eleven years of reliable smolt outmigration data from Afognak Lake, we hope to better predict freshwater (egg to smolt) survival at smaller lakes to compare with survival rates at larger, productive lakes (volume wise; Appendix A19). Based on the mark-recapture sockeye salmon smolt outmigration estimates, egg to smolt survival averaged 1.0% and ranged from 0.1% to 1.8% (2003–2012; Appendix A2). Excluding the last two years (2012–2013) where the mark-recapture and life history-based estimates diverge, egg to smolt survival averaged 1.1%. For comparison, the life history-based estimates using large, productive lakes averaged 1.45%. Given the tendency to overestimate smolt production using a survival rate of 1.45%, future life history-based estimates should be lowered to 1.1% following Afognak Lake data.

The large difference between population estimates in 2013 would seem to indicate poor egg to smolt survival. The below average zooplankton density, biomass, and sizes may indicate top-down pressure and less than favorable feeding conditions (Appendices A11 and 12). Alternatively, the outmigration of younger (age-1), robust smolt would indicate more favorable rearing conditions (Figure 19). In fact, 2013 had the best smolt condition and energy density since the inception of the project (2003). Considering smolt robustness, it is likely that significant mortality occurred early, when juveniles shifted their diet from zooplankton to insects or prior to dependence on zooplankton.

It is possible that predation and competition from juvenile coho feeding in Afognak Lake contributed to poor egg to smolt survival. Ruggerone and Rogers (1992) found significant predation (up to 59% of sockeye salmon fry) by juvenile coho salmon on sockeye salmon fry in Chignik Lake. In 2013, juvenile coho salmon were collected from the shoals in May during the course of juvenile sockeye salmon sampling. The examination of juvenile coho salmon stomach contents confirmed predation on juvenile sockeye salmon at station 5 during the juvenile lake assessment study. Of the 25 coho salmon stomachs examined, 22% had sockeye fry present, and one had 11 fry. More extensive sampling in terms of increased sample size and stations sampled should be considered in the future to determine the significance of juvenile coho salmon predation on lake rearing sockeye salmon.

ADULT SALMON ASSESSMENT

The adult sockeye salmon escapement into Afognak Lake has consistently met the lower escapement goal in the last nine years (Table 6; Appendix A13; Figure 20). Additionally, the sockeye salmon escapement has met or been near the upper bound of the BEG in the last four years.

A total of 6,311 adult sockeye salmon were harvested from the Southeast Afognak Section (statistical area 252-34) in 2013 (Table 6). Although, the commercial harvest was below average (12,546; 1978–2012), it was above the most recent five years (5,713) and above pre-fertilization (5,507) averages (1978–1988; Table 6; Jackson et al. 2013). These pre-fertilization averages exclude 1989 when the commercial fishery was closed due to the Exxon Valdez oil spill.

The Afognak Lake sockeye salmon escapement is typically comprised of ocean-age-3 fish, followed by ocean-age-2 fish (Appendix A14; Figure 21). Ocean-age-1 fish average just over 5% of Afognak Lake's escapement, while ocean-age-4 fish make a negligible contribution. Average ocean age for the sockeye salmon escapement has increased in the last four years (2010–2013; Appendix A14).

Return per spawner (R/S) for sockeye salmon in Afognak Lake tends to mirror escapement data, increasing when escapements are low and decreasing when escapements are large (Figure 22).

The average R/S in Afognak Lake is 1.4, ranging from 0.1 to 3.9 (Appendix A13). For comparison with other Kodiak Archipelago systems, average R/S for Ayakulik Lake is 1.6, average R/S for Karluk Lake is 1.9, and average R/S for Frazer Lake is 2.1 (Moore 2013b).

Sufficient sockeye salmon smolt outmigration data has been collected from Afognak Lake to begin determining ocean survival (2000–2013). Comparing smolt outmigration numbers and ages with the number and ages of returning adults was assessed for five or six years, depending on smolt age. Survival of age-1 smolt was the greatest, with an average smolt to adult survival (ocean survival) of 18.3%, ranging from 5.9 to 40.3% (Appendix A19). Average ocean survival for age-2 smolt was 16.8%, ranging from 1.1 to 35.1%. Overall, smolt survival averaged 13.9% (2003–2007).

Monitoring of adult coho salmon escapement into Afognak Lake is secondary to monitoring sockeye salmon escapement. Additionally, removal of the weir is dependent on budgetary constraints and not assessing coho salmon escapement. Therefore, coho salmon escapement counts through the weir are imprecise and dependent on run timing and the date of weir removal.

Coho salmon escapement has averaged approximately 6,000 fish since the 1980s and currently has no escapement goal established (Nelson et al. 2005). An SEG of 3,500–8,000 (passage through the weir by 15 August) was established by Nelson and Lloyd (2001) but was eliminated due to early weir removal (Nelson et al. 2005). In 2013, the coho salmon escapement of 13,090 was above average. In fact, three of the last four years of coho salmon escapements have been near or above average (Appendix A5).

Comparing weir removal dates to coho salmon escapement reveals only small coho escapements when the weir was removed prior to 25 August (Figure 23). Accordingly, since 2003, only three years likely have meaningful coho salmon escapement data (2010, 2012, and 2013). To illustrate, since 2003, on average, the weir remained in place through 18 August (Table 17). Coho salmon escapements for the same time frame averaged 3,358 (2003–2013; Appendix A5). Previously, on average, the weir remained in place through 12 September (1990–2001). Coho salmon escapements for the same time frame averaged 11,466 (1990–2001; Appendix A5).

In light of concerns about possible competition and predation on juvenile sockeye salmon in Afognak Lake by juvenile coho salmon, it would be prudent to extend weir operations to more closely monitor the coho salmon escapement.

LIMNOLOGICAL ASSESSMENT

Temperatures in the lake were above a 24-year average (1989–2012) during seasonal limnological sampling (Appendix A6) and above average for the last four years of temperature data using a logger (Table 9). The lake was stratified from June through August (Figure 11). DO values were slightly above the 24-year average (Appendix A7). Euphotic zone depth (EZD) values indicated that, on average, the first 8.8 m of the water column at the sampling stations were photosynthetically active. With an average lake depth of 8.6 m, this suggests that the majority of Afognak Lake was capable of primary production throughout the sampling season. The historic mean EZD value (9.4 m; 1987–2012) was slightly more than that of 2013 (Appendix A8).

Seasonal measurements of mean nutrient and algal pigment concentrations generally showed little variation over the sampling season, with the exception of nitrogen components. From a historical perspective, pH and alkalinity were slightly above average, which can be expected with an increase in the lake temperature (Wetzel 1983; Appendix A9). Phosphorus components were below the historical average (Appendix A10) and nitrogen components were consistent, with the exception of TKN, which was roughly 2.5 times the historical average and the highest value ever observed. TKN in part represents organic forms of nitrogen. Organic nitrogen can be introduced into lakes via precipitation, nitrogen-fixing bacteria or blue-green algae, and groundwater runoff (Wetzel 1983). Blue-green algae biovolumes were roughly 45 times greater in 2013 than any other year and therefore may have contributed to the increased TKN concentrations. However, because TKN concentrations were fairly consistent throughout the sampling season and the blue-green algae bloom occurred in August and September, it is more likely that groundwater runoff and precipitation caused the increase. Chlorophyll and phaeophytin were comparable to their averages. The abundance of nitrogen and decreased phosphorus concentration, coupled with average chl-*a* (primary production), suggests that phosphorous was more limiting to algal production than nitrogen but adequate rates of photosynthesis occurred as evidenced by the sizeable phytoplankton biomass.

Typically, phytoplankton communities are dominated by either diatoms or flagellates (Officer and Ryther 1980). Diatoms are the preferred phytoplankton prey for zooplankton in northern lakes and tend to dominate in oligotrophic systems with sufficient silicon concentration (Officer and Ryther 1980). Several of the larger oligotrophic lakes in Kodiak are predominately composed of diatom phytoplankton communities (Finkle 2013; Thomsen 2011). Low nutrient levels favor some diatom species because they can store phosphorous unlike other phytoplankton taxa (Wehr and Sheath 2003). Dominant species of phytoplankton in Afognak Lake have varied over the four years of sample collection but the community typically has been composed of species that can tolerate oligotrophic nutrient levels and frequent physical disturbances (Wehr and Sheath 2003). For example, the diatoms *Cyclotella* and *Tubellaria*, which comprised a large portion of the 2013 diatom community, are responsive to frequent changes in environmental conditions and function well at low nutrient levels.

Mean phytoplankton biomass in Afognak Lake has increased tremendously in the four years of data collection; the 2013 biomass was two hundred times that of 2012, and nearly 2,000 times that of 2010 (Appendix A15). Likewise, mean nitrogen (TKN) concentration has increased immensely in the last four years. Because the predominant phytoplankton species are more responsive to environmental variables and it is unlikely TKN concentrations increased from blue-green algae metabolizing nitrogen, precipitation events may be a driver of nitrogen and phytoplankton dynamics. Considering the record rain and snow fall that occurred in Kodiak during 2012 and 2013 (ACRC 2013), this hypothesis is plausible.

The seasonal mean zooplankton density and biomass estimates were low in Afognak Lake over the sampling season and near the 5-year average. Recent biomasses continue to remain near the starvation level of 100 mg/m^2 for rearing salmonids (2009–2013; Mazumder and Edmundson 2002). Data from the cladoceran *Bosmina* suggested that juvenile sockeye salmon may overgraze this key taxa; *Bosmina* were small (mean length of 0.28 mm) and well below the juvenile sockeye salmon minimum elective feeding threshold of 0.40 mm (Kyle 1992). The low biomass of zooplankton in Afognak Lake may also be the result of competition for resources with aquatic insects, inedible phytoplankton, or temperature (Thorp and Covich 2001).

JUVENILE (LAKE REARING) ASSESSMENT

Collection of lake rearing juvenile sockeye salmon from shoal sites were productive in 2013. Mid-lake juvenile sockeye salmon samples remained difficult to obtain. Age-1 juvenile sockeye salmon collected from mid-lake sites had greater energy content (cal/g) than those collected from the shoals, while age-0 juvenile sockeye salmon collected from the shoal sites had greater energy content (Appendices A16–A18). The greatest mean energy content was observed in 2010 at a shoal site for an age-0 juvenile sockeye salmon, and the lowest mean energy content was observed in 2011 at a mid-lake site for an age-1 juvenile. However, these generalizations could be the result of small sample sizes.

Seasonal fluctuations in energy content closely match seasonal fluctuations in condition factor for age-1 juvenile sockeye salmon (Figures 14 and 25). The energy content of age-0 juvenile sockeye salmon did not exhibit a similar trend with condition factor (Figures 14 and 24). This disparity between energy content and condition factor for age-0 juvenile sockeye salmon was most pronounced in June (2013; May in 2012), when age-0 juvenile sockeye salmon contained a higher percentage of insects. Finkle (2004) found that Black Lake (Alaska Peninsula) juvenile sockeye salmon feeding on chironomid larvae (insect larvae) provided higher energy content than those eating zooplankton. Considering the findings above, using energy content seems to be a better measure of age-0 juvenile sockeye salmon fitness, rather than condition, because condition, a ratio of length to weight, does not account for the actual energy content of food that was consumed.

Each year of the study results showed an increase in average energy content as the season progressed, although this trend was more pronounced in age-1 juvenile sockeye salmon. Age-0 juvenile sockeye salmon showed greater energy content at the beginning of the season, which is likely due to energy stores remaining from recently absorbed yolk sacs (Cummins and Wuychek 1971; Crossin et al. 2004; Hendry and Berg 1999; Kamler 2008; Schindler and Eby 1997). After depletion of yolk sacs, energy content of age-0 juvenile sockeye salmon declined, but soon thereafter energy levels increased following similar trends in age-1 juvenile fish collected.

Rates of energy gain varied temporally between years. In 2011 and 2013, the greatest caloric gain occurred during the early summer months, while in 2012 the greatest caloric gain occurred during the mid-summer months (Figure 26). This is most likely due to inter-annual variation in temperature and consumption as growth rates of sockeye salmon are related to temperature and ration size (Brett et al. 1969). Thus far, energy densities of Afognak Lake rearing sockeye salmon corroborate the relationship between temperature and growth. Energy densities of fish were higher during periods of warmer temperatures and lower during periods of cooler temperatures (Figure 27). Further exploration of temperature, growth, consumption rates, and metabolic rates of Afognak Lake juveniles through construction of bioenergetics models, is part of a concurrent University of Alaska Fairbanks (UAF) graduate project (N. Richardson, ADF&G, unpublished data).

For 2010 through 2012, visual estimates were used to proportion zooplankton and insect stomach contents. Visually estimating stomach content proportions can be highly subjective and is dependent on the individual processing the samples. Using improved and refined methods in 2013, a more quantitative approach was used to determine both an index of stomach fullness and species composition within the diets, thus allowing for better evaluation of juvenile sockeye salmon foraging with greater confidence than previous years. However, because of yearly differences in methods and analysis in conjunction with the difficulties of capturing representative proportions of fish from each age class, during each month, and at every site, the ability to compare diets among years is extremely limited. However, some general information can be gathered from across the years.

Littoral or shoal areas are important rearing and foraging habitat for Afognak Lake juvenile sockeye salmon as they were consistently captured in these locations. Published data on habitat use of juvenile sockeye salmon in other lake systems have shown a high use of near shore habitat during early summer months and especially for newly emerged age-0 sockeye salmon (Rogers 1973). However, after fish increase in size, which reduces the risk of predation, and when zooplankton production has increased, sockeye generally move off shore and utilize mid-water habitats sometime in June or July (Rogers 1973). Afognak Lake sockeye salmon do not display this same behavior as all age classes and sizes were captured at shoal sites throughout the summer and into the fall.

Over the four years, numerous attempts to capture juveniles at mid-water sites were attempted following methods used during other sockeye lake studies (Bear 2011; Finkle 2004; Griffiths 2012; Honnold and Schrof 2001; Kyle and Koenings 1988). Mid-water trawling was conducted across the lake before, during, and after crepuscular hours to account for observed diel vertical migration and at depths that previous hydroacoustic surveys in Afognak Lake have showed to support high densities of fish (White et al. 1990). The capture of hundreds of sticklebacks during lake trawling indicates the trawl net was actively fishing. While net avoidance by juvenile sockeye salmon may be a possibility, the mid-water catch per unit effort was dramatically lower than beach seining in shoal locations, suggesting that shoal (littoral zone) areas of Afognak Lake are highly utilized and important for all age classes throughout the year.

This extensive use of shoal habitats may be a result of the unique characteristics of Afognak Lake. Compared to most sockeye salmon rearing lakes, Afognak Lake is relatively small (in volume), shallow, and has an extensive littoral zone which warms quickly. Afognak Lake also has lower zooplankton density, biomass, and a different species composition than typical sockeye salmon rearing lakes. Although zooplankton, particularly *Daphnia* and *Bosmina*, have been observed as dominant prey in other sockeye diet studies (Koenings and Kyle 1987), aquatic insects, especially emergent chironomids, are the dominant prey for juvenile Afognak sockeye salmon. Similarly, juvenile sockeye salmon diet in Black Lake, which is also shallow, is dominated by chironomids (Griffiths 2012). Shallow lakes can provide higher temperatures near the lake bottom (Finkle 2004), potentially increasing benthic production of aquatic insects such as chironomids.

Zooplankton, however, may be a critical prey item for age-0 juvenile sockeye salmon in Afognak Lake. Although a higher abundance of zooplankton occurred in mid-water diets, among the shoal samples in 2013, age-0 juvenile sockeye salmon were the only fish that showed heavy foraging on zooplankton in shoal habitats. Ontogenetic shifts in diet were observed for age-0 juvenile sockeye salmon as zooplankton comprised a large portion of the diet early in the season but contributed less to diet composition with each month. A similar trend was observed in 2011, but not in 2010 (Figure 17). These annual differences in diet trends may be due to the subjective nature of visual estimates used before quantitative methods were applied in determining diet composition. The ontogenetic diet shift observed in 2011 and 2013 may be due to the gape size of smaller fish limiting foraging opportunities to smaller prey items (size selection) such as zooplankton. As age-0 juvenile sockeye salmon grow and increase their gape size and swimming ability, their ability to successfully forage on larger, higher energy prey items such as an insect increases.

To reduce variability that may be introduced from differences in feeding intensity over the diel cycle, in 2012 and 2013, lake rearing juveniles were collected at the same time during evening crepuscular hours. Separate age classes show a difference in preferential prey but the similarity in the stomach fullness index values shown throughout the 2013 season suggests that each age class has equal foraging capabilities and each location offers sufficient foraging opportunity. Previous years have not shown a similar pattern but this may be due to using visual estimates combined with the high variability in maximum stomach volume of individual fishes. Armstrong et al. (2013) described the plasticity of a fish's digestive system, showing the same fish can have a different maximum stomach capacity during different times of the year.

Large numbers of juvenile coho salmon and threespine stickleback were captured at shoal sites in Afognak Lake. Competition for prey from juvenile coho salmon and threespine stickleback has been well documented in Alaska (Parr 1972; Hale 1981; Ruggerone and Rogers 1992). Competition by threespine sticklebacks is currently being studied as a graduate project in Afognak Lake (N. Richardson, ADF&G, unpublished data).

To ascertain whether predation by juvenile coho salmon is occurring, 25 juvenile coho were collected in May from the shoals during the course of juvenile sockeye salmon sampling. Examination of the coho stomach contents confirmed that predation of juvenile sockeye salmon was occurring by juvenile coho salmon at station five (Figure 2). Four of the eight juvenile coho salmon samples examined at station five had juvenile sockeye salmon present; one contained 11 fry. Of the 17 remaining juvenile coho salmon stomachs examined, none had sockeye salmon fry in them (Table 18). Considering this, competition and predation by juvenile coho salmon should be more extensively conducted in the future to document possible interspecies interactions.

Dolly Varden may also contribute to the predation in Afognak Lake but Roelofs (1964) examined this possibility and found no merit. First, Roelofs observed the bulk of the Dolly Varden to have migrated out of the river prior to the smolt outmigration. Second, Roelofs examined numerous Dolly Varden stomachs and found no sockeye salmon present. Additionally, he found that Dolly Varden return to the lake in July and examination of the stomachs indicated that they did not feed in the river.

CLIMATE CHANGE

Pacific salmon abundance fluctuates on a large-scale and regionally with trends in climate events, such as an El Niño, La Niña, and the Pacific Decadal Oscillation (PDO; Beamish et al. 1999). Alaskan salmon populations seem to switch between high and low production, responding to changes in North Pacific climate regimes (Hare and Francis 1994). Supporting this statement, sockeye salmon experienced a decrease in production in the late 1940s and an increase in production in the late 1970s with shifts in climate (Hare and Francis 1994).

Most climate change models predict that northern latitudes will significantly increase in temperature (ranging from 2–7°C; IPPC 2001). This temperature change will likely result in ocean circulation pattern changes (Welch et al. 1995). Peterman and Dorner (2012) found evidence for a recent, large scale shift in sockeye salmon abundance, with stocks south of Yakutat decreasing in abundance and stocks north of Yakutat remaining stable. When compared with previous shifts, it appears that the boundary, presently at Yakutat, has shifted north (Peterman and Dorner 2012).

Generally speaking, when considering historical records, Alaska salmon are more abundant when the climate warms (Adkison and Finney 2003). Considering these shifts in sockeye salmon abundance, it’s evident that changes in ocean circulation patterns influence ocean survival. Welch et al. (1995) postulates that climate change will likely result in ocean circulation pattern changes and those changes will possibly negate any benefits from increased temperatures. Also, because salmon reside near the surface, significant increases in temperature will likely force salmon north, to compensate for increased metabolic rates.

Adult sockeye salmon may be able to move north in the ocean but juvenile sockeye salmon inhabit lakes and must tolerate or adapt to changes in their local environment. Griffiths (2012) discovered that freshwater lakes with diverse characteristics and habitat react differently to increases in air temperature (Black and Chignik Lakes). She concluded that thermal regime changes, caused by increases in air temperature, would reduce juvenile sockeye salmon growth in Black Lake; a shallow, well mixed lake. Alternately, Chignik Lake; a deep, stratified lake, would respond positively and increase its capacity to support juvenile sockeye salmon.

Warmer lake temperatures will shift the spring thaw earlier and lengthen the growing season but warmer temperatures will also increase metabolic rates, forcing juveniles to alter feeding behavior and seek refuge in cooler, deeper water. Additionally, lakes will stratify earlier and become more stratified, altering nutrient availability. Although increased temperatures will likely increase phytoplankton and zooplankton production, Carter (2010) also points out that earlier stratification resulted in decreases in some systems because of food availability timing and warmer temperatures can reduce zooplankton clutch size and reproductive activity. Productivity and emergence of insects, a key prey for sockeye salmon juveniles in Afognak Lake during May, will likely be altered. If changes in insect emergence do not coincide with juvenile needs, significant mortality may occur. Warmer temperatures will also alter precipitation with increased rain and storm events causing more floods and decreased snow pack, causing more droughts. In time, timing of emergence, smolt outmigration, adult returns, and spawning will likely become earlier.

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REFERENCES CITED

ACRC (Alaska Climate Research Center). 2013. City summary archive. http://climate.gi.alaska.edu/city-archive?field_year_list_value=All&field_month_value=All&field_city_value=Kodiak (accessed November 7, 2013).

Adkison, M. D. and B. P. Finney. 2003. The long-term outlook for salmon returns to Alaska. Alaska Fishery Research Bulletin 10(2):83-94.

Armstrong, J. B, and M. H. Bond. 2013. Phenotype flexibility in wild fish:Dolly Varden regulate assimilative capacity to capitalize on annual pulsed subsides. Journal of Animal Ecology 82: 966-975.

Baer, R. T. 2011. Afognak Lake sockeye salmon stock monitoring, 2010. Alaska Department of Fish and Game, Fisheries Data Series No. 11-27, Anchorage.

Bagenal, T. B. and F. W. Tesch. 1978. Age and growth. pp. 101-136 [*In*] T. Bagenal, editor. Methods for assessment of fish production in fresh waters. IBP Handbook No. 3, third edition. Blackwell Scientific Publications, London.

Beamish, R. J., D. J. Noakes, G. A. Mc Farlane, L. Klyashtorin, V. V. Ivanov, and V. Kurashov. 1999. The regime concept and natural trends in the production of Pacific salmon. Canadian Journal of Fisheries and Aquatic Sciences 56:516-526.

Bradford, M. J. 1995. Comparative review of Pacific salmon survival rates 1995. Canadian Journal of Fisheries and Aquatic Sciences 52:1327-1338.

Brett, J. R., J. E. Shelbourn, and C. T. Shoop. 1969. Growth rate and body composition of fingerling sockeye salmon. *Oncorhynchus nerka*, in relation to temperature and ration size. Journal of the Fisheries Research Board of Canada, 26(9): 2363-2394.

Carlson, S. R., L. G. Coggins Jr., and C. O. Swanton. 1998. A simple stratified design for mark-recapture estimation of salmon smolt abundance. Alaska Fisheries Research Bulletin 5:88-102.

Carter, J. L. 2010. Responses of zooplankton populations to four decades of climate warming in lake in southwestern Alaska. Master of Science thesis. University of Washington.

Clutter, R., and L. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. International Pacific Salmon Fisheries Commission, Bulletin 9, New Westminster, British Columbia, Canada.

Crossin, G. T., S. G. Hinch, A. P. Farrell, D. A. Higgs, A. G. Lotto, J. D. Oakes, and M. C. Healey. 2004. Energetics and morphology of sockeye salmon: effects of upriver migratory distance and elevation. J. Fish Biol. 65(3): 788–810.

Cummins, K.W. and J. C. Wuycheck. 1971. Caloric equivalents for investigations in ecological energetics. International Association of Theoretical and Applied Limnology 18: 1–158.

Drucker, B. 1970. Red salmon studies at Karluk Lake, 1968. U.S. Bureau of Commercial Fisheries, Auke Bay Biological Laboratory Administrative Report 55p.

Edmondson, W. T. 1959. Fresh-water biology. Second edition. John Wiley and sons, New York.

Finkle, H. 2004. Assessing Juvenile sockeye salmon (*Oncorhynchus nerka*) energy densities and their habitat quality in the Chignik Watershed, Alaska. Master of Science thesis. University of Alaska, Fairbanks.

Finkle, H. 2013. Autonomous salmon lake mapping and limnological assessment of Karluk Lake, 2012. Alaska Department of Fish and Game, Fishery Data Series No. 13-39, Anchorage.

Fuerst, B. 2013. Kodiak management area weir descriptions and salmon escapement report, 2013. Alaska Department of Fish and Game, Regional Information Report *In prep*, Kodiak.

Ginetz, R. M. J. 1977. A review of the Babine Lake development project 1961-1976. Environment Canada. Fish and Marine Services Technical Report Service Number Pac-T-77-6, 192 p.

REFERENCES CITED (Continued)

Griffiths, J. R. 2012. Climate change and geomorphic evolution in an Alaskan watershed and implications for salmon production. Doctor of philosophy thesis. University of Washington.

Hale, S. S. 1981. Freshwater habitat relationships: Threespine stickleback. Alaska Department of Fish and Game, Habitat Division, Anchorage, Alaska.

Hare, S. R. and R. C. Francis. 1994. Climate change and salmon production in the Northeast Pacific Ocean. *In* R. J. Beamish. Climate change and northern fish populations. Can. Spec. Publ. Fish Aquat. Sci. 121, p. 357-372.

Hendry, A.P., and O. K. Berg, 1999. Secondary sexual characters, energy use, senescence, and the cost of reproduction in sockeye salmon. Can. J. Zool. 77 (11): 1663-1675

Honnold, S. G., and S. Schrof. 2001. A summary of salmon enhancement and restoration in the Kodiak Management Area through 2001: a report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Regional Information Report 4K01-65, Kodiak.

Honnold, S. G. and S. Schrof. 2004. Stock assessment and restoration of the Afognak Lake sockeye salmon run. Fisheries Resource Monitoring Program. U.S. Fish and Wildlife Service, Office of Subsistence Management, Fishery Information, Services Division, Final Project Report No. FIS 03-047, Anchorage, Alaska.

Honnold, S. G., M. J. Witteveen, M. B. Foster, I. Vining, and J. J. Hasbrouck. 2007. Review of escapement goals for salmon stocks in the Kodiak Management Area, Alaska. Alaska Department of Fish and Game, Fishery Manuscript No. 07-10, Anchorage.

IPPC (Intergovernmental Pannel on Climate Change). 2001. Climate change 2001: impacts, adaptation, and vulnerability. Cambridge University Press, New York, NY.

INPFC (International North Pacific Fisheries Commission). 1963. Annual Report 1961. Vancouver, British Columbia.

Jackson, J., B. Fuerst, G. Spalinger, and M. Keyse. 2013. Kodiak Management Area commercial salmon fishery annual management report, 2013. Alaska Department of Fish and Game, Fishery Management Report, *In prep*, Anchorage.

Kamler, E. 2008. Resource allocation in yolk-feeding fish. Reviews in Fish Biology and Fisheries, 18(2), 143-200.

