

Fishery Management Report No. 09-20

**A Seasonal Summary of the Hidden Lake Sockeye
Salmon Stocking Project and Related Criteria for
2008**

by

Steven E. Thomsen

April 2009

Alaska Department of Fish and Game

Divisions of Sport Fish and Commercial Fisheries



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Weights and measures (metric)		General		Measures (fisheries)	
centimeter	cm	Alaska Administrative Code	AAC	fork length	FL
deciliter	dL			mid-eye to fork	MEF
gram	g	all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.	mid-eye to tail fork	METF
hectare	ha			standard length	SL
kilogram	kg	all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.	total length	TL
kilometer	km				
liter	L	at	@	Mathematics, statistics	
meter	m	compass directions:		<i>all standard mathematical signs, symbols and abbreviations</i>	
milliliter	mL	east	E	alternate hypothesis	H _A
millimeter	mm	north	N	base of natural logarithm	e
		south	S	catch per unit effort	CPUE
Weights and measures (English)		west	W	coefficient of variation	CV
cubic feet per second	ft ³ /s	copyright	©	common test statistics	(F, t, χ^2 , etc.)
foot	ft	corporate suffixes:		confidence interval	CI
gallon	gal	Company	Co.	correlation coefficient	
inch	in	Corporation	Corp.	(multiple)	R
mile	mi	Incorporated	Inc.	correlation coefficient	
nautical mile	nmi	Limited	Ltd.	(simple)	r
ounce	oz	District of Columbia	D.C.	covariance	cov
pound	lb	et alii (and others)	et al.	degree (angular)	°
quart	qt	et cetera (and so forth)	etc.	degrees of freedom	df
yard	yd	exempli gratia		expected value	E
		(for example)	e.g.	greater than	>
Time and temperature		Federal Information Code	FIC	greater than or equal to	≥
day	d	id est (that is)	i.e.	harvest per unit effort	HPUE
degrees Celsius	°C	latitude or longitude	lat. or long.	less than	<
degrees Fahrenheit	°F	monetary symbols		less than or equal to	≤
degrees kelvin	K	(U.S.)	\$, ¢	logarithm (natural)	ln
hour	h	months (tables and figures): first three letters	Jan,...,Dec	logarithm (base 10)	log
hour	h			logarithm (specify base)	log ₂ , etc.
minute	min	registered trademark	®	minute (angular)	'
second	s	trademark	™	not significant	NS
		United States (adjective)	U.S.	null hypothesis	H ₀
Physics and chemistry		United States of America (noun)	USA	percent	%
all atomic symbols		U.S.C.	United States Code	probability	P
alternating current	AC	U.S. state	use two-letter abbreviations (e.g., AK, WA)	probability of a type I error (rejection of the null hypothesis when true)	α
ampere	A			probability of a type II error (acceptance of the null hypothesis when false)	β
calorie	cal			second (angular)	"
direct current	DC			standard deviation	SD
hertz	Hz			standard error	SE
horsepower	hp			variance	
hydrogen ion activity (negative log of)	pH			population	Var
parts per million	ppm			sample	var
parts per thousand	ppt, ‰				
volts	V				
watts	W				

FISHERY MANAGEMENT REPORT NO. 09-20

**A SEASONAL SUMMARY OF THE HIDDEN LAKE SOCKEYE SALMON
STOCKING PROJECT AND RELATED CRITERIA FOR 2008**

by
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ABSTRACT

Investigation of a sockeye salmon *Oncorhynchus nerka* enhancement stocking project was initiated on the Hidden Lake system in 1987 to provide increased harvest opportunities for fishermen in the Kodiak Management Area. Because Hidden Lake lies within the boundaries of the Kodiak National Wildlife Refuge, the project is subject to U.S. Fish and Wildlife Service oversight and guiding principles. In an effort to ensure that the project remains compatible with the Kodiak National Wildlife Refuge mission, the Alaska Department of Fish and Game monitors specific criteria outlined in the Hidden Lake Management Plan.

The 2008 water quality criteria yielded an average seasonal total nitrogen to total phosphorus ratio of 57:1, a total ammonia level of 5.7 µg/L, and a chlorophyll-*a* level of 0.64 µg/L. The zooplankton data revealed an average seasonal *Diaptomus* to *Cyclops* density ratio of 0.02:1, a weighted copepod biomass of 2.1 mg/m³, a *Bosmina* to *Daphnia* density ratio of 1.80:1, a weighted cladoceran biomass of 6.0 mg/m³, and a weighted *Bosmina* size (average length) of 0.47 mm. A total of 353,801 juveniles were stocked in 2008. A total of 5,715 adult sockeye salmon were harvested in the Foul Bay Special Harvest Area and reported on commercial fish harvest tickets.

The Hidden Lake stocking project met all the criteria specified in the Hidden Lake Management Plan and was compatible with Kodiak National Wildlife Refuge purposes.

Key words: Hidden Lake, Foul Bay, Special Harvest Area, *Oncorhynchus nerka*, sockeye salmon, stocking, Kodiak National Wildlife Refuge, U.S. Fish and Wildlife Service, Kodiak Regional Aquaculture Association, Special Use Permit, limnology, zooplankton, chlorophyll *a*, ADF&G, KNWR, FBSHA, USFWS, HLMP.

INTRODUCTION

This report summarizes the 2008 and historical (initiated in 1987) project data collected to monitor the Hidden Lake sockeye salmon *Oncorhynchus nerka* stocking project. Hidden Lake and the activities associated with the sockeye salmon stocking project are located within the boundaries of the Kodiak National Wildlife Refuge (KNWR) and are therefore subject to U.S. Fish and Wildlife Service (USFWS) and KNWR guiding principles and conditions. Such conditions are described in the Hidden Lake Management Plan (HLMP; Chatto 2002; Figure 1) and are permitted under the special conditions described in the Hidden Lake Special Use Permit (HLSUP). The intent of this report is to fulfill the reporting requirements as outlined in the HLMP and HLSUP. This report compares the results of the Alaska Department of Fish and Game (ADF&G) studies to the HLMP criteria to ensure that the project remains compatible with the KNWR purposes.

Hidden Lake was devoid of salmon due to a large waterfall in its outlet stream that is impassable to anadromous fish. The stocking project was designed to utilize the abundant zooplankton population in the lake to produce smolt that would emigrate to the ocean and return as adults to Foul Bay (Honnold and Schrof 2001; Figure 1). Adult runs returning to Foul Bay would then be harvested in a terminal area, which would reduce possible interactions with wild stocks. Conservative stocking levels are recommended to maintain stable nutrient and zooplankton levels in Hidden Lake that would support a long-term enhancement project (Kyle 1996). Additional benefits of the project would be to assess the response of the lake's zooplankton community to predation by juvenile salmon, monitor freshwater growth of the stocked sockeye salmon, and determine fry-to-adult survival.

In 1992, the ADF&G, in cooperation with the Kodiak Regional Aquaculture Association (KRAA), submitted proposals to the USFWS to stock sockeye salmon into Hidden Lake in the Afognak Unit of the KNWR (Chatto 2002; White 1992). The KNWR prepared an Environmental Assessment (EA) for the proposed project, which resulted in a Finding of No Significant Impact

(FONSI). A temporary HLSUP for the Hidden Lake project was issued to the ADF&G by the KNWR in 1992, to allow the project to proceed until a thorough review of the baseline data could be completed and a comprehensive management plan developed that would contain criteria specific to Hidden Lake.

