Fishery Management Report No. 07-51

Chignik Watershed Ecological Assessment Project Season Report, 2006

by

Heather Finkle

September 2007

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

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

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ABSTRACT

Examining the responses to environmental disturbances can help us to understand how and why a population changes. We seek to understand how recent geomorphological changes in the Chignik watershed, located on the south side of the Alaska Peninsula, have affected the life history strategies of juvenile sockeye salmon and the watershed's health. Water quality, zooplankton, and catch data were seasonally assessed in 2006 to describe the mechanisms behind changes in rearing strategies and migratory behavior of juvenile sockeye salmon. Black Lake, a large, shallow nursery lake at the head of the system that has gradually lost depth over time, was not limited by primary production in 2006. However, Black Lake zooplankton biomass levels were low (28.16 mg dry wt/m^2) in June and July, which typically occurs before the downstream migration of juvenile sockeye salmon to Chignik Lake in July and August. August zooplankton samples were not collected from Black Lake in 2006. As all sampled Black Lake juvenile sockeye salmon were age 0., this indicated that they did not overwinter in Black Lake, but in lower portions of the watershed. The lower portions of the watershed have remained diverse, but fairly stable rearing environments. In Chignik Lake, primary production was not limited, but zooplankton biomass was low (293.75 mg dry wt/m^2) until June, which suggested top-down grazing pressure by juvenile sockeye salmon. Chignik Lagoon may serve as an alternative rearing area to release some of the grazing pressure in Chignik Lake imposed by the arrival of Black Lake fish. The migratory behavior of Black Lake juvenile sockeye salmon may be attributed to both physical conditions and forage availability. This project has indicated that sufficient habitat diversity exists within the Chignik watershed to help temper the effects of geomorphological changes to Black Lake upon its juvenile sockeye salmon. These data have been valuable for understanding the ecology of the watershed and for the management of its natural resources.

Key words: Chignik watershed, euphotic volume, limnology, juvenile sockeye salmon, zooplankton.

INTRODUCTION

Life history diversity and habitat heterogeneity are important for maintaining stable population dynamics under conditions of environmental change (Cattanéo et al. 2002; Reiman and Dunham 2000). Identifying and understanding responses to natural disturbances can yield valuable insights into the depth to which a disturbance can impact an ecosystem and the resiliency of its biota (Cattanéo et al. 2002; Detenbeck et al. 1992; Tonn et al. 2004). The Chignik watershed, located on the south side of the Alaska Peninsula, has recently experienced substantial geomorphological changes (Buffington 2001). Data from the Chignik watershed ecological assessment have been used to describe sockeye salmon *Oncorhynchus nerka* production trends and life history strategies in light of these physical changes (Bouwens and Finkle 2003; Finkle 2004). This study seeks to identify and understand the relationships among the Chignik watershed and its resident fauna relative to its dynamic ecosystem. This report serves to summarize the data from the 2006 sampling season.

Two lakes, two rivers, a lagoon, and various small creeks compose the Chignik watershed (Figure 1). Black Lake, at the head of the system, is an atypical sockeye salmon nursery lake; it is large (41.1 km^2), shallow (mean depth of 1.9 m, maximum depth 4.2 m; Ruggerone et al. 1993), and turbid. The large (24.1 km^2) and deep (mean depth of 26 m) Chignik Lake receives Black Lake run-off via the Black River. Both lakes are considered oligotrophic (Kyle 1992) and each maintains its own genetically distinct sockeye salmon run (Templin et al. 1999). The early run, which returns in June and July (sustainable escapement goal of 350,00 to 400,000 sockeye salmon; Witteveen et al. 2005), spawns in Black Lake and its tributaries. The smaller late run (sustainable escapement goal of 200,000 to 250,000 sockeye salmon; Witteveen et al. 2005), which returns from July through September, utilizes the beaches of Chignik Lake and its tributaries for spawning. Chignik Lake drains into the Chignik Lagoon through the Chignik River. The lagoon is shallow (<20 m), grassy and is composed of silted and cobbled beaches.

Chinook salmon *O. tshawytscha*, coho salmon *O. kisutch*, pink salmon *O. gorbuscha,* Dolly Varden *Salvelinus malma*, threespine stickleback *Gasterosteus aculeatus*, ninespine stickleback *Pungitius pungitius*, pond smelt *Hypomesus olidus*, starry flounder *Platyichthys stellatus*, pygmy whitefish *Prosopium coulteri,* and coastrange sculpin *Cottus aleuticus* are present throughout the Chignik system (Narver 1966; Parr 1972).

Over the last 20 years, Black Lake has been progressively getting shallower; currently it is at two-thirds of its 1968 mean depth of 3.0 m (Dahlberg 1968; Ruggerone et al. 1999). Roughly 40 years ago a natural sill, which created a hydrostatic dam, was lost when the confluence of the West Fork and Black rivers shifted approximately 4.8 km downstream (Buffington 2001). The loss of the hydrostatic dam increased the velocity of effluent from Black Lake, reducing its lake depth (Buffington 2001). With the reduction of lake depth, the Alec River, Black Lake's main tributary, now partially drains through Fan Creek (Figure 2). A sand spit has also formed, which begins approximately 1.5 km north of the Fan Creek outlet and extends across roughly two-thirds of the lake's width.

The reduced water volume of Black Lake, although nutrient rich (Finkle 2005), has been thought to negatively impact sockeye salmon rearing (Ruggerone et al. 1999). The frequent strong winds create a turbid environment for Black Lake rearing juvenile sockeye salmon (Finkle 2005; Ruggerone 1994), which may affect their success as visual predators (Doble and Eggers 1978). The lake's turbidity may also negatively affect the foraging ability of resident zooplankton populations (Kirk and Gilbert 1990). Warm water temperatures have been shown to influence the estival downstream migration of Black Lake juvenile sockeye salmon as rearing conditions become more metabolically taxing (Finkle 2004).

Density dependent limitations such as competition have also been suggested to influence migratory behavior (Rice et al. 1994). The loss of Black Lake rearing habitat may stress the available forage base, intensifying competition and creating top-down pressures. Top-down pressures are often reflected through decreased zooplankton size, which have been observed in Chignik and Black Lake *Bosmina* (Bouwens and Finkle 2003; Kerfoot 1987; Kyle 1992). For Black Lake, which possesses an abundant and preferred larval insect forage base, the subsequent departure from the water column by these insects when they hatch removes an important dietary component for rearing juvenile sockeye salmon. This late-summer event consequently increases competition and imposes greater top-down pressures on the Black Lake zooplankton forage base, which may cause juvenile sockeye salmon to seek forage elsewhere in the watershed. Competition and top-down pressures may also be exacerbated in Chignik Lake by the arrival of Black Lake fish, causing further downstream migration of juvenile sockeye salmon to avoid competition.

Chignik Lagoon may serve as a rearing ground for juvenile sockeye salmon seeking refuge from rearing limitations in the watershed. Phinney (1968) indicated that migratory movement of juvenile sockeye salmon from Chignik Lake to Chignik Lagoon might occur. Underyearling (age 0.) sockeye salmon have been observed to migrate from limited lake-rearing habitats and survive in marine conditions (Rice et al. 1994). This migratory behavior may exist in the Chignik watershed, if rearing limitations occur in Chignik or Black Lakes. Conversely, the upstream movement of sockeye salmon fry in the Chignik River may suggest that fry travel from Chignik Lagoon and Chignik River to over-winter in Chignik Lake (Iverson 1966). However, this observation has not been documented since the 1960s. Ultimately, the role of Chignik Lagoon in the life history strategies of juvenile sockeye salmon is still poorly understood, yet the lagoon cannot be dismissed as an alternate nursery area.

With the recent morphological changes to Black Lake, it is necessary to reestablish benchmarks of water quality, primary production, and secondary production in order to define and understand how those changes have affected resident populations throughout the watershed. These data will provide valuable insight into the mechanisms that drive the life history strategies of the watershed's fauna. These data will also enable the construction of a platform from which to reassess the current carrying capacity and thus escapement goals for the Chignik watershed relative to the present ecological conditions and fishery production levels.

OBJECTIVES

The objectives of this project were to

1) describe the physical characteristics of Black and Chignik Lakes, which include temperature, dissolved oxygen, and light penetration profiles,

2) describe the nutrient availability and primary production of Black and Chignik Lakes,

3) describe the zooplankton forage base available to juvenile sockeye salmon in Black and Chignik Lakes,

4) document the relative abundance of juvenile sockeye salmon throughout the Chignik watershed, and

5) describe the age and size characteristics of juvenile sockeye salmon throughout the Chignik watershed.

METHODS

LIMNOLOGY

One limnology/zooplankton sampling station was set on Black Lake in June 2006 (Figure 2; Appendix A). In May 2006, four sampling stations were established on Chignik Lake (Figure 3; Appendix A). Zooplankton samples and temperature, dissolved oxygen, and light penetration data were gathered at all four Chignik Lake stations but only Stations 2 and 4 were dedicated to the collection of water samples (Figure 3). Each station's location was logged with a global positioning system (GPS) and marked with a buoy. Sampling was conducted following protocols established by Finkle and Bouwens (2001). Water and zooplankton sampling occurred once every three weeks. Sampling occurred in June and July in Black Lake and from May to August in Chignik Lake (Table 1).

Dissolved Oxygen, Light, and Temperature

Water temperature (°C) and dissolved oxygen (mg/L) levels were measured with a YSI Y-52 meter. Readings were recorded at half-meter intervals to a depth of 5 m, then the intervals increased to one meter. Upon reaching a depth of 25 m, the intervals increased to every five meters. A mercury thermometer was used to ensure the meter's calibration.

Measurements of photosynthetically active wavelengths (kLux) were taken with an International Light IL1400A photometer. Readings began above the surface, at the surface, and proceeded at half-meter intervals until reaching a depth of 5 m. Readings were then recorded at one-meter intervals until the lake bottom or 0 kLux light penetration was reached. The mean euphotic zone depth (EZD) was determined (Koenings et al. 1987) for each lake and incorporated into a model for estimating sockeye salmon fry production (Koenings and Kyle 1997). One-meter temperature and dissolved oxygen measurements were compared to assess the physical conditions in the euphotic zones of each lake.

Secchi disc readings were collected from each station to measure water transparency. The depths at which the disc disappeared when lowered into the water column and reappeared when raised in the water column were recorded and averaged.

Water Sampling

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

One-liter samples were passed through 4.25-cm diameter 0.7-µm Whatman™ GF/F filters under 15 to 20-psi vacuum pressure for particulate N, P, and C analyses. For chlorophyll-*a* analysis, one liter of lake water from each depth sampled was filtered through a 4.25-cm diameter 0.7-µm Whatman™ GF/F filter, adding approximately 5 ml of $MgCO_3$ solution to the last 50 ml of the sample water during the filtration process. Upon completion of filtration, all filters were placed in individual petri dishes, labeled and frozen. For each sampled depth, 120 ml of sample water and 2 ml of Lugol's acetate were placed in a 125-ml poly bottle for phytoplankton analysis and stored at room temperature until processing.

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

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

Zooplankton

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

JUVENILE SOCKEYE SALMON SAMPLING

A beach seine was used to sample juvenile sockeye salmon. The sampling adhered to the following protocol.

Beach Seine

Eight sites (four Black Lake sites and four Chignik Lagoon sites; Figures 2 and 4) were routinely sampled every month beginning in May (Black Lake site 3 was not sampled due to the close proximity to sites 2 and 4; Table 1). Beach seine sampling of Chignik Lake and Chignik River was not conducted in the 2006 sampling season because of budget constraints. The beach seine sampling cycle started in Chignik Lagoon and proceeded upstream to minimize recapturing outmigrating fish. A 3-mm mesh, 10-m long, 1-m deep seine was used.

One beach seine set was made per site, unless the net deployed poorly and required an additional attempt. Either two people (one on shore acting as an anchor and the other wading off shore to make the haul) or a boat (haul) and one person (anchor) were used to make the set, dependent on weather conditions. The net was set similarly between sampling events to standardize effort.

Distribution, Abundance, and Size

Fish collected with the beach seine were identified and enumerated. The species composition of large catches (>500 fish) was estimated to prevent handling mortality. Up to 40 juvenile sockeye salmon and up to 20 juvenile Chinook and coho salmon each were randomly sampled per sampling event. Age, weight, and length (AWL) data, as described by Bouwens et al. (2000), were collected from the first 20 juvenile sockeye salmon greater than or equal to 45 mm in length. Length measurements were taken from an additional 20 juvenile sockeye salmon if present in the catch and greater than or equal to 45 mm in length. Juvenile coho and Chinook salmon caught during a sampling event were sampled (up to 20 for each species) only for length. AWL sampled fish were stored in a plastic ziplock bag with water until processed.

Scales were taken from the preferred area (INPFC 1963) of each fish sampled for AWL and placed on a labeled glass slide. Weight was measured to the nearest 0.1 g, and fork length (FL) was measured to the nearest 1 mm. All juvenile sockeye salmon scales were aged on a microfiche reader (Eyecom 3000) under 36X or 60X magnification and recorded in European notation (Koo 1962). AWL data were compiled in a database for comparison. Relative condition factor was determined for fish in each rearing area following the methods outlined by Quinn and Deriso (1999).

RESULTS

LIMNOLOGY

Temperature and Dissolved Oxygen

Black Lake

On June 5, the 1-m temperature in Black Lake was 13.2 °C, increasing to 15.2 °C on July 3 (Table 2; Figure 5). Dissolved oxygen levels at the 1-m depth went from 11.0 mg/L to 11.3 mg/L over the same time frame (Table 3; Figure 5). During the summer sampling season, temperature, and dissolved oxygen levels generally remained similar throughout the water column: a slight decrease from 14.3 °C on the surface to 12.8 °C at a depth of 2.5 m occurred on June 5 (Table 2; Figure 5).

Chignik Lake

One-meter temperatures in May, June, and July were 4.8, 8.1, and 11.8 °C respectively (Table 4; Figure 6). Temperatures in Chignik Lake were fairly homogenous over depth in May, June, and July (Table 4; Figure 6). Temperature variability did not exceed 1.9 °C over depth during any of the sampling events (Table 4; Figure 6). The 1-m dissolved oxygen level on May 25 was 16.1 mg/L, 12.9 mg/L on June 13, and 15.3 mg/L on July 12, (Table 5; Figure 6). Dissolved oxygen levels showed little variation over depth from May through July with the exception of fluctuations at depths around 10 m in May (Table 5; Figure 6).

Light Penetration and Water Transparency

Black Lake

Light penetrated the entire water column in Black Lake during the 2006 sampling season (Table 6; Figure 7). The EZD of Black Lake exceeded its average depth of 1.9 m, therefore, the mean lake depth was used to calculate the euphotic volume (EV) of 78.1 x 10^6 m^3 (Table 7; Figure 7). During the 2006 sampling season, water transparency in Black Lake ceased at a mean depth of 1.9 m.

Historical light penetration and water transparency data are available for comparison in Appendix B.

Chignik Lake

Light penetration ceased at a depth of 13 m in May and at 14 m in July (Table 8; Figure 7). The EZD was 4.60 m in May, 5.14 m in June, and 8.52 m in July (Table 7). The EV in Chignik Lake averaged 195.73 x 10^6 m^3 for the 2006 sampling season (Table 7; Figure 7). For the 2006 season, water transparency in Chignik Lake ceased at a mean depth of 2.2 m.

Historical light penetration and water transparency data are available for comparison in Appendix B.

Water Quality Parameters, Nutrient Levels, and Photosynthetic Pigments

Black Lake

The pH in Black Lake averaged 8.01 and alkalinity averaged 20.5 mg/L $CaCO_3$ (Table 9). TP averaged 20.4 mg/L P and FRP averaged 9.1 μg/L P in Black Lake in 2006 (Table 9). TKN was 216.0 μg/L N on average for Black Lake (Table 9). Ammonia averaged approximately 11.0 μg/L N, and nitrate + nitrite had a mean of 0.9 μg/L N in 2006+ (Table 9). Of the photosynthetic pigments, chlorophyll *a* averaged 4.44 μg/L and phaeophytin *a* had a seasonal mean of 0.76 μg/L (Table 9).