Koenings, J. P., and R. D. Burkett. 1987. Populations characteristics of sockeye salmon (*Oncorhynchus nerka)* smolt relative to temperature regimes, euphotic volume, fry density, and forage base within Alaska lakes. Pages 216-234 [*In*] H. D. Smith, L. Margolis, and C. C. Woods, editors. Sockeye salmon (*Oncorhynchus nerka)* population biology and future management. Canadian Special Publication of Fisheries and Aquatic Sciences 96.

Koenings, J. P., J. A. Edmundson, G. B. Kyle, and J. M. Edmundson. 1987. Limnology field and laboratory manual: Methods for assessing aquatic production. Alaska Department of Fish and Game, FRED Division Report Series 71, Juneau.

Koenings, J. P., and G. B. Kyle. 1997. Consequences to juvenile sockeye salmon and the zooplankton community resulting from intense predation. Alaska Fishery Research Bulletin 4(2): 120-135.

Koo, T. S. Y. 1962 Age designation in salmon. Pages 37-48 [*In*] T.S.Y. Koo, editor. Studies of Alaska red salmon. University of Washington Publications in Fisheries, New Series, Volume I, Seattle.

Kyle, G. B. 1992. Assessment of lacustrine productivity relative to juvenile sockeye salmon *Oncorhynchus nerka* production in Chignik and Black Lakes: results from 1991 surveys. Alaska Department of Fish and Game, FRED Division Report Series 119, Juneau.

Mazumder, A., & Edmundson, J. A. 2002. Impact of fertilization and stocking on trophic interactions and growth of juvenile sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences, 59(8), 1361-1373.

McCafferty, W.P. 1983. Aquatic entomology: the fisherman's and ecologists' illustrated guide to insects and their relatives. Jones and Bartlett Publishers, Boston, Massachusetts.

Moore, M. L . 2013a. Kodiak Management Area sockeye salmon catch and escapement sampling operational plan, 2013. [*In*] Salmon research operational plans for the Kodiak Area, 2013. Alaska Department of Fish and Game, Regional Information Report 4K13-04, Kodiak.

Moore, M. L. 2013b. Kodiak management area salmon escapement and catch sampling results, 2013. Alaska Department of Fish and Game, Regional Information Report *In prep*, Kodiak.

Mosher, K. H. 1968. Photographic atlas of sockeye salmon scales. Bureau of the U.S. Fish and Wildlife Service. Fishery Bulletin 67(2):243-280.

Nemeth, M. J., M. J. Witteveen, M. B. Foster, H. Finkle, J. W. Erickson, J. S. Schmidt, S. J. Fleischman, and D. Tracy. 2010. Review of escapement goals in 2010 for salmon stocks in the Kodiak Management Area, Alaska. Alaska Department of Fish and Game, Fishery Manuscript Series No. 10-09, Anchorage.

Nelson, P. A. and D. S. Lloyd. 2001. Escapement goals for Pacific salmon in the Kodiak, Chignik, and Alaska Peninsula/Aleutian Islands Areas of Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K01-66, Kodiak.

Nelson P. A., M. J. Witteveen, S. G. Honnold, I. Vining, and J. J. Hasbrouck. 2005. Review of salmon escapement goals in the Kodiak Management Area. Alaska Department of Fish and Game, Fishery Manuscript No. 05-05, Anchorage.

Officer, C. B., and J. H. Ryther. 1980. The possible importance of silicon in marine eutrophication. Marine Ecology Progress Series 3:83-91.Robson, D. S., and H. A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 93:215-226.

Parr Instrument Company. 1999. Operating Instruction Manual 1266 No. 367M. Moline, Illinois.

Parr, W. H. 1972. Interactions between sockeye salmon and lake resident fish in the Chignik Lakes, Alaska. M.S. Thesis, University of Washington, Seattle. 102pp.

Pennak, R. W. 1989. Fresh-water invertebrates of the United States, 2nd Edition. John Wiley and Sons. New York. 803 p.

Peterman, R. M. and B. Dorner. 2012. A widespread decrease in productivity of sockeye salmon (*Oncorhynchus nerka*) population in western North America. Ca. J. Fish. Aquat. Sci. 69: 1255-1260.

Pollard, W. R., C. F. Hartman, C. Groot, and P. Edgell. 1997. Field identification of coastal juvenile salmonids. Harbour Publishing. Maderia Park, British Columbia, Canada.

Roelofs, R. W. 1964. Further studies of the Afognak Lake system. Alaska Dept. of Fish & Game, Information leaflet 41.

Ruhl, D. C. 2013. Westward Region limnology and Kodiak Island laboratory analysis operational plan. Alaska Department of Fish and Game, Division of Commercial Fisheries. Regional Operational Plan CF.4K.2013.01, Kodiak.

Rogers, D.E. 1973. Abundance and size of juvenile sockeye salmon, Oncorhynchus nerka, and associated species in Lake Aleknagik, Alaska in relation to their environment. Fisheries Bulletin. 71: 1061-1075

Ruggerone, G. T. and D. E. Rogers. 1992. Predation on sockeye salmon fry by juvenile coho salmon in the Chignik Lakes, Alaska: implications for salmon management. North American Journal of Fisheries Management vol. 12, No. 1: 87-102.

Schindler, D.E. and L. A. Eby. 1997. Stoichiometry of fishes and their prey: implications for nutrient recycling. Ecology 78: 1816–1831.

Schrof, S. T., S. G. Honnold, C. J. Hicks and J. A. Wadle. 2000. A summary of salmon enhancement, rehabilitation, evaluation, and monitoring efforts conducted in the Kodiak management area through 1998. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K00-57, Kodiak.

REFERENCES CITED (Continued)

Thompson, S. K. 1987. Sample size for estimating multinomial proportions. The American Statistician 41(1):42-46.

Thomsen, S. E. 2011. A Compilation of the 2010 Spiridon Lake sockeye salmon enhancement project results: A report to the Kodiak National Wildlife Refuge. Alaska Department of Fish and Game, Regional Information Report 4K11-13, Kodiak.

Thomsen, S. E. 2013. Afognak Lake sockeye salmon monitoring project operational plan, 2013. [*In*] Salmon research operational plans for the Kodiak Area, 2013. Alaska Department of Fish and Game, Regional Information Report 4K13-04, Kodiak.

Thomsen, S. E., and N. Richardson. 2013. Afognak Lake sockeye salmon stock monitoring, 2012. Alaska Department of Fish and Game, Fisheries Data Series No. 13-40, Anchorage.

Thorp, J. H., and A. P. Covich. 2001. Ecology and classification of North American freshwater invertebrates. Second Edition, Academic Press, San Diego.

Todd, G. T. 1994. A lightweight, inclined-plane trap for sampling salmon smolt in rivers. Alaska Fisheries Research Bulletin 1(2):168-175.

Wehr, J. D., and R. G. Sheath. 2003. Freshwater algae of North America – ecology and classification. Academic Press, San Diego.

Welch, D. W., A. I. Chigirinsky, and Y. Ishida. 1995. Upper thermal limits on the oceanic distribution of Pacific salmon (*Oncorhynchus spp*) in the spring. Canadian Journal of Fisheries and Aquatic Sciences 52:489-503.

Wetzel, R. G. 1983. Limnology. New York. CBS College Publishing.

White, L. E., G. B. Kyle, S. G. Honnold, and J. P. Koenings. 1990. Limnological and fisheries assessment of sockeye salmon (*Oncorhynchus nerka)* production in Afognak Lake. Alaska Department of Fish and Game. FRED Division Report 103, Juneau.

TABLES AND FIGURES

Table 1.–Estimated abundance of sockeye salmon smolt outmigrating from Afognak Lake, 2013.

Stratum (h)	Starting date	Ending date	Catch (u_h)	Released (M_h)	Recaptured (m_h)	Carlson Trap efficency (%)	Estimate (U_h)	Variance (U_h)	95% Confidence Interval	
									lower	upper
1	8-May	26-May	10,123	201	38	19.3	52,432	55,672,176	37,808	67,056
2	27-May	2-Jun	9,250	582	107	18.5	49,933	18,854,409	41,422	58,444
3	3-Jun	10-Jun	8,167	282	22	8.1	100,518	387,878,482	61,917	139,119
4	11-Jun	18-Jun	7,947	507	48	9.6	82,438	123,574,935	60,650	104,226
5	19-Jun	27-Jun	1,419	319	22	7.2	19,712	15,267,794	12,053	27,370
Total			36,906	1,891	237	12.6	305,033	601,247,796	213,849	396,216
							SE=	24,520		

Note: The parameters h, M_h, m_h, U_h, and u_h are used to calculate the outmigration estimate and are defined on page 6.

Table 2.–Sockeye salmon smolt catch, number of AWL samples collected, mark-recapture releases, recoveries, and trap efficiency estimates from Afognak River by stratum, 2013.

Date	Daily Catch	AWL Samples	Marked Releases[a]	Marked Recoveries	Carlson Trap Efficiency
		Stratum 1			
8-May	0	0	0	0	19.3%
9-May	1	0	0	0	19.3%
10-May	2	0	0	0	19.3%
11-May	8	3	0	0	19.3%
12-May	12	5	0	0	19.3%
13-May	69	5	0	0	19.3%
14-May	175	5	0	0	19.3%
15-May	110	4	0	0	19.3%
16-May	239	5	0	0	19.3%
17-May	514	10	0	0	19.3%
18-May	63	5	0	0	19.3%
19-May	571	10	201	36	19.3%
20-May	337	5	0	2	19.3%
21-May	726	15	0	0	19.3%
22-May	566	10	0	0	19.3%
23-May	1,662	35	0	0	19.3%
24-May	1,657	30	0	0	19.3%
25-May	1,741	35	0	0	19.3%
26-May	1,670	35	0	0	19.3%
Total Stratum 1	10,123	217	201	38	19.3%
		Stratum 2			
27-May	1371	25	600	98	18.5%
28-May	1150	25	0	9	18.5%
29-May	1614	35	0	0	18.5%
30-May	1821	35	0	0	18.5%
31-May	830	15	0	0	18.5%
1-Jun	1461	30	0	0	18.5%
2-Jun	1003	20	0	0	18.5%
Total Stratum 2	9,250	185	600	107	18.5%

-continued-

Table 2.–Page 2 of 2.

Date	Daily Catch	AWL Samples	Marked Releases[a]	Marked Recoveries	Carlson Trap Efficiency
		Stratum 3			
3-Jun	713	15	344	21	8.1%
4-Jun	218	5	0	1	8.1%
5-Jun	1,257	24	0	0	8.1%
6-Jun	844	15	0	0	8.1%
7-Jun	1,130	20	0	0	8.1%
8-Jun	1,232	25	0	0	8.1%
9-Jun	1,180	25	0	0	8.1%
10-Jun	1,593	30	0	0	8.1%
Total Stratum 3	8,167	159	344	22	8.1%
		Stratum 4			
11-Jun	1,945	40	534	33	9.6%
12-Jun	1,027	20	0	14	9.6%
13-Jun	1,766	35	0	1	9.6%
14-Jun	907	15	0	0	9.6%
15-Jun	1,342	25	0	0	9.6%
16-Jun	460	10	0	0	9.6%
17-Jun	287	5	0	0	9.6%
18-Jun	213	5	0	0	9.6%
Total Stratum 4	7,947	155	534	48	9.6%
		Stratum 5			
19-Jun	425	10	390	10	7.2%
20-Jun	371	5	0	10	7.2%
21-Jun	103	5	0	1	7.2%
22-Jun	86	5	0	1	7.2%
23-Jun	97	5	0	0	7.2%
24-Jun	114	5	0	0	7.2%
25-Jun	91	5	0	0	7.2%
26-Jun	54	5	0	0	7.2%
27-Jun	78	5	0	0	7.2%
Total Stratum 5	1,419	50	390	22	7.2%
Total Strata 1–5	36,906	766	2,069	237	12.6%

[a] The number of marked releases for each strata were adjusted using delayed mortality tests. For example, in stratum 2, three of the 100 (3%) marked fish held for delayed mortality died, so the release (600) was lowered by 3% to 582.

Table 3.–Theoretical production of Afognak Lake sockeye salmon eggs, emergent fry, and smolt by age from brood years 2010 and 2011 and predicted smolt outmigration for 2013.

Production		Brood Year		Estimate 2013
Parameter	Assumption	2010	2011	FW-age-1 and -2 smolt
Escapement		52,255	49,193	
Females spawners	61% (2010) 61% (2011)[a]	31,876	30,008	
Deposited Eggs	2,539 (2010) 2,697 (2011)[b]	80,933,164	80,930,848	
Emergent Fry	7% egg-to-fry survival[c]	5,665,321	5,665,159	
Smolt	21% fry-to-smolt survival[d]	1,189,718	1,189,683	
2013 Smolt Emigration	77% FW-age-1, 23% FW-age-2 [e]	272,445	917,246	1,189,691

[a] Female sex composition derived from 2010 and 2011 sex data obtained from adult age, length, and sex sampling.

[b] Actual fecundity of Afognak Lake sockeye salmon as reported from Pillar Creek Hatchery (2010 and 2011).

[c] Egg to fry survival assumption from Drucker (1970), Bradford (1995), and Koenings and Kyle (1997).

[d] Fry to smolt survival assumptions from Koenings and Kyle (1997).

[e] Age composition assumptions derived from the average 2013 smolt age class estimate.

Table 4.–Length, weight, and condition of sockeye salmon smolt, by stratum and age, from the Afognak River, 2013.

Stratum	Date		Sample	Length (mm)		Weight (g)		Condition (*K*)	
	Starting	Ending	Size	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
				Age-1					
1	8-May	26-May	37	74.6	0.52	3.4	0.07	0.81	0.005
2	27-May	2-Jun	147	74.2	0.25	3.3	0.04	0.81	0.003
3	3-Jun	10-Jun	151	75.8	0.21	3.6	0.03	0.82	0.004
4	11-Jun	18-Jun	149	77.7	0.20	4.0	0.03	0.84	0.004
5	19-Jun	27-Jun	50	80.8	0.43	4.8	0.09	0.91	0.009
Totals			534	76.6	0.32	3.8	0.05	0.84	0.005
				Age-2					
1	8-May	26-May	179	85.7	0.22	5.0	0.04	0.79	0.003
2	27-May	2-Jun	37	84.4	0.54	4.8	0.10	0.80	0.007
3	3-Jun	10-Jun	3	88.7	3.84	5.2	0.20	0.75	0.066
4	11-Jun	18-Jun	1	78.0	0.00	3.9	0.00	0.82	0.000
5	19-Jun	27-Jun	0						
Totals			220	84.2	1.15	4.7	0.09	0.79	0.019
				Age-3					
1	8-May	26-May	0						
2	27-May	2-Jun	1	88.0	0.00	5.4	0.00	0.79	0.000
3	3-Jun	10-Jun	0						
4	11-Jun	18-Jun	0						
5	19-Jun	27-Jun	0						
Totals			1	88.0	0.00	5.4	0.00	0.79	0.000

Table 5.–Estimated outmigration abundance of Afognak Lake sockeye salmon smolt by time period (stratum) and age class, 2013.

	Date			Age			
Stratum	Starting	Ending		1	2	3	Total
1	8-May	26-May	Number	9,321	43,110	0	52,432
			Percent	17.8%	82.2%	0.0%	
2	27-May	2-Jun	Number	39,635	10,002	296	49,933
			Percent	79.4%	20.0%	0.6%	
3	3-Jun	10-Jun	Number	98,533	1,985	0	100,518
			Percent	98.0%	2.0%	0.0%	
4	11-Jun	18-Jun	Number	81,905	533	0	82,438
			Percent	99.4%	0.6%	0.0%	
5	19-Jun	27-Jun	Number	19,712	0	0	19,712
			Percent	100.0%	0.0%	0.0%	
Total			Number	249,106	55,630	296	305,033
			Percent	81.7%	18.2%	0.1%	

Table 6.–Afognak Lake sockeye salmon escapement, harvest, and total run estimates, 1978–2013.

		Harvest [a]			
Year	Escapement	Commercial [b]	Subsistence [c]	Total	Total Run
1978	52,701	3,414	1,632	5,046	57,747
1979	82,703	2,146	2,069	4,215	86,918
1980	93,861	28	3,352	3,380	97,241
1981	57,267	16,990	3,648	20,638	77,905
1982	123,055	21,622	3,883	25,505	148,560
1983	40,049	4,349	3,425	7,774	47,823
1984	94,463	6,130	3,121	9,251	103,714
1985	53,563	1,980	6,804	8,784	62,347
1986	48,328	2,585	3,450	6,035	54,363
1987	25,994	1,323	2,767	4,090	30,084
1988	39,012	14	2,350	2,364	41,376
1989	88,825	0	3,859	3,859	92,684
1990	90,666	22,149	4,469	26,618	117,284
1991	88,557	47,237	5,899	53,136	141,693
1992	77,260	2,196	4,638	6,834	84,094
1993	71,460	1,848	4,580	6,428	77,888
1994	80,570	17,362	3,329	20,691	101,261
1995	100,131	67,665	4,390	72,055	172,186
1996	101,718	106,141	11,023	117,164	218,882
1997	132,050	10,409	12,412	22,821	154,871
1998	66,869	26,060	4,690	30,750	97,619
1999	95,361	34,420	5,628	40,048	135,409
2000	54,064	14,124	7,572	21,696	75,760
2001	24,271	0	4,720	4,720	28,991
2002	19,520	0	1,279	1,279	20,799
2003	27,766	0	604	604	28,370
2004	15,181	0	567	567	15,748
2005	21,577	356	696	1,052	22,629
2006	22,933	6	451	457	23,390
2007	21,070	0	490	490	21,560
2008	26,874	1,098	594	1,692	28,566
2009	31,358	363	971	1,334	32,692
2010	52,255	9,755	2,146	11,901	64,156
2011	49,193	13,952	1,770	15,722	64,915
2012	41,553	3,398	1,711	5,109	46,662
2013	42,153	6,311	573	6,884	49,037
Average (1978–2012)	60,345	12,546	3,571	16,117	76,462
Average (2000–2012)	31,355	3,312	1,813	5,125	36,480
Average (2010–2013)	46,289	8,354	1,550	9,904	56,193

[a] Sport harvest data does not have enough respondents to provide reliable estimates and was determined to be negligible.

[b] Statistical fishing section 252-34 (Southeast Afognak Section).

[c] Data as of 12/30/2013 from ADF&G subsistence catch database 1978–2013.

Table 7.–Afognak Lake adult sockeye salmon escapement by statistical week and age class, 2013.

	Date		Sample		Age							
Stat Week	Starting	Ending	Size		1.1	1.2	1.3	1.4	2.1	2.2	2.3	Total Fish
21	17-May	23-May	0	Percent	0.0	5.0	85.0	0.0	0.0	0.0	10.0	
				Numbers	0	0	1	0	0	0	0	1
22	24-May	30-May	40	Percent	0.0	5.0	85.0	0.0	0.0	0.0	10.0	
				Numbers	0	108	1,834	0	0	0	216	2,158
23	31-May	6-Jun	134	Percent	0.5	7.7	80.7	0.0	0.0	1.1	10.1	
				Numbers	50	608	7,086	0	0	101	904	8,750
24	7-Jun	13-Jun	176	Percent	0.2	20.1	70.8	0.0	0.0	1.8	7.1	
				Numbers	17	1,951	6,695	0	0	169	662	9,493
25	14-Jun	20-Jun	73	Percent	0.0	30.9	56.8	0.0	0.0	4.3	8.0	
				Numbers	0	3,024	5,769	0	0	424	809	10,026
26	21-Jun	27-Jun	112	Percent	0.0	27.4	59.3	0.0	0.0	5.0	8.2	
				Numbers	0	1,092	2,250	0	0	163	278	3,783
27	28-Jun	4-Jul	67	Percent	0.0	18.7	56.2	0.0	0.0	9.9	15.2	
				Numbers	0	500	1,556	0	0	270	405	2,731
28	5-Jul	11-Jul	35	Percent	0.4	21.6	45.2	0.0	0.0	9.9	22.8	
				Numbers	2	286	591	0	0	143	288	1,310
29	12-Jul	18-Jul	56	Percent	1.5	21.0	47.5	0.9	0.0	5.5	23.7	
				Numbers	9	114	265	2	0	32	135	557
30	19-Jul	25-Jul	0	Percent	0.6	24.9	45.8	3.6	0.0	5.5	19.6	
				Numbers	0	4	8	1	0	1	4	18
31	26-Jul	1-Aug	18	Percent	0.0	24.3	38.5	3.8	0.0	12.4	21.0	
				Numbers	0	56	90	10	0	21	42	218
32	2-Aug	8-Aug	36	Percent	0.0	16.9	25.4	0.1	0.0	27.3	30.3	
				Numbers	0	485	729	4	0	777	862	2,857

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Table 7.–Page 2 of 2.

Stat Week	Date Starting	Date Ending	Sample Size		Age 1.1	1.2	1.3	1.4	2.1	2.2	2.3	Total Fish
33	9-Aug	15-Aug	0	Percent	0.0	16.7	25.0	0.0	0.0	27.8	30.6	
				Numbers	0	27	40	0	0	45	49	161
34	16-Aug	22-Aug	0	Percent	0.0	16.7	25.0	0.0	0.0	27.8	30.6	
				Numbers	0	9	14	0	0	15	17	54
35	23-Aug	29-Aug	0	Percent	0.0	16.7	25.0	0.0	0.0	27.8	30.6	
				Numbers	0	6	9	0	0	10	11	36
Totals			747	Percent	0.2	19.6	63.9	0.0	0.0	5.1	11.1	100.0
				Numbers	78	8,269	26,939	17	0	2,169	4,682	42,153

Table 8.–Mean length of Afognak Lake adult sockeye salmon escapement by sex and age class, 2013.

	Age							
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	Total
Males								
Mean Length (mm)	404.0	475.4	545.8	0.0	0.0	496.3	536.0	519.3
Standard Error	4.00	3.83	2.3	0.00	0.00	6.11	6.22	2.66
Range	400–408	402–582	447–609			445–534	448–632	400–632
Sample Size	2	89	154	0	0	20	31	296
Females								
Mean Length (mm)	0.0	475.1	522.8	495.0	0.0	475.8	525.2	514.3
Standard Error	0.00	4.40	1.47	0.00	0.00	4.80	3.69	2.15
Range		406–595	335–600	495–495		443–504	470–579	406–600
Sample Size	0	66	311	1	0	17	56	451
All								
Mean Length (mm)	404.0	475.3	530.4	495.0	0.0	486.8	529.1	516.3
Standard Error	4.00	2.88	1.34	0.00	0.00	4.27	3.28	1.41
Range	400–408	402–595	435–609	495–495		443–534	448–632	400–632
Sample Size	2	155	465	1	0	37	87	747

Table 9.–Data logger temperatures (°C) at 1 m water depth, station 2, Afognak Lake, 2010–2013.

	Temperature (°C)											
	Average				Maximum				Minimum			
Month	2010	2011	2012	2013	2010	2011	2012	2013	2010	2011	2012	2013
May	7.3	7.3	7.3	8.1	9.2	9.9	9.5	10.6	5.9	6.6	5.7	7.1
June	11.3	11.0	12.3	13.3	13.5	13.7	16.7	17.4	8.8	8.5	8.1	9.0
July	14.0	15.1	14.4	17.5	15.7	17.1	17.3	21.8	12.4	13.1	12.4	14.3
August	14.8	15.8	14.8	16.1	16.1	17.6	16.3	18.8	14.0	14.5	14.3	15.2
September	14.3	12.4	12.5	14.5	15.7	14.8	15.0	15.9	11.8	10.7	9.8	13.3
October	9.9	10.4	9.4	–	11.8	10.7	9.9	–	8.2	10.0	9.2	–
Spring (May–June)	9.3	9.1	9.8	10.7	13.5	13.7	16.7	17.4	5.9	6.6	5.7	7.1
Summer (July–Aug)	14.4	15.4	14.6	16.8	16.1	17.6	17.3	21.8	12.4	13.1	12.4	14.3
Fall (Sept–Oct)	12.1	11.4	11.0	14.4	15.7	14.8	15.0	15.9	8.2	10.0	9.2	13.3
Season (May–Oct)	12.3	12.8	12.6	14.4	16.1	17.6	17.3	21.8	5.9	6.6	5.7	7.1

Note: Spring consists of May–June, Summer consists of July–August, and Fall consists of September–October.

Table 10.–General water chemistry and algal pigment concentrations at 1 m water depth, station 1, Afognak Lake, 2013.

Date	pH (units)	Alkalinity (mg/L)	Chlorophyll *a* (µg/L)	Phaeophytin *a* (µg/L)
15-May	7.30	12.0	1.60	0.36
12-Jun	7.58	11.5	0.96	0.38
22-Jul	7.54	11.5	0.96	0.16
20-Aug	7.40	12.0	2.08	0.38
18-Sep	7.28	12.5	0.96	0.61
Average	7.42	11.9	1.31	0.38
SD	0.14	0.4	0.51	0.16

Table 11.–Seasonal phosphorus and nitrogen concentrations at 1 m water depth, station 1, Afognak Lake, 2013.

Date	Total filterable-P (µg/L)	Filterable reactive-P (µg/L)	Total-P (µg/L)	Reactive Silicon (µg/L)	Ammonia (µg/L)	Total Kjeldahl Nitrogen (µg/L)	Nitrate + Nitrite (µg/L)	Total Nitrogen (µg/L)	TN:TP ratio
15-May	2.1	2.3	3.7	3,201.5	13.6	303.0	53.0	356.0	213.1
12-Jun	1.9	2.1	4.0	2,724.2	5.0	435.0	28.4	463.4	256.5
22-Jul	1.6	1.0	4.1	2,771.1	15.9	422.0	1.8	423.8	228.9
20-Aug	2.3	1.3	4.5	2,561.8	23.7	338.0	2.0	340.0	167.3
18-Sep	1.8	0.8	5.3	2,747.9	8.7	376.0	18.3	394.3	164.7
Average	1.9	1.5	4.3	2,801.3	13.4	374.8	20.7	395.5	206.1
SD	0.3	0.7	0.6	238.3	7.2	55.6	21.3	50.1	39.8

Table 12.–Seasonal weighted mean zooplankton density, biomass, and size by individual station from Afognak Lake, 2013.

Station	*n*		*Epischura*	*Diaptomus*	*Cyclops*	Other Copepods	*Bosmina*	*Daphnia*	*Holopedium*	Other Cladocerans	Total Copepods	Total Cladocerans	Total all zooplankton
1	5	density (no/m^2)	12,155	106	4,979	7,022	50,334	6,502	2,856	12,718	24,262	72,410	96,672
		%	12.6%	0.1%	5.2%	7.3%	52.1%	6.7%	3.0%	13.2%	25.1%	74.9%	100.0%
		biomass (mg/m^2)	37.4	0.4	6.6	–[a]	34.6	7.6	4.7	–[a]	44.3	46.9	91.2
		%	41.0%	0.4%	7.2%	–[a]	37.9%	8.4%	5.1%	–[a]	48.6%	51.4%	100.0%
		size (mm)	0.87	0.91	0.61	–[a]	0.28	0.53	0.45	–[a]			
2	5	density (no/m^2)	8,567	0	1,741	11,874	41,465	1,932	1,200	6,295	22,182	50,892	73,073
		%	11.7%	0.0%	2.4%	16.2%	56.7%	2.6%	1.6%	8.6%	30.4%	69.6%	100.0%
		biomass (mg/m^2)	14.7	0.0	2.9	–[a]	33.0	2.8	2.3	–[a]	17.5	38.1	55.7
		%	26.4%	0.0%	5.1%	–[a]	59.3%	5.0%	4.2%	–[a]	31.5%	68.5%	100.0%
		size (mm)	0.71		0.69	–[a]	0.29	0.58	0.48	–[a]			
All Data		density (no/m^2)	10,361	53	3,360	9,448	45,900	4,217	2,028	9,506	23,222	61,651	84,873
		%	12.2%	0.1%	4.0%	11.1%	54.1%	5.0%	2.4%	11.2%	27.4%	72.6%	100.0%
		biomass (mg/m^2)	26.0	0.2	4.7	–[a]	33.8	5.2	3.5	–[a]	30.9	42.5	73.4
		%	35.5%	0.2%	6.4%	–[a]	46.0%	7.1%	4.7%	–[a]	42.1%	57.9%	100.0%
		size (mm)	0.79	0.91	0.65	–[a]	0.28	0.56	0.47	–[a]			

Note: *n*= the number of samples collected.

