Fishery Management Report No. 06-54

Chignik Watershed Ecological Assessment Project Season Report, 2005

by

Heather Finkle

November 2006

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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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (CONT.)

LIST OF APPENDICES

Appendix **Page**

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 *Oncorhynchus nerka* and the watershed's health. Water quality, zooplankton, and catch data were seasonally assessed in 2005 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 2005. However, Black Lake zooplankton biomass was low (<264.00 mg dry wt/m^2) until June 27 followed by an increase to 494 mg dry wt/m^2 on July 26, which coincided with the the downstream migration of juvenile sockeye salmon to Chignik Lake in July and August. 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 morphologically diverse, but fairly stable rearing environments. In Chignik Lake, primary production was not limited; however, zooplankton production was low (<273.00 mg dry wt/m^2) until July, which suggested top-down grazing pressure by juvenile sockeye salmon and other planktivorous fishes. 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 (Reiman and Dunham 2000; Cattanéo et al. 2002). 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 (Detenbeck et al. 1992; Cattanéo et al. 2002; 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 2005 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, maximum depth 64.0 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 (escapement goal of 350,000 to 400,000 sockeye salmon; Witteveen et al. 2005), spawns in Black Lake and its tributaries. The smaller late run (escapement goal of 200,000 to 2500,000 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). It was suggested that 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 three miles 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 (Ruggerone 1994; Finkle 2005), 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 by decreased zooplankton size, which have been observed in Chignik and Black Lake *Bosmina* (Kerfoot 1987; Kyle 1992; Bouwens and Finkle 2003). 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.

Chignik Lagoon may serve as a rearing ground for juvenile sockeye salmon seeking refuge from rearing limitations in Chignik and Black lakes. 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.

Definitive ecological assessments of the Chignik watershed have not been performed since the sockeye salmon escapement goals were initially estimated in the late 1960s (Narver 1966; Dahlberg 1968; Phinney 1968; Burgner et al. 1969). 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 May 2005 (Figure 2; Appendix A). In early May 2005, four sampling stations were established on Chignik Lake (Figure 3). 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, beginning in May and ending in August (Table 1).

Dissolved Oxygen, Light, and Temperature

Water temperature (°C) and dissolved oxygen (mg/L) levels were measured with a YSI Y-52 meter. Readings were recorded at half-meter intervals to a depth of 5 m, then the intervals increased to one meter. Upon reaching a depth of 20 m, the intervals 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 Corning Student 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

Two gear types were used to sample juvenile sockeye salmon: beach seine and fyke net. The sampling protocol was as follows:

Beach Seine

Eight sites (four Black Lake sites and four Chignik Lagoon sites; Figures 2 and 4) were routinely sampled approximately every three weeks beginning in May (Table 2). Beach seine sampling of Chignik Lake and Chignik River was not conducted in the 2004 or 2005 sampling seasons 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.

Fyke Net

A fyke net with 3.05 by 1.22-m wings, a 1.22 by 1.22-m opening and a 3.66-m body with 6.4-mm mesh was used to sample the Black River. The net was set at a site below the effluent of Black Lake roughly once a month in July and August, which coincides with the timing of the downstream migration of Black Lake fish (Table 3; Figure 2).

Distribution, Abundance, and Size

Fish collected with the beach seine and fyke net were identified and enumerated. 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. Length measurements were taken from an additional 20 juvenile sockeye salmon if present in the catch. 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 May 13, the 1-m temperature in Black Lake was 10.6 °C, increasing to 14.4 °C on June 16 where it was also on July 20 until increasing to 17.5 °C on August 15 (Table 4; Figure 5). Dissolved oxygen levels at the 1-m depth varied from 10.9 mg/L to 11.3 mg/L to 11.2 mg/L to 10.0 mg/L over the same time frame (Table 5; Figure 5). During the summer sampling season, temperature, and dissolved oxygen levels remained similar throughout the water column (Figure 5).

Chignik Lake

One-meter temperatures in May, June, July, and August were 4.6, 11.1, 12.9, and 14.0 °C, respectively (Table 6; Figure 6). Temperatures in Chignik Lake were fairly homogenous over depth in May, June, and August (Table 6; Figure 6). Mild temperature variability (3.7 °C) existed over depth on June 14 (Table 6; Figure 6). The 1-m dissolved oxygen level on May 9 was 14.9 mg/L, 12.5 mg/L on June 14, 11.3 on July 16, and 10.5 mg/L on August 11 (Table 7; Figure 6). Dissolved oxygen levels showed little variation over depth from May through August with the exception of fluctuations at depths below 24 m in May and June (Table 7; Figure 6).

Light Penetration and Water Transparency

Black Lake

Light penetrated the entire water column in Black Lake during the 2005 sampling season (Table 8; 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 9; Figure 7). For the 2005 season, water transparency ceased at a mean depth of 1.2 m.

Chignik Lake

Light penetration ceased at a depth of 28 m in May and at 22 m in August (Table 10; Figure 7). The EZD was 11.76 m in May, 10.24 m in June, 11.33 m in July, and 8.40 m in August (Table 9). The EV in Chignik Lake averaged 235.7 x 10^6 m^3 for the 2005 sampling season (Table 10; Figure 7). For the 2005 season, water transparency ceased at a mean depth of 2.8 m.

Water Quality Parameters, Nutrient Levels, and Photosynthetic Pigments

Black Lake

The pH in Black Lake averaged 7.62 and alkalinity averaged 25.0 mg/L $CaCO_3$ (Table 11). Total P (TP) averaged 27.9 mg/L P, mean TFP was 8.6 mg/L P, and FRP averaged 7.2 μg/L P in Black Lake in 2005 (Table 11). TKN was 324.5 μg/L N on average for Black Lake, however it should be noted that this high average was driven by the 638.0 μg/L N sample concentration from August 15, which may have been contaminated for reasons unknown (Table 11). Ammonia averaged approximately 3.9 μg/L N, and nitrate + nitrite had a mean of 1.9 μg/L N in 2005 (Table 11). Of the photosynthetic pigments, chlorophyll *a* averaged 4.97 μg/L and phaeophytin *a* had a seasonal mean of 0.98 μg/L (Table 11).

Chignik Lake

The pH in Chignik Lake averaged 7.57 and alkalinity averaged 23.8 mg/L $CaCO_3$ (Table 12). Total P averaged 15.8 mg/L P, mean TFP was 6.6 mg/L P, and FRP averaged 6.0 μg/L P for Chignik Lake in 2005 (Table 12). TKN was 199.5 μg/L N on average, ammonia averaged approximately 6.2 μg/L N, and nitrate + nitrite had a mean of 110.9 μg/L N in 2005 (Table 12). Of the photosynthetic pigments, chlorophyll *a* averaged 3.27 μg/L and phaeophytin *a* had a seasonal mean of 0.65 μg/L (Table 12).

Zooplankton

Black Lake

Copepod abundance (42,994/m^2) was greater than cladoceran abundance (7,962/m^2) on May 13 in Black Lake (Table 13; Figure 8; Appendix B). On August 15, the cladoceran abundance (456,475/m^2) exceeded the copepod abundance (104,034/m^2; Table 13; Figure 8; Appendix B).

On average, the most prevalent identifiable genera of copepods were *Cyclops* (46,842/m^2) and *Epischura* (18,113/m^2); copepod nauplii (juveniles) were also abundant with a seasonal mean of 38,150/m^2 (Table 13; Figure 8; Appendix B). *Bosmina* was the most prevalent cladoceran in Black Lake in 2005 (Table 13).

Copepod biomass was dominated by *Cyclops* from May (19.74 mg/m^2) through August (58.71 mg/m^2; Table 14; Appendix B). The majority of cladoceran biomass, including ovigerous individuals, was comprised of *Bosmina* throughout the 2005 sampling season with a weighted average of 223.73 mg/m^2 (Table 14; Appendix B). For the season, cladoceran biomass (232.39 mg/m^2) was greater on average than copepod biomass (66.83 mg/m^2; Table 14; Figure 9). This was driven by a large *Bosmina* biomass estimates on July 26 and August 18 (Table 14; Figure 9).

Average seasonal lengths of the major zooplankton in Black Lake were 0.76 mm for *Diaptomus*, 0.54 mm for C*yclops*, 0.34 mm for *Bosmina*, and 0.27 mm for *Chydorinae* (Table 15). Ovigerous *Bosmina* (0.40 mm) were longer than non-egg bearing *Bosmina*.

Chignik Lake

The average seasonal copepod density (350,559/m^2) was greater than the average seasonal cladoceran density (142,259/m^2) in 2005 (Table 16). *Cyclops* (120,322/m^2), *Epischura* (51,946/m^2), and *Diaptomus* (49,367/m^2) were the densest genera of copepods on average during the 2005 season (Table 16; Figure 10; Appendix C). *Bosmina* (88,990/m^2) and *Daphnia* (15,787/m^2) were the densest cladocerans (Table 16; Figure 10; Appendix C). The total average density of copepod and cladoceran zooplankton was less in Black Lake (353,238/m^2) than in Chignik Lake (492,818/m^2) in 2005 (Tables 13 and 16). A spike in both copepod and cladoceran density occurred by August 11 in Chignik Lake (Table 16; Figure 10).

Biomass estimates of the copepod *Cyclops* were substantially greater than biomass estimates of other copepod and cladocerans from May through July (Table 17; Appendix C). The copepod *Diaptomus* had the greatest biomass of all identified zooplankton in August (381.44 mg/m^2; Table 17). *Bosmina* and *Daphnia* biomass levels generally increased from May to August (Table 17). For the 2005 season, copepods (391.17 mg/m^2) had a greater biomass on average than cladocerans (152.84 mg/m^2) for a total average of 544.02 mg/m^2 in Chignik Lake zooplankton, which was greater than that of Black Lake (Tables 14 and 17; Figures 9 and 11). Similar to Black Lake zooplankton, a relatively large increase in both copepod and cladoceran biomass occurred in August (Table 17; Figure 11; Appendix C).

Average seasonal lengths of the major non-egg bearing zooplankton in Chignik Lake were 0.84 mm for *Diaptomus*, 0.61 mm for C*yclops*, 0.55 mm for *Epischura*, 0.35 mm for *Bosmina*, and 0.54 mm for *Daphnia* (Table 18). Ovigerous zooplankton were consistently longer than non-egg bearing individuals (Table 18).

JUVENILE SOCKEYE SALMON

A total of 1,402 AWL sampled juvenile sockeye salmon were captured in Black Lake, Black River and Chignik Lagoon. Of those AWL-sampled fish, 70.0% were estimated to be age-0., 25.1% were age-1., 4.9% were age-2., and no age-3. fish were captured (Table 19).

Black Lake and Black River

Beach seine catch rates in Black Lake were the greatest during June with 79 fish per haul; catch rates were 20 fish per haul in May, 10 fish per haul in July, and zero fish per haul by August (Table 20). By sample day, stickleback, pygmy whitefish, and juvenile coho salmon were more

abundant than juvenile sockeye salmon in May, July, and August beach seine catches (Appendix D).

Fyke net events in the Black River yielded 300 sockeye salmon in July and no sockeye salmon in May and August (Table 21). The June fyke net catch was comprised of stickleback (Appendix D). The August fyke net catch was comprised mainly of juvenile coho salmon, pond smelt, and stickleback (Appendix D).

Of the 182 aged sockeye salmon caught in Black Lake and Black River, all were age-0. fish (Table 22).

The mean length of Black Lake juvenile sockeye salmon was 48 mm in June, which increased to 63 mm by July (Table 23). Condition factor for Black Lake age-0. sockeye salmon increased from 0.94 in June to 1.17 in July (Table 23). Black River age-0. sockeye salmon averaged 59 mm in July (Table 23). Condition factor averaged 1.23 for age-0. fish that were captured from Black River in July (Table 23). Variability in length occurred over the sampling season for fish captured from both areas with a general trend of increasing length over time (Figure 12).

Chignik Lagoon

Chignik Lagoon beach seine catch rates were 13 fish per haul in May, 65 fish per haul in June, and 24 fish per haul in August (Table 20). The timing of the sampling that occurred at the beginning and the end of June mitigated the July sampling effort. Dolly Varden, juvenile coho salmon, pond smelt, and stickleback were present in Chignik Lagoon catches (Appendix D).

The seasonal average age composition for Chignik Lagoon beach seine catches was 50.9% age-0., 41.0% age-1., and 8.1% age-2. fish (Table 24; Figure 13). The age-0. component increased from 32.0% in May to 60.9% in August (Table 24; Figure 13). Age-1. component percentages declined from May to August (Table 24; Figure 13).

Average lengths of age-0. juvenile sockeye salmon increased over the sampling season (Table 25; Figure 14). Average lengths of age-1. and age-2. fish varied over the sampling season (Table 25; Figure 14). Average lengths of juvenile sockeye salmon varied greatly from May through August (Figure 15). Condition factor indices increased over the sampling period for all age groups of fish (Table 25).

DISCUSSION

The 2005 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; Forsberg and Ryding 1980, Carlson and Simpson 1996). Nutrient levels during the 2005 sampling season in Black Lake and Chignik Lake were comparable to the past five 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 (11.8 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 5.03 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, an adequate volume of nitrogen was available for phytoplankton production, and thus had the potential to meet primary (zooplankton) consumption demands. Additionally, phosphorous concentrations were in excess of 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 2005. The chlorophyll-*a* production in Chignik Lake was considered high with a seasonal mean chlorophyll-*a*: phaeophytin-*a* ratio of 5:1, which suggested that zooplankton were not limited by phytoplankton production. In Chignik Lake, photosynthetic pigments were more concentrated in 2000, 2001 and 2004 than in 2005. In 2005, zooplankton density was considered moderate to low by some indices (Mazumder and Edmundson 2002), although greater than or comparable to 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 2005.