Chignik Lake

The pH in Chignik Lake averaged 7.70 and alkalinity averaged 24.8 mg/L $CaCO_3$ (Table 10). Total P averaged 16.0 mg/L P and FRP averaged 8.9 μg/L P for Chignik Lake in 2006 (Table 10). TKN was 86.0 μg/L N on average, ammonia averaged approximately 14.1 μg/L N, and nitrate + nitrite had a mean of 129.9 μg/L N in 2006 (Table 10). It should be noted that TKN was highly variable during 2006; it measured 18.0 μg/L N on May 25, 76.0 μg/L N on June 13, and 164.0 μg/L N on July 12. Of the photosynthetic pigments, chlorophyll *a* averaged 6.6 μg/L and phaeophytin *a* had a seasonal mean of 0.9 μg/L (Table 10).

Zooplankton

Black Lake

Historical Black Lake zooplankton data are available for comparison in Appendices C1-C4.

Copepod abundance (44,586/m^2) was greater than cladoceran abundance (1,593/m^2) on June 5 in Black Lake (Table 11; Figure 8; Appendix C2). On July 3, the copepod abundance (35,828/m^2) was greater than the cladoceran abundance (10,748/m^2; Table 11; Figure 8; Appendix C2). On average, the most prevalent identifiable genera of copepod was *Cyclops* (31,582/m^2); copepod nauplii (juveniles of unidentifiable genera) were also abundant with a seasonal mean of 7,564/m^2 (Table 11; Figure 8; Appendix C2). *Chydorinae* was the most prevalent cladoceran in Black Lake in 2006 (Table 11).

Copepod biomass was dominated by *Cyclops* in June (23.01 mg/m^2) and July (21.16 mg/m^2; Table 12; Appendix C4). The majority of cladoceran biomass, including ovigerous individuals, was comprised of *Bosmina* throughout the 2006 sampling season with a weighted average of 2.14 mg/m^2 (Table 12; Appendix C4). Copepod biomass was greater than cladoceran biomass over the sampling period in 2006 (Table 12; Figure 9; Appendix C4). It should be noted that because zooplankton sampling was absent in August for Black Lake, the 2006 seasonal averages may not truly reflect seasonal zooplankton trends in Black Lake; recent historical zooplankton data have shown dramatic increases in *Bosmina* biomass (Appendix C3).

Average seasonal lengths of the major zooplankton in Black Lake were 0.67 mm for *Diaptomu*s, 0.47 mm for C*yclops*, 0.36 mm for *Bosmina*, and 0.26 mm for *Chydorinae* (Table 13).

Chignik Lake

Historical Chignik Lake zooplankton data are available for comparison in Appendices D1-D4.

The average seasonal copepod density (314,482/m^2) was greater than the average seasonal cladoceran density (68,413/m^2) in 2006 (Table 14). Not including ovigerous zooplankton, *Cyclops* (175,889/m^2), *Epischura* (6,842/m^2), and *Diaptomus* (17,350/m^2) were the densest genera of copepods on average during the 2006 season (Table 14; Figure 10; Appendix D2). *Bosmina* (37,553/m^2) and *Daphnia* (8,053/m^2) were the densest cladocerans (Table 14; Figure 10; Appendix D2). The total average density of copepod and cladoceran zooplankton was less in Black Lake (46,378/m^2) than in Chignik Lake (382,895/m^2) in 2006, however the Black Lake sampling season was shorter than in past years, which may bias this comparison (Tables 11 and 14; Appendix D1). A spike in both copepod (July 12) and cladoceran (August 20) density occurred inthe Chignik Lake samples (Table 14; Figure 10).

Biomass estimates of the copepod *Cyclops* were substantially greater than biomass estimates of other copepod and cladocerans from May through August (Table 15; Appendix D4). The copepod *Cyclops* had the greatest biomass of all identified zooplankton in July (460.40 mg/m^2; Table 15; Appendix D4). *Bosmina* and *Daphnia* biomass levels generally increased from May to August (Table 15; Appendix D4). For the 2006 season, copepods (511.91 mg/m^2) had a greater biomass on average than cladocerans (74.24 mg/m^2) for a combined weighted average of 586.15

mg/m^2 Chignik Lake zooplankton, which was greater than that of Black Lake (Tables 12 and 15; Figures 9 and 11; Appendices C4 and D4).

Average seasonal lengths of the major non-egg bearing zooplankton in Chignik Lake were 0.83 mm for *Diaptomus*, 0.78 mm for C*yclops*, 0.53 mm for *Epischura*, 0.35 mm for *Bosmina*, and 0.52 mm for *Daphnia* (Table 16). Ovigerous zooplankton were generally longer than non-egg bearing individuals (Table 16).

JUVENILE SOCKEYE SALMON

Of the AWL sampled juvenile sockeye salmon that were captured in Black Lake and Chignik Lagoon with a beach seine, 51.8% were estimated to be age-0., 41.0% were age-1., 7.2% were age-2., and no age-3. fish were captured (Table 17).

Black Lake

Juvenile sockeye salmon beach seine catch rates in Black Lake were the greatest during June with 144 fish per haul and minimal in July with 6 fish per haul (Table 18). Stickleback, pond smelt, and juvenile coho salmon were more abundant than juvenile sockeye salmon in the July beach seine catch (Appendix E1).

Of the 599 sockeye salmon caught in Black Lake, all were age-0. fish (Table 19). It should be noted that majority of sockeye salmon captured in Black Lake were considered fry and assumed to be their first year of life (age-0.) because of their small size (<45 mm).

The mean length of Black Lake juvenile sockeye salmon was less than 45 mm in June, which increased to 50 mm by July (Table 20). Condition factor for Black Lake age-0. sockeye salmon was 1.33 in July (Table 20). Variability in length occurred over the sampling season for fish captured in July (Figure 12).

Chignik Lagoon

Chignik Lagoon juvenile sockeye salmon beach seine catch rates were 14 fish per haul in May and 78 fish per haul in June (Table 18). The late timing of the sampling that occurred at the beginning and the end of June mitigated the July sampling effort. Stickleback, Dolly Varden, and juvenile Chinook salmon were common in Chignik Lagoon catches (Appendix E1).

The seasonal average age composition for Chignik Lagoon beach seine catches was 41.2% age-0., 50.0% age-1., and 8.8% age-2. fish (Table 21; Figure 13). The age-0. component decreased from 77.8% in May to 35.6% in June (Table 21; Figure 13). Age-1. component percentages increased from May to June (Table 21; Figure 13).

Average lengths and weights of age-0. and age-1. juvenile sockeye salmon increased over the sampling season (Table 22; Figure 14). Average lengths of juvenile sockeye salmon varied greatly from May through June (Figure 15). Condition factor indices increased over the sampling period for all age groups of sampled fish (Table 22).

DISCUSSION

The 2006 water quality data indicated that nutrient levels in both lakes could be classified as being at low production (oligotrophic) levels as defined by several trophic state indices (Carlson 1977; Carlson and Simpson 1996; Forsberg and Ryding 1980). Nutrient levels during the 2006 sampling season in Black Lake and Chignik Lake were comparable to the past six years, and were comparable to other Alaska lakes (Honnold et al. 1996; Schrof and Honnold 2003).

Nutrient data can indicate limitations in aquatic environments. A comparison of total nitrogen (TN) to total phosphorous is a simple indicator of aquatic ecosystem health as both are necessary for primary production (Wetzel 1983; UF 2000). Nitrogen-phosphorous ratios of less than 10:1 indicate nitrogen limitations (USEPA 2000). In Black Lake, the average ratio of total nitrogen to total phosphorous (11.2 TN:1 TP) suggested that nitrogen was not a limiting nutrient (USEPA 2000). A comparison of the photosynthetic pigment, chlorophyll *a*, to its byproduct, phaeophytin *a*, showed that chlorophyll-*a* concentrations were not proportionally high (seasonal mean of 5.84 chlorophyll *a* to 1 phaeophytin *a*). This indicated that the potential for rapid algal (phytoplankton) growth existed in Black Lake because chlorophyll *a* was readily available for photosynthesis (COLAP 2001). Thus, even if nitrogen limitations existed, as described by the TN/TP ratios, an adequate volume of nitrogen was available for phytoplankton production, and thus had the potential to meet primary (zooplankton) consumption demands. In other words, nitrogen was not a limiting nutrient and phosphorous concentrations were in excess of the levels needed for primary production in Black Lake. Additionally, when primary production is taxed, phaeophytin-*a* levels tend to exceed chlorophyll-*a* levels (COLAP 2001). Phaeophytin-*a* levels did not exceed chlorophyll-*a* levels in either lake in 2006. The chlorophyll-*a* production in Chignik Lake was considered high with a seasonal mean chlorophyll-*a*: phaeophytin-*a* ratio of 7.3:1, which suggested that zooplankton were not limited by phytoplankton production. In Chignik Lake, photosynthetic pigments were more concentrated in 2000 and 2004 than in 2006. In 2006, zooplankton density was considered moderate to low by some indices (Mazumder and Edmundson 2002), although greater than density levels in past years. Therefore, despite the morphological changes to the watershed, primary nutrients did not appear to be a limiting factor in the ecosystem in 2006.

The pH in each lake may also suggest that primary production was not limited. Respiration by aquatic plants and animals contributes carbon dioxide to lake water supplemental to inflows of rain water exposed to atmospheric carbon dioxide and from underground water exposed to mineral formations and bacteria (Wetzel 1983). Photosynthesis uses dissolved carbon dioxide, which acts like carbonic acid (H_2CO_3) in water. The removal of carbon dioxide through photosynthesis, in effect, reduces the acidity of the water, therefore pH increases, while respiration adds carbon dioxide, increasing acidity and therefore lowering pH (Wetzel 1983). The seasonal pH levels in Black Lake remained consistent with levels from the 1960s (Narver 1966) and well within a safe pH range of roughly 4.5 to 9.5 (Wetzel 1983). The pH levels in Chignik Lake were slightly higher than pH levels from the 1960s (ranging from 7.2 to 7.5 on average; Narver 1966), and, like Black Lake, the pH levels declined (acidity increased) as the summer growing season slowed with waning daylight hours following the summer solistice. This may then suggest that ample nutrients were available to sustain primary production levels capable of producing noticeable seasonal fluctuations in pH. The recent increased pH levels in Chignik Lake may also suggest that juvenile sockeye salmon production has be come more competitive as indicated by a decline in zooplankton biomass. This, in turn, allows the phytoplankton biomass to increase and remove greater quantities of carbon dioxide from the water through photosynthesis, increasing the overall level of pH in Chignik Lake.

Bottom-up limitations can influence zooplankton communities (Kerfoot 1987; Kyle 1996; Stockner and MacIsaac 1996). Changes in phytoplankton species composition mediated by physical factors such as turbidity and temperature can negatively affect zooplankton consumption and assimilation rates (Wetzel 1983). Cladocerans, which are selective feeders, can have periods of reduced growth or reproduction in the absence of preferred forage (Dodson and Frey 2001). Similarly, Kirk and Gilbert (1990) noted that suspended particles dilute food concentrations in the water column reducing cladoceran population growth rates. For Black Lake zooplankton, this would infer that physical conditions such as turbidity have a greater impact upon the population than primary nutrients because primary nutrients do not appear to be limiting and lake visibility is often poor. Kirk and Gilbert (1990) also indicated that turbid environments favor rotifers over cladocerans, which is an observed trend in both Black and Chignik lakes. These observations suggest that turbidity influences the zooplankton populations in both lakes. In 2006, the Black Lake chlorophyll-*a* levels and turbidity were greater than in past years. Zooplankton densities were depressed during the 2006 sampling season. However, because samples were not collected in August, these densities may not accurately reflect seasonal zooplankton trends in Black Lake. Yet, the low June and July zooplankton densities may still suggest that the zooplankton population may have been negatively affected by physical conditions such as turbidity earlier in the 2006 season (Finkle 2005; UF 2000).

Planktivorous fishes can exert top-down pressures on zooplankton communities (Kyle 1996; Stockner and MacIsaac 1996). Evidence of overgrazed zooplankton populations can be reflected by a reduction in cladoceran body length and shifts in species composition (Kyle 1992; Schindler 1992). In Chignik and Black lakes, *Bosmina* on average were below the minimum elective feeding threshold of 0.40 mm for juvenile sockeye salmon (Kyle 1992). This suggests that top-down grazing pressures were removing the larger *Bosmina* from the zooplankton population.

Density estimates for copepods fluctuated in species composition on intra- and interannual time scales in Black and Chignik lakes. Historically in Black Lake, the greatest in-season average zooplankton densities fluctuate between *Cyclops* and *Bosmina*, with a large increase of *Bosmina* in August. This *Bosmina* spike coincides with the migration of Black Lake juvenile sockeye salmon to Chignik Lake, which suggests that the impact and magnitude of top-down pressures are greater than bottom-up pressures in Black Lake as biomass increases with a reduction in grazing pressure. Although sampling was not conducted in Black Lake during August, 2006, it appeared that the zooplankton population was behaving consistently with prior years' data based on the results for June and July. Chignik Lake *Cyclops* had a greater average biomass than other copepods in every year except 2003 when *Diaptomus* was the copepod with the highest density on average. During the 2004 and 2005 sampling seasons, the dominant zooplankton taxa in Chignik Lake fluctuated among *Cyclops*, *Diaptomus*, and *Daphnia*. These data suggest that top-down limitations occurred in Chignik Lake as changes in zooplankton taxa composition are often associated with predation (Donald et al. 2001; Helminen and Sarvala 1997). Additionally, zooplankton communities have been observed to shift from copepod to cladoceran species upon the initial recovery from a disturbance (Harig and Bain 1998). In 2006, *Cyclops* were the most abundant taxa throughout the sampling season, suggesting the Chignik Lake zooplankton community may still have been subjected to the effects of heavy predation or turbidity.

Changes in nutrients and forage bases can significantly impact higher trophic levels such as secondary or tertiary consumers (Kyle et al. 1988; Milovskaya et al. 1998). For the Chignik watershed, these negative changes can cause migratory behavior and/or decreased juvenile sockeye salmon freshwater survival (Bouwens and Finkle 2003; Parr 1972; Ruggerone 1994).

Thus, it is important to know and understand patterns of resource abundance and habitat usage in this dynamic watershed to enhance management of the system and conserve its resources.

Juvenile sockeye salmon have been observed to migrate in July from Black Lake to Chignik Lake (Finkle 2005; Narver 1966; Parr 1972; Ruggerone 1994). The lack of a substantial, if any, age-1. sockeye salmon component in Black Lake catches from 2000 to 2006 supports this observation because it indicates that age-0. fish are leaving the lake before the onset of winter. Similarly, Black Lake juvenile sockeye salmon catch rates declined from May to August during all five years of this study when August sampling occurred (Finkle 2005). Causes for the downstream migration of Black Lake fish have been attributed to low winter oxygen levels (Ruggerone 1994), density dependence (Narver 1966; Parr 1972), and temperature (Finkle 2004). The relatively high temperatures (~20 °C) that Black Lake can reach may influence the juvenile sockeye salmon rearing behavior in multiple ways. Field observations from the 2003 and 2004 sampling seasons noted that in July when the water temperature exceeded 15 °C, which is considered a metabolic productivity threshold for sockeye salmon (Brett et al. 1969), catch rates declined considerably. The shallow nature of Black Lake prevents a thermocline formation in the water column. This denies juvenile sockeye salmon the opportunity to vertically migrate from metabolically taxing warm temperatures to the refuge of cooler temperatures, which has been observed as a rearing strategy used by fishes exposed to similar conditions in other studies (Morgan and Metcalfe 2001; Sogard and Olla 2000;). Thus, Black Lake fish may be seeking the cooler, and less metabolically taxing, rearing environment of Chignik Lake. The warm water temperatures also coincided with the hatch of chironomid larvae, which are vital forage for Black Lake fish (Bouwens and Finkle 2003). Thus, when the chironomid larvae hatch and leave the water column, they become unavailable as a food source, which increases the grazing pressure on the zooplankton population. This increase in competition for food and the metabolically taxing rearing temperatures may contribute to the causes of the downstream migration of Black Lake juvenile sockeye salmon (Finkle 2004). However, further investigations are still required to verify these hypotheses.