[a] Other copepods and cladocerans are composed of immature species that are too small to measure to generate a biomass estimate.

Table 13.–Summary of Afognak Lake phytoplankton monthly and mean biomass, by phylum, 2013.

		Phylum														
		Chlorophyta (Green Algae)		Chrysophyta (Golden-brown Algae)		Bacillariophyta (Diatoms)		Cryptophyta (crytomonads)		Pyrrhophyta (Dinoflagellate)		Haptophyta		Cyanobacteria Blue-green Algae		Total
Date	Station	Biomass (mg/m^3)	%	Biomass (mg/m^3)	%	Biomass (mg/m^3)	%	Biomass (mg/m^3)	%	Biomass (mg/m^3)	%	Biomass (mg/m^3)	%	Biomass (mg/m^3)	%	Biomass (mg/m^3)
2010	1	1	0.5	14	10.7	38	30.0	8	6.2	65	51.2	0	0.0	2	1.4	127
2011	1	17	2.7	267	40.8	229	34.9	40	6.1	42	6.4	9	1.3	50	7.7	655
2012	1	52	4.6	0	0.0	728	63.7	134	11.8	210	18.4	0	0.0	18	1.6	1,143
2013	1	12,640	5.3	85,184	36.0	117,046	49.5	13,003	5.5	6,261	2.6	0	0.0	2,394	1.0	236,527
Mean		3,178	5.3	21,366	35.8	29,510	49.5	3,296	5.5	1,644	2.8	2	0.0	616	1.0	59,613
Median		35	3.9	140	15.6	479	53.2	87	9.7	137	15.3	0	0.0	34	3.8	899

Table 14.–Length, weight, and condition of juvenile sockeye salmon from Afognak Lake, 2013.

Sample Dates by Month	Location	Sample Size	Weight (g) Mean	Weight (g) Standard Error	Length (mm) Mean	Length (mm) Standard Error	Condition Mean	Condition Standard Error
				Age-0				
May	Shoal	0						
	Mid-lake	0						
June	Shoal	36	0.7	0.31	39.3	5.62	1.00	0.22
	Mid-lake	4	0.7	0.31	40.0	4.76	0.96	0.12
July	Shoal	80	1.0	0.65	44.7	7.17	1.04	0.11
	Mid-lake	6	1.0	0.54	42.7	6.77	1.21	0.18
August	Shoal	46	1.6	0.50	51.1	5.34	1.18	0.16
	Mid-lake	3	2.0	0.31	54.7	3.51	1.20	0.07
September	Shoal	0						
	Mid-lake	0						
Mean	Shoal	162	1.1	0.49	45.0	6.04	1.07	0.17
	Mid-lake	13	1.2	0.38	45.8	5.02	1.12	0.12
	All Samples	175	1.2	0.44	45.4	5.53	1.10	0.14
				Age-1				
May	Shoal	59	2.7	0.52	67.7	4.41	0.86	0.05
	Mid-lake	0						
June	Shoal	49	3.7	0.61	72.4	5.07	0.96	0.10
	Mid-lake	1	2.8		63.0		1.12	
July	Shoal	19	4.8	1.08	74.7	5.99	1.15	0.22
	Mid-lake	2	4.3	0.21	71.0	1.41	1.19	0.13
August	Shoal	18	4.8	0.71	73.6	3.78	1.19	0.11
	Mid-lake	0						
September	Shoal	0						
	Mid-lake	0						
Mean	Shoal	145	4.0	0.73	72.1	4.81	1.04	0.12
	Mid-lake	3	3.6	0.21	67.0	1.41	1.16	0.13
	All Samples	148	3.8	0.47	69.6	3.11	1.10	0.13
				Age-2				
May	Shoal	10	4.5	0.41	81.1	3.21	0.85	0.09
	Mid-lake	0						
June	Shoal	0						
	Mid-lake	0						
Mean	Shoal	10	4.5	0.41	81.1	3.21	0.85	0.09
	Mid-lake	0						
	All Samples	10	4.5	0.41	81.1	3.21	0.85	0.09
Totals	Shoal	317	3.2	0.54	66.1	4.69	0.99	0.13
	Mid-lake	16	2.4	0.30	56.4	3.21	1.14	0.13
	All Samples	333	2.8	0.42	61.2	3.95	1.06	0.13

Table 15.–Calories, stomach fullness, and percentage of insects and zooplankton within the stomachs of juvenile sockeye salmon from Afognak Lake, 2013.

Sample Dates by Month	Location	Sample Size	Stomach Fullness (%)	Insects (%)	Zooplankton (%)	Sample Size	cal/g Mean	cal/g Standard Error
				Age-0				
May	Shoal					0		
	Mid-lake					0		
June	Shoal	21	40.5	41.9	58.1	15	6,052	269.01
	Mid-lake					4	5,791	138.11
July	Shoal	64	29.5	14.0	86.0	19	5,715	196.63
	Mid-lake	2	69.8			6	5,688	145.12
August	Shoal	35	34.0	5.6	94.4	8	5,830	258.47
	Mid-lake					3	5,805	146.15
September	Shoal					0		
	Mid-lake					0		
Mean	Shoal	120	34.7	20.5	79.5	42	5,866	241.37
	Mid-lake	2	69.8			13	5,761	143.13
	All Samples	122	52.2	20.5	79.5	55	5,814	192.25
				Age-1				
May	Shoal	42	29.8	1.5	98.5	17	5,088	124.24
	Mid-lake					0		
June	Shoal	33	43.1	0.0	100.0	16	5,307	254.08
	Mid-lake					1	5,642	
July	Shoal	11	31.5	5.5	94.5	8	5,671	318.41
	Mid-lake					2	5,873	33.99
August	Shoal	12	31.3	2.8	97.2	6	5,925	263.68
	Mid-lake					0		
September	Shoal					0		
	Mid-lake					0		
Mean	Shoal	98.0	33.9	2.5	97.6	47	5,498	240.10
	Mid-lake					3	5,757	33.99
	All Samples	98.0	33.9	2.5	97.6	50	5,627	137.05
				Age-2				
May	Shoal	7	16.8	1.7	98.3	3	4,895	150.18
	Mid-lake					0		
June	Shoal					0		
	Mid-lake					0		
Mean	Shoal	7.0	16.8	1.7	98.3	3	4,895	150.18
	Mid-lake					0		
	All Samples	7.0	16.8	1.7	98.3	3	4,895	150.18
Totals	Shoal	225.0	28.5	8.2	91.8	92	5,419	210.55
	Mid-lake	2	69.8			16	5,759	88.56
	All Samples	227.0	34.3	8.2	91.8	108	5,589	149.56

Note: Methodology for determining stomach fullness was changed from observation to a grid technique in 2013.

Table 16.–Stomach contents of age-0, age-1, and age-2 juvenile sockeye salmon from Afognak Lake, by month, 2013.

	Age-0			Age-1				Age-2
Prey Taxa	June	July	August	May	June	July	August	May
Arachnida	0.2	0.2	0.5	0.1	0	0.2	0.3	0.3
Coleoptera	0.0	0.1	0.5	0	0	0.5	0.2	0.0
Collembola	1.3	0.1	3.3	0.1	0.6	0	0.7	0.0
Diptera	47.2	75.7	66.6	87.6	95.2	53.8	63.4	89.4
Egg unid	0.0	0.0	0.2	0	0	0	0	0.0
Hymenoptera	0.0	0.6	5.6	0.2	0.1	7.6	7.1	0.4
Insecta larvae	0.6	0.1	0.0	0.3	0	0	0.4	0.9
Insecta pupae	0.0	0.0	0.6	0	0	0	0	0.0
Insecta sp.	8.8	9.2	17.1	10.1	4	32.5	25.1	6.4
Seed	0.0	0.0	0.0	0	0	0	0	0.9
Zooplankton	41.9	14.0	5.6	1.5	0	5.5	2.8	1.7

Note: Values are percentages.

Table 17.–Dates the Afognak Weir was installed and removed by year, 1990–2013.

Year	Weir Installed	Weir Removed	Removal Date Value
1990	5/27	9/17	261
1991	5/24	9/8	252
1992	5/24	9/15	259
1993	5/23	9/12	256
1994	5/28	9/18	262
1995	5/29	9/12	256
1996	5/23	9/11	255
1997	5/21	9/13	257
1998	5/20	9/9	253
1999	5/24	9/12	256
2000	5/23	9/11	255
2001	5/26	9/7	251
2002	5/28	8/25	238
2003	5/15	8/23	236
2004	5/15	8/6	219
2005	5/15	8/19	232
2006	5/21	8/4	217
2007	5/21	8/17	230
2008	5/23	8/8	221
2009	5/20	8/6	219
2010	5/19	9/7	251
2011	5/17	8/20	233
2012	5/23	8/25	238
2013	5/23	8/27	240
Average (1990–2001)			256 (12 Sept)
Average (2003–2013)			231 (18 Aug)

Table 18.–Afognak Lake juvenile coho salmon stomach content, May, 2013.

Date	Site	Fish Number	Length (mm)	Stomach Contents: Sockeye Fry	Leech	Trichoptera	Diptera	Other
22-May	1	3	115	0	0	2	14	0
22-May	1	4	123	0	1	0	0	0
22-May	2	5	102	0	0	0	5	0
22-May	3	6	73	0	0	3	19	0
22-May	3	7	98	0	0	0	16	Seed (1)
9-Jun	3	20	89	0	6	0	51	0
9-Jun	3	21	110	0	0	0	0	0
9-Jun	3	22	116	0	0	0	0	0
22-May	4	8	135	0	0	0	0	0
22-May	4	9	127	0	0	7	2	0
22-May	4	10	118	0	1	0	0	0
22-May	4	11	110	0	1	0	0	0
23-May	4	15	102	0	1	0	9	0
23-May	4	16	116	0	0	1	42	0
23-May	4	17	98	0	0	0	0	0
9-Jun	4	23	109	0	0	0	0	0
9-Jun	4	24	104	0	0	0	31	Eggs (78), Hymenoptera (2), Coleoptera (2)
20-May	5	1	110	2	1	0	32	Mulluska (1)
20-May	5	2	112	11	0	0	3	Amphipoda (1)
22-May	5	12	128	0	0	0	0	0
22-May	5	13	115	7	0	2	16	Plecoptera (1), Odontata (1)
22-May	5	14	117	0	0	0	0	0
23-May	5	18	118	0	0	0	5	Stickleback (3)
23-May	5	19	109	0	0	2	0	0
9-Jun	5	25	97	3	0	6	48	Hymenoptera (1), Coleoptera (3)
Average (All Sites)			110	1	0	1	12	
Average (Site 1)			119	0	1	1	7	
Average (Site 2)			102	0	0	0	5	
Average (Site 3)			97	0	1	1	17	
Average (Site 4)			113	0	0	1	9	
Average (Site 5)			113	3	0	1	13	

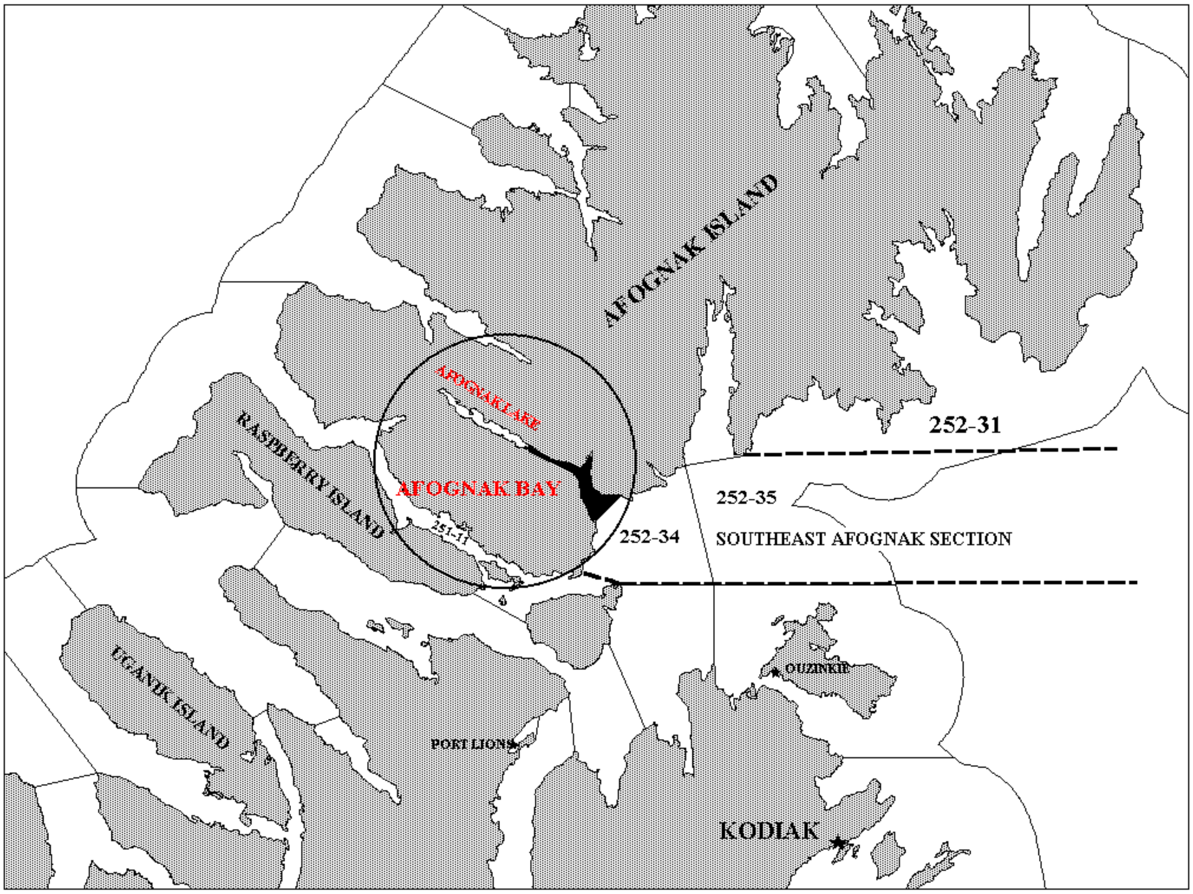

Figure 1.–Map depicting the location of the city of Kodiak, the villages of Port Lions and Ouzinkie, and their proximity to the Afognak Lake drainage on Afognak Island.

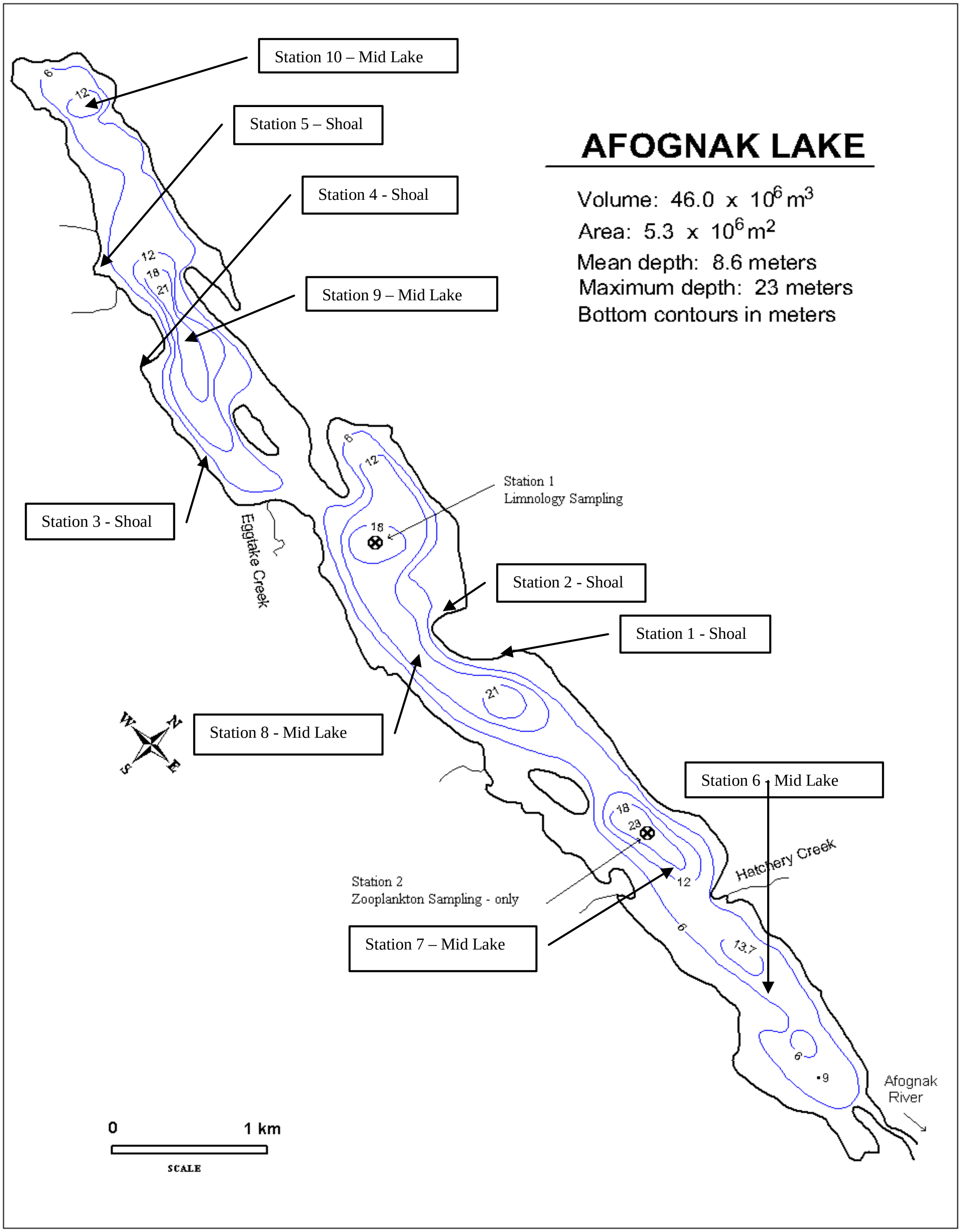

Figure 2.–Bathymetric map showing the limnology, zooplankton, and juvenile lake sampling stations on Afognak Lake.

Figure 3.–Downstream view of the juvenile sockeye salmon trapping system, 2013.

Figure 4.–Aerial view of the adult salmon enumeration weir in Afognak River, 2013.

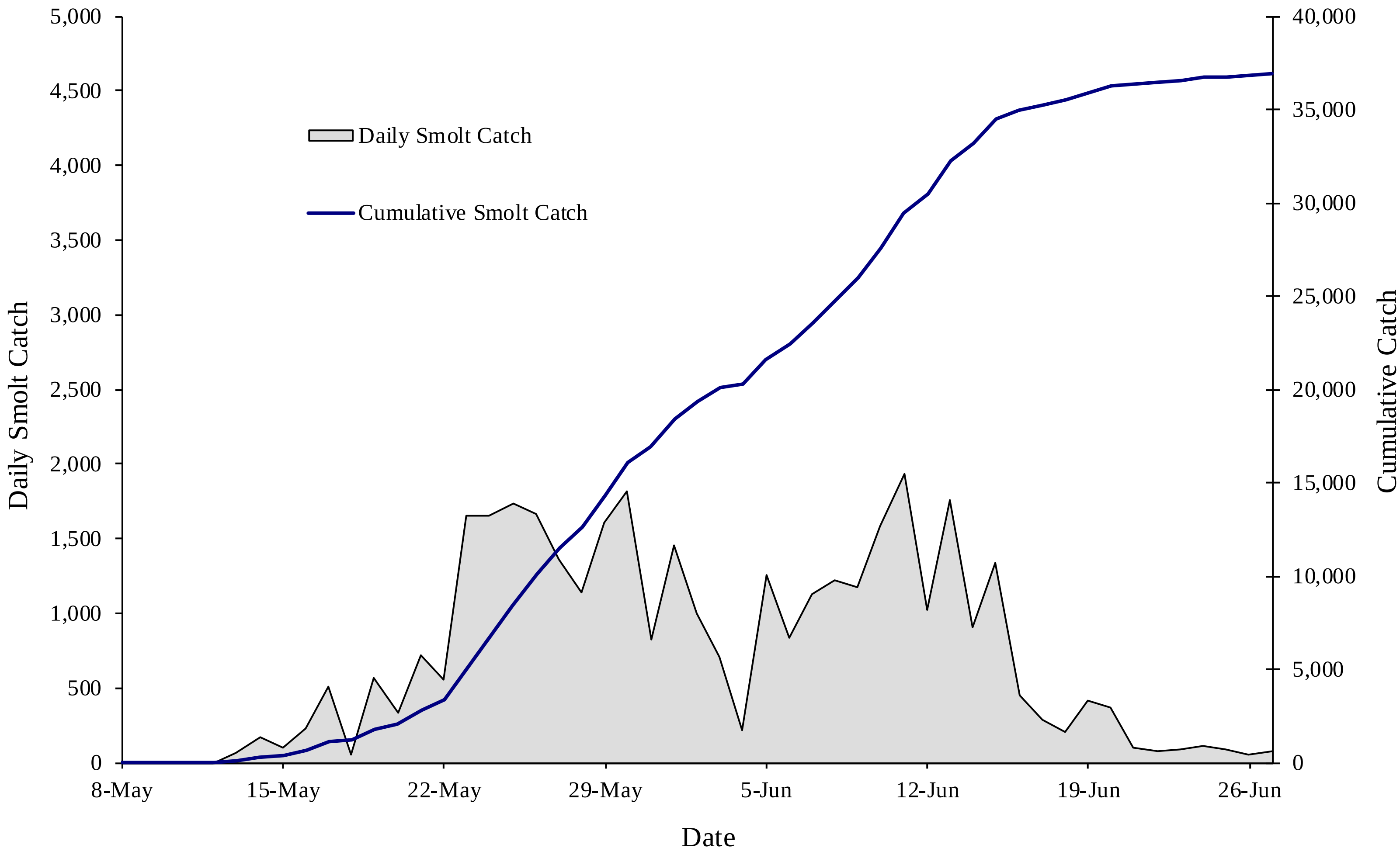

Figure 5.–Daily and cumulative sockeye salmon smolt trap catch from 8 May to 27 June in the Afognak River, 2013.

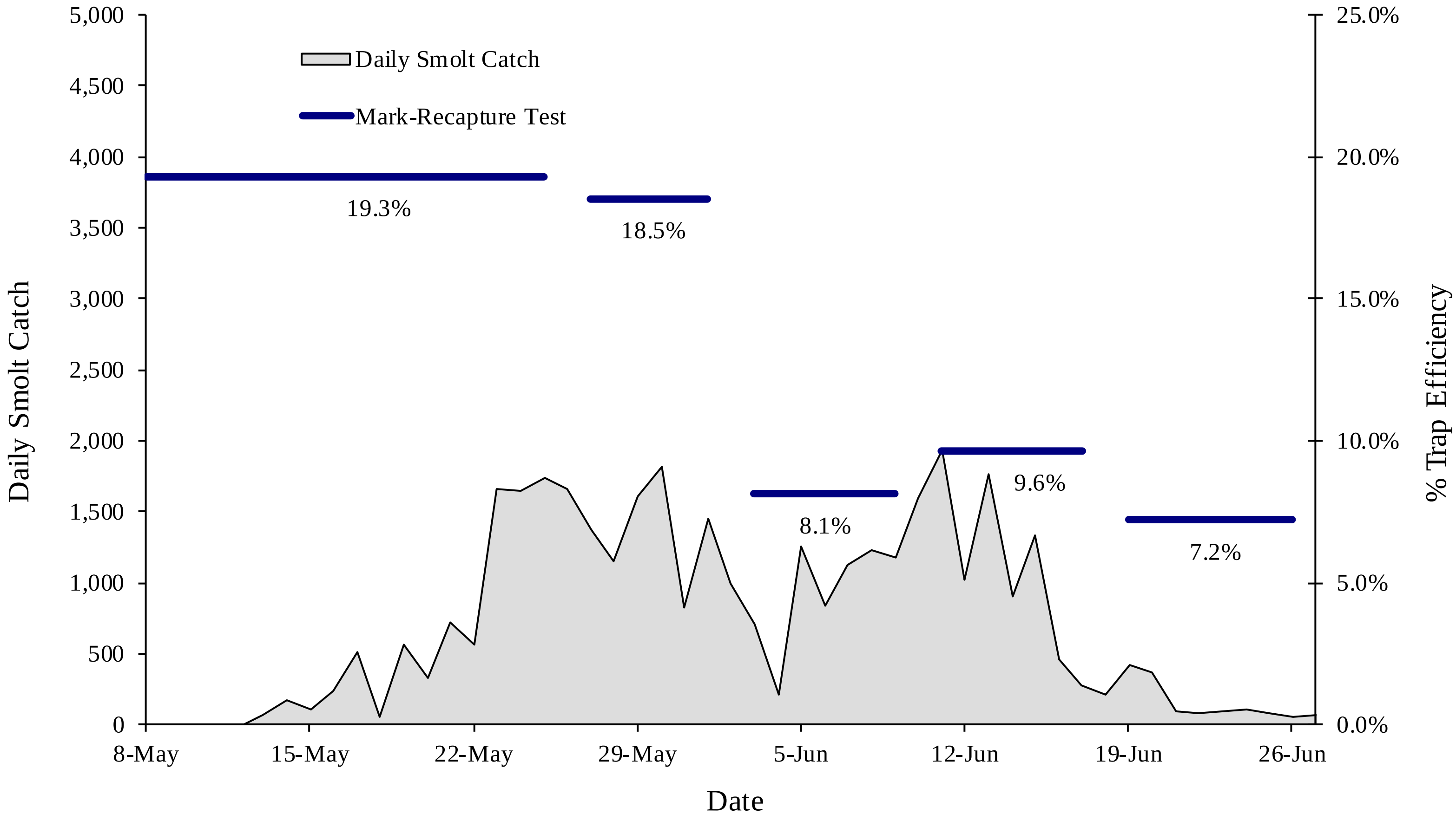

Figure 6.–Daily sockeye salmon smolt trap catch and trap efficiency estimates by strata from 8 May to 27 June in the Afognak River, 2013.

