Fishery Management Report No. 11-25

A Seasonal Summary of the Hidden Lake Sockeye Salmon Stocking Project and Related Criteria for 2010

by

Steven Thomsen

April 2011

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. 11-25

A SEASONAL SUMMARY OF THE HIDDEN LAKE SOCKEYE SALMON STOCKING PROJECT AND RELATED CRITERIA FOR 2010

by
Steven Thomsen
Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

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The Kodiak Regional Aquaculture Association (KRAA) funds the general operations of the Hidden Lake sockeye salmon stocking project and Pillar Creek Hatchery. The Division of Commercial Fisheries provides biological oversight and evaluation in the management of returning adult runs to the enhanced or rehabilitated systems associated with hatchery stocking projects.

The Fishery Management Reports series was established in 1989 by the Division of Sport Fish for the publication of an overview of management activities and goals in a specific geographic area, and became a joint divisional series in 2004 with the Division of Commercial Fisheries. 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.

Steven E. Thomsen
Alaska Department of Fish and Game, Division of Commercial Fisheries,
211 Mission Road, Kodiak, AK 99615, USA

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ABSTRACT

A sockeye salmon *Oncorhynchus nerka* enhancement stocking project was initiated at Hidden Lake 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 Hidden Lake Management Plan directs the Alaska Department of Fish and Game to collect water quality and zooplankton data, record juvenile salmon stocking numbers, and document the commercial salmon harvest to ensure the project remains compatible with the Kodiak National Wildlife Refuge mission.

In 2010, Hidden Lake had a seasonal mean total nitrogen to total phosphorus ratio of 109:1, a seasonal mean total ammonia level of 4.9 μg/L, and a seasonal mean chlorophyll-*a* concentration of 0.22 μg/L. The lake's zooplankton community had a seasonal mean *Diaptomus* to *Cyclops* density ratio of <0.01:1, a weighted seasonal mean copepod biomass of 2.29 mg/m^3, a seasonal mean *Bosmina* to *Daphnia* density ratio of 2.01:1, a weighted seasonal mean cladoceran biomass of 2.61 mg/m^3, and a weighted seasonal mean *Bosmina* length of 0.41 mm. A total of 344,782 sockeye salmon juveniles were released into Hidden Lake in 2010. A total of 31,871 adult sockeye salmon were harvested in the Foul Bay Special Harvest Area as reported on commercial fish harvest tickets.

The 2010 Hidden Lake enhancement project met all the KNWR monitoring criteria, except for the total nitrogen to total phosphorus ratio and the *Diaptomus*:*Cyclops* density ratio. A stocking release of approximately 200,000 sockeye salmon fry and 45,000 pre-smolt was recommended for Hidden Lake in 2011.

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, *Cyclops*, *Diaptomus*, *Bosmina*, *Daphnia*, *Holopedium*.

INTRODUCTION

Hidden Lake (58°23' N lat, 152°42' W long) 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 km^2 (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 *Oncorhynchus mykiss*, Dolly Varden char *Salvelinus malma*, three-spine stickleback *Gasterosteus aculeatus*, and freshwater sculpin *Cottus aleuticus* (Honnold and Schrof 2001).

The stocking project was designed to utilize the abundant zooplankton population in the lake to produce sockeye salmon *O. nerka* smolt that would emigrate to the ocean and return as adults to Foul Bay (Honnold and Schrof 2001; Figure 1). Adult sockeye salmon runs returning to Foul Bay would then be harvested in a terminal area, which would reduce possible interactions with wild stocks. The project allows for evaluating the response of the lake's zooplankton community to predation by juvenile salmon, monitoring of freshwater growth of the stocked sockeye salmon, and estimating fry-to-adult survival.

Because Hidden Lake is located within the boundaries of the Kodiak National Wildlife Refuge (KNWR), and the activities associated with the sockeye salmon stocking project are therefore subject to U.S. Fish and Wildlife Service (USFWS) and KNWR guiding principles and conditions (Chatto 2002). Such conditions are described in the Hidden Lake Management Plan (HLMP; Chatto 2002) and are permitted under the special conditions described in the Hidden Lake Special Use Permit (HLSUP). In 1992, the Alaska Department of Fish and Game (ADF&G), in cooperation with the Kodiak Regional Aquaculture Association (KRAA), submitted proposals to the USFWS to stock sockeye salmon into Hidden Lake (Chatto 2002;

White 1992). The KNWR prepared an Environmental Assessment 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 twice (2002, 2007) to continue the project in Hidden Lake.

Juvenile sockeye salmon have been stocked into Hidden Lake annually since 1992 (Finkle and Byrne 2010). 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. Limnological data has been collected at Hidden Lake since 1987 (Honnold and Schrof 2001). Zooplankton density and biomass and water chemistry and nutrient parameters are collected annually as part of the HLMP (Appendices A1 through A4).

Conservative stocking levels were recommended to maintain stable nutrient and zooplankton levels in Hidden Lake and support a long-term enhancement project (Kyle 1996). In 2001, Honnold and Schrof (2001) reviewed zooplankton interactions in Hidden Lake and concluded that juvenile sockeye salmon stocking had little effect on zooplankton composition when stocking levels were lower than 300,000 juveniles.

This report summarizes the 2010 and historical project data collected to monitor the Hidden Lake sockeye salmon enhancement project and fulfill the reporting requirements as outlined in the HLMP and HLSUP, ensuring that the project remains compatible with the KNWR mission (Kyle 1996).

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 with specific limnological and fishery criteria were established from data collected at Hidden Lake from 1992 to 1999 (Honnold and Schrof 2001; Table 1). 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 which must be monitored are lake nutrient concentrations (total nitrogen, phosphorus, ammonia, and chlorophyll *a*), zooplankton size, density and biomass, juvenile stocking density, and adult harvest estimates (Table 1).

MANAGEMENT PLAN OBJECTIVES

The management plan contains four objectives:

1. Monitor water quality in Hidden Lake to ensure compatibility with the HLMP criteria,
2. Monitor zooplankton in Hidden Lake to ensure compatibility with the HLMP criteria,

3. Stock juvenile sockeye salmon at densities based on historical and annual limnological data, and
4. Document the commercial salmon harvest within the FBSHA to evaluate supplemental commercial harvest.

METHODS

LIMNOLOGICAL MONITORING

Comparative criteria specified in the HLMP were: total nitrogen (TN) to total phosphorus (TP) ratio, total ammonia (TA), chlorophyll *a* (Chl *a*), *Diaptomus* to *Cyclops* density ratio, copepod biomass, *Bosmina* to *Daphnia* density ratio, cladoceran biomass, and cladoceran (*Bosmina*) average size.

Lake Sampling Protocol

Samples were collected from Hidden Lake five times from May to September at approximately four-week intervals. One sampling station was established in the deepest basin of the lake using a Global Positioning System (GPS; Figure 2). Samples were collected following standard ADF&G sampling procedures from Koenings et al. (1987), Thomsen (2008), and Foster et al. (2010a).

Water samples for chemistry and nutrient analysis were collected at the 1 m (epilimnion) depth using a 4 L Van Dorn bottle and emptied into separate, pre-cleaned polyethylene carboys, which were kept cool and dark until processed at the Near Island Laboratory in Kodiak. A vertical zooplankton haul was made at the station using a 0.2 m diameter conical net with 153 μm mesh. The net was pulled manually at a constant speed (~0.5 m/s) from approximately 1-m off the lake bottom. The contents from the tow were emptied into a 125 ml poly bottle and preserved in 10% neutralized formalin.

General Water Chemistry and Nutrients

Unfiltered water was analyzed for TP, Total Kjeldahl Nitrogen (TKN), pH, and alkalinity. Sample water was filtered through a rinsed 4.25 cm diameter Whatman™[1] GF/F filter pad and stored frozen in phosphate-free soap washed polyethylene bottles. Filtered water was analyzed for total filterable phosphorus (TFP), filterable reactive phosphorus (FRP), nitrate + nitrite (N+N), and TA. A Spectronic Genesys 5 Spectrophotometer (SG5) was used for TP, TFP, FRP, N+N, and TA analyses.

The potassium persulfate-sulfuric acid digestion method described in Koenings et al. (1987) and Thomsen (2008) adapted from methods in Eisenreich et al. (1975) was used for TP analysis. Unfiltered frozen water samples were sent to the South Dakota State University laboratory for the TKN analysis using the EPA 351.3 (Nesslerization; AWWA 1998) method. The pH of water samples was measured with a Corning™ 430 meter, while alkalinity (mg/L as $CaCO_3$) was determined from 100 ml of unfiltered water titrated with 0.02 N H_2SO_4 to a pH of 4.5 and measured with a Mettler Toledo ™ Seven Easy pH meter. Separate meters were used for the measurement of pH and alkalinity for added speed and accuracy.

Determination of TFP used the same methods as those for TP utilizing filtered water. The potassium persulfate-sulfuric acid method described in Koenings et al. (1987) and Thomsen

[1] Product names used in this publication are included for completeness but do not constitute product endorsement.

(2008) was used for FRP analysis. Samples for N+N were analyzed using the cadmium reduction column method described in Koenings et al. (1987) and Thomsen (2008). The phenol-sodium hypochlorite method described in Koenings et al. (1987) and Thomsen (2008) was used for determining TA. Total nitrogen, the sum of TKN and N+N, were calculated for each sample in addition to the molar ratio of TN to TP. TN:TP ratio $\frac{\text{molar weight of nitrogen=14; molar weight of phosphorus=31.}}{}$

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 and in individual plexiglass slides until analyzed. Filters were then ground in 90% buffered acetone using a mortar and pestle, 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 12 mL with 90% acetone (Koenings et al. 1987; Thomsen 2008). The extracts were analyzed using a SG5 spectrophotometer using methods described in Koenings et al. (1987) and Thomsen (2008).

Zooplankton

For zooplankton analysis, cladocerans and copepods were identified according to taxonomic keys by Edmondson (1959), Wetzel (1983), and Thorp and Covich (2001). Zooplankton 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 genus or species (typically animals are grouped at the genus or species level) if possible were measured to the nearest 0.01 mm, a student's t-test was then employed to determine the number of measurements needed to meet sample size requirements (Koenings et al. 1987; 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./m^3). Biomass was estimated using density and weight, using species-specific linear regression equations between length and dry weight derived by Koenings et al. (1987).

STOCKING

Stocking densities for Hidden Lake were determined by estimating the lake's rearing capacity based on inseason zooplankton biomass from May through July, prior to the hatchery egg takes (Finkle and Byrne 2010). Afognak Lake sockeye salmon eggs were collected in early August of 2009 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 the juvenile salmon were then aerially released into Hidden Lake via fixed wing aircraft.

HARVEST AND ESCAPEMENT MONITORING

Commercial harvest within the FBSHA was monitored by ADF&G personnel during the fishery opening while stationed on board the *M/V K-HI-C* (Figure 1). Monitoring activities included assessing sockeye salmon run strength, recording fishing effort, estimating the commercial catch by species, and sampling a portion of the sockeye salmon catch for age, sex, length (ASL) data (Foster et al. 2010b; Honnold and Schrof 2001). The ADF&G fish ticket database was used to

generate end-of-season catch summaries. No escapement surveys of Hidden Creek were conducted in 2010.

RESULTS

HIDDEN LAKE MONITORING PLAN CRITERIA

Total Nitrogen to Total Phosphorus Ratio

The 2010 total nitrogen to total phosphorus molar ratio (TN:TP) in Hidden Lake of 109:1 did not meet the desired criteria (≤ 106:1) specified in the HLMP (Tables 1 and 2; Appendix A3). This TN:TP ratio was above the 1992 to 2009 average of 95:1 and has exceeded the desired criteria the last two years.

