Fishery Management Report No. 06-16

Chignik Watershed Ecological Assessment Project Season Report, 2004

by

Heather Finkle

March 2006

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

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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

FISHERY MANAGEMENT REPORT NO. 06-16

CHIGNIK WATERSHED ECOLOGICAL ASSESSMENT PROJECT SEASON REPORT, 2004

by

Heather Finkle
Division of Commercial Fisheries, Kodiak

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

March 2006

The Division of Sport Fish Fishery Management Reports series was established in 1989 for the publication of an overview of Division of Sport Fish management activities and goals in a specific geographic area. Since 2004, the Division of Commercial Fisheries has also used the Fishery Management Report series. Fishery Management Reports are intended for fishery and other technical professionals, as well as lay persons. Fishery Management Reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm. This publication has undergone regional peer review.

Heather Finkle,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
211 Mission Road, Kodiak, AK 99615, USA

This document should be cited as:
Finkle, H. 2006. Chignik watershed ecological assessment project season report, 2004. Alaska Department of Fish and Game, Fishery Management Report No. 06-16, Anchorage.

TABLE OF CONTENTS

Page

LIST OF TABLES ii

LIST OF FIGURES ii

LIST OF APPENDICES iii

ABSTRACT 1

INTRODUCTION 1

OBJECTIVES 3

METHODS 3

Limnology 3
- Dissolved Oxygen, Light, and Temperature 3
- Water Sampling 4
- Zooplankton 4

Juvenile Sockeye Salmon Sampling 5
- Beach Seine 5
- Fyke Net 5
- Distribution, Abundance, and Size 5

RESULTS 5

Limnology 5
- Temperature and Dissolved Oxygen 5
  - Black Lake 5
  - Chignik Lake 6
- Light Penetration and Water Transparency 6
  - Black Lake 6
  - Chignik Lake 6
- Water Quality Parameters, Nutrient Levels, and Photosynthetic Pigments 6
  - Black Lake 6
  - Chignik Lake 6
- Zooplankton 7
  - Black Lake 7
  - Chignik Lake 7

Juvenile Sockeye Salmon 8
- Black Lake and Black River 8
- Chignik Lagoon 8

DISCUSSION 9

ACKNOWLEDGEMENTS 12

REFERENCES CITED 12

TABLES AND FIGURES 17

APPENDIX A. LIMNOLOGY SAMPLING STATION COORDINATES 57

APPENDIX B. ZOOPLANKTON DATA 59

APPENDIX C. CATCH DATA 65

LIST OF TABLES

Table **Page**

1. Limnology and zooplankton sampling dates, 2004. 18
2. Dates of beach seine sample sites by area and site, 2004. All sites were sampled on each sampling day. 18
3. Dates of fyke net samples in Black River, 2004. 18
4. Water temperature, by depth and date, for Black Lake, 2004. 19
5. Dissolved oxygen levels by depth and date, for Black Lake, 2004. 19
6. Water temperature, averaged over all stations, by depth and date for Chignik Lake, 2004 20
7. Dissolved oxygen levels, averaged over all stations, by depth and date for Chignik Lake, 2004 21
8. Average monthly solar illuminance readings by depth and date for Black Lake, 2004 22
9. Euphotic Zone Depth (EZD) and Euphotic Volume (EV) of Black and Chignik Lakes, by month, 2004. 22
10. Average monthly solar illuminance readings by depth and date for Chignik Lake, 2004. 23
11. Seasonal water quality parameters, nutrient concentrations, and photosynthetic pigments for Chignik Lake (by station) and Black Lake, 2004. 24
12. Water quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Black Lake, 2004 25
13. Water quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Chignik Lake, 2004 26
14. Average number of zooplankton per m2 from Black Lake by sample date, 2004 27
15. Biomass estimates (mg dry weight/m2) of the major Black Lake zooplankton taxon by sample date, 2004. 28
16. Average lengths (mm) of zooplankton in Black Lake by sample date, 2004 29
17. Average number of zooplankton per m2 from Chignik Lake, by sample date, 2004. 30
18. Biomass estimates (mg dry weight/m2) of the major zooplankton species in Chignik Lake by sample date, 2004 32
19. Average length (mm) of zooplankton from Chignik Lake by sample date, 2004 33
20. Total catch of juvenile sockeye salmon, by age and location, from the Chignik watershed, 2004. 34
21. Total beach seine hauls, total catch, and catch per haul, by month, of juvenile sockeye salmon from the Chignik watershed, 2004 35
22. Fyke net hours fished, total catch, and catch per hour, by month, of juvenile sockeye salmon from Black River, 2004 36
23. Total catch of juvenile sockeye salmon from Black Lake and Black River, by age and gear type, 2004 37
24. Average length, weight, and condition factor by age and gear type for juvenile sockeye salmon captured in Black Lake and Black River, 2004 38
25. Total beach seine catch, by age, of juvenile sockeye salmon from Chignik Lagoon, 2004 39
26. Average length, weight, and condition factor by age of juvenile sockeye salmon captured by beach seine in Chignik Lagoon, 2004. 40

LIST OF FIGURES

Figure **Page**

1. Chignik watershed and location on the Alaska Peninsula (inset). 41
2. Black Lake and its sampling sites. 42
3. Chignik Lake and its sampling sites. 43
4. Chignik Lagoon and its sampling sites. 44
5. Mean monthly temperature and dissolved oxygen profiles for Black Lake, 2004. 45
6. Mean monthly temperature and dissolved oxygen profiles for Chignik Lake, 2004 46
7. Average light penetration curves relative to mean depth, EZD, and maximum depth for Chignik and Black Lakes, 2004. 47
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, 2004. 48
9. Mean biomass per m^2 of the major copepods and cladocerans in Black Lake, by sample date, 2004. 49

LIST OF FIGURES (CONT.)

Figure **Page**

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, 2004. 50
11. Mean biomass per m^2 of the major copepods and cladocerans in Chignik Lake, by sample date, 2004. 51
12. Length frequency histograms by month of juvenile sockeye salmon captured with a beach seine, and fyke net from Black Lake and Black River, 2004. 52
13. -Estimated age percentages in beach seine catches by month from Chignik Lagoon, 2004. 53
14. Mean lengths of beach seine catches by age and month from Chignik Lagoon, 2004. 54
15. Length frequency histograms by month of juvenile sockeye salmon captured with a beach seine from Chignik Lagoon, 2004. 55

LIST OF APPENDICES

Appendix **Page**

A1. Location of the limnology sampling stations in Black and Chignik lakes, 2004. 58
B1. Average number of zooplankton per m^3 from Black Lake by sample date, 2004. 60
B2. Biomass estimates (mg dry weight/m^3) of the major zooplankton species, by sample date, from Black Lake, 2004. 61
B3. Average number of zooplankton per m^3 from Chignik Lake, 2004. 62
B4. Biomass estimates (mg dry weight/m^3) of the major zooplankton species, by sample date, from Chignik Lake, 2004. 63
C1. Beach seine catch data, 2004. 66
C2. Fyke net catch data from Black River, 2004.. 69

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 2004 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 2004. However, Black Lake zooplankton were low (<79.00 mg dry wt/m^2) until the downstream migration of juvenile sockeye salmon to Chignik Lake in July and August. As almost 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, although primary production was not limited, zooplankton production was low (<368.00 mg dry wt/m^2) until August, 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 (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 2004 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 (escapement objective of 350,00 to 400,000 sockeye salmon; Witteveen et al. 2005), spawns in Black Lake and its tributaries. The smaller late run (escapement objective of 250,000 to 300,000 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, causing further downstream migration of juvenile sockeye salmon to avoid competition.

Chignik Lagoon may also 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.

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 2004 (Figure 2; Appendix A). In early May 2004, 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

Two vertical zooplankton tows were made at each limnology station with a 0.2-m diameter, 153-micron net from one meter above the lake bottom to the surface. One 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). The other 125-ml sample was stored in a poly bottle and frozen for stable isotope stock identification analysis to be conducted at a later date.

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 every three weeks beginning in May (Table 2). Beach seine sampling of Chignik Lake and Chignik River was not conducted in the 2004 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.

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).

Distribution, Abundance, and Size

Fish collected with the beach seine, fyke net and townet 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 15, the 1-m temperature in Black Lake was 9.1 °C, increasing to 11.7 °C in June and to 18.7 °C on July 12 and decreasing to 16.9 °C on August 18 (Table 4; Figure 6). Dissolved oxygen levels at the 1-m depth went from 11.5 mg/L to 11.1 mg/L to 8.7 mg/L to 10.0 mg/L over the same time frame (Table 5; Figure 6). During the summer sampling season, temperature, and dissolved oxygen levels remained similar throughout the water column (Figure 6).

Chignik Lake

One-meter temperatures in May, June, July, and August were 5.9, 8.2, 12.9, and 13.5 °C respectively (Table 6; Figure 7). Temperatures in Chignik Lake were fairly homogenous over depth in May, June, and August (Table 6; Figure 7). Mild temperature variability (3.4 °C) existed over depth on July 8 and the 1-m temperature increased to 12.9 °C (Table 6; Figure 7). The 1-m dissolved oxygen level on May 14 was 13.4 mg/L, 12.6 mg/L on June 8, 10.6 on July 8, and 11.0 mg/L on August 9 (Table 7; Figure 7). Dissolved oxygen levels showed little variation over depth from May through August (Table 7; Figure 7).

Light Penetration and Water Transparency

Black Lake

Light penetrated the entire water column in Black Lake during the 2004 sampling season (Table 8; Figure 8). 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 8). For the 2004 season, water transparency ceased at a mean depth of 2.1 m.

Chignik Lake

Light penetration ceased at a depth of 17 m in May and at 14 m in August (Table 10; Figure 8). The EZD was 4.61 m in May, 10.52 m in July, and 7.03 m in August (Table 9). The EV in Chignik Lake averaged 267.7 x 10^6 m^3 for the 2004 sampling season (Table 10; Figure 8). For the 2004 season, water transparency ceased at a mean depth of 2.3 m.

Water Quality Parameters, Nutrient Levels, and Photosynthetic Pigments

Black Lake

The pH in Black Lake averaged 7.81 and alkalinity averaged 30.2 mg/L $CaCO_3$ (Tables 11 and 12). All phosphorous-based nutrient concentrations in Black Lake were the lowest since the onset of this study in 2000 (Table 11). Total P (TP) averaged 22.2 mg/L P, mean TFP was 5.1 mg/L P, and FRP averaged 2.6 μg/L P in Black Lake in 2004 (Tables 11 and 12). TKN was 188.8 μg/L N on average for Black Lake, ammonia averaged approximately 9.7 μg/L N, and nitrate + nitrite had a mean of 3.7 μg/L N in 2004 (Tables 11 and 12). Of the photosynthetic pigments, chlorophyll *a* averaged 3.60 μg/L and phaeophytin *a* had a seasonal mean of 0.15 μg/L (Tables 11 and 12).

Chignik Lake

The pH in Chignik Lake averaged 7.62 and alkalinity averaged 22.4 mg/L $CaCO_3$ (Tables 11 and 13). Total P averaged 18.5 mg/L P, mean TFP was 6.5 mg/L P, and FRP averaged 4.1 μg/L P for Chignik Lake in 2004 (Tables 11 and 13). TKN was 146.5 μg/L N on average, ammonia averaged approximately 9.1 μg/L N, and nitrate + nitrite had a mean of 128.0 μg/L N in 2004 (Tables 11 and 13). Of the photosynthetic pigments, chlorophyll *a* averaged 4.02 μg/L and phaeophytin *a* had a seasonal mean of 0.32 μg/L (Tables 11 and 13).

Zooplankton

Black Lake

Copepod abundance (34,236/m^2) was greater than cladoceran abundance (3,980/m^2) on May 15 in Black Lake (Table 14; Figures 9 and 10; Appendix B). On August 17, the cladoceran abundance (2,148,620/m^2) exceeded the copepod abundance (407,112/m^2; Table 14; Figures 9 and 10; Appendix B). On average, the most prevalent identifiable genera of copepods were *Cyclops* (46,198/m^2) and *Epischura* (37,649/m^2); copepod nauplii (juveniles) were also abundant with a seasonal mean of 40,509/m^2 (Table 14; Figure 9; Appendix B). *Bosmina* was the most prevalent cladoceran in Black Lake in 2004 (Table 14). The abundance of both cladocerans and copepods was dramatically greater than prior months on August 18 (Table 14; Figure 9).

Copepod biomass was dominated by *Cyclops* in May (17.82 mg/m^2) and by *Diaptomus* from June (43.79 mg/m^2) through August (153.28 mg/m^2; Table 15). The majority of cladoceran biomass was comprised of *Bosmina* throughout the 2004 sampling season with an average of 332.11 mg/m^2 (Table 15). For the season, cladoceran biomass (463.03 mg/m^2) was greater on average than copepod biomass (119.95 mg/m^2; Table 15; Figure 10). This was driven by a large *Bosmina* biomass on August 18 (Table 15; Figure 10).

Average seasonal lengths of the major zooplankton in Black Lake were 0.80 mm for *Diaptomu*s, 0.50 mm for C*yclops*, 0.31 mm for *Bosmina*, and 0.21 mm for *Chydorinae* (Table 16). Ovigerous *Bosmina* (0.38 mm) were longer than non-egg bearing *Bosmina*.

Chignik Lake

The average seasonal copepod density (336,447/m^2) was greater than the average seasonal cladoceran density (114,570/m^2) in 2004 (Table 17). *Cyclops* (140,871/m^2), *Epischura* (67,163/m^2), and *Diaptomus* (45,467/m^2) were the densest genera of copepods on average during the 2004 season (Table 17; Figure 11). *Bosmina* (59,929/m^2) and *Daphnia* (29,824/m^2) were the densest cladocerans (Table 17; Figure 11). The total average density of copepod and cladoceran zooplankton was greater in Black Lake (718,192/m^2) than in Chignik Lake (451,017/m^2) in 2004 (Tables 14 and 17). A spike in both copepod and cladoceran density occurred by August 9 in Chignik Lake (Table 17; Figure 11).

Biomass estimates of the copepod *Cyclops* were substantially greater than biomass estimates of other copepod and cladocerans from May through July (Table 18). The copepod *Diaptomus* had the greatest biomass of all identified zooplankton in August (294.36 mg/m^2: Table 18). *Bosmina* and *Daphnia* biomass levels increased from May to August (Table 18). For the 2004 season, copepods (341.89 mg/m^2) had a greater biomass on average than cladocerans (123.13 mg/m^2) for a total average of 465.03 mg/m^2 Chignik Lake zooplankton, which was slightly less than that of Black Lake (Table 18; Figure 12). Similar to Black Lake zooplankton, an increase in both copepod and cladoceran biomasses occurred in August (Table 18; Figure 12).

Average seasonal lengths of the major non-egg bearing zooplankton in Chignik Lake were 0.81 mm for *Diaptomu*s, 0.54 mm for C*yclops*, 0.55 mm for *Epischura*, 0.33 mm for *Bosmina*, and 0.53 mm for *Daphnia* (Table 19). Ovigerous zooplankton were consistently longer than non-egg bearing individuals (Table 19).

JUVENILE SOCKEYE SALMON

Of the 5,538 AWL sampled juvenile sockeye salmon that were captured throughout the entire watershed by all gear types, 68.5% were estimated to be age-0., 21.0% were age-1., 10.5% were age-2., and no age-3. fish were captured (Table 20).

Black Lake and Black River

Beach seine catch rates in Black Lake were the greatest during May with 91 fish per haul; catch rates declined from 69 fish per haul in June and 14 fish per haul in July to one fish per haul by August (Table 21). Stickleback, pygmy whitefish, and juvenile coho salmon were more abundant than juvenile sockeye salmon in July and August beach seine catches (Appendix C).

Fyke net catches in the Black River yielded 201 sockeye salmon in July and 31 sockeye salmon in August (Table 22). The early-July fyke net catch was comprised mainly of juvenile sockeye salmon (Appendix C). The late-July and August fyke net catches were comprised mainly of pygmy whitefish, pond smelt, juvenile coho salmon, and stickleback (Appendix C).

Of the 313 aged sockeye salmon caught in Black Lake and Black River, 311 were age 0. and two were age-1. fish (Table 23). The two age-1. fish were captured with a fyke net in Black River (Table 23).

