Fishery Data Series No. 08-43

Hugh Smith Lake Sockeye Salmon Adult and Juvenile Studies, 2007

by

Andrew W. Piston

September 2008

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

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

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

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Andrew W. Piston

Alaska Department of Fish and Game, Division of Commercial Fisheries, Ketchikan

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

September 2008

This manuscript was fully financed by ongoing grants from the Southeast Sustainable Salmon Fund: Hugh Smith and Ketchikan Area Sockeye Escapement project (45443) and the SSSF Hugh Smith Lake Juvenile Sockeye project (45218).

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Andrew W. Piston
Alaska Department of Fish and Game, Division of Commercial Fisheries,
2030 Sea Level Drive, Suite 205, Ketchikan, AK, USA

This document should be cited as:
Piston, A. W. 2008. Hugh Smith Lake sockeye salmon adult and juvenile studies, 2007. Alaska Department of Fish and Game, Fishery Data Series No. 08-43, Anchorage.

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ABSTRACT

In 2006, Hugh Smith Lake sockeye salmon were de-listed as a *management stock of concern* by the Alaska Board of Fisheries. This decision was based primarily on the fact that escapements into the lake were above the upper end of the escapement goal range, from 2003 to 2005. In 2007, we continued weir operations at the lake and additional studies designed to provide information important for evaluating the ongoing rehabilitation efforts at the lake. Our goal was to identify factors limiting the productivity of sockeye salmon at various stages of their life history within Hugh Smith Lake. Along with monitoring adult escapements, we estimated total juvenile sockeye salmon production, mid-summer-to-spring survival rates of sockeye fry, fry-emigration timing from Buschmann and Cobb creeks, habitat changes within Buschmann Creek, and zooplankton production within the lake, and we conducted a Dolly Varden predation study at the spring smolt weir. We have no reason to suspect that habitat changes or secondary productivity have been responsible for the past declines in escapement at Hugh Smith Lake. The upper end of the escapement goal range of 8,000–18,000 adult sockeye salmon, which includes stocked fish, has now been surpassed for five consecutive years. Stocked fish returning to Hugh Smith Lake continued to show abnormal behavior and distribution in the lake and likely experienced poor spawning success. High harvest rates appear to be the principle cause of past declines in this stock, however, commercial fishing effort in the seine and gillnet fisheries near the mouth of Boca de Quadra inlet declined substantially since the early 1990s. The stocked fish returning to Hugh Smith Lake in 2007 were the last fish expected to return from the pre-smolt stocking program, and the adult sockeye salmon escapement at Hugh Smith Lake will be 100% wild fish in 2008.

Key words: Hugh Smith Lake, sockeye salmon, *Oncorhynchus nerka*, stock of concern, lake stocking, escapement, escapement goal, hydroacoustics, zooplankton, habitat, Dolly Varden.

INTRODUCTION

In 2003, the Alaska Board of Fisheries adopted Hugh Smith Lake sockeye salmon as a management stock of concern, due to a long-term decline in escapement (Geiger et al. 2003). Escapements averaged 17,500 during the 1980s, 12,000 during the 1990s, and only 5,000, from 1998 to 2002. The Board of Fisheries adopted an action plan to rebuild the sockeye salmon run to levels that would meet the escapement goal range of 8,000–18,000 adult sockeye salmon (Hugh Smith Lake Sockeye Salmon Action Plan, Final Report to the Board of Fish, RC-106, February 2003). The action plan directed the Alaska Department of Fish and Game (ADF&G) to review stock assessment and rehabilitation efforts at the lake and contained measures to reduce commercial harvests of Hugh Smith Lake sockeye salmon when returns were projected to be below the lower end of the escapement goal range. The rehabilitation effort included a hatchery stocking program in which the fry were fed to pre-smolt size from late May through July while rearing in net-pens in the lake. Eggs for this program were collected at the mouth of Buschmann Creek, which is one of the primary spawning tributaries for sockeye salmon in Hugh Smith Lake. This stocking of pen-reared fry occurred from 1999 to 2003, and all released fry had thermal otolith marks. The final returns of adult fish from this stocking program returned to the lake as 3-ocean fish in 2007.

Escapements of adult sockeye salmon at Hugh Smith Lake have improved steadily since reaching a low of 1,100 in 1998, and from 2003 to 2006, escapements surpassed the upper end of the escapement goal range of 8,000 to 18,000 adult sockeye salmon (Piston et al. 2007). Although large numbers of fish were passed through the counting weir in these recent years, the behavior and distribution of the stocked portion of the run within the system indicated that many of these fish did not fully contribute to juvenile production (Geiger et al. 2005; Piston et al. 2007). Estimates for the wild portion of the spawning escapement have also shown improvement in recent years. In 2005 and 2006, escapements of wild sockeye salmon reached the escapement goal for the first time since 1997 (Piston et al. 2007). Because of the positive trends at the lake through 2005, the Hugh Smith Lake sockeye salmon stock was de-listed as a management stock of concern at the 2006 Board of fisheries meeting.

Here, I summarize the information collected in 2007 concerning the Hugh Smith Lake sockeye salmon stock. In 2007, ADF&G continued weir operations and studies designed to evaluate the rehabilitation efforts at the lake. This was the final year of the juvenile sockeye salmon study that has been ongoing since 2004. As in the past three years, we looked at a variety of factors that are important for assessing rehabilitation efforts and the overall health of the sockeye salmon population, including the adult sockeye salmon escapement, total juvenile sockeye salmon production, mid-summer to spring survival rates of sockeye fry, fry emigration timing from Buschmann and Cobb creeks, habitat changes within Buschmann Creek, and zooplankton production within the lake. Our goal was to identify factors limiting the productivity of sockeye salmon at various stages of their life history within Hugh Smith Lake and to monitor the final return of 3-ocean stocked fish.

In 2007, we added Dolly Varden (*Salvelinus malma*) predation sampling to our study of factors affecting juvenile sockeye salmon survival. Hugh Smith Lake has a large population of Dolly Varden, many of which are anadromous and pass through the smolt weir during May and early June (e.g., 13,750 in 2006). Armstrong (1974, 1984) found that anadromous Dolly Varden from streams in Southeast Alaska that lack a suitable wintering lake will move to saltwater in the fall to search nearby streams for proper wintering habitat. The large number of Dolly Varden emigrating from Hugh Smith Lake each spring suggests that the lake may be an important wintering area for Dolly Varden in Boca de Quadra Inlet. Hugh Smith Lake is the first easily accessible lake that Dolly Varden originating from systems further up Boca de Quadra Inlet would encounter while prospecting for suitable wintering areas. Dolly Varden have been documented to prey on juvenile salmon to varying degrees (Roos 1959; Lagler and Wright 1962), but the extent of predation, if any, at the outlet of Hugh Smith Lake is not known. The effect that the smolt weir structure could have on the relationship between Dolly Varden and emigrating salmon smolt at Hugh Smith Lake has also not been investigated.

STUDY SITE

Hugh Smith Lake (55° 06’ N, 134° 40’ W; Orth 1967) is located 97 km southeast of Ketchikan, on mainland Southeast Alaska, in Misty Fjords National Monument (Figure 1). The lake is organically stained, with a surface area of 320 ha, mean depth of 70 m, maximum depth of 121 m, and volume of $222.7 \cdot 10^6$ m^3 (Figure 2). The lake empties into Boca de Quadra inlet via 50-m-long Sockeye Creek (ADF&G stream number 101-30-10750). Sockeye salmon spawn in two inlet streams: Buschmann Creek flows northwest 4 km to the head of the lake (ADF&G stream number 101-30-10750-2006, Beaver Pond Channel 101-30-10750-3003); and Cobb Creek flows north 8 km to the southeast head of the lake (ADF&G stream number 101-30-10750-2004, Figure 2). Cobb Creek has a barrier to anadromous migration approximately 0.8 km upstream from the lake. Hugh Smith Lake is meromictic, and water located below 60 m does not interact with the upper freshwater layer of the lake.

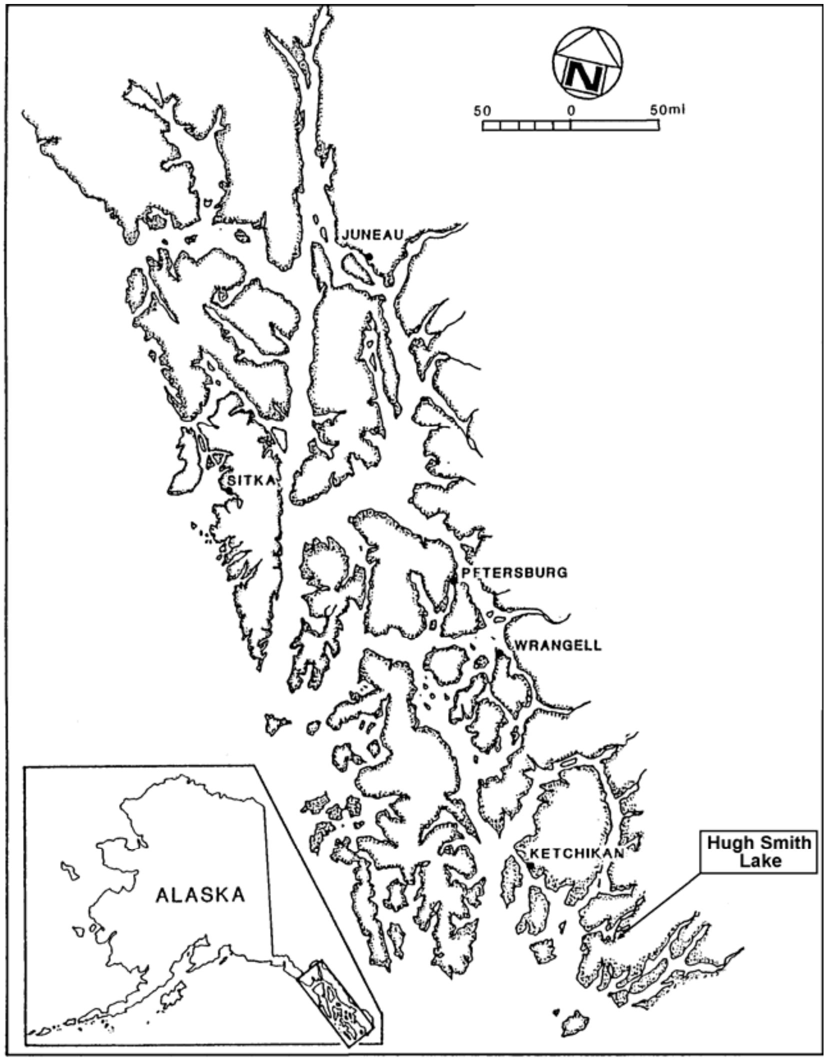

Figure 1.–The location of Hugh Smith Lake in Southeast Alaska.

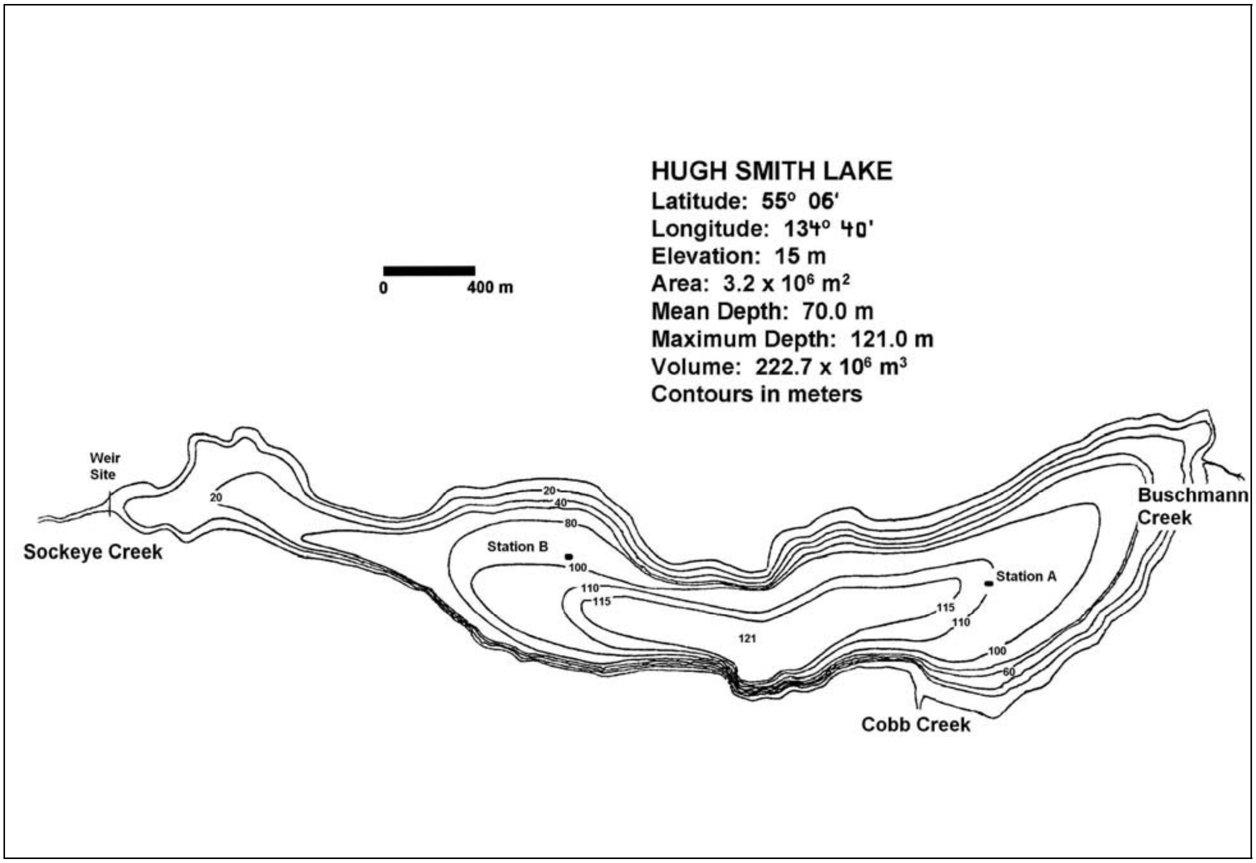

Figure 2.–Bathymetric map of Hugh Smith Lake, Southeast Alaska, showing the location of the weir site, stations A and B, the primary inlet streams, and other features of the lake system.