Mean Total Ammonia

The 2010 seasonal mean concentration for ammonia was 4.9 μg/L (Tables 1 and 3; Appendix A3). This ammonia concentration was below the 1992 to 2009 average (6.8 μg/L; Table 3) and within the criteria of ≥16.2 μg/L specified in the HLMP (Table 1).

Mean Chlorophyll *a*

The 2010 seasonal mean Chl-*a* concentration in Hidden Lake was 0.22 μg/L (Tables 1 and 3). The average Chl-*a* concentration met the HLMP criteria of ≥ 0.17 μg/L but was below the 1992 to 2009 average (0.61 μg/L; Table 3).

Mean Copepod Biomass

The seasonal mean copepod biomass in 2010 was 2.29 mg/m^3, which met the HLMP criteria of ≥ 0.40 mg/m^3, but was below the average copepod biomass from 1992 to 2009 (3.69 mg/m3; Tables 1, 4, and 5). The seasonal mean copepod density was 1,076/m^{3}and the average copepod density from 1992 to 2009 was 2,162/m^3(Table 4). Mean copepod density is not specified as criteria in the HLMP.

Diaptomus to *Cyclops* Density Ratio

No *Diaptomus* we found in 2010, therefore, the *Diaptomus:Cyclops* density ratio did not meet the minimum criteria (≥ 0.01:1) specified in the HLMP (Tables 1 and 5). The average ratio from 1992 to 2009 was 0.02:1 (Table 5).

Mean Cladoceran Biomass

There was an average cladoceran biomass of 2.61 mg/m^3 and an average density of 1,149/m^3 in Hidden Lake in 2010 (Tables 4 and 6). The 2010 biomass was above the minimum criteria of ≥ 2.20 mg/m^3 specified in the HLMP (Tables 1 and 4). Average cladoceran biomass in 2010 was less than the average biomass from 1992 to 2009 (4.28 mg/m^3). The 2010 average density was less than the 1992–2009 average density (1,247 mg/m^3; Tables 4 and 6). Mean cladoceran density is not specified as criteria in the HLMP.

Bosmina to *Daphnia* Density Ratio

The *Bosmina:Daphnia* density ratio in 2010 of 2.01:1 was above the minimum criterion (≥ 0.17:1) specified in the HLMP (Tables 1 and 6). The average ratio from 1992 to 2009 was (4.79:1; Table 6).

Mean Cladoceran (*Bosmina*) Size

The cladoceran *Bosmina* averaged 0.41 mm in length in 2010 which met the criterion (> 0.40 mm) specified in the HLMP (Tables 1 and 7). The average size of *Bosmina* from 1992 to 2009 was 0.47 mm.

HIDDEN LAKE SPECIAL USE PERMIT MONITORING

Stocking

Juvenile sockeye salmon were stocked in Hidden Lake on two occasions in 2010. Approximately 297,829 fry (average weight of 0.38 g) were stocked on 27 May and 46,953 pre-smolt (average weight of 10.6 g) were stocked on 4 October (Table 8). This stocking level (344,782) is slightly above the average (297,280) number of sockeye salmon stocked from 1992 to 2009 (Table 8; Figure 3).

Smolt Monitoring

Smolt monitoring at Hidden Creek was discontinued after 2002, when it was deemed unnecessary jointly by KNWR and ADF&G. In past years, sockeye salmon smolt were monitored (1993–2002), coho salmon juveniles were stocked (1988–1989, 1991), and hydroacoustic surveys were conducted ((1994–2001) in Hidden Lake (Appendices B1, B2, and B3).

Harvest Monitoring

During 2010, commercial salmon were harvested on 25 days in the FBSHA (Table 9). In total, 4 Chinook *O. tshawytscha*, 31,871 sockeye, 366 coho (*O. kisutch*), 35,006 pink *O. gorbuscha* and 713 chum *O. keta* salmon were harvested in the FBSHA in 2010. The sockeye salmon harvest of 31,871 was above the 1995 to 2009 average of 21,824 (Table 10). The commercial harvest of non-targeted salmon species was higher than historical averages for most species (1995–2009; 2 coho; 186 pink; and 154 chum salmon) and lower than the historical average for Chinook (1995–2009; 31 Chinook; Table 10). The commercial fishery in the FBSHA open on 9 June and closed on 19 August.

On-site ADF&G monitoring staff collected scales from 600 sockeye salmon from the commercial fishery in FBSHA in 2010. Sockeye salmon age composition from the FBSHA is provided in Table 10. The 2010 age components were as follows: age 1.2 (83.5%), age 1.3 (10.7%), and age 2.2 (3.7%). From 1995–2009, the age -1.2 component comprised 61.9% and the age -1.3 component comprised 29.9% of the harvest (Table 11).

Escapement Monitoring

Salmon escapement surveys of Hidden Creek were deemed unnecessary jointly by KNWR and ADF&G and discontinued after 1999.

NON-CRITERION MONITORING (HLMP/SUP)

Lake Temperature

Mean surface temperatures for Hidden Lake were 8.4°C in the spring, 14.4°C in the summer, and 13.0°C in the fall (Appendix A5). Historic mean temperatures (1990–2009) were 7.8°C in the spring, 15.1°C in the summer, 10.5°C in the fall.

Mean surface temperatures for Hidden Lake were 4.9°C in the spring, 5.8°C in the summer, and 5.9°C in the fall (Appendix A5). Historic mean temperatures (1990–2009) were 4.4°C in the spring, 5.6°C in the summer, 6.0°C in the fall.

Spring, summer, and fall surface and bottom temperatures were greater in 2010 than those in 2009 (Appendix A5). Monthly average temperatures, following, better account for variations in spring, summer, and fall sampling schedules over the course of the project. In 2010, monthly surface temperatures were above average (1990–2009) in May and September and below average in June, July, and August, while bottom temperatures remained above average throughout the season (Appendix A6).

Total Zooplankton Abundance

The 2010 seasonal mean zooplankton density in Hidden Lake was 2,225/m^3 and the biomass was 4.90 mg/m^3 (Table 4). The 2010 zooplankton density and biomass was lower than the historical average (1992–2009; 3,410/m^3; 7.97 mg/m^3; Table 4; Figure 3). Total zooplankton density and biomass were not specified as criteria in the HLMP but are presented here because they are easily calculated from the data and relevant to the discussion.

FACTORS RELATED TO SMOLT SURVIVAL, AGE, AND GROWTH

Juvenile Sockeye Salmon Survival

Without a smolt monitoring project for the Hidden Lake enhancement project since 2002, assessment of juvenile sockeye salmon production was estimated using fry to adult sockeye salmon survival. Sockeye salmon juvenile to adult survival (1992–2005) averaged 7.2%, varying from a low of 0.7% to a high of 19.0% (Appendix B4). Survival estimates for sockeye salmon stocking after 2005 cannot be fully addressed until future outmigrations are fully recruited.

Lake Temperature

In general, juvenile to adult survival in Hidden Lake did not appear to increase when lake temperature increased ($P > 0.05$).

Zooplankton

Juvenile to adult survival in Hidden Lake did not appear to increase when zooplankton abundance or size increased. However, when the size of *Holopedium* (lagged a year) increased, the survival of age-1. sockeye salmon smolt increased ($R^2 = 0.5542$, $P< 0.05$; Figure 4).

Juvenile Sockeye Salmon Age and Growth

Lake Temperature

In general, juvenile age and growth in Hidden Lake did not appear to increase when lake temperature increased ($P > 0.05$).

Zooplankton

Robust smolt body size is typically indicative of a healthy lake system not exceeding the rearing capacity (Honnold and Schrof 2001). The condition of sockeye salmon smolt appeared independent of the length and abundance of most cladocerans and copepods (Appendix B1). However, the condition of age-1. sockeye salmon smolt appeared to improve when the length of *Epischura* decreased ($R^2 = 0.3638$; $P< 0.001$). An increased length and weight in age-1. sockeye

salmon smolt was not correlated with the size of *Epischura* decreased (weight $R^2 = 0.1081$, $P = 0.047$; length $R^2 = 0.0318$; $P < 0.05$). Additionally, when *Bosmina* abundance increased, the condition of age-1. sockeye salmon smolt increased (condition $R^2 = 0.5933$, $P < 0.001$; weight $R^2 = 0.509$, $p = 0.050$; length $R^2 = 0.4247$, $P <= 0.001$; Tables 4 and 6; Appendix B1).

Age-2. sockeye salmon smolt have historically comprised a small proportion of the outmigration in Hidden Lake (Appendix B4). Age-2. sockeye salmon smolt showed similar trends to age-1. sockeye salmon smolt growth with respect to the abundance of *Bosmina* (Tables 4 and 6; Appendix B1).

Zooplankton Size and Abundance

Juvenile Sockeye Salmon Grazing

In Hidden Lake, zooplankton abundance oscillated around a stocking level of approximately 300,000 juvenile sockeye salmon (Figure 5). In general, when juvenile sockeye salmon stocking exceeded 300,000, total zooplankton biomass decreased and when stocking levels were below 300,000, total zooplankton biomass increased.

Generally, increased juvenile sockeye salmon stocking levels decreased cladoceran abundance rapidly while copepod abundance decreased moderately (Tables 4, 5, and 8; Thomsen 2010). However, the abundance of *Holopedium* showed little decline and the abundance of *Diaptomus* declined sharply after juvenile stocking began in 1992 (Table 5; Thomsen 2010).

The stocking strategy of juvenile sockeye salmon appeared to have impacted the zooplankton in Hidden Lake. The stocking of pre-smolt into Hidden Lake may affect zooplankton abundance to a greater extent than fry (Thomsen 2010). In general, pre-smolt appeared to crop small copepods as shown by the decreased abundance and increased length of *Cyclops* when pre-smolt were stocked. *Epischura* and *Diaptomus* exhibited no similar trends (Thomsen 2010). Alternately, fry predominately cropped the cladocerans (except *Daphnia*); as shown by the decreased abundance and increased lengths when fry were stocked (Thomsen 2010). Cladoceran lengths were not noticeably affected when pre-smolt were stocked. Fingerlings were stocked into Hidden Lake at low densities on four occasions, making it difficult to draw any conclusions.

DISCUSSION

Relationships surrounding “whole lake” interactions and smolt production are complex. Hidden Lake, as a barren system, provides a unique opportunity to explore these complex interactions. Barren lakes typically have lower productivity than lakes with returning adult sockeye salmon due to a lack of marine-derived nutrient input from the carcasses of returning adult sockeye salmon. These lakes rely on allochthonous inputs as the entire source of nutrients (Kyle 1996; Sweetman 2001). Despite annual fluctuations, the seasonal means for these nutrients were within criterion ranges found in oligotrophic lakes and have remained relatively constant over the twenty-one year data set (1990–2010; Honnold et al. 1996).

The Hidden Lake sockeye salmon stocking project met all but two of the criteria specified in the HLMP in 2010. The first of these, the *Diaptomus:Cyclops* density ratio, has met the HLMP criteria in five of the last seven years, including 2009 (Table 5; Appendix A4). Second, the TN:TP ratio has met the HLMP criteria in 4 of the last seven years. Although the TN:TP ratio did not met the HLMP criteria in the last two years, the 2010 ratio should be acceptable given the

seasonal variance of nutrient components used to calculate the ratio (TKN SD = 45.2; N+N SD = 14.3; TP SD = 0.2; Table 3).