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 2005, the Black Lake chlorophyll-*a* levels and turbidity were greater and zooplankton density was less than in 2004. This suggested that the zooplankton population grew and efficiently utilized its forage base in 2004, but may have been negatively affected by physical conditions such as turbidity in 2005 (UF 2000; Finkle 2005). Chignik Lake, however, had low levels of chlorophyll *a* and turbidity but increased zooplankton production in 2005, which were trends similar to those in 2004.

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 smaller than 0.35 mm, which falls 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. In Black Lake, the greatest in-season average zooplankton densities fluctuated among *Cyclops*, *Bosmina*, and *Diaptomus*, with a large increase of *Bosmina* in August. This *Bosmina* spike coincided 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 increased with a reduction in

grazing pressure. Chignik Lake *Cyclops* had a greater average biomass than other copepods in 2000, 2001, 2002, 2004, and 2005; however, *Diaptomus* was the copepod with the highest density on average in 2003. During the 2004 sampling season, the dominant zooplankton taxa in Chignik Lake fluctuated among *Cyclops*, *Diaptomus*, and *Daphnia*. These data also suggest that top-down limitations occurred in Chignik Lake as changes in zooplankton taxa composition are often associated with predation (Helminen and Sarvala 1997; Donald et al. 2001).

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 (Parr 1972; Ruggerone 1994; Bouwens and Finkle 2003). 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 (Narver 1966; Parr 1972; Ruggerone 1994, Finkle 2005). The lack of a substantial, if any, age-1. sockeye salmon component in 2000, 2002, 2003, 2004, and 2005 Black Lake catches 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 (Finkle 2006). 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) 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 (Sogard and Olla 2000; Morgan and Metcalfe 2001). 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 may force 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 catch data, which suggested that age-2. fish did not survive the winter or left the system and did not overwinter. Catch data from Chignik Lagoon in 2005 also showed a lower proportion of age-2.

fish compared to past beach seine sample data (Finkle 2006). 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 during their age 0. and age 1. stages, and therefore had decreased survival due to increased competition from the increase in 2001 and 2002 offspring. In 2005, a relatively small age-2. component was present in Chignik Lagoon and Chignik Smolt Enumeration catches. These catches also coincided with increased zooplankton production and reduced turbidity in Chignik Lake.

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). 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 presmolt sockeye salmon go to sea, continue to rear in the lagoon, or return to rear and overwinter in Chignik Lake as few adults return with evidence of only one year (age 0.) of freshwater growth. It is also uncertain how any of those rearing strategies influence the survival or metabolic processes, such as scale growth, of a presmolt salmon. 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 2005 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 biological 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 and zooplankton sampling dates, 2005.

Lake	Date	Type of sampling
Black Lake	13-May	Water and zooplankton
	16-Jun	Water and zooplankton
	25-Jul	Water and zooplankton
	15-Aug	Water and zooplankton
Chignik Lake	9-May	Water and zooplankton
	14-Jun	Water and zooplankton
	16-Jul	Water and zooplankton
	11-Aug	Water and zooplankton

Table 2.-Dates of beach seine sampling sites by area and site, 2005.

Black Lake	Chignik Lagoon
13-May	7-May
7-Jun	6-Jun
5-Jul	30-Jun
4-Aug	3-Aug

Table 3.-Dates of fyke net sampling in Black River, 2005.

Date
7-Jun
5-Jul
4-Aug

Table 4.-Water temperature, by depth and date, for Black Lake, 2005.

Depth	Temperature (°C)			
(m)	13-May	16-Jun	20-Jul	15-Aug
0.0	10.8	14.3	14.5	17.9
0.5	10.7	14.4	14.4	17.8
1.0	10.6	14.4	14.4	17.5
1.5	10.6	14.4	14.4	16.9
2.0	10.5	14.4	14.4	16.7
2.5	10.4	14.4	14.4	16.3
3.0	10.4	14.4	14.4	16.1
3.5	10.3	14.4	14.4	16.1

Table 5.-Dissolved oxygen levels by depth and date, for Black Lake, 2005.

Depth	Dissolved oxygen (mg/L)			
(m)	13-May	16-Jun	20-Jul	15-Aug
0.0	10.8	11.6	11.4	9.9
0.5	10.9	11.4	11.3	10.0
1.0	10.9	11.3	11.2	10.0
1.5	11.0	11.3	11.2	10.1
2.0	11.0	11.2	11.1	9.9
2.5	11.1	11.1	11.1	9.9
3.0	11.1	11.0	11.1	9.8
3.5	11.1	11.0	10.8	9.8

Table 6.-Water temperature, averaged over all stations, by depth and date for Chignik Lake, 2005.

Depth	Temperature (°C)			
(m)	9-May	14-Jun	16-Jul	11-Aug
0.0	4.9	11.7	13.2	14.3
0.5	4.7	11.3	13.1	14.2
1.0	4.6	11.1	12.9	14.0
1.5	4.5	10.5	12.7	13.9
2.0	4.5	10.2	12.6	13.8
2.5	4.4	10.0	12.5	13.7
3.0	4.4	9.9	12.4	13.7
3.5	4.3	9.8	12.4	13.6
4.0	4.3	9.6	12.3	13.5
4.5	4.3	9.6	12.3	13.4
5.0	4.3	9.6	12.2	13.4
6.0	4.3	9.5	12.2	13.3
7.0	4.2	9.1	12.2	13.2
8.0	4.2	8.9	12.1	13.2
9.0	4.2	8.8	12.1	13.2
10.0	4.2	8.7	12.1	13.1
11.0	4.2	8.6	12.0	13.1
12.0	4.2	8.5	12.0	13.1
13.0	4.2	8.5	11.9	13.0
14.0	4.2	8.4	11.8	13.0
15.0	4.2	8.4	11.7	13.0
16.0	4.1	8.3	11.6	13.0
17.0	4.1	8.3	11.6	12.9
18.0	4.1	8.2	11.4	12.9
19.0	4.1	8.2	11.3	12.9
20.0	4.1	8.2	11.3	12.8
21.0	4.1	8.2	11.2	12.8
22.0	4.1	8.2	11.1	12.8
23.0	4.1	8.2	11.1	12.8
24.0	4.1	8.1	11.0	12.7
25.0	4.1	8.1	10.7	12.7
30.0	4.1	8.0	10.4	12.4

Note: The meter cable was 30 m in length.

Table 7.-Dissolved oxygen levels, averaged over all stations, by depth and date for Chignik Lake, 2005.

Depth	Dissolved oxygen (mg/L)			
(m)	9-May	14-Jun	16-Jul	11-Aug
0.0	14.8	11.6	11.3	10.4
0.5	14.9	12.8	11.4	10.5
1.0	14.9	12.5	11.3	10.5
1.5	14.9	12.3	11.2	10.6
2.0	14.9	12.5	11.2	10.6
2.5	14.9	12.7	11.2	10.6
3.0	14.8	12.8	11.2	10.6
3.5	15.0	12.8	11.2	10.6
4.0	15.0	12.9	11.2	10.6
4.5	15.0	13.0	11.2	10.6
5.0	15.0	13.1	11.2	10.6
6.0	15.0	13.2	11.2	10.7
7.0	15.0	13.2	11.2	10.7
8.0	15.0	13.2	11.2	10.7
9.0	15.0	13.2	11.1	10.7
10.0	15.0	13.2	11.1	10.6
11.0	15.1	13.2	11.1	10.7
12.0	15.1	13.2	11.0	10.6
13.0	15.1	13.2	11.0	10.7
14.0	15.0	13.2	10.9	10.6
15.0	15.1	13.2	10.9	10.7
16.0	15.0	13.1	10.8	10.7
17.0	15.1	13.1	10.9	10.6
18.0	15.0	13.1	10.7	10.6
19.0	15.1	13.0	10.8	10.6
20.0	15.0	12.9	10.8	10.6
21.0	15.0	13.0	10.8	10.6
22.0	14.9	13.0	10.7	10.5
23.0	15.8	12.9	10.7	10.5
24.0	15.0	12.9	10.6	10.5
25.0	14.9	10.3	10.6	10.5
30.0	13.1	13.0	10.4	10.2

Note: The meter cable was 30 m in length.

Table 8.-Average monthly solar illuminance readings by depth and date for Black Lake, 2000 to 2005.

Solar illuminance (kLux)										
	2005					2000	2001	2002	2003	2004
Depth	May	June[b]	July	August	Average	Average	Average	Average	Average	Average
0.0	524.0	ND	1,720.0	7,750.0	3,331.3	1,998.3	1,372.8	6,204.5	646.2	4,534.7
0.5	139.7	ND	862.0	2,600.0	1,200.6	1,059.7	867.3	3,594.0	366.8	2,588.2
1.0	162.4	ND	376.0	843.0	460.5	619.3	427.3	2,496.5	232.9	1,491.6
1.5	174.3	ND	267.0	354.0	265.1	309.4	281.1	1,273.2	144.9	302.9
2.0	144.4	ND	121.6	241.0	169.0	166.7	206.0	498.1	59.0	217.1
2.5	167.3	ND	88.2	135.2	130.2	90.7	177.4	336.2	28.0	383.2
3.0	122.5	ND	62.3	101.2	95.3	56.3	10.7	414.1	16.3	392.7
3.5[a]	212.0	ND	-	-	212.0	24.0	-	-	-	-

[a] Lake depth at the sampling station exceeded 3.0 m only during May 2005 and the 2000 sampling season.

[b] ND = no data.

Table 9.-Euphotic Zone Depth (EZD) and Euphotic Volume (EV) of Black and Chignik Lakes, by month, 2000 to 2005.

		2005					2000	2001	2002	2003	2004
Lake		May	June[d]	July	August	Average[a]	Average[a]	Average[a]	Average[a]	Average[a]	Average[a]
Chignik	EZD	11.76	10.24	11.33	8.40	9.78	8.22	15.52	14.99	4.98	11.11
	Mean EV[c]	283.4	246.8	273.1	202.5	235.7	198.1	374.0	361.4	120.1	267.7
Black[b]	EZD	6.12	ND	3.91	2.82	5.30	3.72	3.72	4.94	3.76	3.63
	Mean EV[c]	78.1	ND	78.1	78.1	78.1	78.1	78.1	78.1	78.1	78.1

[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.

[d] ND = no data. Meter not functional.

Table 10.-Average monthly solar illuminance readings by depth and date for Chignik Lake, 2000 to 2005.

Solar illuminance (kLux)										
	2005					2000	2001	2002	2003	2004
Depth	May	June	July	August	Average	Average	Average	Average	Average	Average
0.0	549.3	5,345.0	2,473.0	5,272.5	3,872.8	2,473.4	1,799.3	1,393.3	1,156.8	4,491.7
0.5	340.0	5,067.3	1,644.0	3,018.0	2,331.0	1,768.3	1,053.3	1,040.9	681.6	3,478.6
1.0	384.0	2,546.5	1,389.0	1,501.5	1,445.3	1,214.3	733.7	746.5	413.5	2,797.6
1.5	102.3	1,813.5	1,106.5	1,167.0	1,136.8	710.5	614.0	1,023.8	168.0	1,976.9
2.0	170.1	1,666.0	750.5	762.3	756.4	523.8	474.7	417.1	90.5	1,585.7
2.5	212.1	1,311.8	561.0	777.5	669.3	365.9	367.4	283.4	57.6	1,127.7
3.0	169.1	1,256.8	463.0	568.0	515.5	252.8	308.9	214.8	30.7	903.2
3.5	126.4	1,044.5	413.4	481.8	447.6	183.6	270.8	158.9	20.5	643.0
4.0	104.9	837.8	350.4	369.0	359.7	127.3	216.6	122.4	12.7	425.1
4.5	81.9	680.5	304.8	292.0	298.4	91.5	171.6	87.9	8.1	336.5
5.0	71.3	488.5	266.7	253.1	259.9	73.4	140.7	67.2	4.9	263.6
6.0	51.6	311.1	205.6	168.6	187.1	36.8	98.3	39.9	2.7	166.7
7.0	27.2	253.4	128.1	108.5	118.3	21.5	66.9	24.1	1.4	93.8
8.0	19.8	174.8	84.9	68.9	76.9	11.5	46.0	15.6	0.7	61.3
9.0	11.5	124.9	60.0	43.9	52.0	6.2	33.6	9.6	0.6	33.9
10.0	8.2	76.4	43.0	27.2	35.1	3.8	24.7	6.4	0.5	19.7
11.0	5.8	63.8	32.9	16.9	24.9	2.3	11.7	4.6	0.3	11.7
12.0	3.3	41.2	22.9	10.7	16.8	1.5	8.6	3.8	0.4	8.6
13.0	2.1	25.7	18.1	6.5	12.3	1.0	6.5	3.3	-	5.6
14.0	1.7	19.8	10.1	4.0	7.0	0.7	5.2	2.9	-	3.8
15.0	0.9	14.1	8.3	2.5	5.4	0.6	4.3	2.4	-	3.7
16.0	0.6	8.8	5.1	1.6	3.3	0.8	3.8	2.4	-	2.4
17.0	0.5	5.4	3.1	1.0	2.1	0.7	3.3	1.9	-	2.4
18.0	0.3	4.2	2.1	0.7	1.4	0.4	2.9	2.9	-	1.6
19.0	0.2	3.4	1.2	0.4	0.8	0.4	2.7	2.7	-	1.0
20.0	0.2	2.2	0.7	0.2	0.5	0.4	2.5	2.5	-	10.3
21.0	0.1	0.2	0.6	0.1	0.3	0.3	2.3	2.3	-	9.8
22.0	0.1	0.1	0.4	0.1	0.2	0.3	2.5	2.5	-	9.8
23.0	0.1	0.1	0.3	-	0.2	0.2	2.5	2.5	-	5.6
24.0	0.1	-	0.2	-	0.1	-	3.4	3.4	-	5.2
25.0	0.1	-	0.1	-	0.1	-	4.2	4.2	-	4.7
26.0	0.1	-	0.1	-	-	-	2.1	2.1	-	-
27.0	0.1	-	-	-	-	-	1.6	1.6	-	-
28.0	0.1	-	-	-	-	-	1.5	1.5	-	-
29.0	-	-	-	-	-	-	1.6	1.6	-	-
30.0	-	-	-	-	-	-	1.5	1.5	-	-

Table 11.-Water quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Black Lake, 2000 to 2005.