The mean length of Black Lake juvenile sockeye salmon was 38 mm in May, which increased to 74 mm by August (Table 24). Condition factor for Black Lake age-0. sockeye salmon increased from 0.84 in May to 1.10 in July, and decreased to 0.89 in August (Table 24). The age-0. sockeye salmon captured in Black River averaged 69 mm in July and 65 mm in August (Table 24). The single age-1. sockeye salmon captured in Black River was 79 mm in July and the individual captured in August was 68 mm in length (Table 24). Condition factors varied for age-0. (1.00-1.05) and age-1. (0.86-1.16) fish from Black River (Table 24). Variability in length occurred over the sampling season for fish captured from both areas with a general trend of increasing length over time (Figure 13).

Chignik Lagoon

Chignik Lagoon beach seine catch rates were 177 fish per haul in May and 53 fish per haul in June (Table 21). Catch rates were 196 fish per haul in July and 39 fish per haul in August (Table 21). Dolly Varden, pond smelt, and stickleback were common in Chignik Lagoon catches (Appendix C).

The seasonal average age composition for Chignik Lagoon beach seine catches was 56.9% age-0., 30.1% age-1., and 13.0% age-2. fish (Table 25; Figure 14). The age-0. component increased from 35.0% in May to 75.9% in August (Table 25; Figure 14). Age-1. and age-2. percentages declined from June to August (Table 25; Figure 14).

Average lengths of age-0. juvenile sockeye salmon increased over the sampling season (Table 26; Figure 15). Average lengths of age-1. and age-2. fish varied over the sampling season (Table 26; Figure 15). Two length modes were present in May: a small size group ranging between 29-35 mm and a larger size group ranging between 55-97 mm (Figure 16). Average lengths of juvenile sockeye salmon varied greatly from June through August (Figure 16). Condition factor indices increased over the sampling period for age-0. fish (Table 26). Age-1. and age-2. fish condition factor varied over the sampling season (Table 26).

DISCUSSION

The 2004 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 2004 sampling season in Black Lake and Chignik Lake were comparable to the past four 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 (9.4 TN:1 TP) suggested that nitrogen was a limiting nutrient (USEPA 2000). However, a comparison of the photosynthetic pigment, chlorophyll *a*, to its byproduct, phaeophytin *a*, showed that chlorophyll-*a* concentrations were proportionally high (seasonal mean of 24.02 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, despite the nitrogen limitations 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 necessarily 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 2004. The chlorophyll-*a* production in Chignik Lake was considered high with a seasonal mean chlorophyll-*a*: phaeophytin-*a* ratio of 12.55:1, which suggested that zooplankton were not limited by phytoplankton production. In Chignik Lake, photosynthetic pigments were more concentrated in 2000 and 2001 than in 2004. In 2004, 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 2004.

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 also indicated that turbid environments favor rotifers over cladocerans (1990), which is an observed trend in both Black and Chignik lakes. These observations suggest that turbidity influences the zooplankton populations in both lakes. However, in 2004, the chlorophyll-*a* levels were lower and zooplankton density was comparable to or greater than in past years. This suggested that the zooplankton population grew and efficiently utilized its forage base (UF 2000; Bouwens and Finkle 2003), and it may therefore be more strongly affected by other factors such as top-down limitations.

Planktivorous fishes can exert top-down pressures on zooplankton communities (Kyle 1996; Stockner and MacIsaac 1996). Evidence of overgrazed zooplankton populations can be reflected in 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 0.33 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, and 2004, 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, and 2004 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 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 refugia 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 weater 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 2002-2004 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 component compared to past beach seine samples 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 survival, due to increased competition from the increase in 2001 and 2002 offspring.

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 2004 and 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. 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 2004 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.

ACKNOWLEDGEMENTS

Thanks are extended to Chris Owens, Hector Bravo, Jim Emerson, Matt Gandel, Eric Newland, and Roy West who aided in data collection. Paul Horn, Ken Bouwens, and Kevin Clark provided field support. Ken Bouwens, Mary Forner, Matt Foster, Lucinda Neel, Patti Nelson, and Mark Witteveen offered their technical expertise. Switgard Duesterloh, Steve Thomsen, and Mark Witteveen reviewed previous versions of this manuscript. The use of trade names does not imply endorsement by the Alaska Department of Fish and Game.

REFERENCES CITED

Bouwens, K. A. and E. J. Newland. 2004. Sockeye salmon smolt investigations on the Chignik River system, 2003. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 4K04-24, Kodiak.

Bouwens, K. A. and H. Finkle. 2003. Chignik watershed ecological assessment project season report, 2001. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 4K03-10, Kodiak.

Bouwens, K. A., A. Pérez-Fuentetaja and I. J. Edwards. 2000. Sockeye salmon smolt investigations on the Chignik River System, 1999. Alaska Department of Fish and Game, Division of Commercial Fisheries. Regional Information Report No. 4K00-35, Kodiak.

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

Buffington, J. M. 2001. Geomorphic Reconnaissance of the Black Lake Area, Alaska Peninsula (Draft). University of Idaho. Boise.

Burgner, R.L., C. J. DiCostanzo, R.J. Ellis, G.Y. Harry, Jr., W.L. Hartman, O.E. Kerns, Jr., O.A. Mathisen, and W.F. Royce. 1969. Biological studies and estimates of optimum escapements of sockeye salmon in the major river systems in southwestern Alaska. U. S. Fish Wildl. Serv., Fish. Bull. 67(2): 405-459.

Carlson, R. E. 1977. A Trophic State Index for Lakes. Limnol. and Oceanog. 22(2):361-369.

Carlson, R. E. and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society.

Cattanéo, F., N. Lamouroux, P. Breil, and H. Capra. 2002. The influence of hydrological and biotic processes on brown trout (*Salmo trutta*) population dynamics. Canadian Journal of Fisheries and Aquatic Sciences 59:12-22.

COLAP (Congress on Lake and Pond Associations, Inc.). 2001. Standard operating procedures for chlorophyll *a* sampling. Boston, Massachusetts.

Dahlberg, M. L. 1968. Analysis of the dynamics of sockeye salmon returns to the Chignik Lakes, Alaska. Ph. D. Thesis. University of Washington. Seattle.

Detenbeck, N. E., P. W. DeVore, G. J. Niemi, and A. Lima. 1992. Recovery of temperate-stream fish communities from disturbance: a review of case studies and a synthesis of theory. Ecology of Freshwater Fish 16:33-53.

Doble, B. D. and D. E. Eggers. 1978. Diel feeding chronology, rate of gastric evacuation, daily ration, and prey selectivity in Lake Washington juvenile sockeye salmon (*Oncorhynchus nerka*). Transactions of the American Fisheries Society 107(1):36-45.

Dodson, S. I. and D. G. Frey. 2001. The Cladocera and other Branchiopoda *in* Ecology and Systematics of North American Freshwater Invertebrates. 2nd Edition. J.E. Thorpe and A.P. Covich (eds.) Academic Press.

Donald, D. B., R. D. Vinebrooke, R. S. Anderson, J. Syrgiannis, and M. D. Graham. 2001. Recovery of zooplankton assemblages in mountain lakes from the effects of introduced sport fish. Can. J. Fish. Aquat. Sci. 58:1822-1830.

REFERENCES CITED (Cont.)

Edmundson, J. A., L. E. White, S.G. Honnold and G. B. Kyle. 1994. Assessments of sockeye salmon production in Akalura Lake. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report No. 5J94-17, Juneau.

Finkle, H. 2004. Assessing juvenile sockeye salmon (*Oncorhynchus nerka*) energy densitiies and their habitat quality in the Chignik watershed, Alaska. M. S. thesis. Univ. Alaska Fairbanks.

Finkle, H. 2005. Chignik watershed ecological assessment project season report, 2003. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Management Report No. 05-20, Anchorage.

Finkle, H. and E. J. Newland. 2005. Sockeye salmon smolt investigations on the Chignik River, 2004. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Data Series No. 05-16, Kodiak.

Finkle, H. and K. A. Bouwens. 2001. Chignik watershed ecological assessment project season report, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 4K01-51, Kodiak.

Forsberg, C. and S. O. Ryding. 1980. Eutrophication parameters and trophic state indices in 30 Swedish waste-receiving lakes. Archiv fur Hydrobiologie 88:189-207.

Helminen, H. and J. Sarvala. 1997. Responses of Lake Pyhäjärvi (southwestern Finland) to variable recruitment of the major planktivorous fish, vendace (*Coregonus albula*). Can. J. Fish. Aquat. Sci. 54:32-40.

Honnold, S. G., J. A. Edmundson, and S. Schrof. 1996. Limnological and fishery assessment of 23 Alaska Peninsula and Aleutian area lakes, 1993-1995: an evaluation of potential sockeye and coho salmon production. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 4K96-52.

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

Iverson, R. H. 1966. Biology of juvenile sockeye salmon resident in Chignik River, Alaska. M.S. thesis. Oregon State University, Corvallis.

Kerfoot, W. C. 1987. Cascading effects and indirect pathways. p. 57-69 *in* Kerfoot, W. C. and A. Sih. {ed.} Predation: Direct and indirect impacts on aquatic communities. University Press of New England. Hanover and London.

Kirk, K. L. and J. J. Gilbert. 1990. Suspended clay and the population dynamics of planktonic rotifers and cladocerans. Ecology 71(5):1741-1755.

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

Koenings, J. P., J. A. Edmundson, G. B. Kyle, J. M. Edmundson, and R. B. Burkett. 1987. Limnology field and laboratory manual: Methods for assessing aquatic production. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement, and Development, No. 71. Juneau.

Koo, T. S. Y. 1962. Age designation in salmon. Univ. Washington Publ. in Fish., New Ser. 1 (2): 37-48.

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

Kyle, G. B. 1996. Stocking sockeye salmon (*Oncorhynchus nerka*) in barren lakes of Alaska: effects on the macrozooplankton community. Fisheries Research 28 (1996) 29-44.

Kyle, G. B., J. P. Koenings and B. M. Barrett. 1988. Density-dependent, trophic level responses to an introduced run of sockeye salmon (*Oncorhynchus nerka)* at Frazer Lake, Kodiak Island, Alaska. Can. J. Fish. Aquat. Sci. 45:856-867.

Mazumder, A. and J.A. Edmundson. 2002. Impact of fertilization and stocking on trophic interactions and growth of juvenile sockeye salmon (*Oncorhynchus nerka*). Can. J. Fish. Aquat. Sci. 59:1361-1373.

REFERENCES CITED (Cont.)

Milovskaya, L. V., M. M. Selifonov, and S. A. Sinyakov. 1998. Ecological functioning of Lake Kuril relative to sockeye salmon production. N. Pac. Anadr. Fish Comm. Bull. No. 1: 434-442.

Morgan, I. J. and N. B. Metcalfe. 2001. The influence of energetic requirements on the preferred temperature of overwintering juvenile Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 58:762-768.

Narver, D. W. 1966. Pelagial ecology and carrying capacity of sockeye in the Chignik Lakes, Alaska. Ph.D. Thesis. Univ. of Washington, Seattle.

Parr, W. H., Jr. 1972. Interactions between sockeye salmon and resident lake fish in the Chignik Lakes, Alaska. M. Sc. thesis. Univ. of Washington, Seattle.

Phinney, D. E., 1968. Distribution, abundance, and growth of postsmolt sockeye salmon in Chignik Lagoon, Alaska. M. Sc. thesis. Univ. of Washington, Seattle.

Quinn, T. J., II and R. B. Deriso. 1999. Quantitative fish dynamics. Oxford University Press, New York, New York.

Reiman, B. E. and J. B. Dunham. 2000. Metapopulations and salmonids: a synthesis of life history patterns and empirical observations. Ecology of Freshwater Fish 9: 51-64.

Rice, S. D., R. E. Thomas, and A. Moles. 1994. Physiological and growth differences in three stocks of underyearling sockeye salmon (*Oncorhynchus nerka*) on early entry into seawater. Can. J. Fish. Aquat. Sci. 51:974-980.

Ruggerone, G. T. 1994. Investigations of salmon populations, hydrology, and limnology of the Chignik Lakes, Alaska, during 1993. Natural Resources Consultants, Inc. Seattle Wa.

Ruggerone, G. T., C. Harvey, J. Bumgarner, and D.E. Rogers. 1993. Investigations of salmon populations, hydrology, and limnology of the Chignik Lakes, Alaska, during 1992. Report for Chignik Regional Aquaculture Association. Univ. of Washington, School of Fisheries, Fish. Res. Inst. FRI-UW-9302.

Ruggerone, G. T., R. Steen, and R. Hilborn. 1999. Chignik Lakes Research: Investigations of salmon populations, hydrology, and limnology of the Chignik Lakes, Alaska. Univ. of Washington School of Fisheries, Fish. Res. Inst. FRI-UW-9907.

Schindler, D. E. 1992. Nutrient regeneration of sockeye salmon (*Oncorhynchus nerka*) fry and subsequent effects on zooplankton and phytoplankton. Can. J. Fish. Aquat. Sci. 49:2498-2506.

Schrof, S. T. and S. G. Honnold. 2003. Salmon enhancement, rehabilitation, evaluation, and monitoring efforts conducted in the Kodiak Management Area through 2001. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 4K03-41, Kodiak.

Sogard, S. M. and B. L. Olla. 2000. Endurance of simulated winter conditions by age-0 walleye pollock: effects of body size, water temperature and energy stores. Journal of Fish Biology 56:1-21.

Stockner, J. G. and E. A. MacIssac. 1996. British Colombia lake enrichment programme: Two decades of habitat enhancement for sockeye salmon. Regulated Rivers: Research and Management, Vol. 12, 547-561.

Templin, W., L. Seeb, P. Crane, and J. Seeb. 1999. Genetic analysis of sockeye salmon populations from the Chignik watershed. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 5J99-08.

Thomsen, S., S. Honnold, S. Schrof, and K. Spalinger. 2002. Kodiak Island Lake Assessment/Limnology Project Laboratory Analysis Operational Plan, 2002. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional information Report No. 4K02-36, Kodiak.

Tonn, W. M., P. W. Langlois, E. E. Prepas, A. J. Danylchuk, and S. M. Boss. 2004. Winterkill cascade: indirect effects of a natural disturbance on littoral macroinvertebrates in boreal lakes. Journal of the North American Benthological Society 23(2):237-250.

UF (University of Florida). 2000. A beginner's guide to water management – nutrients (circular 102). Department of Fisheries and Aquatic Sciences, Institute of Food and Agriculture. Gainsville.

REFERENCES CITED (Cont.)

USEPA (United States Environmental Protection Agency). 2000. Nutrient criteria technical guidance manual: lakes and reservoirs. Washington, D. C.

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

Witteveen, M. J., H. Finkle, P. A. Nelson, J. J. Hasbrouck, and I. Vining. 2005. Review of Salmon Escapement Goals in the Chignik Management Area. Alaska Department of Fish and Game, Fishery Manuscript No. 05-06, Anchorage.

TABLES AND FIGURES

Table 1.-Limnology and zooplankton sampling dates, 2004.

Lake	Date	Type of sampling
Black Lake	15-May	Water and zooplankton
	15-Jun	Water and zooplankton
	12-Jul	Water and zooplankton
	17-Aug	Water and zooplankton
Chignik Lake	14-May	Water and zooplankton
	8-Jun	Water and zooplankton
	8-Jul	Water and zooplankton
	9-Aug	Water and zooplankton

Table 2.-Dates of beach seine sample sites by area and site, 2004. All sites were sampled on each sampling day.

Black Lake	Chignik Lagoon
21-May	21-May
4-Jun	2-Jun
15-Jun	12-Jun
2-Jul	18-Jun
20-Jul	28-Jun
31-Jul	6-Jul
16-Aug	15-Jul
	23-Jul
	4-Aug
	13-Aug

Table 3.-Dates of fyke net samples in Black River, 2004.

Date
14-Jun
8-Jul
9-Aug

Table 4.-Water temperature, by depth and date, for Black Lake, 2004.

Depth (m)	Temperature (°C)			
	15-May	15-Jun	12-Jul	17-Aug
0.0	9.1	11.8	18.3	17.0
0.5	9.1	11.8	18.6	16.9
1.0	9.1	11.7	18.7	16.9
1.5	9.2	11.7	18.7	16.9
2.0	9.2	11.7	18.7	16.8
2.5	9.2	11.7	18.8	16.8
3.0	9.2	11.6	18.8	16.8
3.5	-	-	-	-

Table 5.-Dissolved oxygen levels by depth and date, for Black Lake, 2004.

Depth (m)	Dissolved oxygen (mg/L)			
	15-May	15-Jun	12-Jul	17-Aug
0.0	11.5	11.2	9.2	10.0
0.5	11.5	11.2	8.9	10.0
1.0	11.5	11.1	8.7	10.0
1.5	11.5	11.1	8.7	9.9
2.0	11.4	11.1	8.7	9.9
2.5	11.4	11.1	8.7	9.9
3.0	11.3	11.2	8.7	9.9
3.5	-	-	-	-

Table 6.-Water temperature, averaged over all stations, by depth and date for Chignik Lake, 2004. The meter cable was 30 m in length.