The previous assessment of Hidden Lake by Honnold and Schrof (2001) suggested a stocking threshold of 300,000 juvenile sockeye salmon. The addition of another twelve years of data analysis (1999 to 2009) seems to support their assessment. The stocking level in 2010 (344,782) was slightly above the possible threshold and resulted in a slight decrease in the average zooplankton abundance in 2010.

Water temperatures are commonly known to play a key role in primary production (Sommer and Shutter and Ing 1997; Lengfellner 2008). Increases in lake temperatures typically contribute to an increase in production at each trophic level; thus increasing the abundance of phytoplankton and potentially increasing zooplankton and juvenile sockeye salmon abundance and body size (George and Harris 1985). Spring, summer, and fall surface and bottom temperatures were greater in 2010 than average (Appendix A5). The above average temperatures in 2010 may have resulted in increased juvenile growth and survival.

The length of *Epischura* appears to be a key factor in Hidden Lake. The condition and survival of age-1. sockeye salmon smolt improved with a decreased length of *Epischura*. This may arise because decreased predation by larger *Epischura* on other zooplankton species may have left more zooplankton available for juvenile sockeye salmon. Notably, the length of *Epischura* was below average in 2010, possibly resulting in increased juvenile growth and survival because smaller *Epishura* appear less able to compete.

The sockeye salmon commercial harvest from FBSHA was at its highest level since 2002. The harvest has steadily increased in the last four years, mirroring increases in juvenile sockeye salmon released into Hidden Lake.

CONCLUSIONS

Nutrient and primary production data were all within a normal range for Hidden Lake and is typical for an oligotrophic lake. Although, the TN:TP ratio did not met the HLMP criteria in the last two years, the 2010 ratio should be acceptable given the seasonal variance of nutrient components used to calculate the ratio.

Hidden Lake has supported a varying level of sockeye salmon stocking and an oscillating zooplankton population throughout the enhancement project (1990–2010). Zooplankton and juvenile sockeye salmon abundance oscillate out of phase suggesting that zooplankton abundance is top-down controlled and suggests a stocking threshold of approximately 300,000 juveniles. Although, the *Diaptomus:Cyclops* density ratio did not met the HLMP ratio for 2010, the remainder of the zooplankton criterion met the HLMP. Recently increased juvenile stocking levels have resulted in an increased commercial harvest.

Based on previous studies and the preliminary findings within this report, lake temperature and the length of *Epischura* appear to have an important influence on sockeye salmon production in Hidden Lake.

This investigation of Hidden Lake data brings forward some interesting possible zooplankton interactions. In the interest of furthering understanding, we will continue to explore possible relationships in Hidden Lake. Future development of a limnology database will assist in the exploration of these and other relationships in Hidden Lake.

OUTLOOK FOR 2011

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 into Hidden Lake in 2011 are 200,000 fry and 45,000 pre-smolt for a total release of 245,000 (Finkle and Byrne 2010). The preliminary stocking numbers may be adjusted if the in-season zooplankton findings warrant modification. All other operations and monitoring projects planned for 2011 are expected to be consistent with the 2010 monitoring goals and objectives.

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REFERENCES CITED

ADF&G (Alaska Department of Fish and Game). 1994. Alaska sockeye salmon culture manual. Special Fisheries Report No. 6. Juneau.

AWWA (American Water Works Association). 1998. Standard methods for the examination of water and wastewater, 20th Edition., Washington D.C.

Chatto, D. T. 2002. Hidden Lake sockeye enhancement project management plan. U.S. Fish and Wildlife Service, Kodiak National Wildlife Refuge, Kodiak.

Edmondson, W. T. 1959. Freshwater biology, *second edition*. John Wiley and Sons, Inc. USA

Eisenreich, S. J., R. T. Banner, and D. E. Armstrong. 1975. A simplified phosphorous analysis technique. Environ Letters 9:43-53.

Finkle, H., and G. Byrne. 2010. Pillar Creek Hatchery annual management plan, 2010. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Management Report No. 10-35, Kodiak

Foster, B. M., R T. Baer, S. Thomsen, and D. Ruhl. 2010a. Near Island limnology laboratory and Kodiak Archipelago lake assessment project operational plan, 2010. [*In*] Salmon research operational plans for the Kodiak Area, 2010. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K10-03, Kodiak.

Foster, B. M., R. T. Baer, S. Thomsen, and D. Ruhl. 2010b. Kodiak Management Area Sockeye Salmon Catch and Escapement Sampling Operational Plan, 2010. [*In*] Salmon research operational plans for the Kodiak Area, 2010. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K10-03, Kodiak.

George, D.G., and G.P. Harris. 1985. The effects of climate on long-term changes in the crustacean zooplankton biomass of L. Windermere, U. K. Nature (London) 316:526-539.

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, Division of Commercial Fisheries Management and Development, Regional Information Report 4K96-52, Kodiak.

Honnold, S. G. and S. T. Schrof. 2001. The results of sockeye salmon *Oncorhynchus nerka* stocking into Hidden Lake on the Kodiak National Wildlife Refuge: juvenile and adult production, commercial harvest, and ecosystem effects, 1987-1999. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K01-32, Kodiak.

Koenings, J. P., J. A. Edmundson, G. B. Kyle, and J. M. Edmundson. 1987. Limnology field and laboratory manual: Methods for assessing aquatic production. Alaska Department of Fish and Game, FRED Division Report Series 71, Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/FRED.071.pdf

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

Shutter. B.J. and K.K. Ing. 1997. Factors affecting the production of zooplankton in lakes. Canadian Journal of Aquatic Science Volume 54.

Sommer U. and K. Lengfellner. 2008. Climate change and the timing, magnitude and composition of the phytoplankton spring bloom. Global Change Biology 14: 1199-1208p.

Sweetman, J. N. 2001. Factors influencing zooplankton populations in Alaskan sockeye salmon (*Oncorhynchus nerka*) nursery lakes; insights from limnological and paleolimnological analyses. Master of Science Thesis, University of Alaska, Fairbanks.

Thomsen, S. 2008. Kodiak Island lake assessment/limnology project and laboratory analysis operational plan. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K08-04, Kodiak.

REFERENCES CITED (Continued)

Thomsen, S. 2010. A seasonal summary of the Hidden Lake sockeye salmon stocking project and related criteria for 2009. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K10-46, Kodiak.

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

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

White, L. E. 1992. Limnology and fisheries assessment of the potential production of sockeye salmon (*Oncorhynchus nerka*) in Hidden Lake. Alaska Department of Fish and Game, Fred Division. Cooperative Agreement No. 90-013, Kodiak.

TABLES AND FIGURES

Table 1.–Hidden Lake monitoring criteria specified in the Hidden Lake Management Plan (HLMP) and limnological and fishery data, and the 2010 results.

HLMP monitoring criteria	HLMP Threshold	2010 results
Limnology Monitoring		
Mean Total Nitrogen : Total Phosphorous Molar Ratio	≤ 106	109
Mean Total Ammonia (µg/L)	≥ 16.2	4.9
Mean Chlorophyll *a* (Chl *a*) (µg/L)	≥ 0.17	0.22
Diaptomus:*Cyclops* Density Ratio	≥ 0.01	0.00
Mean Copepod Biomass (mg/m^3)	≥ 0.40	2.29
Bosmina:*Daphnia* Density Ratio	≥ 0.17	2.01
Mean Cladoceran Biomass (mg/m^3)	≥ 2.20	2.61
Cladoceran (*Bosmina*) average size (mm)	> 0.40	0.41
Stocking		
Sockeye	—[a]	344,782
Commercial Harvest from the FBSHA[b]		
Chinook	—[a]	4
Sockeye	—[a]	31,871
Coho	—[a]	366
Pink	—[a]	35,006
Chum	—[a]	713

[a] Not a specified threshold criteria in the HLMP.

[b] Foul Bay Special Harvest Area – statistical area 251-41.

Table 2.–Seasonal mean total Kjeldahl nitrogen, nitrate+nitrite, total phosphorus concentrations, and total nitrogen to total phosphorus ratio by weight from the epilimnion (1m) of Hidden Lake, 1987, 1990–2010.

Year	Depth (m)	TKN (µg/L)	NO^3+NO^2 (µg/L)	TP (µg/L)	TN:TP Ratio
1987	1	90.1	82.0	4.2	91
1990	1	101.3	65.9	3.9	94
1991	1	75.2	53.4	4.1	70
1992	1	93.7	64.9	4.0	87
1993	1	102.0	45.7	3.7	88
1994	1	120.3	19.7	4.6	67
1995	1	108.6	39.4	3.8	87
1996	1	92.6	38.9	3.4	85
1997	1	93.0	20.1	3.1	80
1998	1	100.5	13.3	3.1	83
1999	1	92.8	51.3	3.1	104
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
2009	1	152.5	59.9	2.5	188
2010	1	77.6	25.8	2.1	109
Mean (1987–1991)	1	88.9	67.1	4.1	85
Mean (1992–2009)	1	116.8	40.0	4.2	95

Note: Means are separated (1987–1991 and 1992–2009) to account for pre-stocking and stocking differences.

TKN = total Kjeldahl nitrogen.

NO^3+NO^2 = nitrate + nitrite.

TP = total phosphorus.

TN:TP = total nitrogen to total phosphorus ratio by molar weight.

ND = no data.

Table 3.–Summary of seasonal mean nutrient and algal pigment concentrations by station and depth for Hidden Lake, 1987, 1990–2010.

		Total		Total		Filterable		Total Kjeldahl							
	Depth	Phosphorus		Filterable-P		Reactive-P		Nitrogen		Ammonia		Nitrate+Nitrite		Chlorophyll *a*	
Year	(m)	(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 (µg/L)	SD	Total Filterable-P (µg/L)	SD	Filterable Reactive-P (µg/L)	SD	Total Kjeldahl Nitrogen (µg/L)	SD	Ammonia (µg/L)	SD	Nitrate+Nitrite (µg/L)	SD	Chlorophyll *a* (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
2009	1	2.5	0.5	0.7	0.2	3.6	1.7	152.5	19.1	5.8	2.3	59.9	21.1	0.48	0.2
2010	1	2.1	0.6	2.1	0.2	1.4	0.2	77.6	45.2	4.9	0.9	25.8	14.3	0.22	0.2
mean (1987–1991)	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 (1992–2009)	1	4.2	2.1	2.5	1.3	2.2	1.1	116.8	42.7	6.8	3.9	40.0	16.9	0.61	0.3

Note: Means are separated (1987–1991 and 1992–2009) to account for pre-stocking and stocking differences.
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, 1990–2010.