	2005					2000	2001	2002	2003	2004
	13-May	16-Jun	20-Jul	15-Aug	Average	Average	Average	Average	Average	Average
pH	7.76	7.72	7.62	7.37	7.62	7.43	7.53	7.45	7.46	7.81
Alkalinity (mg/L)	27.0	26.5	20.5	26.0	25.0	13.0	32.5	32.3	32.3	30.2
Total P (mg/L P)	24.6	15.7	29.9	41.5	27.9	57.0	35.0	22.0	41.7	22.2
TFP (mg/L P)	7.6	10.2	6.8	9.7	8.6	11.0	10.0	10.0	9.8	5.1
FRP (µg/L P)	6.2	13.6	3.2	5.8	7.2	4.0	7.0	5.0	5.8	2.6
TKN (µg/L N)	196.0	146.0	318.0	638.0	324.5	ND	ND	323.5	256.8	188.8
Ammonia (µg/L N)	2.1	3.2	5.6	4.5	3.9	37.0	3.3	4.4	3.7	9.7
Nitrate + Nitrite (µg/L N)	3.0	1.6	1.9	1.2	1.9	64.0	4.5	8.3	25.2	3.7
Chlorophyll *a* (µg/L)	1.92	1.92	9.61	6.41	4.97	18.06	4.26	2.64	5.12	3.60
Phaeophytin *a* (µg/L)	0.32	0.32	1.60	1.67	0.98	9.98	11.94	1.44	1.78	0.15

[a] No acid for alkalinity titration.

[b] ND = no data.

Table 12.-Water quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Chignik Lake, 2000 to 2005.

	2005					2000	2001	2002	2003	2004
	9-May	14-Jun	16-Jul	11-Aug	Average[a]	Average	Average	Average	Average	Average
pH	7.63	7.69	7.60	7.37	7.57	7.84	7.50	7.45	7.38	7.62
Alkalinity (mg/L)	25.3	26.0	21.1	22.6	23.8	15.1	24.8	24.6	23.6	22.4
Total P (mg/L P)	15.9	16.0	11.6	19.7	15.8	13.2	27.6	19.7	16.7	18.5
TFP (mg/L P)	8.3	5.8	4.7	7.7	6.6	5.3	12.2	8.5	7.5	6.5
FRP (µg/L P)	8.4	6.4	2.9	6.2	6.0	4.8	8.4	4.6	5.8	4.1
TKN (µg/L N)[b]	183.0	309.0	178.0	128.0	199.5	230.0	99.5	119.7	99.0	146.5
Ammonia (µg/L N)	4.4	3.3	10.3	6.8	6.2	29.8	10.3	10.5	10.1	9.1
Nitrate + Nitrite (µg/L N)	197.8	77.4	83.3	85.0	110.9	102.6	132.9	117.4	166.6	128.0
Chlorophyll *a* (µg/L)	6.84	2.96	1.68	1.60	3.27	9.47	4.69	2.34	2.30	4.02
Phaeophytin *a* (µg/L)	0.71	0.74	0.67	0.47	0.65	1.69	1.31	1.34	0.51	0.32

[a] Averaged values do not always exactly match the values reported in Table 11 due to rounding.

[b] No acid for alkalinity titration.

Table 13.-Average number of zooplankton per m^2 from Black Lake by sample date, 2005.

Taxon	Sample date 5/13	6/16	7/20	8/15	Seasonal average
Copepods:					
Epischura	2,389	42,463	15,924	11,677	18,113
Ovig. *Epischura*	-	-	-	-	-
Diaptomus	-	8,493	2,123	4,246	3,716
Ovig. *Diaptomus*	-	-	-	1,062	266
Cyclops	20,701	59,448	45,648	61,571	46,842
Ovig. *Cyclops*	-	-	-	-	-
Harpaticus	-	-	-	-	-
Napulii	19,904	65,817	41,401	25,478	38,150
Total copepods	42,994	176,221	105,096	104,034	107,086
Cladocerans:					
Bosmina	3,981	71,125	316,348	423,567	203,755
Ovig. *Bosmina*	3,185	44,586	60,510	11,677	29,990
Daphnia l.	-	-	-	-	-
Ovig. *Daphnia l.*	-	-	-	-	-
Chydorinae	796	12,739	14,862	21,231	12,407
Total cladocerans	7,962	128,450	391,720	456,475	246,152
Total copepods + cladocerans	50,956	304,671	496,816	560,509	353,238

Table 14.-Biomass estimates (mg dry weight/m^2) of the major Black Lake zooplankton taxon by sample date, 2005.

Taxon	Sample date 5/13	6/27	7/26	8/18	Seasonal average	Weighted average
Copepods:						
Epischura	1.94	34.53	12.95	9.50	14.73	14.29
Diaptomus	-	16.64	4.16	8.32	7.28	8.26
Cyclops	19.74	56.68	43.52	58.71	44.66	44.28
Harpaticus	-	-	-	-	-	-
Total copepods	21.68	107.85	60.63	76.52	66.67	66.83
Cladocerans:						
Bosmina	4.04	72.19	321.08	429.90	206.80	180.73
Ovigerous *Bosmina*	5.34	74.77	101.47	19.58	50.29	43.00
Daphnia longiremis	-	-	-	-	-	
Chydorinae	0.55	8.86	10.33	14.76	8.63	8.66
Total cladocerans	9.93	155.81	432.88	464.24	265.72	232.39
Total Biomass	31.62	263.66	493.51	540.76	332.39	299.22

Note: Seasonal averages were estimated using average lengths and weighted averages were estimated using weighted lengths.

Table 15.-Average lengths (mm) of zooplankton in Black Lake by sample date, 2000 to 2005.

	2005					2000	2001	2002	2003	2004
	Sample date				Seasonal	Seasonal	Seasonal	Seasonal	Seasonal	Seasonal
Taxon	5/13	6/16	7/20	8/15	average	average	average	average	average	average
Copepods:										
Epischura	0.55	0.53	0.58	0.53	0.55	0.62	0.53	0.79	0.51	0.51
Diaptomus	-	0.83	0.66	0.78	0.76	0.82	0.86	0.63	0.84	0.80
Cyclops	0.55	0.47	0.54	0.59	0.54	0.54	0.56	0.47	0.50	0.50
Harpaticus	-	-	-	-	-	-	0.70	-	0.45	-
Napulii	-	-	-	-	-	-	0.29	0.20	-	-
Cladocerans:										
Bosmina	0.38	0.34	0.30	0.32	0.34	0.33	0.24	0.32	0.32	0.31
Ovigerous *Bosmina*	0.50	0.43	0.36	0.41	0.40	0.39	0.31	0.37	0.47	0.38
Daphnia l.	-	-	-	-	-	0.38	0.27	-	0.73	0.27
Chydorinae	0.23	0	0.27	0.29	0.27	0.27	0.17	0.24	0.28	0.28

Note: Lengths are not weighted to estimate the seasonal average.

Table 16.-Average number of zooplankton per m^2 from Chignik Lake, by sample date, 2005.

Taxon	Sample date 5/9	6/14	7/15	8/11	Seasonal average
Copepods:					
Epischura	5,772	12,191	24,416	165,406	51,946
Ovigerous *Epischura*	-	-	-	-	-
Diaptomus	8,028	10,699	18,976	159,767	49,367
Ovigerous *Diaptomus*	-	1,509	2,455	7,298	2,816
Cyclops	179,074	96,802	98,859	106,555	120,322
Ovigerous *Cyclops*	398	1,742	20,236	19,175	10,388
Harpaticus	398	-	-	995	348
Napulii	32,444	28,563	54,804	345,674	115,371
Total copepods:	226,115	151,506	219,746	804,870	350,559
Cladocerans:					
Bosmina	1,261	10,151	56,263	288,283	88,990
Ovigerous *Bosmina*	199	3,334	22,094	74,244	24,968
Daphnia longiremis	2,256	4,893	6,303	49,695	15,787
Ovigerous *Daphnia longiremis*	1,593	1,062	5,042	17,649	6,336
Chydorinae	1,062	3,085	9,621	10,948	6,179
Total cladocerans:	6,370	22,525	99,323	440,818	142,259
Total Copepods + Cladocerans	232,484	174,032	319,069	1,245,687	492,818

Table 17.-Biomass estimates (mg dry weight/m^2) of the major zooplankton species in Chignik Lake by sample date, 2005.

Taxon	Sample date 5/9	6/14	7/15	8/11	Seasonal average	Weighted average
Copepods						
Epischura	4.40	9.80	25.73	133.97	43.47	43.39
Ovigerous *Epischura*	-	-	-	-	-	-
Diaptomus	19.41	23.36	65.08	381.44	122.32	121.30
Ovigerous *Diaptomus*	-	13.54	18.73	60.33	23.15	23.08
Cyclops	182.76	191.14	133.37	124.95	158.06	153.87
Ovigerous *Cyclops*	1.31	5.38	105.38	85.88	49.49	49.32
Harpaticus	0.26	-	-	0.16	0.11	0.21
Total Copepods:	208.15	243.21	348.28	786.73	396.59	391.17
Cladocerans						
Bosmina	1.91	12.40	50.37	253.74	79.61	79.44
Ovigerous *Bosmina*	-	5.97	29.89	88.21	31.02	31.01
Daphnia longiremis	2.93	6.67	5.91	61.63	19.29	19.18
Ovigerous *Daphnia longiremis*	3.89	2.43	15.46	55.68	19.36	19.24
Chydorinae	0.79	1.86	6.81	6.49	3.99	3.97
Total Cladocerans:	9.52	29.34	108.44	465.75	153.26	152.84
Total Biomass	217.67	272.54	456.73	1,252.48	549.85	544.02

Note: Seasonal averages were estimated using average lengths and weighted averages were estimated using weighted lengths.

Table 18.-Average length (mm) of zooplankton from Chignik Lake by sample date, 2000 to 2005.

Taxon	2005 Sample date 5/14	6/9	7/8	8/9	2005 Seasonal average	2000 Seasonal average	2001 Seasonal average	2002 Seasonal average	2003 Seasonal average	2004 Seasonal average
Copepods:										
Epischura	0.54	0.56	0.55	0.55	0.55	0.65	0.75	0.64	0.50	0.55
Ovigerous *Epischura*	-	-	-	-	-	0.58	0.72	-	-	0.00
Diaptomus	0.83	0.83	0.89	0.83	0.84	1.12	0.90	0.98	0.83	0.81
Ovigerous *Diaptomus*	-	1.33	1.24	1.26	1.27	0.63	0.34	1.14	1.07	1.17
Cyclops	0.53	0.68	0.63	0.58	0.61	0.64	0.80	0.58	0.55	0.54
Ovigerous *Cyclops*	0.96	0.94	1.04	1.05	1.00	1.00	1.03	1.01	1.04	1.04
Harpaticus	0.45	-	-	0.50	0.48	0.24	0.40	0.45	0.47	0.43
Napulii	-	-	-	-	-	-	0.26	0.26	-	0.00
Cladocerans:										
Bosmina	0.40	0.35	0.32	0.31	0.35	0.38	0.33	0.31	0.34	0.33
Ovigerous *Bosmina*	-	0.46	0.38	0.37	0.40	0.44	0.39	0.40	0.42	0.41
Daphnia longiremis	0.57	0.57	0.48	0.55	0.54	0.55	0.47	0.55	0.53	0.53
Ovigerous *Daphnia longiremis*	0.75	0.72	0.81	0.84	0.78	0.53	0.67	0.87	0.80	0.80
Chydorinae	0.29	0.25	0.28	0.26	0.27	0.30	0.11	0.28	0.27	0.29

Note: Lengths are not weighted to estimate the seasonal average.

Table 19.-Total catch of juvenile sockeye salmon, by age and location, from the Chignik watershed, 2005.

Location		Age 0.	1.	2.	3.	Total
Black Lake/Black River		100.0%	0.0%	0.0%	0.0%	100.0%
	Sample	102	0	0	0	102
	Total catch[a]	734	0	0	0	734
Chignik Lagoon		50.9%	41.0%	8.1%	0.0%	100.0%
	Sample	82	66	13	0	161
	Total catch[a]	340	274	54	0	668
Combined		70.0%	25.1%	4.9%	0.0%	100.0%
	Sample	184	66	13	0	263
	Total catch[a]	981	352	69	0	1,402

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

Table 20.-Total beach seine hauls, total catch, and catch per haul, by month, of juvenile sockeye salmon from the Chignik watershed, 2000 to 2005.

		2005			2000	2001	2002	2003	2004
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
Black Lake	May	4	80	20	-	75	241	23	91
	June	4	315	79	328	16	405	11	69
	July	4	39	10	59	11	225	4	14
	August	4	0	0	14	-	3	1	1
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	4	50	13	22	218	3	12	177
	June	8	523	65	39	93	200	47	53
	July	ND	ND	-	26	79	141	50	196
	August	4	95	24	138	307	-	4	39

Note: ND = no data.

Table 21.-Fyke net hours fished, total catch, and catch per hour, by month, of juvenile sockeye salmon from Black River, 2000 to 2005.

	2005			2000	2001	2002	2003	2004
Month	Total hours	Total sockeye catch	Sockeye catch/hour	Sockeye catch/hour	Sockeye catch/hour	Sockeye catch/hour	Sockeye catch/hour	Sockeye catch/hour
May	ND	ND	-	13	5	-	-	-
June	1.50	0	0	0	1	1	0	0
July	1.81	300	166	77	-	11	< 1	< 1
August	2.80	0	0	-	-	1	0	0

Note: ND = no data.

Table 22.-Total catch of juvenile sockeye salmon from Black Lake and Black River, by age and gear type, 2005.