The migration of Black Lake fish has forced Chignik Lake to support the majority of the watershed's juvenile sockeye salmon during the overwintering period. This increased rearing population can negatively impact resource availability in Chignik Lake. Comparisons of juvenile sockeye salmon age class compositions may offer evidence of rearing limitations in Chignik Lake. Data from the Chignik Smolt Enumeration project showed a decline in the percentage of outmigrating age-2. sockeye salmon in 2002, 2003, and 2004 (Bouwens and Newland 2004; Finkle and Newland 2005). An age-3. component was not present in the 2002-2005 data, which suggests that age-2. fish did not survive the winter or left the system and did not overwinter. Catch data from Chignik Lagoon in 2004 also showed a low proportion of age-2. fish compared to past beach seine sample data (Finkle 2005). These declines sequentially followed the overescapements of adults to both lakes in 2001 (a total of 1,136,918 sockeye salmon escaped) and to Chignik Lake in 2002 (344,519 sockeye salmon escaped). This may suggest that the age-2. population had poor freshwater rearing conditions, and therefore poor survival, due to increased competition from the increase in 2001 and 2002 offspring. In 2006, an age-2. component was present in Chignik Lagoon and Chignik Smolt Enumeration catches. These catches also coincided with increased zooplankton production in Chignik Lake.

Additionally, a comparison of present Chignik Lagoon juvenile sockeye salmon catch data to historical data (Phinney 1968) indicated that the current average smolt size (63 mm) has remained fairly homogenous over the summer sampling season as opposed to steadily increasing (from 76 to 97 mm), as was observed in the 1960s. This may suggest that because of the mid-summer downstream migration of Black Lake fish into Chignik Lake, the outmigration timing of Chignik sockeye salmon smolt has changed to accommodate the current rearing conditions in the watershed.

Underyearling sockeye salmon may successfully migrate to sea from resource limited freshwater rearing environments (Rice et al. 1994). Relatively substantial numbers of presmolt sockeye salmon have been captured in Chignik Lagoon in past years (Bouwens and Finkle 2003). Corroborating these observations, a larger proportion of age-0. fish (19 to 23%) composed the 2005 and 2006 Chignik River sockeye salmon smolt outmigrations compared to prior years (Finkle and Ruhl 2007). Juvenile sockeye salmon have been observed to migrate upstream from Chignik Lagoon to Chignik Lake as age-0. fish and outmigrate to sea the following spring (Iverson 1966). However, it is uncertain what proportion of these juvenile sockeye salmon go to sea, continue to rear in the lagoon, or return to rear and overwinter in Chignik Lake. Chignik Lagoon has provided a strong forage base of amphipods, pericardians, and other small crustacean taxa, which may alleviate some of the top-down pressure in Chignik Lake (Bouwens and Finkle 2003). Although the rearing and migratory behaviors of juvenile sockeye salmon in Chignik Lagoon are not completely understood, the lagoon appears to be another rearing habitat for juvenile sockeye salmon.

In light of the 2006 Chignik Watershed Ecological Assessment data, it is apparent that certain seasonal migratory and abundance trends have reoccurred. Repeated observation of these trends has elucidated patterns of diverse habitat use and alternate rearing strategies, which are vital for maintaining stable population dynamics under conditions of environmental change in the watershed. These data paired with Chignik sockeye salmon smolt outmigration and past ecological assessment data have also proven instrumental for enhancing management of the system by targeting the lower end of the escapement goals of the watershed. The data from these studies have been incorporated into current management decisions with the aim of improving sockeye salmon production. Continued observation of the watershed following these effects may indicate if the rearing environments are at their peak production levels or are limited or overtaxed.

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TABLES AND FIGURES

Table 1.–Limnology, zooplankton, and beach seine sampling events, 2006.

Location	Date	Type of sampling
Black Lake	5-Jun	Water, zooplankton, and beach seine
	3-Jul	Water, zooplankton, and beach seine
Chignik Lagoon	22-May	Beach seine
	22-Jun	Beach seine
Chignik Lake	25-May	Water and zooplankton
	13-Jun	Water and zooplankton
	12-Jul	Water and zooplankton
	20-Aug	Water and zooplankton

Table 2.–Water temperature, by depth and date, for Black Lake, 2006.

Depth	Temperature (°C)	
(m)	5-Jun	3-Jul
0.0	14.3	15.1
0.5	13.6	15.2
1.0	13.2	15.2
1.5	13.0	15.2
2.0	12.9	15.2
2.5	12.8	15.2
3.0	12.8	- [a]

[a] Bottom depth did not exceed 2.5 m on July 3, 2007.

Table 3.–Dissolved oxygen levels by depth and date, for Black Lake, 2006.

Depth	Dissolved oxygen (mg/L)	
(m)	5-Jun	3-Jul
0.0	11.3	11.1
0.5	11.1	11.3
1.0	11.0	11.3
1.5	11.0	11.3
2.0	11.1	11.3
2.5	11.1	11.3
3.0	11.4	- [a]

[a] Bottom depth did not exceed 2.5 m on July 3, 2007.

Table 4.–Water temperature, averaged over all stations, by depth and date for Chignik Lake, 2006.

Depth	Temperature (°C)		
(m)	25-May	13-Jun	12-Jul
0.0	5.2	8.3	11.9
0.5	4.9	8.1	11.8
1.0	4.8	8.1	11.8
1.5	4.7	8.0	11.7
2.0	4.6	8.0	11.7
2.5	4.5	8.0	11.6
3.0	4.5	7.9	11.6
3.5	4.5	7.9	11.6
4.0	4.4	7.8	11.5
4.5	4.4	7.8	11.5
5.0	4.3	7.8	11.5
6.0	4.3	7.7	11.4
7.0	4.3	7.6	11.4
8.0	4.3	7.6	11.3
9.0	4.2	7.5	11.2
10.0	4.2	7.5	11.2
11.0	4.2	7.5	11.1
12.0	4.2	7.4	11.1
13.0	4.2	7.4	11.0
14.0	4.2	7.3	11.0
15.0	4.2	7.3	10.9
16.0	4.1	7.2	10.9
17.0	4.1	7.2	10.8
18.0	4.1	7.2	10.7
19.0	4.1	7.1	10.6
20.0	4.1	7.1	10.6
21.0	4.0	7.1	10.5
22.0	4.0	7.1	10.5
23.0	4.0	7.1	10.4
24.0	4.0	7.0	10.4
25.0	4.0	7.0	10.3
30.0	4.0	6.9	10.0

Table 5.–Dissolved oxygen levels, averaged over all stations, by depth and date for Chignik Lake, 2006.

Depth	Dissolved oxygen (mg/L)		
(m)	25-May	13-Jun	12-Jul
0.0	17.2	12.9	15.4
0.5	16.3	12.9	15.4
1.0	16.1	12.9	15.3
1.5	16.2	12.8	15.3
2.0	15.8	12.8	15.3
2.5	15.6	12.8	15.3
3.0	15.6	12.8	15.3
3.5	15.2	12.8	15.2
4.0	15.1	12.8	15.2
4.5	15.0	12.9	15.2
5.0	14.9	12.9	15.3
6.0	14.7	12.8	15.3
7.0	14.5	12.9	15.2
8.0	14.3	12.9	15.2
9.0	14.4	12.9	15.2
10.0	14.4	12.8	15.2
11.0	14.4	13.0	15.2
12.0	14.4	13.0	15.2
13.0	14.5	13.1	15.2
14.0	14.7	13.1	15.2
15.0	14.8	13.2	15.2
16.0	15.0	13.3	15.1
17.0	15.1	13.3	15.1
18.0	15.2	13.4	15.1
19.0	15.2	13.5	15.1
20.0	15.3	13.5	15.1
21.0	15.3	13.6	15.1
22.0	15.3	13.7	15.2
23.0	15.3	13.8	15.2
24.0	15.4	13.9	15.2
25.0	15.4	13.9	15.2
30.0	15.9	14.2	15.2

Table 6.–Average monthly solar illuminance readings by depth and date for Black Lake, 2006.

	Solar illuminance (kLux)				
Depth	May	June	July[a]	August[a]	Average
0.0	5,830.0	917.0	ND	ND	3,373.5
0.5	5,550.0	456.0	ND	ND	3,003.0
1.0	3,270.0	266.0	ND	ND	1,768.0
1.5	2,110.0	157.0	ND	ND	1,133.5
2.0	1,117.0	100.3	ND	ND	608.7
2.5	772.0	72.0	ND	ND	422.0
3.0	745.0	49.8	ND	ND	397.4

[a] ND = no data.

Table 7.–Euphotic Zone Depth (EZD) and Euphotic Volume (EV) of Black and Chignik lakes, by month, 2006.

		2006				
Lake		May	June	July	August	Average[a]
Black[b]	EZD	ND	5.77	4.57	ND	5.28
	Mean EV[c]	ND	78.10	78.10	ND	78.10
Chignik	EZD	4.60	5.14	8.52	ND	8.12
	Mean EV[c]	110.96	123.82	205.32	ND	195.73

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

[b] The mean depth of Black Lake is 1.9 m; this value was used for the EV calculations instead of the EZDs, which exceeded 1.9 m.

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

Table 8.–Average monthly solar illuminance readings by depth and date for Chignik Lake, 2006.

	Solar illuminance (kLux)				
Depth	May	June	July	August[a]	Average
0.0	5,172.5	1,378.8	1,829.3	ND	2,793.5
0.5	3,498.3	692.0	1,093.5	ND	1,761.3
1.0	2,559.8	361.8	644.5	ND	1,188.7
1.5	1,807.0	193.3	506.9	ND	835.7
2.0	1,449.3	127.3	181.8	ND	586.1
2.5	816.5	82.8	198.7	ND	366.0
3.0	830.8	55.1	169.9	ND	351.9
3.5	664.3	38.3	152.5	ND	285.0
4.0	486.3	29.0	244.0	ND	253.1
4.5	381.0	22.6	182.0	ND	195.2
5.0	296.3	19.1	141.5	ND	152.3
6.0	172.5	21.5	101.6	ND	98.5
7.0	101.3	29.8	47.7	ND	59.6
8.0	60.1	0.5	26.9	ND	29.2
9.0	37.0	-	20.2	ND	28.6
10.0	20.2	-	9.4	ND	14.8
11.0	9.0	-	5.7	ND	7.4
12.0	3.7	-	3.3	ND	3.5
13.0	0.8	-	1.9	ND	1.4
14.0	-	-	1.1	ND	1.1
15.0	-	-	-	ND	-
16.0	-	-	-	ND	-
17.0	-	-	-	ND	-
18.0	-	-	-	ND	-
19.0	-	-	-	ND	-
20.0	-	-	-	ND	-
21.0	-	-	-	ND	-
22.0	-	-	-	ND	-
23.0	-	-	-	ND	-
24.0	-	-	-	ND	-
25.0	-	-	-	ND	-
26.0	-	-	-	ND	-
27.0	-	-	-	ND	-
28.0	-	-	-	ND	-
29.0	-	-	-	ND	-
30.0	-	-	-	ND	-

[a] ND = no data.

Table 9.–Water quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Black Lake, 2006.

	5-Jun	3-Jul	Average
pH	8.13	7.89	8.01
Alkalinity (mg/L)	23.0	18.0	20.5
Total P (mg/L P)	17.4	23.4	20.4
TFP (mg/L P)[a]	ND	ND	-
FRP (μg/L P)	8.8	9.4	9.1
TKN (μg/L N)	166.0	266.0	216.0
Ammonia (μg/L N)	12.5	9.4	11.0
Nitrate + Nitrite (μg/L N)	0.9	0.9	0.9
Chlorophyll *a* (μg/L)	3.74	5.13	4.44
Phaeophytin *a* (μg/L)	0.37	1.15	0.76

[a] ND = no data.

Table 10.–Water quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Chignik Lake, 2006.

	25-May	13-Jun	12-Jul	Average
pH	7.78	7.65	7.66	7.70
Alkalinity (mg/L)	24.0	20.8	29.8	24.8
Total P (mg/L P)	15.0	19.6	13.3	16.0
TFP (mg/L P)[a]	ND	ND	ND	-
FRP (μg/L P)	5.1	12.6	8.9	8.9
TKN (μg/L N)	18.0	76.0	164.0	86.0
Ammonia (μg/L N)	ND	11.8	16.5	14.1
Nitrate + Nitrite (μg/L N)	148.0	131.8	110.0	129.9
Chlorophyll *a* (μg/L)	8.6	8.7	2.4	6.6
Phaeophytin *a* (μg/L)	0.7	1.2	0.7	0.9

[a] ND =no data.

Table 11.–Average number of zooplankton per m^2 from Black Lake by sample date, 2006.

Taxon	Sample date 6/5	7/3	Seasonal average
Copepods			
Epischura	-	-	-
Ovig. *Epischura*	-	-	-
Diaptomus	-	1,592	796
Ovig. *Diaptomus*	-	-	-
Cyclops	32,909	30,255	31,582
Ovig. *Cyclops*	-	-	-
Harpaticus	531	-	266
Nauplii	11,146	3,981	7,564
Total copepods	44,586	35,828	40,207
Cladocerans			
Bosmina	1,062	3,583	2,323
Ovig. *Bosmina*	-	1,592	796
Daphnia l.	-	-	-
Ovig. *Daphnia l.*	-	-	-
Chydorinae	531	5,573	3,052
Total cladocerans	1,593	10,748	6,171
Total copepods + cladocerans	46,179	46,576	46,378

Table 12.–Biomass estimates (mg dry weight/m^2) of the major Black Lake zooplankton taxon by sample date, 2006.

Taxon	Sample date 6/5	7/3	Seasonal average[a]	Weighted average[a]
Copepods				
Epischura	-	-	-	-
Diaptomus	-	2.21	1.11	1.11
Cyclops	23.01	21.16	22.08	22.11
Harpaticus	0.35	-	0.17	0.17
Total copepods	23.36	23.37	23.36	23.39
Cladocerans				
Bosmina	1.22	4.11	2.66	2.14
Ovigerous *Bosmina*	-	1.67	0.83	0.83
Daphnia longiremis	-	-	-	-
Chydorinae	0.30	3.18	1.74	1.80
Total cladocerans	1.52	8.96	5.24	4.77
Total Biomass	24.88	32.33	28.60	28.16

[a] Seasonal averages were estimated using average lengths and weighted averages were estimated using weighted lengths.

Table 13.–Average lengths (mm) of zooplankton in Black Lake by sample date, 2006.

Taxon	Sample date 6/5	7/3	Seasonal average
Copepods			
Epischura	-	-	0.00
Diaptomus	-	0.67	0.67
Cyclops	0.47	0.46	0.47
Harpaticus	0.45	-	0.45
Nauplii	-	-	-
Cladocerans			
Bosmina	0.42	0.29	0.36
Ovigerous *Bosmina*	-	0.34	0.34
Daphnia l.	-	-	-
Chydorinae	0.25	0.26	0.26

Table 14.–Average number of zooplankton per m^2 from Chignik Lake, by sample date, 2006.