	Cladoceran		Copepod		Total		Cladoceran to Copepod ratios [a]	
Year	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	7.53	3,820	9.32	5,876	16.85	0.54:1	0.45:1
1990	1,581	5.24	4,193	12.58	5,774	17.82	0.38:1	0.29:1
1991	818	3.69	3,526	9.04	4,344	12.73	0.23:1	0.29:1
1992	873	3.79	3,130	6.26	4,003	10.05	0.28:1	0.38:1
1993	829	2.74	309	0.67	1,138	3.41	2.68:1	0.80:1
1994	1,162	5.05	153	0.44	1,315	5.49	7.59:1	0.92:1
1995	1,215	4.75	1,171	2.87	2,386	7.62	1.04:1	0.62:1
1996	692	2.21	2,170	4.93	2,862	7.14	0.32:1	0.31:1
1997	683	3.84	373	0.78	1,056	4.62	1.83:1	0.83:1
1998	1,281	4.13	1,110	2.68	2,391	6.81	1.15:1	0.61:1
1999	618	2.85	3,357	6.00	3,975	8.85	0.18:1	0.32:1
2000	728	2.48	601	1.05	1,329	3.53	1.21:1	0.70:1
2001	1,156	2.73	339	1.07	1,495	3.80	3.41:1	0.72:1
2002	3,282	9.54	1,452	2.50	4,734	12.04	2.26:1	0.79:1
2003	1,631	5.67	8,517	12.28	10,148	17.95	0.19:1	0.32:1
2004	1,701	7.36	3,564	5.63	5,265	12.99	0.48:1	0.57:1
2005	1,165	3.06	6,221	6.89	7,386	9.95	0.19:1	0.31:1
2006	1,317	6.05	1,280	2.96	2,597	9.01	1.03:1	0.67:1
2007	869	1.71	3,142	4.78	4,011	6.49	0.28:1	0.26:1
2008	1,631	5.99	797	2.08	2,428	8.07	2.05:1	0.74:1
2009	1,620	3.12	1,234	2.50	2,854	5.62	1.31:1	0.56:1
2010	1,149	2.61	1,076	2.29	2,225	4.90	1.07:1	0.53:1
mean (1987–1991)	1,485	5.49	3,846	10.31	5,331	15.80	0.39:1	0.35:1
mean (1992–2009)	1,247	4.28	2,162	3.69	3,410	7.97	1.53:1	0.58:1

Note: Means are separated (1987–1991 and 1992–2009) to account for pre-stocking and stocking differences.

[a] Values are 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, 1990–2010.

	#	*Diaptomus*		*Cyclops*		Totals		
Year	Sample Events	Density (no./m^3)	Biomass (mg/m^3)	Density (no./m^3)	Biomass (mg/m^3)	Density (no./m^3)	Biomass (mg/m^3)	*Diaptomus* to *Cyclops* Ratio [a]
1987	3	803	2.40	3,017	6.92	3,820	9.32	0.27 :1
1990	4	1,106	5.05	3,087	7.53	4,193	12.58	0.36 :1
1991	5	782	2.70	2,744	6.34	3,526	9.04	0.28 :1
1992	6	804	1.66	2,326	4.60	3,130	6.26	0.35 :1
1993	6	0	0.00	309	0.67	309	0.67	0.00 :1
1994	7	0	0.00	153	0.44	153	0.44	0.00 :1
1995	7	0	0.00	1,171	2.87	1,171	2.87	0.00 :1
1996	6	1	0.00	2,169	4.93	2,170	4.93	0.00 :1
1997	6	1	0.00	372	0.78	373	0.78	0.00 :1
1998	5	0	0.00	1,110	2.68	1,110	2.68	0.00 :1
1999	5	0	0.00	3,357	6.00	3,357	6.00	0.00 :1
2000	5	0	0.00	601	1.05	601	1.05	0.00 :1
2001	5	0	0.00	339	1.07	339	1.07	0.00 :1
2002	5	0	0.00	1,452	2.50	1,452	2.50	0.00 :1
2003	4	6	0.01	8,511	12.27	8,517	12.28	0.00 :1
2004	4	70	0.33	3,494	5.30	3,564	5.63	0.02 :1
2005	4	57	0.08	6,164	6.81	6,221	6.89	0.01 :1
2006	5	56	0.06	1,224	2.90	1,280	2.96	0.05 :1
2007	4	7	0.02	3,135	4.76	3,142	4.78	0.00 :1
2008	4	12	0.04	785	2.04	797	2.08	0.02 :1
2009	4	8	0.05	1,226	2.45	1,234	2.50	0.01 :1
2010	5	0	0.00	1,076	2.29	1,076	2.29	0.00 :1
mean (1987–1991)		897	3.38	2,949	6.93	3,846	10.31	0.30 :1
mean (1992–2009)		57	0.13	2,105	3.56	2,162	3.69	0.02 :1
mean (1993–2009)		13	0.03	2,092	3.50	2,105	3.54	0.01 :1

Note: Means are separated (1987–1991 and 1992–2009) to account for pre-stocking and stocking differences.

[a] Values are 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, 1990–2010.

Year	# Sample Events	*Bosmina* Density (no./m^3)	*Bosmina* Biomass (mg/m^3)	*Daphnia* Density (no./m^3)	*Daphnia* Biomass (mg/m^3)	*Holopedium* Density (no./m^3)	*Holopedium* Biomass (mg/m^3)	Totals Density (no./m^3)	Totals Biomass (mg/m^3)	*Bosmina* to *Daphnia* Ratio [a]
1987	3	1,059	2.73	788	2.59	209	2.21	2,056	7.53	1.34 :1
1990	4	1,028	3.01	502	1.70	51	0.53	1,581	5.24	2.05 :1
1991	5	529	1.46	177	0.46	112	1.77	818	3.69	2.99 :1
1992	6	614	1.58	86	0.25	173	1.96	873	3.79	7.14 :1
1993	6	89	0.21	526	0.99	214	1.54	829	2.74	0.17 :1
1994	7	574	1.17	389	1.00	199	2.88	1,162	5.05	1.48 :1
1995	7	764	1.62	203	0.49	248	2.64	1,215	4.75	3.76 :1
1996	6	535	1.09	20	0.03	137	1.09	692	2.21	26.75 :1
1997	6	277	0.45	177	0.28	229	3.11	683	3.84	1.56 :1
1998	5	724	1.30	454	1.50	103	1.33	1,281	4.13	1.59 :1
1999	5	210	0.32	258	0.68	150	1.85	618	2.85	0.81 :1
2000	5	376	0.85	53	0.08	299	1.55	728	2.48	7.09 :1
2001	5	585	1.25	46	0.13	525	1.35	1,156	2.73	12.72 :1
2002	5	1,639	3.74	1,218	3.81	425	1.99	3,282	9.54	1.35 :1
2003	4	878	3.04	437	0.78	316	1.85	1,631	5.67	2.01 :1
2004	4	847	3.68	442	1.25	412	2.43	1,701	7.36	1.92 :1
2005	4	583	1.13	392	0.69	190	1.24	1,165	3.06	1.49 :1
2006	5	505	1.05	182	0.28	630	4.72	1,317	6.05	2.77 :1
2007	4	551	1.07	180	0.27	138	0.37	869	1.71	3.06 :1
2008	4	366	0.78	203	0.34	1,062	4.87	1,631	5.99	1.80 :1
2009	4	262	0.48	30	0.05	1,328	2.59	1,620	3.12	8.73 :1
2010	5	560	0.90	279	0.48	310	1.23	1,149	2.61	2.01 :1
mean (1987–1991)		872	2.40	489	1.58	124	1.50	1,485	5.49	1.78 :1
mean (1992–2009)		577	1.38	294	0.72	377	2.19	1,247	4.28	4.79 :1

Note: Means are separated (1987–1991 and 1992–2009) to account for pre-stocking and stocking differences.

[a] Values are based on mean density.

Table 7.–Seasonal weighted mean lengths (mm) of zooplankton taxa in Hidden Lake, 1987, 1990–2010.

Year	*Epishura*	*Diaptomus*	*Cyclops*	*Bosmina*	*Daphnia*	*Holopedium*
1987	1.74	0.88	0.81	0.52	0.86	0.97
1990	1.92	1.02	0.83	0.55	0.87	0.96
1991	1.60	0.93	0.81	0.54	0.77	1.14
1992	1.37	0.77	0.76	0.52	0.81	1.00
1993	1.17		0.79	0.50	0.66	0.83
1994	1.48		0.90	0.47	0.76	0.92
1995	0.91		0.83	0.47	0.74	0.84
1996	0.91	1.10	0.81	0.47	0.62	0.83
1997	1.34		0.77	0.42	0.62	0.87
1998	1.16		0.82	0.44	0.86	0.90
1999	1.33		0.72	0.40	0.76	0.93
2000	1.15		0.71	0.49	0.59	0.71
2001	0.98		0.93	0.48	0.79	0.53
2002	1.15		0.71	0.49	0.83	0.70
2003	0.75	1.15	0.67	0.46	0.70	0.76
2004	1.45	1.16	0.69	0.48	0.84	0.75
2005	0.55	0.68	0.58	0.46	0.64	0.78
2006	1.23	1.17	0.82	0.47	0.61	0.84
2007	0.75	0.89	0.67	0.46	0.59	0.55
2008	1.67	0.95	0.86	0.47	0.63	0.67
2009	1.19	1.15	0.76	0.44	0.60	0.48
2010	0.56		0.78	0.41	0.63	0.65
mean (1987–1991)	1.75	0.94	0.82	0.54	0.83	1.02
mean (1992–2009)	1.14	1.00	0.77	0.47	0.70	0.77

Note: Means are separated (1987–1991 and 1992–2009) to account for pre-stocking and stocking differences. Blank cells reflect when *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, 1992–2010.

Year	# Fry	Date/Size [a]	# Fingerling	Date/Size [a]	# Pre-Smolt	Date/Size [a]	Total Stocked
1992					260,000	5-Sep/6.0 g	260,000
1993	448,000	29-Apr/0.25 g	106,600	4-Jun/0.5 g			554,600
1994	250,000	5-May/0.25 g					250,000
1995					98,650	2-Nov/9.5 g	98,650
1996	252,000	14-May/0.4 g			138,800	15-Oct/9.0 g	390,800
1997			287,700	4-Jun/0.6 g	167,500	22-Oct/9.5 g	455,200
1998					340,400	4-Sep/7.0 g	340,400
1999					310,000	6-Oct/9.4 g	310,000
2000	172,000	20-Jun/0.7 g			332,400	24-Aug/5.0 g	504,400
2001			66,500	25-May/0.8 g	249,000	5-Oct/13.5 g	315,500
2002					51,600	2-Oct/11.0 g	51,600
2003					31,006	14-Sep/13.9 g	31,006
2004					70,736	7,8-Oct/8.95 g	70,736
2005			113,679	23-Jun/1.4 g	74,663	3-Oct/11.7 g	188,342
2006	253,100	19-May/0.45 g			168,568	10-Oct/11.76 g	421,668
2007	300,315	17-Jun/0.42 g			199,992	29-Sep/9.56 g	500,307
2008	153,925	9-Jun/0.4 g			199,876	27-28-Sep/7.5 g	353,801
2009	149,300	17-Jun/0.42 g			104,730	2-Oct/9.17 g	254,030
2010	297,829	27-May/0.38 g			46,953	4-Oct/10.6 g	344,782
mean (1992–2009)							297,280

Note: Stocking sizes reported from the hatchery were not always reported to the same number of digits.

[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), 2010.

Date	Chinook	Sockeye	Coho	Pink	Chum
9-Jun					
10-Jun					
11-Jun					
13-Jun					
14-Jun					
15-Jun					
16-Jun	0	1,614	0	0	0
17-Jun	0	2,362	0	0	0
18-Jun	0	2,090	0	1	0
19-Jun					
20-Jun	0	1,816	0	1	0
21-Jun					
22-Jun					
25-Jun					
26-Jun					
27-Jun					
28-Jun					
30-Jun					
4-Jul					
7-Jul					
8-Jul					
23-Jul					
24-Jul					
5-Aug					
19-Aug					
Total	4	31,871	366	35,006	713

Note: Cells are left blank when data is confidential.

Table 10.–Commercial harvest by species by year in the Foul Bay Special Harvest Area (statistical area 251-41), 1995–2010.