Area	Gear type	Month	Total sockeye catch	Sample					Estimated age[a]				
				0.	1.	2.	3.	Total	0.	1.	2.	3.	Total
Black Lake	Beach seine	May	80	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				80	0	0	0	80	80	0	0	0	80
	Beach seine	June	315	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				56	0	0	0	56	315	0	0	0	315
	Beach Seine	July	39	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				26	0	0	0	26	39	0	0	0	39
	Beach Seine	August	0	-	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-	-
Black Lake Total		All	434	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				162	0	0	0	162	434	0	0	0	434
Black River	Fyke	June	0	-	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-	-
	Fyke	July	300	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				20	0	0	0	20	300	0	0	0	300
	Fyke	August	0	-	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-	-
Black River Total		All	300	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				20	0	0	0	20	300	0	0	0	300
Black Lake/River Total		All	734	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				182	0	0	0	182	734	0	0	0	734

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

Table 23.-Average length, weight, and condition factor by age and gear type for juvenile sockeye salmon captured in Black Lake and Black River, 2005.

Gear type	Month	Age	Sample size	Length (mm)		Weight (g)		Condition factor	
				Average	SD	Average	SD	Average	SD
Beach seine	May	0	0	-	-	-	-	-	-
	June	0	56	48	17.1	0.5	0.39	0.94	0.34
	July	0	26	63	16.0	3.0	0.82	1.17	0.30
	August	0	0	-	-	-	-	-	-
Fyke net	June	0	0	-	-	-	-	-	-
	July	0	300	59	13.5	2.6	0.62	1.23	0.28
	August	0	0	-	-	-	-	-	-

Table 24.-Total beach seine catch, by age, of juvenile sockeye salmon from Chignik Lagoon, 2005.

Month	Total sockeye catch	Sample					Estimated age[a]				
		0.	1.	2.	3.	Total	0.	1.	2.	3.	Total
May	50	32.0%	64.0%	4.0%	0.0%	100.0%	32.0%	64.0%	4.0%	0.0%	100.0%
		8	16	1	0	25	16	32	2	0	50
June	523	51.1%	37.8%	11.1%	0.0%	100.0%	51.1%	37.8%	11.1%	0.0%	100.0%
		46	34	10	0	90	267	198	58	0	523
July	ND[b]	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-
August	95	60.9%	34.8%	4.3%	0.0%	100.0%	60.87%	34.8%	4.3%	0.0%	100.0%
		28	16	2	0	46	58	33	4.13	0	95.00
All	668	50.9%	41.0%	8.1%	0.0%	100.0%	50.9%	41.0%	8.1%	0.0%	100.0%
		82	66	13	0	161	340	274	54	0	668

[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 25.-Average length, weight, and condition factor by age of juvenile sockeye salmon captured by beach seine in Chignik Lagoon, 2005.

			Length (mm)		Weight (g)		Condition factor	
Month	Age	Sample size[a]	Average	SD	Average	SD	Average	SD
May	0	8	53	8.1	1.1	0.17	0.69	0.17
	1	16	69	14.8	2.5	0.54	0.74	0.16
	2	1	88	4.8	0.8	0.33	0.88	0.05
June	0	46	58	20.1	1.8	0.69	0.90	0.31
	1	34	72	21.9	3.8	1.42	0.92	0.28
	2	10	80	13.5	4.8	0.85	0.92	0.16
July	0	ND	-	-	-	-	-	-
	1	ND	-	-	-	-	-	-
	2	ND	-	-	-	-	-	-
August	0	27	59	16.3	2.2	13.62	1.05	0.29
	1	16	69	14.9	3.5	12.38	1.00	0.21
	2	2	89	6.8	7.7	5.59	1.11	0.09

[a] ND = No data.

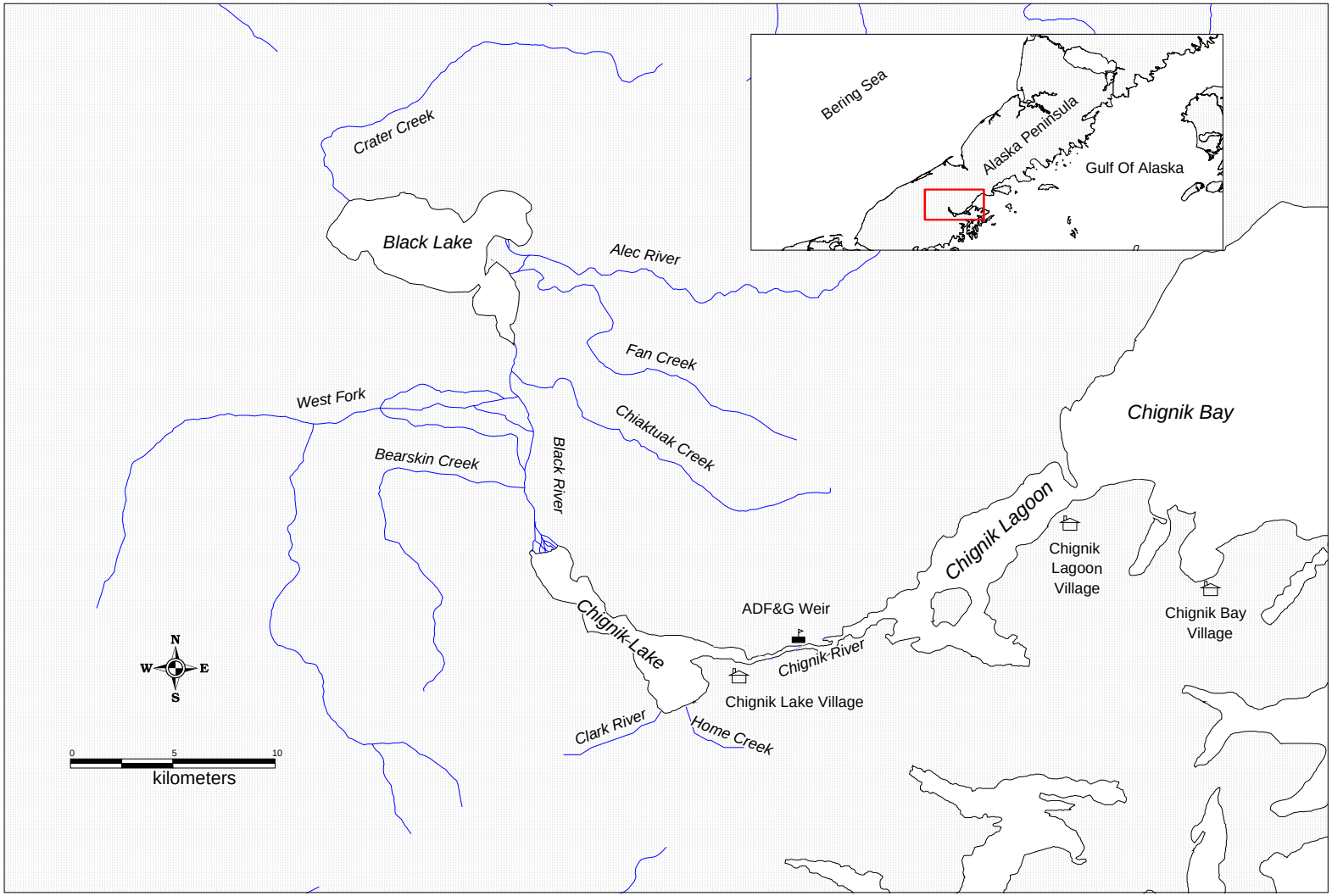

Figure 1.-Chignik watershed and location on the Alaska Peninsula (inset).

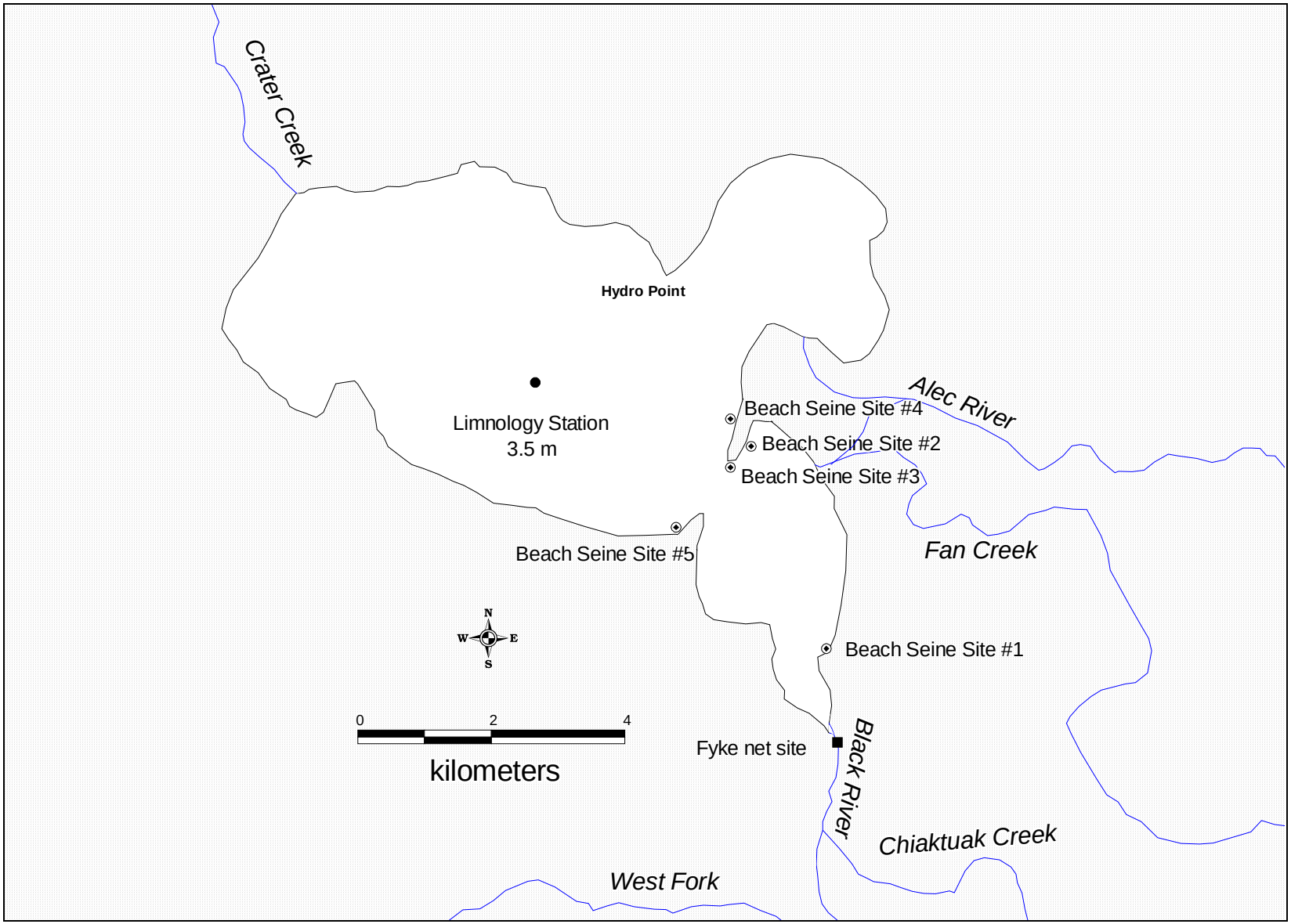

Figure 2.-Black Lake sampling sites.

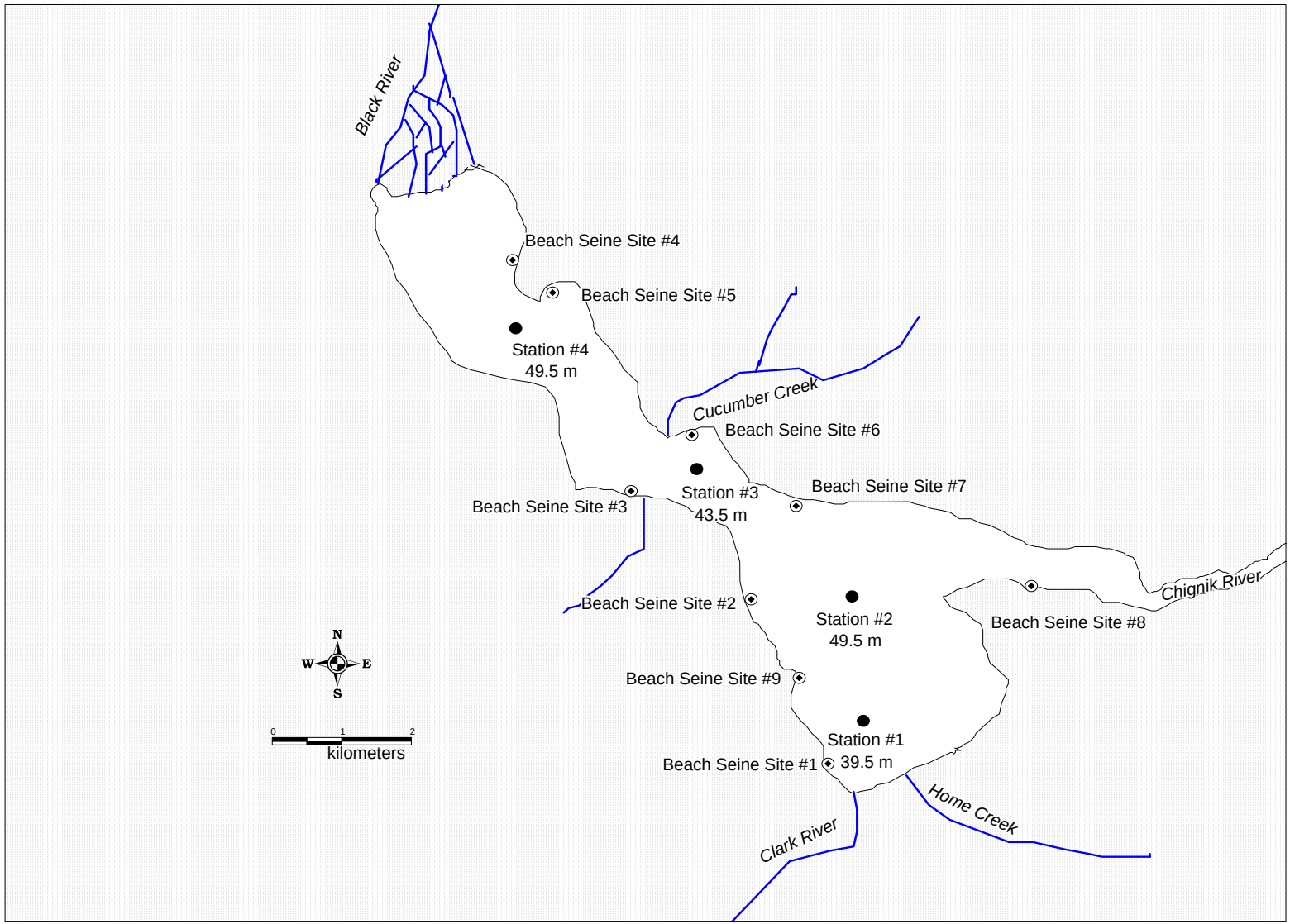

Figure 3.-Chignik Lake sampling sites.
Note: Beach seine sampling was not performed in Chignik Lake in 2005.