In 2001, the ADF&G consolidated existing information (excluding brown bear and wildlife studies) from the Hidden Lake stocking project into one document (Honnold and Schrof 2001), which was then used as a reference to write the original KNWR HLMP (Chatto 2002). The HLMP was authorized by KNWR in April 2002 and the ADF&G has been issued a 5-year renewable HLSUP on two occasions to continue stocking and monitoring work in the KNWR.

Juvenile sockeye salmon have been stocked into Hidden Lake annually since 1992 (Duesterloh and Byrne 2008). The returning adult sockeye salmon are harvested in the Foul Bay Special Harvest Area (FBSHA; Figure 1). The ADF&G has annually monitored the fishery and attempted to sample a portion of the sockeye salmon commercial catch since 1995.

MANAGEMENT PLAN MONITORING CRITERIA

The purpose of the HLMP is to outline how the various components of the lake stocking project will be managed to remain compatible with the KNWR's mission and to serve as a reference document to guide any proposed changes to project operations (Chatto 2002).

Monitoring guidelines were established from data collected at Hidden Lake from 1992 to 1999 (Honnold and Schrof 2001). Specific limnological and fishery criteria were developed for comparative purposes. If measurements fall outside the criteria specified in the HLMP and HLSUP for any given attribute for two or more years, then the stocking project may need adjustments to meet the guidelines and purposes of the KNWR (Chatto 2002). Specific attributes monitored include lake nutrient concentrations (total nitrogen, phosphorus, ammonia, and chlorophyll *a*), zooplankton size, density and biomass, juvenile stocking, and adult harvest estimates (Table 1).

DESCRIPTION OF STUDY AREA

Hidden Lake (58° 23'N, 152° 42'W) is located on the northwest side of Afognak Island (approximately 72 km northwest of the city of Kodiak; Figure 1). The lake is 4.4 km long, up to 0.6 km wide, and has a surface area 1.9 km² (Figure 2). Hidden Lake is at an elevation of 68 m, has a mean depth of 10.8 m, and a maximum depth of 42.0 m. The Hidden Lake outlet stream (Hidden Lake Creek) is approximately 2.4 km long and empties into the north arm of Foul Bay. A waterfall impassable to migratory fish is located approximately 1.6 km upstream from the ocean.

Resident fish in Hidden Lake include rainbow trout *O. mykiss*, Dolly Varden char *Salvelinus malma*, three spine stickleback *Gasterosteus aculeatus*, and freshwater sculpin *Cottus aleuticus* (Honnold and Schrof 2001).

METHODS

LIMNOLOGICAL MONITORING

To follow HLMP guidelines the ADF&G monitors specific limnological and fishery attributes (Chatto 2002; Table 1). Attributes measured include total nitrogen (TN) to total phosphorus (TP) ratio, total ammonia (TA), chlorophyll *a* (Chl *a*), *Diatomus* to *Cyclops* density ratio, copepod

biomass, *Bosmina* to *Daphnia* density ratio, cladoceran biomass, and cladoceran (*Bosmina*) average size. In addition to monitoring the specific attributes specified by the HLMP guidelines, the ADF&G tracks KRAA stocking levels, reports the number of salmon harvested in the FBSHA, and measures other limnological attributes including: filterable reactive phosphorous (FRP; orthophosphate), total filterable phosphorous (TFP), Total Kjeldahl Nitrogen (TKN), Nitrate + Nitrite (N+N; No3+No2), and Phaeophytin *a*. Total Nitrogen is derived by adding TKN and N+N.

Lake Sampling Protocol

To obtain the limnology data, ADF&G personnel traveled to Hidden Lake in a fixed wing aircraft at approximately four to five week intervals (five times total) from May to September. A sampling station was established in the deepest basin of the lake and identified at the lake surface by a buoy (Figure 2). The location was recorded and verified with Global Positioning System (GPS) equipment. Prior to 2000, water samples were collected from the epilimnion (at a depth of 1 m) and the hypolimnion (at a depth ≥ 25 m). After 2000, water samples were only collected from the epilimnion to reduce sampling costs. Samples were collected following standard ADF&G sampling procedures (Foster et al. 2009; Thomsen 2008).

Water samples were collected with a 4 L Van Dorn bottle, and the samples were transferred into pre-cleaned polyethylene carboys, which were kept cool and dark in the float of the plane until processed at the laboratory in Kodiak. Vertical zooplankton tows were made at each station using a 0.2 m diameter conical net with 153 μm mesh. The net was pulled manually at a constant speed ($\sim 0.5 \text{ m sec}^{-1}$) from approximately 1 m off the lake bottom to the surface. The contents from each tow were transferred into a 125 ml polyethylene bottle and preserved in 10% neutralized formalin.

General Water Chemistry and Nutrients

Unfiltered water was analyzed for TP, TKN, pH, and alkalinity. Sample water was filtered through a rinsed 4.25 cm diameter Whatman GF/F filter pad and stored frozen in phosphate free soap-washed polyethylene bottles. Filtered water was analyzed for TFP, FRP, N+N, and TA. TP, TFP, FRP, N+N, and TA were analyzed using a Spectronic Genesys 5 Spectrophotometer (SG5).

TP was analyzed using the potassium persulfate-sulfuric acid digestion method described in Koenings et al. (1987) adapted from methods in Eisenreich et al. (1975). Unfiltered frozen water samples were sent to the South Dakota University laboratory for the TKN analysis using the EPA 351.3 (Nesslerization) method. The pH of water samples was measured with a Corning 430 meter, while alkalinity (mg L^{-1} as CaCO_3) was determined from 100 ml of unfiltered water titrated with 0.02 N H_2SO_4 to a pH of 4.5 and measured with a Mettler Toledo Seven Easy pH meter.

TFP was determined using the same methods as those for TP utilizing filtered water. FRP was determined using the potassium persulfate-sulfuric acid method described in Koenings et al. (1987). Samples for N+N were analyzed using the cadmium reduction column method described in Koenings et al. (1987). TA was determined using the phenol-sodium hypochlorite method described in Koenings et al. (1987). Total nitrogen, the sum of TKN and N+N, were calculated for each sample in addition to the ratio of total nitrogen to total phosphorus.

Chlorophyll *a*

For chl-*a* analysis, 1.0 L of water from each sample was filtered through a Whatman GF/F filter under 15 psi vacuum pressure. Approximately 5 mL of magnesium chloride (MgCO_3) were added

to the final 50 mL of water near the end of the filtration process for sample preservation. Filters were stored frozen in individual plexiglass slides until analyzed. Filters were then ground in 90% buffered acetone using a mortar and pestel, and the resulting slurry was refrigerated in separate 15 mL glass centrifuge tubes for 2 to 3 hours to ensure maximum pigment extraction. Pigment extracts were centrifuged, decanted, and diluted to 15 mL with 90% acetone (Koenings et al. 1987). The extracts were analyzed using a SG5 Spectrophotometer using methods described in Thomsen (2008).

Zooplankton

For zooplankton analysis, cladocerans and copepods were identified according to taxonomic keys by Edmondson (1959). Zooplankton samples were measured in triplicate 1-mL subsamples taken with a Hansen-Stempel pipette and placed in a Sedgewick-Rafter counting chamber. Lengths from a minimum of 15 animals of each species or group (typically animals are grouped at the genus or species level) were measured to the nearest 0.01 mm, a student's t-test was then employed (Thomsen 2008), and the mean was calculated. Density is the number of individuals per unit volume and reported in this publication as the number per meter cubed (No./m³). Biomass was estimated using density and species-specific linear regression equations between length and dry weight derived by Koenings et al. (1987).