Taxon	Sample date 5/25	6/13	7/12	8/20	Seasonal average
Copepods					
Epischura	2,654	2,289	4,247	18,179	6,842
Ovigerous *Epischura*	-	-	-	-	-
Diaptomus	1,327	12,739	7,962	47,373	17,350
Ovigerous *Diaptomus*	-	1,194	796	3,583	1,393
Cyclops	253,649	145,104	205,680	99,124	175,889
Ovigerous *Cyclops*	-	-	72,718	25,876	24,648
Harpaticus	531	3,085	1,062	664	1,335
Nauplii	13,668	13,436	45,117	275,876	87,024
Total copepods	271,829	177,846	337,580	470,674	314,482
Cladocerans					
Bosmina	464	199	7,431	142,118	37,553
Ovigerous *Bosmina*	-	-	1,858	31,715	8,393
Daphnia longiremis	2,256	3,682	3,450	22,824	8,053
Ovigerous *Daphnia longiremis*	664	299	796	2,654	1,103
Chydorinae	664	3,483	33,970	15,127	13,311
Total cladocerans	4,047	7,663	47,505	214,438	68,413
Total copepods + cladocerans	275,876	185,509	385,084	685,111	382,895

Table 15.–Biomass estimates (mg dry weight/m^2) of the major zooplankton species in Chignik Lake by sample date, 2006.

Taxon	Sample date 5/25	6/13	7/12	8/20	Seasonal average[a]	Weighted average[a]
Copepods						
Epischura	2.58	2.25	1.05	12.97	4.71	5.47
Ovigerous *Epischura*	-	-	-	-	-	-
Diaptomus	2.92	50.29	10.15	78.75	35.53	37.70
Ovigerous *Diaptomus*	-	16.11	4.42	36.31	14.21	28.39
Cyclops	281.59	349.64	460.40	141.97	308.40	300.73
Ovigerous *Cyclops*	-	-	240.96	174.63	103.90	138.65
Harpaticus	0.32	2.41	-	0.57	0.82	0.96
Total Copepods	287.41	420.70	717.00	445.19	467.57	511.91
Cladocerans						
Bosmina	0.72	0.25	3.65	114.21	29.71	36.75
Ovigerous *Bosmina*	-	-	0.87	38.33	9.80	12.21
Daphnia longiremis	3.57	3.36	1.91	26.59	8.86	10.21
Ovigerous *Daphnia longiremis*	1.63	0.69	0.77	6.96	2.51	2.80
Chydorinae	0.41	1.88	13.16	10.09	6.38	6.60
Total Cladocerans	6.34	6.18	20.37	196.18	57.26	74.24
Total Biomass	293.75	426.88	737.36	641.36	524.84	586.15

[a] Seasonal averages were estimated using average lengths and weighted averages were estimated using weighted lengths.

Table 16.–Average length (mm) of zooplankton from Chignik Lake by sample date, 2006.

Taxon	Sample date 5/25	6/13	7/12	8/20	Seasonal average
Copepods					
Epischura	0.58	0.58	0.46	0.52	0.53
Ovigerous *Epischura*	-	-	-	-	-
Diaptomus	0.73	1.03	0.84	0.71	0.83
Ovigerous *Diaptomus*	-	1.50	1.4	1.36	1.42
Cyclops	0.58	0.82	1.10	0.62	0.78
Ovigerous *Cyclops*	-	-	1.33	1.18	1.26
Harpaticus	0.42	-	-	0.51	0.46
Nauplii	-	-	-	-	-
Cladocerans					
Bosmina	0.39	0.37	0.33	0.30	0.35
Ovigerous *Bosmina*	-	-	0.33	0.36	0.34
Daphnia longiremis	0.62	0.44	0.49	0.53	0.52
Ovigerous *Daphnia longiremis*	0.75	0.73	0.67	0.76	0.73
Chydorinae	0.27	0.24	0.30	0.27	0.27

Table 17.–Total catch of juvenile sockeye salmon, by age and location, from the Chignik watershed, 2006.

Location		Age 0.	1.	2.	3.	Total
Black Lake		100.0%	0.0%	0.0%	0.0%	100.0%
	Sample	15	0	0	0	15
	Total catch[a]	599	0	0	0	599
Chignik Lagoon		41.2%	50.0%	8.8%	0.0%	100.0%
	Sample	28	34	6	0	68
	Total catch[a]	58	71	13	0	142
Combined		51.8%	41.0%	7.2%	0.0%	100.0%
	Sample	43	34	6	0	83
	Total catch[a]	384	304	54	0	741

[a] Total sockeye catches are not apportioned based on fish lengths greater or less than 45 mm.

Table 18.–Total beach seine hauls, total catch, and catch per haul, by month, of juvenile sockeye salmon from the Chignik watershed, 2006.

		2006[a]			2000	2001	2002	2003	2004	2005
Area	Month	Number of hauls	Total Sockeye catch	Sockeye catch/haul	Sockeye catch/haul	Sockeye catch/haul	Sockeye catch/haul	Sockeye catch/haul	Sockeye catch/haul	Sockeye catch/haul
Black Lake	May	ND	ND	-	-	75	241	23	91	20
	June	4	575	144	328	16	405	11	69	79
	July	4	24	6	59	11	225	4	14	10
	August	ND	ND	-	14	-	3	1	1	0
Chignik Lake	May	ND	ND	-	-	209	31	-	-	-
	June	ND	ND	-	4	94	24	3	-	-
	July	ND	ND	-	26	15	32	6	-	-
	August	ND	ND	-	9	22	19	3	-	-
Chignik River	May	ND	ND	-	198	-	406	-	-	-
	June	ND	ND	-	-	274	492	443	-	-
	July	ND	ND	-	363	494	262	272	-	-
	August	ND	ND	-	219	219	-	104	-	-
Chignik Lagoon	May	3	42	14	22	218	3	12	177	13
	June	4	310	78	39	93	200	47	53	65
	July	ND	ND	-	26	79	141	50	196	-
	August	ND	ND	-	138	307	-	4	39	24

[a] ND = no data.

Table 19.–Total catch of juvenile sockeye salmon from Black Lake, by age and gear type, 2006.

			Total sockeye	Sample					Estimated age[a]				
Area	Gear type	Month	catch	0.	1.	2.	3.	Total	0.	1.	2.	3.	Total
Black Lake	Beach seine	June	575	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				575	0	0	0	575	575	0	0	0	575
	Beach seine	July	24	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				15	0	0	0	15	24	0	0	0	24
Black Lake Total		All	599	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				590	0	0	0	590	599	0	0	0	599

[a] Age compositions are not apportioned to total sockeye catches based on fish lengths greater or less than 45 mm.

Table 20.–Average length, weight, and condition factor by age and gear type for juvenile sockeye salmon captured in Black Lake, 2006.

				Length (mm)		Weight (g)		Condition factor	
Gear type	Month	Age	Sample size	Average	SD	Average	SD	Average	SD
Beach seine	May	0	0	-	-	-	-	-	-
	June[a]	0	0	-	-	-	-	-	-
	July	0	15	50	10.0	1.8	0.40	1.33	0.26
	August	0	0	-	-	-	-	-	-

[a] AWL estimates are based on fish with lengths equal to or greater than 45 mm.

Table 21.–Total beach seine catch, by age, of juvenile sockeye salmon from Chignik Lagoon, 2006.

	Total sockeye	Sample					Estimated age[a]				
Month	catch	0.	1.	2.	3.	Total	0.	1.	2.	3.	Total
May	42	77.8%	22.2%	0.0%	0.0%	100.0%	77.8%	22.2%	0.0%	0.0%	100.0%
		7	2	0	0	9	33	9	0	0	42
June	310	35.6%	54.2%	10.2%	0.0%	100.0%	35.6%	54.2%	10.2%	0.0%	100.0%
		21	32	6	0	59	110	168	32	0	310
July	ND[b]	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-
August	ND[b]	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-
All	352	41.2%	50.0%	8.8%	0.0%	100.0%	41.2%	50.0%	8.8%	0.0%	100.0%
		28	34	6	0	68	145	176	31	0	352

[a] Age compositions are not apportioned to total sockeye catches based on fish lengths greater or less than 45 mm.
[b] ND = No data.

Table 22.–Average length, weight, and condition factor by age of juvenile sockeye salmon captured by beach seine in Chignik Lagoon, 2006.

			Length (mm)		Weight (g)		Condition factor	
Month	Age	Sample size[a, b]	Average	SD	Average	SD	Average	SD
May	0	2	45	6.4	0.6	0.10	0.69	0.10
	1	2	67	5.1	2.5	0.19	0.82	0.06
	2	0	-	-	-	-	-	-
June	0	21	58	14.0	1.6	0.44	0.90	0.22
	1	32	76	22.4	4.3	1.35	0.95	0.28
	2	6	83	11.0	5.3	0.71	0.93	0.12
July	0	ND	-	-	-	-	-	-
	1	ND	-	-	-	-	-	-
	2	ND	-	-	-	-	-	-
August	0	ND	-	-	-	-	-	-
	1	ND	-	-	-	-	-	-
	2	ND	-	-	-	-	-	-

[a] AWL estimates are based on fish with lengths equal to or greater than 45 mm.
[b] ND = No data.

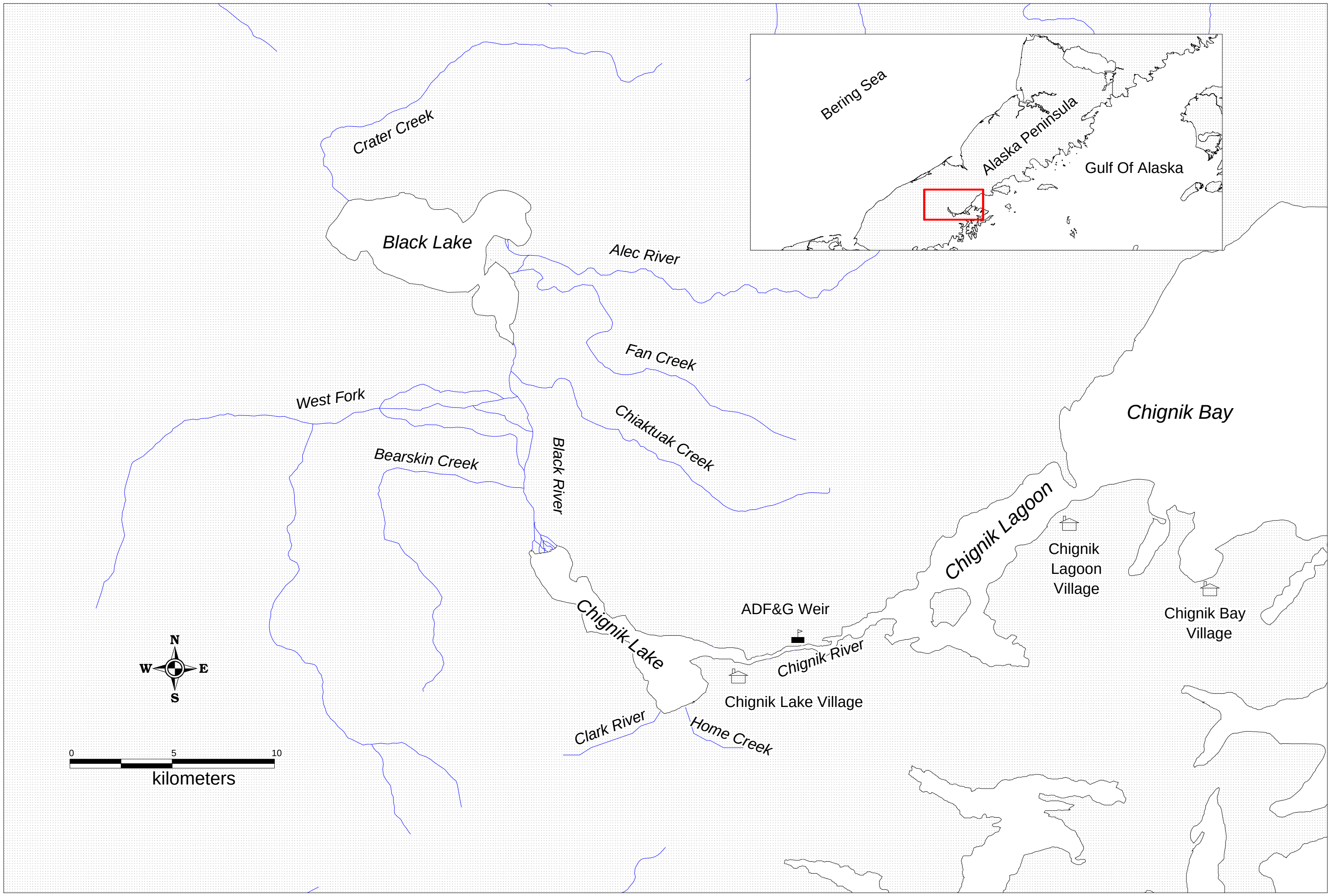

Figure 1.–Chignik watershed and location on the Alaska Peninsula (inset).

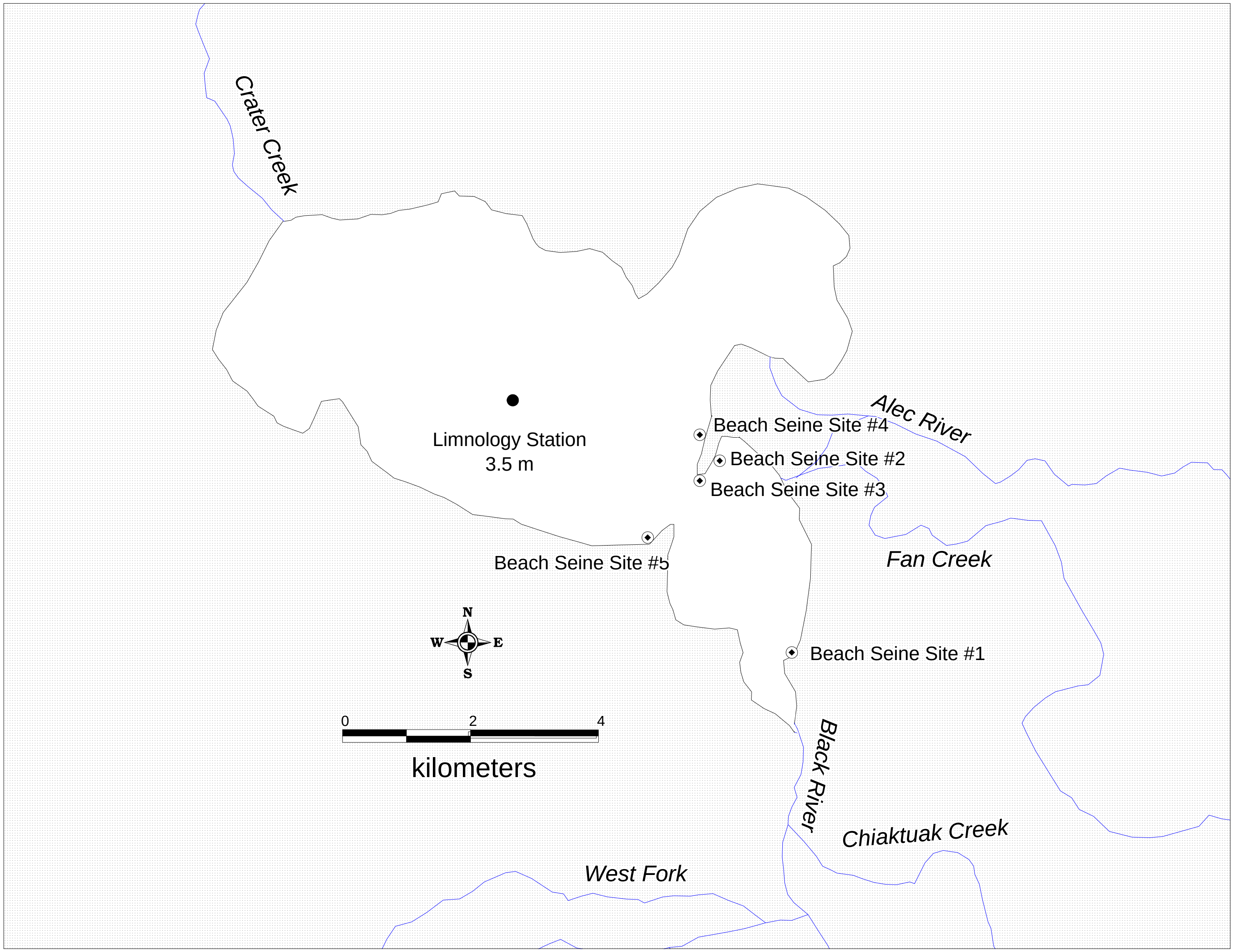

Figure 2.–Black Lake sampling sites.