Year	Chinook	Sockeye	Coho	Pink	Chum
1995	15	31,190 [a]	0	20	8
1996	6	29,708 [a]	15	7	63
1997	0	13,751 [a]	0	5	2
1998	17	8,270	0	55	57
1999	12	41,042	0	415	364
2000	5	23,643 [a]	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	7,389 [a]	0	0	0
2006	16	1,181 [a]	15	525	92
2007	7	703	1	46	149
2008	2	5,715	5	375	126
2009	1	6,508	0	3	1
2010	4	31,871	366	35,006	713
mean (1995–2009)	31	20,218	2	186	154

[a] Historical harvest numbers differ from previous reports due to fish ticket editing.

Table 11.–Estimated age composition of adult sockeye salmon harvest from Foul Bay Special Harvest Area (statistical area 251-41), 1995–2005, 2009–2010.

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	29,271	0	494	34	0	0	322	0	0	31,190
		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	100.0
1996 [b]	537	Numbers	297	0	0	9,328	119	18,360	1,485	0	0	119	0	0	29,708
		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	100.0
1997 [b]	562	Numbers	578	0	0	6,078	14	6,119	481	14	28	344	41	28	13,751
		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	100.0
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	100.0
1999	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	100.0
2000 [b]	733	Numbers	331	0	0	14,777	0	7,069	969	0	24	473	0	0	23,643
		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	100.0
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	100.0
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	100.0
2003	669	Numbers	44	0	0	40,221	0	9,205	867	0	0	844	0	0	51,181
		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	100.0
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	100.0
2005 [b]	232	Numbers	0	0	0	96	0	5,478	96	0	0	1,720	0	0	7,389
		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	100.0

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Table 11.–Page 2 of 2.

Year	Sample Size		Ages 1.1	0.2	0.3	1.2	2.1	1.3	2.2	3.1	1.4	2.3	3.2	2.4	Total [a]
2009	328	Numbers	655	0	0	2,321	20	2,758	278	0	0	476	0	0	6,508
		Percent	10.1	0.0	0.0	35.7	0.3	42.4	4.3	0.0	0.0	7.3	0.0	0.0	100.0
2010	544	Numbers	117	0	0	26,598	59	3,398	1,172	0	59	469	0	0	31,871
		Percent	0.4	0.0	0.0	83.5	0.2	10.7	3.7	0.0	0.2	1.5	0.0	0.0	100.0
mean	555	Numbers	8,333	37	34	183,166	601	88,551	9,737	14	51	5,057	41	28	295,677
(1995-2009)		Percent	2.8	0.0	0.0	61.9	0.2	29.9	3.3	0.0	0.0	1.7	0.0	0.0	100.0

Note: Includes fish harvested in the Foul Bay SHA (reported in statistical area 251-41) only. Due to difficulties allocating harvest in statistical area 251-40 FBSHA harvest may be under reported. Age data from the 1994 harvest is not included in the table. No samples were collected from 2006–2008.

[a] Due to rounding the age composition numbers and total column may differ.

[b] Historical harvest numbers have changed slightly due to database editing.

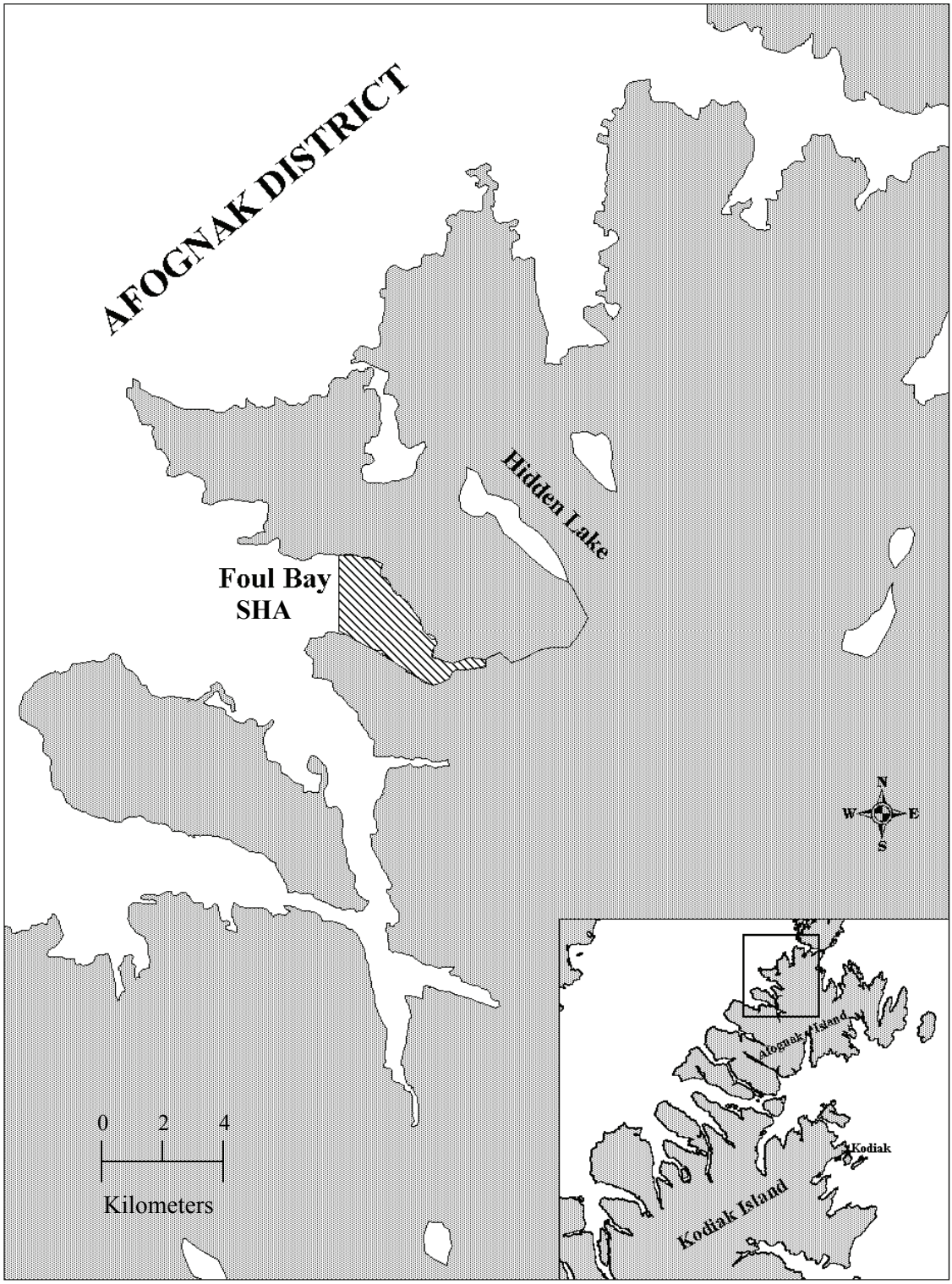

Figure 1.–Location of Hidden Lake and the Foul Bay Special Harvest Area on Afognak Island.

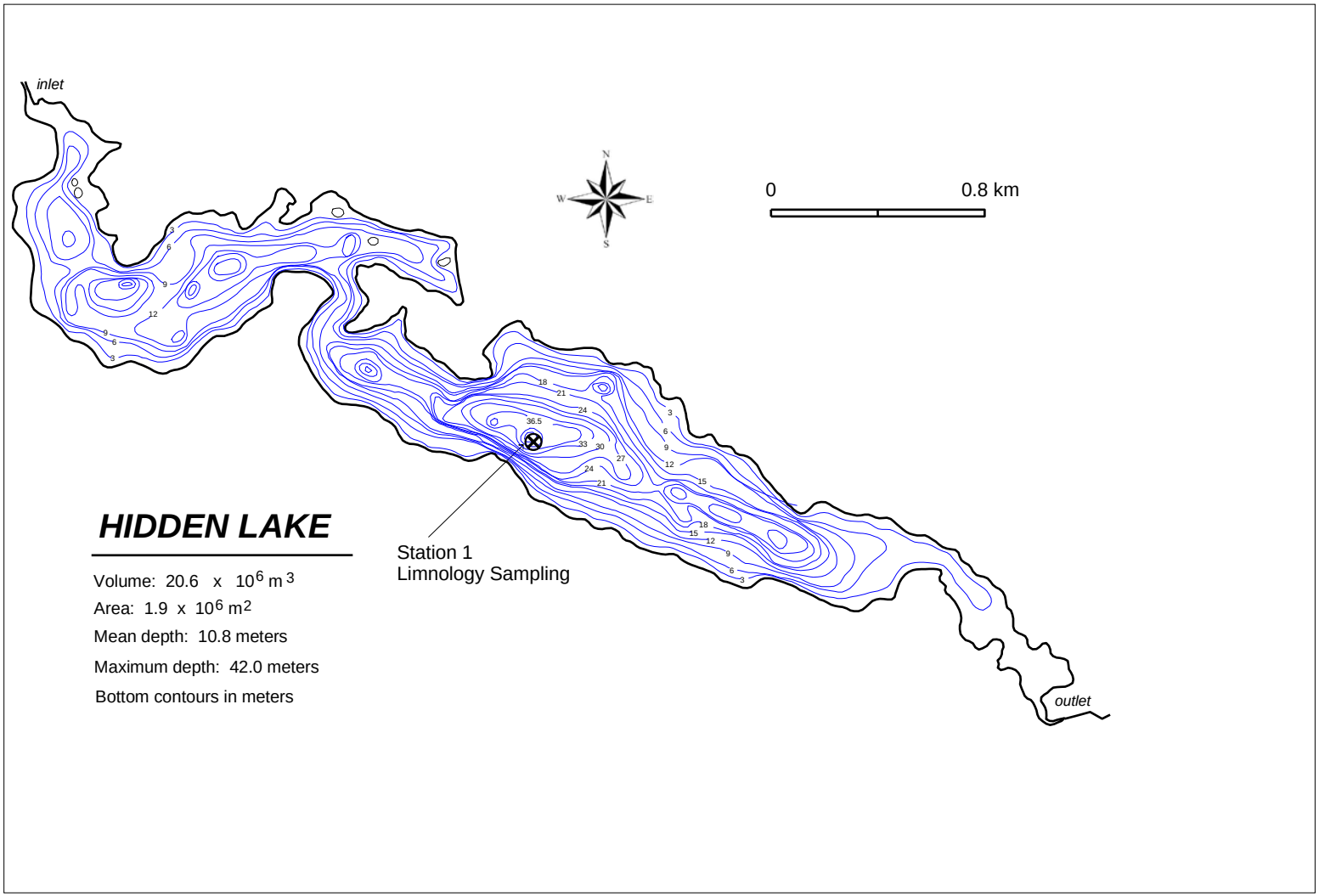

Figure 2.–Morphometric map showing the limnology sampling station on Hidden Lake.