STOCKING

Stocking densities for Hidden Lake were based on in-season zooplankton biomass prior to the hatchery egg takes (May through July; Duesterloh and Byrne 2008). Afognak Lake sockeye salmon eggs were collected in early August of 2008 by Pillar Creek Hatchery (PCH) personnel using standard fish culture procedures (ADF&G 1994). Eggs were flown back to Kodiak, incubated and reared at PCH, and juvenile salmon were aerially released into Hidden Lake via fixed wing aircraft.

HARVEST AND ESCAPEMENT MONITORING

ADF&G personnel monitored the commercial harvest within the FBSHA during the fishery opening while stationed on board the *M/V K-HI-C* (Figure 1). Monitoring goals were designed to include the assessment of sockeye salmon run strength, recording the fishing effort, estimating the commercial catch by species, and sampling a portion of the sockeye salmon catch for age data (ADF&G 2008; Honnold and Schrof 2001). Although personnel were on site and prepared to collect harvest data, there was no opportunity to collect samples due to a very low sockeye salmon harvest. No escapement surveys of Hidden Creek were conducted in 2008.

RESULTS AND DISCUSSION

LIMNOLOGICAL MONITORING

Total Nitrogen to Total Phosphorus Ratio

The 2008 total nitrogen to total phosphorus molar ratio (TN:TP) in Hidden Lake of 57:1 met the desired criteria ($\leq 106:1$) specified in the HLMP (Tables 1 and 2). This TN:TP ratio was below the 1992 to 2007 average (92:1). The lower TN:TP ratio in 2008 is due to a decrease in the seasonal TKN concentration and an increase in TP.

Total Ammonia

The 2008 seasonal average concentration of ammonia in Hidden Lake was 5.7 µg/L (Tables 1 and 3). This ammonia concentration was below the 1992 to 2007 average (7.0 µg/L) and also well below the criteria of ≤ 16.2 µg/L specified in the HLMP (Table 1).

Chlorophyll *a*

The seasonal mean Chl-*a* concentration in Hidden Lake was 0.64 µg/L (Tables 1 and 3). As noted in Table 1, the Chl-*a* concentrations met the criteria of ≥ 0.17 µg/L (Table 1). The 2008 Chl-*a* concentration was similar to the 1992 to 2007 average (0.61 µg/L).

Total Zooplankton

The seasonal mean zooplankton density in Hidden Lake was 2,428/m³ and the biomass was 8.1 mg/m³ (Table 4). The 2008 zooplankton density was approximately 1,078/m³ less than the average density from 1992 to 2007 (3,506/m³), while the 2008 total biomass was identical to the average biomass of 8.1 mg/m³ during the same time period (Table 4; Figure 3).

Diaptomus to Cyclops Density Ratio

The *Diaptomus:Cyclops* density ratio of 0.02:1 met the minimum criteria ($\geq 0.01:1$) specified in the HLMP (Tables 1 and 5). The average ratio from 1992 to 2007 was 0.03:1. Since 1992, the density of *Diaptomus* has met the minimum criteria ($\geq 0.01:1$) specified in the HLMP in only three years (2004, 2006, and 2008).

Copepod Density and Biomass

The average copepod density in 2008 was 797/m³ and the biomass was 2.1 mg/m³ (Table 5). The 2008 copepod biomass met the HLMP criteria of ≥ 0.40 mg/m³ (Table 1). The average density of copepods from 1992 to 2007 was 2,306/m³, three times the 2008 average copepod density (Table 4). The average biomass was 3.9 mg/m³, less than two times the 2008 average copepod biomass (Table 4). The disparity in density and biomass can be attributed to the large size of *Cyclops* in 2008 (Table 7). The 2008 average size of *Cyclops* (0.86 mm) is the third largest recorded and indicates that copepods are not being overgrazed (Table 7).

Bosmina to Daphnia Density Ratio

The *Bosmina:Daphnia* density ratio in 2008 of 1.80:1 was above the minimum criteria ($\geq 0.17:1$) specified in the HLMP (Tables 1 and 6). The average ratio from 1992 to 2007 was 4.73:1.

Cladoceran Density and Biomass

There was an average of 1,631/m³ cladocerans in Hidden Lake in 2008 and an average biomass of 6.0 mg/m³ (Tables 4 and 6). The 2008 biomass was above the minimum criteria of ≥ 2.20 mg/m³ (Tables 1 and 4). Average biomass in 2008 was greater than the average biomass from 1992 to 2007 (4.2 mg/m³; Tables 4 and 6). The greater cladoceran biomass in 2008 can be largely attributed to a large biomass of *Holopedium* (4.9 mg/m³).

Cladoceran (*Bosmina*) Size

The cladoceran *Bosmina* averaged 0.47 mm in length in 2008 which met the criteria (> 0.40 mm) specified in the HLMP (Tables 1 and 7). The average size of *Bosmina* from 1992 to 2007 was 0.47 mm.

STOCKING

Juvenile sockeye salmon were stocked in Hidden Lake on two occasions in 2008. Approximately 153,925 fry (average weight of 0.4 g) were stocked on June 9 and 199,876 pre-smolt (average weight of 7.5 g) were stocked on September 27-28 (Table 8). This stocking level (353,801) is slightly above the average (296,451) number of sockeye salmon stocked from 1992 to 2007 (Table 8; Figure 3).

HARVEST MONITORING

Commercial salmon harvests in the FBSHA occurred in June and July, 2008 (Table 9). In 2008, 2 Chinook salmon *O. tshawytscha*, 5,715 sockeye salmon, 5 coho salmon *O. kisutch*, 375 pink salmon *O. gorbuscha* and 227 chum salmon *O. keta* were harvested in the FBSHA.

Due to the limited harvest, the on-site monitoring staff did not collect any commercial salmon harvest samples in 2008. Table 10 provides historical average age composition from 1995 to 2005. Historically, the age 1.2 component represents 62.3% and the age 1.3 component 29.9%, of the harvest.

The 2008 sockeye salmon harvest (5,715) was larger than the last two years (2006 and 2007) but still well below the 1995-2007 average (24,028; Table 11). The commercial harvest of non-targeted Chinook and chum salmon was less than historical averages (Chinook, 36; chum, 165). The commercial harvest of non-targeted coho and pink salmon (coho, 3; pink, 199) was slightly greater than historical averages. The commercial fishery in the FBSHA closed on July 6.

OUTLOOK FOR 2009

The brood source for Hidden Lake juvenile releases has primarily been from the Afognak Lake sockeye salmon stock. The projected releases of juvenile sockeye salmon in 2009 are 150,000 fry and 150,000 pre-smolt for a total projected release of 300,000 sockeye salmon into Hidden Lake (personal communication, S. T. Schrof, ADF&G fisheries biologist, Kodiak Alaska). The preliminary stocking numbers may be adjusted if the in-season zooplankton findings warrant modification. All other operations and monitoring projects planned for 2009 are expected to be consistent with the 2008 monitoring goals and objectives.

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TABLES AND FIGURES

Table 1.–Hidden Lake monitoring criteria specified in the Hidden Lake Management Plan (HLMP) and limnological and fishery data, and the 2008 results.