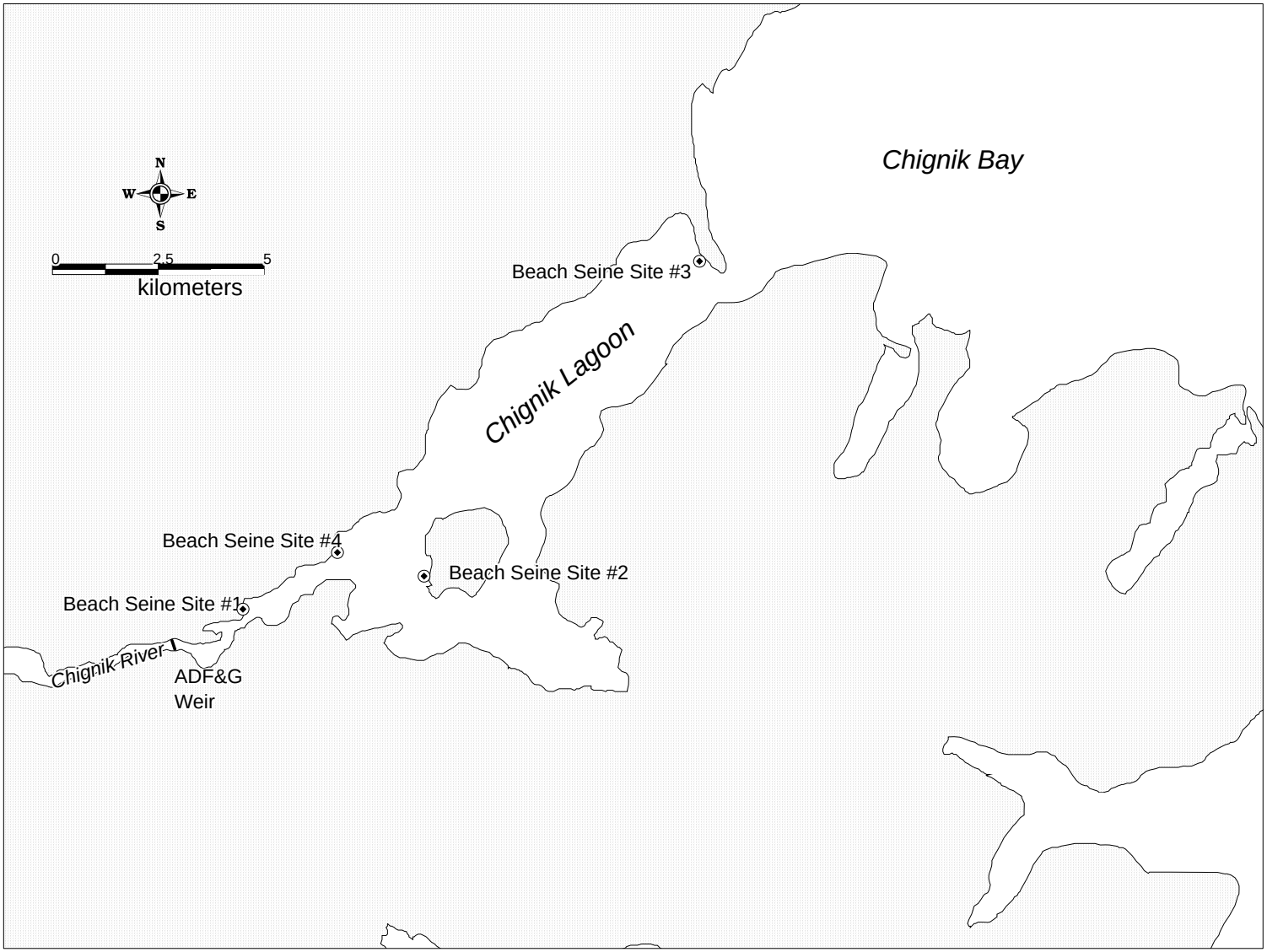

Figure 4.-Chignik Lagoon sampling sites.

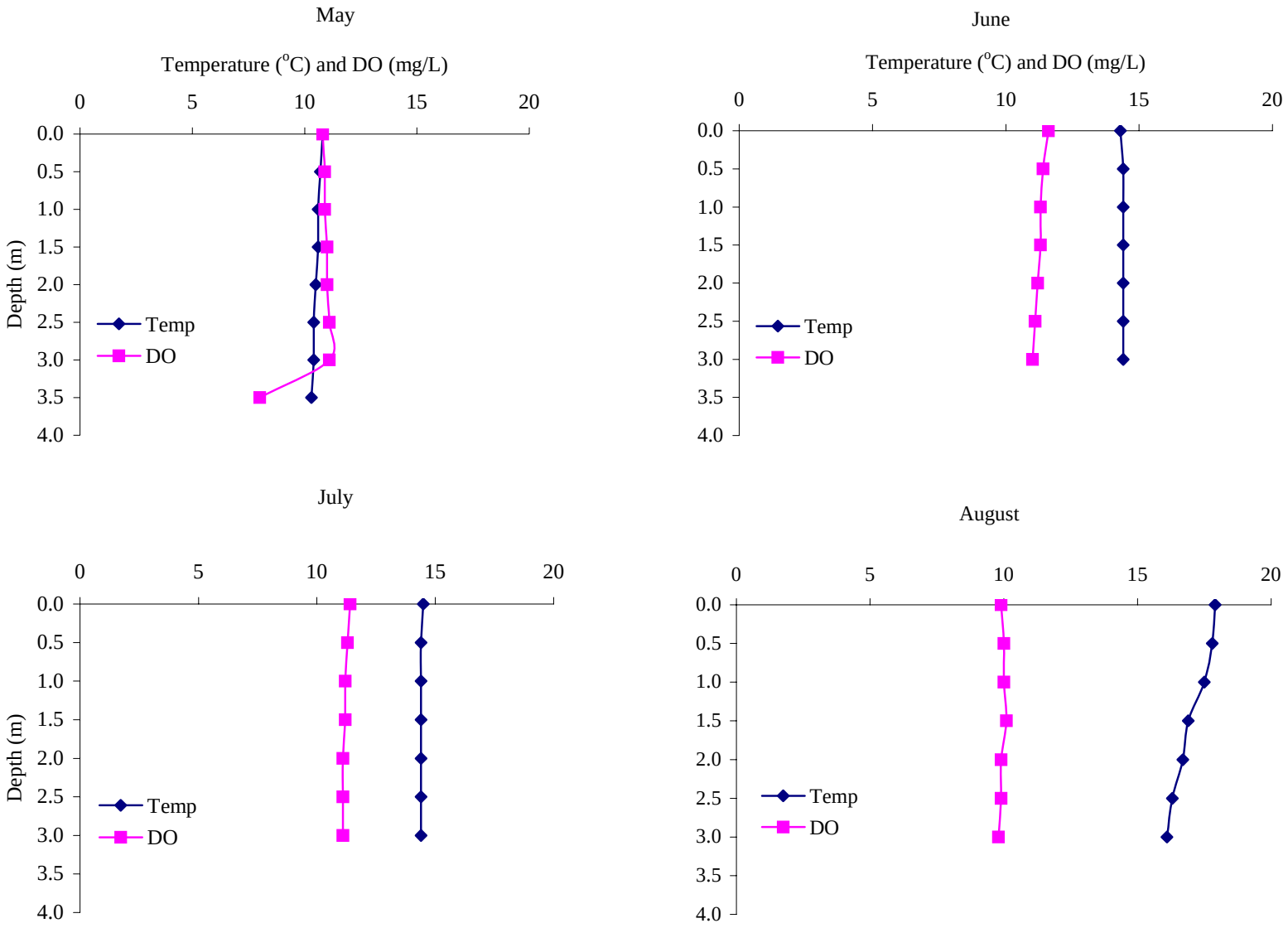

Figure 5.-Mean monthly temperature and dissolved oxygen profiles for Black Lake, 2005.

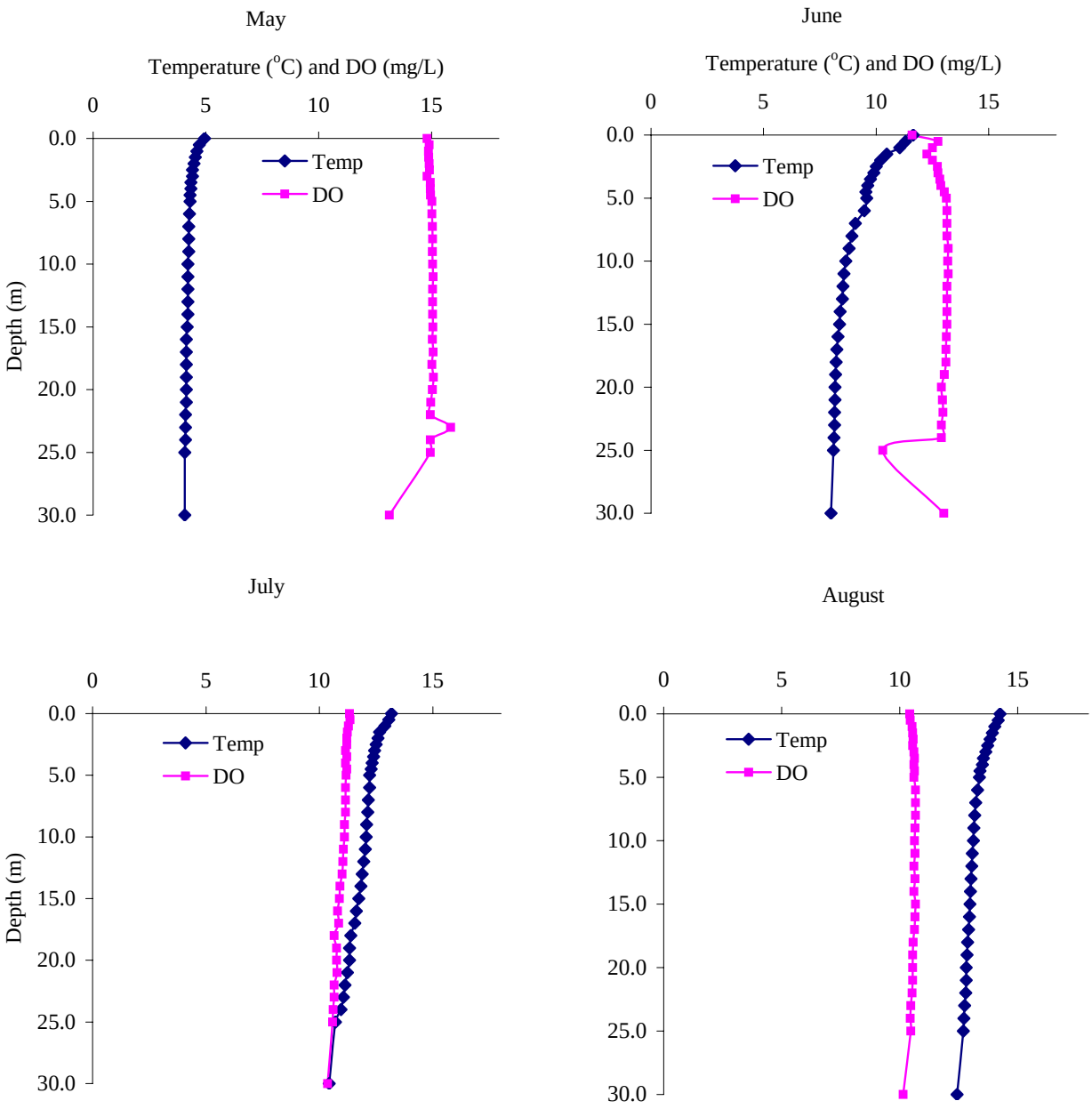

Figure 6.-Mean monthly temperature and dissolved oxygen profiles for Chignik Lake, 2005.