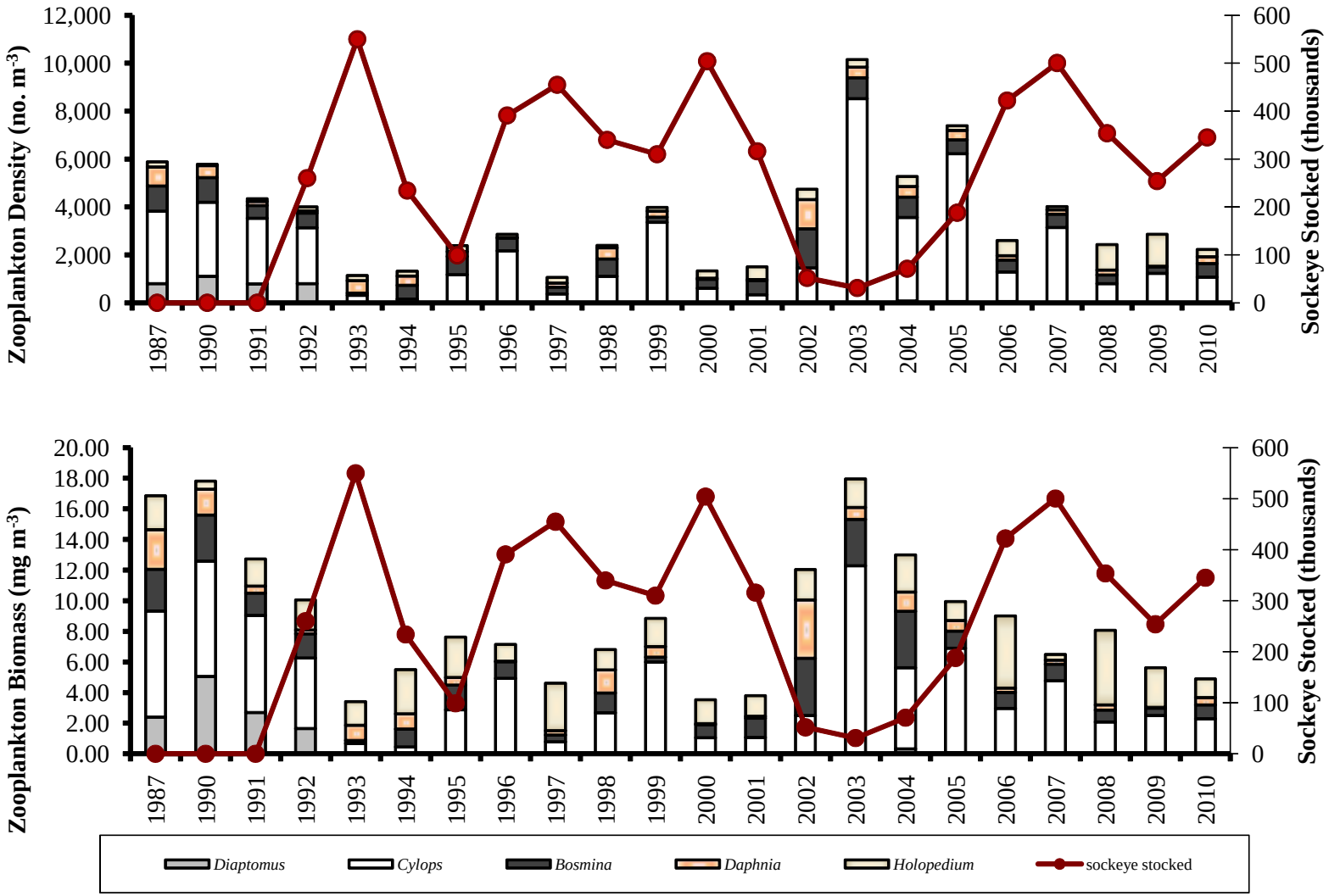

Figure 3.–Zooplankton density (A) and biomass (B) compared to sockeye salmon stocking levels for Hidden Lake, 1987, 1990–2010.

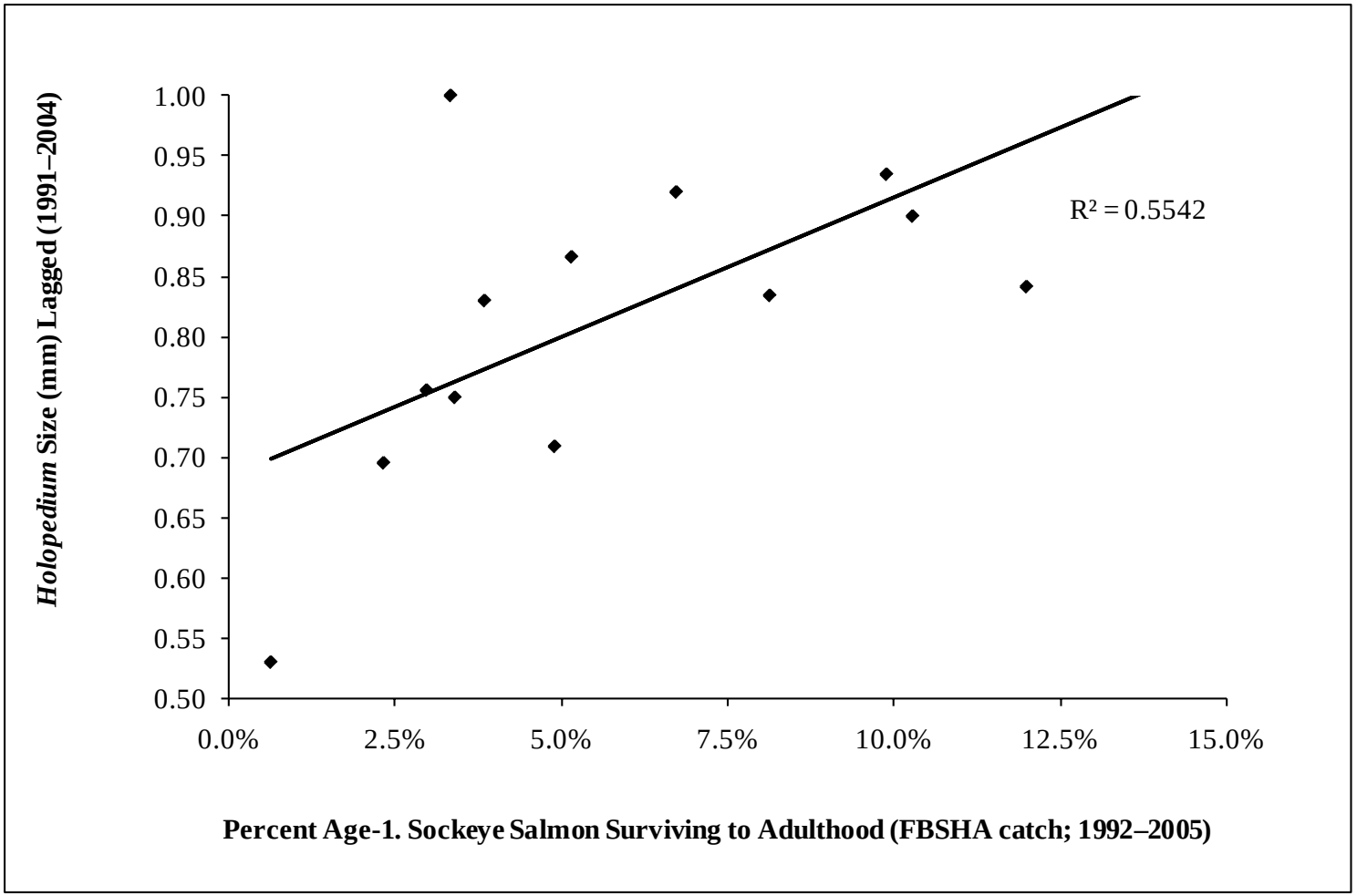

Figure 4.–Lagged *Holopedium* size (mm) compared to the percentage of age-1. sockeye salmon surviving to adulthood for Hidden Lake, 1992–2005.

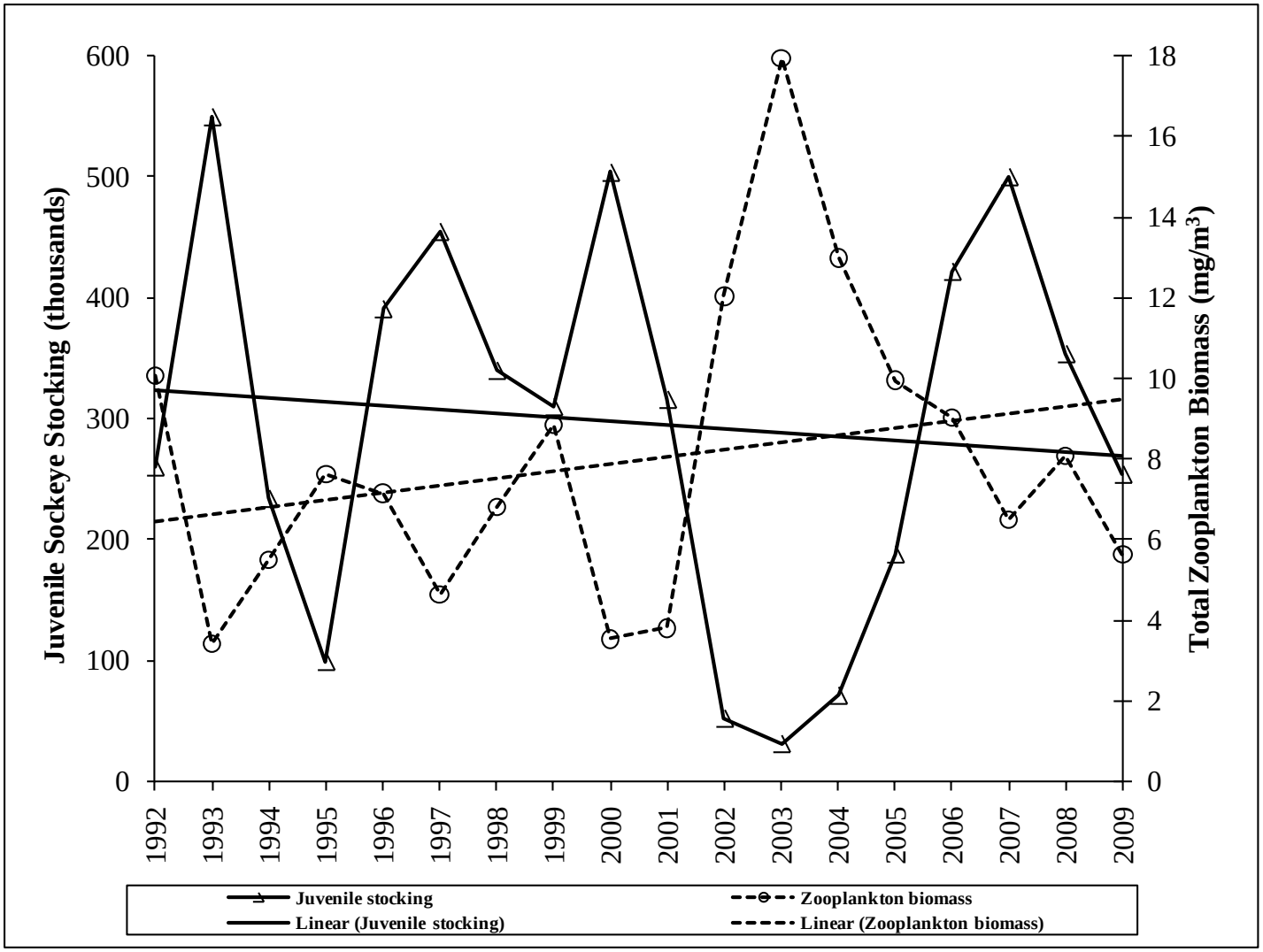

Figure 5.–Juvenile sockeye salmon stocking compared to zooplankton biomass for Hidden Lake, 1992–2010.

APPENDIX A. HISTORICAL LIMNOLOGICAL DATA

Appendix A1.–Limnological sampling stations and total samples collected at Hidden Lake, 1987–2010.

Year	Sampling Stations	Total Samples
1987	1	3
1989	1	1
1990	1	4
1991	1	5
1992	1	6
1993	1	6
1994	1, 2	7
1995	1, 2	7
1996	1, 2	6
1997	1, 2	6
1998	1	5
1999	1	5
2000	1	5
2001	1	5
2002	1	5
2003	1	4
2004	1	4
2005	1	4
2006	1	5
2007	1	4
2008	1	5
2009	1	4
2010	1	5

Appendix A2.–Summary of seasonal mean water chemistry parameters by station and depth for Hidden Lake, 1987, 1990–2010.