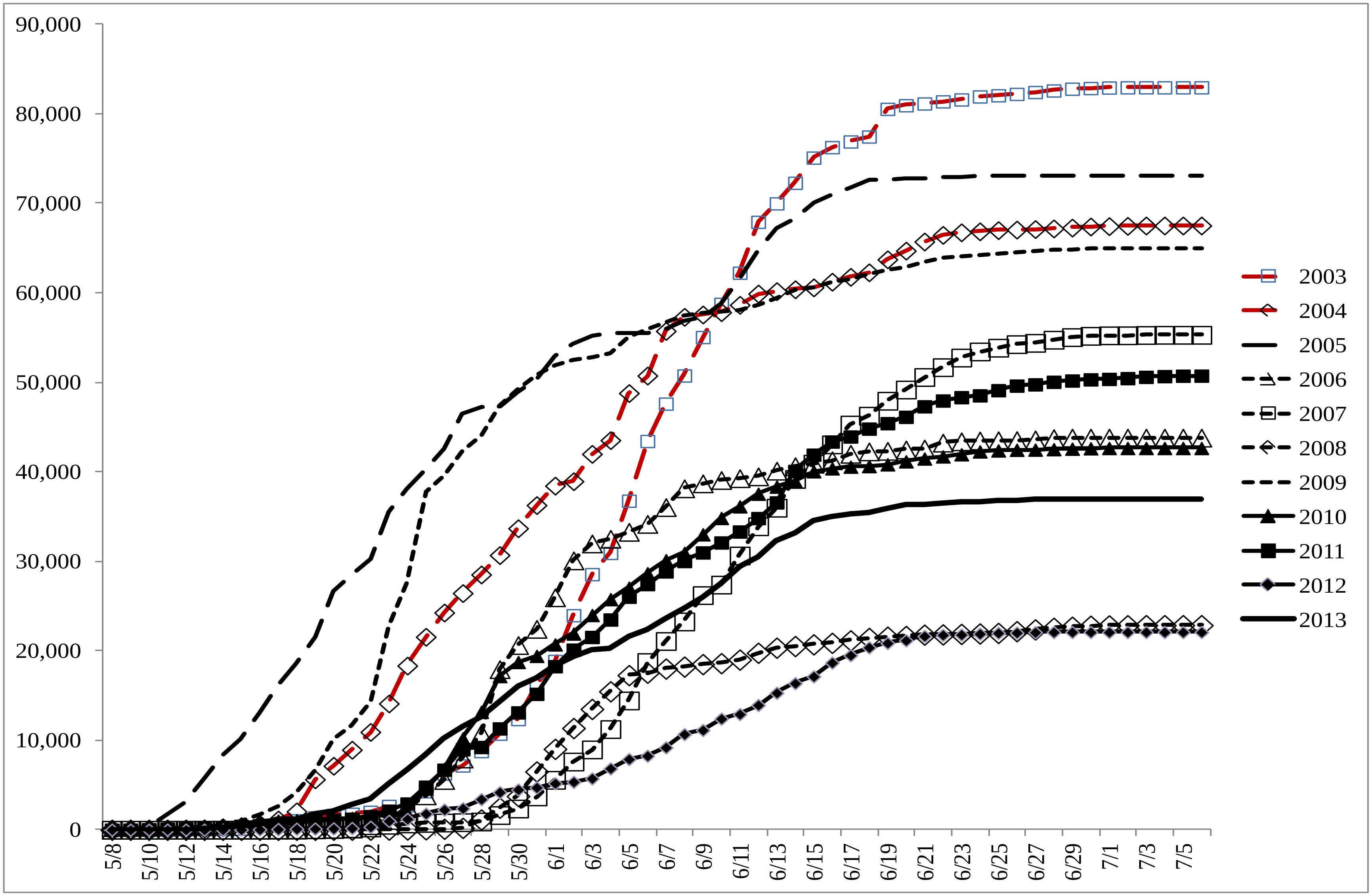

Figure 7.–Cumulative sockeye salmon smolt trap catch in the Afognak River, 2003–2013.

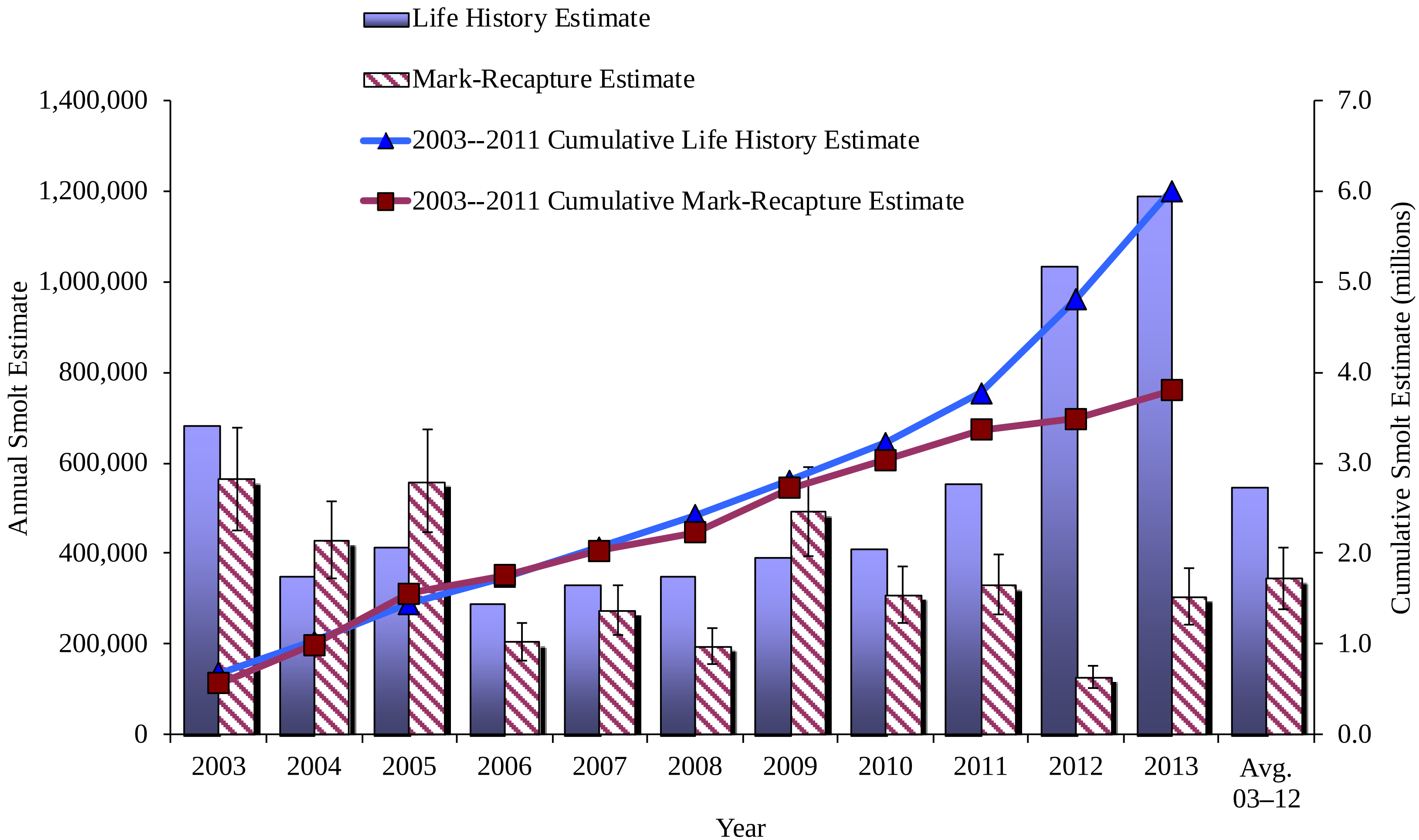

Figure 8.–Comparison of sockeye salmon smolt abundance estimates from life history and mark-recapture models, 2003–2013.

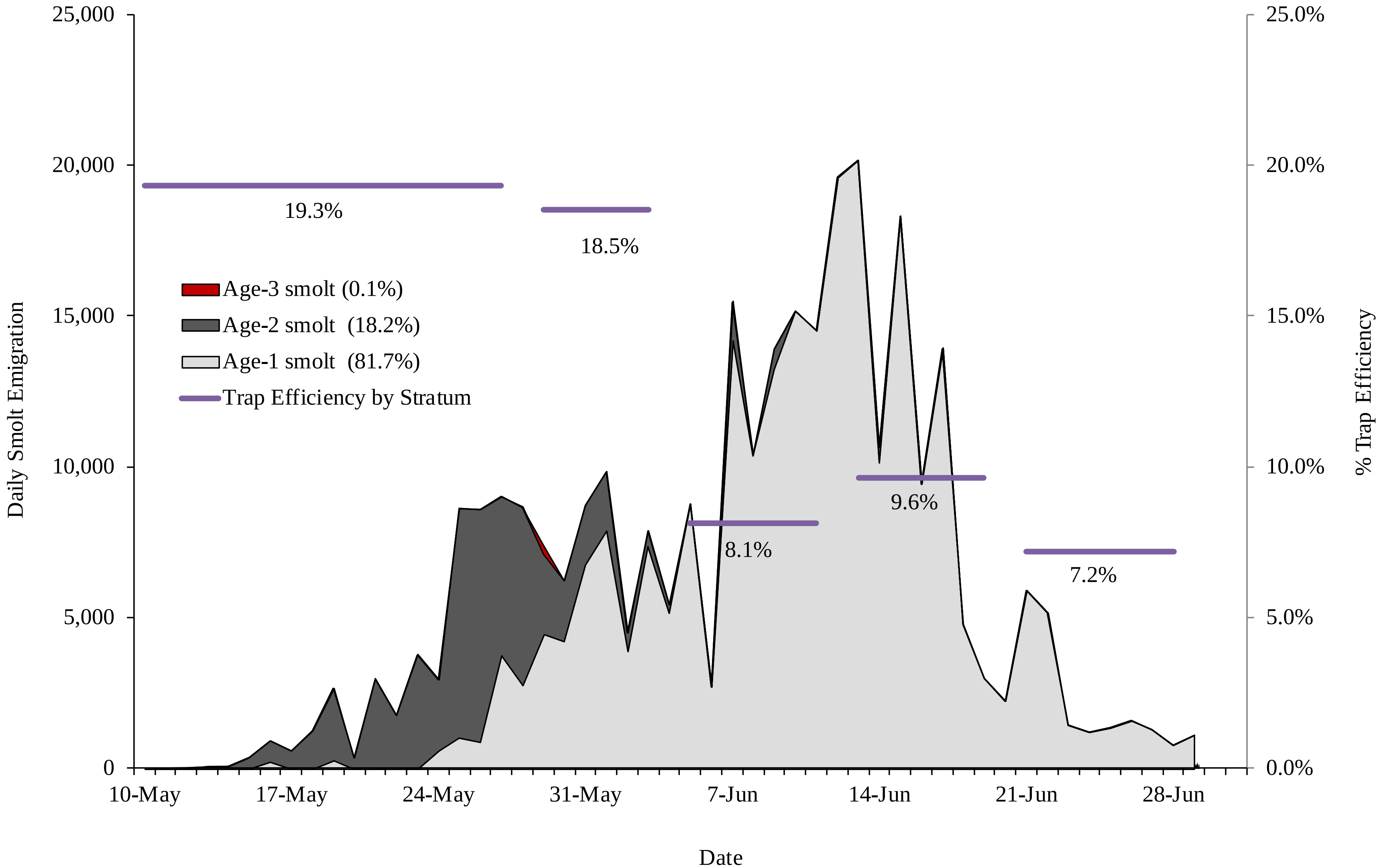

Figure 9.–Afognak Lake sockeye salmon smolt daily outmigration estimates by age class, 2013.

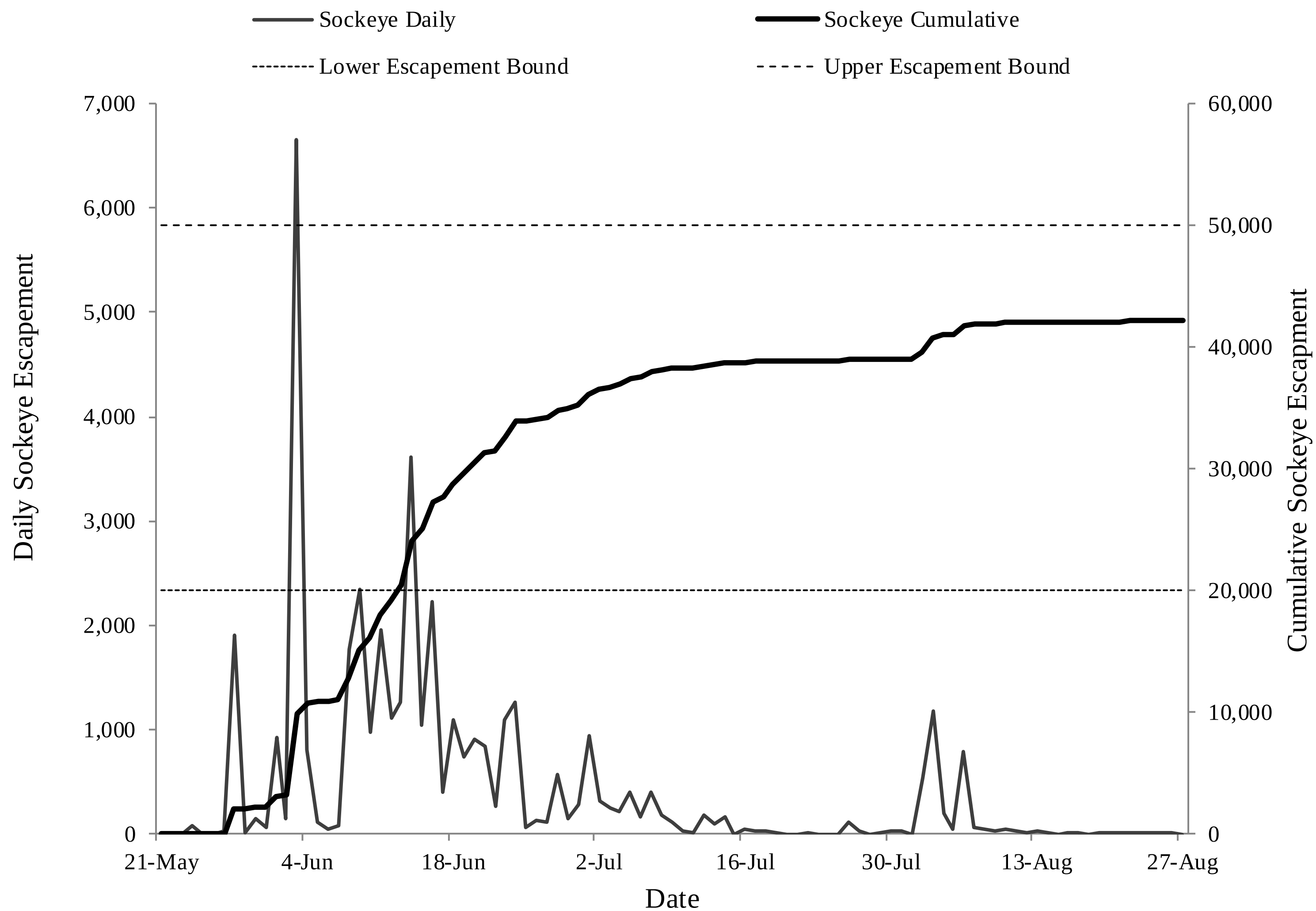

Figure 10.–Afognak Lake adult sockeye salmon daily and cumulative escapement, 2013.

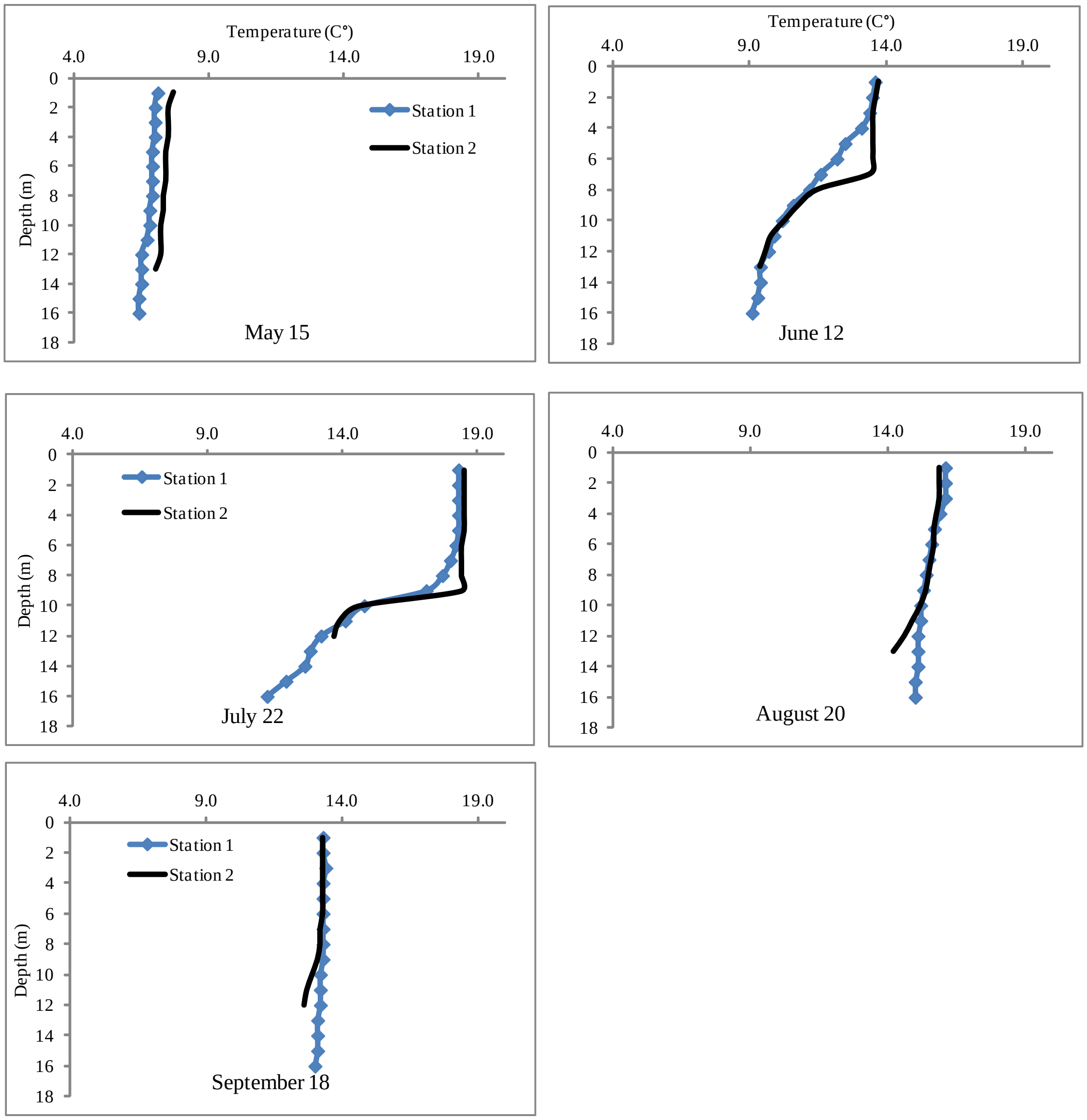

Figure 11.–Temperature profiles by station, by sampling date from Afognak Lake, 2013.

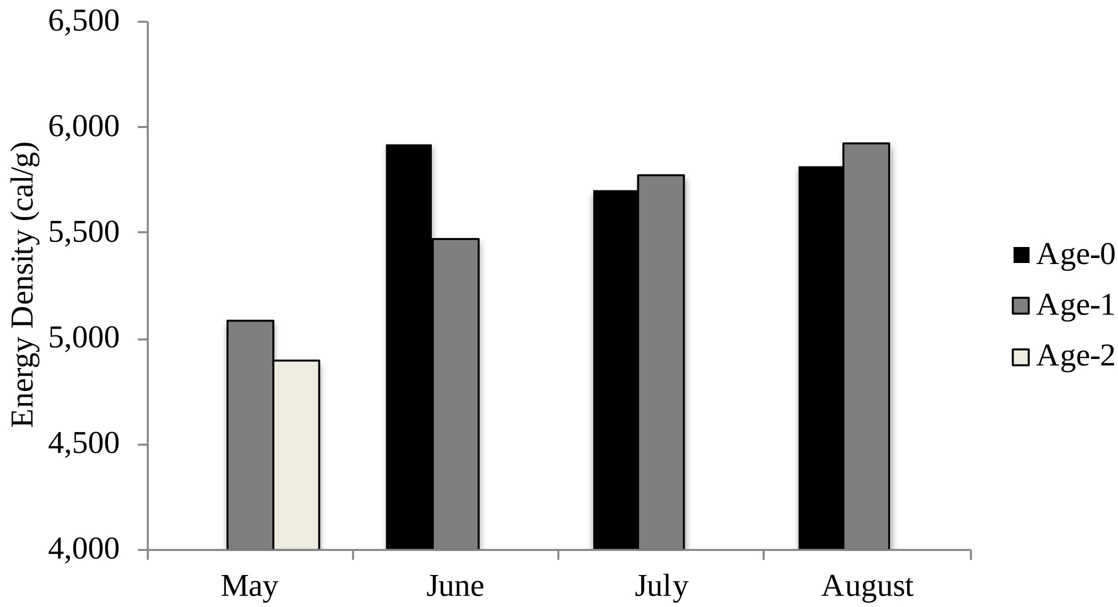

Figure 12.–Calorie content of lake rearing juvenile sockeye salmon by age and month from Afognak Lake, 2013.

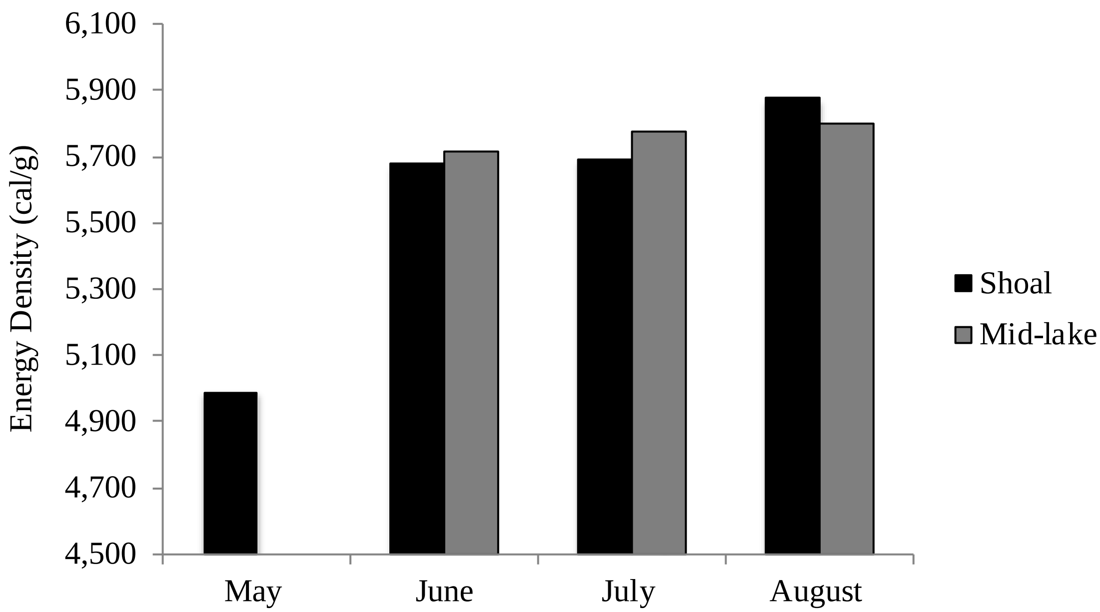

Figure 13.–Calorie content of lake rearing juvenile sockeye salmon by location and month from Afognak Lake, 2013.

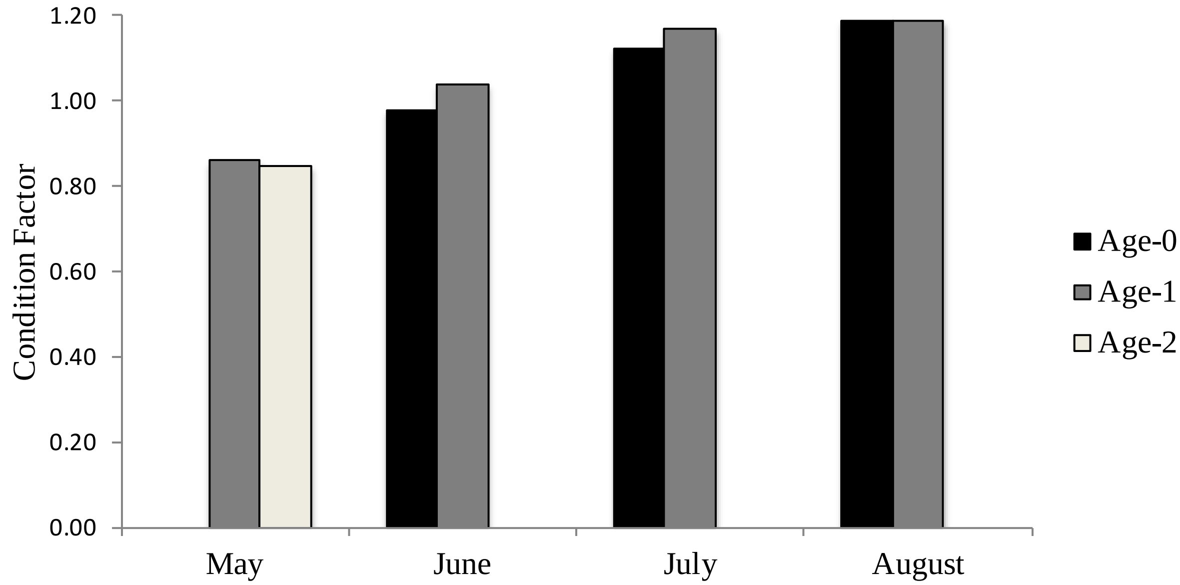

Figure 14.–Condition of lake rearing juvenile sockeye salmon by age and month from Afognak Lake, 2013.