HLMP monitoring criteria		2008 results
<u>Limnology Monitoring</u>		
Mean Total Nitrogen : Total Phosphorous Molar Ratio	≤ 106	57
Mean Total Ammonia (µg/L)	≤ 16.2	5.7
Mean Chlorophyll <i>a</i> (Chl <i>a</i>) (µg/L)	> 0.17	0.64
<i>Diaptomus</i> : <i>Cyclops</i> Density Ratio	> 0.01	0.02
Mean Copepod Biomass (mg/m ³)	> 0.40	2.10
<i>Bosmina</i> : <i>Daphnia</i> Density Ratio	> 0.17	1.80
Mean Cladoceran Biomass (mg/m ³)	> 2.20	6.00
Cladoceran (<i>Bosmina</i>) average size (mm)	> 0.40	0.47
<u>Stocking</u>		
Sockeye	^a	353,801
<u>Commercial Harvest from the FBSHA ^b</u>		
Chinook	^a	2
Sockeye	^a	5,715
Coho	^a	5
Pink	^a	375
Chum	^a	227

^a = not a specified criteria in the HLMP.

^b = Foul Bay Special Harvest Area - statistical area 251-41.

Table 2.–Seasonal mean total Kjeldahl nitrogen (TKN), nitrate+nitrite (No3+No2), total phosphorus (TP) concentrations, and total nitrogen to total phosphorus ratio by weight (TN:TP) from the epilimnion (1m) 1987, 1990-2008 and hypolimnion (>25m) 1987, 1990-1999 of Hidden Lake.

Year	Depth (m)	TKN (µg/L N)	No3+No2 (µg/L N)	TP (µg/L P)	TN:TP Ratio	
1987	1	90.1	82.0	4.2	91	
	25	80.7	90.9	4.0	94	
1990	1	101.3	65.9	3.9	94	
	29	79.2	88.7	2.1	177	
1991	1	75.2	53.4	4.1	70	
	30	82.9	70.4	3.1	110	
1992	1	93.7	64.9	4.0	87	
	27	98.8	74.3	5.1	76	
1993	1	102.0	45.7	3.7	88	
	42	84.2	90.4	3.1	124	
1994	1	120.3	19.7	4.6	67	
	40	88.2	54.9	4.3	74	
1995	1	108.6	39.4	3.8	87	
	43	91.7	64.2	3.6	95	
1996	1	92.6	38.9	3.4	85	
	42	80.4	72.5	3.7	91	
1997		93.0	20.1	3.1	80	
	43	87.7	47.7	3.3	91	
1998	1	100.5	13.3	3.1	83	
	42	98.2	17.2	3.2	80	
1999	1	92.8	51.3	3.1	104	
	42	81.0	73.0	3.2	107	
2000	1	ND	48.2	4.9	–	
2001	1	99.5	25.8	5.1	54	
2002	1	115.0	24.2	5.5	56	
2003	1	102.7	57.1	4.7	75	
2004	1	179.8	43.0	8.1	61	
2005	1	152.0	37.0	7.7	54	
2006	1	234.3	40.4	2.1	290	
2007	1	90.0	44.0	2.8	106	
2008	1	57.0	46.7	4.0	57	
Mean 87-91 (1meter):		1	88.9	67.1	4.1	85
Mean 92-07 (1 meter):		1	118.4	37.6	4.3	92

ND = No data, TKN's were not analyzed.

– = Could not calculate TN:TP ratio.

Table 3.–Summary of seasonal mean nutrient and algal pigment concentrations by station and depth for Hidden Lake, 1987, 1990-2008.

Year	Depth (m)	Total Phosphorus		Total filterable-P		Filterable reactive-P		Total Kjeldahl nitrogen		Ammonia		Nitrate+nitrite		Chlorophyll <i>a</i>	
		(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD
1987	1	4.2	0.4	2.2	0.7	0.9	0.1	90.1	2.4	4.3	3.1	82.0	11.7	0.15	0.0
	25	4.0	1.6	2.9	0.9	1.1	0.2	80.7	11.4	4.6	3.2	90.9	5.7	0.06	0.1
1990	1	3.9	2.2	3.6	3.8	2.1	1.1	101.3	48.7	3.8	4.3	65.9	11.3	0.29	0.0
	29	2.1	1.2	1.4	0.3	1.2	0.2	79.2	34.0	6.1	2.3	88.7	16.4	0.11	0.0
1991	1	4.1	1.9	4.0	3.1	3.4	2.6	75.2	44.5	12.0	4.1	53.4	25.1	0.18	0.1
	30	3.1	0.7	2.5	0.7	1.9	0.8	82.9	19.1	13.6	3.4	70.4	13.7	0.07	0.1
1992	1	4.0	0.4	2.0	0.4	1.8	0.2	93.7	41.0	4.1	2.9	64.9	15.8	0.22	0.1
	27	5.1	3.8	2.5	0.9	2.4	1.1	98.8	34.3	3.7	2.5	74.3	16.0	0.11	0.1
1993	1	3.7	2.6	5.1	6.3	3.0	3.3	102.0	30.9	12.6	11.4	45.7	22.1	0.79	0.4
	42	3.1	1.6	2.4	1.1	1.9	1.1	84.2	23.4	16.2	9.0	90.4	16.1	0.20	0.2
1994	1	4.6	1.7	1.7	0.5	1.2	0.5	120.3	33.3	4.3	2.5	19.7	19.9	1.11	0.3
	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.87	0.9
	40	4.3	2.3	1.5	0.5	1.2	0.4	88.2	17.7	7.4	3.8	54.9	3.4	0.08	0.1
1995	1	3.8	2.2	2.2	1.6	1.7	1.2	108.6	24.6	9.7	3.0	39.4	15.8	0.77	0.3
	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.70	0.3
	43	3.6	2.2	2.0	0.8	1.3	0.7	91.7	12.9	10.2	1.9	64.2	3.6	0.22	0.2
1996	1	3.4	0.9	3.6	0.4	1.9	0.2	92.6	8.0	3.8	4.6	38.9	13.8	0.51	0.1
	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.46	0.1
	42	3.7	1.5	3.6	0.8	1.9	0.4	80.4	7.1	7.2	3.7	72.5	5.1	0.14	0.1
1997	1	3.1	1.4	1.9	0.4	1.6	0.3	93.0	8.8	7.8	8.3	20.1	13.2	0.39	0.1
	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.41	0.1
	43	3.3	1.2	2.7	1.1	2.2	1.1	87.7	14.2	15.1	9.5	47.7	3.0	0.12	0.1

-continued-

Table 3.–Page 2 of 2.