Year	Station	Depth (m)	Specific Conductivity (umhos/cm)	SD	pH (Units)	SD	Alkalinity (mg/L)	SD	Turbidity (NTU)	SD	Color (Pt units)	SD	Calcium (mg/L)	SD	Magnesium (mg/L)	SD	Iron (ug/L)	SD
1987	1	1	41.3	1.2	6.7	0.2	7.5	1.5	0.5	0.4	9.7	2.1	2.7	0.1	0.4	0.2	83.3	98.5
	1	25	42.0	1.7	6.7	0.2	6.7	1.5	0.6	0.4	11.7	2.5	2.8	0.2	0.6	0.2	94.3	86.6
1990	1	1	62.8	2.0	6.9	0.2	8.2	1.3	0.7	0.3	17.0	7.6	3.7	0.6	1.1	0.6	52.0	16.0
	1	29	66.3	3.1	6.7	0.2	8.5	0.9	0.5	0.1	13.0	2.0	3.9	0.5	1.1	0.3	39.8	9.3
1991	1	1	45.0	8.2	6.8	0.1	9.0	1.0	0.7	0.4	17.4	6.3	3.3	0.6	0.8	0.1	33.8	14.6
	1	30	46.2	8.3	6.8	0.2	10.3	1.9	0.5	0.2	15.6	3.0	3.3	0.5	0.9	0.3	37.8	10.7
1992	1	1	47.0	1.4	6.6	0.1	8.5	1.5	0.7	0.5	10.7	0.8	4.0	0.4	0.8	0.5	33.2	10.4
	1	27	47.3	1.0	6.5	0.2	10.6	5.3	0.8	0.7	12.0	1.1	3.5	0.8	1.0	0.6	68.7	88.7
1993	1	1	50.5	3.9	6.6	0.2	9.1	1.4	0.8	0.4	10.2	1.6	3.8	0.4	0.9	0.3	34.8	9.3
	1	42	50.3	3.1	6.5	0.2	8.8	1.0	0.6	0.5	10.7	2.3	4.0	0.2	0.9	0.3	54.0	27.2
1994	1	1	47.9	2.9	6.5	0.2	7.2	0.6	0.7	0.3	11.6	1.5	3.2	0.5	1.0	0.3	56.2	22.7
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	40	46.6	1.3	6.3	0.3	7.1	0.7	0.5	0.3	12.6	1.0	3.0	0.1	0.9	0.3	46.8	17.5
1995	1	1	50.0	4.2	6.4	0.1	8.7	1.5	0.9	0.9	15.3	5.7	3.0	0.5	1.0	0.6	78.6	104.4
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	43	50.3	1.4	6.2	0.1	7.3	0.2	0.4	0.2	12.3	1.8	2.8	0.3	0.8	0.5	38.9	7.4
1996	1	1	50.3	1.6	6.6	0.2	8.2	0.7	0.8	0.7	14.8	1.9	2.9	0.3	0.9	0.4	36.8	9.5
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	42	51.5	1.6	6.3	0.1	7.4	0.3	0.5	0.3	16.5	2.1	2.7	0.1	0.9	0.4	22.8	7.5
1997	1	1	49.2	1.2	6.9	0.1	9.9	1.5	0.4	0.1	12.0	1.7	2.9	0.2	0.8	0.3	29.3	9.3
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	43	50.5	0.8	6.7	0.1	9.6	0.7	0.4	0.1	14.3	1.9	2.8	0.1	0.8	0.3	28.3	8.4
1998	1	1	43.3	1.0	6.9	0.0	9.8	1.7	0.9	0.5	13.3	1.0	3.0	0.5	0.7	0.2	24.5	6.6
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	42	44.8	1.5	6.8	0.1	9.3	0.5	0.9	0.4	13.8	0.4	3.0	0.5	0.7	0.2	26.1	3.5
1999	1	1	49.4	1.5	6.8	0.3	8.9	0.7	0.6	0.6	11.6	1.1	3.3	0.3	1.0	0.2	41.8	12.5
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	42	50.2	0.8	6.6	0.2	8.4	0.5	0.5	0.3	11.4	0.5	3.4	0.1	1.0	0.2	40.4	8.0

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Appendix A2.–Page 2 of 2.

Year	Station	Depth (m)	Specific Conductivity (umhos/cm)	SD	pH (Units)	SD	Alkalinity (mg/L)	SD	Turbidity (NTU)	SD	Color (Pt units)	SD	Calcium (mg/L)	SD	Magnesium (mg/L)	SD	Iron (ug/L)	SD
2000	1	1	ND	ND	7.3	0.2	7.2	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2001	1	1	ND	ND	7.2	0.1	8.1	1.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2002	1	1	ND	ND	6.8	0.1	8.1	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2003	1	1	ND	ND	6.7	0.1	7.6	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2004	1	1	ND	ND	6.9	0.2	8.8	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2005	1	1	ND	ND	6.7	0.1	7.8	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2006	1	1	ND	ND	6.7	0.1	7.5	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2007	1	1	ND	ND	6.7	0.1	8.1	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2008	1	1	ND	ND	6.7	0.1	8.2	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2009	1	1	ND	ND	7.0	0.2	9.1	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2010	1	1	ND	ND	7.0	0.2	7.1	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: ND = no data.

Appendix A3.–Summary of seasonal mean nutrient and algal pigment concentrations by station and depth for Hidden Lake, 1987, 1990–2010.

Year	station	Depth	Total-P		Total Filterable-P		Filterable Reactive-P		Total Kjeldahl Nitrogen		Ammonia		Nitrate+ Nitrite		Reactive Silicon		Chlorophyll *a*	
		(m)	(ug/L)	SD	(ug/L)	SD	(ug/L)	SD	(ug/L)	SD	(ug/L)	SD	(ug/L)	SD	(ug/L)	SD	(ug/L)	SD
1987	1	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	1840.0	436.6	0.15	0.0
	1	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	1875.0	454.7	0.06	0.1
1990	1	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	1906.8	318.5	0.29	0.0
	1	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	1956.5	172.9	0.11	0.0
1991	1	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	1727.4	83.1	0.18	0.1
	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	1733.8	205.8	0.07	0.1
1992	1	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	1746.5	74.0	0.22	0.1
	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	1806.0	99.2	0.11	0.1
1993	1	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	1721.7	133.1	0.79	0.4
	1	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	1896.0	82.5	0.20	0.2
1994	1	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	1651.6	101.5	1.11	0.3
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.87	0.9
	1	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	1813.9	82.5	0.08	0.1
1995	1	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	1893.9	248.5	0.77	0.3
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.70	0.3
	1	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	1934.7	112.9	0.22	0.2
1996	1	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	1650.3	85.1	0.51	0.1
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.46	0.1
	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	1754.7	30.3	0.14	0.1
1997	1	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	1792.5	136.3	0.39	0.1
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.41	0.1
	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	1908.8	136.2	0.12	0.1
1998	1	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	1651.0	227.2	0.45	0.2
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.18	0.2
	1	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	1627.5	214.0	0.38	0.2
1999	1	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	1857.0	46.3	0.17	0.1
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	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	1997.6	83.8	0.09	0.1

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Year	Station	Depth (m)	Total-P (ug/L)	SD	Total Filterable-P (ug/L)	SD	Filterable Reactive-P (ug/L)	SD	Total Kjeldahl Nitrogen (ug/L)	SD	Ammonia (ug/L)	SD	Nitrate+ Nitrite (ug/L)	SD	Reactive Silicon (ug/L)	SD	Chlorophyll *a* (ug/L)	SD
2000	1	1	4.9	4.0	2.8	1.3	1.4	1.1	<60	ND	11.9	10.3	83.1	31.2	ND	ND	1.03	1.2
2001	1	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	ND	ND	0.64	0.2
2002	1	1	5.5	4.0	2.0	0.7	2.0	1.3	115.0	26.9	6.2	2.3	24.2	15.6	ND	ND	0.60	0.1
2003	1	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	ND	ND	0.70	0.2
2004	1	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	ND	ND	0.48	0.3
2005	1	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	ND	ND	0.48	0.2
2006	1	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	ND	ND	0.72	0.4
2007	1	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	ND	ND	0.72	0.2
2008	1	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	ND	ND	0.64	0.3
2009	1	1	2.5	0.5	0.7	0.2	3.6	1.7	152.5	19.1	5.8	2.3	59.9	21.1	ND	ND	0.48	0.2
2010	1	1	2.1	0.6	2.1	0.2	1.4	0.2	77.6	45.2	4.9	0.9	25.8	14.3	661.9	126.5	0.22	0.2

Note: ND = no data.

Appendix A4.–Weighted mean zooplankton density (no./m^2) and biomass (mg/m^2) by species (station 1) for Hidden Lake, 1987–2010.

	#	*Epischura*			*Diaptomus*			*Cyclops*			*Bosmina*			*Daphnia*			*Holopedium*		
	sample	Density	Biomass	Size	Density	Biomass	Size	Density	Biomass	Size	Density	Biomass	Size	Density	Biomass	Size	Density	Biomass	Size
Year	events	(no/m^2)	(mg/m^2)	mm	(no/m^2)	(mg/m^2)	mm	(no/m^2)	(mg/m^2)	mm	(no/m^2)	(mg/m^2)	mm	(no/m^2)	(mg/m^2)	mm	(no/m^2)	(mg/m^2)	mm
1987	3	204	4	1.74	24,080	72	0.88	90,499	208	0.81	31,766	82	0.52	23,629	78	0.86	6,281	66	0.97
1989	1	2,654	44	1.58	91,826	259	0.98	107,219	203	0.74	91,826	226	0.51	16,985	76	0.99	4,246	38	0.91
1990	4	133	4	1.92	33,174	152	1.02	92,622	226	0.83	30,852	90	0.55	15,061	51	0.87	1,526	16	0.96
1991	5	411	7	1.60	23,447	81	0.93	82,307	190	0.81	15,864	44	0.54	5,320	14	0.77	3,372	53	1.14
1992	6	288	3	1.37	17,693	37	0.77	51,177	101	0.76	13,498	35	0.52	1,894	5	0.81	3,813	43	1.00
1993	6	1,561	11	1.17	0	0	-	12,062	26	0.79	3,463	8	0.50	20,510	39	0.66	8,364	60	0.83
1994	7	2,781	38	1.48	0	0	-	6,104	18	0.90	22,943	47	0.47	15,543	40	0.76	7,635	73	0.92
1995	7	1,926	7	0.91	0	0	-	46,846	115	0.83	30,553	65	0.47	8,104	19	0.74	9,912	75	0.84
1996	6	3,556	12	0.91	35	0	1.10	88,924	202	0.81	21,939	45	0.47	832	1	0.62	5,609	41	0.83
1997	6	1,203	12	1.34	35	0	-	15,262	32	0.77	11,366	18	0.42	7,244	12	0.62	9,404	76	0.87
1998	5	1,316	9	1.16	0	0	-	45,527	110	0.82	29,667	53	0.44	18,605	62	0.86	4,242	38	0.90
1999	5	1,656	17	1.33	0	0	-	137,626	246	0.72	8,630	13	0.40	10,576	28	0.76	6,136	60	0.93
2000	5	1,911	13	1.15	0	0	-	26,285	46	0.71	16,199	37	0.49	2,284	3	0.59	13,188	69	0.71
2001	5	7,020	29	0.98	0	0	-	12,399	39	0.93	20,459	44	0.48	1,598	4	0.79	19,421	49	0.53
2002	5	7,166	48	1.15	0	0		53,649	94	0.71	63,442	145	0.49	48,301	152	0.83	16,122	76	0.70
2003	4	398	1	0.75	199	1	1.15	338,575	519	0.67	34,833	68	0.46	17,516	39	0.71	12,739	74	0.76
2004	4	1,194	15	1.45	2,787	18	1.16	140,300	230	0.69	33,506	74	0.48	17,755	59	0.84	16,136	95	0.75
2005	4	2,389	2	0.55	2,389	3	0.68	260,801	289	0.58	24,761	48	0.46	16,534	29	0.64	8,015	52	0.78
2006	5	1,932	16	1.23	584	2	0.93	45,679	109	0.82	21,476	45	0.47	7,622	12	0.61	24,490	185	0.84
2007	4	1,128	2	0.75	265	1	0.88	109,342	167	0.67	20,303	40	0.46	6,701	10	0.59	4,843	13	0.55
2008	5	658	13	1.67	425	2	0.95	28,583	75	0.86	13,445	29	0.47	7,282	12	0.63	38,954	180	0.68
2009	4	66	0	1.19	265	2	1.15	42,529	85	0.76	9,156	17	0.44	1,062	2	0.60	45,249	88	0.48
2010	5	478	0	0.56	0	0	-	35,987	78	0.79	20,037	32	0.41	9,846	17	0.63	10,456	43	0.66
mean (1987–2009)	5	1,889	14	1.24	8,964	29	0.97	83,378	151	0.77	25,907	58	0.48	12,316	34	0.73	12,259	69	0.81

Appendix A5.–Temperatures (°C) measured at the 1-meter and near bottom strata in the Spring, (May–June), Summer (July–August), and Fall (September–October) for Hidden Lake, 1990–2010.