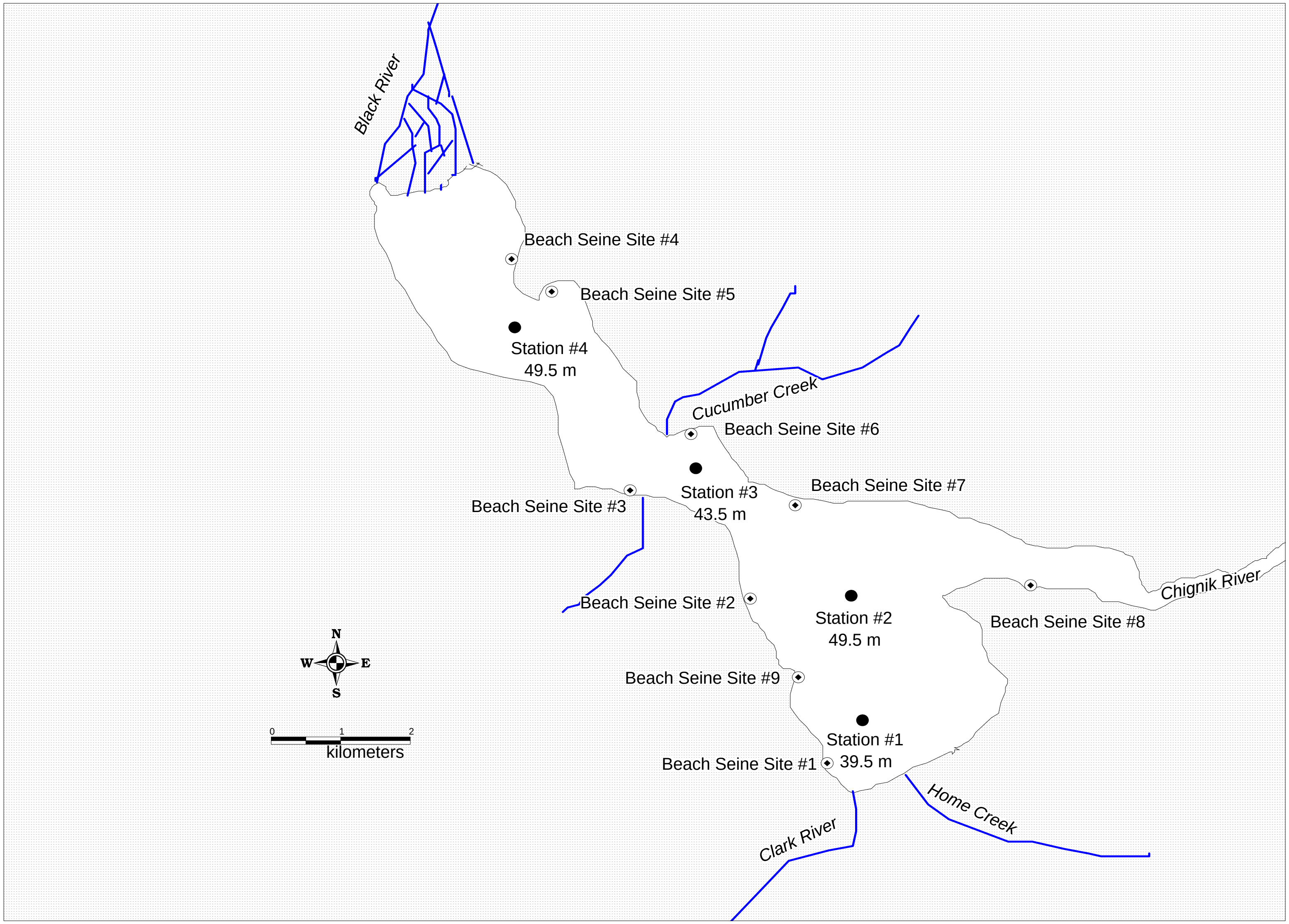

Figure 3.–Chignik Lake sampling sites.

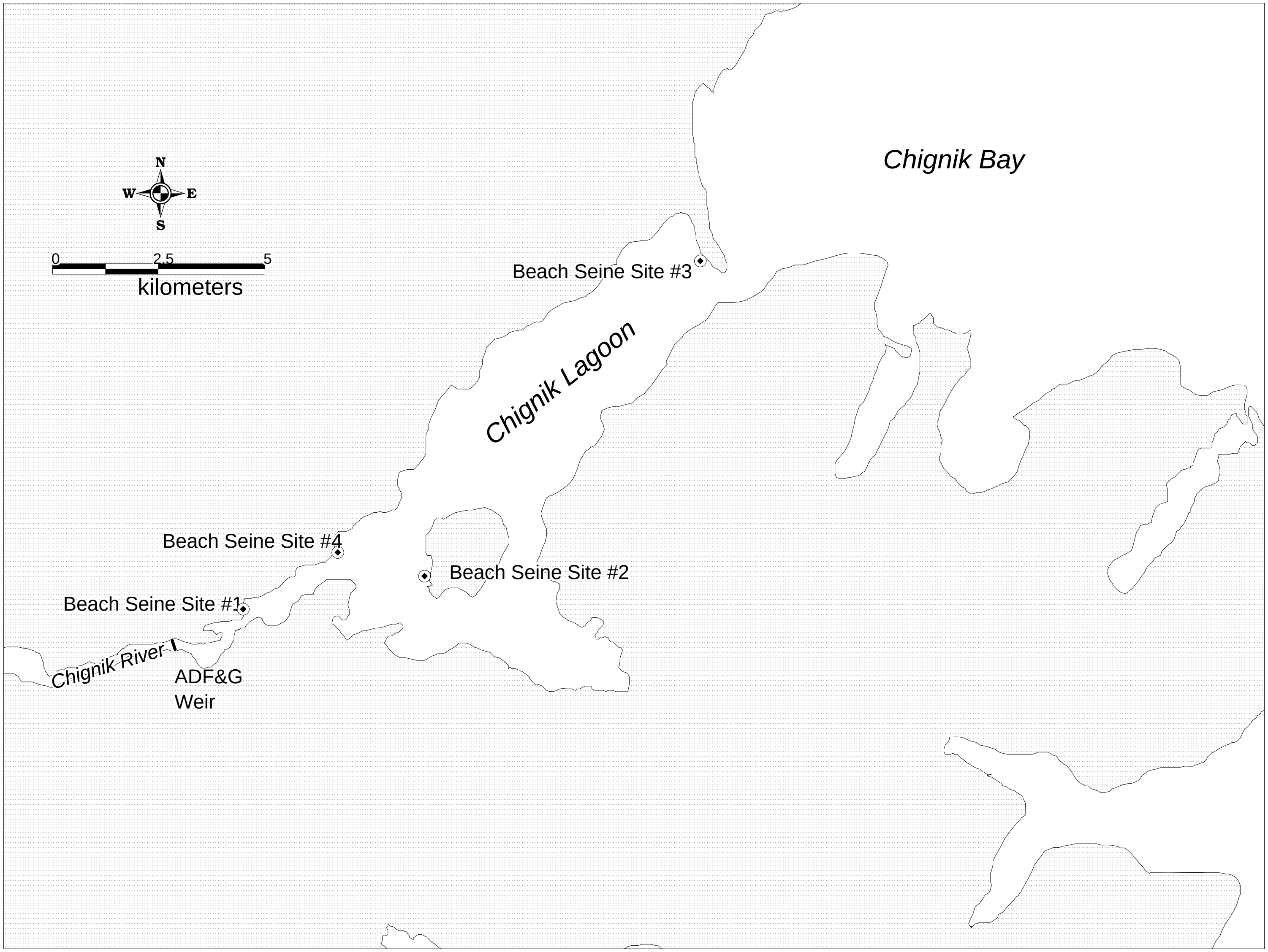

Figure 4.–Chignik Lagoon sampling sites.

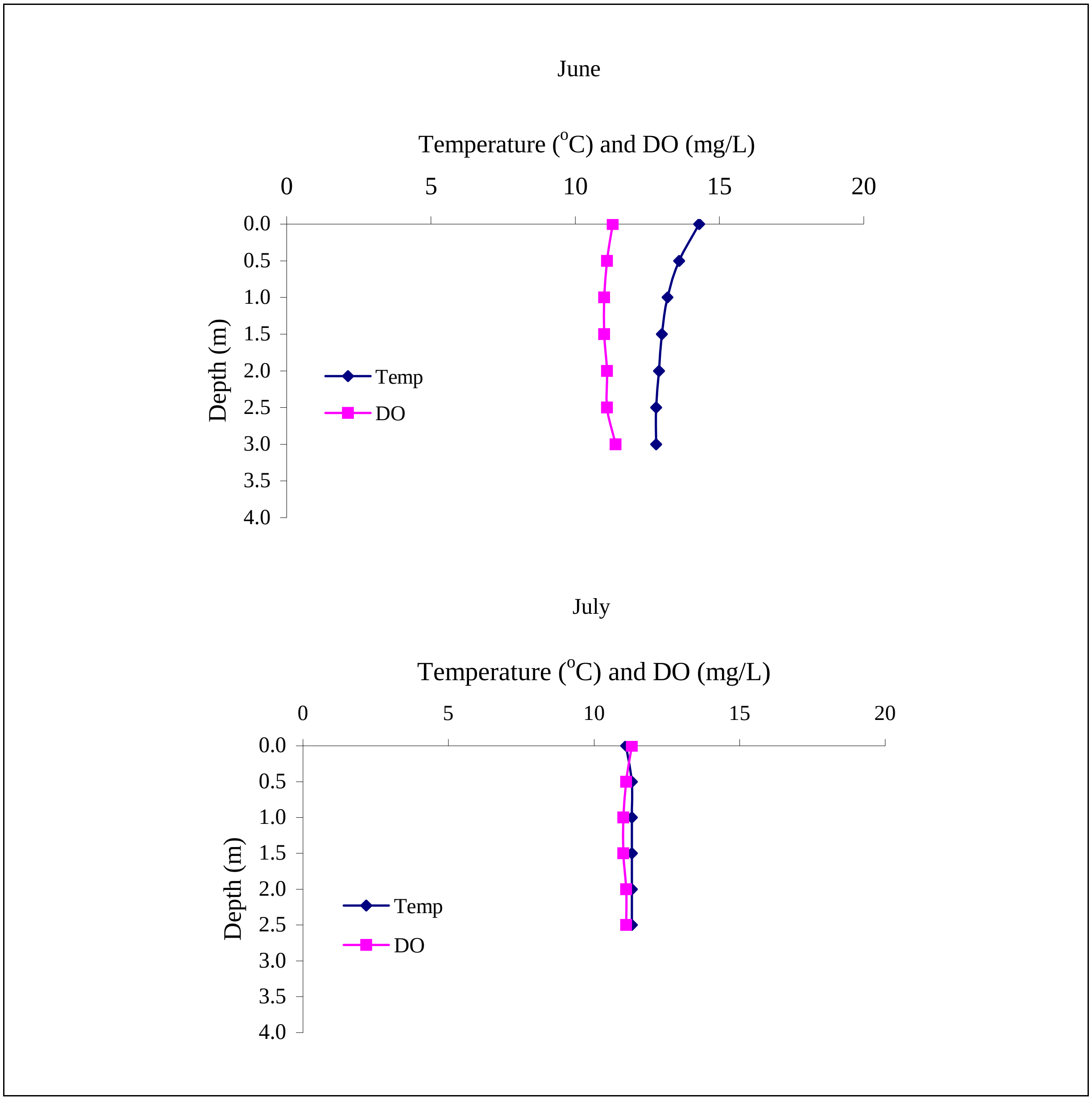

Figure 5.–Mean monthly temperature and dissolved oxygen profiles for Black Lake, 2006.

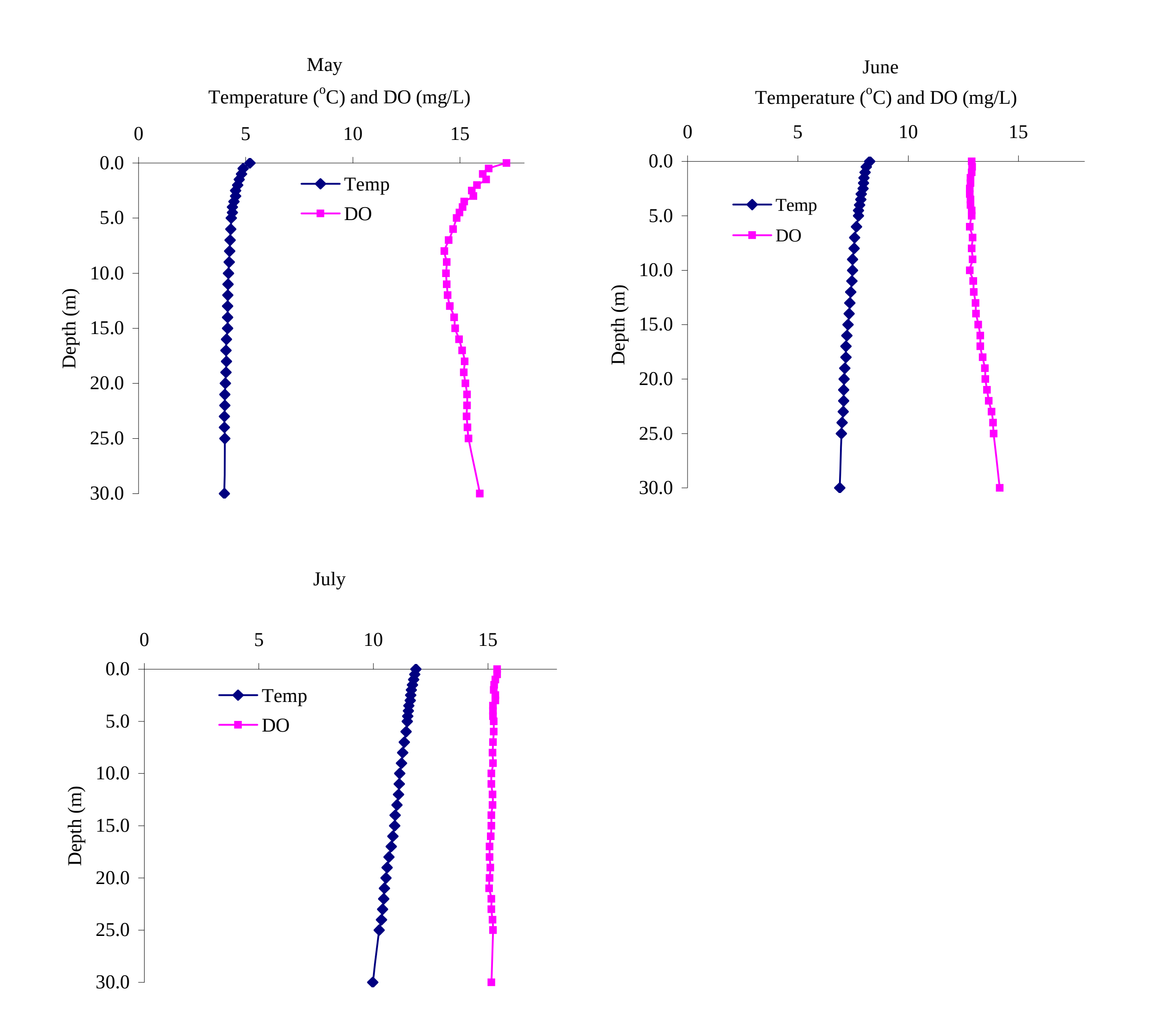

Figure 6.–Mean monthly temperature and dissolved oxygen profiles for Chignik Lake, 2006.