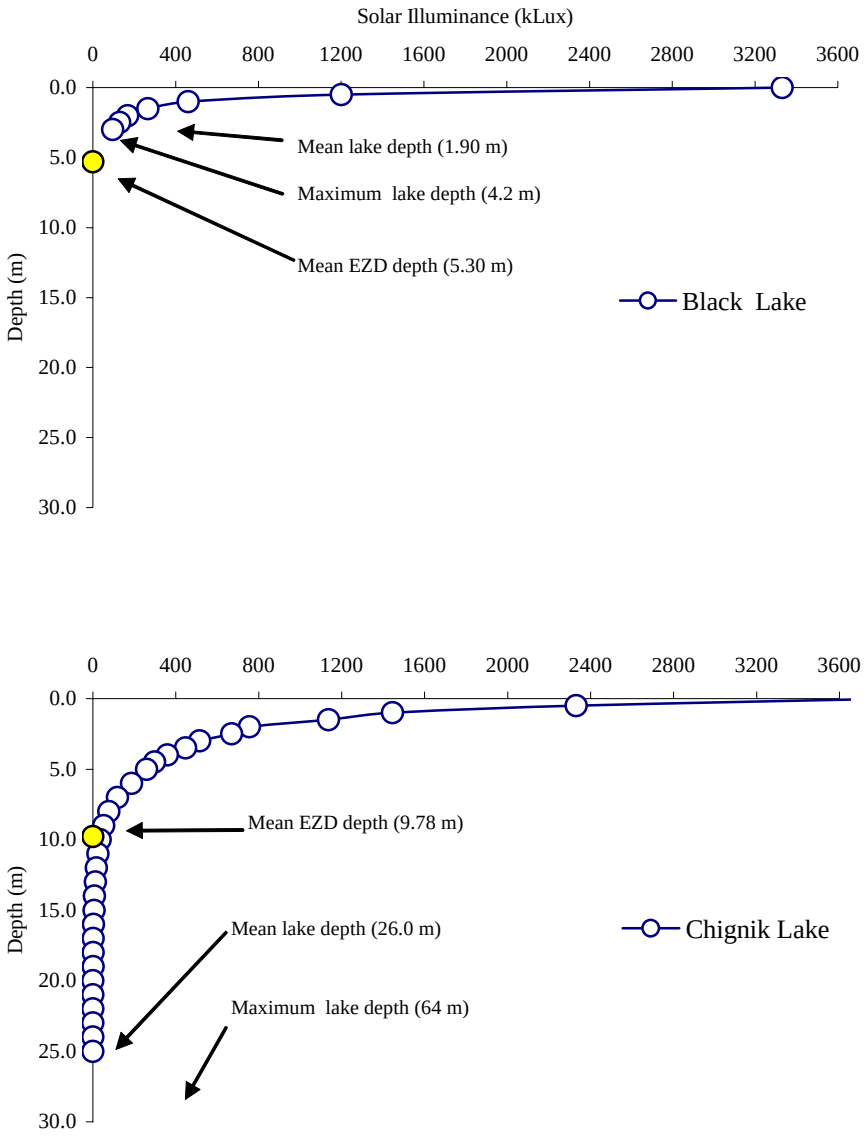

Figure 7.-Average light penetration curves relative to mean depth, EZD, and maximum depth for Chignik and Black Lakes, 2005.

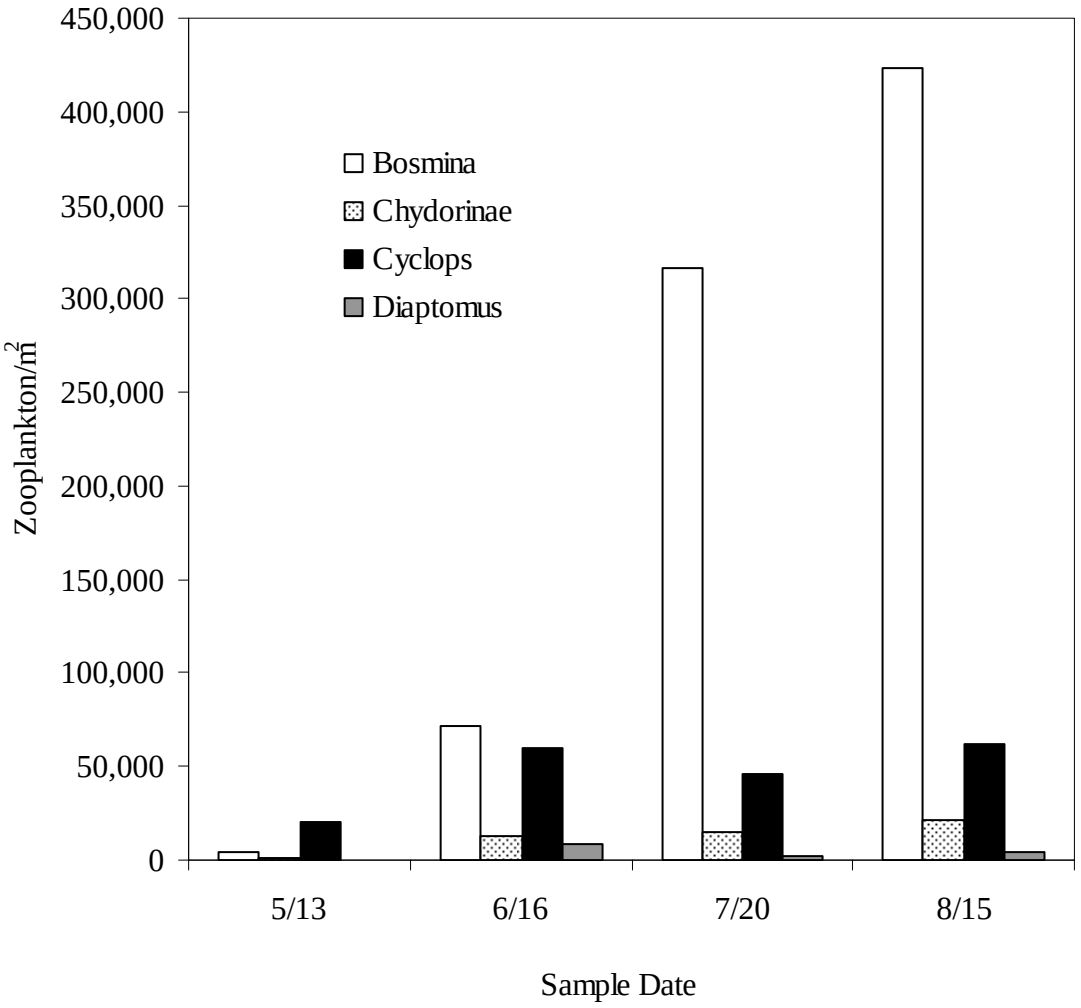

Figure 8.-Number of zooplankton per m^2 of the major copepods (*Cyclops* and *Diaptomus*) and cladocerans (*Bosmina* and *Chydorinae*) in Black Lake, by sample date, 2005.

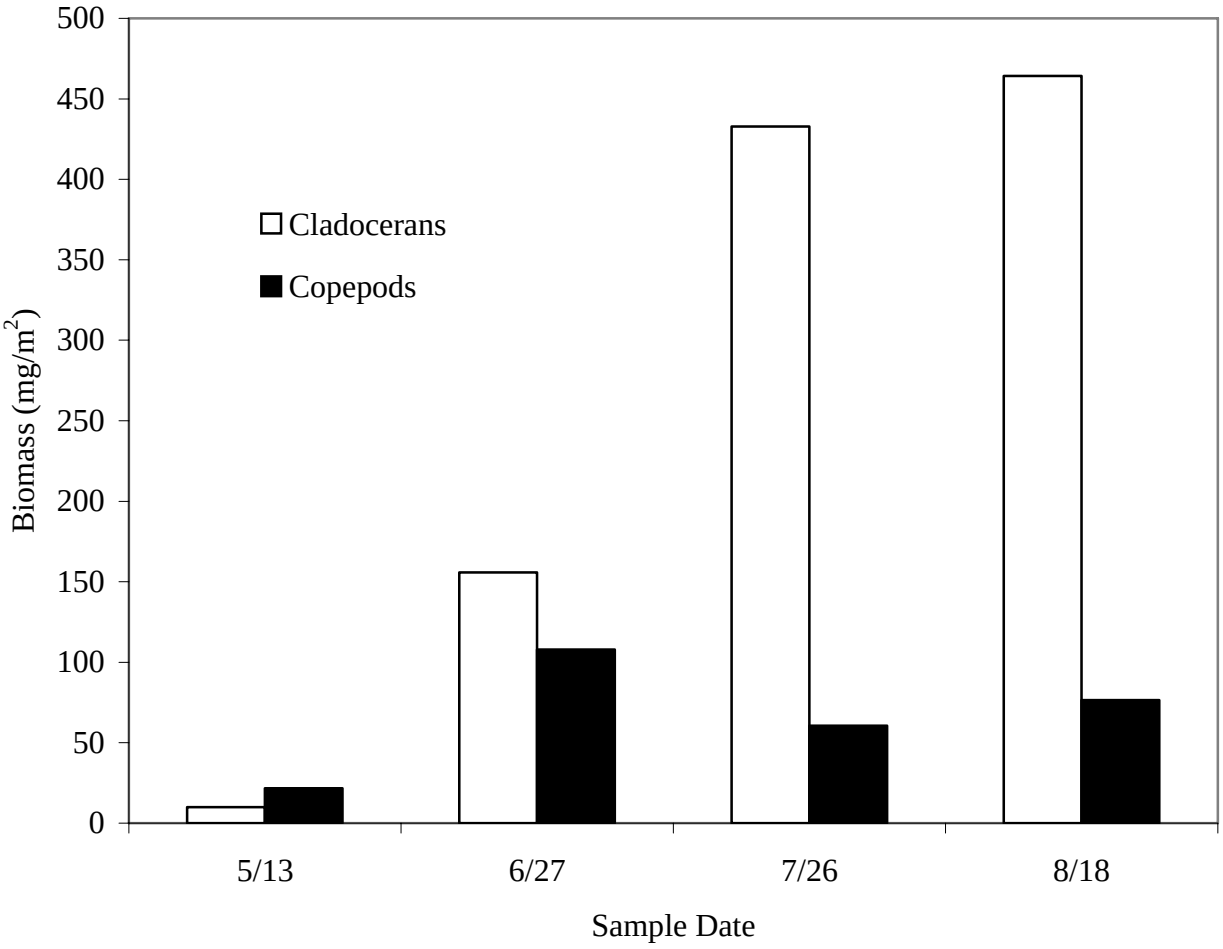

Figure 9.-Mean biomass per m^2 of the major copepods and cladocerans in Black Lake, by sample date, 2005.

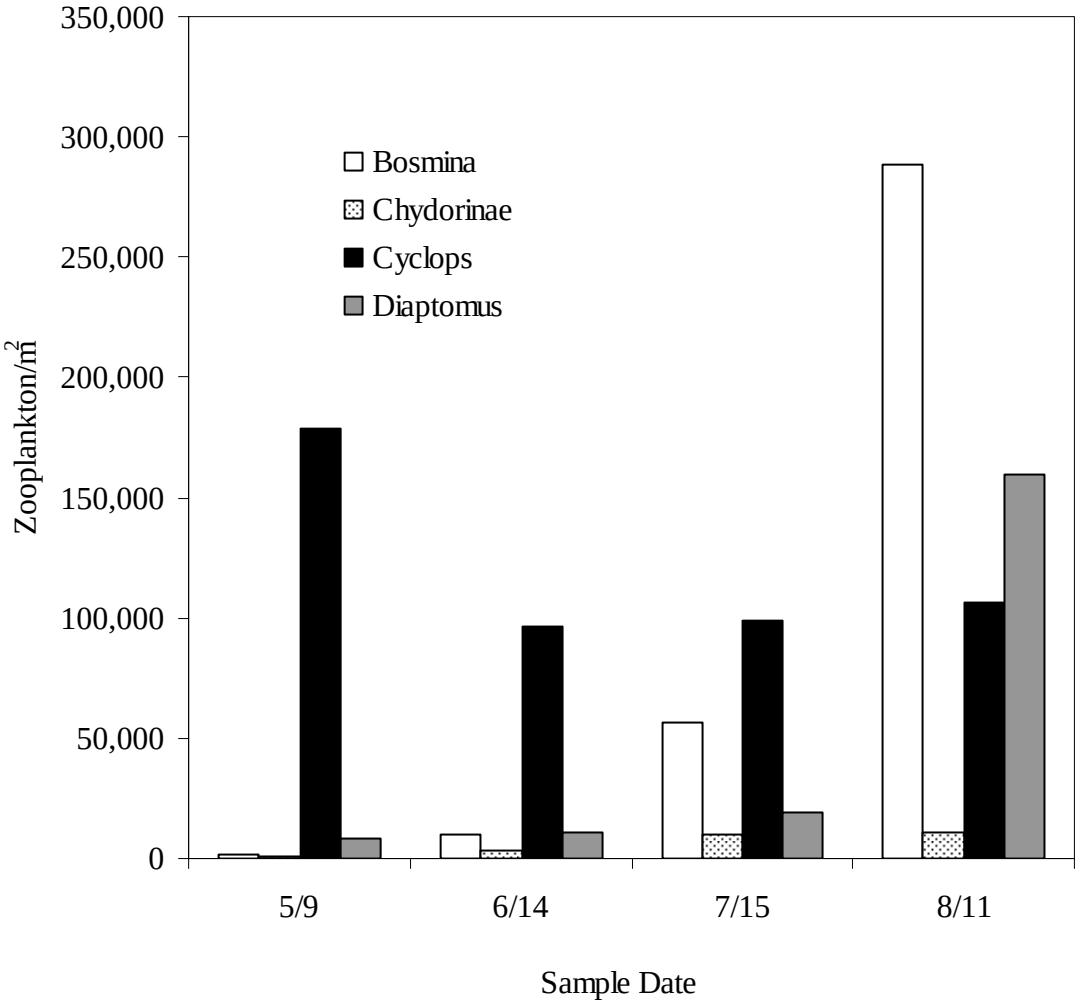

Figure 10.-Number of zooplankton per m^2 of the major copepods (*Cyclops* and *Diaptomus*) and cladocerans (*Bosmina* and *Chydorinae*) in Chignik Lake, by sample date, 2005.