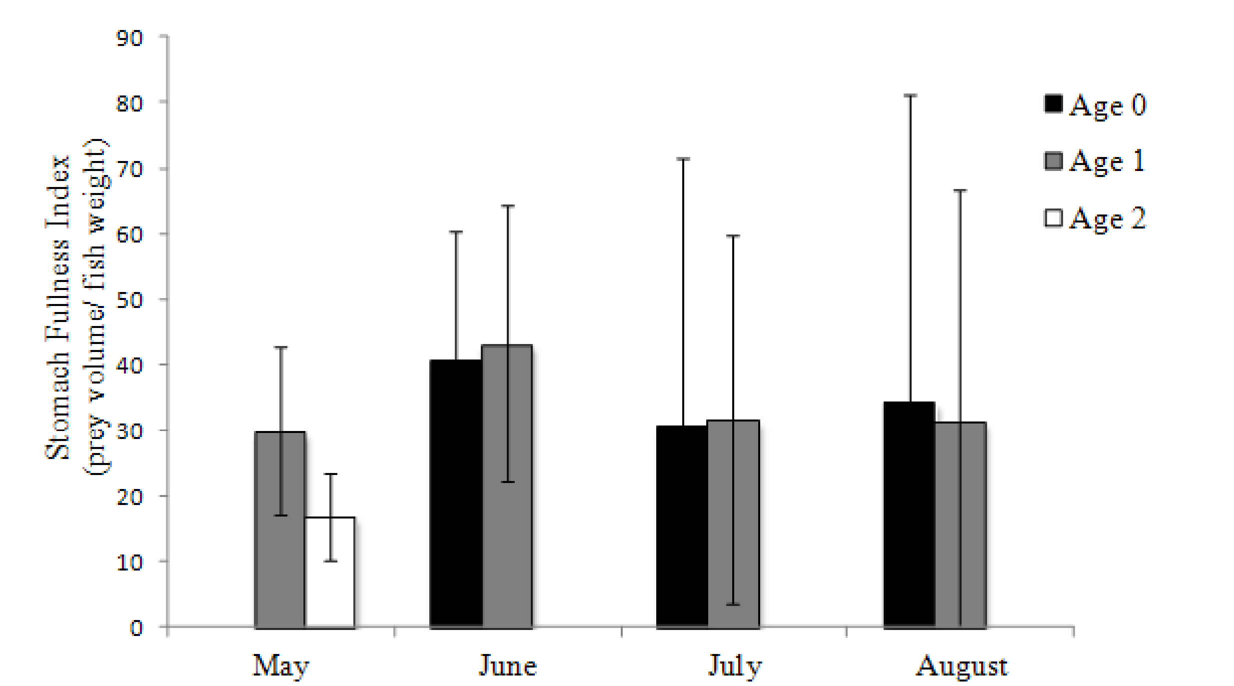

Figure 15.–Stomach fullness index of lake rearing juvenile sockeye salmon by age and month from Afognak Lake, 2013.

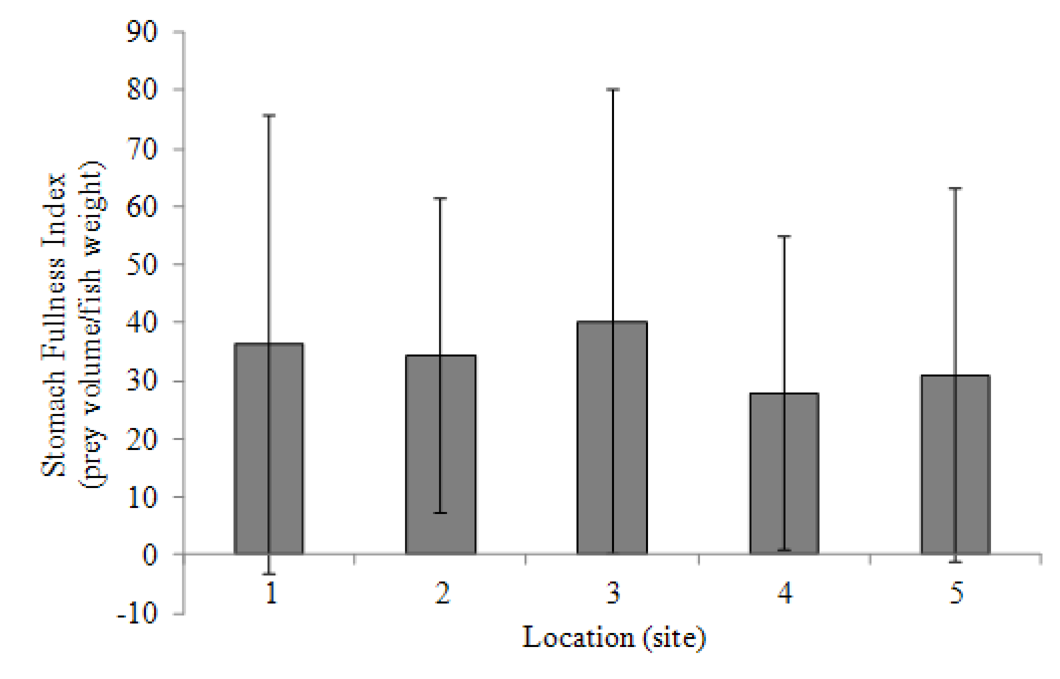

Figure 16.–Stomach fullness index of all lake rearing juvenile sockeye salmon by site from Afognak Lake, 2013.

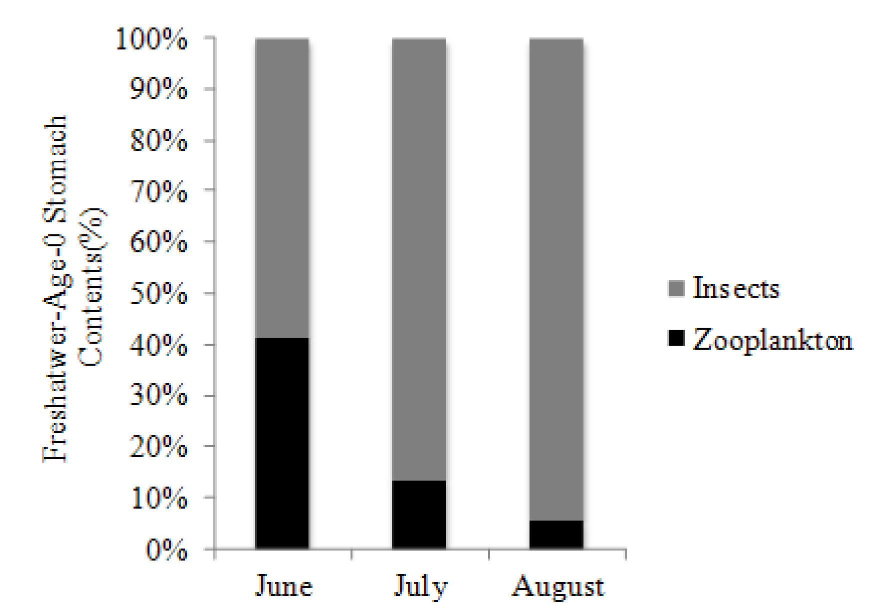

Figure 17.–Percentage of insects and zooplankton within the stomachs of lake rearing age-0 juvenile sockeye salmon from Afognak Lake, 2013.

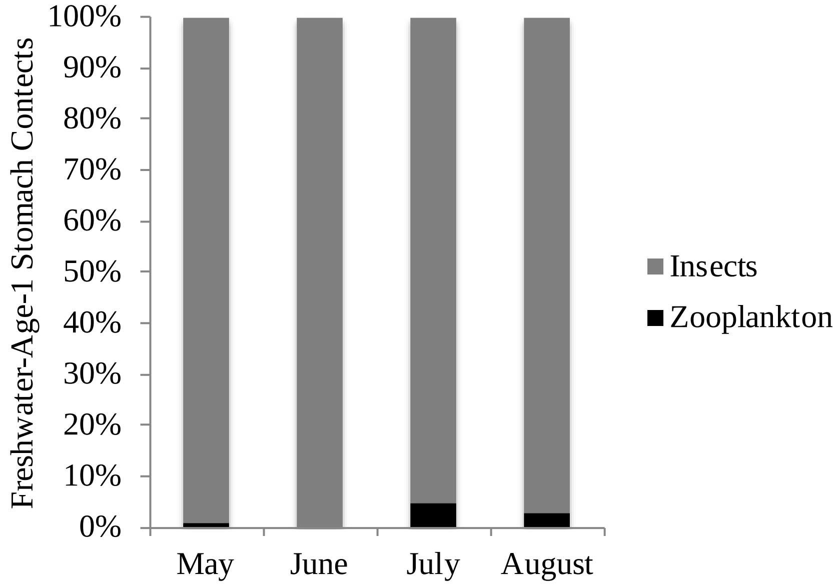

Figure 18.–Percentage of insects and zooplankton within the stomachs of lake rearing age-1 juvenile sockeye salmon from Afognak Lake, 2013.

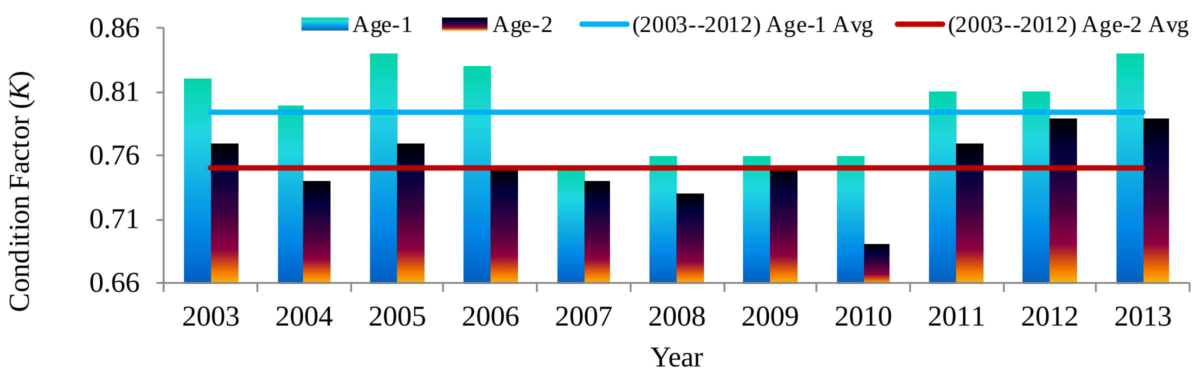

Figure 19.–Relative condition (*K*) of Afognak Lake smolt by year and age, 2003–2013.

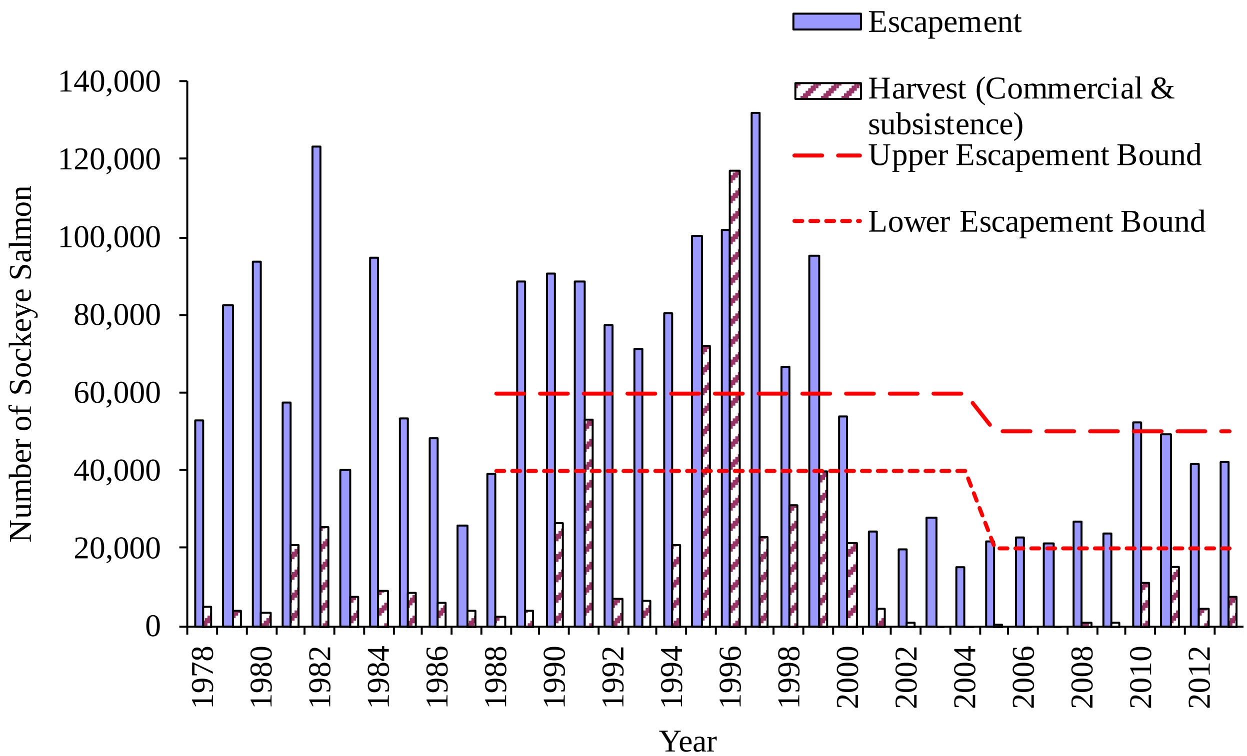

Figure 20.–Escapement and harvest of Afognak Lake sockeye salmon, 1978–2013.

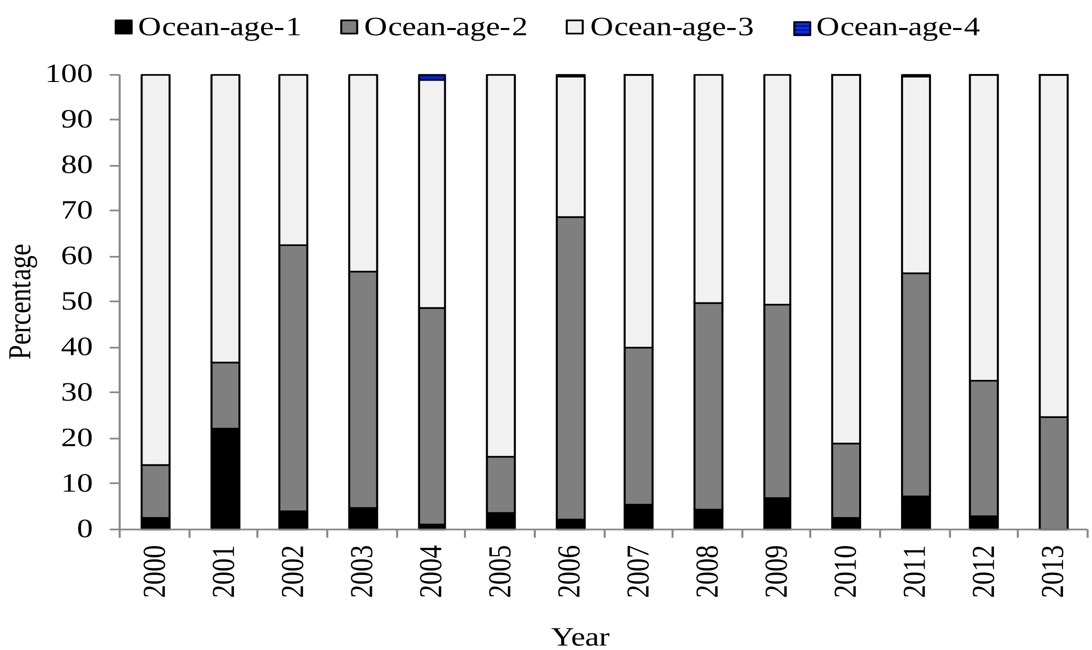

Figure 21.–Percentage of sockeye salmon escapement into Afognak Lake, by ocean age, and year, 2000–2013.

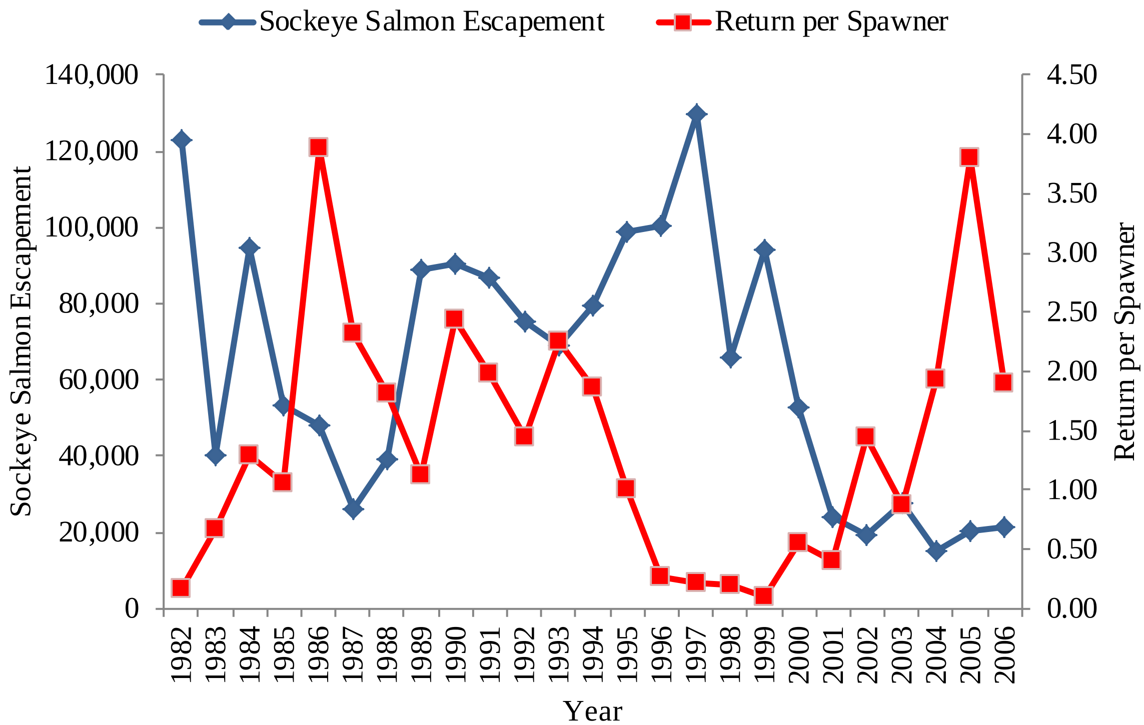

Figure 22.–Relationship between sockeye salmon escapement into Afognak Lake and return per spawner, 1982–2006.

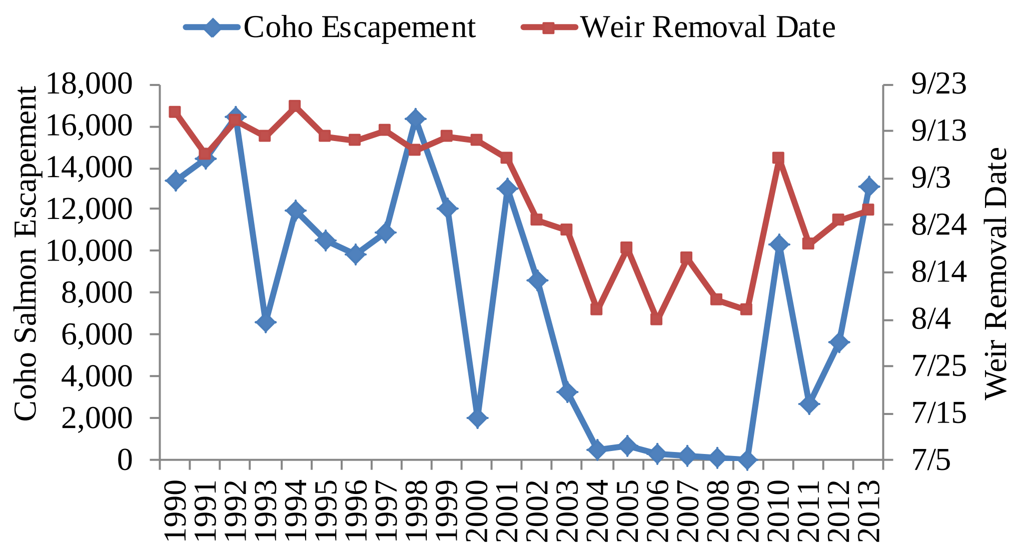

Figure 23.–Afognak Weir removal date compared to coho escapement by year, 1990–2013.

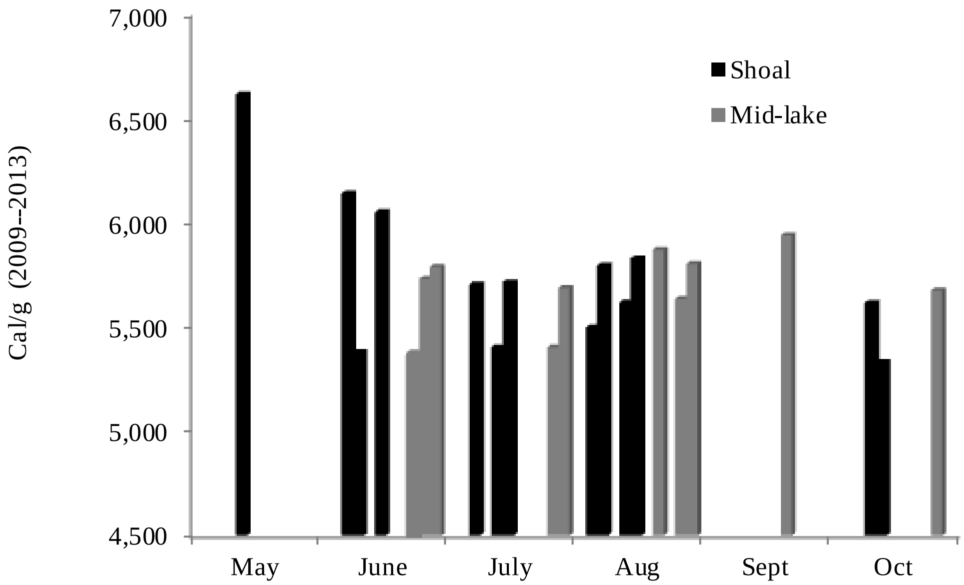

Figure 24.–Mean caloric content (cal/g) of age-0 juvenile sockeye salmon captured in Afognak Lake by sample date, 2009–2013.

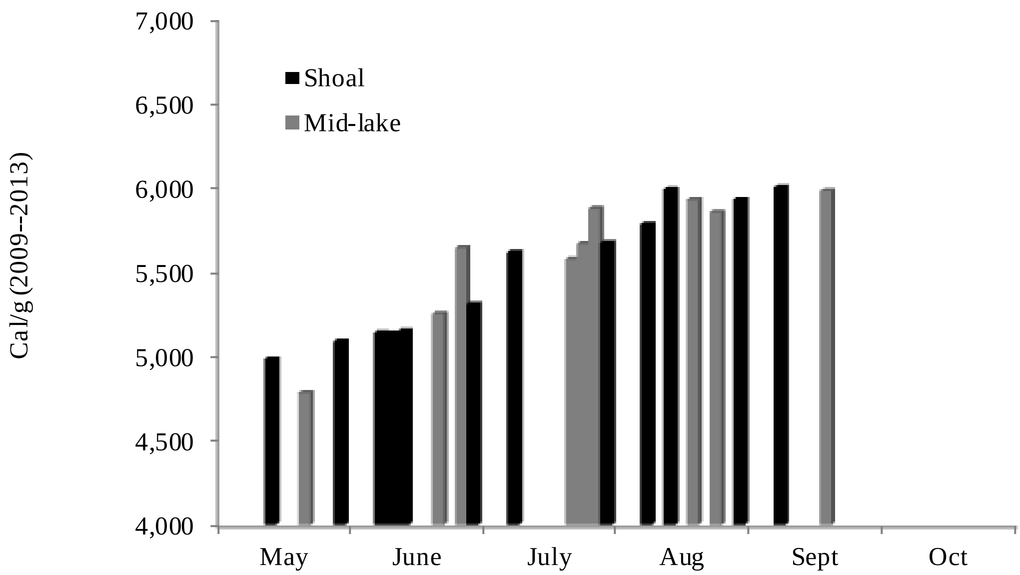

Figure 25.–Mean caloric content (cal/g) of age-1 juvenile sockeye salmon captured in Afognak Lake by sample date, 2009–2013.

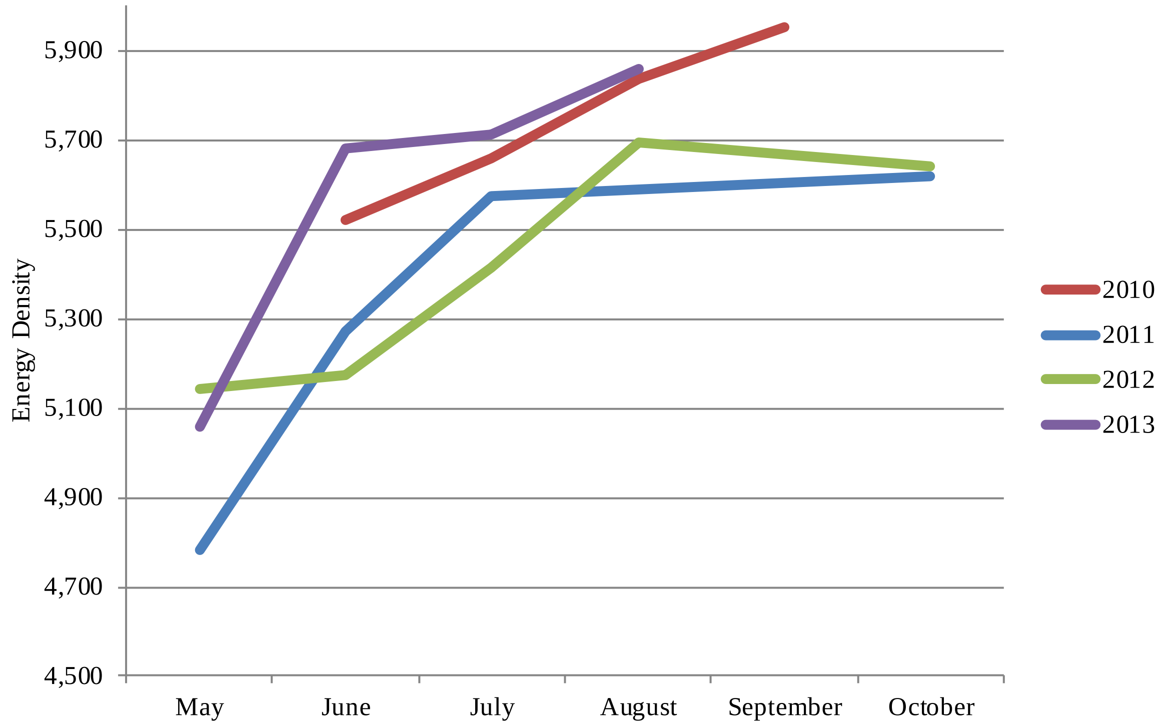

Figure 26.–Energy density of juvenile sockeye salmon from Afognak Lake, by month, by year, 2010–2013.

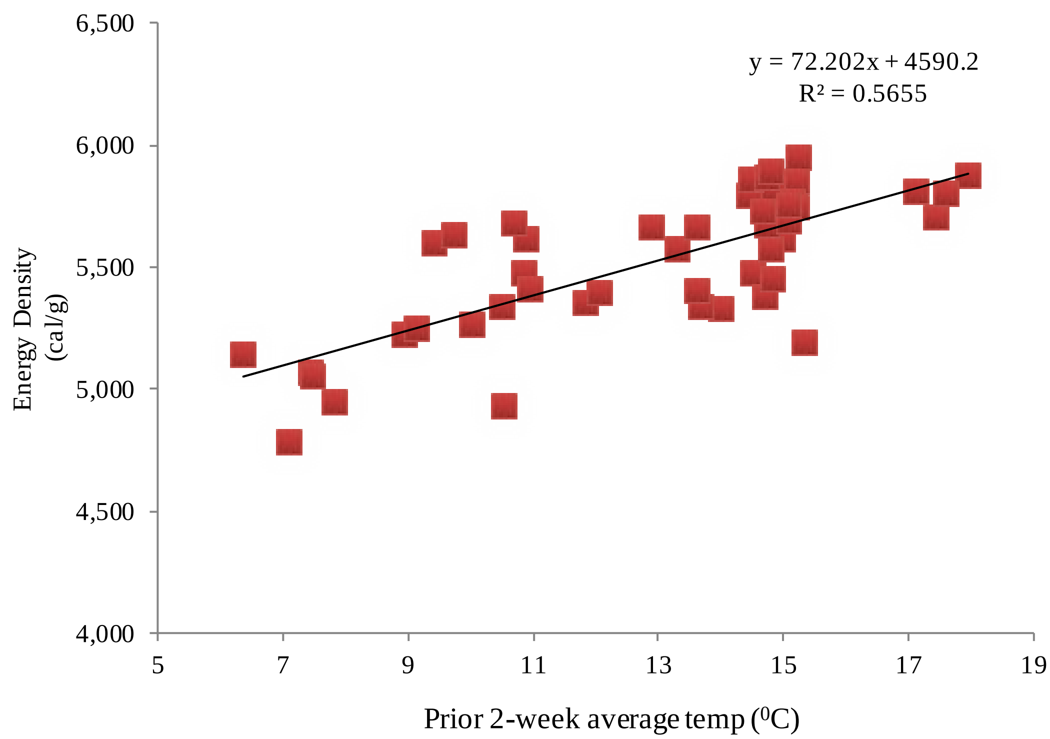

Figure 27.–Energy density of juvenile sockeye salmon from Afognak Lake, by lake temperature, 2013.