METHODS

ZOOPLANKTON PRODUCTIVITY

In order to determine whether secondary production in the lake is currently a limiting factor for sockeye salmon production, we assessed the biomass and density of the zooplankton population, as well as trends in size of the various zooplankton species. Zooplankton samples were collected at two sampling stations, station A and B, located at opposite ends of the lake, using a 0.5 m diameter, 153 μm mesh conical net. Vertical zooplankton tows were pulled from a depth of 50 m to the surface at a constant speed of 0.5 m · sec^{-1}. The net was rinsed prior to removing the organisms, and all specimens were preserved in buffered 10% formalin. Samples were analyzed at the ADF&G Kodiak Limnology Lab, using methods detailed in the Alaska Department of Fish and Game Limnology Field and Laboratory Manual (Koenings et al. 1987) and summarized in Edmundson et al. (1991). Density and biomass of taxa were averaged between station A and B, for each date of sampling. The density estimates have a relative error of 20–25% of the true value (unpublished memorandum from John Edmundson, ADF&G, 21 May 2002). Here we present data collected in June, August, September, and October of 2006. In 2007, samples were collected in April, June, August, and October, but analysis of these samples was not completed at the time of this report.

BUSCHMANN CREEK HABITAT EVALUATION

What we have generally referred to as Buschmann Creek is actually made up of two separate creeks, draining two separate valleys, which come together in their lower reaches. The stream flowing in from the valley to the southeast is Buschmann Creek (ADF&G stream number 101-30-10750-2006), and the tributary flowing out of the northeast valley that meets Buschmann Creek at what we call the Main Fork is referred to as the Beaver Pond Channel (ADF&G stream number 101-30-10750-3003, Figure 3). The Beaver Pond Channel is so named because there have consistently been one or more beaver dams and at least one associated pond along its length. The primary changes that have been noted by field crews at the lake involve the division of flow between three channels in lower Buschmann Creek. In some years a higher percentage of water from Buschmann Creek moves into two channels that flow through the old hatchery site, referred to as the Hatchery Channel and Side Channel C (Figure 3).

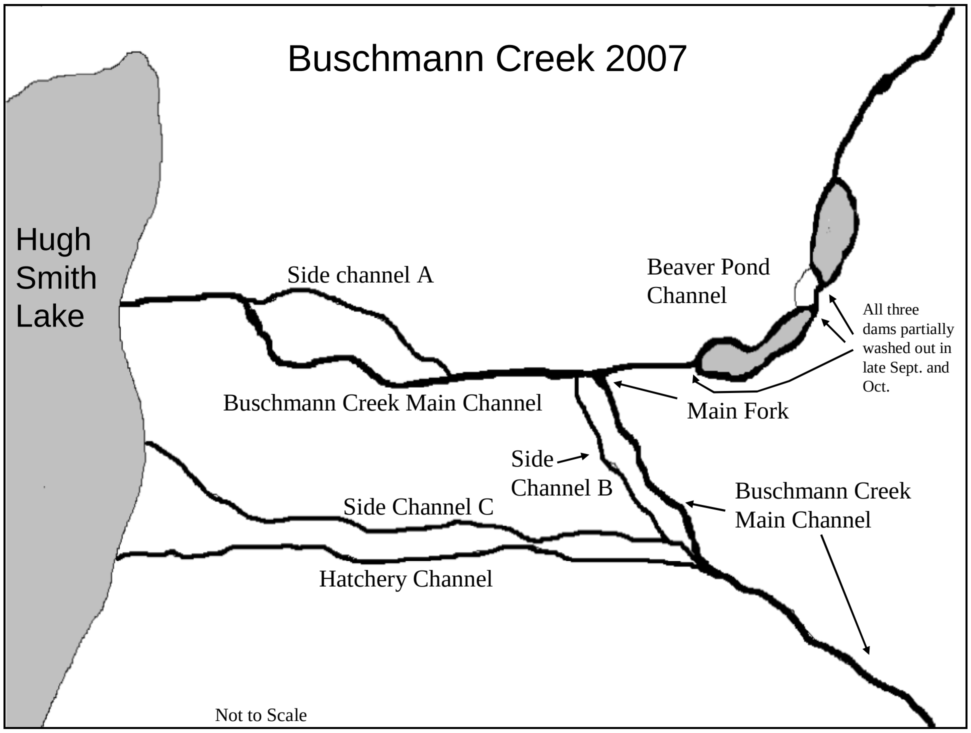

Figure 3.–Schematic diagram of the main channels of lower Buschmann Creek, as of November 2007.

The lower reach of the Buschmann Creek drainage, from the mouth to the main fork and to the top of the hatchery channel, is flat, unstable, and prone to frequent changes to its stream channel. Although we have anecdotal information concerning recent stream channel changes in this tributary, we lack detailed information on the extent, duration, and frequency of these changes. In order to better assess the effects of habitat changes on this stock's productivity, we mapped the main channels of lower Buschmann Creek and inventoried the quantity and quality of spawning habitat in 2004.

In 2007, we conducted foot surveys of the various channels in Buschmann Creek to determine if any significant changes occurred since the 2006 season. Because only minor changes were observed, the changes were documented, but no complete inventory of lower Buschmann Creek was conducted.

STREAM TEMPERATURE MONITORING

Under-gravel stream temperatures in the various channels of lower Buschmann Creek were monitored year round, using StowAway Tidbit™ Temperature Loggers (Onset Computer Corp.[1]). These measurements provided us with comparative temperature profiles between the two major tributaries of the lake and between the various channels of Buschmann Creek. Two temperature loggers were placed in the main channel of Buschmann Creek, two were placed in the section between the main fork and the upstream end of the Hatchery Channel, one was set in the Lower Beaver Pond channel, and three were set in the Hatchery Channel (Figure 3). In addition, two thermographs were set in Cobb Creek, approximately 150 m upstream of the mouth, to assess differences in temperature regimes between Buschmann Creek and Cobb Creek. One additional thermograph was used to record the air temperatures near the mouth of Buschmann Creek. Stream temperature data from the thermographs were transferred in the field via an Onset Optic Shuttle and brought to Ketchikan for analysis. Cumulative thermal units (CTUs) for each stream were calculated by summing average daily temperatures throughout the period in question.

FRY PRODUCTION

Hydroacoustic Surveys

In 2007, we conducted hydroacoustic surveys of Hugh Smith Lake to estimate the number of rearing sockeye salmon fry present during the months of July, August, September, and October. We had intended to conduct a spring survey, prior to the beginning of smolt emigration, but the lake was still partly frozen in mid-April. Hugh Smith Lake was divided into five sampling areas based on surface area. Four replicate, orthogonal transects were randomly selected from each sampling area. These 20 transects remained fixed throughout the entire study to increase the precision of the estimated change in population size. Hydroacoustic sampling of each transect was conducted during post-sunset darkness in one night. A Biosonics DT-X™ scientific echosounder (430 kHz, 7.3° split-beam transducer) with Biosonics Visual Acquisition © version 5.0 software was used to collect the data. Ping rate was set at five pings sec^{-1}, pulse width at 0.3 ms, and a constant boat speed of about 2.0 m sec^{-1} was maintained. A target strength of -40 dB to -70 dB was used to represent fish within the size range of juvenile sockeye salmon and other small pelagic fish.

Fish-target density ($\mathrm{targets \cdot m^2}$) was estimated using Biosonics software (User Guide, Visual Analyser™ 4.1, BioSonics, Inc.), using the echo integration technique as described in MacLennan and Simmonds (1992). Mean target density for each sampling area was calculated as the average of the four replicate transects. A total-target estimate for each of the sampling areas was calculated as the product of the mean target density and the surface area of each of the sampling areas. Summing the area estimates of total targets resulted in an estimate of total targets for the entire lake. The variance of the total-target estimate within an area was calculated based on 3-degrees-of-freedom estimates for each group of transects. Because the estimate of total targets in each section was essentially independent (neglecting any movement of fry from one

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[1] Reference to trade names does not imply endorsement by Alaska Department of Fish and Game.

section to the other during the data collection), an estimate of the sample variance of the estimate of the total targets in the entire lake was formed by summing the 3-degrees-of-freedom sample variances across the five sections. Sampling error for the estimate of total targets for the entire lake was measured and reported with the coefficient of variation (Sokal and Rohlf 1995).

In conjunction with the hydroacoustic surveys, we collected pelagic fish samples using a 2 m × 2 m trawl net. A Bayesian hierarchical model was used to apportion the population estimates by species based on our trawl samples (Appendix A). We conducted eight nighttime trawls at various depths during each survey. The captured fish were euthanized with MS-222, preserved in 90% alcohol, and transported to the ADF&G laboratory in Ketchikan, where the fry were measured (snout-to-fork length in mm) and weighed (grams). Based on past fry sampling at Hugh Smith Lake, all sockeye salmon fry under 45 mm fork length were assumed to be age 0. Scales were collected from all fish over 45 mm in fork length for aging.

Fry Emigration Timing

To determine the timing of fry emigration from the inlet streams into Hugh Smith Lake, we deployed fyke nets in the lower reaches of Buschmann and Cobb creeks. The nets were only operated in July, with the purpose of determining when sockeye fry had ceased entering the lake. Our first hydroacoustic survey of the summer was conducted only after sockeye fry were no longer entering the lake from the inlet streams. A fyke net was set on 4, 12, and 18 July in Buschmann Creek and on 4 July in Cobb Creek. All fry captured in the nets were counted out of the holding boxes and immediately released. The Buschmann Creek site likely provided a higher catch rate than our site at Cobb Creek due to its narrower channel, which funneled a higher percentage of stream flow into the net.

SMOLT PRODUCTION

A smolt weir was used from 1981 to 2007 to sample and count coho and sockeye salmon smolt emigrating from Hugh Smith Lake (see Geiger et al. 2003 for a physical description of weir). Our research personnel counted all species through the smolt weir and collected scale samples and length-weight data from sockeye smolt. Scale samples were collected at a rate of 16 fish per day when fewer than 100 fish were captured at the weir on a daily basis, and 28 fish per day when more than 100 fish were captured per day. The length (snout-to-fork in mm) and weight (to the nearest 0.1 g) was recorded for each fish sampled. A preferred-area scale smear (Clutter and Whitesel 1956) was taken from each fish and mounted on a 2.5 cm × 7.5 cm glass slide, four fish per slide. A video-linked microscope was used to age sockeye smolt scales at the Ketchikan office.

We know that the total smolt weir count has tended to be an underestimate of the true emigration size, due to fish passing before and after the weir was installed and from fish that escaped past the weir uncounted. From 1996 to 2005, the smolt weir efficiency averaged about 70% for coho salmon smolt (L. Shaul, ADF&G, personal communication). Smolt weir data from 1983–1990 (Shaul 1994) showed that the smolt weir efficiency was highly variable and averaged approximately 41% for coho salmon smolt.

DOLLY VARDEN PREDATION SAMPLING

Dolly Varden char were sampled at the outlet of the lake using a hoop trap, rod and reel, and the smolt weir trap. Sampling took place during the last two weeks of May. We examined the stomach contents of 30 Dolly Varden per week and attempted to divide the 30 weekly samples into 10 samples from each gear type noted above. This allowed us to determine if the predation rate, if any, was higher inside the smolt weir trap where Dolly Varden and sockeye salmon smolt were forced into close contact.