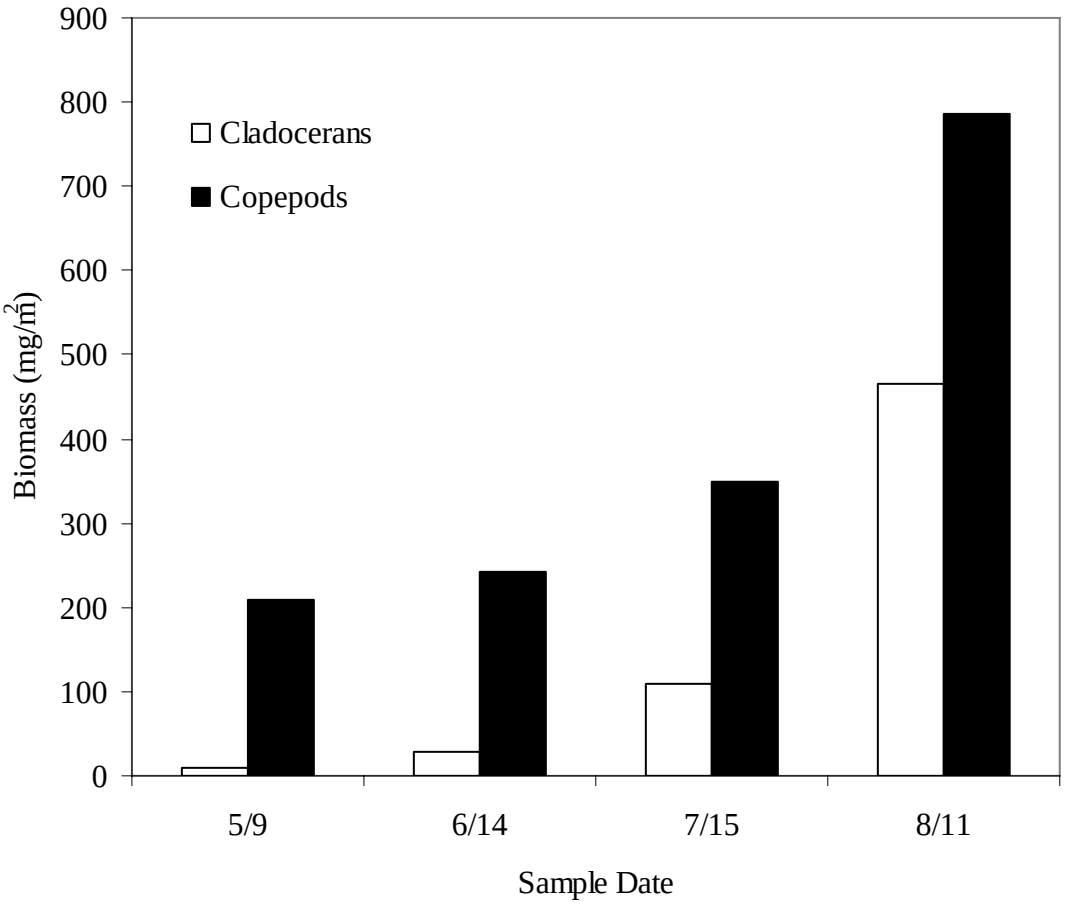

Figure 11.-Mean biomass per m^2 of the major copepods and cladocerans in Chignik Lake, by sample date, 2005.

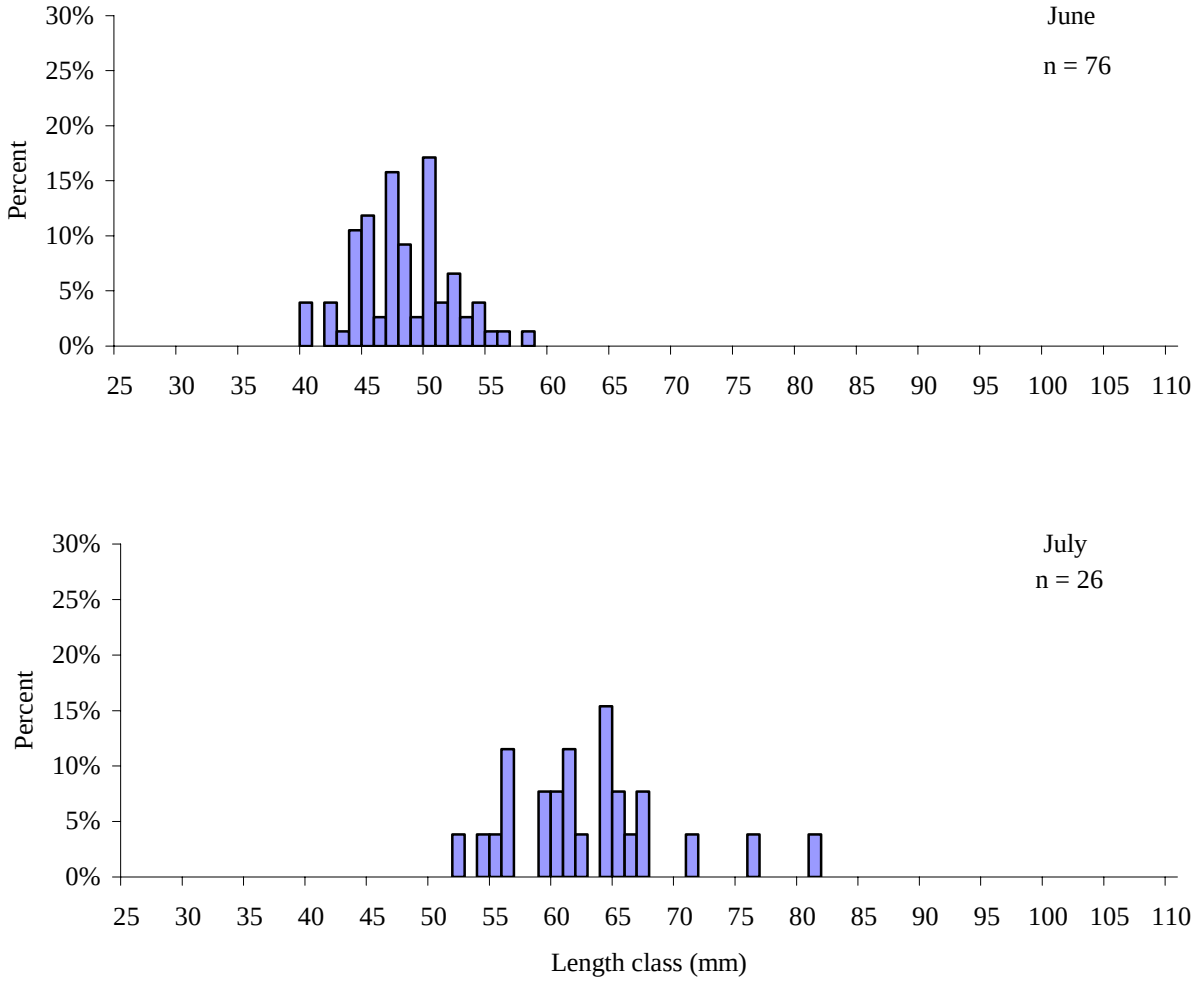

Figure 12.-Length frequency histograms by month of juvenile sockeye salmon captured with a beach seine, and fyke net from Black Lake and Black River, 2005.

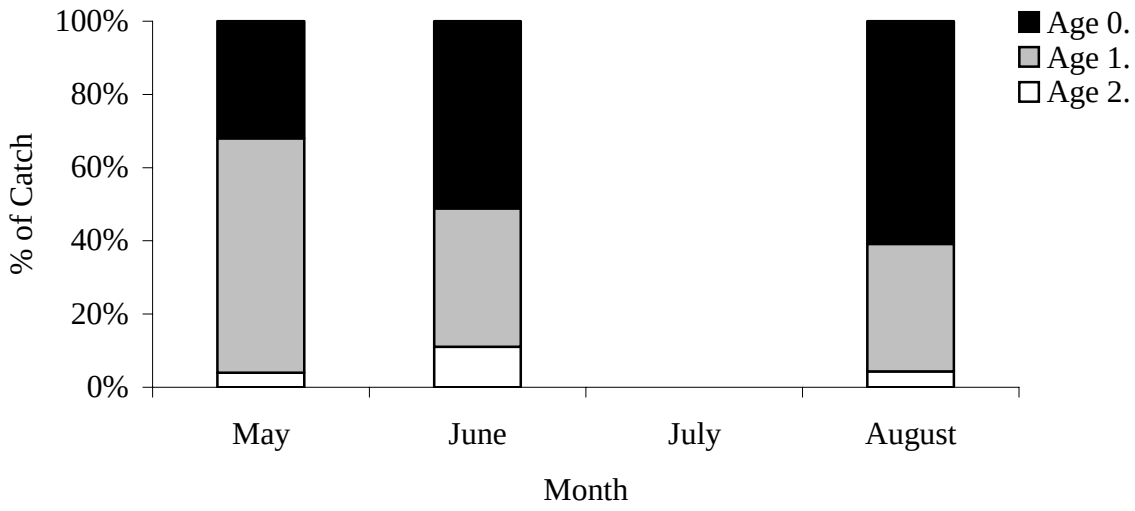

Figure 13.-Estimated age percentages in beach seine catches by month from Chignik Lagoon, 2005.

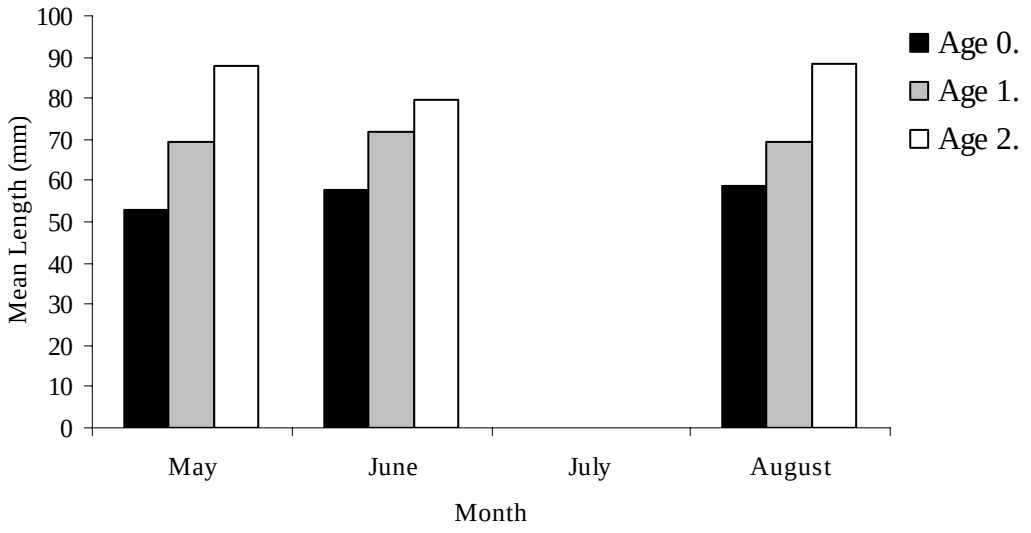

Figure 14.-Mean lengths of beach seine catches by age and month from Chignik Lagoon, 2005.

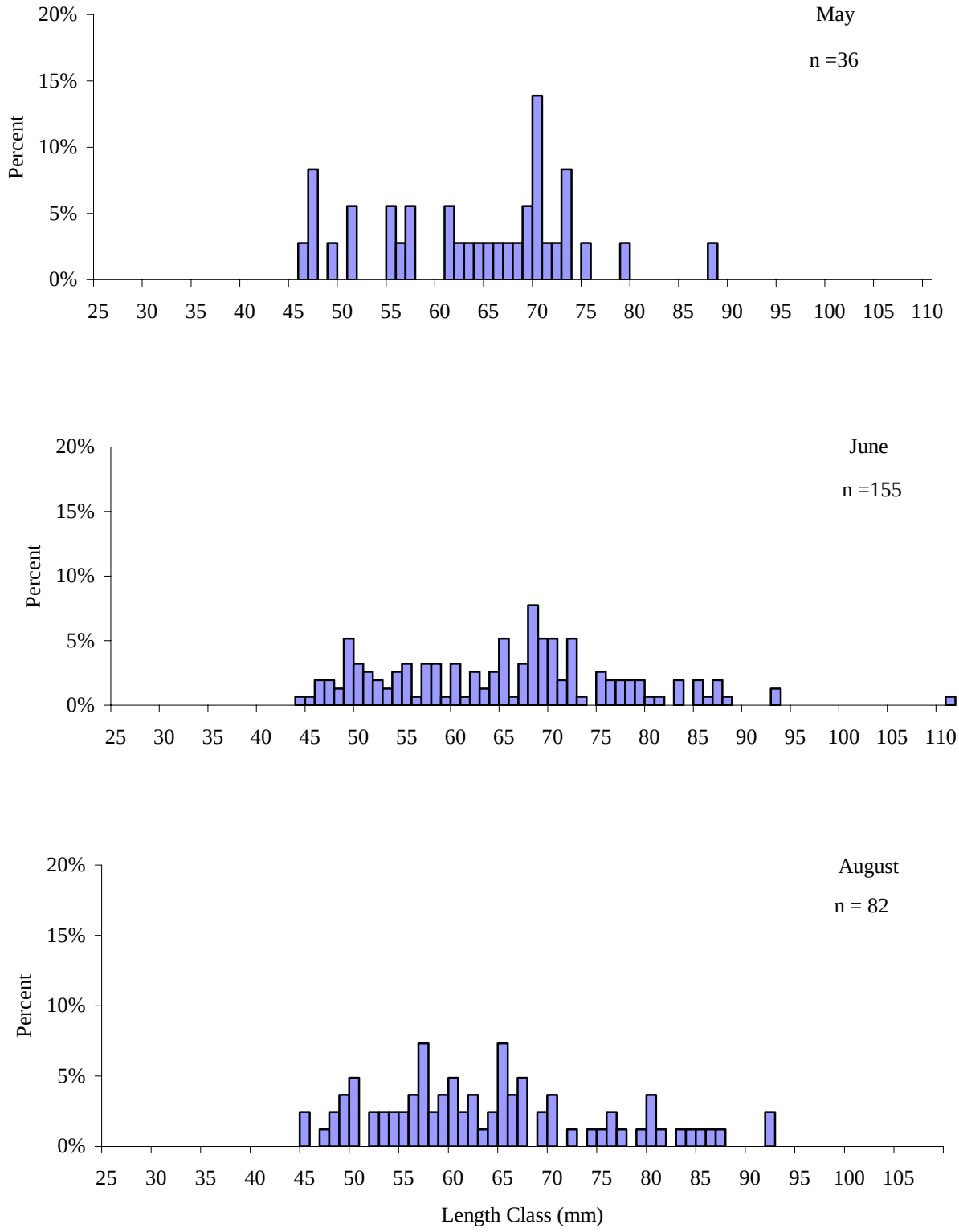

Figure 15.-Length frequency histograms by month of juvenile sockeye salmon captured with a beach seine from Chignik Lagoon, 2005.