APPENDIX A. SUPPORTING HISTORICAL INFORMATION

Appendix A1.–Population estimates of sockeye salmon smolt outmigrations from Afognak Lake 2003–2013.

Stratum	Starting	Ending	Catch	Released	Recaptured	Average Trap	Estimate	Variance	95% Confidence Interval	
(h)	date	date	(u_h)	(M_h)	(m_h)	efficency (%)	(U_h)	(U_h)	lower	upper
					2003					
1	5/12	5/19	1,387	239	5	2.1%	55,480	430,580,280	14,809	96,151
2	5/20	5/25	2,912	239	5	2.1%	116,480	1,893,665,280	31,188	201,772
3	5/26	5/31	11,966	706	161	22.8%	52,222	13,071,832	45,136	59,308
4	6/1	6/7	31,358	638	133	20.8%	149,536	131,461,163	127,063	172,008
5	6/8	6/10	11,153	686	257	37.5%	29,698	2,175,656	26,807	32,589
6	6/11	6/18	18,696	679	103	15.2%	122,243	121,222,146	100,663	143,823
7	6/19	6/26	4,762	506	79	15.6%	30,179	9,629,085	24,097	36,261
8	6/27	7/3	736	218	17	7.8%	8,955	3,968,174	5,050	12,859
Total			82,970	3,911	760	19.9%	564,793	2,605,773,616	374,814	754,772
							SE=	51,047		
					2004					
1	5/11	5/26	24,278	525	56	10.7%	224,039	773,437,348	169,530	278,548
2	5/27	6/3	17,727	547	96	17.6%	100,148	84,689,189	82,111	118,186
3	6/4	6/11	16,658	700	211	30.1%	55,081	10,062,676	48,864	61,299
4	6/12	6/19	5,086	613	119	19.4%	26,023	4,609,226	21,815	30,231
5	6/20	7/3	3,779	581	88	15.1%	24,712	5,883,161	19,958	29,466
Total			67,528	2,966	570	18.6%	430,004	878,681,600	371,905	488,104
							SE=	29,643		

Note: SE = standard error

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Stratum (h)	Starting date	Ending date	Catch (u_h)	Released (M_h)	Recaptured (m_h)	Average Trap efficency (%)	Estimate (U_h)	Variance (U_h)	95% Confidence Interval lower	upper
					2005					
1	5/10	5/21	27,226	489	70	14.3%	184,879	404,815,551	145,443	224,314
2	5/22	5/26	13,627	518	43	8.3%	155,259	488,664,939	111,932	198,587
3	5/27	6/5	15,210	482	44	9.1%	158,499	493,724,194	114,948	202,050
4	6/6	6/27	17,634	368	103	28.0%	61,593	25,786,901	51,640	71,546
Total			73,697	1,857	260	14.9%	560,230	1,412,991,585	486,554	633,906
							SE=	37,590		
					2006					
1	5/16	6/1	25,983	312	73	23.6%	110,017	123,618,701	88,224	131,809
2	6/2	6/6	8,199	515	98	19.2%	42,726	14,930,053	35,153	50,299
3	6/7	6/16	7,108	485	95	19.8%	35,975	10,850,929	29,519	42,432
4	6/17	6/29	2,534	492	75	15.4%	16,435	3,056,035	13,009	19,861
Total			43,824	1,804	341	19.5%	205,153	152,455,718	180,952	229,353
							SE=	12,347		
					2007					
1	5/10	6/5	14,450	415	51	12.5%	115,690	221,784,590	86,501	144,879
2	6/6	6/12	19,469	202	124	61.5%	31,680	3,089,891	28,235	35,125
3	6/13	6/20	15,281	510	82	16.2%	94,135	88,847,348	75,660	112,609
4	6/21	6/27	5,216	541	108	20.1%	25,914	4,978,154	21,541	30,288
5	6/28	7/4	899	401	44	11.2%	8,031	1,307,504	5,790	10,272
Total			55,315	2,070	409	19.9%	275,450	320,007,488	240,388	310,512
							SE=	17,889		

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Appendix A1.–Page 3 of 4.

Stratum (h)	Starting date	Ending date	Catch (u_h)	Released (M_h)	Recaptured (m_h)	Average Trap efficency (%)	Estimate (U_h)	Variance (U_h)	95% Confidence Interval lower	upper
					2008					
1	5/16	5/31	6,516	202	44	21.2%	29,434	14,766,057	21,903	36,966
2	6/1	6/11	12,500	394	32	8.4%	149,621	605,011,907	101,411	197,831
3	6/12	6/19	2,559	244	53	22.0%	11,989	2,079,787	9,162	14,815
4	6/20	7/3	1,290	306	62	20.5%	5,896	454,235	4,575	7,217
Total			22,865	1,147	191	18.3%	196,941	622,311,987	148,046	245,835
							SE=	24,946		
					2009					
1	5/10	5/22	14,338	381	65	17.3%	82,891	85,202,787	64,799	100,983
2	5/23	6/1	37,537	356	50	14.3%	262,568	1,137,808,443	196,454	328,681
3	6/2	6/9	5,829	420	43	10.5%	55,727	62,257,984	40,261	71,192
4	6/10	6/21	5,753	425	35	8.5%	68,080	115,400,599	47,025	89,136
5	6/22	7/3	1,510	93	5	6.4%	23,732	75,639,388	6,686	40,778
Total			64,967	1,674	198	11.4%	492,998	1,476,309,201	417,689	568,306
							SE=	38,423		
					2010					
1	5/9	5/17	1,026	150	10	7.3%	14,090	15,502,483	6,373	21,807
2	5/18	5/24	788	385	28	7.5%	10,489	3,516,305	6,813	14,164
3	5/25	5/31	17,620	274	39	14.6%	120,961	305,577,452	86,699	155,224
4	6/1	6/7	10,687	275	50	18.5%	57,852	52,723,880	43,620	72,084
5	6/8	6/14	8,802	228	36	16.2%	54,477	65,755,815	38,584	70,371
6	6/15	6/21	2,566	464	27	6.0%	42,585	59,405,936	27,478	57,691
7	6/22	7/1	1,172	488	65	13.5%	8,677	1,026,613	6,691	10,663
Total			42,661	2,263	255	11.9%	309,130	443,075,935	267,874	350,387
								SE= 21,049		

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Stratum (h)	Starting date	Ending date	Catch (u_h)	Released (M_h)	Recaptured (m_h)	Average Trap efficency (%)	Estimate (U_h)	Variance (U_h)	95% Confidence Interval lower	95% Confidence Interval upper
					2011					
1	5/9	6/5	29,701	511	84	16.6%	178,755	311,317,921	144,206	213,303
2	6/6	6/13	10,539	200	35	17.9%	58,843	77,082,015	41,635	76,051
3	6/14	6/20	9,567	462	70	15.3%	62,442	46,195,379	49,120	75,763
4	6/21	6/27	3,628	169	27	16.5%	21,979	14,015,319	14,641	29,317
5	6/28	7/6	974	300	36	12.3%	7,930	1,506,726	5,524	10,336
Total			54,409	1,642	252	15.7%	329,949	450,117,359	288,393	371,502
								SE= 21,201		
					2012					
1	5/8	6/1	5,197	350	69	20.0%	26,037	7,745,327	20,583	31,492
2	6/2	6/7	4,010	314	43	14.0%	28,744	15,972,827	20,911	36,578
3	6/8	6/15	7,933	347	78	22.7%	34,988	11,950,503	28,213	41,764
4	6/16	6/23	4,672	438	55	12.8%	36,632	20,785,598	27,696	45,568
5	6/24	6/28	280	463	88	19.2%	1,460	25,218	1,149	1,771
Total			22,092	1,913	333	17.7%	127,862	56,479,474	98,551	157,173
								SE=7,515		
					2013					
1	5/8	5/26	10,123	201	38	19.3%	52,432	55,672,176	37,808	67,056
2	5/27	6/2	9,250	582	107	18.5%	49,933	18,854,409	41,422	58,444
3	6/3	6/10	8,167	282	22	8.1%	100,518	387,878,482	61,917	139,119
4	6/11	6/18	7,947	507	48	9.6%	82,438	123,574,935	60,650	104,226
5	6/19	6/27	1,419	319	22	7.2%	19,712	15,267,794	12,053	27,370
Total			36,906	1,891	237	12.6%	305,033	601,247,796	213,849	396,216
								SE=24,520		
Average (2003–2013)			51,567			16.4%	345,231			
SD (2003–2013)			19,948			3.3%	148,437			
Average (2010–2013)			39,017			14.5%	267,993			
SD (2010–2013)			13,430			2.7%	94,056			

Appendix A2.–Mean and percentage composition by year of sockeye salmon smolt sampled from outmigrants at Afognak Lake, 2003–2013.

	Age						
Year	1	%	2	%	3	%	Total
2003	373,513	66.1%	191,279	33.9%	0	0.0%	564,793
2004	387,584	90.1%	42,420	9.9%	0	0.0%	430,004
2005	521,025	93.0%	39,205	7.0%	0	0.0%	560,230
2006	146,527	71.4%	58,626	28.6%	0	0.0%	205,153
2007	237,383	86.2%	38,067	13.8%	0	0.0%	275,450
2008	92,018	46.7%	104,923	53.3%	0	0.0%	196,941
2009	427,141	86.6%	64,560	13.1%	1,296	0.3%	492,998
2010	237,716	76.9%	71,415	23.1%	0	0.0%	309,130
2011	250,741	76.0%	79,207	24.0%	0	0.0%	329,948
2012	99,541	77.6%	28,321	22.4%	0	0.0%	127,861
2013	249,107	81.7%	55,630	18.2%	296	0.1%	305,033
Mean (2010–2013)	209,276	78.0%	58,643	21.9%	74	0.0%	267,993
Mean (2003–2012)	277,319	77.1%	71,802	22.9%	130	0.0%	349,251

Appendix A3.–Mean weight, length, and condition factor by age for sockeye salmon smolt sampled at Afognak Lake, 1987–2001, and 2003–2013.

		Age-1				Age-2			
Year	Sampling Period	Sample Size (n)	Weight (g)	Length (mm)	Condition (K)	Sample Size (n)	Weight (g)	Length (mm)	Condition (K)
1987	8-Jun	36	3.6	74.9	0.85	186	3.6	79.3	0.86
1988	15-Jun	202	4.1	77.9	0.90	0			
1989	15-Jun	208	4.1	76.8	0.91	2	5.2	78.0	1.10
1990	23 May–24 June	544	2.5	68.8	0.76	21	3.4	77.3	0.73
1991	13 May–26 June	1,895	3.1	72.9	0.78	176	3.9	78.3	0.81
1992	7 June–20 June	268	3.8	77.0	0.82	37	3.8	76.9	0.83
1993	24 May–30 May	274	3.0	72.7	0.78	21	3.3	74.8	0.79
1994	17 May–23 May	138	3.0	72.0	0.81	142	4.7	84.3	0.79
1995	31 May–13 June	394	2.8	69.4	0.84	5	3.6	78.8	0.74
1996	5 June–11 June	54	4.6	80.9	0.87	339	4.8	81.6	0.88
1997	24 May–30 May	76	4.3	81.7	0.78	122	4.4	82.1	0.79
1998	24 May–30 May	116	2.6	66.4	0.82	46	6.6	88.0	0.90
1999	31 May–6 June	96	2.8	74.6	0.66	98	2.1	66.6	0.69
2000	31 May–13 June	84	4.9	81.5	0.89	100	5.6	85.3	0.89
2001	11 June–13 June	44	7.0	90.1	0.93	17	5.8	85.6	0.92
2002		0				0			
2003	12 May–3 July	1,031	4.2	79.1	0.82	383	4.2	81.4	0.77
2004	11 May–3 July	1,370	3.6	75.7	0.80	81	3.6	78.7	0.74
2005	10 May–27 June	1,248	3.9	76.8	0.84	65	4.2	81.3	0.77
2006	16 May–29 June	765	3.0	70.8	0.83	202	3.8	79.6	0.75
2007	21 May–2 July	960	2.6	70.4	0.75	129	3.4	76.5	0.74
2008	26 May–28 June	169	3.4	75.9	0.76	164	4.0	81.7	0.73
2009	13 May–29 June	1053	3.5	76.7	0.76	205	5.3	88.8	0.75
2010	9 May–1 July	601	2.6	69.9	0.76	198	3.9	82.1	0.69
2011	9 May–6 July	757	3.1	71.8	0.81	128	3.7	78.4	0.77
2012	8 May–28 June	378	3.1	72.5	0.81	134	3.9	79.1	0.78
2013	8 May–27 June	534	3.8	76.6	0.84	220	4.7	84.2	0.79
Avgerage (1987–2012)		491	3.6	75.1	0.81	115	4.2	80.2	0.80
Avgerage (2003–2012)		833	3.3	74.0	0.79	169	4.0	80.8	0.75
Avgerage (2010–2013)		568	3.2	72.7	0.81	170	4.1	81.0	0.76

Appendix A4.–Estimated age composition of the Afognak Lake sockeye salmon escapement, 1985–2013.

	Sample		Ages								
Year	Size (n)		1.1	1.2	2.1	1.3	2.2	1.4	2.3	3.2	Total *a*
1985	691	Percent	0.0	26.0	0.0	51.1	14.1	0.4	8.4	0.0	100.0
		Numbers	15	14,027	0	27,506	7,593	206	4,525	0	53,872
1986	484	Percent	0.6	10.1	0.2	74.8	5.8	0.2	8.1	0.0	100.0
		Numbers	300	4,893	100	36,150	2,796	100	3,895	0	48,333
1987	647	Percent	5.2	32.2	1.0	45.3	2.5	0.0	13.8	0.0	100.0
		Numbers	1,376	8,513	257	11,992	660	0	3,645	0	26,474
1988	933	Percent	0.7	59.5	3.2	24.2	11.2	0.0	0.9	0.0	100.0
		Numbers	257	23,227	1,233	9,441	4,363	0	350	0	39,012
1989	543	Percent	8.7	11.4	3.1	50.8	24.1	0.0	1.8	0.0	100.0
		Numbers	7,688	10,142	2,781	45,149	21,429	0	1,636	0	88,825
1990	1,053	Percent	0.7	46.7	0.6	22.6	8.6	0.3	20.5	0.0	100.0
		Numbers	598	42,314	554	20,518	7,754	262	18,614	0	90,666
1991	1,062	Percent	0.3	14.7	0.2	76.6	3.5	0.0	4.6	0.0	100.0
		Numbers	295	13,055	195	67,808	3,099	0	4,105	0	88,557
1992	1,025	Percent	21.2	22.2	9.9	29.9	3.8	0.5	12.3	0.0	100.0
		Numbers	16,360	17,114	7,680	23,096	2,938	394	9,527	0	77,260
1993	852	Percent	16.6	10.7	17.2	30.3	12.3	0.0	12.5	0.2	100.0
		Numbers	11,838	7,634	12,318	21,676	8,815	0	8,965	162	71,460
1994	840	Percent	9.6	30.6	4.1	35.2	10.3	0.1	9.6	0.1	100.0
		Numbers	7,703	24,648	3,337	28,387	8,315	62	7,707	64	80,570
1995	848	Percent	2.3	21.8	0.8	56.3	10.8	0.1	7.8	0.0	100.0
		Numbers	2,282	21,786	838	56,366	10,773	147	7,778	0	100,131
1996	1,119	Percent	16.1	9.2	2.1	44.0	2.1	0.2	26.0	0.1	100.0
		Numbers	16,339	9,398	2,183	44,744	2,094	184	26,428	81	101,718
1997	1,168	Percent	5.1	25.9	6.6	45.8	2.0	0.0	14.6	0.0	100.0
		Numbers	6,704	34,145	8,697	60,416	2,632	41	19,247	0	132,050
1998	1,240	Percent	19.0	8.0	7.1	49.1	10.6	0.4	5.5	0.0	100.0
		Numbers	12,720	5,371	4,767	32,826	7,099	250	3,684	0	66,869
1999	1,195	Percent	1.1	38.8	0.5	9.5	42.7	0.2	6.6	0.5	100.0
		Numbers	1,030	36,992	506	9,043	40,720	232	6,278	455	95,361

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Year	Sample Size (n)		Ages 1.1	1.2	2.1	1.3	2.2	1.4	2.3	3.2	Total *a*
2000	1,161	Percent	2.1	2.5	0.3	15.7	6.0	0.0	69.1	3.3	100.0
		Numbers	1,121	1,348	188	8,484	3,228	0	37,382	1,806	54,064
2001	790	Percent	1.4	11.0	6.2	23.4	3.2	0.0	39.3	0.0	100.0
		Numbers	334	2,681	1,496	5,683	775	0	9,540	0	24,271
2002	238	Percent	0.1	1.0	3.2	32.6	24.7	0.0	4.8	32.8	100.0
		Numbers	19	194	625	6,358	4,830	0	935	6,399	19,520
2003	498	Percent	4.1	22.6	0.2	0.8	25.7	0.0	29.6	2.8	100.0
		Numbers	1,148	6,273	66	233	7,141	0	8,229	770	27,766
2004	566	Percent	1.1	44.3	0.2	19.0	1.8	0.0	26.8	0.0	100.0
		Numbers	170	6,720	25	2,888	280	3	4,073	0	15,181
2005	572	Percent	3.2	10.0	0.6	82.0	2.2	0.0	1.3	0.0	100.0
		Numbers	683	2,153	136	17,697	472	0	280	0	21,577
2006	613	Percent	2.5	63.1	0.0	22.1	2.6	0.0	9.4	0.0	100.0
		Numbers	569	14,481	0	5,075	596	36	2,156	0	22,933
2007	590	Percent	5.1	32.5	0.3	54.4	2.1	0.0	5.6	0.0	100.0
		Numbers	1,076	6,844	67	11,461	436	8	1,178	0	21,070
2008	643	Percent	4.3	41.6	0.3	49.4	3.7	0.0	0.6	0.0	100
		Numbers	1,165	11,177	87	13,269	1,003	0	173	0	26,874
2009	776	Percent	4.5	39.9	2.7	47.7	2.3	0.0	2.8	0.0	100
		Numbers	1,412	12,520	852	14,969	722	0	884	0	31,358
2010	954	Percent	2.6	15.8	0.2	80.6	0.5	0.1	0.2	0.0	100
		Numbers	1,377	8,234	103	42,108	267	52	114	0	52,255
2011	750	Percent	4.2	40.2	3.3	28.5	8.8	0.3	14.7	0.0	100
		Numbers	2,086	19,771	1,606	14,015	4,340	152	7,222	0	49,193
2012	767	Percent	2.3	15.7	0.8	56.7	14.0	0.1	10.4	0.0	100
		Numbers	968	6,531	325	23,565	5,800	48	4,315	0	41,553
2013	747	Percent	0.2	19.6	0.0	63.9	5.1	0.0	11.1	0.0	100
		Numbers	78	8,269	0	26,939	2,169	17	4,682	0	42,153
Avgerage (1992–2012)		Percent	6.1	24.2	3.2	38.7	9.2	0.1	14.7	1.9	
		Numbers	4,148	12,191	2,186	21,065	5,394	77	7,909	464	53,954
Avgerage (2003–2012)		Percent	3.4	32.6	0.9	44.1	6.4	0.1	10.1	0.3	
		Numbers	1,065	9,470	327	14,528	2,106	30	2,862	77	30,976
Avgerage (2010–2013)		Percent	2.4	22.8	1.1	57.4	7.1	0.1	9.1	0.0	
		Numbers	1,127	10,701	509	26,657	3,144	67	4,083	0	46,289

a Totals include some age classes not listed.

Appendix A5.–Afognak Weir cumulative escapement counts by year and species, 1990–2013.

Year	Sockeye	Chinook	Pink	Coho	Chum	Steelhead Down	Steelhead Up	All Species
1990	90,666	0	27,808	13,380	0	191	61	132,106
1991	88,557	0	13,985	14,409	0	392	24	117,367
1992	77,260	0	28,945	16,415	0	202	34	122,856
1993	71,460	2	21,830	6,637	0	173	44	100,146
1994	80,570	5	49,756	11,965	8	356	11	142,671
1995	100,131	3	42,738	10,542	0	335	46	153,795
1996	101,718	0	11,307	9,856	14	154	103	123,152
1997	132,050	1	19,122	10,908	4	563	8	162,656
1998	66,869	3	101,177	16,374	14	150	78	184,665
1999	95,361	8	30,959	12,092	11	783	31	139,245
2000	54,064	8	67,003	2,036	8	185	18	123,322
2001	24,271	1	25,228	12,981	6	118	4	62,609
2002	19,520	1	76,242	8,654	3	67	0	104,487
2003	27,766	1	34,330	3,256	13	221	1	65,588
2004	15,181	2	9,563	492	40	63	3	25,344
2005	21,577	2	41,594	715	0	59	0	63,947
2006	22,933	4	9,235	312	11	80	0	32,575
2007	21,070	0	11,777	225	9	309	1	33,391
2008	26,874	0	15,716	147	1	316	0	43,054
2009	31,358	0	895	13	6	383	1	32,656
2010	52,255	1	62,237	10,288	59	256	1	125,097
2011	49,193	0	4,241	2,700	4	128	0	56,266
2012	41,553	1	111,928	5,701	5	91	0	159,279
2013	42,153	1	17,400	13,090	1	78	0	64,723
4-year Average (2010–2013)	46,289	1	48,952	7,945	17	138	0	101,341
10-year Average (2003–2012)	31,992	1	28,992	3,358	14	180	1	63,811
Average (1990–2001)	81,915	3	36,655	11,466	5	300	39	130,383
Average (1990–2012)	54,585	2	35,673	7,406	10	233	17	97,510

Appendix A6.–Temperatures (°C) measured at the 1-meter and near bottom strata in the spring (May–June), summer (July–August), and fall (September–October) for Afognak Lake, 1989–2013.

	Spring		Summer		Fall	
Year	Surface	Bottom	Surface	Bottom	Surface	Bottom
1989	7.8	7.0	16.3	12.8	15.3	13.6
1990	9.4	8.3	14.8	13.6	11.9	11.4
1991	6.2	5.7	15.1	12.5	12.4	12.1
1992	10.0	8.9	15.5	13.9	11.1	11.0
1993	11.9	10.4	17.6	14.5	13.5	12.6
1994	10.8	8.8	15.5	13.5	10.2	9.7
1995	8.8	7.3	15.2	12.8	12.5	11.9
1996	11.5	9.7	15.2	13.9	11.1	10.5
1997	10.3	7.5	17.6	10.6	14.1	12.4
1998	7.9	7.7	14.3	13.0	11.8	11.6
1999	7.0	6.2	15.1	11.4	10.4	10.1
2000	9.7	8.7	15.0	13.1	10.1	10.0
2001	9.1	7.0	17.1	10.2	12.9	12.5
2002	10.0	7.8	16.0	10.8	9.3	9.2
2003	9.7	5.5	18.3	12.9	11.5	11.3
2004	9.2	8.2	15.1	11.7	13.1	12.9
2005	11.8	9.5	18.1	13.5	13.6	13.5
2006	9.2	8.0	15.8	12.5	12.6	12.5
2007	9.2	6.7	15.4	9.5	12.4	12.3
2008	8.6	6.9	14.7	13.3	11.9	11.4
2009	11.1	8.4	17.4	13.9	12.4	12.2
2010	8.7	8.1	15.1	14.2	14.9	14.1
2011	8.2	7.4	14.7	12.6	12.1	11.5
2012	10.2	7.6	14.4	12.2	11.8	11.9
2013	10.4	7.8	17.2	13.1	13.3	13.0
Avgerage (1989–2012)	9.4	7.8	15.8	12.6	12.2	11.7
Avgerage (2010–2013)	9.4	7.7	15.4	13.0	13.0	12.6

Appendix A7.–Dissolved oxygen concentrations (mg /L) measured at the 1-meter and near bottom strata in the spring (May–June), summer (July–August), and fall (September–October) for Afognak Lake, 1989–2013.

	Spring		Summer		Fall	
Year	Surface	Bottom	Surface	Bottom	Surface	Bottom
1989	11.7	11.2	10.3	9.2	13.1	10.3
1990	14.0	11.8	9.5	8.6	9.6	8.9
1991	12.6	11.1	10.9	8.2	10.5	9.4
1992	11.5	10.8	10.1	8.7	10.8	10.8
1993	10.9	9.8	9.5	7.5	10.5	10.1
1994	11.0	9.8	10.0	8.1	11.3	10.9
1995	11.4	11.3	10.0	8.4	10.5	9.8
1996	10.9	10.5	10.0	7.7	11.2	11.1
1997	10.5	10.7	9.0	4.6	10.2	7.6
1998	11.8	11.7	10.2	6.1	10.2	10.0
1999	11.9	11.5	9.6	6.2	10.9	10.4
2000	11.0	9.1	9.7	6.8	10.5	10.1
2001	9.7	9.6	9.3	4.7	9.0	8.1
2002	10.8	9.3	9.8	0.1	10.5	10.1
2003	12.0	11.1	9.2	5.5	18.0	10.3
2004	12.9	11.2	11.5	8.1	10.5	6.4
2005	10.8	10.2	9.5	5.1	9.5	8.7
2006	10.9	10.0	9.8	8.3	10.5	10.0
2007	11.4	10.8	9.2	6.6	10.6	9.9
2008	12.5	10.7	9.5	8.9	9.5	9.9
2009	10.9	10.3	9.0	7.9	8.9	8.6
2010	10.8	9.8	9.7	8.8	10.2	9.8
2011	12.2	11.9	10.2	8.4	10.2	9.9
2012	12.1	11.8	10.7	9.7	11.0	10.6
2013	12.2	11.9	9.9	7.6	10.0	9.7
Avgerage (1989–2012)	11.5	10.7	9.8	7.2	10.7	9.6
Avgerage (2010–2013)	11.8	11.3	10.1	8.6	10.4	10.0

Appendix A8.–Average euphotic zone depth (EZD), light extinction coefficient (K_d), Secchi disk transparency, and euphotic volume (EV) for Afognak Lake, 1989–2013.