Due to the high density of Dolly Varden immediately upstream of the smolt weir, we anticipated that the set times for the hoop trap could be kept to one hour or less, in order to reduce the chances of atypical feeding occurring within the trap (Murphy and Willis 1996). Our intention was to compare the frequency of occurrence of sockeye smolt in the diet of char captured using hook and line to those captured in the hoop trap. Fish were anesthetized using a clove oil solution, measured for mideye-to-fork length, and then sampled for stomach contents. The stomach contents of each fish were removed by flushing with the use of a small water pump (Murphy and Willis 1996). Stomach contents that were clearly identifiable as salmon smolt were preserved in individually marked bottles of alcohol for later identification to species, if possible.

ADULT ESCAPEMENT

Weir Counts

ADF&G operated an adult salmon counting weir at the outlet of the lake, approximately 50 m from saltwater, from 1967 to 1971, and again from 1981 to 2007. The weir was an aluminum bi-pod, channel, and picket design, with an upstream trap for enumerating and sampling salmon. The integrity of the weir was verified by periodic underwater inspections and through a secondary mark-recapture study (see below). The weir was operated from mid-June to early November in 2007. Beginning in 2003, in order to minimize handling of fish, we enumerated fish through the weir by pulling one or two pickets at a counting station, prior to 1 August. We placed a white board on the bottom of the streambed at the counting station to aid in fish identification. Once coho salmon began to enter the lake (typically around August 1st) we reverted to dipping fish out of the trap, as it was very important that all coho salmon were examined for missing adipose fins, which indicated the presence of coded-wire tags. Hugh Smith Lake coho salmon are an important indicator stock in southeast Alaska (Shaul et al. 2005). In 2007, we built a secondary trap designed to allow for free passage of fish into the lake, while allowing us to quickly close the trap when a coho salmon entered. We monitored the secondary trap with a camera so that in the event we failed to stop a coho salmon we were still able to identify it as adipose-clipped or unclipped. The modified trap allowed us to continue passing a portion of the sockeye salmon freely through the pickets throughout the season, while continuing to meet the goals of the ongoing coho salmon study at the lake.

Mark Recapture

As in past years, we conducted a two-sample mark-recapture population study, in conjunction with weir operations, to estimate the total spawning population of sockeye and coho salmon at Hugh Smith Lake during the 2007 season. These studies helped to determine if fish passed by the weir uncounted, or if sockeye salmon entered the lake before the weir was fish tight in mid-June. Adult sockeye salmon were marked at a rate of 10% with a readily identifiable fin clip at the weir. Fish that were to be marked were dip-netted from the trap, anesthetized, clipped, scale-sampled, and released upstream next to the trap to recover. Fish that did not appear healthy were not marked with a fin-clip. The population of fish passing through the weir was stratified through time on the following schedule: right ventral fin clip, 16 June–18 July; left ventral fin clip, 19

July–15 August; and partial dorsal fin clip, 16 August–November. All (100%) jack sockeye salmon that passed through the trap were marked on the same fin-clipping schedule as adults. Separate mark-recapture estimates were generated for adults and jacks.

We used Stratified Population Analysis System (SPAS) software (Arnason et al. 1996) to generate mark-recapture estimates of the total spawning population of sockeye salmon. SPAS was designed for analysis of two-sample mark-recapture data where marks and recoveries take place over a number of strata. This program was based on work by Chapman and Junge (1956), Darroch (1961), Seber (1982), and Plante (1990). We used this software to calculate: 1) maximum likelihood (ML) Darroch estimates and pooled-Petersen (Chapman's modified) estimates, and their standard errors; 2) X^2 tests for goodness-of-fit based on the deviation of predicted values (fitted by the ML Darroch estimate) from the observed values; and 3) two X^2 tests of the validity of using fully pooled data—a test of complete mixing of marked fish between release and recovery strata, and a test of equal proportions of marked fish in the recovery strata. We chose full pooling of the data (i.e., the pooled-Petersen estimate) if either of these tests was not significant ($p>0.05$). The manipulation of release and recovery strata in calculating estimates (the method used in SPAS) was presented and discussed at length by Schwarz and Taylor (1998). Again, two separate analyses were conducted: one for adults and one for jacks.

We deemed the weir count to be "verified" if it fell within the 95% confidence interval of the mark-recapture estimate of adult sockeye salmon, in which case the weir count was entered as the official escapement estimate. This was the same criterion as used in previous years (Geiger et al. 2003). The escapement goal range for this system is 8,000–18,000 spawners. The escapement goal was judged to have been met if the weir count was within 8,000 to 18,000 adult sockeye salmon, and the weir count was within the 95% confidence interval of the mark-recapture estimate for adult sockeye salmon. The escapement goal would have been deemed to have not been met if the weir count and the mark-recapture estimates were both outside of the escapement goal range. In the case where one or the other estimate fell within the escapement goal range, the weir count would have been used, unless the weir count was below the lower end of the 95% confidence interval of the mark-recapture estimate. Prior to the study we agreed to use the mark-recapture "point" estimate and not one or the other end of a confidence interval, for the purpose of judging the escapement objective.

Adult Length, Sex, and Scale Sampling

The age composition of adult sockeye salmon at Hugh Smith Lake was determined from a minimum of 600 scale samples collected from live fish at the weir. We began the season by taking scale samples at a rate of 1 in 10 (10%). Therefore, we simply took scales from all fish that were dipped from the trap for fin clipping. We lowered our scale sampling rate inseason, when it became clear that we would surpass our goal of 600 scale samples. The sex and length (mideye-to-fork to the nearest mm) was recorded for each fish sampled. One scale was taken from the preferred area (INPFC 1963), mounted on a gum card, and prepared for analysis as described by Clutter and Whitesel (1956). The weekly age-sex distribution, the seasonal age-sex distribution weighted by week, and the mean length by age and sex weighted by week were calculated using equations from Cochran (1977; pages 52, 107–108, and 142–144, Appendix B).

Escapement Otolith Sampling

We estimated the proportion of stocked, otolith-marked sockeye salmon in the escapement by collecting a systematic otolith sample from every 100th adult sockeye salmon that was passed through the weir over the entire duration of the run. We assumed that this sampling rate would yield a reasonable, self-weighted estimate of the stocked portion of the run, while at the same time it would have minimal impact on the run should the escapement come in below the lower bound of the escapement goal of 8,000–18,000 adult sockeye salmon.

We used standard sampling theory (Cochran 1977) to estimate the mean proportions (and standard errors) of stocked and wild sockeye salmon. Because the sample was a systematic sample rather than a random sample, the estimate of the variance is not strictly appropriate if the otolith-marked fish had different entry timing than wild fish. However, we expect the square root of the variance to overstate the standard error of the estimate, and we will assume that it is a reasonable approximation. We compared the proportion of stocked to wild fish in the escapement in each third of the run, based on the historical run-timing of sockeye salmon at the weir since 1982.

From 2002 to 2007, we also collected otoliths opportunistically from dead fish that were recovered from three sampling areas: on the spawning grounds at Buschmann and Cobb creeks, and on the adult weir. Sampling was distributed over the length of the spawning season. The carcass condition of each fish sampled for otoliths was recorded as spawned, unspawned, or bear-killed. For each of the three sampling areas a sub-sample of 96 otoliths was randomly selected for analysis from the bulk samples using a random number generator. The three sets of otolith samples, one each from Buschmann Creek, Cobb Creek, and the weir, were analyzed at the ADF&G Commercial Fisheries Thermal Mark Laboratory, Juneau, Alaska. This information was used to determine the distribution within the system of returning fish from the stocking program.

RESULTS

ZOOPLANKTON PRODUCTIVITY

Here we present results from our zooplankton sampling conducted in 2006. In 2007, samples were collected in April, June, August, and October. Analysis of the 2007 samples has not been completed at this time and will be included in a future report.

In 2006, the seasonal mean density of zooplankton was 349,000 per m^2, which is well above the 1981–2006 average of 306,000 per m^2. The seasonal mean density of cladocerans was the second highest level recorded at Hugh Smith Lake since 1981, while the density of copepods was close to the long-term average of 184,000 per m^2 (Figure 4). The seasonal mean density of *Bosmina*, the numerically dominant cladoceran in Hugh Smith Lake, was 87,000 per m^2, which represents an increase from 2005 and is above the long term average of 79,000 per m^2, from 1981–2006 (Stations A & B combined, Figure 5). The seasonal mean density of *Cyclops*, the numerically dominant copepod in Hugh Smith Lake, was 176,000 per m^2, which is equal to the long term average, from 1981–2006 (Figure 5). The seasonal mean density of *Daphnia* was well above average and approached the highest levels we have seen at the lake at 43,000 per m^2 (Figure 5). The mean weighted length of *Cyclops*, *Bosmina*, and *Daphnia l.* all showed slight increases from 2005 (Figure 6).

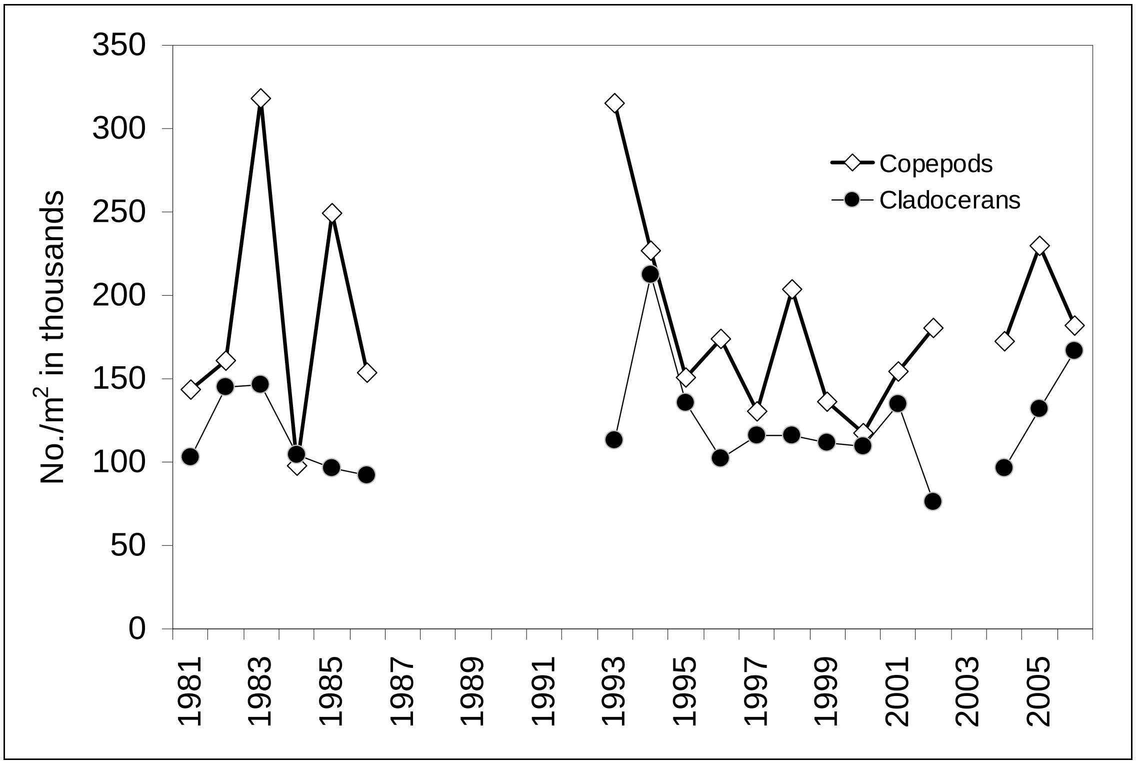

Figure 4.–Seasonal mean density of copepods and cladocerans in Hugh Smith Lake, from 1981–2006.