Year	Depth (m)	Total Phosphorus		Total filterable-P		Filterable reactive-P		Total Kjeldahl nitrogen		Ammonia		Nitrate+nitrite		Chlorophyll <i>a</i>	
		(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD
1998	1	3.1	1.0	2.4	0.8	1.7	0.9	100.5	11.5	5.5	4.5	13.3	4.8	0.45	0.2
	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.18	0.2
	42	3.2	0.5	2.5	0.8	1.8	0.8	98.2	16.6	6.4	3.8	17.2	5.8	0.38	0.2
1999	1	3.1	0.4	1.7	0.3	1.2	0.3	92.8	8.9	10.7	1.6	51.3	20.7	0.17	0.1
	42	3.2	0.3	1.9	0.2	1.3	0.3	81.0	7.3	15.1	4.4	73.0	10.3	0.09	0.1
2000	1	4.9	4.0	2.8	1.3	1.4	1.4	ND	ND	11.9	10.3	48.2	15.1	1.03	1.2
2001	1	5.1	1.8	4.1	2.6	3.3	3.7	99.5	19.7	5.5	4.4	25.8	12.3	0.64	0.2
2002	1	5.5	4.0	2.0	0.7	2.0	1.3	115	26.9	6.2	2.3	24.2	15.6	0.60	0.1
2003	1	4.7	2.3	1.6	1.0	3.2	0.6	102.7	21.3	3.7	3.2	57.1	18.6	0.70	0.2
2004	1	8.2	8.3	4.5	4.6	3.1	1.4	179.8	120.6	7.4	2.0	43.0	22.1	0.48	0.3
2005	1	7.7	2.3	5.0	1.2	3.8	0.4	152.0	22.0	4.7	2.3	37.1	22.2	0.48	0.2
2006	1	2.1	1.2	1.4	0.8	2.2	1.2	234.3	276.4	8.4	2.8	40.4	17.8	0.72	0.4
2007	1	2.8	0.4	1.3	0.4	1.3	0.3	90.0	20.3	5.5	0.2	44.0	14.0	0.72	0.2
2008	1	4.0	1.8	1.6	0.3	2.2	0.9	57.0	32.6	5.7	1.9	46.7	18.6	0.64	0.3
mean															
87-91:	1	4.1	1.5	3.2	2.6	2.1	1.3	88.9	31.9	6.7	3.8	67.1	16.0	0.21	0.0
mean															
92-07:	1	4.4	2.2	2.7	1.5	2.1	1.1	118.4	44.9	7.0	4.1	38.3	16.5	0.61	0.3

SD = Standard deviation

ND = No data

Table 4.–Summary of the Hidden Lake weighted mean density and biomass of Cladocerans and Copepods and their density ratio, 1987, 1990-2008.

Year	Cladoceran		Copepod		Total		Cladoceran to Copepod ratios ^a	
	Density (No./m ³)	Biomass (mg/m ³)	Density (No./m ³)	Biomass (mg/m ³)	Density (No./m ³)	Biomass (mg/m ³)	Abundance Ratio	Biomass Ratio
1987	2,056	7.5	3,820	9.3	5,876	16.8	0.54 :1	0.45 :1
1990	1,581	5.2	4,193	12.6	5,774	17.8	0.38 :1	0.29 :1
1991	818	3.8	3,526	9.0	4,344	12.8	0.23 :1	0.30 :1
1992	873	3.8	3,130	6.3	4,003	10.1	0.28 :1	0.38 :1
1993	829	2.7	309	0.7	1,138	3.4	2.68 :1	0.79 :1
1994	1,162	5.1	153	0.4	1,315	5.5	7.59 :1	0.92 :1
1995	1,215	4.8	1,171	2.9	2,386	7.6	1.04 :1	0.62 :1
1996	692	2.2	2,170	4.9	2,862	7.1	0.32 :1	0.31 :1
1997	683	3.8	373	0.8	1,056	4.6	1.83 :1	0.83 :1
1998	1,281	4.1	1,110	2.7	2,391	6.8	1.15 :1	0.61 :1
1999	618	2.9	3,357	6.0	3,975	8.9	0.18 :1	0.32 :1
2000	728	2.5	601	1.1	1,329	3.5	1.21 :1	0.70 :1
2001	1,156	2.7	339	1.1	1,495	3.8	3.41 :1	0.72 :1
2002	3,282	9.5	1,452	2.5	4,734	12.0	2.26 :1	0.79 :1
2003	1,631	5.7	8,517	12.3	10,148	18.0	0.19 :1	0.32 :1
2004	1,701	7.4	3,564	5.6	5,265	13.0	0.48 :1	0.57 :1
2005	1,165	3.1	6,221	6.9	7,386	9.9	0.19 :1	0.31 :1
2006	1,317	6.1	1,280	3.0	2,597	9.0	1.03 :1	0.67 :1
2007	869	1.7	3,142	4.8	4,011	6.5	0.28 :1	0.26 :1
2008	1,631	6.0	797	2.1	2,428	8.1	2.05 :1	0.74 :1
mean 87-91:	1,485	5.5	3,846	10.3	5,331	15.8	0.39 :1	0.35 :1
mean 92-07:	1,200	4.2	2,306	3.9	3,506	8.1	1.51 :1	0.57 :1

^a = Values based on predominate species only.

Table 5.–Hidden Lake weighted mean Copepod density and biomass by species and the *Diaptomus* to *Cyclops* density ratio, 1987, 1990-2008.

Year	# Sample Events	<i>Diaptomus</i>		<i>Cyclops</i>		Totals		<i>Diaptomus</i> to <i>Cyclops</i> Ratio ^a
		Density No./m ³	Biomass mg/m ³	Density No./m ³	Biomass mg/m ³	Density No./m ³	Biomass mg/m ³	
1987	3	803	2.4	3,017	6.9	3,820	9.3	0.27 :1
1990	4	1,106	5.1	3,087	7.5	4,193	12.6	0.36 :1
1991	5	782	2.7	2,744	6.3	3,526	9.0	0.28 :1
1992	6	804	1.7	2,326	4.6	3,130	6.3	0.35 :1
1993	6	0	0.0	309	0.7	309	0.7	0.00 :1
1994	7	0	0.0	153	0.4	153	0.4	0.00 :1
1995	7	0	0.0	1,171	2.9	1,171	2.9	0.00 :1
1996	6	1	0.0	2,169	4.9	2,170	4.9	0.00 :1
1997	6	1	0.0	372	0.8	373	0.8	0.00 :1
1998	5	0	0.0	1,110	2.7	1,110	2.7	0.00 :1
1999	5	0	0.0	3,357	6.0	3,357	6.0	0.00 :1
2000	5	0	0.0	601	1.1	601	1.1	0.00 :1
2001	5	0	0.0	339	1.1	339	1.1	0.00 :1
2002	5	0	0.0	1,452	2.5	1,452	2.5	0.00 :1
2003	4	6	0.0	8,511	12.3	8,517	12.3	0.00 :1
2004	4	70	0.3	3,494	5.3	3,564	5.6	0.02 :1
2005	4	57	0.1	6,164	6.8	6,221	6.9	0.01 :1
2006	5	56	0.1	1,224	2.9	1,280	3.0	0.05 :1
2007	4	7	0.0	3,135	4.8	3,142	4.8	0.00 :1
2008	4	12	0.0	785	2.0	797	2.1	0.02 :1
mean 87-91:		897	3.4	2,949	6.9	3,846	10.3	0.30 :1
mean 92-07:		63	0.1	2,243	3.7	2,306	3.9	0.03 :1

a = Values based on mean density.

Table 6.—Summary of the Hidden Lake weighted mean density and biomass of Cladocerans by species and the *Bosmina* to *Daphnia* density ratio, 1987, 1990-2008.