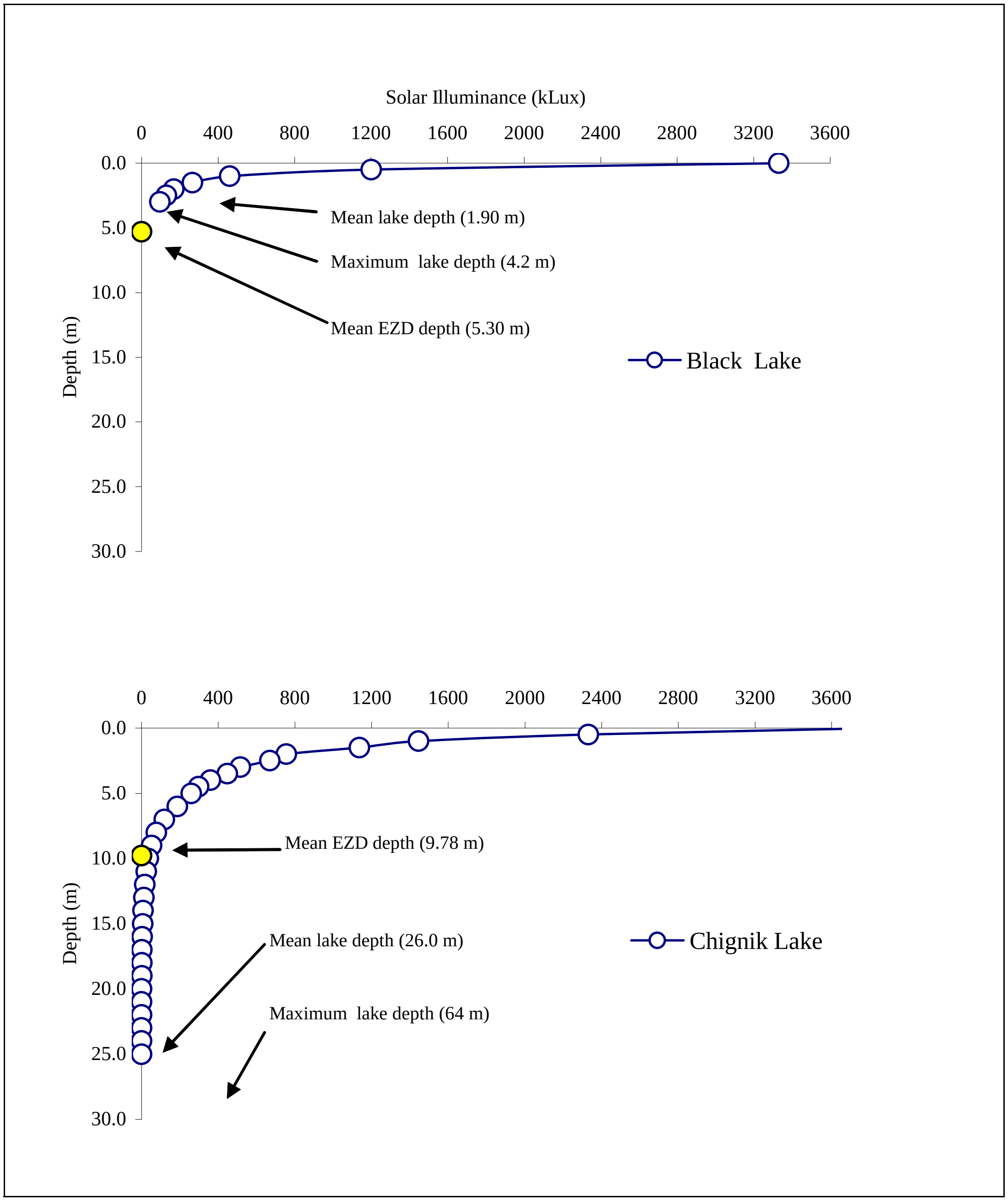

Figure 7.–Average light penetration curves relative to mean depth, EZD, and maximum depth for Black and Chignik lakes, 2006.

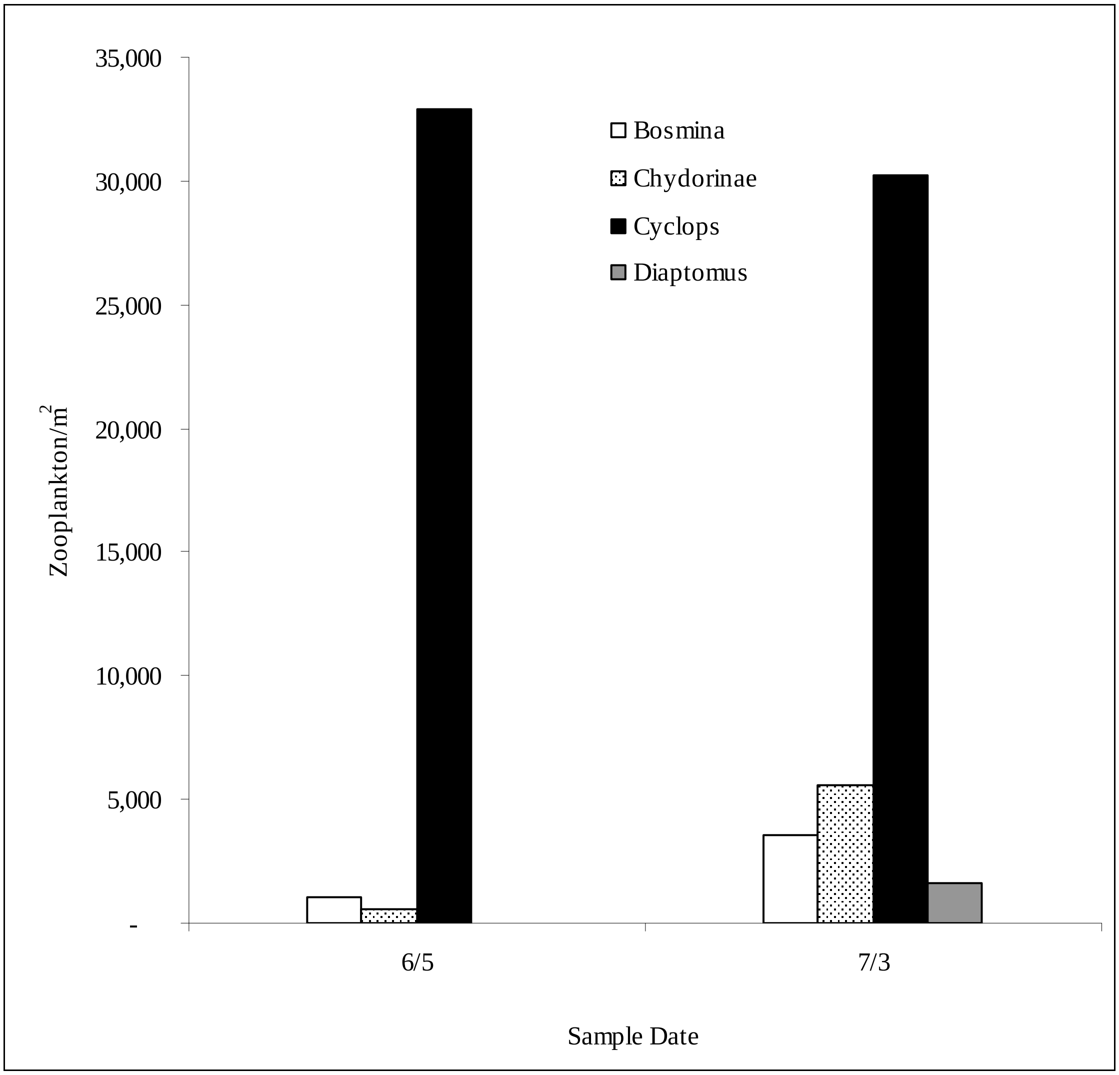

Figure 8.–Number of zooplankton per m^2 of the major copepods (*Cyclops* and *Diaptomus*) and cladocerans (*Bosmina* and *Chydorinae*) in Black Lake, by sample date, 2006.

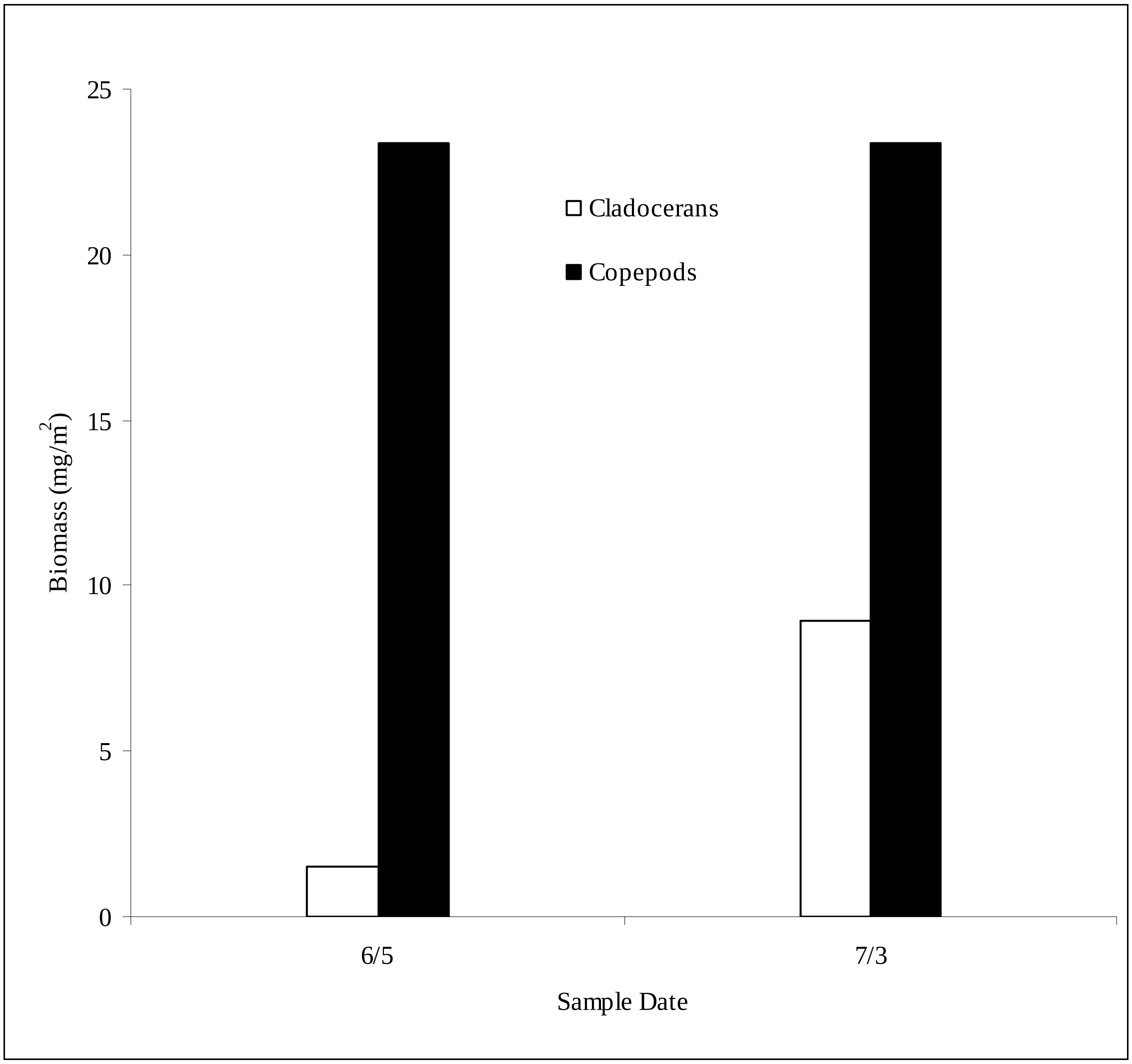

Figure 9.– Mean biomass per m^2 of the major copepods and cladocerans in Black Lake, by sample date, 2006.

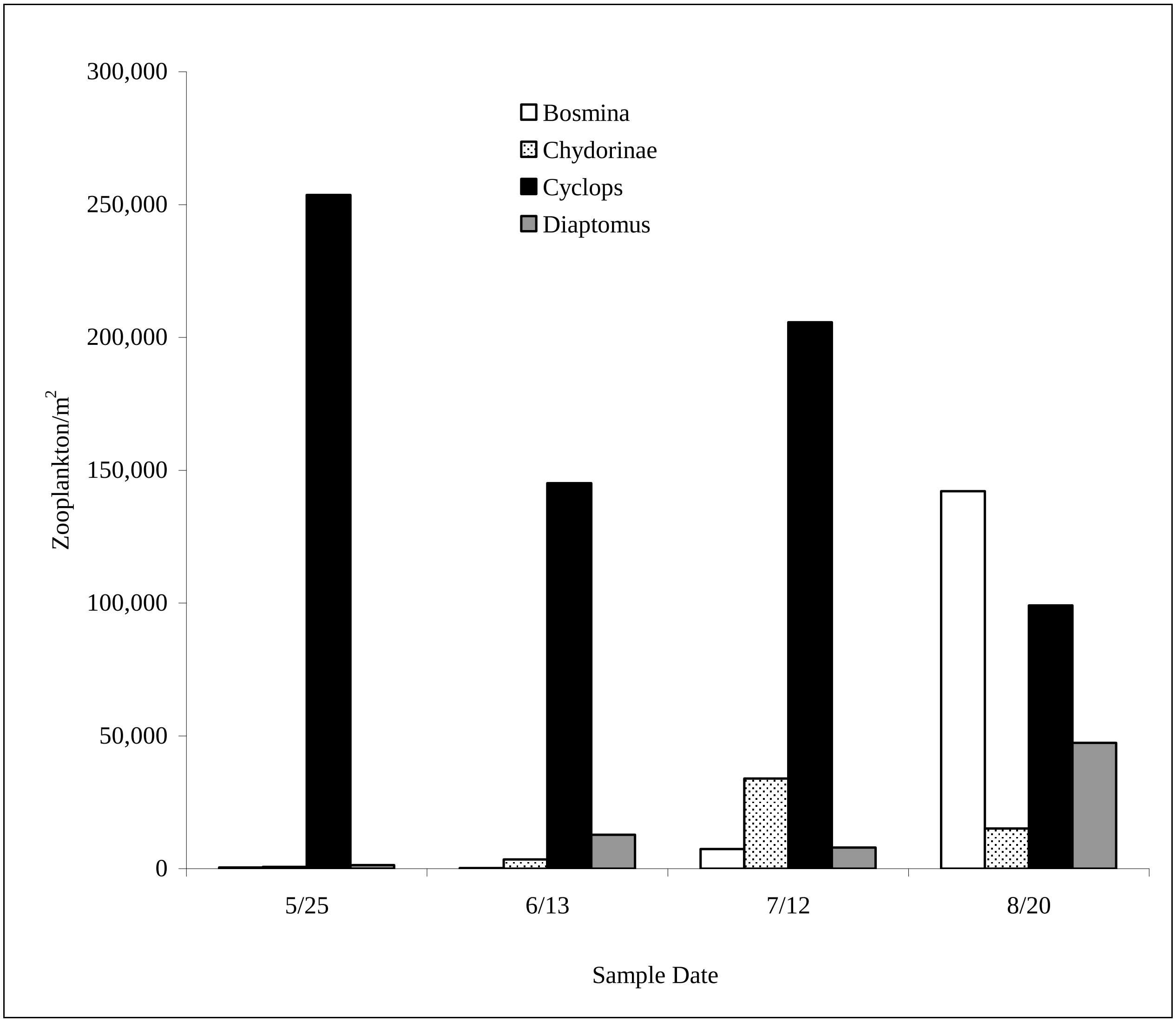

Figure 10.–Number of zooplankton per m^2 of the major copepods (*Cyclops* and *Diaptomus*) and cladocerans (*Bosmina* and *Chydorinae*) in Chignik Lake, by sample date, 2006.