Depth (m)	Temperature (°C)			
	14-May	8-Jun	8-Jul	9-Aug
0.0	6.2	8.3	13.4	13.6
0.5	6.0	8.2	13.1	13.6
1.0	5.9	8.2	12.9	13.5
1.5	5.8	8.2	12.7	13.5
2.0	5.7	8.2	12.4	13.7
2.5	5.7	8.1	12.2	13.7
3.0	5.6	8.1	12.0	13.7
3.5	5.6	8.1	11.8	13.6
4.0	5.6	8.1	11.7	13.6
4.5	5.6	8.1	11.6	13.6
5.0	5.5	8.1	11.5	13.6
6.0	5.5	8.1	11.4	13.6
7.0	5.5	8.1	11.2	13.5
8.0	5.5	8.1	11.1	13.5
9.0	5.5	8.1	11.0	13.4
10.0	5.5	8.1	10.9	13.4
11.0	5.5	8.0	10.9	13.4
12.0	5.5	8.0	10.8	13.4
13.0	5.5	8.1	10.8	13.3
14.0	5.5	8.1	10.7	13.3
15.0	5.5	8.1	10.7	13.3
16.0	5.5	8.1	10.7	13.3
17.0	5.5	8.0	10.6	13.2
18.0	5.5	8.0	10.6	13.2
19.0	5.4	8.0	10.5	13.1
20.0	5.4	8.0	10.5	12.9
21.0	5.3	8.0	10.4	12.8
22.0	5.4	8.0	10.4	12.6
23.0	5.3	8.0	10.2	12.5
24.0	5.3	8.0	10.2	12.4
25.0	5.3	8.0	10.2	12.3
30.0	5.3	8.0	10.0	11.9

Table 7.-Dissolved oxygen levels, averaged over all stations, by depth and date for Chignik Lake, 2004. The meter cable was 30 m in length.

Depth	Dissolved oxygen (mg/L)			
(m)	14-May	8-Jun	8-Jul	9-Aug
0.0	13.2	12.4	10.3	11.1
0.5	13.3	12.5	10.5	11.1
1.0	13.4	12.6	10.6	11.0
1.5	13.4	12.6	10.7	11.1
2.0	13.5	12.6	10.8	11.3
2.5	13.6	12.6	10.8	11.3
3.0	13.5	12.7	10.8	11.3
3.5	13.6	12.7	10.9	11.3
4.0	13.5	12.6	10.9	11.3
4.5	13.6	12.6	10.9	11.3
5.0	13.7	12.6	11.0	11.3
6.0	13.7	12.6	11.0	11.3
7.0	13.7	12.7	11.0	11.2
8.0	13.7	12.7	11.0	11.2
9.0	13.6	12.6	11.0	11.2
10.0	13.6	12.6	11.0	11.2
11.0	13.6	12.6	11.0	11.1
12.0	13.7	12.6	11.0	11.1
13.0	13.7	12.7	11.0	11.1
14.0	13.7	12.6	11.1	11.1
15.0	13.7	12.6	11.1	11.1
16.0	13.7	12.6	11.1	11.1
17.0	13.7	12.6	11.1	11.1
18.0	13.7	12.6	11.1	11.0
19.0	13.7	12.6	11.1	10.9
20.0	13.6	12.6	11.1	10.8
21.0	13.2	12.6	11.1	10.7
22.0	13.5	12.6	11.0	10.6
23.0	13.5	12.6	11.0	10.1
24.0	13.6	12.6	11.0	9.2
25.0	13.6	12.6	11.0	9.0
30.0	13.6	12.6	11.0	10.3

Table 8.-Average monthly solar illuminance readings by depth and date for Black Lake, 2004. Seasonal averages for 2000-2003 are provided for comparison.

	Solar illuminance (kLux)								
	2004					2000	2001	2002	2003
Depth	May	June	July	August	Average	Average	Average	Average	Average
0.0	4,850.0	ND	2,911.0	5,843.0	4,534.7	1,998.3	1,372.8	6,204.5	646.2
0.5	3,150.0		1,887.5	2,727.0	2,588.2	1,059.7	867.3	3,594.0	366.8
1.0	2,170.0		1,024.7	1,280.0	1,491.6	619.3	427.3	2,496.5	232.9
1.5	1,520.0		600.3	307.0	302.9	309.4	281.1	1,273.2	144.9
2.0	1,100.0		478.3	171.8	217.1	166.7	206.0	498.0	59.0
2.5	757.0		302.9	89.6	383.2	90.7	177.4	336.2	28.0
3.0[b]	971.0		116.1	91.0	392.7	56.3	10.7	414.1	16.3
3.5						24.0			

[a] ND = no data.

[b] Lake depth at the sampling station exceeded 3.0 m only during the 2000 sampling season.

Table 9.-Euphotic Zone Depth (EZD) and Euphotic Volume (EV) of Black and Chignik Lakes, by month, 2004. The 2000-2003 seasonal averages are provided for comparison.

		2004					2000	2001	2002	2003
Lake		May	June[d]	July	August	Average[a]	Average[a]	Average[a]	Average[a]	Average[a]
Chignik	EZD (m)	4.61	ND	10.52	7.03	11.11	8.22	15.52	14.99	4.98
	Mean EV[c]	111.2	ND	253.4	169.4	267.7	198.1	374.0	361.4	120.1
Black[b]	EZD (m)	1.18	ND	4.54	2.85	3.63	3.72	3.72	4.94	3.76
	Mean EV[c]	78.1	ND	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] Light meter not operational.

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

Table 10.-Average monthly solar illuminance readings by depth and date for Chignik Lake, 2004. Seasonal averages for 2000-2003 are provided for comparison. The light meter was not operational for the June sample.

	Solar illuminance (kLux)								
	2004					2000	2001	2002	2003
Depth	May	June	July	August	Average	Average	Average	Average	Average
0.0	4,052.5	ND[a]	6,985.0	2,437.6	4,491.7	2,473.4	1,799.3	1,393.3	1,156.8
0.5	3,365.0		5,317.8	1,753.1	3,478.6	1,768.3	1,053.3	1,040.9	681.6
1.0	3,126.8		4,124.3	1,141.9	2,797.6	1,214.3	733.7	746.5	413.5
1.5	1,803.0		3,526.5	601.1	1,976.9	710.5	614.0	1,023.8	168.0
2.0	1,721.0		2,523.0	513.0	1,585.7	523.8	474.7	417.1	90.5
2.5	1,445.5		1,580.4	357.1	1,127.7	365.9	367.4	283.4	57.6
3.0	1,056.3		1,376.7	276.8	903.2	252.8	308.9	214.8	30.7
3.5	735.3		1,005.6	188.1	643.0	183.6	270.8	158.9	20.5
4.0	582.0		544.7	148.7	425.1	127.3	216.6	122.4	12.7
4.5	492.1		403.5	113.8	336.5	91.5	171.6	87.9	8.1
5.0	365.3		343.7	81.7	263.6	73.4	140.7	67.2	4.9
6.0	262.1		190.7	47.4	166.7	36.8	98.3	39.9	2.7
7.0	148.6		107.4	25.4	93.8	21.5	66.9	24.1	1.4
8.0	110.4		59.2	14.2	61.3	11.5	46.0	15.6	0.7
9.0	59.1		34.5	8.2	33.9	6.2	33.6	9.6	0.6
10.0	34.4		20.3	4.5	19.7	3.8	24.7	6.4	0.5
11.0	20.9		11.8	2.5	11.7	2.3	11.7	4.6	0.3
12.0	14.0		10.6	1.3	8.6	1.5	8.6	3.8	0.4
13.0	9.0		7.5	0.4	5.6	1.0	6.5	3.3	
14.0	6.3		4.8	0.3	3.8	0.7	5.2	2.9	
15.0	4.1		3.3		3.7	0.6	4.3	2.4	
16.0	2.5		2.2		2.4	0.8	3.8	2.4	
17.0	1.7		3.0		2.4	0.7	3.3	1.9	
18.0			1.6		1.6	0.4	2.9	1.2	
19.0			1.0		1.0	0.4	2.7	0.5	
20.0			10.3		10.3	0.4	2.5	1.1	
21.0			9.8		9.8	0.3	2.3		
22.0			9.8		9.8	0.3	2.5		
23.0			5.6		5.6	0.2	2.5		
24.0			5.2		5.2		3.4		
25.0			4.7		4.7		4.2		
30.0							2.1		
35.0							1.6		
40.0							1.5		
45.0							1.6		
50.0							1.5		

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

Table 11.-Seasonal water quality parameters, nutrient concentrations, and photosynthetic pigments for Chignik Lake (by station) and Black Lake, 2004.

	Chignik Lake			Black Lake
	Station 2	Station 4	Average[a]	Average
pH	7.66	7.58	7.60	7.81
Alkalinity (mg/L $CaCO_3$)	24.0	20.8	22.4	30.2
Total P (mg/L P)	17.1	20.0	18.5	22.2
TFP (mg/L P)	6.2	6.9	6.5	5.1
FRP ((g/L P)	4.0	4.3	4.1	2.6
TKN ((g/L N)	146.5	ND[b]	146.5	188.8
Ammonia ((g/L N)	9.4	8.8	9.1	9.7
Nitrate + Nitrite ((g/L N)	127.1	128.9	128.0	3.7
Chlorophyll *a* ((g/L)	4.12	3.93	4.02	3.60
Phaeophytin *a* ((g/L)	0.36	0.28	0.32	0.15

[a] Averaged values do not always exactly match the values reported in Table 12 due to rounding.

[b] ND = no data.

Table 12.-Water quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Black Lake, 2004. Seasonal averages from 2000-2003 are provided for comparison.

	2004					2000	2001	2002	2003
	15-May	15-Jun	12-Jul	17-Aug	Average	Average	Average	Average	Average
pH	7.81	7.76	7.84	7.84	7.81	7.43	7.53	7.45	7.46
Alkalinity (mg/L $CaCO_3$)	ND[a]	28.5	28.0	34.0	30.2	13.0	32.5	32.3	32.3
Total P (mg/L P)	23.7	20.7	16.3	28.0	22.2	57.0	35.0	22.0	41.7
TFP (mg/L P)	5.7	4.2	4.2	6.3	5.1	11.0	10.0	10.0	9.8
FRP (μg/L P)	3.0	1.8	3.1	2.5	2.6	4.0	7.0	5.0	5.8
TKN (μg/L N)	176.0	130.0	172.0	277.0	188.8	ND[b]	ND[b]	323.5	256.8
Ammonia (μg/L N)	8.7	6.4	10.2	13.6	9.7	37.0	3.3	4.4	3.7
Nitrate + Nitrite (μg/L N)	5.6	2.0	2.2	4.8	3.7	64.0	4.5	8.3	25.2
Chlorophyll *a* (μg/L)	2.88	1.28	1.92	8.33	3.60	18.06	4.26	2.64	5.12
Phaeophytin *a* (μg/L)	0.03	0.06	0.32	0.19	0.15	9.98	11.94	1.44	1.78

[a] No acid for alkalinity titration.

[b] ND = no data.

Table 13.-Water quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Chignik Lake, 2004. All stations and depths are averaged for each sample date. Seasonal averages from 2000-2003 are provided for comparison.

	2004					2000	2001	2002	2003
	14-May	8-Jun	8-Jul	9-Aug	Average[a]	Average	Average	Average	Average
pH	7.67	7.46	7.64	7.72	7.62	7.84	7.50	7.45	7.38
Alkalinity (mg/L $CaCO_3$)	ND[b]	21.0	23.8	22.5	22.4	15.1	24.8	24.6	23.6
Total P (mg/L P)	19.0	20.5	16.1	18.6	18.5	13.2	27.6	19.7	16.7
TFP (mg/L P)	8.1	9.3	4.7	4.1	6.5	5.3	12.2	8.5	7.5
FRP (μg/L P)	4.9	3.9	4.3	3.6	4.1	4.8	8.4	4.6	5.8
TKN (μg/L N)	193.0	159.0	122.0	112.0	146.5	230.0	99.5	119.7	99.0
Ammonia (μg/L N)	8.9	6.5	10.5	10.6	9.1	29.8	10.3	10.5	10.1
Nitrate + Nitrite (μg/L N)	204.4	124.4	89.8	93.5	128.0	102.6	132.9	117.4	166.6
Chlorophyll *a* (μg/L)	4.73	7.37	1.76	2.24	4.02	9.47	4.69	2.34	2.30
Phaeophytin *a* (μg/L)	0.32	0.42	0.31	0.23	0.32	1.69	1.31	1.34	0.51

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

[b] No acid for alkalinity titration.

Table 14.-Average number of zooplankton per m^2 from Black Lake by sample date, 2004. The 2000-2003 seasonal averages are included for comparison.

Taxon	2004 Sample date 5/15	2004 Sample date 6/15	2004 Sample date 7/12	2004 Sample date 8/17	2004 Seasonal average	2000 Seasonal average	2001 Seasonal average	2002 Seasonal average	2003 Seasonal average
Copepods:									
Epischura	1,592	24,482	21,019	103,503	37,649	7,850	2,654	2,605	6,303
Ovig. *Epischura*	0	0	0	0	0	127	0	0	0
Diaptomus	3,185	19,108	10,828	66,879	25,000	3,575	1,239	5,893	11,080
Ovig. *Diaptomus*	0	597	0	0	149	0	0	0	1,327
Cyclops	22,293	27,468	10,828	124,204	46,198	35,398	7,307	25,622	19,042
Ovig. *Cyclops*	0	0	0	0	0	0	0	0	266
Harpaticus	0	0	0	2,123	531	0	531	0	531
Napulii	7,166	30,454	14,013	110,403	40,509	21,967	6,458	13,385	24,350
Total copepods	34,236	102,109	56,688	407,112	150,036	68,917	18,188	47,505	62,898
Cladocerans:									
Bosmina	1,592	63,893	20,382	1,509,554	398,855	38,455	25,779	32,379	285,496
Ovig. *Bosmina*	0	8,360	8,280	343,949	90,147	10,446	4,883	13,384	39,809
Daphnia l.	796	0	0	0	199	868	372	0	1,526
Ovig. *Daphnia l.*	0	0	0	0	0	0	0	0	0
Chydorinae	1,592	0	19,108	295,117	78,954	11,632	526,097	11,697	3,517
Total cladocerans	3,980	72,253	47,770	2,148,620	568,156	61,401	557,130	57,460	330,348
Total copepods + cladocerans	38,216	174,362	104,458	2,555,732	718,192	130,318	575,318	104,965	393,246
Rotifers:									
Kellicottia	6,369	42,994	32,484	31,847	28,424	19,682	1,469	7,605	45,880
Asplanchna	0	0	0	50,955	12,739	119	59,820	2,432	299
Keratella	1,062	0	0	133,758	33,705	32,428	16,490	10,684	12,241
Conochilus	3,185	501,592	546,497	961,783	503,264	173,424	7,502	70,268	178,742
other rotifers	3,185	0	1,911	3,484,076	872,293	4,618	3,981	139,134	764,928
Total rotifers	13,801	544,586	580,892	4,662,419	1,450,425	230,271	89,261	230,122	1,002,090

Table 15.-Biomass estimates (mg dry weight/m^2) of the major Black Lake zooplankton taxon by sample date, 2004. The 2000-2003 season averages are included for comparison. Seasonal averages were estimated using average lengths and weighted averages were estimated using weighted lengths.