Year	EZD (m)	SD	K_d (m^{-1})	SD	Secchi (m)	SD	EV ($10^6 m^3$)	SD
1987	8.43	1.14	NA	NA	4.7	1.4	44.65	6.04
1988	11.91	2.78	NA	NA	4.2	0.5	63.14	14.73
1989	13.30	3.28	-0.38	0.10	4.80	0.41	70.50	17.40
1990	9.05	2.90	-0.56	0.23	3.58	0.60	47.98	15.37
1991	10.05	2.80	-0.50	0.18	2.71	0.53	53.28	14.86
1992	10.24	1.78	-0.45	0.07	2.75	0.87	54.27	9.45
1993	9.32	2.32	-0.51	0.11	3.43	0.51	49.38	12.31
1994	7.40	1.40	-0.60	0.10	3.42	0.38	39.20	7.41
1995	7.40	1.33	-0.61	0.12	2.45	0.56	39.21	7.06
1996	7.96	1.70	-0.58	0.14	3.52	0.40	42.19	9.03
1997	8.48	1.32	-0.56	0.12	3.23	0.75	44.92	7.00
1998	7.49	0.76	-0.59	0.07	3.69	1.23	39.68	4.04
1999	8.81	2.92	-0.57	0.12	3.00	0.61	46.71	15.49
2000	9.82	1.60	-0.46	0.07	3.35	0.63	52.07	8.47
2001	11.04	3.35	-0.46	0.12	3.95	1.14	58.52	17.74
2002	10.52	0.57	-0.41	0.02	4.25	0.54	55.75	3.03
2003	9.80	1.31	-0.44	0.05	4.50	0.23	51.95	6.94
2004	9.13	1.27	-0.47	0.06	4.15	0.58	48.39	6.71
2005	9.80	0.83	-0.45	0.05	4.78	0.64	51.96	4.41
2006	9.02	1.02	-0.49	0.07	4.04	0.71	47.83	5.43
2007	9.47	1.17	-0.49	0.08	4.15	0.71	50.17	6.23
2008	9.07	1.47	-0.51	0.08	4.38	0.38	48.08	7.81
2009	9.37	0.41	-0.48	0.03	4.40	0.72	49.65	2.19
2010	10.03	1.29	-0.44	0.06	4.50	0.80	53.16	6.84
2011	8.20	1.12	-0.55	0.09	4.25	0.59	43.46	5.94
2012	9.81	0.59	-0.45	0.03	4.90	0.38	51.99	3.10
2013	8.75	1.06	-0.52	0.07	4.65	0.58	46.37	5.64
Avgerage (1987–2012)	9.42	1.63	-0.50	0.09	3.88	0.65	49.80	8.54
Avgerage (2010–2013)	9.20	1.02	-0.49	0.06	4.58	0.59	48.95	6.01

Note: Values are updated to reflect current database calculations (Heather Finkle, ADF&G, Personal Communication). SD = standard deviation.

Appendix A9.–Summary of seasonal mean water chemistry parameters by station and depth for Afognak Lake, 1987–2013.

Year	Station	Depth (m)	Sp. Conductivity (µmhos cm)	SD	pH (Units)	SD	Alkalinity (mg/L)	SD	Turbidity (NTU)	SD	Color (Pt units)	SD	Calcium (mg/L)	SD	Magnesium (mg/L)	SD	Iron (µg/L)	SD
1987	1	1	47	2.6	6.7	0.2	10.0	0.8	0.8	0.3	8	1.7	3.6	0	0.6	0	76	34.9
	1	17	46	2.8	6.7	0.4	9.5	1.0	0.7	0.4	8	2.6	4	0	1	0	58	17.3
1988	1	1	51	5.9	6.7	0.5	10.8	1.3	1.4	1.0	12	2.4	4.7	ND	1.6	ND	50	13.6
	1	15	50	0.5	6.9	0.2	11.3	1.0	1.1	0.8	10	1.3	ND	ND	ND	ND	81	77.7
	2	1	51	3.7	6.9	0.1	10.5	1.7	1.4	1.1	12	3.2	ND	ND	ND	ND	63	22.3
	2	10	50	2.3	6.8	0.1	10.3	0.6	1.5	1.2	9	2.9	ND	ND	ND	ND	96	52.7
1989	1	1	64	1.9	7.0	0.5	10.6	1.5	2.4	3.5	8	4.4	4.0	0.6	1.1	0.9	44	10.5
	1	15	63	1.0	6.9	0.2	10.2	1.6	0.7	0.1	10	0.7	4.3	0.2	1.2	0.8	51	19.3
	2	1	63	0.8	7.0	0.3	10.4	1.3	0.8	0.2	10	1.1	3.8	0.4	1.5	0.6	53	9.1
	2	12	65	3.3	6.9	0.4	10.6	2.2	0.8	0.2	10	1.4	4.4	0.1	1.4	0.3	91	39.1
1990	1	1	41	1.7	6.8	0.1	6.3	0.5	0.8	0.4	14	3.4	2.9	1.4	0.4	0.3	121	24.3
	1	16	41	1.0	6.7	0.2	6.1	0.6	0.7	0.4	11	2.2	3.2	1.8	0.4	0.3	128	38.7
1991	1	1	38	0.8	6.7	0.1	10.4	7.8	0.9	0.3	13	0.8	2.1	0.3	0.8	0.5	210	31.1
	1	14	38	1.0	6.6	0.2	6.9	0.3	0.9	0.2	16	3.9	1.9	0.1	0.8	0.5	190	45.0
1992	1	1	35	1.2	6.6	0.2	5.8	1.0	0.9	0.5	12	3.4	2.5	0.9	0.6	0.3	157	9.3
	1	24	35	0.5	6.3	0.1	4.9	1.0	0.8	0.6	11	1.5	2.5	1.2	0.6	0.3	162	56.9
1993	1	1	37	1.0	6.6	0.1	7.5	2.7	0.5	0.1	7	7.5	2.2	0.4	1.3	1.1	104	34.9
	1	25	39	4.0	6.4	0.4	7.8	2.1	0.5	0.2	10	10.7	2.6	0.9	0.8	0.1	134	52.0
1994	1	1	39	6.5	6.6	0.2	6.2	2.0	1.1	0.8	5	3.2	2.2	0.9	0.6	0.2	141	44.0
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	26	36	0.9	6.3	0.3	6.5	2.5	0.7	0.3	6	4.7	2.2	0.5	0.6	0.2	197	87.7
1995	1	1	60	5.6	6.6	0.2	9.8	1.0	2.0	0.8	11	2.6	3.7	1.4	1.3	0.4	85	45.6
	1	17	60	5.4	6.5	0.2	10.0	1.3	2.3	1.2	9	2.0	3.4	0.5	1.6	0.5	101	33.0
	2	1	58	4.9	6.6	0.2	9.7	1.1	1.9	0.9	11	4.3	3.2	0.3	1.1	0.3	87	55.9
	2	11	58	4.3	6.5	0.2	9.6	1.1	2.0	0.8	10	5.5	3.5	0.4	1.3	0.3	101	53.9
1996	1	1	56	1.5	6.7	0.2	10.5	0.7	1.4	1.0	10	2.5	3.2	0.5	1.3	0.2	54	25.9
	1	18	57	2.7	6.6	0.1	11.2	1.9	1.5	0.7	9	0.5	3.1	0.5	1.1	0.3	72	33.2
	2	1	56	1.4	6.7	0.1	10.7	1.0	1.2	0.6	9	1.3	3.1	0.5	1.1	0.3	54	25.7
	2	11	57	1.1	6.7	0.1	10.7	1.0	1.5	0.6	11	2.6	2.9	0.5	1.5	0.3	89	43.4

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Year	Station	Depth (m)	Sp. Conductivity (µmhos cm)	SD	pH (Units)	SD	Alkalinity (mg/L)	SD	Turbidity (NTU)	SD	Color (Pt units)	SD	Calcium (mg/L)	SD	Magnesium (mg/L)	SD	Iron (µg/L)	SD
1997	1	1	53	0.6	7.1	0.2	12.1	1.6	1.1	0.1	9	1.9	3.1	0.4	1.1	0.3	28	16.6
	1	18	58	6.7	6.8	0.2	13.9	3.5	1.7	0.4	10	0.8	2.9	0.5	1.7	1.1	68	37.7
	2	1	53	0.8	7.1	0.1	11.7	0.5	1.0	0.2	11	3.8	3.0	0.3	1.0	0.3	34	17.3
	2	13	53	0.5	7.0	0.1	11.9	0.3	1.3	0.5	10	3.0	2.9	0.3	1.0	0.3	44	25.8
1998	1	1	49	0.6	7.0	0.1	12.6	1.3	1.7	1.2	18	10.7	3.2	0.5	0.8	0.2	26	15.0
	1	18	48	ND	7.0	ND	11.8	ND	2.0	ND	11	ND	3.3	ND	1.0	ND	48	ND
1999	1	1	58	0.0	6.8	0.2	11.1	0.6	1.6	1.0	11	1.7	3.3	0.3	1.4	0.1	82	43.8
2000	1	1	ND	ND	7.1	0.2	8.7	2.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2001	1	1	ND	ND	7.2	0.4	10.1	2.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2002	1	1	ND	ND	7.2	0.5	10.1	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2003	1	1	ND	ND	6.9	0.1	9.8	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2004	1	1	ND	ND	6.9	0.1	11.4	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	18	ND	ND	6.8	0.1	10.9	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2005	1	1	ND	ND	6.8	0.1	10.9	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2006	1	1	ND	ND	6.8	0.1	11.3	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2007	1	1	ND	ND	6.8	0.1	10.9	1.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2008	1	1	ND	ND	6.7	0.2	11.4	1.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2009	1	1	ND	ND	7.0	0.4	11.7	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2010	1	1	ND	ND	7.2	0.1	9.5	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2011	1	1	ND	ND	7.4	0.1	11.3	1.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2012	1	1	ND	ND	7.5	0.2	11.1	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2013	1	1	ND	ND	7.4	0.1	11.9	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Averages:																		
Pre-fertilization yrs. 1987–1989			55	3.0	6.8	0.3	10.5	1.3	1.3	1.2	10	2.6	4.0	0.3	1.2	0.5	57	18.1
Fertilization yrs. 1990–2000		1	49	2.1	6.8	0.2	9.5	1.7	1.2	0.6	11	3.6	2.9	0.6	1.0	0.3	91	30.0
All yrs. 1987–2012		1	50	2.3	6.9	0.2	10.1	1.4	1.3	0.8	10	3.3	3.2	0.6	1.0	0.4	81	26.7
Post-fertilization yrs. 2001–2012		1	ND	ND	7.0	0.2	10.8	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-year 2010–2013		1	ND	ND	7.3	0.1	11.0	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

NTU=Nephelometric Turbidity Scale.

PT units=Platinum-Cobalt Scale.

Appendix A10.–Summary of seasonal mean nutrient and algal pigment concentrations by station and depth for Afognak Lake, 1987–2013.

	Station	Depth	Total Phosphorus		Total filterable-P		Filterable reactive-P		Total Kjeldahl Nitrogen		Ammonia		Nitrate +Nitrite		Reactive Silicon		Organic Carbon		Chlorophyll *a*		Phaeophytin *a*	
Year		(m)	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD
1987	1	1	8.8	3.6	3.1	1.5	1.6	0.3	130	5.6	5	2.6	135	57.8	3255	719.8	144	30	0.64	0.21	0.54	0.19
	1	17	6.7	1.0	2.8	0.6	1.4	0.2	116	14.5	13	11.7	148	51.6	3313	706.9	102	26	0.32	0.21	0.41	0.02
1988	1	1	8.1	2.2	4.7	1.9	2.7	0.6	140	18.9	4	2.0	60	36.0	2509	344.9	247	52	1.64	1.02	0.74	0.17
	1	15	7.8	1.2	4.1	0.8	2.6	0.1	124	10.6	7	6.3	67	32.9	2528	200.4	179	27	2.13	3.17	0.99	0.83
	2	1	8.0	2.8	5.7	4.4	3.1	0.8	128	17.6	3	1.9	60	31.3	2602	134.1	183	44	1.58	1.22	0.72	0.33
	2	10	7.9	2.3	3.5	1.6	2.3	0.1	133	9.6	8	5.7	54	13.2	2499	107.6	300	176	2.76	3.50	1.02	0.32
1989	1	1	8.3	2.8	4.2	0.6	2.4	0.4	139	17.8	3	3.4	67	47.0	2714	197.7	ND	ND	0.92	0.39	0.54	0.17
	1	15	6.5	0.7	3.9	0.5	2.5	0.2	134	11.1	9	10.8	77	32.3	2803	150.6	ND	ND	0.65	0.34	0.51	0.26
	2	1	7.1	1.6	4.2	0.7	2.8	0.5	126	10.0	3	4.1	70	45.6	2752	209.4	ND	ND	0.75	0.18	0.41	0.18
	2	12	8.8	4.5	4.8	2.1	2.5	0.3	131	30.4	13	16.0	77	40.9	2813	161.1	ND	ND	0.67	0.20	0.51	0.22
1990	1	1	4.5	1.5	2.9	4.2	3.7	1.7	128	16.5	8	3.0	40	29.1	3250	247.5	145	13.0	0.34	0.19	0.17	0.03
	1	16	5.1	2.3	1.3	1.3	2.8	1.1	118	22.7	10	4.2	65	29.1	3390	154.5	144	30.6	0.21	0.03	0.28	0.07
1991	1	1	5.0	2.8	3.2	0.6	2.3	0.4	151	22.6	11	1.8	57	21.3	2865	108.6	ND	ND	0.31	0.21	0.27	0.07
	1	14	4.6	1.5	6.0	3.5	4.5	3.2	138	12.3	14	5.0	70	23.2	2966	156.3	ND	ND	0.22	0.14	0.22	0.08
1992	1	1	3.8	0.5	4.1	2.5	3.1	2.4	135	13.9	3	1.7	62	26.1	3163	158.9	199	64.1	0.44	0.29	0.28	0.13
	1	24	3.9	1.7	4.0	3.2	2.6	1.7	127	12.8	10	4.1	93	23.1	3182	198.0	163	52.9	0.31	0.25	0.28	0.12
1993	1	1	4.5	0.8	3.7	1.3	2.8	0.5	148	18.5	5	2.2	49	30.4	3132	220.6	147	53.3	1.01	0.31	0.36	0.03
	1	25	4.9	1.3	8.5	11.7	6.8	9.9	136	17.3	19	10.1	98	31.7	3380	244.0	121	47.5	0.52	0.21	0.45	0.14
1994	1	1	5.7	0.7	4.5	3.3	3.6	2.3	160	23.8	3	1.7	40	21.4	2843	122.4	114	33.0	0.56	0.26	0.28	0.08
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.56	0.34	0.34	0.10
	1	26	5.3	1.1	4.8	3.9	4.2	3.2	160	17.7	15	9.7	74	23.8	3177	285.5	128	52.1	0.36	0.21	0.27	0.09
1995	1	1	8.7	2.7	3.0	1.5	2.0	1.1	168	21.6	9	14.1	66	22.1	1873	735.0	ND	ND	3.92	2.44	1.13	0.62
	1	17	8.1	2.0	1.9	1.1	1.1	0.4	187	47.1	35	44.3	45	35.0	2046	618.4	ND	ND	3.13	1.75	1.10	0.54
	2	1	7.4	2.1	2.1	1.2	1.7	1.0	169	31.0	9	14.0	54	33.2	1942	753.9	ND	ND	4.20	2.90	1.05	0.65
	2	11	7.2	1.7	2.2	2.0	1.6	1.1	157	26.0	16	17.4	52	34.1	2143	805.6	ND	ND	3.27	2.18	1.05	0.62
1996	1	1	9.2	2.6	3.4	0.7	2.8	0.3	161	34.0	18	13.9	40	29.2	2465	297.2	225	80.3	2.39	1.16	0.82	0.38
	1	18	8.2	2.7	2.4	0.7	2.2	0.3	161	56.5	36	37.6	51	27.8	2663	176.1	190	73.1	1.40	0.56	0.81	0.37
	2	1	8.8	2.6	2.7	0.8	2.2	0.4	160	37.3	8	14.6	41	25.9	2466	275.0	226	52.5	1.77	0.50	0.85	0.36
	2	11	8.4	2.8	3.4	1.6	2.9	1.3	147	41.3	29	24.5	50	25.9	2630	220.7	169	55.7	1.07	0.29	0.77	0.31
1997	1	1	7.3	1.9	2.7	1.0	2.6	0.9	155	33.9	14	14.2	22	23.9	2347	354.4	273	63.8	2.56	1.42	1.51	0.66
	1	18	7.2	1.5	2.6	0.5	2.3	0.4	194	68.6	64	53.3	55	14.5	2995	503.5	197	28.8	1.12	0.50	1.08	0.38
	2	1	6.9	1.7	3.6	1.8	3.1	1.5	156	37.8	13	15.8	17	21.8	2435	351.3	252	62.8	1.68	1.25	1.19	0.83
	2	13	6.5	1.4	2.8	1.9	2.3	0.8	148	38.7	21	12.4	30	20.1	2584	433.5	156	50.6	1.33	1.17	1.06	0.76

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Year	Station	Depth (m)	Total Phosphorus (µg/L)	SD	Total filterable-P (µg/L)	SD	Filterable reactive-P (µg/L)	SD	Total Kjeldahl Nitrogen (µg/L)	SD	Ammonia (µg/L)	SD	Nitrate +Nitrite (µg/L)	SD	Reactive Silicon (µg/L)	SD	Organic Carbon (µg/L)	SD	Chlorophyll *a* (µg/L)	SD	Phaeophytin *a* (µg/L)	SD
1998	1	1	9.0	1.7	3.3	0.8	1.9	0.0	193	7.7	21	13.9	38	15.9	2387	73.0	152	118.8	0.10	0.04	0.04	0.02
	1	18	7.5	ND	3.7	ND	1.9	ND	182	ND	25	ND	63	ND	2311	ND	36	ND	0.09	ND	0.03	ND
1999	1	1	17.7	18.3	8.6	10.2	6.8	10.0	247	147.2	36	42.6	124	35.2	2390	431.5	261	122.2	2.94	3.19	0.56	0.35
2000	1	1	9.5	4.3	3.1	1.6	1.8	1.6	57	36.6	19	12.5	72	36.1	ND	ND	ND	ND	2.43	1.46	1.10	0.80
2001	1	1	7.8	5.1	6.4	5.2	8.2	6.7	115	22.2	5	3.6	38	32.5	ND	ND	ND	ND	2.37	0.53	0.30	0.20
2002	1	1	6.4	2.3	4.5	3.1	1.5	0.9	131	15.4	5	2.5	27	18.8	ND	ND	ND	ND	1.36	0.14	0.30	0.20
2003	1	1	6.5	3.0	2.2	0.8	2.1	0.8	ND	ND	6	1.8	54	26.9	ND	ND	ND	ND	1.20	0.20	0.50	0.40
2004	1	1	6.2	3.5	4.3	3.2	2.0	0.7	169	103.8	9	2.8	61	31.5	2764	342.8	ND	ND	1.15	0.18	0.28	0.08
	1	18	5.9	2.3	6.2	8.3	3.5	3.5	ND	ND	19	13.2	80	28.4	2914	277.1	ND	ND	0.70	0.35	0.19	0.11
2005	1	1	11.4	4.4	7.6	3.6	3.6	3.1	161	45.6	4	2.0	41	34.8	2701	243.7	ND	ND	1.60	0.68	0.24	0.11
2006	1	1	7.2	4.3	2.2	1.6	2.3	1.1	97	59.6	7	1.7	28	30.8	ND	ND	ND	ND	1.92	0.32	0.50	0.09
2007	1	1	3.6	0.4	1.1	0.3	1.1	0.6	115	32.4	6	0.7	56	39.5	ND	ND	ND	ND	1.47	0.43	0.21	0.08
2008	1	1	3.8	1.1	2.3	1.5	1.6	0.9	113	28.6	6	0.6	65	42.3	ND	ND	ND	ND	1.22	0.66	0.58	0.37
2009	1	1	4.8	1.1	1.3	0.3	1.8	1.0	131	29.7	4	0.8	39	40.0	ND	ND	ND	ND	1.92	0.64	0.63	0.33
2010	1	1	4.4	0.8	2.5	0.4	1.7	0.3	19	15.7	4	0.8	23	32.1	2363	682.2	ND	ND	1.12	0.16	0.63	0.25
2011	1	1	5.8	0.6	2.5	0.4	4.7	2.0	209	21.3	18	6.9	42	27.2	2440	254.8	ND	ND	1.19	0.62	0.62	0.23
2012	1	1	3.8	0.2	1.7	0.2	0.8	0.3	299	59.3	6	3.6	34	36.0	2806	235.5	ND	ND	1.74	0.59	0.12	0.06
2013	1	1	4.3	0.6	1.9	0.3	1.5	0.7	375	55.6	13	7.2	21	21.3	2801	238.3	ND	ND	1.31	0.51	0.38	0.16
Averages:																						
Pre-fertilization yrs. 1987–1989		1	8.0	2.6	4.4	1.8	2.5	0.5	133	14.0	3.6	2.8	79	43.5	2766	321.2	191	42.2	1.10	0.61	0.59	0.21
Fertilization yrs. 1990–2000		1	7.7	3.1	3.6	2.2	2.9	1.7	156	34.5	12.8	11.8	51	26.5	2581	317.6	199	66.4	1.76	1.12	0.69	0.36
All yrs. 1987–2012		1	7.1	2.7	3.6	2.0	2.7	1.5	147	32.9	8.9	6.7	52	31.7	2629	325.8	197	60.8	1.56	0.77	0.56	0.27
Post-fertilization yrs. 2001–2012		1	6.0	2.2	3.2	1.7	2.6	1.5	142	39.4	6.6	2.3	42	32.7	2615	351.8	ND	ND	1.52	0.43	0.41	0.20
4-year 2010–2013		1	4.6	0.6	2.2	0.3	2.2	0.8	225.3	38.0	10.3	4.6	29.6	29.2	2602.6	352.7	ND	ND	1.34	0.47	0.44	0.18

Appendix A11.–Weighted mean zooplankton density, biomass, and size by species for station 1, Afognak Lake, 1987–2013.

Station 1 Year	No. Samples	*Epischura* Density (no/m^2)	*Epischura* Biomass (mg/m^2)	*Epischura* Size (mm)	*Diaptomus* Density (no/m^2)	*Diaptomus* Biomass (mg/m^2)	*Diaptomus* Size (mm)	*Cyclops* Density (no/m^2)	*Cyclops* Biomass (mg/m^2)	*Cyclops* Size (mm)	*Bosmina* Density (no/m^2)	*Bosmina* Biomass (mg/m^2)	*Bosmina* Size (mm)	*Daphnia* Density (no/m^2)	*Daphnia* Biomass (mg/m^2)	*Daphnia* Size (mm)	*Holopedium* Density (no/m^2)	*Holopedium* Biomass (mg/m^2)	*Holopedium* Size (mm)	TOTALS Density (no/m^2)	TOTALS Biomass (mg/m^2)
1987	4	28,835	100	0.91	173	1	1.01	4,127	6	0.65	138,370	134	0.33	3,218	4	0.54	2,574	6	0.52	177,297	251
1988	4	22,360	77	0.91	0	0	-	3,185	5	0.69	106,462	104	0.33	962	2	0.71	1,228	3	0.53	134,197	191
1989	5	16,322	71	0.99	0	0	-	3,663	5	0.66	69,638	59	0.31	1,778	3	0.64	1,347	3	0.48	92,748	141
1990	7	15,378	60	0.95	7	0	0.90	9,987	16	0.68	155,051	134	0.31	3,392	5	0.61	4,944	9	0.47	188,759	224
1991	6	21,278	102	1.02	265	1	0.79	6,606	12	0.74	208,574	193	0.32	4,089	9	0.72	4,025	8	0.50	244,837	325
1992	7	23,468	104	0.99	485	1	0.88	4,807	8	0.68	106,832	108	0.33	5,513	13	0.74	3,306	6	0.45	144,411	240
1993	7	33,893	127	0.94	76	0	0.83	5,960	11	0.72	240,817	247	0.34	7,689	14	0.66	3,715	8	0.50	292,150	407
1994	8	23,713	66	0.85	1,844	7	0.98	10,231	17	0.69	257,749	256	0.33	9,621	18	0.66	7,271	13	0.48	310,429	377
1995	7	16,758	84	1.04	5,596	16	0.87	24,932	39	0.68	212,768	197	0.32	13,740	22	0.62	1,410	2	0.46	275,204	360
1996	5	42,112	223	1.06	191	0	0.49	11,614	19	0.69	350,806	378	0.34	16,072	44	0.78	2,909	5	0.47	423,704	670
1997	6	14,367	69	1.02	5,520	11	0.75	24,567	41	0.69	81,591	66	0.30	11,720	17	0.58	915	1	0.43	138,679	205
1998	4	15,672	62	0.96	1,088	5	1.05	2,070	3	0.67	169,971	144	0.31	10,881	14	0.56	5,441	8	0.42	205,123	236
1999	4	18,737	78	0.97	5,945	24	0.97	6,688	12	0.71	133,175	130	0.33	9,449	20	0.68	2,495	5	0.46	176,489	269
2000	5	57,643	180	0.88	8,121	44	1.09	10,743	16	0.66	114,297	126	0.35	5,042	9	0.64	1,408	2	0.46	116,722	188
2001	5	30,122	66	0.77	2,548	6	0.79	8,121	10	0.61	40,764	33	0.30	1,253	1	0.49	2,638	4	0.43	85,446	120
2002	4	8,174	21	0.82	1,009	3	0.92	6,380	7	0.56	38,256	36	0.32	2,935	3	0.51	557	1	0.41	57,311	71
2003	4	39,743	73	0.73	3,782	7	0.74	3,185	4	0.62	102,110	85	0.30	1,393	2	0.60	1,194	2	0.48	151,407	173
2004	5	23,206	37	0.69	510	1	0.86	6,374	8	0.62	58,598	52	0.31	11,472	16	0.58	2,771	5	0.48	102,931	119
2005	5	21,369	59	0.84	1,592	4	0.83	8,238	10	0.60	82,409	65	0.30	4,979	7	0.57	2,027	3	0.43	120,614	148
2006	5	29,565	92	0.88	3,450	10	0.85	9,915	20	0.76	76,518	61	0.30	8,408	11	0.56	6,348	11	0.46	134,204	205
2007	5	10,913	24	0.78	2,930	9	0.88	7,718	13	0.70	74,257	66	0.31	3,386	5	0.58	1,730	3	0.47	100,934	120
2008	5	16,561	45	0.84	823	2	0.83	2,670	3	0.61	66,762	55	0.30	4,231	7	0.62	3,079	6	0.49	94,126	119
2009	5	13,402	42	0.88	0	0		1,409	2	0.60	31,539	24	0.29	2,866	4	0.54	1,208	2	0.45	50,424	73
2010	5	14,841	48	0.89	212	1	0.82	987	1	0.59	64,830	49	0.29	1,327	2	0.53	1,624	3	0.49	83,821	104
2011	5	16,423	50	0.86	1,911	2	0.61	4,501	6	0.61	43,068	31	0.28	446	1	0.57	2,972	6	0.49	69,321	95
2012	5	23,928	82	0.91	425	1	0.81	3,854	6	0.66	56,359	45	0.30	4,310	7	0.64	1,104	3	0.53	89,980	143
2013	5	12,155	37	0.87	106	0	0.91	4,979	7	0.61	50,334	35	0.28	6,502	8	0.53	2,856	5	0.45	76,932	91
Averages:																					
Pre-fertilization yrs. 1987–1989		22,506	83	0.94	58	0	1.01	3,658	5	0.67	104,823	99	0.32	1,986	3	0.63	1,716	4	0.51	134,747	194
Fertilization yrs. 1990–2000		25,729	105	0.97	2,649	10	0.87	10,746	18	0.69	184,694	180	0.33	8,837	17	0.66	3,440	6	0.46	228,773	318
All yrs. 1987–2012		23,030	79	0.90	1,866	6	0.85	7,405	12	0.66	118,522	111	0.31	5,776	10	0.61	2,702	5	0.47	156,203	214
Post-fertilization yrs. 2001–2012		20,687	53	0.82	1,599	4	0.81	5,279	7	0.63	61,289	50	0.30	3,917	5	0.57	2,271	4	0.47	95,043	124
2010–2013		16,837	54	0.88	664	1	0.79	3,580	5	0.62	53,648	40	0.29	3,146	4	0.57	2,139	4	0.49	80,014	108

Appendix A12.–Weighted mean zooplankton density, biomass, and size by species for station 2, Afognak Lake, 1988–2013.