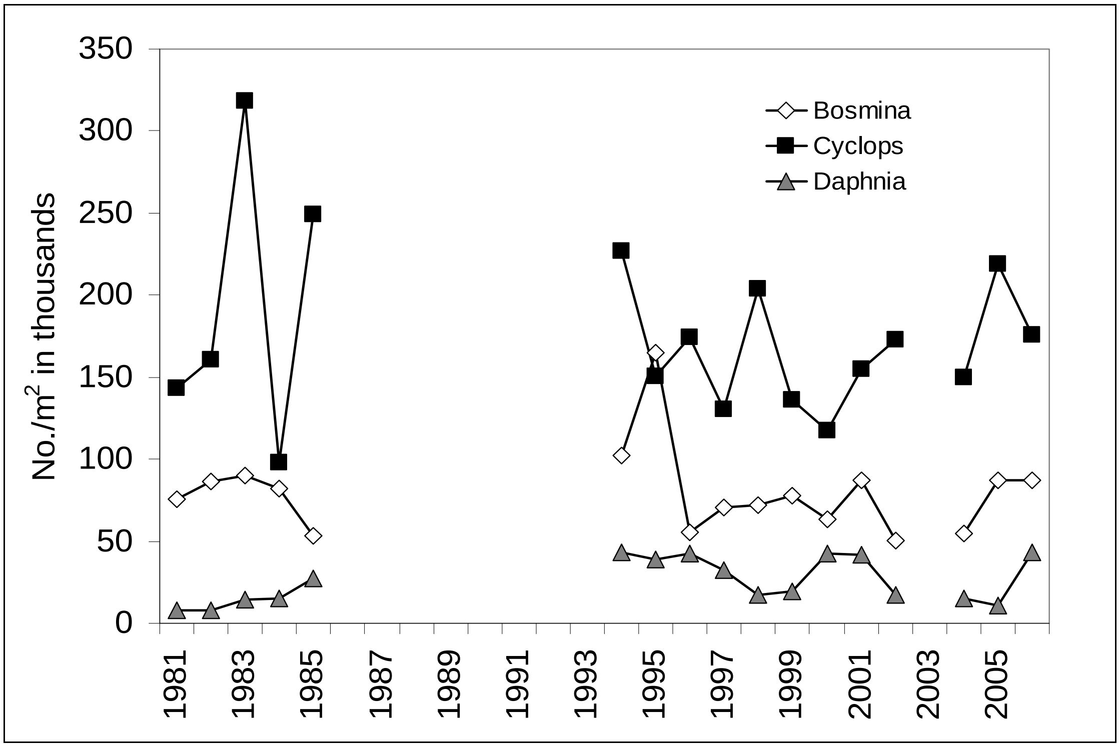

Figure 5.–Seasonal mean density of Bosmina, Cyclops, and Daphnia at Hugh Smith Lake, 1981–2006.

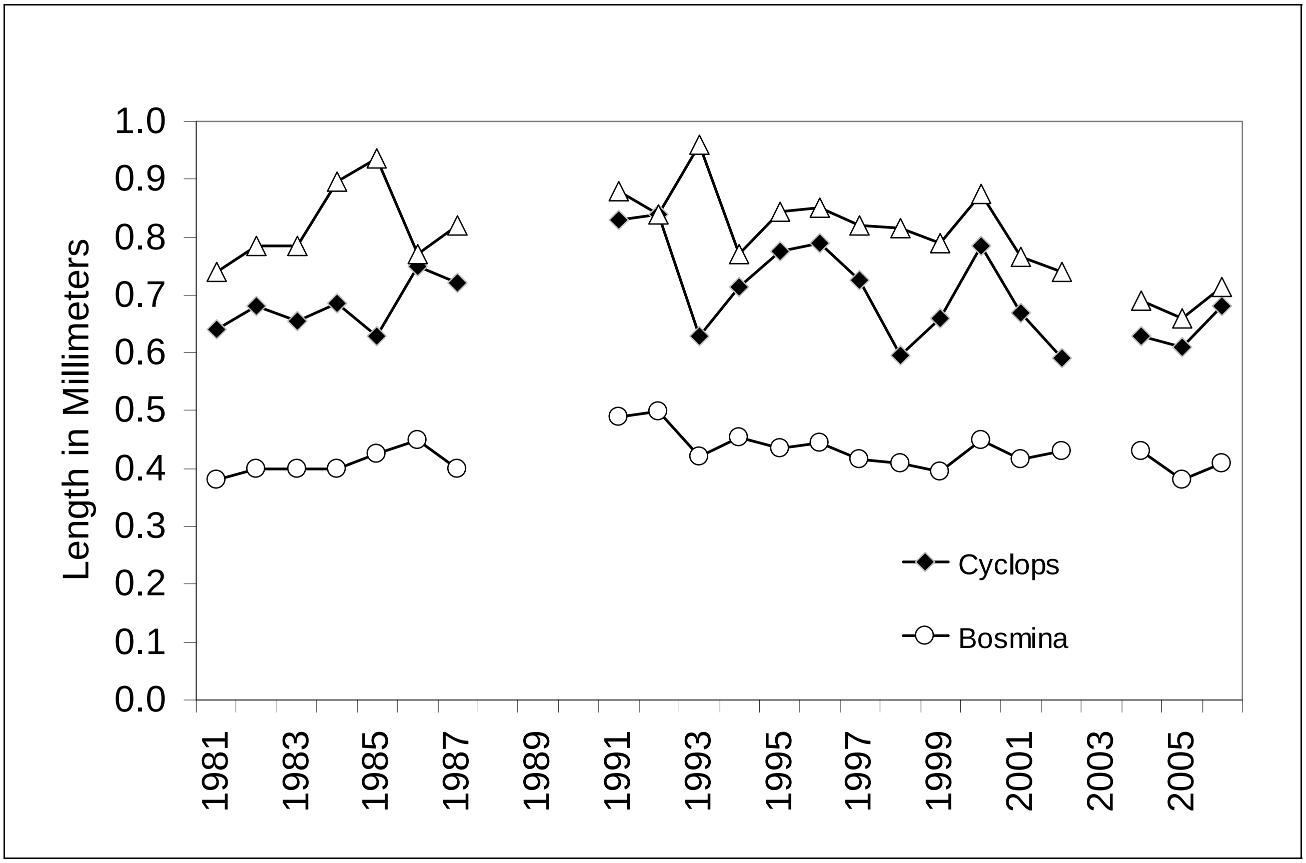

Figure 6.–Seasonal mean weighted length of three primary macrozooplankton species at Hugh Smith Lake, 1981–2006.

BUSCHMANN CREEK HABITAT EVALUATION

Overall, the system appeared to be fairly stable between 2006 and 2007. All of the significant changes noted occurred within the Beaver Pond Channel. During the summer, beavers continued to maintain a dam that had been constructed a short distance above the main fork in 2005 (Piston et al. 2006). During the fall, all three beaver dams present in the survey area were partially washed out by high water, allowing for free passage of fish through the entire reach of the Beaver Pond Channel typically monitored each season. The area immediately above the third dam, which had been a beaver pond complex since at least the mid-1990s, drained, and became a free flowing stream through the remainder of the season. The main channel of Buschmann Creek showed very little change since the 2006 season. It appeared that the Hatchery Channel and Side Channel C (Figure 3) may have had slightly more flow than in 2006, and appeared similar to what we observed in 2005.

Early in September, the number of sockeye salmon in Buschmann Creek was higher than in Cobb Creek. (Tables 1 and 2). The peak count in each stream occurred at the end of September and early October, and numbers of fish appeared higher in Cobb Creek during the peak of spawning. The numerous channels of Buschmann Creek are not all covered during each survey of the creek, so counts there are biased low compared to Cobb Creek, which has a single channel leading to a barrier falls and is easily surveyed in its entirety.

Table 1.–Counts of adult sockeye salmon in Buschmann Creek by stream section, 2007. Blanks indicate that the section was not surveyed on the corresponding date. Surveys conducted in the “Beaver Pond Channel” and “Above Hatchery Channel” sections were of varying length and should not be directly compared between dates.

Date	**2-Sep**	**2-Sep**	**7-Sep**	**7-Sep**	**12-Sep**	**12-Sep**	**24-Sep**	**24-Sep**	**9-Oct**	**9-Oct**
Condition	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead
Mouth Estimate	1,500		4,000		117		300		490	
Main Channel	504						808	27	535	98
Side Channel A			50							
Beaver Pond Channel							82	1	115	9
Fork to Hatchery Ch.	205						257	25	244	59
Above Hatchery Ch.							129	6	28	12
Hatchery Channel	359						622	56	531	143
Stream Total	1,068				443[a]		1,898	115	1,453	321

[a] On 12 September, a stream count was conducted, but the locations of fish were not recorded.

Table 2.–Counts of adult sockeye salmon in Cobb Creek, 2007. Each survey was conducted from the mouth to the barrier falls and covered all available spawning habitat within the creek.

Date	**14-Sep**	**14-Sep**	**19-Sep**	**19-Sep**	**4-Oct**	**4-Oct**	**12-Oct**	**12-Oct**
Condition	Live	Dead	Live	Dead	Live	Dead	Live	Dead
Count	516		1,220	110	3,893	200	2,385	300

STREAM TEMPERATURE MONITORING

Temperature data were collected from Buschmann and Cobb creeks between 28 July 2006 and 18 June 2007. In 2006, we located temperature loggers in areas less prone to being dug up by spawning salmon or washed away by shifting gravel, as happened during the winter of 2005–2006 (Piston et al. 2007). Despite the precautions, we again experienced a significant loss of temperature loggers over the winter of 2006–2007. We were able to retrieve data from Cobb Creek, the lower part of the Main Channel in Buschmann Creek, and the lower hatchery Channel of Buschmann Creek.

From 28 July 2006 to 18 June 2007, temperature profiles of the lower Buschmann Creek Main Channel and Cobb Creek showed a pattern that was typical of temperature comparisons between these streams from 2004 to 2006, with Cobb Creek being warmer than Buschmann Creek through late October and again after late April (Figure 7, Piston et al. 2006 and 2007). In 2007, we obtained temperature information from the Hatchery Channel of Buschmann Creek for the first time. Temperatures in the lower half of Hatchery Channel are modified by a small spring-fed creek that flows in from the south near the abandoned hatchery site. When the hatchery first moved to its Buschmann Creek location in 1902, it used this spring-fed creek, which had been identified as having the warmest water in the area in winter, to provide water for hatchery operations (Roppel 1982). During the winter of 2006–2007, water temperatures in the lower Hatchery Channel were significantly warmer than in Cobb Creek and the lower Main Channel of

Buschmann Creek (Figure 8). From 1 December 2006 to 28 February 2007, the number of cumulative thermal units in the lower Hatchery Channel was 228, compared to only 168 in the Buschmann Creek Main Channel and 84 in Cobb Creek. Most of the suitable spawning habitat in the Hatchery Channel lies above the spring-fed creek, so the warm winter temperatures in the lower Hatchery Channel likely have the greatest benefit for rearing coho salmon fry.

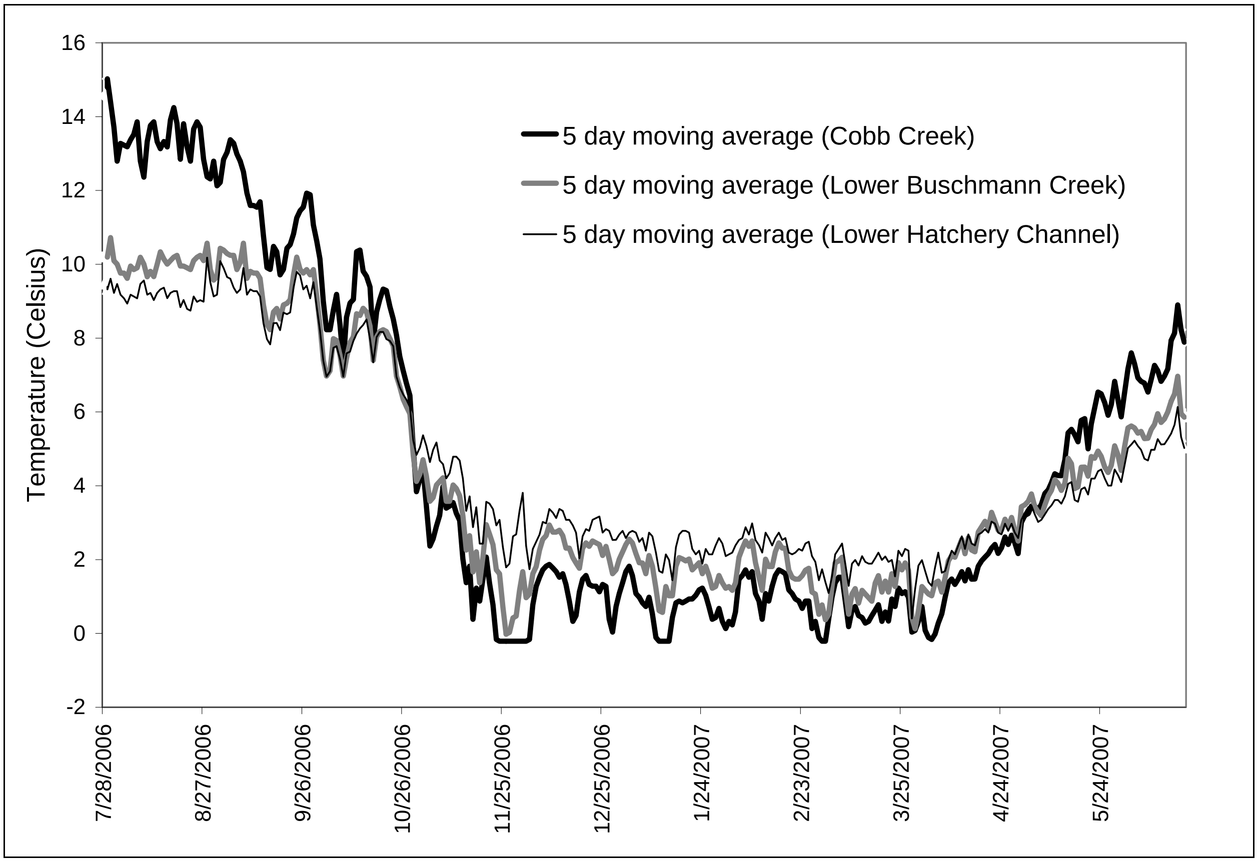

Figure 7.–Stream temperature profile for Cobb Creek, Lower Buschmann Creek Main Channel, and the Buschmann Creek lower Hatchery Channel, 28 July 2006 to 18 June 2007.