	2004						2000		2001		2002		2003	
	Sample date				Seasonal	Weighted	Seasonal	Weighted	Seasonal	Weighted	Seasonal	Weighted	Seasonal	Weighted
Taxon	5/15	6/15	7/12	8/17	average	average	average	average	average	average	average	average	average	average
Copepods:														
Epischura	1.07	16.50	14.17	69.77	25.38	21.24	8.92	7.29	1.82	1.57	7.44	3.55	1.47	3.59
Diaptomus	7.30	43.79	24.82	153.28	57.30	31.52	8.78	8.86	3.50	3.85	24.42	46.95	11.40	42.19
Cyclops	17.82	21.96	8.66	99.29	36.93	35.75	33.55	32.09	7.52	9.12	32.03	36.04	5.82	18.30
Harpaticus	0	0	0	1.38	0.35	0.00	0	0	0.89	0.89	0	0	0.17	0.35
Total copepods	26.19	82.25	47.65	323.72	119.95	88.51	51.25	48.24	13.74	15.43	63.89	86.54	18.86	64.43
Cladocerans:														
Bosmina	1.33	53.20	16.97	1,256.96	332.11	365.58	37.33	32.86	12.75	15.80	69.41	65.10	137.38	290.05
Ovigerous *Bosmina*	0.00	11.28	11.17	463.92	121.59	125.78	14.81	13.49	4.34	5.18	44.01	45.07	37.07	77.61
Daphnia longiremis	0.21	0.00	0.00	0.00	0.05	0.05	0.49	0.46	0.10	0.10	0.00	0.00	1.77	2.29
Chydorinae	0.19	0.00	2.24	34.67	9.28	40.46	1.35	6.59	33.43	5.05	3.51	16.15	0.29	2.38
Total cladocerans	1.73	64.48	30.38	1,755.55	463.03	531.87	53.98	53.40	3.99	26.13	71.84	125.64	176.51	186.16
Total Biomass	27.92	146.73	78.03	2,079.27	582.99	620.38	105.23	101.64	12.89	41.56	106.08	162.42	195.38	218.38

Table 16.-Average lengths (mm) of zooplankton in Black Lake by sample date, 2004. The 2000-2003 seasonal averages are included for comparison. Lengths are not weighted to estimate the seasonal average.

	2004					2000	2001	2002	2003
	Sample date				Seasonal	Seasonal	Seasonal	Seasonal	Seasonal
Taxon	5/15	6/15	7/12	8/17	average	average	average	average	average
Copepods:									
Epischura	0.58	0.55	0.45	0.47	0.51	0.62	0.53	0.79	0.51
Diaptomus	1.11	0.73	0.78	0.58	0.80	0.82	0.86	0.63	0.84
Cyclops	0.53	0.49	0.48	0.48	0.50	0.54	0.56	0.47	0.50
Harpaticus	0	0	0	0	0	0	0.70	0.20	0.45
Napulii	0	0	0	0	0	0	0.29	0.20	0
Cladocerans:									
Bosmina	0.30	0.31	0.29	0.32	0.31	0.33	0.24	0.32	0.32
Ovigerous *Bosmina*	0	0.40	0.36	0.39	0.38	0.39	0.31	0.37	0.47
Daphnia l.	0.27	0	0	0	0.27	0.38	0.27	0	0.73
Chydorinae	0.34	0	0.27	0.24	0.21	0.27	0.17	0.24	0.28

Table 17.-Average number of zooplankton per m^2 from Chignik Lake, by sample date, 2004. The 2000-2002 seasonal averages are included for comparison.

	2004					2000	2001	2002	2003
	Sample date				Seasonal	Seasonal	Seasonal	Seasonal	Seasonal
Taxon	5/14	6/9	7/8	8/9	average	average	average	average	average
Copepods:									
Epischura	6,894	22,506	38,615	200,637	67,163	38,354	9,249	34,939	70,621
Ovigerous *Epischura*	0	0	0	0	0	398	53	0	0
Diaptomus	3,417	7,537	18,246	152,667	45,467	12,988	15,552	25,557	62,275
Ovigerous *Diaptomus*	0	531	3,273	10,616	3,605	780	106	2,760	1,742
Cyclops	132,179	143,816	198,580	88,907	140,871	172,192	38,767	151,287	37,726
Ovigerous *Cyclops*	0	80	6,436	11,611	4,532	1,975	4,399	9,713	1,393
Harpaticus	770	2,548	664	332	1,078	355	292	703	531
Napulii	26,805	31,263	87,912	148,952	73,733	46,439	12,812	75,588	55,971
Total copepods:	170,064	208,280	353,725	613,720	336,447	273,481	81,230	300,549	230,258
Cladocerans:									
Bosmina	929	6,701	29,790	202,296	59,929	58,978	31,356	56,091	73,448
Ovigerous *Bosmina*	133	1,473	7,763	26,407	8,944	14,394	4,386	15,698	14,358
Daphnia longiremis	5,043	6,701	11,810	95,741	29,824	9,157	1,858	17,003	68,073
Ovigerous *Daphnia longiremis*	3,092	1,433	3,583	21,895	7,501	1,312	53	8,373	7,086
Chydorinae	186	5,971	23,089	4,247	8,373	3,989	24,728	9,129	1,115
Total cladocerans:	9,382	22,280	76,035	350,584	114,570	180,396	147,483	163,940	155,712
Total Copepods + Cladocerans	179,446	230,559	429,760	964,304	451,017	453,878	228,713	464,488	385,970

-Continued-

Table 17.-Page 2 of 2.

	2004					2000	2001	2002	2003
	Sample date				Seasonal	Seasonal	Seasonal	Seasonal	Seasonal
Taxon	5/26	6/25	7/25	8/16	average	average	average	average	average
Rotifers:									
Kellicottia	13,376	34,077	22,094	35,032	26,145	15,725	54,625	210,935	118,432
Asplanchna	478	10,709	93,750	553,543	164,620	47,572	30,396	87,102	2,309
Keratella	148,965	454,100	12,341	4,379	154,946	0	46,743	82,710	62,779
Conochilus	1,035	55,892	1,145,502	59,514	315,486	10,649	15,180	189,199	107,245
other rotifers	1,274	5,308	684,713	233,546	231,210	9,554	4,773	586,186	422,094
Total Rotifers:	165,127	560,085	1,958,399	886,014	892,406	83,500	151,716	1,156,132	712,858

Table 18.-Biomass estimates (mg dry weight/m^2) of the major zooplankton species in Chignik Lake by sample date, 2004. The 2000-2003 season averages are included for comparison. Seasonal averages were estimated using average lengths and weighted averages were estimated using weighted lengths.

	2004						2000		2001		2002		2003	
	Sample date				Seasonal	Weighted	Seasonal	Weighted	Seasonal	Weighted	Seasonal	Weighted	Seasonal	Weighted
Taxon	5/14	6/9	7/8	8/9	average	average	average	average	average	average	average	average	average	average
Copepods														
Epischura	6.29	16.23	32.70	143.37	49.65	49.46	70.19	43.38	11.45	17.98	43.40	32.58	35.80	42.13
Ovigerous *Epischura*	0	0	0	0	0	0	1.33	3.03	0.08	0.31	0	0	0	0
Diaptomus	8.32	17.13	52.25	294.36	93.02	92.14	88.02	82.20	25.00	44.54	107.79	114.05	128.06	148.91
Ovigerous *Diaptomus*	0.00	2.86	17.22	46.67	16.69	22.20	5.31	9.43	0.07	0.30	17.46	27.33	7.25	8.63
Cyclops	114.97	270.15	173.39	87.61	161.53	155.46	255.84	250.07	73.54	128.12	159.34	178.97	39.69	46.08
Ovigerous *Cyclops*	0.18	0.23	29.03	52.35	20.45	20.43	9.04	10.43	21.35	33.46	35.85	58.85	3.40	5.66
Harpaticus	0.51	1.29	0.24	0.22	0.57	0.55	0.13	0.29	0.19	0.62	0.35	0.91	0.27	0.45
Total Copepods:	130.26	307.90	304.83	624.58	341.89	340.23	429.84	398.84	131.69	225.33	364.20	412.69	214.46	251.85
Cladocerans														
Bosmina	1.11	6.08	25.72	165.20	49.53	49.46	97.46	76.08	19.58	27.44	48.37	55.74	72.98	85.55
Ovigerous *Bosmina*	0.24	2.23	12.24	31.11	11.45	11.40	28.94	27.89	3.87	5.98	22.37	25.08	22.70	26.37
Daphnia longiremis	7.38	7.35	11.11	123.39	37.31	37.16	11.22	12.56	2.09	5.18	20.49	22.20	37.82	42.73
Ovigerous *Daphnia longiremis*	7.39	3.66	10.05	73.64	23.68	23.62	2.37	3.38	0.05	0.44	28.29	29.61	19.29	23.17
Chydorinae	0.04	0.83	3.18	0.60	1.16	6.03	0.84	3.56	0.54	2.20	1.17	6.95	0.12	0.73
Total Cladocerans:	16.16	20.15	62.30	393.93	123.13	127.67	140.83	123.48	26.12	41.23	120.69	139.59	152.91	178.55
Total Biomass	146.42	328.05	367.13	1,018.52	465.03	467.90	570.68	522.32	157.82	266.57	484.89	552.28	367.37	430.40

Table 19.-Average length (mm) of zooplankton from Chignik Lake by sample date, 2004. The 2000-2003 seasonal averages are included for comparison. Lengths are not weighted to estimate the seasonal average.

	2004					2000	2001	2002	2003
	Sample date				Seasonal	Seasonal	Seasonal	Seasonal	Seasonal
Taxon	5/14	6/9	7/8	8/9	average	average	average	average	average
Copepods:									
Epischura	0.56	0.54	0.56	0.53	0.55	0.65	0.75	0.64	0.50
Ovigerous *Epischura*	0	0	0	0	0	0.58	0.72	0	0
Diaptomus	0.80	0.82	0.87	0.77	0.81	1.12	0.90	0.98	0.83
Ovigerous *Diaptomus*	0	1.2	1.183	1.11	1.17	0.63	0.34	1.14	1.07
Cyclops	0.50	0.65	0.51	0.52	0.54	0.64	0.80	0.58	0.55
Ovigerous *Cyclops*	0	0.90	1.12	1.11	1.04	1.00	1.03	1.01	1.04
Harpaticus	0.45	0.46	0.35	0.45	0.43	0.24	0.40	0.45	0.47
Napulii	0	0	0	0	0	0	0.26	0.26	0
Cladocerans:									
Bosmina	0.39	0.31	0.31	0.30	0.33	0.38	0.33	0.31	0.34
Ovigerous *Bosmina*	0.44	0.44	0.40	0.36	0.41	0.44	0.39	0.40	0.42
Daphnia longiremis	0.59	0.52	0.48	0.53	0.53	0.55	0.47	0.55	0.53
Ovigerous *Daphnia longiremis*	0.73	0.78	0.83	0.87	0.80	0.53	0.67	0.87	0.80
Chydorinae	0	0.29	0.28	0.30	0.29	0.30	0.11	0.28	0.27

Table 20.-Total catch of juvenile sockeye salmon, by age and location, from the Chignik watershed, 2004.

Location		Age 0.	1.	2.	3.	Total
Black Lake/Black River		99.5%	0.5%	0.0%	0.0%	100.0%
	Sample	311	2	0	0	313
	Total catch[a]	1,309	7	0	0	1,316
Chignik Lagoon		56.9%	30.1%	13.0%	0.0%	100.0%
	Sample	294	183	93	0	570
	Total catch[a]	2,402	1,272	548	0	4,222
Combined		68.5%	21.0%	10.5%	0.0%	100.0%
	Sample	605	185	93	0	883
	Total catch[a]	3,794	1,160	583	0	5,538

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

Table 21.-Total beach seine hauls, total catch, and catch per haul, by month, of juvenile sockeye salmon from the Chignik watershed, 2004. Catch per haul data from 2000-2003 are provided for comparison.

		2004			2000	2001	2002	2003
		Number	Sockeye catch	Sockeye	Sockeye	Sockeye	Sockeye	Sockeye
Area	Month	of hauls	Total	catch/haul	catch/haul	catch/haul	catch/haul	catch/haul
Black Lake	May	4	364	91	ND	75	241	23
	June	8	550	69	328	16	405	11
	July	12	165	14	59	11	225	4
	August	4	5	1	14	ND	3	1
Chignik Lake	May	ND	ND	ND	ND	209	31	ND
	June	ND	ND	ND	4	94	24	3
	July	ND	ND	ND	26	15	32	6
	August	ND	ND	ND	9	22	19	3
Chignik River	May	ND	ND	ND	198	ND	406	ND
	June	ND	ND	ND	ND	274	492	443
	July	ND	ND	ND	363	494	262	272
	August	ND	ND	ND	219	219	ND	104
Chignik Lagoon	May	4	707	177	22	218	3	12
	June	16	849	53	39	93	200	47
	July	12	2,354	196	26	79	141	50
	August	8	312	39	138	307	ND	4

ND = no data.

Table 22.-Fyke net hours fished, total catch, and catch per hour, by month, of juvenile sockeye salmon from Black River, 2004. Fyke net catch data from 2000-2003 are provided for comparison. ND = no data.

	2004			2000	2001	2002	2003
Month	Total hours	Total sockeye catch	Sockeye catch/hour	Sockeye catch/hour	Sockeye catch/hour	Sockeye catch/hour	Sockeye catch/hour
May	ND	ND	ND	13	5	ND	ND
June	ND	ND	ND	0	1	1	0
July	26.00	201	8	77	ND	11	< 1
August	25.50	31	1	ND	ND	1	0

Table 23.-Total catch of juvenile sockeye salmon from Black Lake and Black River, by age and gear type, 2004.

			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	May	364	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				45	0	0	0	45	364	0	0	0	364
	Beach seine	June	550	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				124	0	0	0	124	550	0	0	0	550
	Beach Seine	July	165	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				72	0	0	0	72	165	0	0	0	165
	Beach Seine	August	5	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				5	0	0	0	5	5	0	0	0	5
Black Lake Total		All	1,084	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
				246	0	0	0	246	1,084	0	0	0	1,084
Black River	Fyke	July	201	97.5%	2.5%	0.0%	0.0%	100.0%	97.5%	2.5%	0.0%	0.0%	100.0%
				39	1	0	0	40	196	5	0	0	201
	Fyke	August	31	96.3%	3.7%	0.0%	0.0%	100.0%	96.3%	3.7%	0.0%	0.0%	100.0%
				26	1	0	0	27	30	1	0	0	31
Black River Total		All	232	97.0%	3.0%	0.0%	0.0%	100.0%	97.0%	3.0%	0.0%	0.0%	100.0%
				65	2	0	0	67	225	7	0	0	232
Black Lake/River Total		All	1,316	99.4%	0.6%	0.0%	0.0%	100.0%	99.5%	0.5%	0.0%	0.0%	100.0%
				311	2	0	0	313	1,309	7	0	0	1,316

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

Table 24.-Average length, weight, and condition factor by age and gear type for juvenile sockeye salmon captured in Black Lake and Black River, 2004.

Gear type	Month	Age	Sample size	Length (mm) Average	Length (mm) SD	Weight (g) Average	Weight (g) SD	Condition factor Average	Condition factor SD
Beach seine	May	0	45	38	12.4	0.5	0.17	0.84	0.28
	June	0	124	44	21.3	0.9	0.51	0.93	0.42
	July	0	72	58	23.4	2.5	1.09	1.10	0.49
	August	0	5	74	8.6	4.2	0.49	0.89	0.10
Fyke net	July	0	39	69	1.5	4.3	1.46	1.00	0.32
		1	1	79	-	5.0	-	0.86	-
	August	0	26	65	1.3	4.1	1.25	1.05	0.28
		1	1	68	-	4.2	-	1.16	-

Table 25.-Total beach seine catch, by age, of juvenile sockeye salmon from Chignik Lagoon, 2004.

	Total sockeye	Sample					Estimated age[a]				
Month	catch	0.	1.	2.	3.	Total	0.	1.	2.	3.	Total
May	707	35.0%	41.7%	23.3%	0.0%	100.0%	35.0%	41.7%	23.3%	0.0%	100.0%
		21	25	14	0	60	247	295	165	0	707
June	849	26.0%	41.9%	32.1%	0.0%	100.0%	26.0%	41.9%	32.1%	0.0%	100.0%
		56	90	69	0	215	221	355	272	0	849
July	2,354	72.1%	23.5%	4.5%	0.0%	100.0%	72.1%	23.5%	4.5%	0.0%	100.0%
		129	42	8	0	179	1,696	552	105	0	2354
August	312	75.9%	22.4%	1.7%	0.0%	100.0%	75.9%	22.4%	1.7%	0.0%	100.0%
		88	26	2	0	116	237	70	5	0	312
All	4,222	51.6%	32.1%	16.3%	0.0%	100.0%	56.9%	30.1%	13.0%	0.0%	100.0%
		294	183	93	0	570	2,402	1,272	548	0	4,222

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

Table 26.-Average length, weight, and condition factor by age of juvenile sockeye salmon captured by beach seine in Chignik Lagoon, 2004.