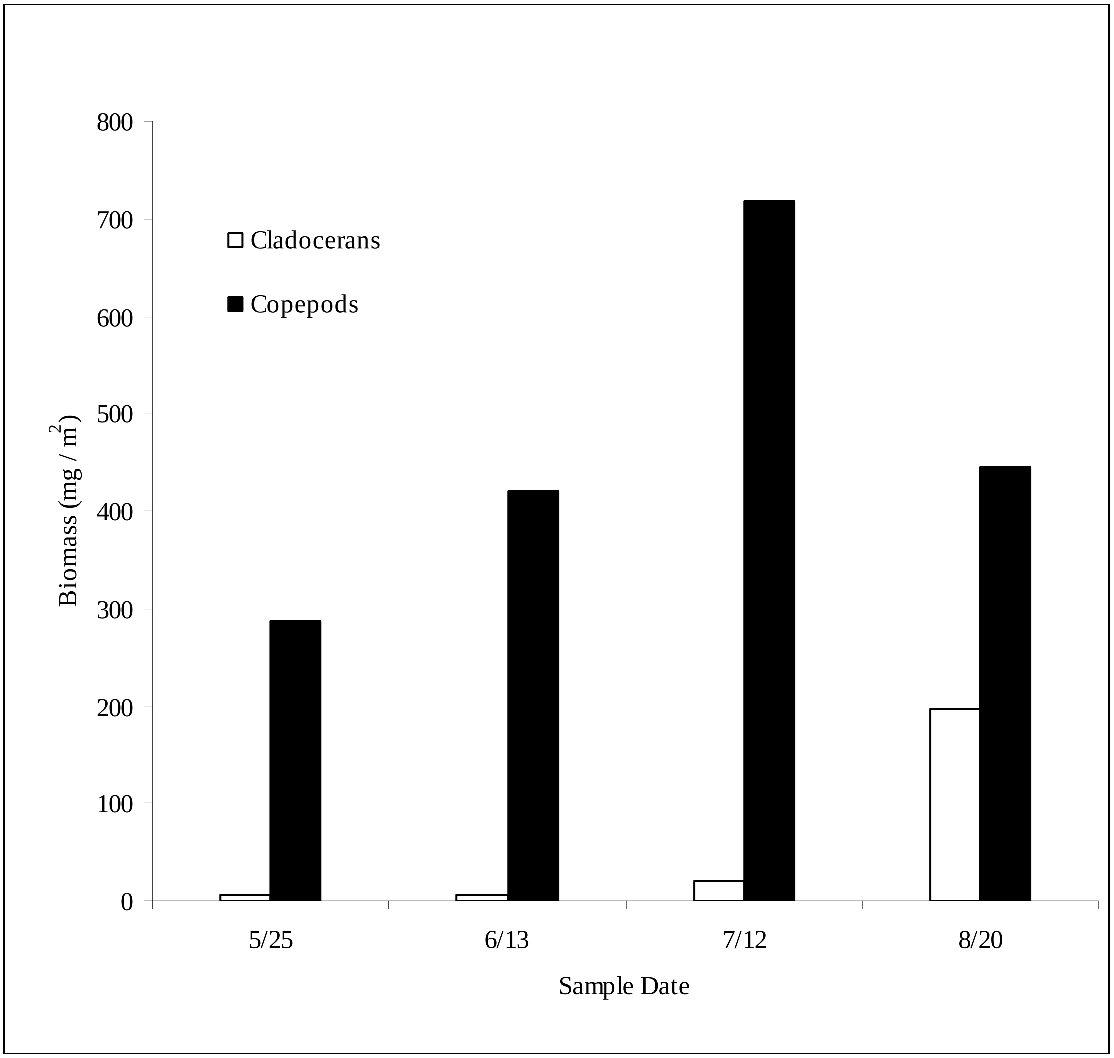

Figure 11.– Mean biomass per m^2 of the major copepods and cladocerans in Chignik Lake, by sample date, 2006.

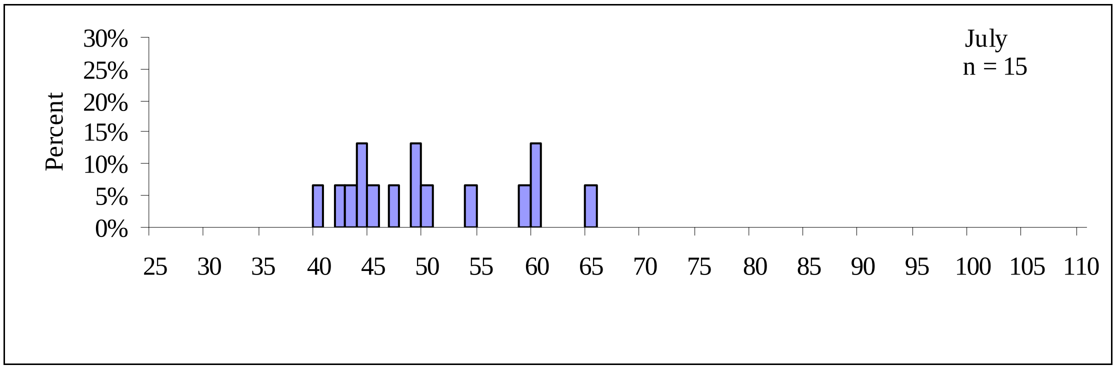

Figure 12.– Length frequency histograms by month of juvenile sockeye salmon captured with a beach seine, from Black Lake, 2006.

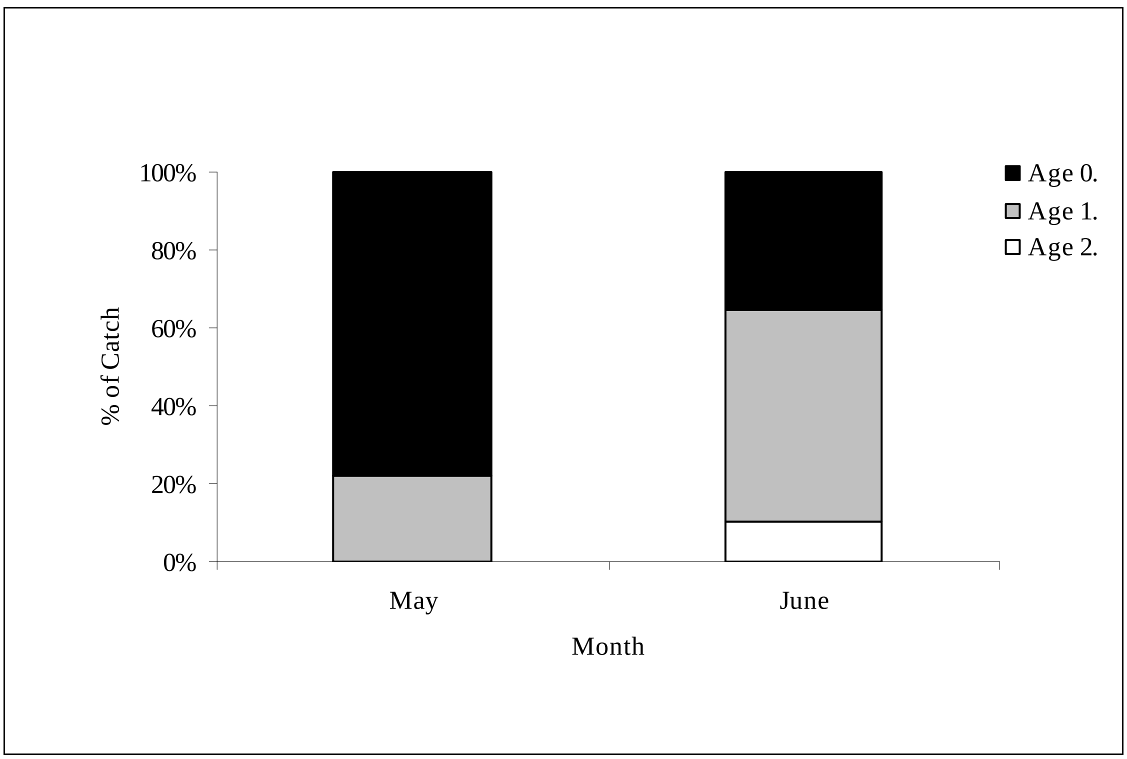

Figure 13.–Estimated age percentages in beach seine catches by month from Chignik Lagoon, 2006.

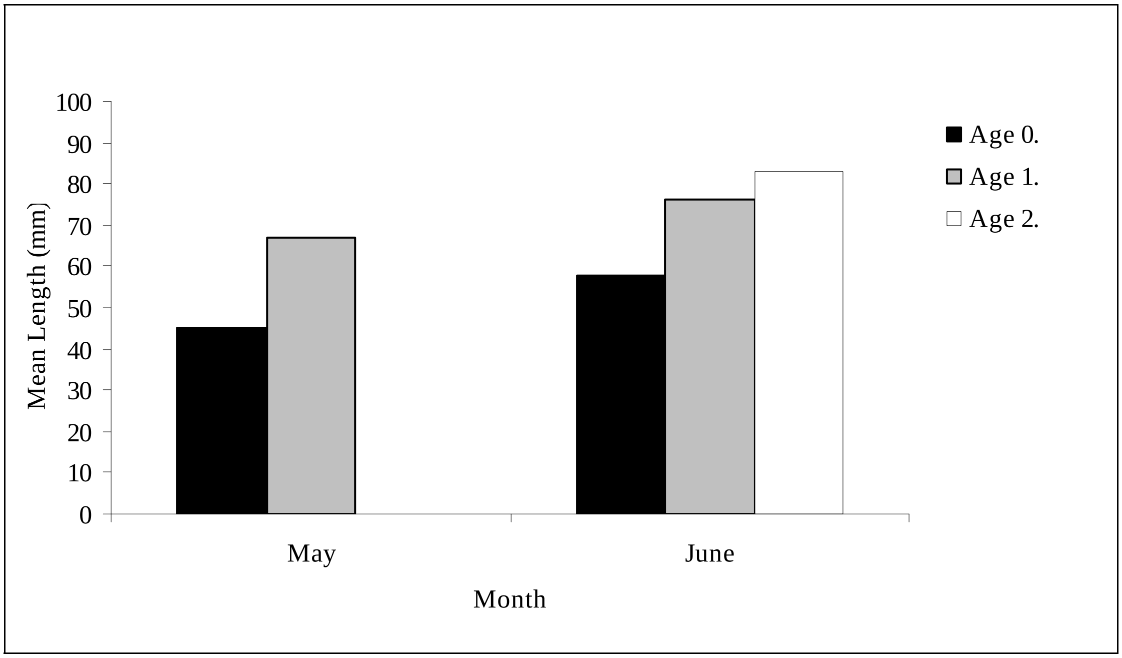

Figure 14.–Mean lengths of beach seine catches by age and month from Chignik Lagoon, 2006.

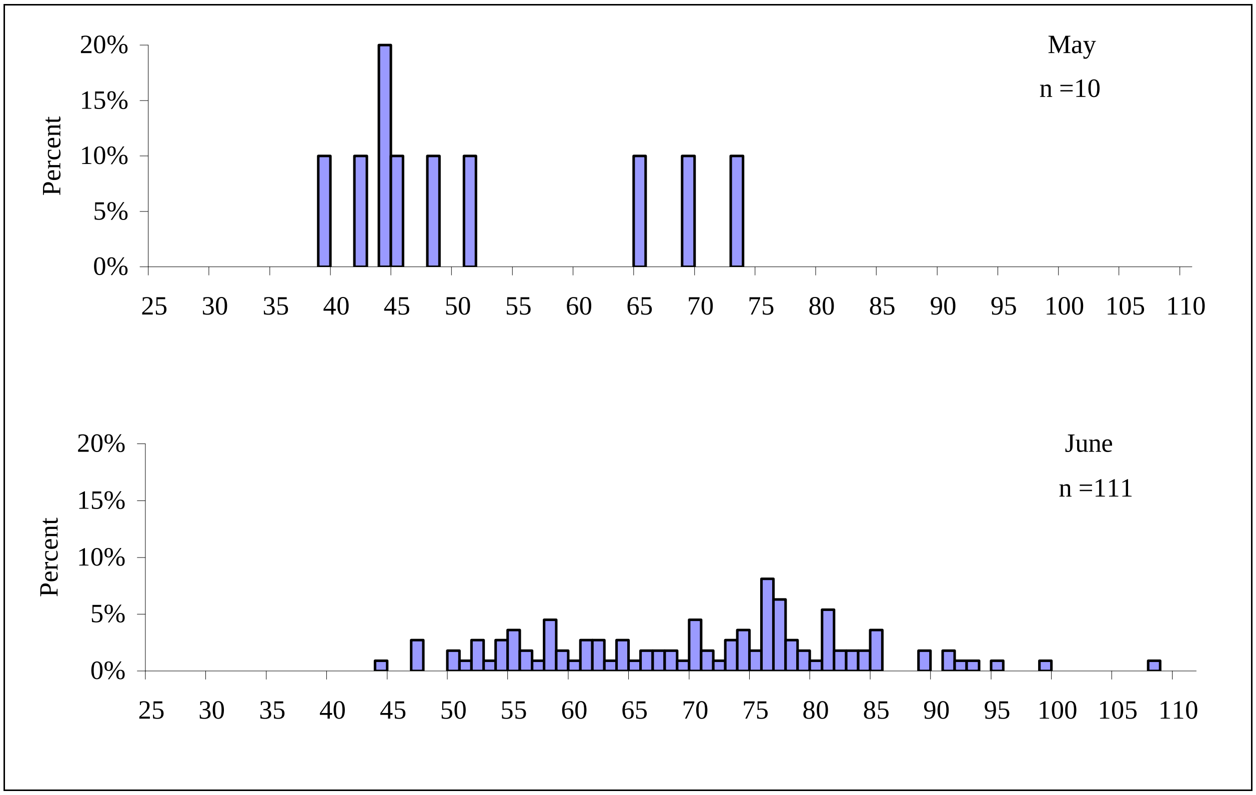

Figure 15.–Length frequency histograms by month of juvenile sockeye salmon captured with a beach seine from Chignik Lagoon, 2006.

APPENDIX A. LIMNOLOGY SAMPLING STATION COORDINATES

Appendix A1.-Location of the limnology sampling stations in Black and Chignik lakes, 2006.

Lake	Station	Latitude (N)	Longitude (W)
Black	1	56.458698°	-159.007037°
Chignik	1	56.238455°	-158.813778°
	2	56.255011°	-158.816263°
	3	56.271962°	-158.850692°
	4	56.290686°	-158.890802°

APPENDIX B. HISTORICAL LIMNOLOGY DATA

Appendix B1.-Seasonal average solar illuminance readings by depth (m) for Black Lake by year, 2000–2005.

	Solar illuminance (kLux)					
Depth	2000	2001	2002	2003	2004	2005
0.0	1,998.3	1,372.8	6,204.5	646.2	4,534.7	3,331.3
0.5	1,059.7	867.3	3,594.0	366.8	2,588.2	1,200.6
1.0	619.3	427.3	2,496.5	232.9	1,491.6	460.5
1.5	309.4	281.1	1,273.2	144.9	302.9	265.1
2.0	166.7	206.0	498.0	59.0	217.1	169.0
2.5	90.7	177.4	336.2	28.0	383.2	130.2
3.0	56.3	10.7	414.1	16.3	392.7	95.3
3.5	24.0	-	-	-	0.0	212.0

Appendix B2.-Euphotic Zone Depth (EZD) and Euphotic Volume (EV) of Black and Chignik Lakes, by year, 2000-2005.

		2000	2001	2002	2003	2004	2005
Lake		Average[a]	Average[a]	Average[a]	Average[a]	Average[a]	Average[a]
Chignik	EZD	8.22	15.52	14.99	4.98	11.11	9.78
	Mean EV[c]	198.10	374.03	361.36	120.09	267.70	235.70
Black[b]	EZD	3.72	3.72	4.94	3.76	3.63	5.30
	Mean EV[c]	78.10	78.10	78.10	78.10	78.10	78.10

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

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

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

Appendix B3.-Seasonal average monthly solar illuminance readings by depth and year for Chignik Lake, 2000-2005.