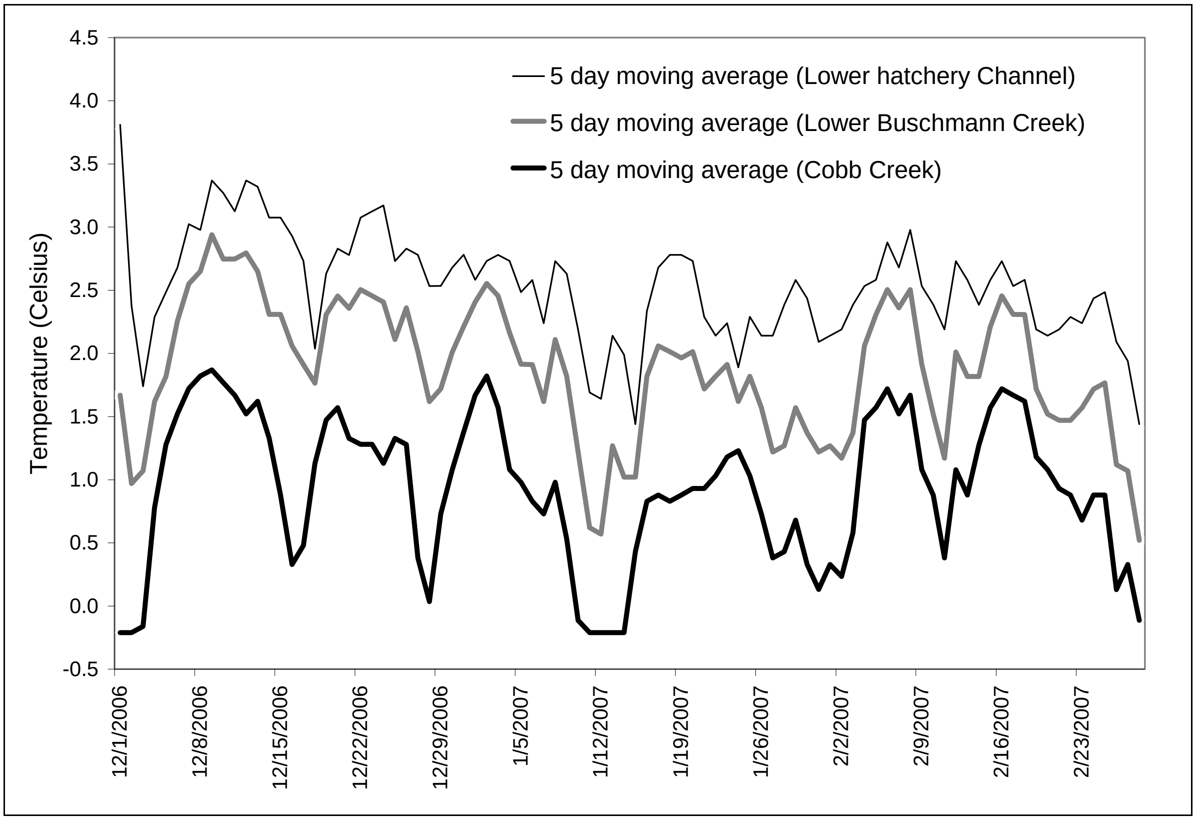

Figure 8.–Winter stream temperature profile for Cobb Creek, lower Buschmann Creek Main Channel, and the Buschmann Creek lower Hatchery Channel, 1 December 2006 to 28 February 2007.

FRY PRODUCTION

Hydroacoustic Surveys

We were unable to conduct a spring survey in 2007 because ice still covered more than half the lake's surface in early-April. Our first survey was conducted during the last week of July, after we determined that most of the next generation of sockeye fry had entered the lake from the spawning tributaries.

The total pelagic fish estimate for the July survey was 640,000 with a standard error of 60,700 (CV 9.49%). We caught a total of 429 fish in eight trawls, including two (0.5%) stickleback (*Gasterosteus aculeatus*) and one cutthroat trout (*Oncorhynchus clarkii*). Of the 426 sockeye fry captured, 96.9% were age 0 and 3.1% were age 1. The total estimate of sockeye fry in the lake was 623,000, with a 95% credible interval of 507,600 to 739,800.

The total pelagic fish estimate for the August survey was 565,500 with a standard error of 69,000 (CV 12.19%). We caught a total of 189 fish in five trawls, all of which were sockeye fry, with the exception of one adult sockeye salmon. Of the 188 sockeye fry captured, 98.9% were age 0 and 0.5% were age 1. The total estimate of sockeye fry in the lake was 552,600, with a 95% credible interval of 420,600 to 687,300.

The total pelagic fish estimate for the September survey was 463,500 with a standard error of 57,500 (CV 12.45%). We caught a total of 149 fish in six trawls, of which only one was a stickleback. Of the 148 sockeye fry captured, 97.3% were age 0 and 2.7% were age 1. The total estimate of sockeye fry in the lake was 446,400, with a 95% credible interval of 335,500 to 557,800.

The total pelagic fish estimate for the October survey was 267,000 with a standard error of 13,500 (CV 5.06%). We caught a total of 27 fish in five trawls, all of which were age 0 sockeye fry. The total estimate of sockeye fry in the lake was 240,200, with a 95% credible interval of 205,800 to 271,700. The late July to late October survival rate of rearing fry was approximately 39%, which is the lowest rate we have seen in the four years we have collected this information (Table 3).

Table 3.–Monthly hydroacoustic estimates of rearing sockeye salmon fry in Hugh Smith Lake and the approximate survival rates from the first survey of the summer to late October, 2004–2007.

	2004	2005	2006	2007
July		475,000	593,800	623,000
August	563,000	327,300		552,600
September	260,000	263,000	426,200	446,400
October	251,000	212,000	420,600	240,200
Approximate Survival Rate	45%	45%	71%	39%

Fry Emigration Timing

In 2007, sockeye fry had ceased entering the lake from Cobb Creek by the time of our first fyke net set on 4 July (only 6 fry captured). We set three times in Buschmann creek, catching 1,200 sockeye fry on 4 July, 335 on 12 July, and 180 on 18 July. This was typical of the pattern we observed in 2004 and 2006, where emigration from Buschmann Creek extended up to five weeks later than in Cobb Creek (Piston et al. 2006 and 2007).

SMOLT PRODUCTION

In 2007, we counted 88,695 sockeye smolt through the smolt weir between 22 April and 2 June (Table 4). However, nearly 2,000 sockeye smolt were passed on 31 May, the last day the smolt weir was fully operational. Although the smolt weir efficiency is never 100% (about 70% for coho salmon smolts, 1996 to 2005; L. Shaul, ADF&G, personal communication) it is possible that higher numbers than normal passed uncounted after the weir was removed this season. We sampled 933 sockeye smolt for scales and determined that the age composition, weighted by week, was 71% age 1, 27% age 2, and 2% age 3 (Figure 9, Table 4).

The freshwater age data presented in table 4, 1981–2001, vary slightly from those reported in Geiger et al. 2003, as several corrections were made (e.g., the percent of age–1 smolt in 1997 was erroneously reported as 11.7% in that report). In addition, the smolt weir count for 1986 that was reported in Geiger et al. 2003, Piston et al. 2006, and Piston et al. 2007 was actually an estimate based on a hydroacoustic survey. A section of the smolt weir was removed from 27–31 May, and researchers at the time probably assumed the hydroacoustic estimate of 373,000 was a better estimate. I judged that this hydroacoustic estimate should not be compared directly to smolt weir estimates and included the actual smolt count for 1986 in table 4 of this report. Although the estimate is certainly biased low, the overall capture efficiency on coho salmon appeared to be higher than in the following three seasons (assessment based on table 15 in Shaul 1994) and the estimate for sockeye salmon smolt in 1986 may be no less accurate than other years during the 1980s.

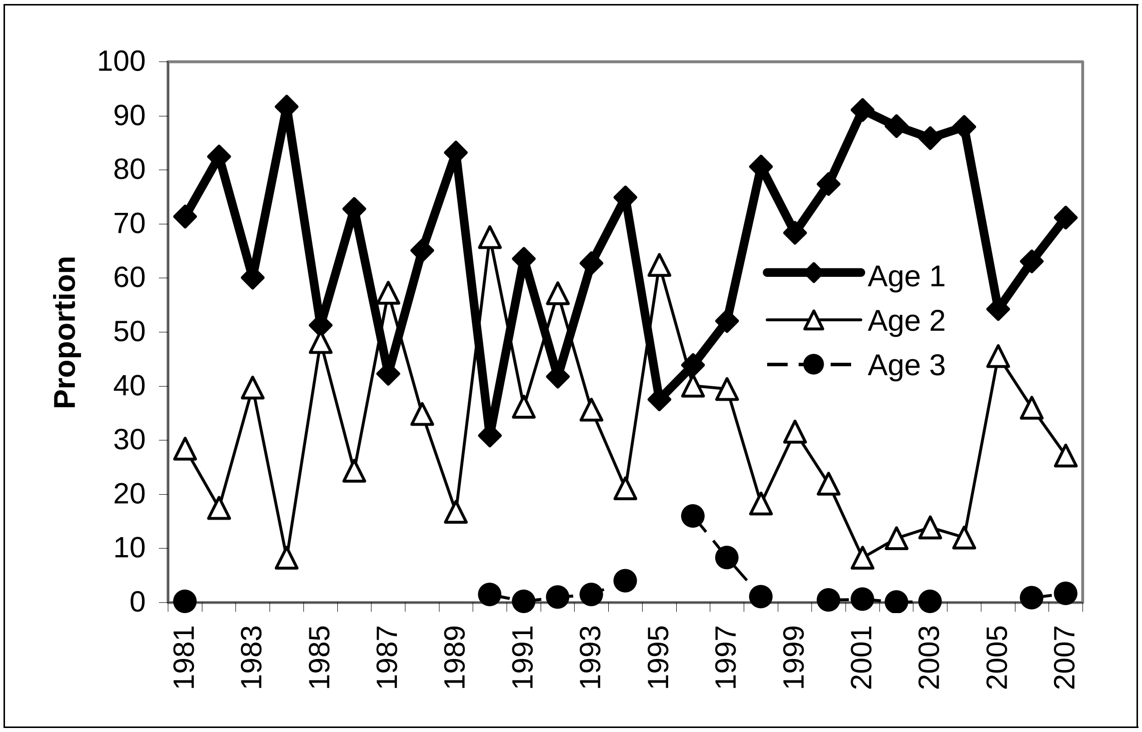

Figure 9.–Age composition of sockeye salmon smolt at Hugh Smith Lake, 1981–2007.

Table 4.–Hugh Smith Lake weir counts of sockeye smolt by smolt year, and stocked fry and pre-smolt releases by year of release, 1981–2007. Proportions of stocked and wild smolt were determined from otolith samples.

Release Year	Hatchery Release Numbers	Release Type	Smolt Year	Total Smolt Counted	Freshwater Age Percent of Total Age 1	Age 2	Age 3	Stocked Smolt Counted	Wild Smolt Counted	Percent Stocked Smolt
			1981	319,000	71%	29%	0%			
			1982	90,000	83%	18%	0%			
			1983	77,000	60%	40%	0%			
			1984	330,000	92%	8%	0%			
			1985	40,000	51%	48%	1%			
			1986	**58,000**[c]	73%	24%	3%			
1986	273,000	Unfed Fry	1987	104,000	42%	57%	1%			
1987	250,000	Unfed Fry	1988	54,000	65%	35%	0%			
1988	1,206,000	Unfed Fry	1989	427,000	83%	17%	0%			
1989	532,800	Unfed Fry	1990	137,000	31%	68%	2%			
1990	1,480,800	Unfed Fry	1991	75,000	64%	36%	0%			
1991			1992	15,000	42%	57%	1%			
1992	477,500	Fed Fry	1993	36,000	63%	36%	2%			
1993			1994	43,000	75%	21%	4%			
1994	645,000	Unfed Fry	1995	19,000	38%	62%	0%			
1995	418,000	Unfed Fry	1996	16,000	44%	40%	16%			
1996	358,000	Unfed Fry/ Pre-Smolt[a]	1997	44,000	52%	40%	8%			
1997	573,000	Unfed Fry	1998	65,000	81%	18%	1%	30,000	34,000	47%
1998	0		1999	42,000	68%	32%	0%	3,000	39,000	4%
1999	202,000	Pre-smolt[b]	2000	72,000	77%	22%	1%	---No data---		
2000	380,000	Pre-smolt[b]	2001	190,000	91%	8%	1%	145,000	44,000	77%
2001	445,000	Pre-smolt[b]	2002	297,000	88%	12%	0%	163,000	134,000	55%
2002	465,000	Pre-smolt[b]	2003	261,000	86%	14%	0%	185,000	76,000	71%
2003	420,000	Pre-smolt[b]	2004	364,000	88%	12%	0%	170,000	194,000	47%
2004	0		2005	77,000	54%	46%	0%		77,000	
2005	0		2006	119,000	63%	36%	1%		119,000	
2006	0		2007	89,000	71%	27%	2%		89,000	

[a] In 1996, SSRAA released 251,123 unfed fry into the lake in May and 106,833 pre-smolt in October. All fish from those releases were otolith marked.