			Length (mm)		Weight (g)		Condition factor	
Month	Age	Sample size	Average	SD	Average	SD	Average	SD
May	0	21	33	6.3	0.3	0.08	0.73	0.14
	1	25	85	14.6	4.1	0.74	1.09	0.19
	2	14	55	12.6	3.7	0.92	0.65	0.15
June	0	56	43	13.1	0.9	0.36	0.86	0.26
	1	90	69	25.2	3.2	1.40	0.93	0.34
	2	69	81	26.4	5.4	1.86	0.98	0.32
July	0	129	60	25.4	2.4	1.16	1.00	0.42
	1	42	68	18.0	3.9	1.16	1.21	0.40
	2	8	89	10.3	7.7	0.92	1.11	0.13
August	0	88	61	22.1	2.5	1.05	1.02	0.37
	1	26	81	14.7	3.9	0.85	1.06	0.22
	2	2	66	3.9	2.8	0.02	0.96	0.06

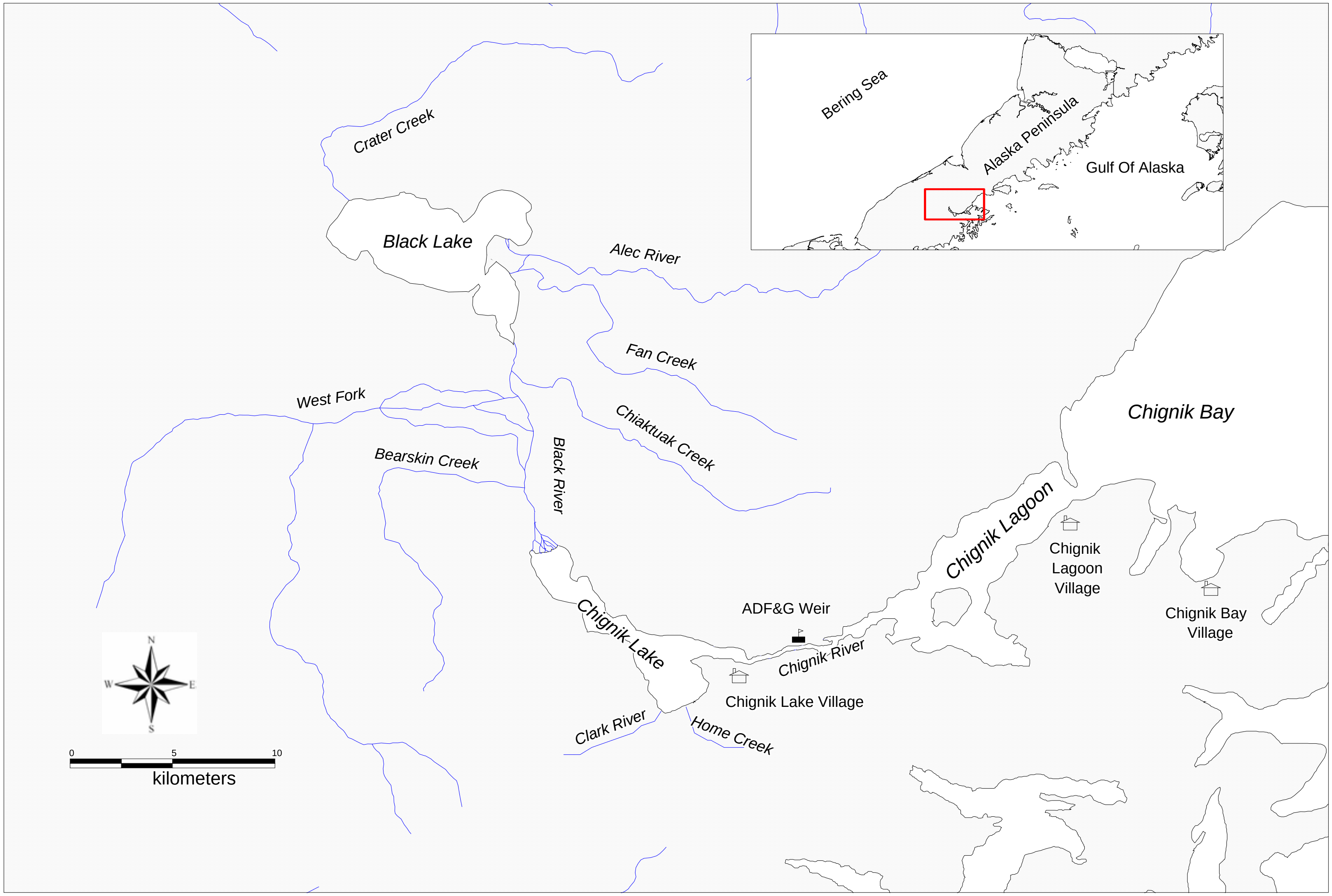


Figure 1.-Chignik watershed and location on the Alaska Peninsula (inset).

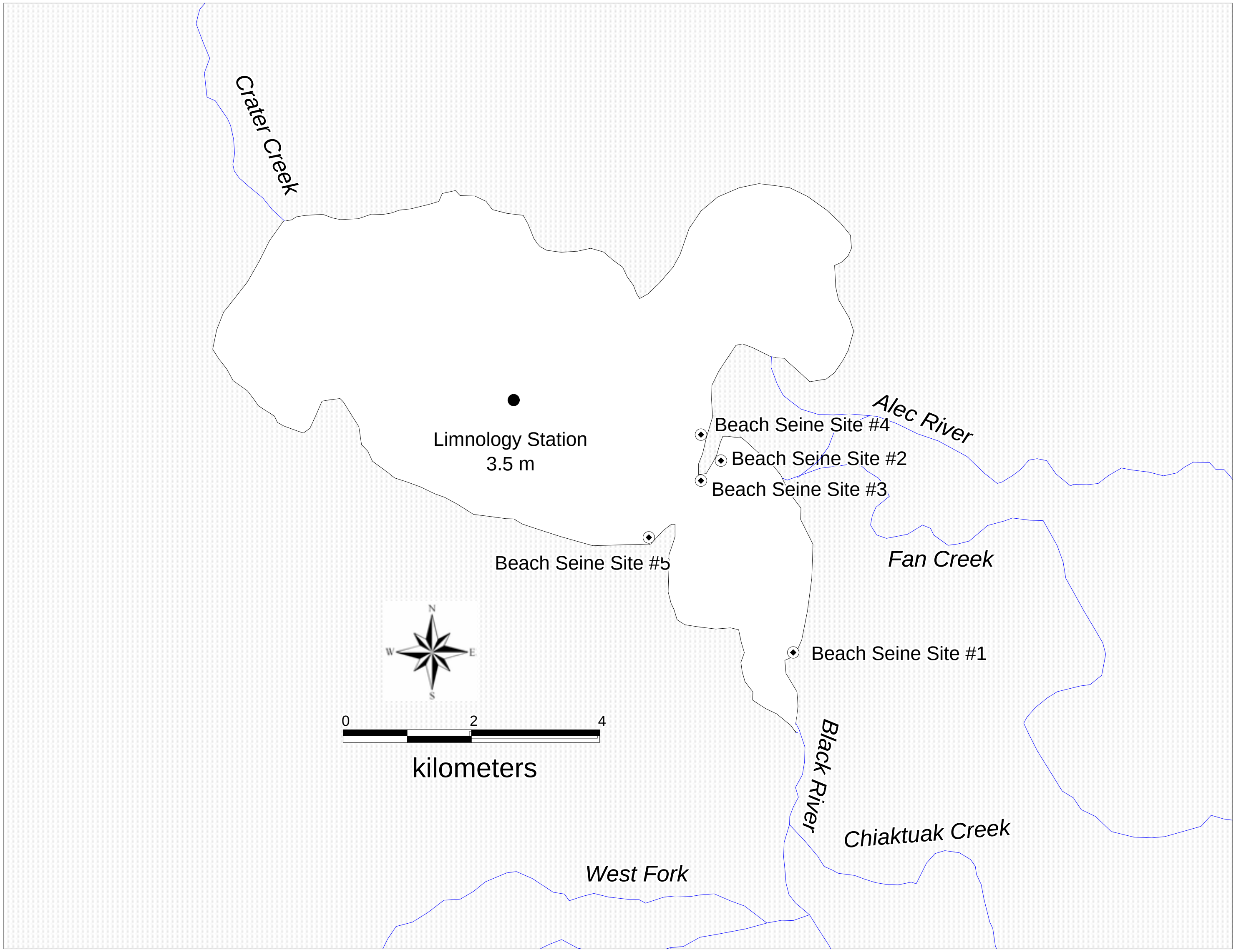


Figure 2.-Black Lake and its sampling sites.

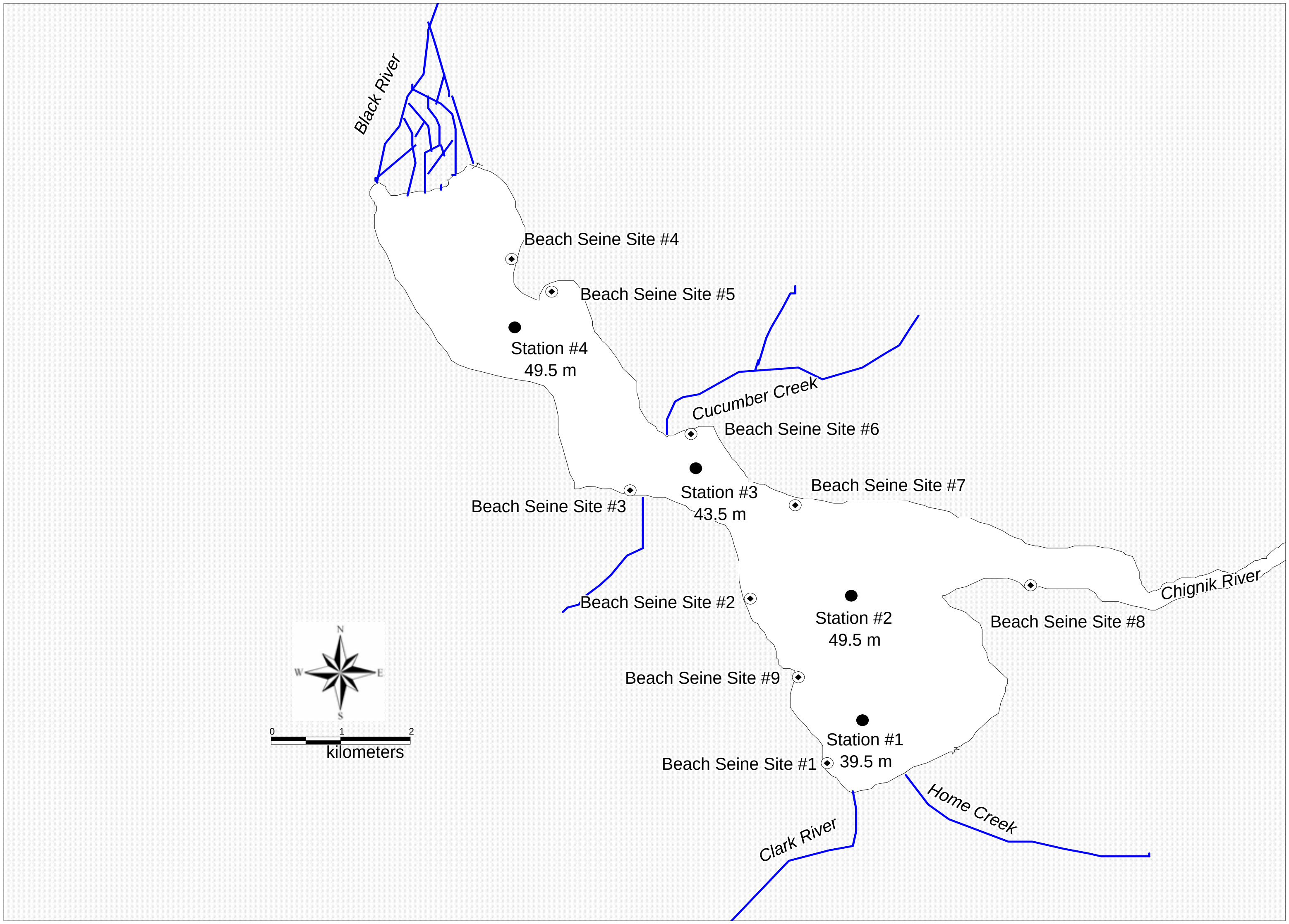


Figure 3.-Chignik Lake and its sampling sites.

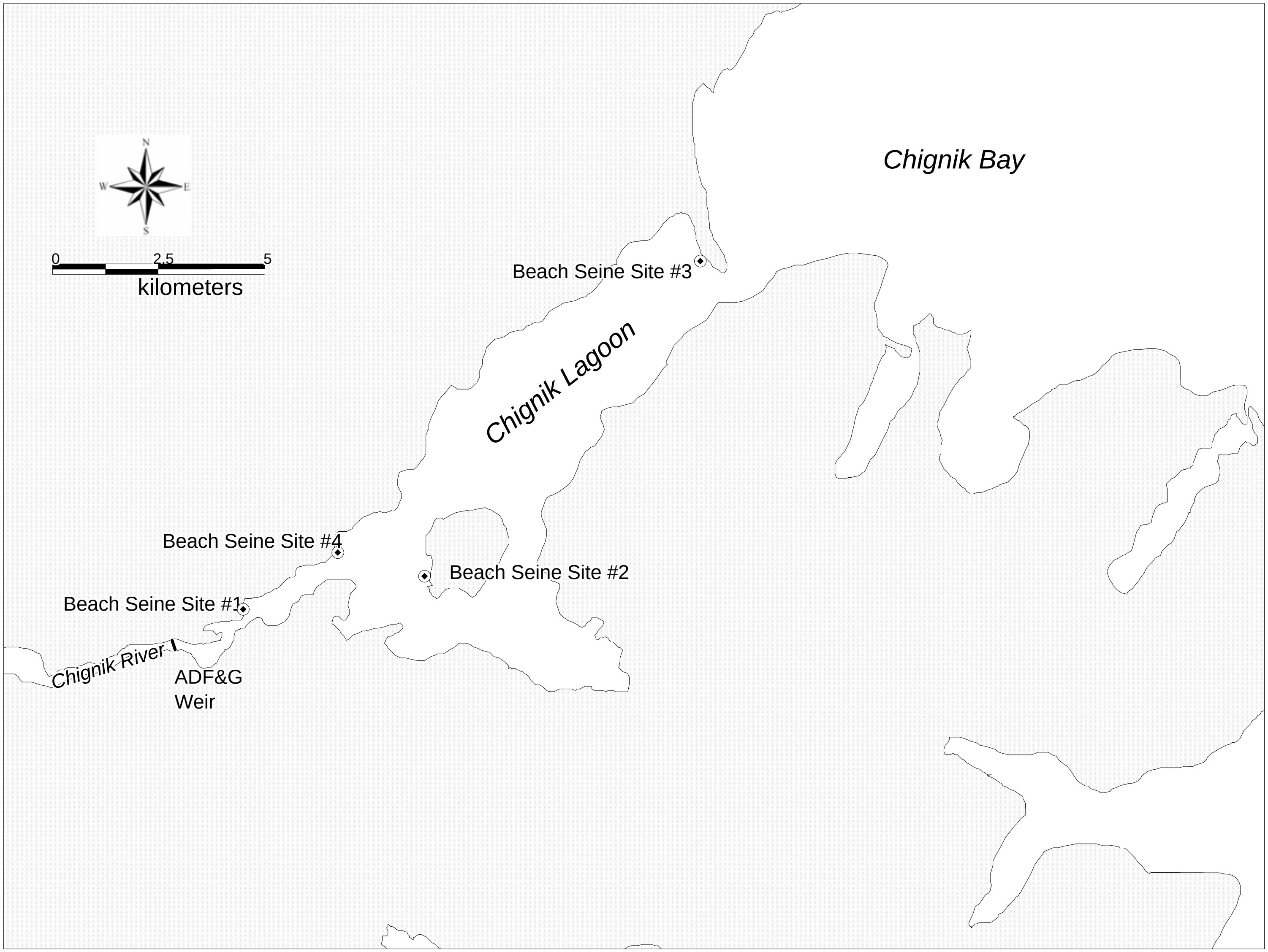


Figure 4.-Chignik Lagoon and its sampling sites.