Year	# Sample Events	<i>Bosmina</i>		<i>Daphnia</i>		<i>Holopedium</i>		Totals		<i>Bosmina</i> to <i>Daphnia</i> Ratio ^a
		Density No./m ³	Biomass mg/m ³							
1987	3	1,059	2.7	788	2.6	209	2.2	2,056	7.5	1.34 :1
1990	4	1,028	3.0	502	1.7	51	0.5	1,581	5.2	2.05 :1
1991	5	529	1.5	177	0.5	112	1.8	818	3.8	2.99 :1
1992	6	614	1.6	86	0.2	173	2.0	873	3.8	7.14 :1
1993	6	89	0.2	526	1.0	214	1.5	829	2.7	0.17 :1
1994	7	574	1.2	389	1.0	199	2.9	1,162	5.1	1.48 :1
1995	7	764	1.6	203	0.5	248	2.6	1,215	4.8	3.76 :1
1996	6	535	1.1	20	0.0	137	1.1	692	2.2	26.75 :1
1997	6	277	0.5	177	0.3	229	3.1	683	3.8	1.56 :1
1998	5	724	1.3	454	1.5	103	1.3	1,281	4.1	1.59 :1
1999	5	210	0.3	258	0.7	150	1.9	618	2.9	0.81 :1
2000	5	376	0.9	53	0.1	299	1.6	728	2.5	7.09 :1
2001	5	585	1.3	46	0.1	525	1.4	1,156	2.7	12.72 :1
2002	5	1,639	3.7	1,218	3.8	425	2.0	3,282	9.5	1.35 :1
2003	4	878	3.0	437	0.8	316	1.9	1,631	5.7	2.01 :1
2004	4	847	3.7	442	1.3	412	2.4	1,701	7.4	1.92 :1
2005	4	583	1.1	392	0.7	190	1.2	1,165	3.1	1.49 :1
2006	5	505	1.1	182	0.3	630	4.7	1,317	6.1	2.77 :1
2007	4	551	1.1	180	0.3	138	0.4	869	1.7	3.06 :1
2008	4	366	0.8	203	0.3	1,062	4.9	1,631	6.0	1.80 :1
mean 87-91:		872	2.4	489	1.6	124	1.5	1,485	5.5	1.78 :1
mean 92-07:		609	1.5	316	0.8	274	2.0	1,200	4.2	4.73 :1

^a = values based on mean density.

Table 7.–Seasonal weighted mean lengths (mm) of zooplankton taxa in Hidden Lake, 1987, 1990-2008.

Year	<i>Diaptomus</i>	<i>Cyclops</i>	<i>Bosmina</i>	<i>Daphnia</i>	<i>Holopedium</i>
1987	0.88	0.81	0.52	0.86	0.97
1990	1.02	0.83	0.55	0.87	0.96
1991	0.93	0.81	0.54	0.77	1.14
1992	0.77	0.76	0.52	0.81	1.00
1993	^a	0.79	0.50	0.66	0.83
1994	^a	0.90	0.47	0.76	0.92
1995	^a	0.83	0.47	0.74	0.84
1996	1.10	0.81	0.47	0.62	0.83
1997	^a	0.77	0.42	0.62	0.87
1998	^a	0.82	0.44	0.86	0.90
1999	^a	0.72	0.40	0.76	0.93
2000	^a	0.71	0.49	0.59	0.71
2001	^a	0.93	0.48	0.79	0.53
2002	^a	0.71	0.49	0.83	0.70
2003	1.15	0.67	0.46	0.70	0.76
2004	1.16	0.69	0.48	0.84	0.75
2005	0.68	0.58	0.46	0.64	0.78
2006	1.17	0.82	0.47	0.61	0.84
2007	0.89	0.67	0.46	0.59	0.55
2008	0.95	0.86	0.47	0.63	0.67
mean 87-91:	0.94	0.82	0.54	0.83	1.02
mean 92-07:	0.99	0.76	0.47	0.71	0.80

^a = *Diaptomus* were not identified in the samples collected.

Table 8.–Sockeye salmon stocking numbers, life stage, size and release date by year into Hidden Lake, 1992-2008.

	Fry	Fingerling	Pre-Smolt	Total Stocked
1992			260,000	260,000
Date/Size ^a			5-Sep/ 6.0 g	
1993	448,000	106,600		554,600
Date/Size ^a	29-Apr/ 0.25 g	4-Jun/ 0.5g		
1994	250,000			250,000
Date/Size ^a	5-May/ 0.25 g			
1995			98,650	98,650
Date/Size ^a			2-Nov/ 9.5 g	
1996	252,000		138,800	390,800
Date/Size ^a	14-May/ 0.4 g		15-Oct/ 9.0 g	
1997		287,700	167,500	455,200
Date/Size ^a		4-Jun/ 0.6 g	22-Oct/ 9.5 g	
1998			340,400	340,400
Date/Size ^a			4-Sep/ 7.0 g	
1999			310,000	310,000
Date/Size ^a			6-Oct/ 9.4 g	
2000	172,000		332,400	504,400
Date/Size ^a	20-Jun/ 0.7 g		24-Aug/ 5.0 g	
2001		66,500	249,000	315,500
Date/Size ^a		25-May/ 0.8 g	5-Oct/ 13.5 g	
2002			51,600	51,600
Date/Size ^a			2-Oct/ 11.0 g	
2003			31,006	31,006
Date/Size ^a			14-Sep/ 13.9 g	
2004			70,736	70,736
Date/Size ^a			7,8-Oct/ 9.0 g	
2005		113,679	74,663	188,342
Date/Size ^a		23-Jun/1.4 g	3-Oct/ 11.7 g	
2006	253,100		168,568	421,668
Date/Size ^a	19-May/0.45 g		10-Oct/ 11.8 g	
2007	300,315		199,992	500,307
Date/Size ^a	17-Jun/0.42g		29-Sep/9.6g	
2008	153,925		199,876	353,801
Date/Size ^a	9-Jun/0.4g		27-28-Sep/7.5g	
mean				
mean 92-07:				296,451

^a = Fry are released from April to July at up to 200% of emergent size (normally 0.15 to 0.5 g depending on the stock). Fingerling are released from June to September at a size of >200% to <2100% of emergent size (normally 0.3 to 5.25 g depending on the stock). Pre-smolt are released from August to November at a size of >2100% of emergent size but not yet at the physiological stage of smolting (normally 5 to 13 g).

Table 9.–Commercial harvest by species by day in the Foul Bay Special Harvest Area (statistical area 251-41), 2008.

Date	Chinook	Sockeye	Coho	Pink	Chum
10-Jun	0	2,477	0	0	0
12-Jun	0	712	0	0	0
13-Jun	0	596	0	0	5
16-Jun	0	1,115	0	0	0
17-Jun	0	304	0	0	0
22-Jun	0	257	0	1	0
1-Jul	1	73	0	12	96
12-Jul	1	181	5	362	126
Total	2	5,715	5	375	227

Table 10.—Estimated age composition of adult sockeye salmon harvest from Foul Bay Special Harvest Area (statistical area 251-41), 1995-2005.