[b] From 1999–2003, fry were pen-reared at the outlet of the lake beginning in late May and released as pre-smolt in late July and early August. All fish from those releases were otolith marked.

[c] The smolt weir count for 1986 that was reported in Geiger et al. 2003, Piston et al. 2006, and Piston et al. 2007 was actually an estimate based on a hydroacoustic survey. A section of the smolt weir was removed from 27–31 May, and researchers at the time probably assumed the hydroacoustic estimate of 373,000 was a better estimate. I judged that this estimate should not be compared directly to other smolt weir estimates and included the actual count for 1986 in this report.

DOLLY VARDEN PREDATION SAMPLING

In 2007, Dolly Varden first appeared at the smolt weir in mid-May, with highest catches occurring in the week leading up to the removal of the smolt weir (Table 5). Sampling for stomach contents started on 17 May and continued until 31 May. A total of 58 Dolly Varden were examined during the two-week sampling period, of which 12 were sampled from the smolt weir trap, 30 were captured with rod and reel, and 16 were captured using baited hoop traps. All 58 fish that were sampled had empty stomachs, with the exception of one fish that contained a small amount of unidentified insect parts. Most fish were described by the field staff as being very skinny, with concave bellies.

Rod and reel proved to be the most effective means of capturing fish for sampling, although it was often difficult to get the fish to bite and many of them were snagged. In order to reduce predation in the smolt weir trap, the trap was set up with a predator guard that only allowed fish below a certain size to enter, so the size of Dolly Varden sampled from the weir trap was biased towards smaller fish. Surprisingly, the baited hoop traps were completely ignored during the daylight hours, despite the fact that large numbers of Dolly Varden were in close proximity to the traps. One set that was soaked over night produced 16 fish, but the bait was untouched and it appeared that the fish may have simply blundered into the trap due to the large number of fish swarming around the location. None of the fish sampled from the baited hoop traps had any of the salmon eggs that were used for bait in their stomachs.

Table 5.–Daily counts of Dolly Varden passed downstream through the Hugh Smith Lake smolt weir, 2007.

Date	Daily	Cumulative
5/12/2007	1	1
5/13/2007	0	1
5/14/2007	0	1
5/15/2007	3	4
5/16/2007	0	4
5/17/2007	12	16
5/18/2007	342	358
5/19/2007	1	359
5/20/2007	98	457
5/21/2007	95	552
5/22/2007	12	564
5/23/2007	530	1,094
5/24/2007	2	1,096
5/25/2007	220	1,316
5/26/2007	1,240	2,556
5/27/2007	81	2,637
5/28/2007	745	3,382
5/29/2007	0	3,382
5/30/2007	2	3,384
5/31/2007	1,120	4,504

ADULT ESCAPEMENT

In 2007, the adult weir was fish-tight from 17 June to 4 November, and we passed 33,743 adult sockeye salmon and 236 jacks into the lake. The total adult sockeye salmon escapement, including fish killed at the weir for otolith samples, was 34,077. The adult escapement exceeded the upper end of the escapement goal range of 8,000–18,000 sockeye salmon for the fifth consecutive year (Figure 10). Stocked fish comprised about 60% of the adult escapement, or about 20,400 fish (SE=913), and wild fish comprised 40% of the escapement, or about 13,700 fish (SE=913). This is the second largest wild sockeye salmon escapement at Hugh Smith Lake since 1992 and is the third consecutive wild escapement within the escapement goal range of 8,000–18,000.

The run-timing through the weir was very late in 2007. The mid-point of the run did not occur until 28 August, the latest 50th-percentile date of the run over the past 26 years (mean=8 August). Nearly 23,000 fish passed the weir after 26 August; about 16,000 of which were stocked fish. Most of these fish entered the system in a nine-day period, 26 August–3 September, and the 75th percentile of the run occurred on 1 September. The run-timing was late for both wild and stocked fish, but stocked fish seemed especially late. For example, between 16 June and 25 August approximately 6,800 wild sockeye salmon passed through the weir, and another 6,800 passed into the lake from 26 August through early November. For stocked fish, only 4,300 fish passed the weir prior to 26 August and 16,000 passed from 26 August through early November; thus nearly 80% of the stocked fish passed the weir after 26 August, compared to 50% of the wild fish.

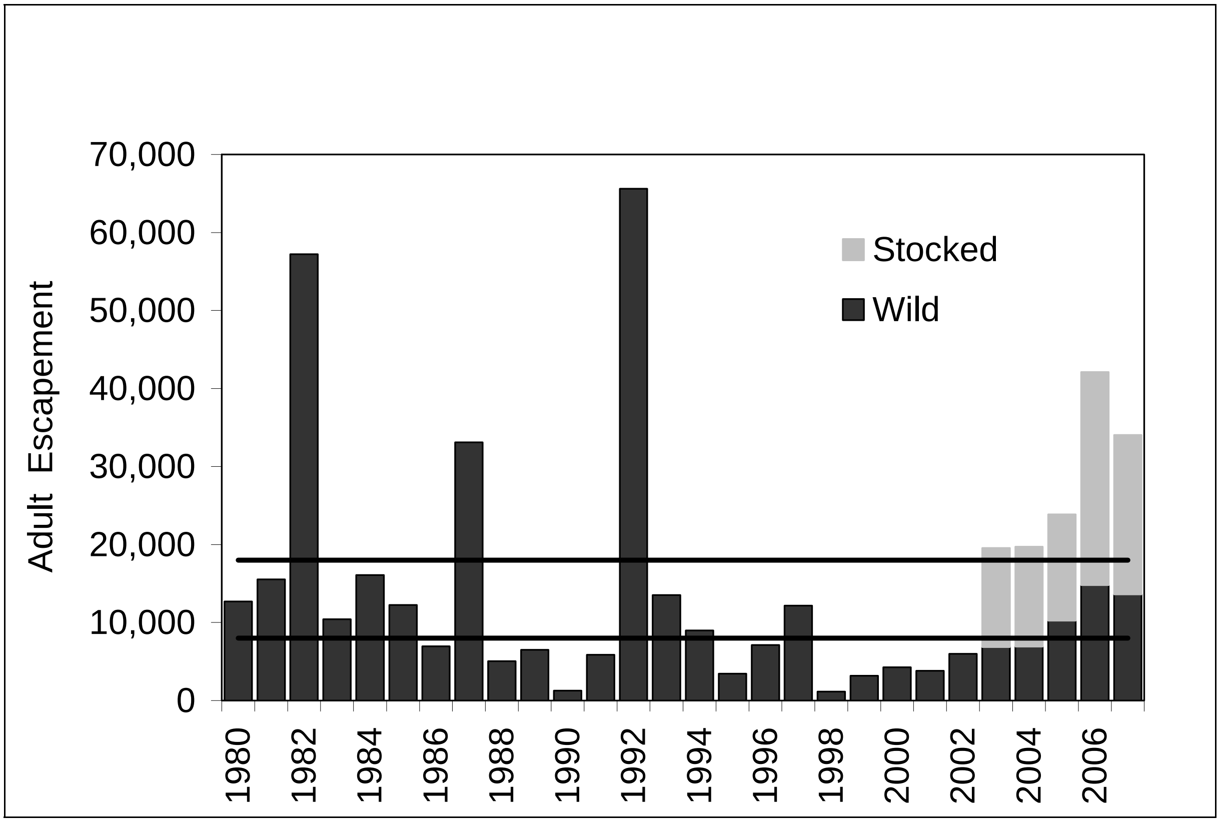

Figure 10.–Annual sockeye salmon escapement at Hugh Smith Lake, 1982–2007. The black horizontal lines show the escapement goal range of 8,000 to 18,000 adult sockeye salmon. This escapement goal range includes both wild and hatchery stocked fish. From 2003 to 2007, the bars are divided to show our estimate of wild (black) and stocked fish (gray).

In 2007, a total of 3,413 adults were marked with different fin clips over three marking strata. Between 16 June and 18 July, 317 adult sockeye salmon were marked with a right ventral fin clip. From 19 July to 15 August, 501 adult sockeye salmon were marked with a left ventral fin clip, and from 16 August to 3 November, 2,595 adult sockeye salmon were marked with a partial dorsal fin clip. Recapture sampling on the spawning grounds was spread out over the course of the spawning season, from 2 September to 28 October (Table 6). We also sampled all dead fish that washed up on the weir through 3 November (Table 6). A total of 1,764 fish were sampled for fin clips, of which 176 were marked (Table 6). The result of a X^2 test of complete mixing of marked fish between the marking and recovery events was significant ($p<0.01$); however, a test for equal proportions of marked fish on the spawning grounds was not significant ($p=0.74$), therefore we used the pooled-Petersen estimate. Our final estimate was 34,000 (SE=2,350: 95% CI=29,500 to 38,500) adult Sockeye salmon. The weir count of 33,743 fell within the 95% confidence interval of the mark-recapture estimate, and we deemed the weir count to be verified by the mark-recapture estimate. A coefficient of variation of 7% easily met our objective of a coefficient of variation of no greater than 15%. We were not able to generate a mark-recapture estimate of the jack population, due to the small numbers of jacks marked at the weir trap (68 fish) and recovered on the spawning grounds (three).

Table 6.–Recapture results for the adult sockeye salmon mark-recapture study, 2007.

		Number of Marked Fish			Number	Total Number
Date	**Sampling Area**	**Left Ventral**	**Right Ventral**	**Dorsal**	**Unmarked**	**Sampled**
2-Sep	Buschmann Creek	5	7	3	116	131
6-Sep	Cobb Creek	0	0	0	4	4
7-Sep	Buschmann Creek	0	4	0	57	61
9-Sep	Cobb Creek	1	5	1	42	49
12-Sep	Buschmann Creek	7	8	7	209	231
14-Sep	Cobb Creek	8	8	3	197	216
17-Sep	Cobb Creek	1	4	2	53	60
20-Sep	Cobb Creek	2	0	2	32	36
22-Sep	Weir	0	0	0	1	1
23-Sep	Weir	0	0	0	2	2
24-Sep	Weir	0	0	1	5	6
25-Sep	Weir	0	0	0	5	5
26-Sep	Weir	0	0	0	5	5
27-Sep	Weir	0	0	2	4	6
28-Sep	Weir	0	0	0	2	2
29-Sep	Weir	0	0	0	4	4
30-Sep	Weir	0	0	1	4	5
30-Sep	Buschmann Creek	1	1	12	73	87
1-Oct	Weir	0	0	0	5	5
2-Oct	Weir	1	0	0	11	12
2-Oct	Cobb Creek	0	0	2	32	34
3-Oct	Weir	0	0	0	13	13
4-Oct	Weir	0	0	0	15	15
4-Oct	Cobb Creek	0	0	5	48	53
5-Oct	Weir	0	0	1	17	18
6-Oct	Buschmann Creek	0	0	3	30	33
6-Oct	Weir	0	0	2	21	23
7-Oct	Weir	0	1	1	12	14
8-Oct	Weir	0	0	3	27	30
9-Oct	Weir	0	0	0	24	24
10-Oct	Weir	0	0	2	23	25
11-Oct	Weir	1	0	4	29	34
12-Oct	Cobb Creek	0	0	2	50	52
12-Oct	Weir	1	0	1	32	34
13-Oct	Weir	0	0	5	29	34
14-Oct	Weir	0	0	4	36	40
15-Oct	Weir	2	1	6	36	45
16-Oct	Weir	0	0	1	24	25
16-Oct	Buschmann Creek	0	1	4	33	38
17-Oct	Weir	1	0	3	40	44
18-Oct	Weir	0	0	3	14	17
18-Oct	Buschmann Creek	0	1	1	25	27
19-Oct	Weir	0	0	0	21	21
20-Oct	Weir	0	0	6	15	21
21-Oct	Weir	0	0	4	21	25
22-Oct	Weir	0	0	1	10	11
23-Oct	Weir	0	0	1	16	17
24-Oct	Weir	0	0	2	7	9
25-Oct	Weir	0	0	0	6	6
26-Oct	Weir	0	0	1	19	20
27-Oct	Weir	0	0	0	10	10
28-Oct	Weir	0	0	1	10	11
28-Oct	Cobb Creek	0	0	0	6	6
29-Oct	Weir	0	0	0	2	2
30-Oct	Weir	0	0	0	1	1
1-Nov	Weir	0	0	0	1	1
2-Nov	Weir	0	0	0	1	1
3-Nov	Weir	0	0	1	1	2
	Total	31	41	104	1,588	1,764

The age composition of the adult sockeye salmon, based on scale data, was 8.4% 2-ocean and 91.6% 3-ocean fish, with age-1.3 fish being the dominant age class (Figure 11, Table 7). Typically, age-1.3 fish have been the dominant age class of sockeye salmon at Hugh Smith Lake, although age-1.2 fish have dominated in a few years where we had a weak return of 3-ocean fish, or in recent years, when large returns of pen-reared stocked fish returned to the lake. In 2007, 3-ocean fish were the only age class returning from the final release from the stocking program in 2003. The estimated number of 2-ocean fish in the escapement (2,829), returned to a level that was typical of numbers observed prior to the pen-reared pre-smolt stocking program (Figure 12). This is a dramatic decrease from the more than 24,000 2-ocean fish in the 2006 escapement (Figure 12). Although we did not obtain separate estimates of age composition between stocked and wild fish, the trends in age composition and numbers of fish by age class over the past six years indicated that the fish from the stocking program tended towards an earlier age at return than was typical for wild fish within the system (Figures 11 and 12).