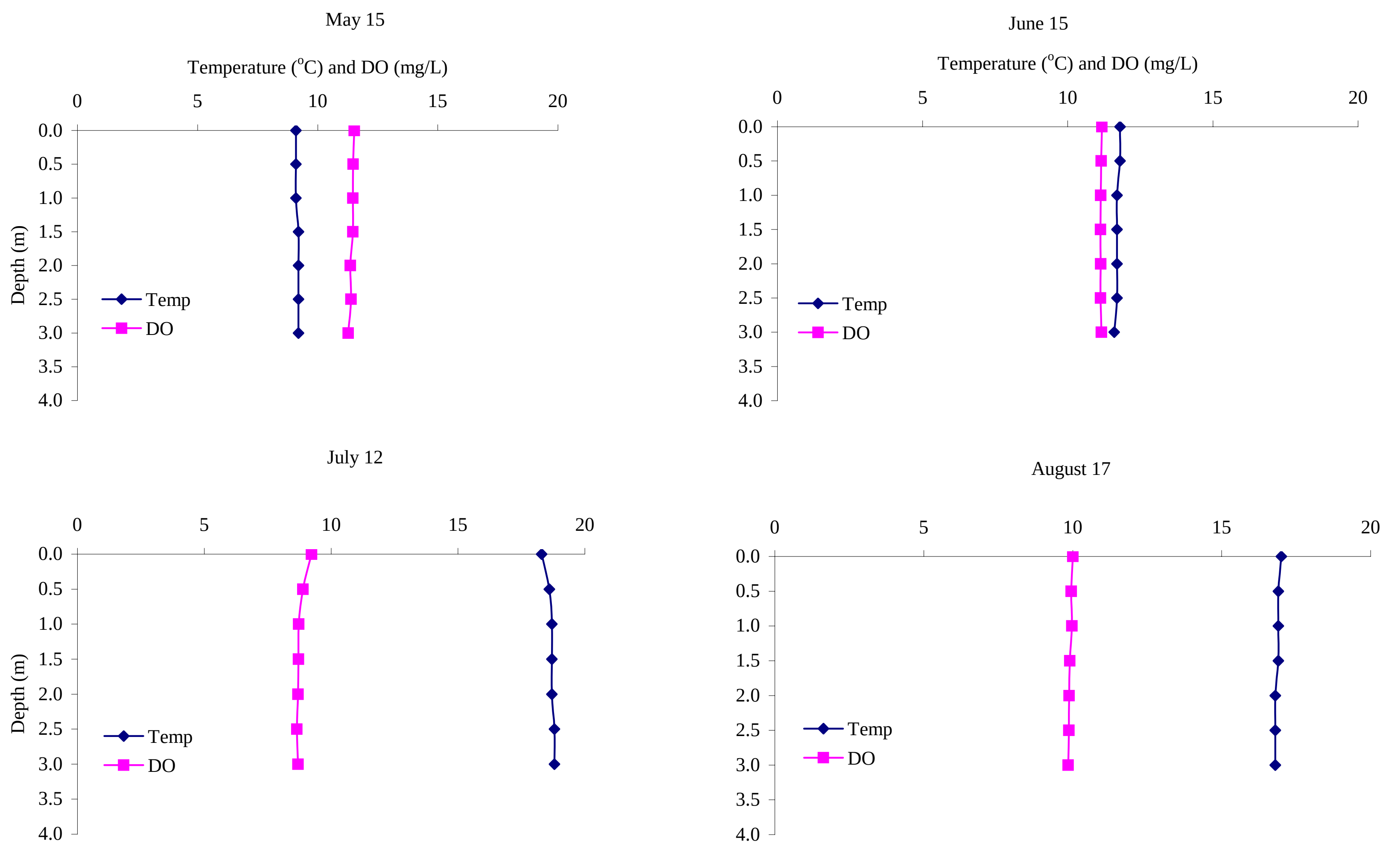


Figure 5.-Mean monthly temperature and dissolved oxygen profiles for Black Lake, 2004.

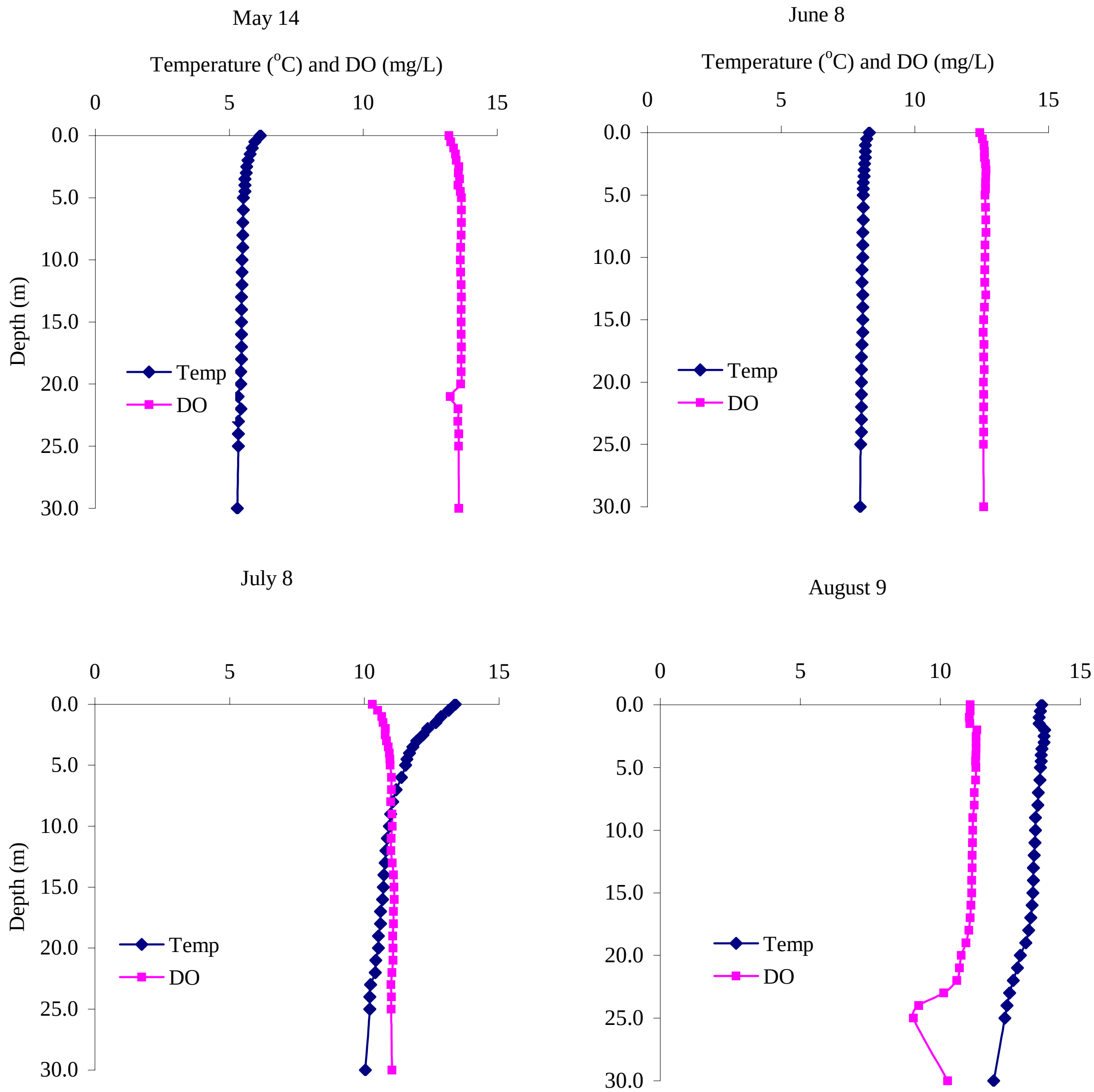
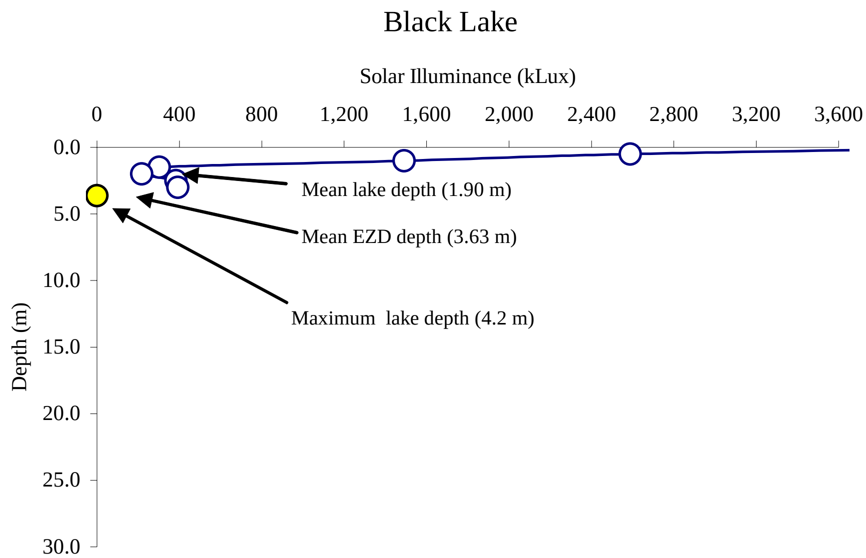


Figure 6.-Mean monthly temperature and dissolved oxygen profiles for Chignik Lake, 2004. Profiles were limited to a depth of 30 m.



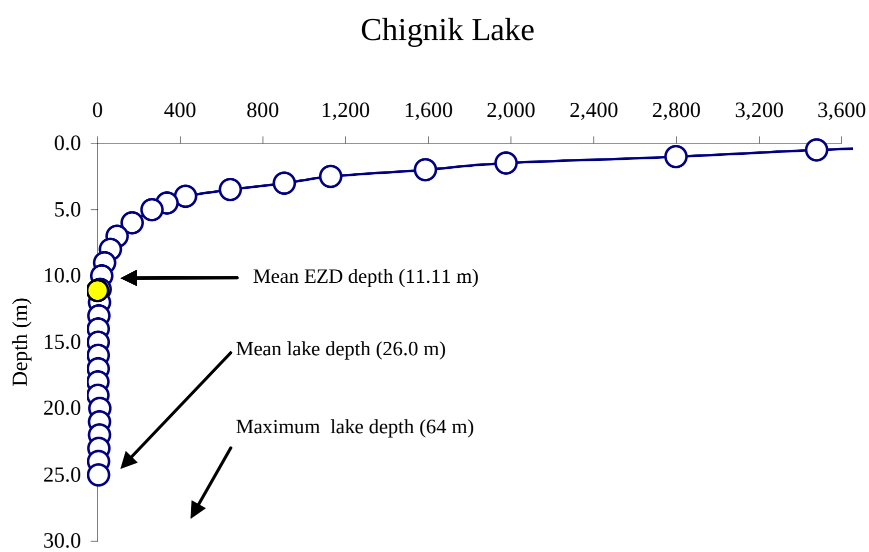


Figure 7.-Average light penetration curves relative to mean depth, EZD, and maximum depth for Chignik and Black Lakes, 2004.

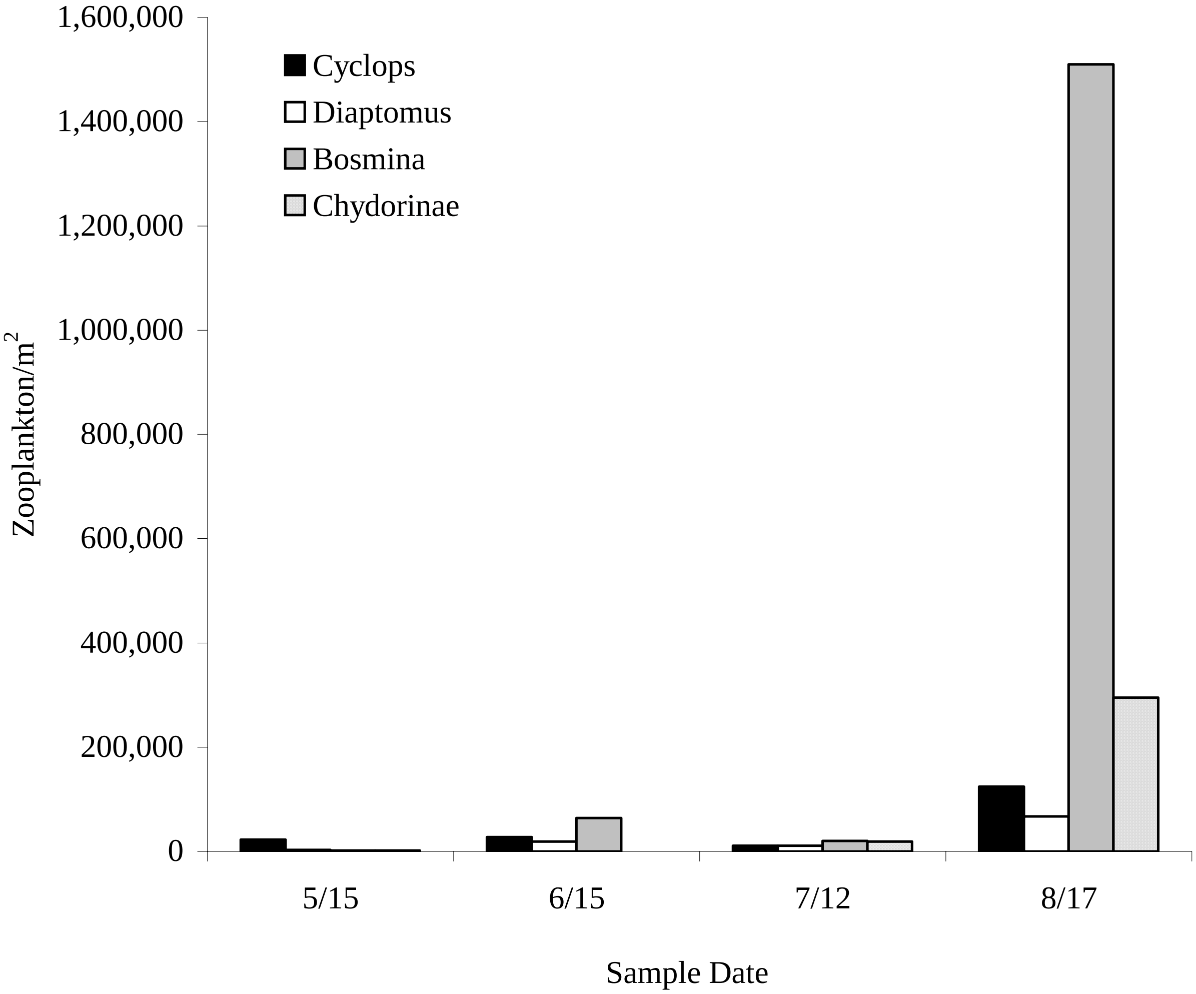


Figure 8.-Number of zooplankton per m^2 of the major copepods (*Cyclops* and *Diaptomus*) and cladocerans (*Bosmina* and *Chydorinae*) in Black Lake, by sample date, 2004.

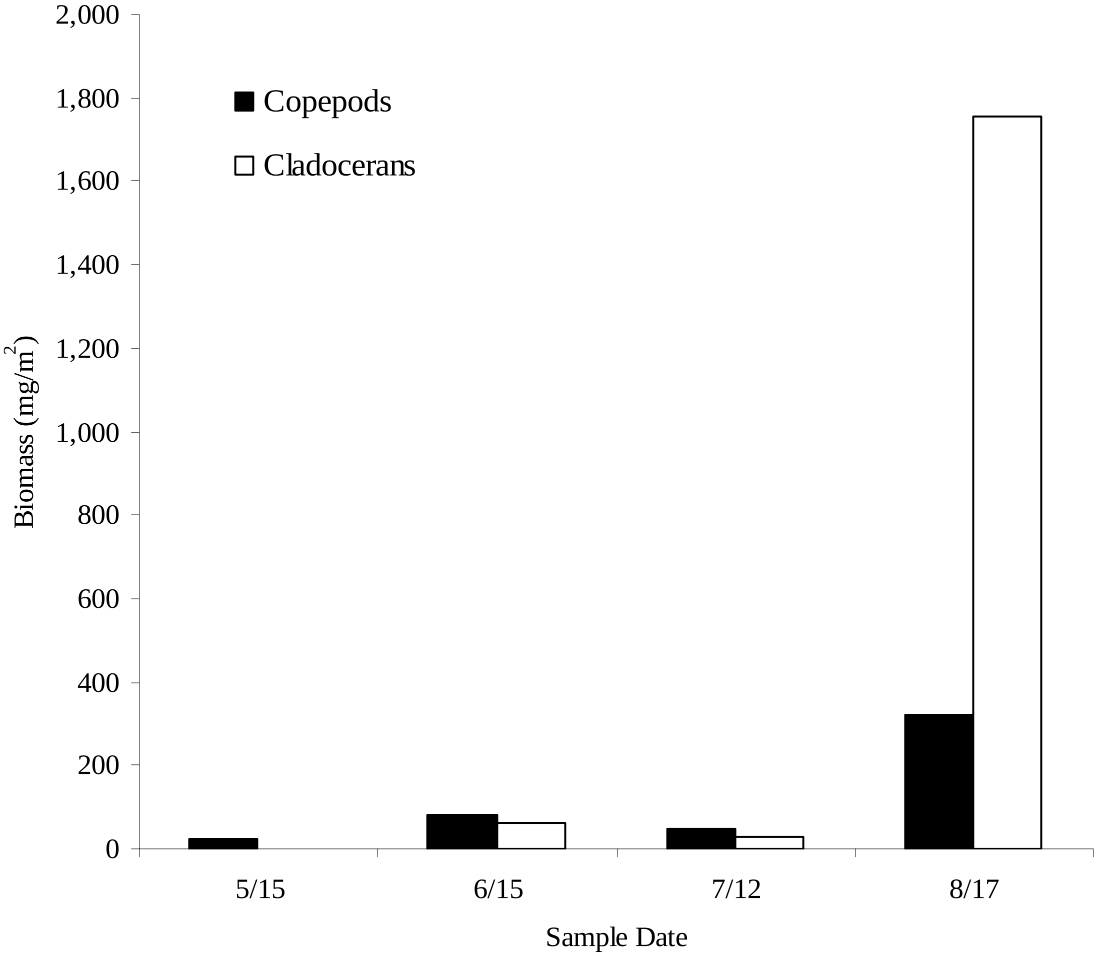


Figure 9.-Mean biomass per m^2 of the major copepods and cladocerans in Black Lake, by sample date, 2004.