Year	Sample Size		Ages											Total ^a	
			1.1	0.2	0.3	1.2	2.1	1.3	2.2	3.1	1.4	2.3	3.2		2.4
1995 ^b	485	Numbers	1,035	0	34	29,272	0	494	34	0	0	322	0	0	31,191
		Percent	3.3	0.0	0.1	93.9	0.0	1.6	0.1	0.0	0.0	1.0	0.0	0.0	100
1996 ^b	537	Numbers	289	0	0	9,160	108	18,050	1,454	0	0	127	0	0	29,189
		Percent	1.0	0.0	0.0	31.4	0.4	61.8	5.0	0.0	0.0	0.4	0.0	0.0	100
1997	562	Numbers	788	0	0	8,288	19	8,344	656	19	38	469	56	38	18,751
		Percent	4.2	0.0	0.0	44.2	0.1	44.5	3.5	0.1	0.2	2.5	0.3	0.2	100
1998	646	Numbers	2,447	0	0	3,949	365	1,054	397	0	0	58	0	0	8,270
		Percent	29.6	0.0	0.0	47.8	4.4	12.7	4.8	0.0	0.0	0.7	0.0	0.0	100
1999 ^b	603	Numbers	68	0	0	36,414	0	1,906	2,450	0	0	204	0	0	41,042
		Percent	0.2	0.0	0.0	88.7	0.0	4.6	6.0	0.0	0.0	0.5	0.0	0.0	100
2000 ^b	733	Numbers	376	0	0	16,768	0	8,022	1,100	0	27	536	0	0	26,829
		Percent	1.4	0.0	0.0	62.5	0.0	29.9	4.1	0.0	0.1	2.0	0.0	0.0	100
2001	551	Numbers	517	0	0	8,602	0	20,206	123	0	0	374	0	0	29,822
		Percent	1.7	0.0	0.0	28.8	0.0	67.8	0.4	0.0	0.0	1.3	0.0	0.0	100
2002	903	Numbers	2,361	37	0	22,160	84	8,588	214	0	0	0	0	0	33,444
		Percent	7.1	0.1	0.0	66.3	0.3	25.7	0.6	0.0	0.0	0.0	0.0	0.0	100
2003	669	Numbers	44	0	0	40,222	0	9,205	867	0	0	844	0	0	51,182
		Percent	0.1	0.0	0.0	78.6	0.0	18.0	1.7	0.0	0.0	1.6	0.0	0.0	100
2004	411	Numbers	0	0	0	9,949	0	7,314	2,343	0	0	123	0	0	19,729
		Percent	0.0	0.0	0.0	50.4	0.0	37.1	11.9	0.0	0.0	0.6	0.0	0.0	100
2005	232	Numbers	0	0	0	96	0	5,487	96	0	0	1,723	0	0	7,402
		Percent	0.0	0.0	0.0	1.3	0.0	74.1	1.3	0.0	0.0	23.3	0.0	0.0	100
1995-2005	6,332	Numbers	7,925	37	34	184,880	575	88,671	9,734	19	65	4,780	56	38	296,851
		Percent	2.7	0.0	0.0	62.3	0.2	29.9	3.3	0.0	0.0	1.6	0.0	0.0	100.0

^a = Due to rounding the age composition sum may differ from the population estimate sum.

^b = Includes fish reported for statistical area 251-40 that were harvested in Foul Bay SHA.

Table 11.—Commercial harvest by species by year in the Foul Bay Special Harvest Area (statistical area 251-41), 1995-2008.

Year	Chinook	Sockeye	Coho	Pink	Chum
1995	15	44,479	0	20	8
1996	6	29,889	15	7	63
1997	0	18,751	0	5	2
1998	17	8,270	0	55	57
1999	12	41,042	0	415	364
2000	5	26,829	0	1	23
2001	104	29,822	0	1,141	53
2002	196	33,444	0	120	1,243
2003	55	51,181	0	80	98
2004	27	19,729	0	0	29
2005	4	7,401	0	0	0
2006	16	819	15	525	92
2007	7	703	1	46	149
2008	2	5,715	5	375	126
mean 1995-2007	36	24,028	3	199	165

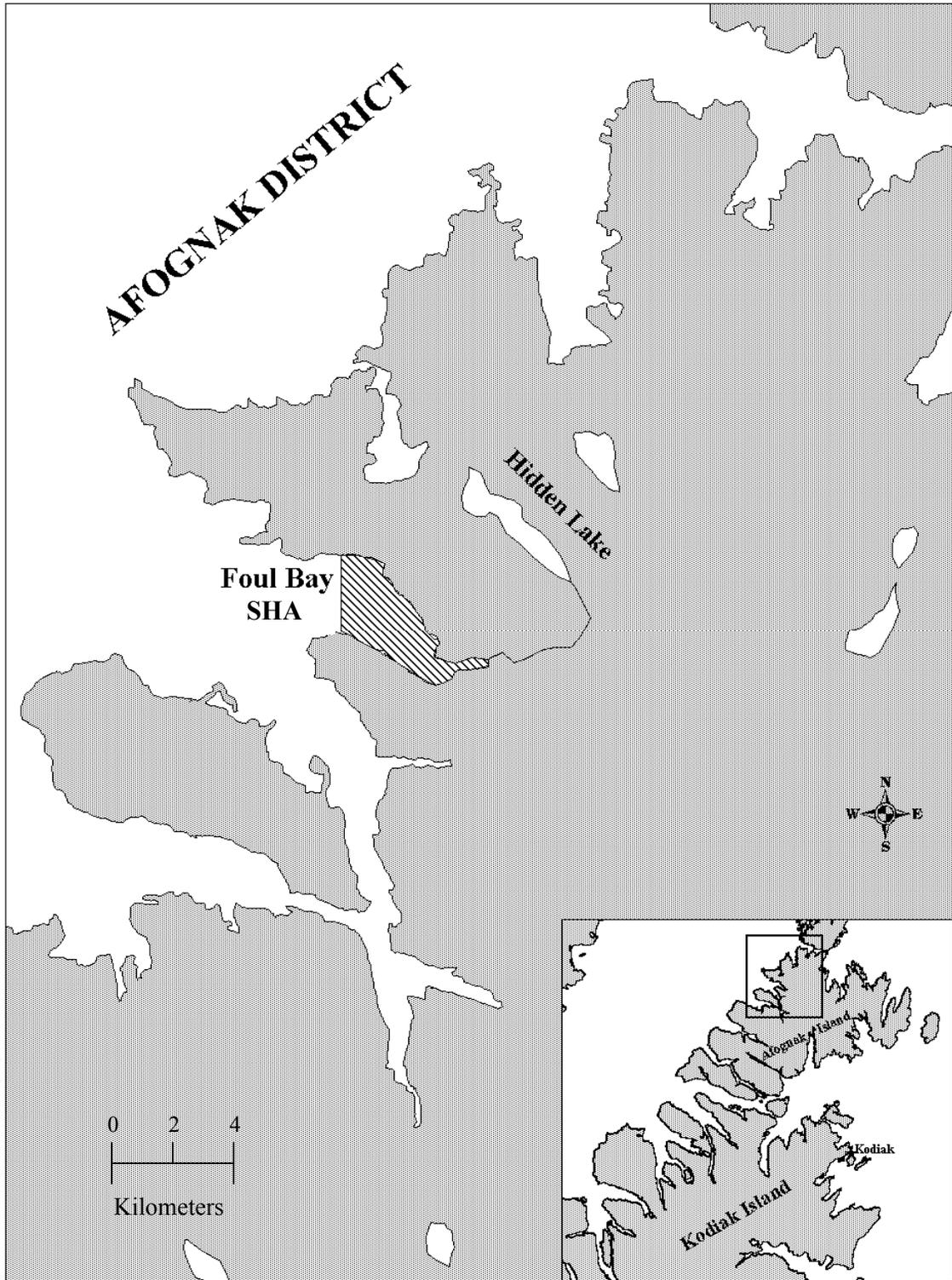


Figure 1.—Location of Hidden Lake and the Foul Bay Special Harvest Area on Afognak Island.