In 2007, we aged all of the otoliths from the systematic sample of 1 out of every 100 sockeye salmon sampled at the weir so that we could obtain an estimate of the age composition of wild fish. However, after removing the hatchery-marked fish from the sample, we were left with only 134 wild fish samples. Despite the fact that all of the age-1.3 hatchery fish were removed from the sample, the remaining otoliths from wild fish showed a lower percentage of 2-ocean fish than the scale data, which included a large number of 3-ocean hatchery fish. We interpreted this to mean that the sample size of otoliths from wild fish was probably too small to estimate the age composition of the wild escapement.

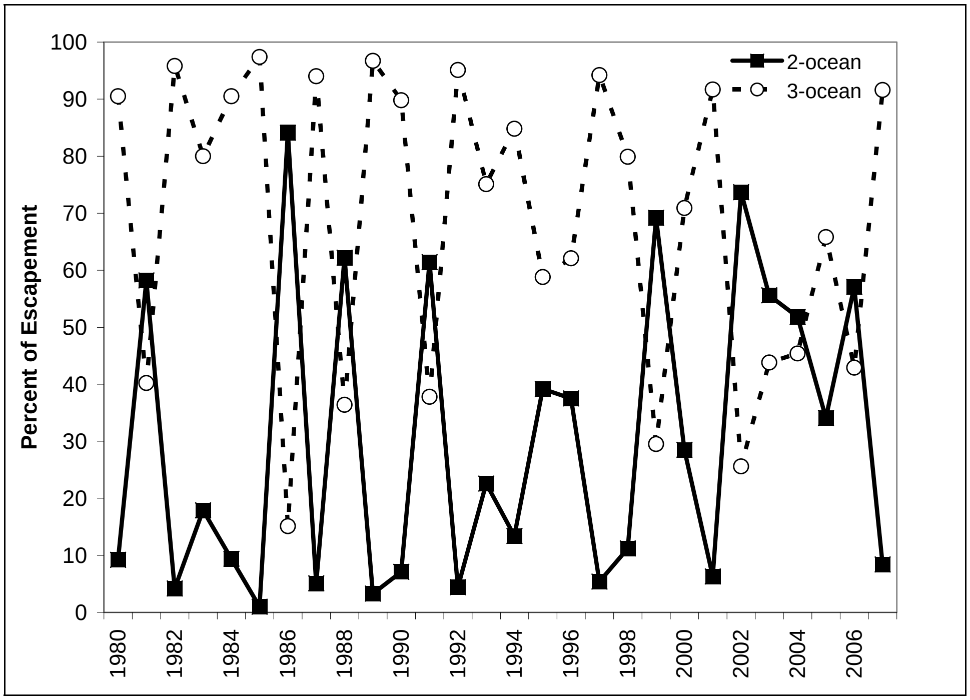

Figure 11.–Annual proportions of 2-ocean and 3-ocean aged sockeye salmon in the Hugh Smith Lake escapement, 1982–2007.

Table 7.–Age composition of the 2007 adult sockeye salmon escapement at Hugh Smith Lake based on scale samples, weighted by statistical week.

		Age Class				
Stat Week		**1.2**	**2.2**	**1.3**	**2.3**	**Total**
25-26	Sample Size			18	4	22
	Esc. Age Class			497	111	608
	Proportion			82%	18%	
	SE of %			8%	8%	
27	Sample Size	1		18	7	26
	Esc. Age Class	24		440	171	635
	Proportion	4%		69%	27%	
	SE of %	4%		9%	9%	
28	Sample Size	1		54	2	56
	Esc. Age Class	25		1,569	58	1,652
	Proportion	2%		96%	4%	
	SE of %	2%		3%	2.5	
29	Sample Size			32	7	39
	Esc. Age Class			736	161	897
	Proportion			82%	18%	
	SE of %			6%	6%	
30	Sample Size	1	2	56	13	72
	Esc. Age Class	32	63	1773	412	2,280
	Proportion	1%	3%	78%	18%	
	SE of %	1%	2%	5%	5%	
31	Sample Size	3	1	27	8	39
	Esc. Age Class	120	40	1,083	321	1,564
	Proportion	8%	3%	69%	21%	
	SE of %	4%	3%	7%	7%	
32	Sample Size		1	32	6	39
	Esc. Age Class		13	414	78	505
	Proportion		3%	82%	15%	
	SE of %		3%	6%	6%	
33	Sample Size		1	6	1	8
	Esc. Age Class		63	376	63	502
	Proportion		13%	75%	13%	
	SE of %		12%	16%	12%	
34	Sample Size	1	1	56	17	75
	Esc. Age Class	81	81	4,508	1,369	6,039
	Proportion	1%	1%	75%	23%	
	SE of %	1%	1%	5%	4.8	
35	Sample Size	24	5	157	19	205
	Esc. Age Class	1,566	326	10,243	1,240	13,375
	Proportion	12%	2%	77%	9.3	
	SE of %	2%	1%	3%	2	
36	Sample Size	3		26	8	37
	Esc. Age Class	306		2,648	815	3,769
	Proportion	8%		70%	22%	
	SE of %	5%		8%	7%	
37-45	Sample Size	1		12	4	17
	Esc. Age Class	114		1,373	458	1,945
	Proportion	6%		71%	24%	
	SE of %	6%		11%	11%	
Total	Escapement by Age Class	2,243	586	25,660	5,254	33,743
	SE of Number	39	9	481	108	
	Proportion by Age Class	7%	2%	76%	16%	
	SE of %	0%	0%	1%	0%	
	Sample Size	34	11	494	96	

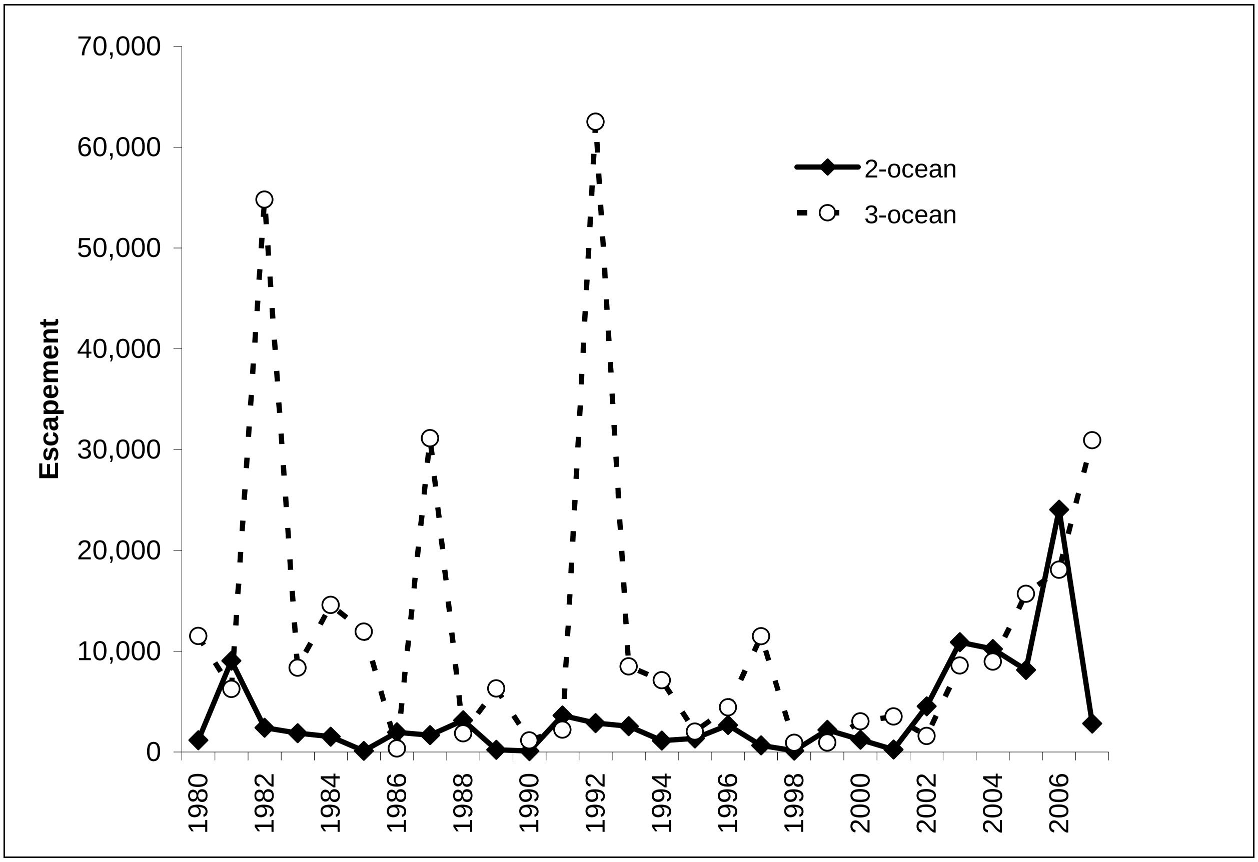

Figure 12.–Annual numbers of 2-ocean and 3-ocean aged sockeye salmon in the Hugh Smith Lake escapement, 1980–2007.

As in the past five seasons (Piston et al. 2007), stocked fish exhibited an unequal spawning distribution within the system in 2007. The vast majority of the fish milling about at the weir and attempting to spawn at the outlet of the lake were otolith marked (92%). Samples from the two primary spawning tributaries showed that approximately 53% of the fish at Cobb Creek and 30% of the fish at Buschmann Creek were otolith marked (Table 8).

Table 8.–Proportion of marked and unmarked otoliths from adult sockeye salmon carcass samples, by recovery location, Hugh Smith Lake, 2002–2007.

		Year					
Sample Location	**Otolith Status**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Buschmann Creek	Unmarked	187	36	96	95	64	67
	%	83%	67%	84%	99%	67%	70%
	Marked	37	18	18	1	32	29
	%	17%	33%	16%	1%	33%	30%
Cobb Creek	Unmarked	19	41	30	43	21	45
	%	17%	32%	36%	45%	22%	47%
	Marked	90	87	53	53	75	51
	%	83%	68%	64%	55%	78%	53%
Weir	Unmarked	4	19	7	3	2	8
	%	6%	9%	5%	3%	2%	8%
	Marked	64	190	144	93	94	88
	%	94%	91%	95%	97%	98%	92%

DISCUSSION

From 2005 to 2007, the wild portions of the sockeye salmon escapements at Hugh Smith Lake were estimated (based on otolith samples) to be over 10,000 fish annually. The upper end of the escapement goal range of 8,000–18,000 adult sockeye salmon, which includes stocked fish, has now been surpassed for five consecutive years. Fishing effort in the seine fishery near the mouth of Boca de Quadra inlet has declined substantially since the early 1990s and there was almost no effort at all in 2007 (Figure 13). From 2000 to 2007, the effort level in the nearby drift gillnet fishery was only about 50% of the effort levels in the preceding 20 years (Figure 13). In 2008, the adult sockeye salmon run at Hugh Smith Lake will be composed entirely of wild fish. The recent decreasing trend in fishing pressure, combined with a significant increase in wild adult escapement since the 1990s, suggests that runs should continue to meet escapement goals in the near future as long as environmental conditions in the lake and marine waters remain favorable for sockeye salmon survival.