Station 2		*Epischura*			*Diaptomus*			*Cyclops*			*Bosmina*			*Daphnia*			*Holopedium*			TOTALS	
Year	No. Samples	Density (no/m^2)	Biomass (mg/m^2)	Size (mm)	Density (no/m^2)	Biomass (mg/m^2)	Size (mm)	Density (no/m^2)	Biomass (mg/m^2)	Size (mm)	Density (no/m^2)	Biomass (mg/m^2)	Size (mm)	Density (no/m^2)	Biomass (mg/m^2)	Size (mm)	Density (no/m^2)	Biomass (mg/m^2)	Size (mm)	Density (no/m^2)	Biomass (mg/m^2)
1988	4	10,656	45	0.98	40	0	1.44	809	1	0.70	108,838	110	0.33	1,405	3	0.65	942	3	0.55	122,690	162
1989	5	10,306	35	0.90	0	0	-	1,261	2	0.66	48,235	40	0.30	420	1	0.63	553	1	0.46	60,775	79
1990	7	12,610	48	0.94	0	0	-	3,460	5	0.66	128,277	108	0.31	2,350	4	0.64	4,026	7	0.47	150,723	172
1991	6	19,285	80	0.97	1,274	4	0.89	4,277	8	0.74	154,341	132	0.31	3,347	6	0.65	5,083	10	0.49	187,607	240
1992	7	8,948	34	0.94	144	1	1.00	1,436	2	0.67	82,879	84	0.33	2,521	5	0.70	1,579	3	0.45	97,507	129
1993	7	19,033	70	0.93	773	1	0.69	3,882	5	0.62	175,106	157	0.32	2,570	5	0.67	3,988	7	0.47	205,352	245
1994	8	11,006	40	0.93	783	3	0.91	2,736	4	0.65	125,352	116	0.32	4,321	7	0.64	2,468	4	0.46	146,666	174
1995	7	12,193	44	0.92	1,168	4	0.94	9,054	11	0.61	111,525	98	0.31	8,902	12	0.58	1,152	1	0.4	143,994	170
1996	5	20,892	99	1.02	255	2	1.17	2,930	6	0.77	219,747	239	0.35	4,331	11	0.76	1,571	2	0.46	249,726	359
1997	6	13,677	57	0.97	3,468	7	0.75	3,822	5	0.64	86,060	63	0.29	9,652	13	0.56	924	1	0.41	117,601	146
1998	0																				
1999	0																				
2000	0																				
2001	0																				
2002	0																				
2003	0																				
2004	5	27,192	44	0.70	32	0	0.95	5,125	8	0.66	34,843	27	0.29	2,187	4	0.62	1,624	3	0.44	71,003	84
2005	5	22,282	60	0.83	0	0	-	2,850	4	0.63	49,992	37	0.29	815	2	0.73	900	1	0.38	76,839	104
2006	5	9,408	14	0.68	510	1	0.78	3,083	5	0.70	44,282	31	0.28	3,571	5	0.59	1,274	2	0.43	62,128	59
2007	5	16,269	63	0.95	1,141	4	0.93	6,693	12	0.71	57,065	49	0.31	934	1	0.55	2,049	4	0.50	84,151	133
2008	5	20,786	51	0.81	1,592	8	1.04	2,484	3	0.59	49,260	38	0.29	786	2	0.67	1,314	2	0.44	76,222	103
2009	5	5,149	11	0.77	106	0	0.70	1,645	2	0.64	16,189	10	0.27	1,380	2	0.51	902	2	0.46	25,371	27
2010	5	4,273	6	0.67	0	0	-	504	1	0.55	25,653	16	0.26	191	0	0.65	1,205	2	0.41	31,826	24
2011	5	12,452	29	0.78	2,017	3	0.71	3,312	6	0.70	55,032	36	0.27	1,077	2	0.59	1,592	3	0.47	75,482	78
2012	5	8,386	29	0.97	1,699	4	0.81	1,964	2	0.61	37,155	28	0.29	743	1	0.57	955	2	0.49	50,902	67
2013	5	8,567	15	0.71	0	0	-	1,741	3	0.69	41,465	33	0.29	1,932	3	0.58	1,200	2	0.48	54,905	56
Averages:																				51,961	60
Pre-fertilization yrs. 1988–1989 Avg		10,481	40	0.94	20	0	1.44	1,035	2	0.68	78,537	75	0.32	913	2	0.64	748	2	0.51	91,733	121
Fertilization yrs. 1990–2000		14,705	59	0.95	983	3	0.91	3,950	6	0.67	135,411	125	0.32	4,749	8	0.65	2,599	4	0.45	162,397	204
All yrs. 1988–2012		13,937	45	0.88	790	2	0.91	3,228	5	0.66	84,728	75	0.30	2,711	4	0.63	1,795	3	0.45	107,188	134
Post-fertilization yrs. 2001–2012		14,022	34	0.80	789	2	0.85	3,073	5	0.64	41,052	30	0.28	1,298	2	0.61	1,313	2	0.45	61,547	75
2010–2013		8,420	20	0.78	929	2	0.76	1,880	3	0.64	39,826	28	0.28	986	1	0.60	1,238	2	0.46	53,279	56

Appendix A13.–Sockeye salmon escapement and adult returns by age for Afognak Lake, 1982–2013.

Brood Year	Escapement	Age Class Returns 0.1	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	4.1	2.4	3.3	Total Return	R/S
1982	123,055	2	0	17	112	5,504	112	0	13,845	762	0	0	371	0	0	0	0	20,726	0.17
1983	40,049	0	0	337	0	9,828	297	0	10,013	4,627	0	0	1,707	0	0	35	0	26,844	0.67
1984	94,463	0	0	1,588	54	24,634	1,307	0	47,110	22,360	0	339	24,078	0	0	0	0	121,471	1.29
1985	53,563	36	96	272	0	10,583	2,902	0	26,542	10,030	0	0	6,568	0	0	65	0	57,094	1.07
1986	48,328	0	0	8,022	35	54,737	717	0	108,494	4,958	0	428	10,370	0	0	0	0	187,760	3.89
1987	25,994	0	0	773	0	20,889	313	0	25,139	3,198	99	0	9,772	177	0	0	0	60,359	2.32
1988	39,012	0	0	472	0	18,628	8,360	0	23,626	9,607	57	77	9,686	80	0	0	0	70,593	1.81
1989	88,825	0	0	17,807	0	8,321	13,427	0	35,677	10,450	157	253	13,374	0	0	397	0	99,863	1.12
1990	90,666	0	0	12,902	0	30,978	4,194	0	96,927	18,526	0	397	56,869	175	0	0	199	221,167	2.44
1991	86,819	0	280	9,681	277	37,463	1,440	0	96,284	4,507	0	48	22,573	0	0	0	0	172,552	1.99
1992	75,370	0	0	3,925	175	20,223	4,698	0	70,857	3,087	0	365	5,377	0	0	0	0	108,706	1.44
1993	68,782	0	0	35,159	0	40,046	10,200	0	47,921	10,364	222	330	8,915	646	0	0	680	154,484	2.25
1994	79,380	0	0	7,863	0	7,842	6,959	74	12,841	57,821	74	0	52,384	2,531	0	0	205	148,593	1.87
1995	98,609	0	0	18,569	0	52,527	718	0	11,888	4,523	0	0	11,396	0	75	0	0	99,696	1.01
1996	100,266	0	0	1,463	0	1,888	264	0	6,789	925	4,213	0	996	6,818	0	0	3,992	27,348	0.27
1997	129,481	0	30	1,571	0	3,202	1,787	0	6,775	5,147	171	0	8,408	787	0	186	875	28,938	0.22
1998	65,809	0	0	399	0	207	666	0	238	7,296	0	3	4,225	0	0	0	0	13,033	0.20
1999	94,011	0	0	20	0	6,409	67	0	2,996	291	0	0	293	0	0	0	0	10,076	0.11
2000	52,648	0	0	1,173	0	6,971	26	0	18,560	495	0	36	2,199	0	0	0	0	29,460	0.56
2001	23,940	0	0	177	164	2,258	142	0	5,176	608	0	8	1,202	0	0	0	0	9,735	0.41
2002	19,334	0	0	716	20	14,769	0	0	11,665	435	0	1	196	0	0	0	0	27,803	1.44
2003	27,448	0	0	580	0	7,074	71	0	14,358	1,054	0	1	890	0	0	0	0	24,028	0.88
2004	15,181	0	0	1,105	0	11,631	90	0	15,538	710	0	64	140	0	0	0	0	29,278	1.93
2005	20,281	0	0	1,238	0	13,151	911	0	51,698	328	0	200	9,530	0	0	0	0	77,056	3.80
2006	21,488	0	0	1,492	0	10,108	127	0	18,494	5,727	0	54	4,876	0	0	0	0	40,878	1.90
2007	20,066	0	0	1,691	0	26,090	2,119	0	26,626	6,553	0	20	5,549	0	0			68,648	3.42
2008	26,052	0	0	2,753	0	7,379	367	0	31,931	2,570	0							45,000	1.73
2009	30,818	0	0	1094	0	9801	0											10,895	0.35
2010	51,831	0	0	92														92	0.00
2011	48,588	0																	
2012	41,146																		
2013	40,889																		
Averages: Pre-fertilization yrs. 1982–1989	64,161	5	12	3,661	25	19,141	3,429	0	36,306	8,249	39	137	9,491	32	0	62	0	80,589	1.54
Fertilization yrs. 1990–2000	85,622	0	28	8,430	41	18,887	2,820	7	33,825	10,271	425	107	15,785	996	7	17	541	92,187	1.12
All yrs. 1982–2006	63,312	2	16	5,093	33	16,795	2,392	3	31,178	7,513	200	104	10,656	449	3	27	238	74,702	1.40
Post-fertilization yrs. 2001–2006	21,279	0	0	885	31	9,832	224	0	19,488	1,477	0	55	2,806	0	0	0	0	34,796	1.73

Note: Escapement reflects egg take removals. Years after 2006 not fully recruited.

Appendix A14.–Number and percentage of sockeye salmon escapement into Afognak Lake, by year, and ocean age, 2000–2013.

	Ocean Age								
Year	1	%	2	%	3	%	4	%	Total Fish
2000	1,361	2.5	6,404	11.8	46,300	85.6	0	0.0	54,064
2001	5,443	22.4	3,490	14.4	15,338	63.2	0	0.0	24,271
2002	804	4.1	11,423	58.5	7,293	37.4	0	0.0	19,520
2003	1,344	4.8	14,410	51.9	12,012	43.3	0	0.0	27,766
2004	194	1.3	7,206	47.5	7,618	50.2	163	1.1	15,181
2005	833	3.9	2,664	12.3	18,080	83.8	0	0.0	21,577
2006	550	2.4	15,234	66.4	7,109	31.0	41	0.2	22,933
2007	1,143	5.4	7,280	34.5	12,640	60.0	8	0.0	21,070
2008	1,252	4.7	12,181	45.3	13,442	50.0	0	0	26,874
2009	2,263	7.2	13,242	42.2	15,853	50.6	0	0	31,358
2010	1,480	2.8	8,501	16.3	42,222	80.8	52	0.1	52,255
2011	3,693	7.5	24,112	49.0	21,237	43.2	152	0.3	49,193
2012	1,294	3.1	12,331	29.7	27,881	67.1	48	0.1	41,553
2013	78	0.2	10,438	24.8	31,621	75.0	17	0.0	42,154
Average (2000–2012)	1,666	5.6	10,652	36.9	19,002	57.4	36	0.1	31,355
Average (2010–2013)	1,636	3.4	13,845	29.9	30,740	66.5	67	0.1	46,289

Appendix A15.–Summary of Afognak Lake phytoplankton seasonal mean biomass, by phylum, 2010–2013.

		Phylum														
		Chlorophyta (Green Algae)		Chrysophyta (Golden-brown Algae)		Bacillariophyta (Diatoms)		Cryptophyta (crytomonads)		Pyrrhophyta (Dinoflagellate)		Haptophyta		Cyanobacteria Blue-green Algae		Total
Date	Station	Biomass (mg/m^3)	%	Biomass (mg/m^3)	%	Biomass (mg/m^3)	%	Biomass (mg/m^3)	%	Biomass (mg/m^3)	%	Biomass (mg/m^3)	%	Biomass (mg/m^3)	%	Biomass (mg/m^3)
2010	1	1	0.5	14	10.7	38	30.0	8	6.2	65	51.2	0	0.0	2	1.4	127
2011	1	17	2.7	267	40.8	229	34.9	40	6.1	42	6.4	9	1.3	50	7.7	655
2012	1	52	4.6	0	0.0	728	63.7	134	11.8	210	18.4	0	0.0	18	1.6	1,143
2013	1	12,640	5.3	85,184	36.0	117,046	49.5	13,003	5.5	6,261	2.6	0	0.0	2,394	1.0	236,527
Mean		3,178	5.3	21,366	35.8	29,510	49.5	3,296	5.5	1,644	2.8	2	0.0	616	1.0	59,613
Median		35	3.9	140	15.6	479	53.2	87	9.7	137	15.3	0	0.0	34	3.8	899

Appendix A16.–Age-0 juvenile sockeye salmon weight, length, condition, calorie content, and stomach content by year, month, and location from Afognak Lake, 2009–2013.

				Age-0										
Date				Weight (g)		Length (mm)		Condition (*K*)		cal/g		Somach Contents		
			Sample		Standard		Standard		Standard		Standard			
Year	Month	Location	Size	Mean	Error	Mean	Error	Mean	Error	Mean	Error	% Full	% Zoo	% Insects
2009	August	Shoal	28	1.1	0.39	45.2	6.04	1.18	0.12	5499.3	274.35	72.9	50.4	49.6
2010	June	Shoal	21	0.5	0.48	35.2	6.19	0.90	0.19	6141.5	375.13	93.6	3.7	96.3
	July	Shoal	23	0.9	0.39	43.6	6.34	1.03	0.14	5704.5	117.13	69.2	36.8	63.2
	August	Shoal	17	2.2	0.64	54.6	6.39	1.29	0.16	5798.5	128.49	48.8	75.0	25.0
	August	Mid-lake	76	2.1	0.57	55.2	4.75	1.25	0.09	5872.2	150.99	52.0	47.6	52.4
	September	Mid-lake	22	2.3	0.65	55.6	5.47	1.29	0.12	5940.9	171.54	50.6	88.8	11.2
2011	June	Shoal	18	2.3	0.47	62.2	5.06	0.96	0.09	5382.7	237.30	73.8	18.8	81.3
	June	Mid-lake	14	2.5	0.56	61.9	4.62	1.07	0.25	5368.6	237.21	40.0	22.5	77.5
	October	Shoal	1	1.8		60.0		0.83		5616.9				
2012	May	Shoal	1	0.3		34.0		0.76		6618.1				
	June	Mid-lake	8	0.5	0.20	35.5	4.00	1.02	0.32	5731.5	318.50	50.7	71.6	28.4
	July	Shoal	125	1.0	0.53	44.4	6.61	1.03	0.17	5404.2	359.68	66.4	25.6	73.3
	July	Mid-lake	3	0.6	0.1	39.3	2.08	0.98	0.04	5403.0		62.5	92.5	7.5
	August	Shoal	76	2.0	0.68	55.3	6.26	1.16	0.12	5618.2	271.54	66.1	9.7	90.3
	August	Mid-lake	49	1.6	0.54	52.5	5.92	1.05	0.08	5635.1	149.21	72.9	53.1	47.4
	October	Shoal	4	2.2	0.43	60.0	3.56	1.01	0.02	5335.3		66.7	69.3	30.7
	October	Mid-lake	24	2.0	0.61	57.5	5.71	1.02	0.11	5676.7	170.78	49.7	80.2	19.8
2013	June	Shoal	36	0.7	0.31	39.3	5.62	1.00	0.22	6,052.4	269.01	40.5	41.9	58.1
	June	Mid-lake	4	0.7	0.31	40.0	4.76	0.96	0.12	5,791.4	138.11			
	July	Shoal	80	1.0	0.65	44.7	7.17	1.04	0.11	5,714.6	196.63	29.5	14.0	86.0
	July	Mid-lake	6	1.0	0.54	42.7	6.77	1.21	0.18	5,688.0	145.12	69.8		
	August	Shoal	46	1.6	0.50	51.1	5.34	1.18	0.16	5,830.4	258.47	34.0	5.6	94.4
	August	Mid-lake	3	2.0	0.31	54.7	3.51	1.20	0.07	5,804.9	146.15			
2009	Mean	Shoal	28	1.1	0.39	45.2	6.04	1.18	0.12	5499.3	274.35	72.9	50.4	49.6
2010	Mean	Shoal	61	1.2	0.50	44.5	6.31	1.07	0.16	5881.5	206.92	70.5	38.5	61.5
	Mean	Mid-lake	98	2.2	0.61	55.4	5.11	1.27	0.10	5906.6	161.27	51.3	68.2	31.8
2011	Mean	Shoal	19	2.1	0.47	61.1	5.06	0.90	0.09	5499.8	237.30	73.8	18.8	81.3
	Mean	Mid-lake	14	2.5	0.56	61.9	4.62	1.07	0.25	5368.6	237.21	40.0	22.5	77.5
2012	Mean	Shoal	206	1.4	0.55	48.4	5.47	0.99	0.10	5452.6	315.61	66.4	34.9	64.8
	Mean	Mid-lake	84	1.2	0.36	46.2	4.43	1.02	0.14	5611.6	212.83	58.9	74.3	25.8
2013	Mean	Shoal	162	1.1	0.49	45.0	6.04	1.07	0.17	5865.8	241.37	34.7	20.5	79.5
	Mean	Mid-lake	13	1.2	0.38	45.8	5.02	1.12	0.12	5761.5	143.13	69.8		
2009–2013	Mean	Shoal	476	1.4	0.48	48.85	5.78	1.04	0.13	5639.8	255.11	63.6	32.6	67.3
	Mean	Mid-lake	209	1.8	0.48	52.33	4.79	1.12	0.15	5662.0	188.61	55.0	55.0	45.0

Appendix A17.–Age-1 juvenile sockeye salmon weight, length, condition, calorie content, and stomach content by year, month, and location from Afognak Lake, 2009–2013.

Age-1														
Date				Weight (g)		Length (mm)		Condition (*K*)		cal/g		Somach Contents		
			Sample		Standard		Standard		Standard		Standard			
Year	Month	Location	Size	Mean	Error	Mean	Error	Mean	Error	Mean	Error	% Full	% Zoo	% Insects
2010	June	Shoal	28	2.7	0.58	66.0	2.53	0.94	0.11	5137.6	150.47	68.6	0.6	99.4
	July	Shoal	26	4.0	0.83	71.1	3.71	1.10	0.10	5614.5	294.94	75.0	21.3	78.7
	August	Shoal	39	4.9	0.62	74.1	2.30	1.19	0.09	5779.6	304.22	55.0	45.1	54.9
	August	Mid-lake	9	4.6	0.48	71.8	3.46	1.24	0.09	5924.1	117.62	32.5	65.0	35.0
	September	Shoal	1	4.7		74.0		1.16		5996.9				
	September	Mid-lake	3	4.9	0.78	74.0	3.00	1.21	0.06	5976.3	184.29			
2011	May	Mid-lake	20	2.5	0.74	65.8	6.81	0.87	0.66	4782.0	487.69	38.8	22.5	77.5
	June	Shoal	19	3.3	0.55	70.8	4.69	0.93	0.60	5133.1	199.43	22.5	45.0	55.0
	June	Mid-lake	15	3.2	0.49	68.0	4.60	1.00	0.11	5249.6	165.41	77.5	5.0	95.0
	August	Mid-lake	2	4.3	0.71	73.5	7.78	1.09	0.17	5573.6	526.91			
2012	May	Shoal	13	1.9	0.47	61.8	4.94	0.82	0.18	4982.1	67.94	33.1	52.1	47.9
	June	Shoal	25	2.7	0.73	66.6	5.93	0.89	0.11	5148.1	252.59	93.5	5.4	94.6
	July	Mid-lake	2	4.6	0.92	73.5	7.78	1.15	0.13	5666.1		80.0	95.0	5.0
	August	Shoal	20	5.9	0.55	80.2	1.98	1.14	0.10	5986.0	68.44	60.0	8.0	92.1
	August	Mid-lake	5	5.7	0.4	79.2	1.30	1.14	0.04	5851.7		68.8	73.8	26.3
	October	Mid-lake	2	4.7	0.57	77.5	2.12	1.01	0.04			37.5	25.0	75.0
2013	May	Shoal	59	2.7	0.52	67.7	4.41	0.86	0.05	5,088	124.24	29.8	1.5	98.5
	June	Shoal	49	3.7	0.61	72.4	5.07	0.96	0.10	5,307	254.08	43.1	0.0	100.0
	June	Mid-lake	1	2.8		63.0		1.12		5,642				
	July	Shoal	19	4.8	1.08	74.7	5.99	1.15	0.22	5,671	318.41	31.5	5.5	94.5
	July	Mid-lake	2	4.3	0.21	71.0	1.41	1.19	0.13	5,873	33.99			
	August	Shoal	18	4.8	0.71	73.6	3.78	1.19	0.11	5,925	263.68	31.3	2.8	97.2
2010	Mean	Shoal	94	4.1	0.67	71.3	2.85	1.10	0.10	5632.1	249.88	66.2	22.3	77.7
	Mean	Mid-lake	12	4.8	0.63	72.9	3.23	1.23	0.07	5950.2	150.96	32.5	65.0	35.0
2011	Mean	Shoal	19	3.3	0.55	70.8	4.69	0.93	0.60	5133.1	199.43	22.5	45.0	55.0
	Mean	Mid-lake	37	3.3	0.65	69.1	6.40	0.99	0.31	5201.7	393.34	58.2	13.8	86.3
2012	Mean	Shoal	58	3.5	0.58	69.5	4.28	0.95	0.13	5372.1	129.66	62.2	21.8	78.2
	Mean	Mid-lake	9	5.0	0.63	76.7	3.73	1.10	0.07	5758.9		62.1	64.6	35.4
2013	Mean	Shoal	145	4.0	0.73	72.1	4.81	1.04	0.12	5497.5	240.10	33.9	2.5	97.6
	Mean	Mid-lake	3	3.6	0.21	67.0	1.41	1.16	0.13	5757.4	33.99			
2009–2013	Mean	Shoal	316	3.7	0.63	70.9	4.16	1.00	0.24	5408.7	204.77	46.2	22.9	77.1
	Mean	Mid-lake	61	4.2	0.53	71.4	3.69	1.12	0.15	5667.1	192.76	50.9	47.8	52.2

Appendix A18.–Age-2 juvenile sockeye salmon weight, length, condition, calorie content, and stomach content by year, month, and location from Afognak Lake, 2009–2013.

Age-2														
Date				Weight (g)		Length (mm)		Condition (*K*)		cal/g		Somach Contents		
			Sample		Standard		Standard		Standard		Standard			
Year	Month	Location	Size	Mean	Error	Mean	Error	Mean	Error	Mean	Error	% Full	% Zoo	% Insects
2010	June	Shoal	1	5.0		81.0		0.94		4,894.0				
2012	May	Shoal	6	3.2	0.27	74.3	3.01	0.79	0.07	4,731.9	53.1	35.0	37.8	62.3
	June	Shoal	4	3.6	0.87	75.3	4.99	0.83	0.07	4,861.2	104.8	25.0	0.0	100.0
2013	May	Shoal	10	4.5	0.41	81.1	3.21	0.85	0.09	4,895.0	150.2	16.8	1.7	98.3
2010	Mean	Shoal	1	5.0		81.0		0.94		4,894.0				
2012	Mean	Shoal	10	3.4	0.57	74.8	4.00	0.81	0.07	4,796.5	79.0	30.0	18.9	81.1
2013	Mean	Shoal	10	4.5	0.41	81.1	3.21	0.85	0.09	4,895.0	150.2	16.8	1.7	98.3
2009–2013	Mean	Shoal	21	4.3	0.49	79.0	3.61	0.87	0.08	4,861.9	114.6	23.4	10.3	89.7

Appendix A19.–Estimated sockeye salmon outmigration and survivals by age and year, 2003–2013.

	Outgoing									Incoming					
	Sockeye Salmon Smolt Outmigration									Age Composition Based on Escapement					
	Estimate by Age and Year					Freshwater-age-1 Survival				Ocean Survival					
Year	Age-1	%	Age-2	%	Total	Eggs Produced [a]	Smolt Estimate	Egg to Smolt Survival		Age-1	% Survival	Age-2	% Survival	Total	% Survival
2003	373,513	66.1%	191,279	33.9%	564,793	33,639,606	373,513	1.1%		22,013	5.9	2,015	1.1	24,028	4.3
2004	387,584	90.1%	42,420	9.9%	430,004	27,740,800	387,584	1.4%		28,338	7.3	940	2.2	29,278	6.8
2005	521,025	93.0%	39,205	7.0%	560,230	28,668,395	521,025	1.8%		66,287	12.7	10,768	27.5	77,055	13.8
2006	146,527	71.4%	58,626	28.6%	205,153	16,031,136	146,527	0.9%		30,149	20.6	10,729	18.3	40,878	19.9
2007	237,383	86.2%	38,067	13.8%	275,450	23,680,758	237,383	1.0%		54,424	22.9	13,355	35.1	67,779	24.6
2008	92,018	46.7%	104,923	53.3%	196,941	23,815,921	92,018	0.4%		37,072	40.3				
2009	427,141	86.6%	64,560	13.1%	492,998	27,337,272	427,141	1.6%							
2010	237,716	76.9%	71,415	23.1%	309,130	28,545,025	237,716	0.8%							
2011	250,741	76.0%	79,207	24.0%	329,948	40,445,235	250,741	0.6%							
2012	99,541	77.6%	28,321	22.4%	127,861	80,933,164	99,541	0.1%							
2013	249,107	81.7%	55,630	18.2%	305,033	80,930,848	249,107	0.3%							
Mean (2003–2012)	277,319	77.1%	71,802	22.9%	349,251			1.0%	Mean (2003–2008)	39,714	18.3				
Mean (2003–2011)	297,072	77.0%	76,634	23.0%	373,850			1.1%	Mean (2003–2007)			7,561	16.8	47,804	13.9