	Spring		Summer		Fall	
Year	Surface	Bottom	Surface	Bottom	Surface	Bottom
1990	7.0	5.8	14.0	6.0	8.0	8.0
1991	0.5	0.0	14.6	5.4	8.5	6.0
1992	7.7	5.0	14.8	6.0	6.8	6.3
1993	11.0	4.8	16.0	5.3	9.5	5.5
1994	8.3	4.5	15.7	5.1	10.7	5.7
1995	7.6	4.6	14.2	5.6	12.3	8.0
1996	9.5	4.7	13.5	5.5	10.5	5.7
1997	11.4	4.2	16.9	5.0	10.6	5.0
1998	8.9	6.2	15.6	6.9	10.4	7.0
1999	5.7	4.1	13.9	5.8	10.5	6.0
2000	5.4	4.2	14.0	5.2	9.6	5.5
2001	9.5	4.6	15.8	5.4	11.8	5.4
2002	8.9	4.0	14.6	4.7	11.0	4.8
2003	9.2	5.2	17.7	6.1	10.6	6.3
2004	10.2	4.9	17.9	6.2	10.1	6.5
2005	8.2	4.4	16.9	5.3	12.6	5.4
2006	7.1	4.5	14.0	5.3	11.6	5.5
2007	8.3	4.8	14.3	5.4	10.8	5.7
2008	4.5	4.0	13.2	5.5	10.8	5.7
2009	7.8	4.4	13.7	5.5	11.0	5.6
2010	8.4	4.9	14.4	5.8	13.0	5.9
Mean (1990–2009)	7.8	4.4	15.1	5.6	10.5	6.0

Note: Measurements were averaged when more than one measurement occurred in the spring, summer, or fall. October temperature measurements have not been collected since 2000.

Appendix A6.–Temperatures (°C) measured at the 1- and 50-meter strata by month, for Hidden Lake, 1990–2010.

	May		June		July		August		September		October	
Year	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
1990	7.0	5.8	ND	ND	14.5	7.5	13.5	5.5	ND	ND	8.0	8.0
1991	0.5	0.0	ND	ND	14.7	3.0	14.5	7.8	11.0	6.0	6.0	6.0
1992	4.5	4.0	10.9	6.0	15.0	6.0	14.5	6.0	8.0	7.0	5.6	5.6
1993	ND	ND	11.0	4.8	17.5	5.0	14.5	5.5	10.5	5.5	8.5	5.5
1994	4.5	3.9	12.0	5.0	14.6	5.1	18.0	5.3	12.8	5.5	8.5	5.9
1995	3.6	3.3	9.6	5.3	14.6	5.6	13.7	5.6	13.7	6.5	10.8	9.4
1996	6.7	4.1	12.3	5.3	12.5	5.4	14.5	5.5	14.0	ND	7.0	5.7
1997	3.4	3.2	12.6	4.6	18.1	4.8	17.7	5.0	16.1	4.9	10.6	5.0
1998	6.4	5.7	11.3	6.6	ND	ND	15.6	6.9	11.4	7.0	9.4	7.0
1999	3.0	2.8	8.3	5.3	13.6	5.8	14.2	5.8	10.5	6.0	ND	ND
2000	5.4	4.2	ND	ND	13.4	5.1	14.5	5.3	10.9	5.4	8.2	5.5
2001	5.2	3.9	13.8	5.2	15.8	5.3	15.7	5.4	11.8	5.4	ND	ND
2002	6.5	3.5	11.3	4.4	14.3	4.6	14.9	4.7	11.0	4.8	ND	ND
2003	6.5	5.2	11.8	6.2	ND	ND	17.7	6.1	10.6	6.3	ND	ND
2004	4.7	3.9	15.7	5.9	ND	ND	17.9	6.2	10.1	6.5	ND	ND
2005	4.4	3.9	11.9	4.9	ND	ND	16.9	5.3	12.6	5.4	ND	ND
2006	3.8	3.7	10.4	5.2	ND	ND	14.0	5.3	11.6	5.5	ND	ND
2007	4.9	4.3	11.6	5.3	ND	ND	14.3	5.4	10.8	5.7	ND	ND
2008	4.5	5.2	11.0	5.2	13.5	5.5	15.0	5.7	10.8	5.7	ND	ND
2009	3.9	3.5	11.7	5.3	ND	ND	13.7	5.5	11.0	5.6	ND	ND
2010	5.5	4.4	11.2	5.4	14.7	5.7	14.1	5.8	13.0	5.9	ND	ND
Mean (1990–2009)	4.7	3.9	11.6	5.3	14.8	5.3	15.3	5.7	11.5	5.8	8.3	6.4

Note: Measurements were averaged when more than one measurement occurred. Measurements were included in a different month if deemed appropriate (Near the end or beginning of the month).

ND = no data.

APPENDIX B. JUVENILE AGE, LENGTH, WEIGHT, AND CONDITION, COHO STOCKING, AND HYDROACOUSTICS

Appendix B1.–Mean age, length, weight, and condition coefficient from sockeye salmon smolt collected from Hidden Creek, 1993–2001.

				Age-1					Age-2				
Year	Statistical Weeks	Dates Collected	Number Sampled	no.	%	Mean Length (mm)	Mean Weight (g)	Condition Factor (K)	no.	%	Mean Length (mm)	Mean Weight (g)	Condition Factor (K)
1993	21	May 17–23	324	324	100.0	100.5	8.5	0.83	0	0.0			
1994	24–27	June 7–July 4	218	214	98.2	122.9	16.2	0.87	4	1.8	145.0	29.1	0.92
1995	23–26	May 31–June 27	153	148	96.7	124.5	20.5	1.00	5	3.3	164.3	45.8	1.02
1996	23–25	May 31–June 20	440	426	96.8	125.3	18.4	0.94	14	3.2	159.5	41.6	0.95
1997	23–26	May 31–June 27	442	439	99.3	109.2	11.4	0.87	3	0.7	120.0	14.7	0.78
1998	22–26	May 24–June 27	462	455	98.5	111.1	12.3	0.89	7	1.5	140.0	24.1	0.87
1999	23–26	May 31–June 27	262	262	100.0	96.6	7.4	0.81	0	0.0			
2000	23–25	May 31–June 20	521	509	97.7	113.4	12.5	0.85	12	2.3	146.8	28.6	0.88
2001	22–26	May 24–June 27	447	441	98.7	95.5	7.4	0.85	6	1.3	97.7	8.1	0.85
2002	23–24	May 31–June 13	243	240	98.8	112.9	12.5	0.86	3	1.2	153	30.2	0.84
mean (1993–2002)			3,512	3,458	98.5	111.2	12.7	0.88	54	1.5	140.8	27.8	0.89

Appendix B2.–Juvenile coho salmon releases into Hidden Lake, 1988–1991.

Release Year	Broodstock	Species Stocked	Life Stage[a]			Total Stocked
			fry	fingerling	presmolt	
1988	Big Kitoi	Coho		137,585		137,585
1989	Big Kitoi	Coho		239,817		239,817
1991	Big Kitoi	Coho		250,889		250,889

[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).

Appendix B3.–Juvenile sockeye salmon estimates based on hydroacoustic fish population surveys of Hidden Lake, 1994–1998 and 2000–2001.

Sample		Sockeye Salmon Estimates[a]		
			95% Confidence Interval	
Year	Month	Number	Low	High
1994	October	91,181	63,700	118,662
1995	November	75,149	35,690	114,608
1996	May	34,347	8,084	60,610
	July	21,241	12,264	30,218
	October	175,154	111,678	238,630
1997	May	103,310	51,157	155,463
	June	25,659	4,603	46,715
1998	April	115,768	90,556	140,980
1999	ND	ND	ND	ND
2000	May	107,390	84,335	130,445
2001	May	24,444	17,719	31,169

[a] Townet surveys were discontinued due to sockeye avoidance of the trawl net.

Appendix B4.–Sockeye smolt stocking and adult survival estimates by age and stocking year, 1992–2010.

Juvenile Stocking		Adult Fresh Water Age							
		Age 1.	Percent	Age 2.	Percent	Age 3.	Percent	Total Adults	Juvenile to Adult
Year	Number	Number	Survival	Number	Survival	Number	Survival	Produced	Survival (%)
1992	260,000	47,371	18.2	1,923	0.7	0	0.0	49,294	19.0
1993	554,600	18,539	3.3	822	0.1	0	0.0	19,361	3.5
1994	250,000	9,631	3.9	620	0.2	0	0.0	10,251	4.1
1995	98,650	6,643	6.7	3,351	3.4	0	0.0	9,994	10.1
1996	390,800	46,883	12.0	1,474	0.4	0	0.0	48,357	12.4
1997	455,200	37,044	8.1	123	0.3	0	0.0	37,167	8.2
1998	340,400	17,566	5.2	1,058	0.3	0	0.0	18,624	5.5
1999	310,000	31,882	10.3	1,074	0.3	0	0.0	32,956	10.6
2000	504,400	49,897	9.9	4,066	0.8	0	0.0	53,963	10.7
2001	315,500	15,480	4.9	109	0.0	0	0.0	15,589	4.9
2002	51,600	331	0.6	37	0.1	0	0.0	368	0.7
2003	31,000	724	2.3	117	0.4	0	0.0	841	2.7
2004	70,700	2,108	3.0	657	0.9	0	0.0	2,765	3.9
2005	188,342	6,417	3.4	758	0.2	0	0.0	7,175	3.8
2006	421,668	5,866	0.6	1,192	0.0	0	0.0	7,058 [a]	1.7 [a]
2007	500,307	27,263	0.1	59	0.0	0	0.0	27,322 [a]	5.5 [a]
2008	353,801	117	0.0	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]
2009	254,030	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]
2010	344,782	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]
Mean (1992–2005)		20,751	6.6	1,156	0.6	0	0.0	21,908	7.2

[a] Numbers are incomplete. Awaiting adult returns.