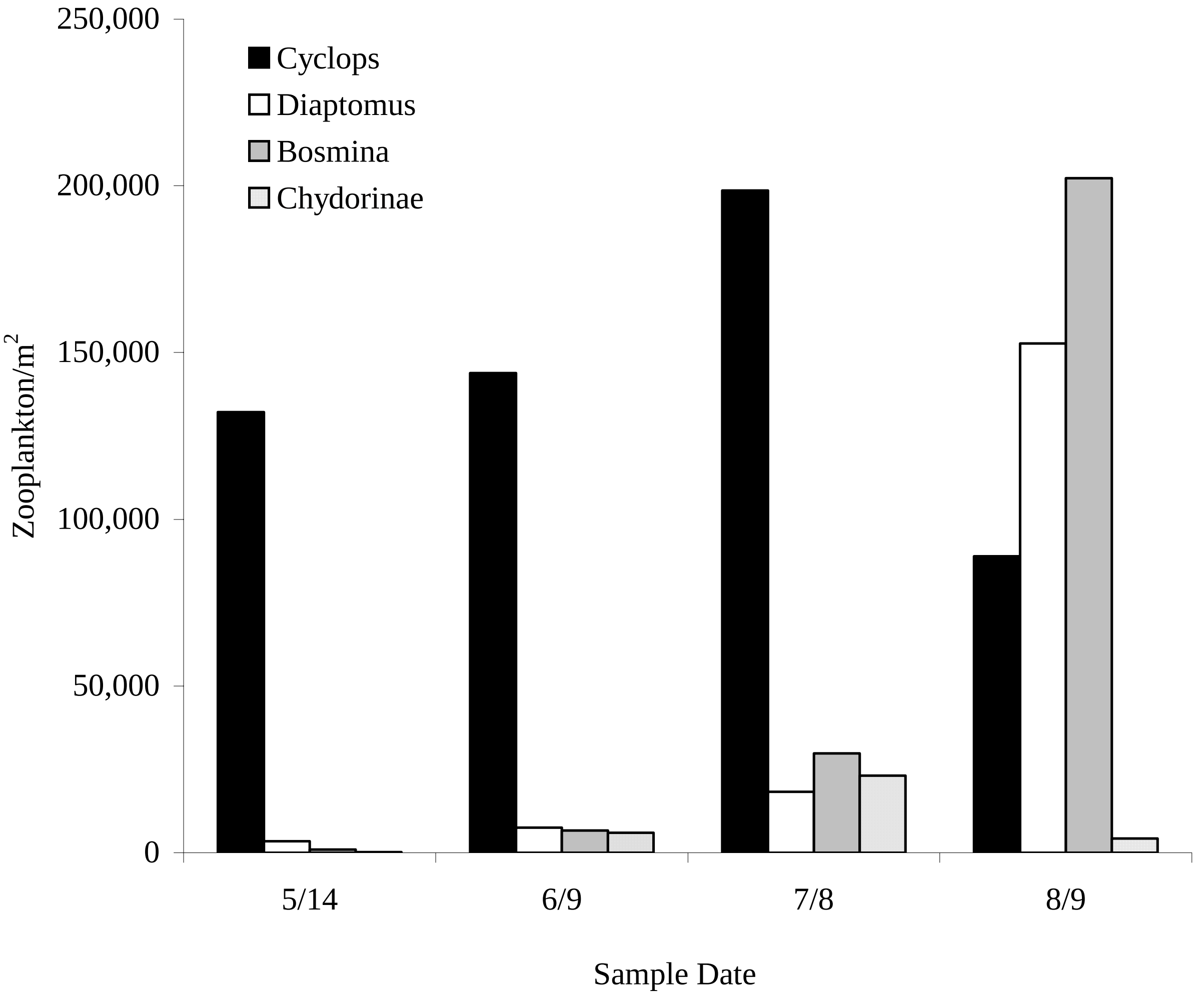


Figure 10.-Number of zooplankton per m^2 of the major copepods (*Cyclops* and *Diaptomus*) and cladocerans (*Bosmina* and *Chydorinae*) in Chignik Lake, by sample date, 2004.

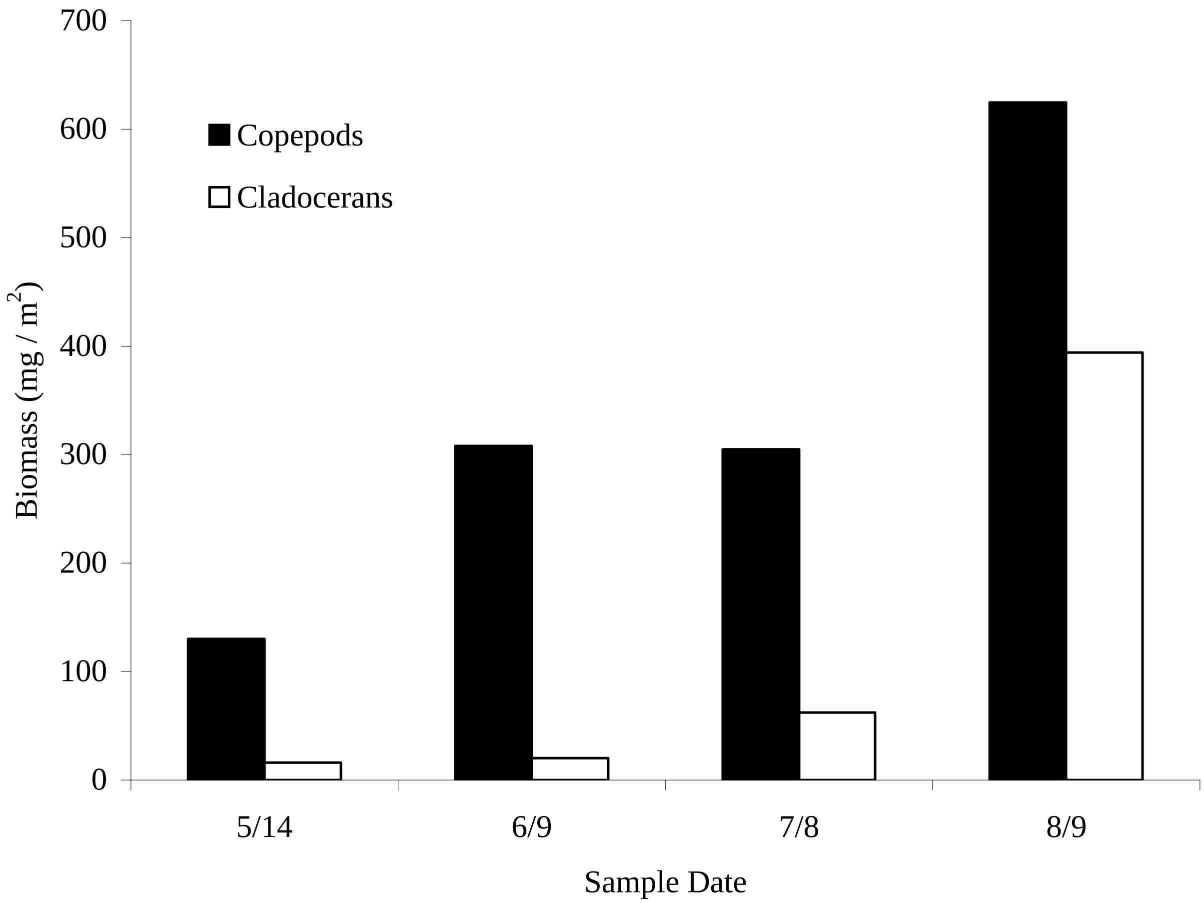


Figure 11.-Mean biomass per m^2 of the major copepods and cladocerans in Chignik Lake, by sample date, 2004.

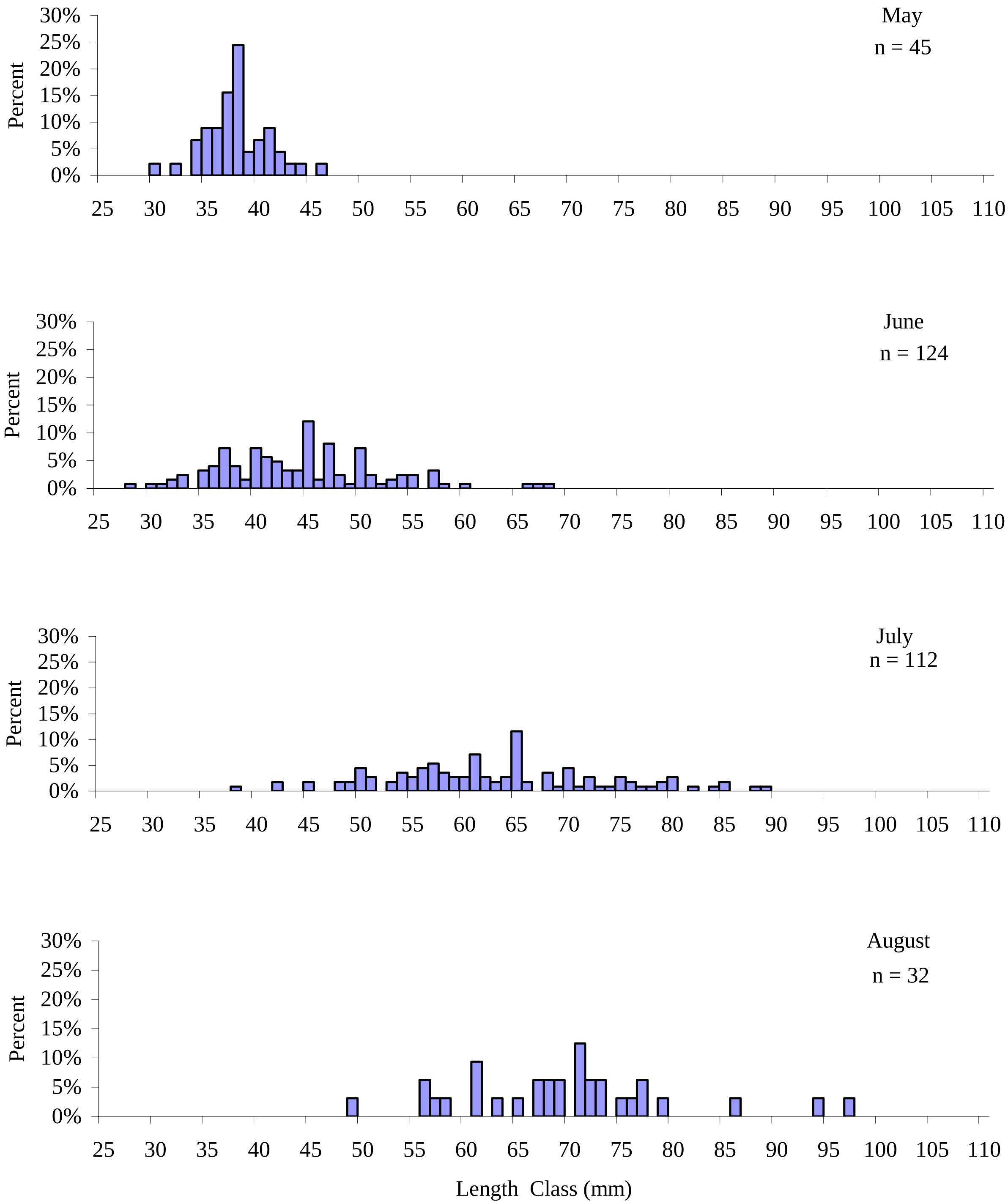


Figure 12.-Length frequency histograms by month of juvenile sockeye salmon captured with a beach seine, and fyke net from Black Lake and Black River, 2004.

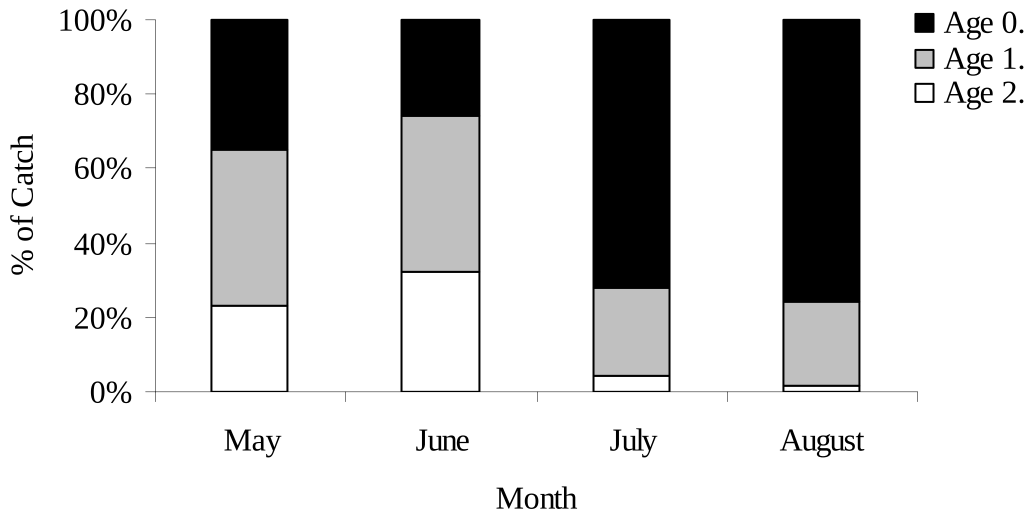


Figure 13.-Estimated age percentages in beach seine catches by month from Chignik Lagoon, 2004.

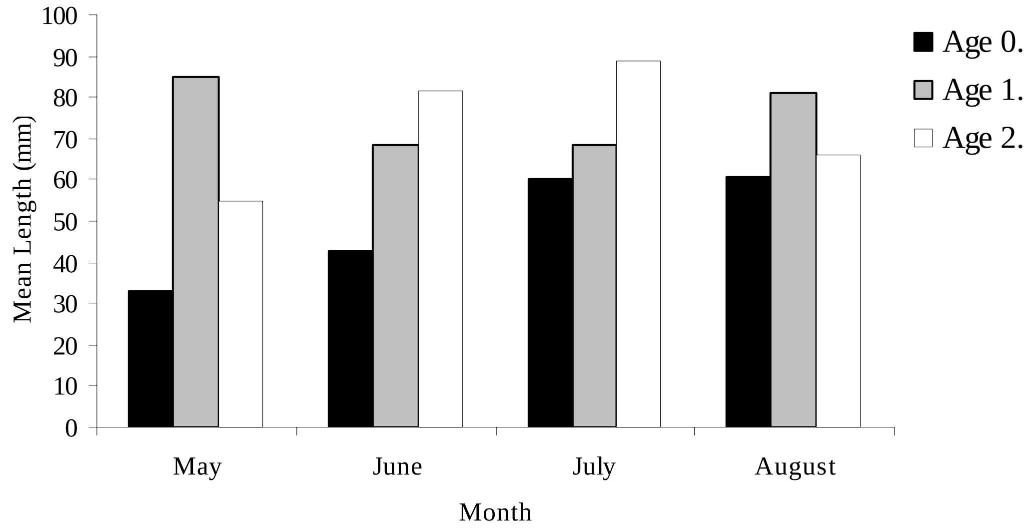


Figure 14.-Mean lengths of beach seine catches by age and month from Chignik Lagoon, 2004.