	Solar illuminance (kLux)					
Depth	2000	2001	2002	2003	2004	2005
0.0	2,473.4	1,799.3	1,393.3	1,156.8	4,491.7	3,872.8
0.5	1,768.3	1,053.3	1,040.9	681.6	3,478.6	2,331.0
1.0	1,214.3	733.7	746.5	413.5	2,797.6	1,445.3
1.5	710.5	614.0	1,023.8	168.0	1,976.9	1,136.8
2.0	523.8	474.7	417.1	90.5	1,585.7	756.4
2.5	365.9	367.4	283.4	57.6	1,127.7	669.3
3.0	252.8	308.9	214.8	30.7	903.2	515.5
3.5	183.6	270.8	158.9	20.5	643.0	447.6
4.0	127.3	216.6	122.4	12.7	425.1	359.7
4.5	91.5	171.6	87.9	8.1	336.5	298.4
5.0	73.4	140.7	67.2	4.9	263.6	259.9
6.0	36.8	98.3	39.9	2.7	166.7	187.1
7.0	21.5	66.9	24.1	1.4	93.8	118.3
8.0	11.5	46.0	15.6	0.7	61.3	76.9
9.0	6.2	33.6	9.6	0.6	33.9	52.0
10.0	3.8	24.7	6.4	0.5	19.7	35.1
11.0	2.3	11.7	4.6	0.3	11.7	24.9
12.0	1.5	8.6	3.8	0.4	8.6	16.8
13.0	1.0	6.5	3.3	-	5.6	12.3
14.0	0.7	5.2	2.9	-	3.8	7.0
15.0	0.6	4.3	2.4	-	3.7	5.4
16.0	0.8	3.8	2.4	-	2.4	3.3
17.0	0.7	3.3	1.9	-	2.4	2.1
18.0	0.4	2.9	1.2	-	1.6	1.4
19.0	0.4	2.7	0.5	-	1.0	0.8
20.0	0.4	2.5	0.5	-	10.3	0.5
21.0	0.3	2.3	1.1	-	9.8	0.3
22.0	0.3	2.5	-	-	9.8	0.2
23.0	0.2	2.5	-	-	5.6	0.2
24.0	-	3.4	-	-	5.2	0.1
25.0	-	4.2	-	-	4.7	0.1
26.0	-	2.1	-	-	-	-
27.0	-	1.6	-	-	-	-
28.0	-	1.5	-	-	-	-
29.0	-	1.6	-	-	-	-
30.0	-	1.5	-	-	-	-

APPENDIX C. BLACK LAKE ZOOPLANKTON DATA

Appendix C1.-The 2000-2005 seasonal average number of zooplankton per m2 from Black Lake.

Taxon	2000 Seasonal average	2001 Seasonal average	2002 Seasonal average	2003 Seasonal average	2004 Seasonal average	2005 Seasonal average
Copepods						
Epischura	7,850	2,654	2,605	6,303	37,649	18,113
Ovig. *Epischura*	127	-	-	-	-	-
Diaptomus	3,575	1,239	5,893	11,080	25,000	3,716
Ovig. *Diaptomus*	-	-	-	1,327	149	266
Cyclops	35,398	7,307	25,622	19,042	46,198	46,842
Ovig. *Cyclops*	-	-	-	266	-	-
Harpaticus	-	531	-	531	531	-
Nauplii	21,967	6,458	13,385	24,350	40,509	38,150
Total copepods	68,917	18,188	47,505	62,898	150,036	107,086
Cladocerans						
Bosmina	38,455	25,779	32,379	285,496	398,855	203,755
Ovig. *Bosmina*	10,446	4,883	13,384	39,809	90,147	29,990
Daphnia l.	868	372	-	1,526	199	-
Ovig. *Daphnia l.*	-	-	-	-	-	-
Chydorinae	11,632	526,097	11,697	3,517	78,954	12,407
Total cladocerans	61,401	557,130	57,460	330,348	568,156	246,152
Total copepds + cladocerans	130,318	575,318	104,965	393,246	718,192	353,238

Appendix C1.-Average number of zooplankton per m^3 from Black Lake by sample date, 2006.

Taxon	Sample Date 6/5	7/3	Seasonal Average
Copepods:			
Epischura	-	-	-
Ovigerous *Epischura*	-	-	-
Diaptomus	-	796	398
Ovigerous *Diaptomus*	-	-	-
Cyclops	16,454	15,127	15,791
Ovigerous *Cyclops*	-	-	-
Harpaticus	265	-	-
Nauplii	5,573	1,990	3,782
Total copepods	22,292	17,913	19,970
Cladocerans:			
Bosmina	531	1,791	1,161
Ovigerous *Bosmina*	-	796	398
Daphnia l.	-	-	-
Ovigerous *Daphnia l.*	-	-	-
Chydorinae	265	2,787	1,526
Total cladocerans	796	5,374	3,085
Total copepods + cladocerans	23,088	23,287	23,055

Appendix C2.-Seasonal biomass estimates (mg dry weight/m^2) of the major Black Lake zooplankton taxa by year, 2000-2005.

	2000		2001		2002		2003		2004		2005	
Taxon	Seasonal average	Weighted average	Seasonal average	Weighted average	Seasonal average	Weighted average	Seasonal average	Weighted average	Seasonal average	Weighted average	Seasonal average	Weighted average
Copepods												
Epischura	8.92	7.29	1.82	1.57	7.44	3.55	1.47	3.59	25.38	21.24	14.73	14.29
Diaptomus	8.78	8.86	3.50	3.85	24.42	46.95	11.40	42.19	57.30	31.52	7.28	8.26
Cyclops	33.55	32.09	7.52	9.12	32.03	36.04	5.82	18.30	36.93	35.75	44.66	44.28
Harpaticus	-	-	0.89	0.89	-	-	0.17	0.35	0.35	-	-	-
Total copepods	51.25	48.24	13.74	15.43	63.89	86.54	18.86	64.43	119.95	88.51	66.67	66.83
Cladocerans												
Bosmina	37.33	32.86	12.75	15.80	69.41	65.10	137.38	290.05	332.11	365.58	206.80	180.73
Ovigerous *Bosmina*	14.81	13.49	4.34	5.18	44.01	45.07	37.07	77.61	121.59	125.78	50.29	43.00
Daphnia longiremis	0.49	0.46	0.10	0.10	-	-	1.77	2.29	0.05	0.05	-	
Chydorinae	1.35	6.59	33.43	5.05	3.51	16.15	0.29	2.38	9.28	40.46	8.63	8.66
Total cladocerans	53.98	53.40	3.99	26.13	71.84	125.64	176.51	186.16	463.03	531.87	265.72	232.39
Total Biomass	105.23	101.64	12.89	41.56	106.08	162.42	195.38	218.38	582.99	620.38	332.39	299.22

Appendix C3.-Biomass estimates (mg dry weight/m^3) of the major zooplankton taxa from Black Lake by sample date, 2006.

Taxon	Sample Date 6/5	Sample Date 7/3	Seasonal Average	Weighted average
Copepods:				
Epischura	-	-	-	-
Diaptomus	-	1.11	0.55	0.55
Cyclops	11.51	10.58	11.04	11.05
Harpaticus	0.17	-	0.09	0.09
Total copepods	11.68	11.68	11.68	11.69
Cladocerans:				
Bosmina	0.61	2.05	1.33	1.07
Ovigerous *Bosmina*	-	0.83	0.42	0.42
Daphnia l.	-	-	-	-
Chydorinae	0.03	0.33	0.18	0.90
Total cladocerans	0.64	3.22	1.93	2.39
Copepods to cladocerans	18.24	3.63	6.06	4.89
Total Biomass	12.32	14.90	13.61	14.08

APPENDIX D. CHIGNIK LAKE ZOOPLANKTON DATA

Appendix D1.-Seasonal average number of zooplankton per m^2 from Chignik Lake by year, 2000-2005.

	2000	2001	2002	2003	2004	2005
Taxon	Seasonal average	Seasonal average	Seasonal average	Seasonal average	Seasonal average	Seasonal average
Copepods:						
Epischura	38,354	9,249	34,939	70,621	67,163	51,946
Ovigerous *Epischura*	398	53	-	-	-	-
Diaptomus	12,988	15,552	25,557	62,275	45,467	49,367
Ovigerous *Diaptomus*	780	106	2,760	1,742	3,605	2,816
Cyclops	172,192	38,767	151,287	37,726	140,871	120,322
Ovigerous *Cyclops*	1,975	4,399	9,713	1,393	4,532	10,388
Harpaticus	355	292	703	531	1,078	348
Nauplii	46,439	12,812	75,588	55,971	73,733	115,371
Total copepods:	273,481	81,230	300,549	230,258	336,447	350,559
Cladocerans:						
Bosmina	58,978	31,356	56,091	73,448	59,929	88,990
Ovigerous *Bosmina*	14,394	4,386	15,698	14,358	8,944	24,968
Daphnia longiremis	9,157	1,858	17,003	68,073	29,824	15,787
Ovigerous *Daphnia longiremis*	1,312	53	8,373	7,086	7,501	6,336
Chydorinae	3,989	24,728	9,129	1,115	8,373	6,179
Total cladocerans:	87,830	62,381	106,294	164,079	114,570	142,259
Total copepods + cladocerans	361,311	143,611	406,843	394,337	451,017	492,818

Appendix D2.-Average number of zooplankton per m^3 from Chignik Lake, 2006**.**

Taxon	Sample Date 5/25	6/13	7/12	8/20	Seasonal Average
Copepods:					
Epischura	64	56	89	379	147
Ovigerous *Epischura*	-	-	-	-	-
Diaptomus	28	263	164	1,003	364
Ovigerous *Diaptomus*	-	23	16	69	27
Cyclops	5,372	3,064	4,247	2,064	3,687
Ovigerous *Cyclops*	-	-	1,508	506	503
Harpaticus	11	62	22	13	27
Nauplii	310	292	930	5,831	1,841
Total copepods:	5,785	3,760	6,975	9,865	6,596
Cladocerans:					
Bosmina	12	5	154	3,037	802
Ovigerous *Bosmina*	-	-	38	699	184
Daphnia longiremis	46	76	71	485	169
Ovigerous *Daphnia longiremis*	13	6	16	55	23
Chydorinae	13	71	701	307	273
Total cladocerans:	84	157	979	4,583	1,451
Total copepods + cladocerans	5,869	3,917	7,954	14,447	8,047

Appendix D3.-Seasonal biomass estimates (mg dry weight/m^2) of the major zooplankton taxa from Chignik Lake by year, 2000-2005.

	2000		2001		2002		2003		2004		2005	
Taxon	Seasonal average	Weighted average	Seasonal average	Weighted average	Seasonal average	Weighted average	Seasonal average	Weighted average	Seasonal average	Weighted average	Seasonal average	Weighted average
Copepods												
Epischura	70.19	43.38	11.45	17.98	43.40	32.58	35.80	42.13	49.65	49.46	43.47	43.39
Ovigerous *Epischura*	1.33	3.03	0.08	0.31	-	-	-	-	-	-	-	-
Diaptomus	88.02	82.20	25.00	44.54	107.79	114.05	128.06	148.91	93.02	92.14	122.32	121.30
Ovigerous *Diaptomus*	5.31	9.43	0.07	0.30	17.46	27.33	7.25	8.63	16.69	22.20	23.15	23.08
Cyclops	255.84	250.07	73.54	128.12	159.34	178.97	39.69	46.08	161.53	155.46	158.06	153.87
Ovigerous *Cyclops*	9.04	10.43	21.35	33.46	35.85	58.85	3.40	5.66	20.45	20.43	49.49	49.32
Harpaticus	0.13	0.29	0.19	0.62	0.35	0.91	0.27	0.45	0.57	0.55	0.11	0.21
Total Copepods:	429.84	398.84	131.69	225.33	364.20	412.69	214.46	251.85	341.89	340.23	396.59	391.17
Cladocerans												
Bosmina	97.46	76.08	19.58	27.44	48.37	55.74	72.98	85.55	49.53	49.46	79.61	79.44
Ovigerous *Bosmina*	28.94	27.89	3.87	5.98	22.37	25.08	22.70	26.37	11.45	11.40	31.02	31.01
Daphnia longiremis	11.22	12.56	2.09	5.18	20.49	22.20	37.82	42.73	37.31	37.16	19.29	19.18
Ovigerous *Daphnia longiremis*	2.37	3.38	0.05	0.44	28.29	29.61	19.29	23.17	23.68	23.62	19.36	19.24
Chydorinae	0.84	3.56	0.54	2.20	1.17	6.95	0.12	0.73	1.16	6.03	3.99	3.97
Total Cladocerans:	140.83	123.48	26.12	41.23	120.69	139.59	152.91	178.55	123.13	127.67	153.26	152.84
Total Biomass	570.68	522.32	157.82	266.57	484.89	552.28	367.37	430.40	465.03	467.90	549.85	544.02

Appendix D4.-Biomass estimates (mg dry weight/m^3) of the major zooplankton taxa, by sample date, from Chignik Lake, 2006.

Taxon	Sample Date 5/25	6/13	7/12	8/20	Seasonal Average	Weighted Average
Copepods:						
Epischura	0.06	0.05	0.02	0.27	0.10	0.12
Ovigerous *Epischura*	-	-	-	-	-	-
Diaptomus	0.06	1.07	0.21	1.64	0.74	0.80
Ovigerous *Diaptomus*	-	0.31	0.09	0.69	0.27	0.54
Cyclops	6.00	7.39	9.52	2.89	6.45	6.36
Ovigerous *Cyclops*	-	-	5.00	3.41	2.10	2.81
Harpaticus	0.01	0.05	0.01	0.01	0.02	0.02
Total copepods:	6.12	8.87	14.84	8.91	9.69	10.58
Cladocerans:						
Bosmina	0.02	0.01	0.08	2.46	0.64	0.80
Ovigerous *Bosmina*	-	-	0.02	0.85	0.22	0.27
Daphnia longiremis	0.07	0.07	0.04	0.57	0.19	0.22
Ovigerous *Daphnia longiremis*	0.03	0.01	0.02	0.14	0.05	0.06
Chydorinae	0.01	0.04	0.27	0.20	0.13	0.14
Total cladocerans:	0.13	0.13	0.42	4.23	1.23	1.49
Copepods to cladocerans	46.66	70.97	35.41	2.11	7.90	7.10
Total Biomass	6.26	9.00	15.26	13.14	10.91	12.07

APPENDIX E. CATCH DATA

Appendix E1.-Beach seine catch data, 2006.

Location	Site	Date	Water temp (°C)	Total sockeye catch	Coho	Chinook	Stickleback	Pond smelt	Dolly Varden	Pygmy whitefish	Other
Black Lake	1	6/5	16.0	232	3	1	264	0	0	0	0
	1	7/3	13.0	6	7	0	17	0	0	1	0
Black Lake	2	6/5	12.0	4	0	0	0	0	0	0	0
	2	7/3	14.0	5	0	0	7	0	0	0	0
Black Lake	4	6/5	12.0	45	0	0	5	0	0	0	0
	4	7/3	14.0	8	0	0	5	1	0	0	1 sculpin
Black Lake	5	6/5	14.0	294	2	2	251	0	0	0	0
	5	7/3	16.0	5	18	0	25	76	0	0	0
Chignik Lagoon	1	5/22	4.0	1	1	0	30	0	0	0	0
	1	6/22	11.0	93	2	41	4,284	0	182	13	0
Chignik Lagoon	2	5/22	5.0	17	0	0	3	0	0	0	0
	2	6/22	13.0	149	3	10	16	0	3	0	0
Chignik Lagoon	3	5/22	ND	0	ND	ND	ND	ND	ND	ND	0
	3	6/22	13.0	0	0	0	31	0	0	0	0
Chignik Lagoon	4	5/22	5.0	24	0	2	35	3	8	0	0
	4	6/22	13.0	68	0	2	237	0	22	0	1 sculpin