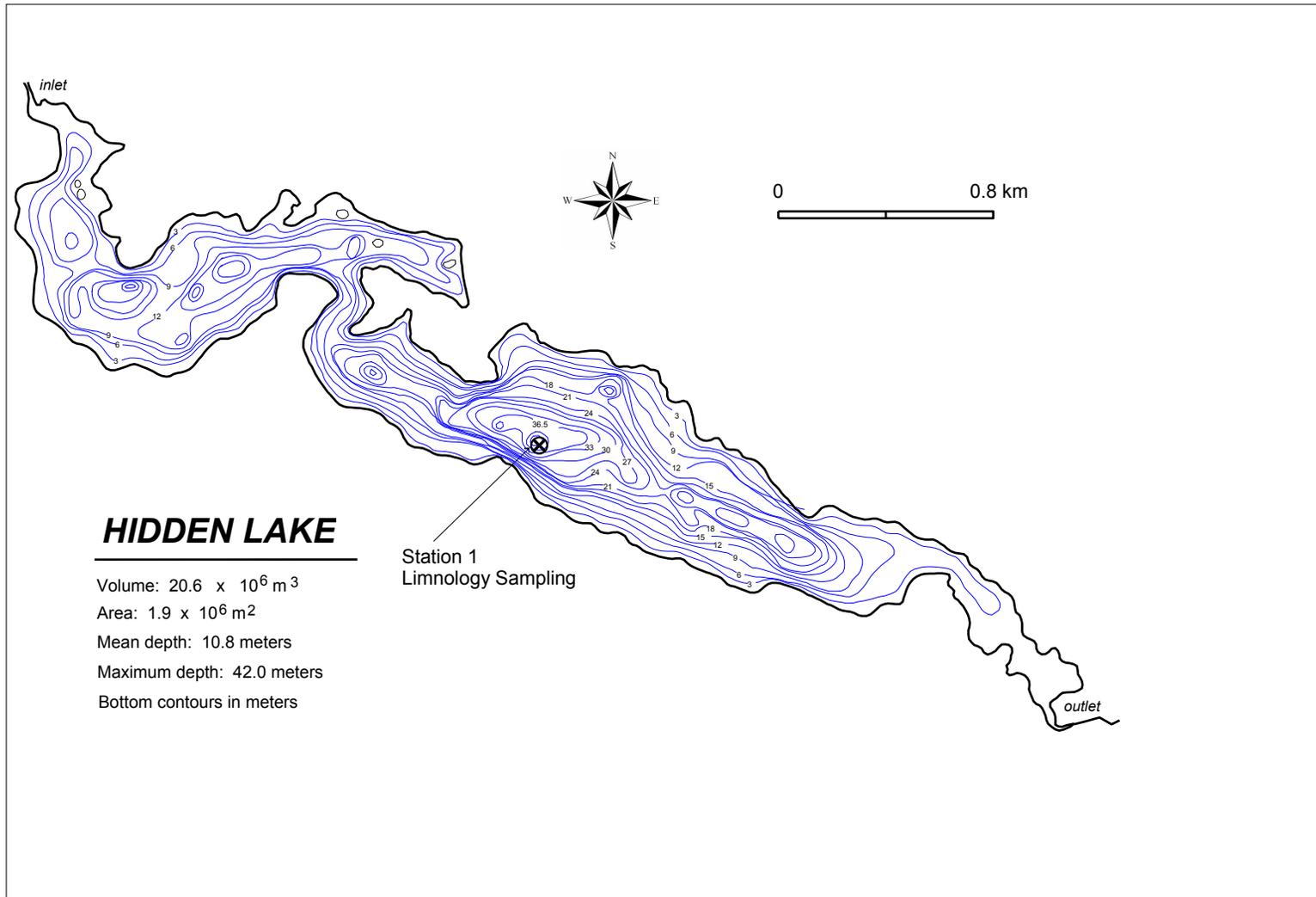


Figure 2.—Morphometric map showing the limnology sampling station on Hidden Lake.

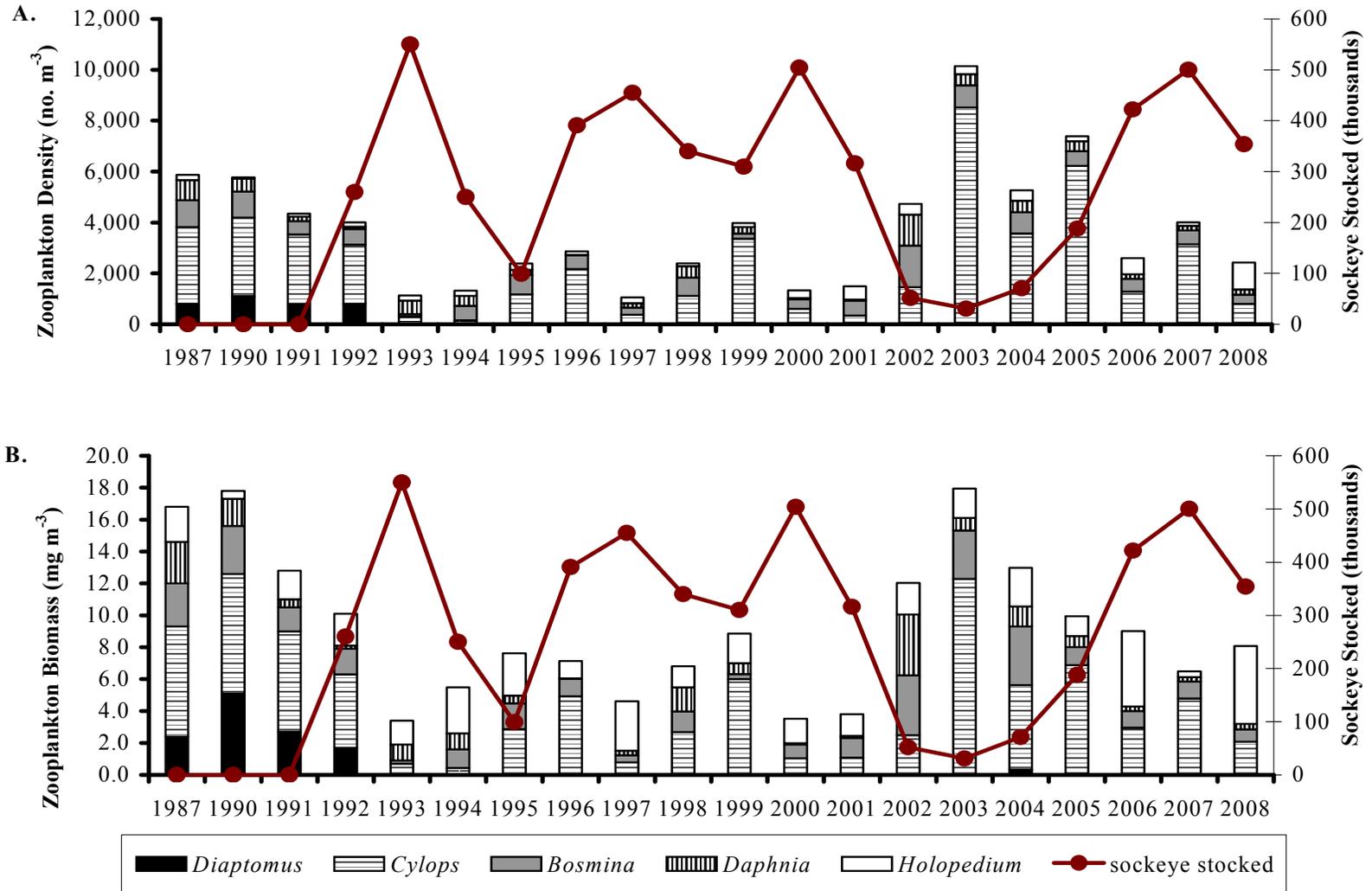


Figure 3.—Zooplankton density (A) and biomass (B) compared to sockeye salmon stocking levels for Hidden Lake, 1987, 1990-2008.