APPENDIX A. LIMNOLOGY SAMPLING STATION COORDINATES

Appendix A1.-Location of the limnology sampling stations in Black and Chignik lakes, 2005.

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

Note: Coordinates are in decimal degrees.

APPENDIX B. BLACK LAKE ZOOPLANKTON DATA

Appendix B1.-The 2000-2004 seasonal average number of zooplankton per m^2 from Black Lake.

Taxon	2000	2001	2002	2003	2004
Copepods:					
Epischura	7,850	2,654	2,605	6,303	37,649
Ovig. *Epischura*	127	-	-	-	-
Diaptomus	3,575	1,239	5,893	11,080	25,000
Ovig. *Diaptomus*	-	-	-	1,327	149
Cyclops	35,398	7,307	25,622	19,042	46,198
Ovig. *Cyclops*	-	-	-	266	-
Harpaticus	-	531	-	531	531
Napulii	21,967	6,458	13,385	24,350	40,509
Total copepods	68,917	18,188	47,505	62,898	150,036
Cladocerans:					
Bosmina	38,455	25,779	32,379	285,496	398,855
Ovig. *Bosmina*	10,446	4,883	13,384	39,809	90,147
Daphnia l.	868	372	-	1,526	199
Ovig. *Daphnia l.*	-	-	-	-	-
Chydorinae	11,632	526,097	11,697	3,517	78,954
Total cladocerans	61,401	557,130	57,460	330,348	568,156
Total copepods + cladocerans	130,318	575,318	104,965	393,246	718,192
Rotifers:					
Kellicottia	19,682	1,469	7,605	45,880	28,424
Asplanchna	119	59,820	2,432	299	12,739
Keratella	32,428	16,490	10,684	12,241	33,705
Conochilus	173,424	7,502	70,268	178,742	503,264
other rotifers	4,618	3,981	139,134	764,928	872,293
Total rotifers	230,271	89,261	230,122	1,002,090	1,450,425

Appendix B2.-Average number of zooplankton per m^3 from Black Lake by sample date, 2005.

Taxon	Sample Date 5/13	6/16	7/20	8/15	Seasonal Average
Copepods:					
Epischura	2,389	14,154	5,308	3,892	6,436
Ovig. *Epischura*	-	-	-	-	-
Diaptomus	-	2,831	708	1,415	1,239
Ovig. *Diaptomus*	-	-	-	354	89
Cyclops	20,701	19,816	15,216	20,524	19,064
Ovig. *Cyclops*	-	-	-	-	-
Harpaticus	-	-	-	-	-
Nauplii	19,904	21,939	13,800	8,493	16,034
Total copepods	42,994	58,740	35,032	34,678	42,861
Cladocerans:					
Bosmina	3,981	23,708	105,449	141,189	68,582
Ovig. *Bosmina*	3,185	14,862	20,170	3,892	10,527
Daphnia l.	-	-	-	-	-
Ovig. *Daphnia l.*	-	-	-	-	-
Chydorinae	796	4,246	4,954	7,077	4,268
Total cladocerans	7,962	42,816	130,573	152,158	83,377
Total copepods + cladocerans	50,956	101,556	165,605	186,836	126,238

Appendix B3.-The 2000-2004 biomass estimates (mg dry weight/m^2) of the major Black Lake zooplankton taxon.

	2000		2001		2002		2003		2004	
Taxon	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
Diaptomus	8.78	8.86	3.50	3.85	24.42	46.95	11.40	42.19	57.30	31.52
Cyclops	33.55	32.09	7.52	9.12	32.03	36.04	5.82	18.30	36.93	35.75
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
Cladocerans:										
Bosmina	37.33	32.86	12.75	15.80	69.41	65.10	137.38	290.05	332.11	365.58
Ovigerous *Bosmina*	14.81	13.49	4.34	5.18	44.01	45.07	37.07	77.61	121.59	125.78
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
Total cladocerans	53.98	53.40	3.99	26.13	71.84	125.64	176.51	186.16	463.03	531.87
Total Biomass	105.23	101.64	12.89	41.56	106.08	162.42	195.38	218.38	582.99	620.38

Appendix B4.-Biomass estimates (mg dry weight/m^3) of the major zooplankton taxa, by sample date, from Black Lake, 2005.

Taxon	Sample Date 5/25	6/22	7/19	8/15	Seasonal Average	Weighted average
Copepods:						
Epischura	1.94	11.51	4.32	3.17	5.23	5.09
Diaptomus	-	5.55	1.39	2.77	2.43	2.75
Cyclops	19.74	18.89	14.51	19.57	18.18	18.21
Harpaticus	-	-	-	-	-	-
Total copepods	21.68	35.95	20.21	25.51	25.84	26.05
Cladocerans:						
Bosmina	4.04	24.06	107.03	143.30	69.61	61.09
Ovig. *Bosmina*	5.34	24.92	33.82	6.53	17.65	15.53
Daphnia l.	-	-	-	-	-	-
Chydorinae	0.11	0.57	0.67	0.96	0.58	2.94
Total cladocerans	9.49	49.56	141.52	150.78	87.84	79.56
Copepods to cladocerans	2.28	0.73	0.14	0.17	0.29	0.33
Total Biomass	31.17	85.51	161.73	176.29	113.67	105.61

APPENDIX C: CHIGNIK LAKE ZOOPLANKTON DATA

Appendix C1.-The 2000-2004 seasonal average number of zooplankton per m^2 from Chignik Lake.

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

Appendix C2.-Average number of zooplankton per m^3 from Chignik Lake, 2005**.**

Taxon	Sample Date 5/14	6/9	7/8	8/9	Seasonal Average
Copepods:					
Epischura	120	259	489	3,493	1,090
Ovigerous *Epischura*	-	-	-	-	-
Diaptomus	171	251	483	3,972	1,219
Ovigerous *Diaptomus*	-	29	60	179	67
Cyclops	3,793	2,078	2,179	2,278	2,582
Ovigerous *Cyclops*	9	33	396	384	205
Harpaticus	9	-	-	23	8
Nauplii	714	737	1,099	7,226	2,444
Total copepods:	4,815	3,387	4,705	17,554	7,615
Cladocerans:					
Bosmina	26	220	1,267	6,802	2,079
Ovigerous *Bosmina*	4	78	548	1,750	595
Daphnia longiremis	53	98	141	1,174	366
Ovigerous *Daphnia longiremis*	43	22	114	406	146
Chydorinae	21	63	202	226	128
Total cladocerans:	147	480	2,272	10,357	3,314
Total Copepods + Cladocerans	4,962	3,867	6,976	27,911	10,929

Appendix C3.-The 2000-2004 season biomass estimates (mg dry weight/m^2) of the major zooplankton species in Chignik Lake.

Taxon	2000		2001		2002		2003		2004	
	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
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
Ovigerous *Diaptomus*	5.31	9.43	0.07	0.30	17.46	27.33	7.25	8.63	16.69	22.20
Cyclops	255.84	250.07	73.54	128.12	159.34	178.97	39.69	46.08	161.53	155.46
Ovigerous *Cyclops*	9.04	10.43	21.35	33.46	35.85	58.85	3.40	5.66	20.45	20.43
Harpaticus	0.13	0.29	0.19	0.62	0.35	0.91	0.27	0.45	0.57	0.55
Total Copepods:	429.84	398.84	131.69	225.33	364.20	412.69	214.46	251.85	341.89	340.23
Cladocerans										
Bosmina	97.46	76.08	19.58	27.44	48.37	55.74	72.98	85.55	49.53	49.46
Ovigerous *Bosmina*	28.94	27.89	3.87	5.98	22.37	25.08	22.70	26.37	11.45	11.40
Daphnia longiremis	11.22	12.56	2.09	5.18	20.49	22.20	37.82	42.73	37.31	37.16
Ovigerous *Daphnia longiremis*	2.37	3.38	0.05	0.44	28.29	29.61	19.29	23.17	23.68	23.62
Chydorinae	0.84	3.56	0.54	2.20	1.17	6.95	0.12	0.73	1.16	6.03
Total Cladocerans:	140.83	123.48	26.12	41.23	120.69	139.59	152.91	178.55	123.13	127.67
Total Biomass	570.68	522.32	157.82	266.57	484.89	552.28	367.37	430.40	465.03	467.90

Appendix C4.-Biomass estimates (mg dry weight/m^3) of the major zooplankton taxa, by sample date, from Chignik Lake, 2005.

Taxon	Sample Date 5/9	6/14	7/15	8/11	Seasonal Average	Weighted Average
Copepods:						
Epischura	0.09	0.21	0.50	2.83	0.91	0.91
Ovigerous *Epischura*	-	-	-	-	-	-
Diaptomus	0.40	0.53	1.78	9.40	3.03	3.00
Ovigerous *Diaptomus*	-	0.26	0.48	1.50	0.56	0.56
Cyclops	3.82	3.89	2.99	2.64	3.33	2.83
Ovigerous *Cyclops*	0.03	0.10	2.03	1.71	0.97	0.70
Harpaticus	0.01	0.00	0.00	0.01	0.00	0.01
Total copepods:	4.35	4.99	7.78	18.08	8.80	9.91
Cladocerans:						
Bosmina	0.04	0.26	1.15	6.02	1.87	1.87
Ovigerous *Bosmina*	-	0.14	0.76	2.12	0.75	0.75
Daphnia longiremis	0.07	0.13	0.13	1.45	0.45	0.48
Ovigerous *Daphnia longiremis*	0.11	0.05	0.33	1.23	0.43	0.45
Chydorinae	0.02	0.04	0.14	0.13	0.08	0.08
Total cladocerans:	0.23	0.62	2.52	10.96	3.58	3.63
Copepods to cladocerans	19.27	8.02	3.09	1.65	2.46	2.73
Total Copepods + Cladocerans	4.57	5.62	10.30	29.04	12.38	13.54

APPENDIX D. CATCH DATA

Appendix D1.-Beach seine catch data, 2005.

Location	Site	Date	Water temp (°C)	Total sockeye catch	Coho	Chi-nook	Stickleback	Pond smelt	Dolly Varden	Pygmy whitefish	Other
Black Lake	1	5/13	14.0	16	5	0	49	0	0	0	0
	1	6/7	14.5	276	9	0	0	125	0	0	0
	1	7/5	19.0	5	26	0	13	0	0	1	0
	1	8/4	20.0	0	10	0	0	0	0	0	0
Black Lake	2	5/13	16.0	56	5	0	0	0	0	0	0
	2	6/7	11.5	0	0	0	10	3	0	0	0
	2	7/5	18.0	0	0	0	1	0	0	0	0
	2	8/4	21.0	0	408	0	55	0	0	0	0
Black Lake	4	5/13	16.0	8	4	0	12	0	0	0	0
	4	6/7	11.5	23	0	0	18	2	0	0	0
	4	7/5	18.0	1	74	0	0	12	0	19	0
	4	8/4	20.0	0	0	0	2	0	0	0	0
Black Lake	5	5/13	13.0	0	15	0	12	0	0	0	0
	5	6/7	12.5	16	0	0	16	0	0	0	0
	5	7/5	17.0	33	26	0	18	0	0	0	0
	5	8/4	19.5	0	8	0	10	0	0	0	0
Chignik Lagoon	1	5/7	9.0	0	0	0	1	0	0	0	0
	1	6/6	10.0	9	8	0	5	0	10	13	0
	1	6/30	15.0	100	24	0	8	2	10	6	0
	1	8/3	15.5	36	92	0	33	23	6	6	0

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Appendix D1.-Page 2 of 2.

Location	Site	Date	Water temp (°C)	Total sockeye catch	Coho	Chi-nook	Stickleback	Pond smelt	Dolly Varden	Pygmy whitefish	Other
Chignik Lagoon	2	5/7	8.0	8	1	0	1	0	0	0	0
	2	6/6	10.0	1	0	0	10	0	0	0	0
	2	6/30	19.0	26	1	0	1	0	0	0	2 sculpin
	2	8/3	15.5	6	6	0	12	1	0	0	0
Chignik Lagoon	3	5/7	8.0	5	12	0	2	0	17	0	0
	3	6/6	10.5	1	2	0	0	0	17	0	1 sculpin, 1 adult sockeye
	3	6/30	17.5	3	1	0	1	0	1	0	2 pinks
	3	8/3	14.5	0	0	0	1	0	2	0	0
Chignik Lagoon	4	5/7	9.5	37	1	0	53	0	0	0	0
	4	6/6	12.5	65	1	0	4	0	1	0	0
	4	6/30	15.5	318	15	0	10	0	0	0	2 sculpin
	4	8/3	16.0	53	7	0	1	6	10	0	0

Appendix D2.-Fyke net catch data from Black River, 2005.

Date pulled	Time Set	Time Pulled	Total time (hrs)	Temp (°C) Water	Temp (°C) Air	Sockeye catch	Other Catch Coho	Chinook	Stickleback	Pond smelt	Dolly	Pygmy whitefish	Other
6/7	16:30	18:00	1.5	13.0	11.0	0	0	0	35	0	0	0	0
7/5	14:35	16:16	1.8	15.5	13.5	300	162	0	17	0	1	0	0
8/4	11:30	14:10	2.8	20.5	15.0	0	165	0	25	15	0	0	0