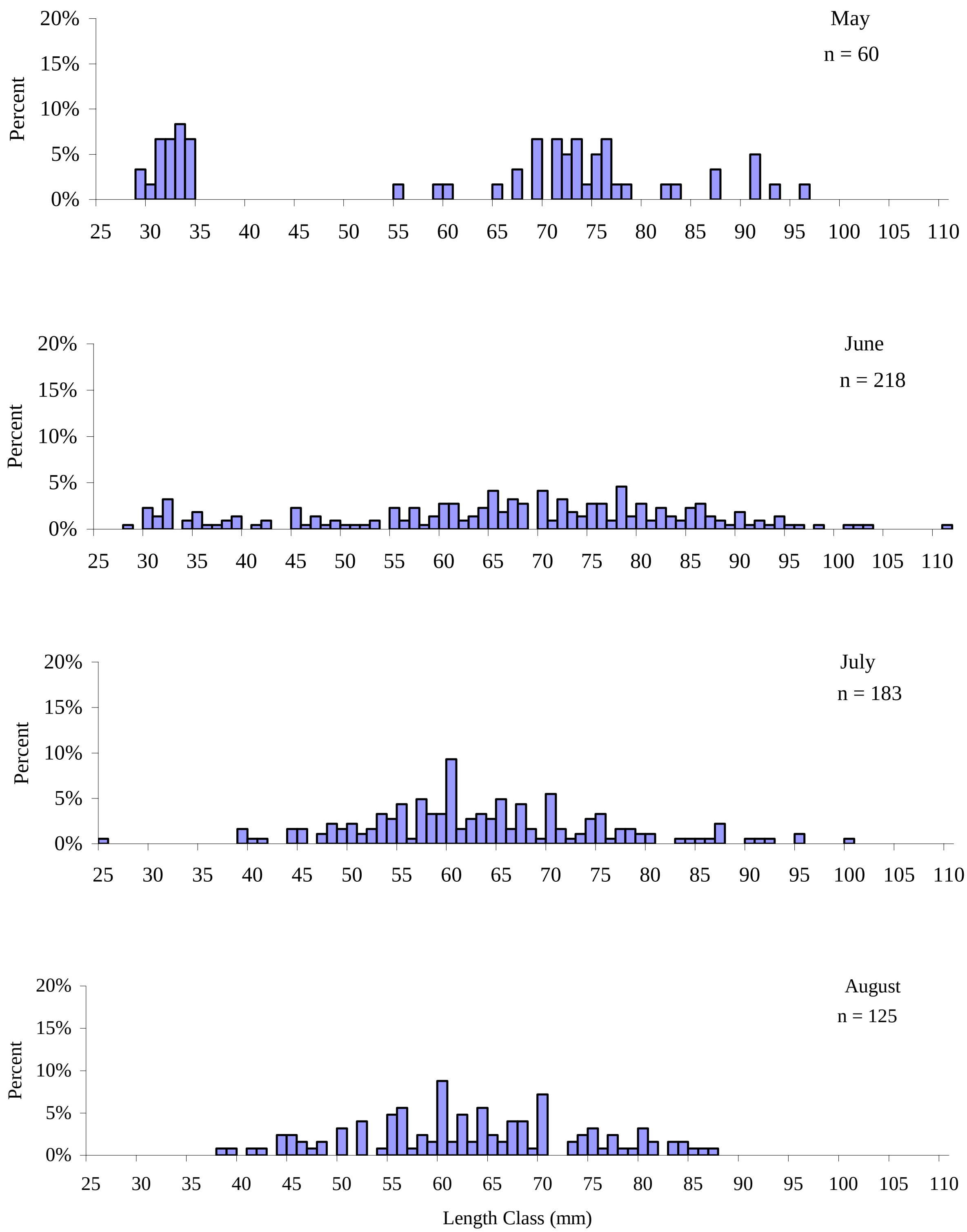


Figure 15.-Length frequency histograms by month of juvenile sockeye salmon captured with a beach seine from Chignik Lagoon, 2004.

APPENDIX A. LIMNOLOGY SAMPLING STATION COORDINATES

Appendix A1.-Location of the limnology sampling stations in Black and Chignik lakes, 2004. Coordinates are in decimal degrees.

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. ZOOPLANKTON DATA

Appendix B1.-Average number of zooplankton per m^3 from Black Lake by sample date, 2004.

Taxon	Sample Date 5/15	6/15	7/12	8/17	Average
Copepods:					
Epischura	796	12,241	10,510	103,503	31,763
Ovig. *Epischura*	0	0	0	0	0
Diaptomus	1,592	9,554	5,414	66,879	20,860
Ovig. *Diaptomus*	0	299	0	0	75
Cyclops	11,146	13,734	5,414	124,204	38,625
Ovig. *Cyclops*	0	0	0	0	0
Harpaticus	0	0	0	2,123	531
Nauplii	3,583	15,227	7,006	110,403	34,055
Total copepods	17,117	51,055	28,344	407,112	125,907
Cladocerans:					
Bosmina	796	31,947	10,191	1,509,554	388,122
Ovig. *Bosmina*	0	4,180	4,140	343,949	88,067
Daphnia l.	398	0	0	0	100
Ovig. *Daphnia l.*	0	0	0	0	0
Chydorinae	796	0	9,554	295,117	76,367
Total cladocerans	1,990	36,127	23,885	2,148,620	552,656
Total copepods + cladocerans	19,107	87,182	52,229	2,555,732	678,563
Rotifers:					
Kellicottia	3,185	21,497	16,242	31,847	18,193
Asplanchna	0	0	0	50,955	12,739
Keratella	531	0	0	133,758	33,572
Conochilus	1,592	250,796	273,248	961,783	371,855
other rotifers	1,592	0	955	3,484,076	871,656
Total rotifers	6,900	272,293	290,445	4,662,419	1,308,014

Appendix B2.-Biomass estimates (mg dry weight/m^3) of the major zooplankton taxa, by sample date, from Black Lake, 2004.

	Sample Date					Weighted
Taxon	5/25	6/22	7/19	8/15	Average	average
Copepods:						
Epischura	0.54	8.25	7.09	69.77	21.41	17.44
Diaptomus	3.65	21.90	12.41	153.28	47.81	23.80
Cyclops	8.91	10.98	4.33	99.29	30.88	29.49
Harpaticus	0	0	0	1.38	0.35	-
Total copepods	13.10	41.13	23.82	323.72	100.44	70.73
Cladocerans:						
Bosmina	0.66	26.60	8.49	1256.96	323.18	356.66
Ovig. *Bosmina*	0	5.64	5.58	463.92	118.78	123.03
Daphnia l.	0.11	0	0	0	0.03	0.03
Chydorinae	0.09	0	1.12	34.67	8.97	38.75
Total cladocerans	0.86	32.24	15.19	1755.55	450.96	518.47
Copepods to cladocerans	15.17	1.28	1.57	0.18	0.22	0.14
Total Biomass	13.96	73.37	39.01	2079.27	551.40	589.20

Appendix B3.-Average number of zooplankton per m^3 from Chignik Lake, 2004**.**

Taxon	Sample Date 5/14	6/9	7/8	8/9	Average
Copepods:					
Epischura	148	553	1,091	4,464	1,564
Ovigerous *Epischura*	0	0	0	0	0
Diaptomus	70	195	415	3,237	979
Ovigerous *Diaptomus*	0	18	64	214	74
Cyclops	2,796	4,144	4,944	1,832	3,429
Ovigerous *Cyclops*	1	3	125	231	90
Harpaticus	15	84	21	7	31
Nauplii	578	766	2,833	3,333	1,877
Total copepods:	3,608	5,763	9,491	13,317	8,045
Cladocerans:					
Bosmina	19	146	723	4,765	1,413
Ovigerous *Bosmina*	3	31	161	584	195
Daphnia longiremis	115	186	274	2,080	663
Ovigerous *Daphnia longiremis*	66	39	70	437	153
Chydorinae	0	165	451	86	175
Total cladocerans:	202	567	1,678	7,952	2,600
Total Copepods + Cladocerans	3,810	6,330	11,169	21,268	10,644
Rotifers:					
Kellicottia	288	952	579	876	674
Asplanchna	10	301	2,094	11,604	3,502
Keratella	3,274	11,914	386	90	3,916
Conochilus	26	1,567	29,744	1,230	8,142
other rotifers	27	169	19,596	4,932	6,181
Total Rotifers:	3,624	14,902	52,399	18,732	22,414

Appendix B4.-Biomass estimates (mg dry weight/m^3) of the major zooplankton taxa, by sample date, from Chignik Lake, 2004.

Taxon	Sample Date 5/14	6/9	7/8	8/9	Average	Weighted Average
Copepods:						
Epischura	0.13	0.42	0.93	3.18	1.17	1.16
Ovigerous *Epischura*	0	0	0	0	0	0
Diaptomus	0.17	0.49	1.16	6.11	1.98	1.96
Ovigerous *Diaptomus*	0	0.10	0.34	0.94	0.34	0.46
Cyclops	2.42	8.39	4.01	1.78	4.15	4.00
Ovigerous *Cyclops*	0	0.01	0.56	1.04	0.40	0.40
Harpaticus	0.01	0.04	0.01	0	0.02	0.01
Total copepods:	2.73	9.45	7.01	13.06	8.06	9.40
Cladocerans:						
Bosmina	0.02	0.13	0.61	3.85	1.15	1.15
Ovigerous *Bosmina*	0	0.05	0.25	0.68	0.25	0.25
Daphnia longiremis	0.17	0.21	0.25	2.64	0.82	0.81
Ovigerous *Daphnia longiremis*	0.15	0.10	0.20	1.46	0.48	0.48
Chydorinae	0	0.02	0.06	0.01	0.02	0.13
Total cladocerans:	0.35	0.51	1.38	8.65	2.72	2.82
Copepods to cladocerans	7.90	18.53	5.10	1.51	2.96	3.33
Total Copepods + Cladocerans	3.08	9.96	8.38	21.71	10.78	12.22

APPENDIX C. CATCH DATA

Appendix C1.-Beach seine catch data, 2004.

Location	Site	Date	Water temp (°C)	Total sockeye catch	Coho	King	Stickleback	Pond smelt	Dolly Varden	Pygmy whitefish	Other
Black Lake	1	5/21	ND[a]	96	1	0	137	2	0	0	0
	1	6/4	10.0	36	16	0	2	0	0	0	0
	1	6/15	14.0	35	14	0	10	0	0	0	0
	1	7/2	14.5	65	6	0	8	1	0	2	0
	1	7/20	15.0	4	439	0	35	0	1	5	0
	1	7/31	18.5	0	47	0	15	0	0	20	0
	1	8/16	21.5	0	58	0	155	0	0	23	0
Black Lake	2	5/21	ND[a]	5	1	0	2	0	0	0	0
	2	6/4	8.5	2	5	0	1	0	0	0	0
	2	6/15	13.5	347	2	0	3	75	0	0	0
	2	7/2	13.0	5	2	0	1	3	0	0	0
	2	7/20	15.0	0	1	0	35	51	0	0	0
	2	7/31	18.5	0	0	0	4	0	0	6	2 sculpin
	2	8/16	20.5	0	37	0	37	0	0	2	0
Black Lake	4	5/21	ND[a]	263	2	0	3	23	0	0	0
	4	6/4	9.0	37	1	0	1	2	0	0	0
	4	6/15	15.0	46	2	0	3	20	0	0	0
	4	7/2	13.0	48	0	0	2	2	0	0	0
	4	7/20	15.5	41	49	0	20	80	0	60	0
	4	7/31	20.0	0	20	0	0	0	0	0	0
	4	8/16	21.0	0	37	0	10	0	0	20	2 sculpin
Black Lake	5	5/21	ND[a]	0	0	0	16	1	0	0	1 sculpin
	5	6/4	11.0	2	1	0	2	0	0	0	0
	5	6/15	14.5	45	2	0	10	0	0	0	0
	5	7/2	15.5	0	7	0	0	0	0	0	0
	5	7/20	15.0	2	111	0	900	0	0	0	0

-Continued-

Appendix C1.-Page 2 of 3.

Location	Site	Date	Water temp (°C)	Total sockeye catch	Coho	King	Stickleback	Pond smelt	Dolly Varden	Pygmy whitefish	Other
Black Lake	5	7/31	18.0	0	28	0	600	0	0	0	0
	5	8/16	21.0	5	104	0	400	0	0	30	0
Chignik Lagoon	1	5/21	8.0	622	39	0	10	4	1	0	2 flounder
	1	6/2	9.0	24	8	0	4	3	5	0	0
	1	6/12	10.0	9	14	0	0	0	0	0	0
	1	6/18	10.0	195	31	24	5	10	10	0	5 sculpin
	1	6/28	10.5	93	17	1	1	1	66	96	0
	1	7/6	14.0	43	49	0	0	0	2	22	0
	1	7/15	14.5	85	26	3	10	3	45	1	0
	1	7/23	15.0	2,010	309	0	1,000	6,000	20	500	0
	1	8/4	16.0	85	62	1	675	300	8	0	25 sculpin, 2 flounder
	1	8/13	15.0	18	16	1	0	118	93	3	0
Chignik Lagoon	2	5/21	9.5	30	0	0	0	0	1	0	1 flounder, 1 pink
	2	6/2	9.0	4	1	0	0	0	0	0	2 flounder
	2	6/12	10.0	9	0	0	0	2	3	0	1 sculpin
	2	6/18	11.5	7	0	0	3	0	1	0	1 chum
	2	6/28	10.5	34	8	1	5	0	14	0	0
	2	7/6	12.5	45	1	0	2	0	2	0	0
	2	7/15	14.5	16	3	1	0	0	5	0	7 flounder
	2	7/23	14.5	2	6	0	0	0	13	1	0
	2	8/4	16.0	4	1	0	20	2	0	0	4 flounder
	2	8/13	15.5	26	5	0	35	2	0	0	0
Chignik Lagoon	3	5/21	8.5	0	0	0	0	0	3	0	0
	3	6/2	8.0	12	0	0	0	0	11	0	3 sculpin
	3	6/12	10.5	43	3	1	1	0	20	0	6 scuplin
	3	6/18	11.5	358	1	1	0	0	75	0	1 sculpin, 1 flounder

-Continued-

Appendix C1.-Page 3 of 3.

Location	Site	Date	Water temp (°C)	Total sockeye catch	Coho	King	Stickleback	Pond smelt	Dolly Varden	Pygmy whitefish	Other
Chignik Lagoon	3	6/28	11.0	0	0	0	1	0	14	0	1 sculpin
	3	7/6	12.0	8	0	0	1	0	5	0	1 pink
	3	7/15	14.5	4	0	0	0	0	6	0	9 sculpin
	3	7/23	14.5	61	0	0	0	0	23	0	3 pinks
	3	8/4	15.5	109	2	0	5	415	5	0	0
	3	8/13	15.5	3	2	0	0	0	18	0	1 sculpin
Chignik Lagoon	4	5/21	8.0	55	1	0	0	0	0	0	0
	4	6/2	9.0	24	3	2	1	0	5	0	2 flounder
	4	6/12	10.0	14	1	0	1	0	1	0	0
	4	6/18	10.0	14	1	0	1	3	0	0	10 flounder
	4	6/28	12.0	9	1	0	0	43	8	0	33 sculpin, 9 flounder
	4	7/6	13.0	13	5	0	0	5	0	0	1 sculpin
	4	7/15	17.0	20	81	0	0	5,000	0	0	15 flounder
	4	7/23	15.0	47	2	0	0	75	0	0	8 sculpin, 4 flounder
	4	8/4	17.5	43	2	0	0	70	0	0	10 sculpin, 5 flounder
	4	8/13	15.0	24	8	0	0	95	2	2	2 sculpin, 15 flounder

[a] ND = no data.

Appendix C2.-Fyke net catch data from Black River, 2004. All fyke net sessions were set on the day prior to the date pulled. ND = no data.

	Time			Temp °C			Other Catch						
Date pulled	Set	Pulled	Total time (hrs)	Water	Air	Sockeye catch	Coho	Chinook	Stickleback	Pond smelt	Dolly	Pygmy whitefish	Other
7/20	22:00	11:00	13.0	ND	ND	143	92	0	15	0	1	0	0
7/30	20:00	9:00	13.0	16.5	14.5	58	53	0	115	55	7	35	0
8/6	21:00	10:10	13.2	14.0	17.0	7	85	0	35	50	3	30	0
8/16	21:40	10:00	12.3	19.0	14.5	24	95	0	3000	45	15	400	17 sculpin