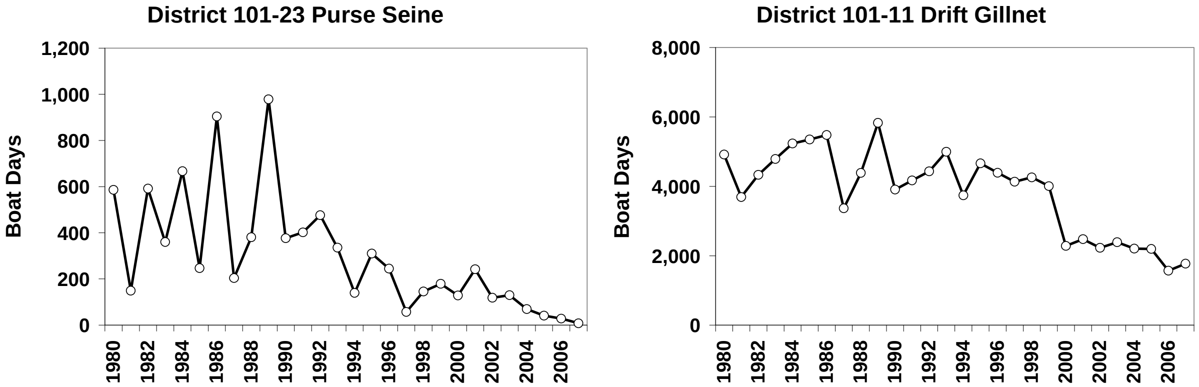

Figure 13.–Fishing effort in boat days for the District 101-23 purse seine fishery and the District 101-11 gillnet fishery, 1980–2007.

Age-1.3 stocked fish from the final release of the pen-rearing program returned in large numbers in 2007 (Figure 10); however, as in past years (Piston et al. 2007), large numbers of the stocked fish milled about near the weir and attempted to spawn in unsuitable habitat (Table 8). Large numbers of stocked fish also entered the primary spawning tributaries, but in the past four years this did not cause the desired effect of increasing juvenile production in the system. Smolt numbers have increased since the late 1990s, but this seems to be related to the upswing in wild escapement, rather than a product of the large returns of stocked fish. For example, even though the total escapement nearly quadrupled in 2003, primarily due to a large influx of stocked fish, the smolt abundance in 2005 actually decreased from 2004 numbers and has remained flat the last two seasons at a level that had been reached prior to the first large returns of stocked fish in 2003 (Figure 14). In 2006, the adult escapement increased to 42,000 fish, but based on the 2007 fall hydroacoustic survey it appears that in 2008 we are unlikely to see any increase in smolt over the recent average. From 2001 to 2007, estimates of wild smolt averaged 105,000 (range: 44,000–194,000).

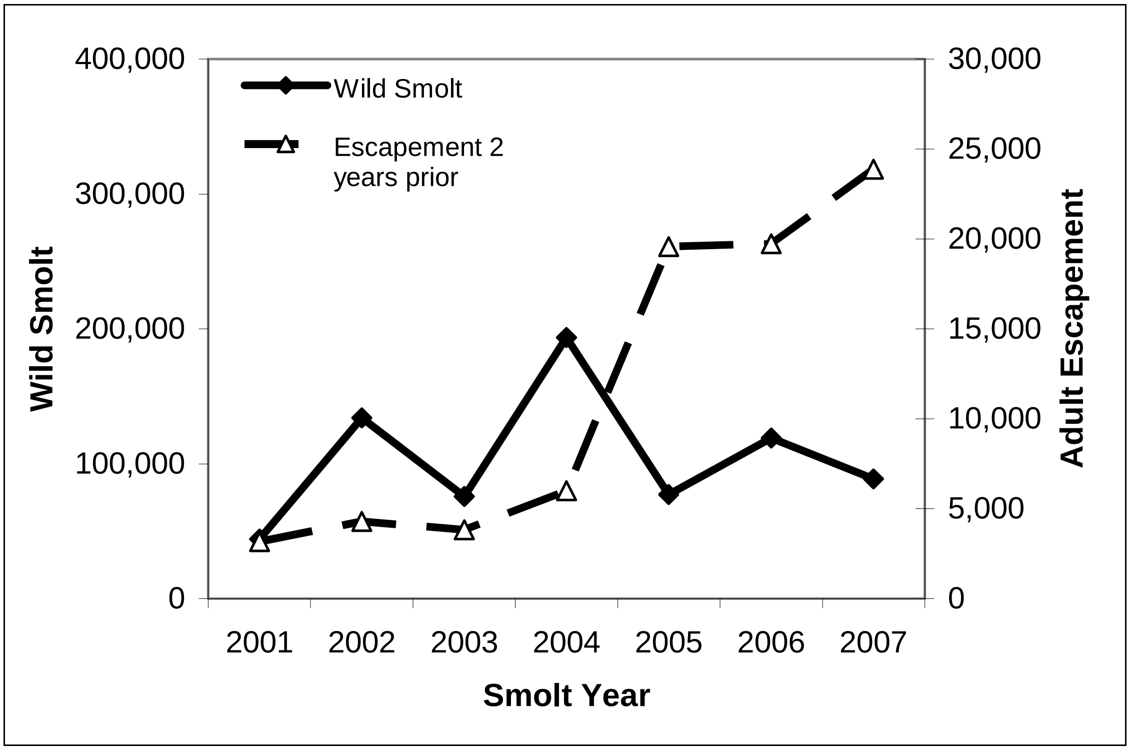

Figure 14.–Smolt weir estimates plotted against adult escapement 2 years prior, 2001–2006.

The results of our monthly hydroacoustic surveys suggest that the survival rate of fry in the lake was slightly lower during the summer of 2007 than it was in the past three seasons. We estimated that the survival rate of juvenile sockeye salmon from late July to late October was approximately 39%, which is considerably lower than our estimated mid-summer to late fall survival rate of 71% in 2006, but relatively close to the 45% mid-summer to late fall survival rates obtained in 2004 and 2005 (Table 3). In 2007, the mortality rate was highest from late September to late October, which is a different pattern than we had seen in the previous three seasons when mortality was initially high and declined through September (Table 3).

A comparison of our 2006 fall hydroacoustic survey and the 2007 smolt weir count indicated that either the hydroacoustic estimate was biased high, or winter survival was much lower than in the past three years. Late ice cover on the lake prohibited us from conducting a spring 2007 hydroacoustic survey; however, assuming a 70% overwinter survival rate from our estimated 421,000 fall fry in 2006, we would have expected 295,000 sockeye fry to have survived the winter. Our 2007 smolt weir count of 88,696 was much lower than expected based on the fall 2006 hydroacoustic survey, even with a 70% smolt weir efficiency factored in. Other assumptions that would need to be made to compare the fall hydroacoustic estimate to the smolt weir count include the number of age-1 holdovers and mortality during the April through May emigration period. It is also possible that the smolt weir efficiency was lower than average in 2007 due to the late timing of the smolt emigration. Nearly 2,000 sockeye smolt were passed on 31 May, the last day the smolt weir was fully operational and the crew reported seeing several schools of sockeye smolt after the weir had been dismantled.

From 2004 to 2007, we monitored the spawning habitat in Buschmann Creek with the goal of providing baseline information that could be used for evaluating the effects of stream channel shifts in lower Buschmann Creek (Piston et al. 2006). Since the initial habitat inventory in 2004, the spawning habitat in Buschmann Creek has been relatively stable. The most significant changes have occurred within the Beaver Pond Channel (Figure 3) where several beaver dams have been repeatedly washed out and rebuilt over the past three seasons. During the fall of 2007 all three of the beaver dams in the area typically surveyed by foot were partially washed out by high water, allowing for free passage of fish through that area of the Beaver Pond Channel. The area immediately above the third dam, which has been a beaver pond complex since at least the mid-1990s, drained, and a free-flowing stream was present late in the season. The Beaver Pond Channel typically had relatively small numbers of spawning sockeye salmon compared to other stream sections in Buschmann Creek, and it is likely that these changes had minimal effect, positive or negative, on the overall production from the system. For example, during a fairly complete survey of all of Buschmann Creek’s various channels on 27 September 2006, only 3% of the 2,526 adult sockeye salmon counted were in the Beaver Pond Channel (Piston et al. 2007). On another broad scale survey conducted on 24 September 2007, only 4% of a total survey estimate of 1,898 adult sockeye salmon were present in the Beaver Pond Channel (Table 1). It is likely that the beaver dams in this section will be quickly rebuilt and the availability of spawning habitat will continue to fluctuate on an annual basis.

Sockeye salmon smolt are clearly not a major springtime prey item for Dolly Varden at Hugh Smith Lake. During the spring smolt emigration period, there was very little, if any, predation of sockeye salmon smolt by the wintering Dolly Varden that leave Hugh Smith Lake concurrently with the smolt. With the exception of one fish that had a small amount of insect parts in its stomach, all of the Dolly Varden we sampled in 2007 had empty stomachs and appeared to be very thin. The presence of the smolt weir does not lead to increased predation rates by Dolly Varden by forcing the fish into close proximity to the sockeye salmon smolt. Studies elsewhere in Alaska have reached similar conclusions about the effects of Dolly Varden predation on salmon smolt.

From 1962–1964, ADF&G conducted a food habit study of Dolly Varden at a weir below Eva Lake, Baranof Island (Armstrong 1965). The results of the study showed that very little predation of salmonids was occurring at that system during the spring emigration period (Armstrong 1965). The researchers sampled 1,372 Dolly Varden over a three-year period and found that approximately 80% of the fish had empty stomachs and only three fish were identified as having juvenile salmon in their stomach contents (Armstrong 1965). The researchers at Eva Lake also reported Dolly Varden mixing with schools of emigrating salmon smolt in front of the weir, but they observed very little feeding behavior in these fish—a similar situation to what we have observed at the Hugh Smith Lake weir.

Morton (1982) reported that out of over three thousand Dolly Varden stomachs examined in Karluck Lake and Karluck River, from 1939–1941, only five juvenile sockeye salmon were identified as prey items. Of 659 downstream migrant Dolly Varden examined at the mouth of the Karluck River in May and June, 1939–1941, 80% had empty stomachs and only four contained juvenile sockeye salmon, despite the fact that sockeye salmon are the most abundant salmon species in the Karluk system (e.g., over one million escapement in 1940; Morton 1982). Fish items made up over 40% of the diet in the Dolly Varden at Karluk Lake during the summer and fall; however, over 96% of the fish items consumed were scavenged salmon eggs and another 2% was scavenged flesh from spawned out adult sockeye salmon (Morton 1982).

The Dolly Varden leaving Hugh Smith Lake probably resume feeding as soon as they reach saltwater and it is possible that predation on sockeye smolt occurs in the estuary. Lagler and

Wright (1962) examined 143 Dolly Varden for stomach contents in the estuary at Little Port Walter, Baranof Island, and found that only four fish (2.8%) had evidence of juvenile salmon remains. They found that capelin, sand lance, and herring made up approximately 90% of the total volume of food in the Dolly Varden they examined. Armstrong (1965) sampled 145 Dolly Varden in Hanus Bay, Baranof Island, and found that of the 102 fish with stomach contents, 22 of them contained juvenile salmon remains. All of the fish remains that were identifiable were of pink and chum salmon, which enter saltwater at much smaller sizes than sockeye and coho salmon smolt and are probably more readily captured by Dolly Varden.

Since the spawning escapement at Hugh Smith Lake reached a low of 1,100 adult sockeye salmon in 1998, we have seen an increasing trend in wild sockeye salmon escapement that has culminated with three consecutive seasons where the wild portion of the escapement was within the escapement goal range. Habitat at the lake remains in a pristine condition and zooplankton productivity was above long-term averages in 2006. The recent decreasing trends in fishing pressure, combined with a significant increase in wild adult escapement and juvenile production since the 1990s, should allow for returns of sockeye salmon to Hugh Smith Lake that continue to meet escapement goals, assuming environmental conditions in the lake and marine waters remain favorable for sockeye salmon survival.

ACKNOWLEDGEMENTS

I would like to thank the following people for their significant contributions to the studies at Hugh Smith Lake. Xinxian Zhang developed the Bayesian model for analyzing trawl data presented in Appendix A, conducted analysis of trawl data, and provided other statistical support and review. Steve Heinl provided oversight and assistance for all of the projects related to Hugh Smith Lake. We thank Nick Olmstead, Molly Kemp, Bob Farley, and Jill Walker for help with nearly every aspect of data collection and operations in the field. Kim Vicchy provided logistical support for the project and occasionally baked special treats for the field crew.

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APPENDIX A.
HYDROACOUSTIC DATA ANALYSIS

SPECIES APPORTIONMENT ANALYSIS

To apportion out the estimates by species, we developed a Bayesian hierarchical model based on an idea of repeated binomial sampling. In short, we assumed that each trawl sample was a binomial sample with parameter p_i that is specific to that one, particular trawl sample. We then assumed that each p_i was drawn from a beta distribution with parameters α and β. In order to develop probability statements about the number of sockeye targets, we assumed the Bayesian posterior distribution of the number of total targets was approximated by a *t*-distribution with a small number of degrees of freedom (like 5, for example). Then the Bayesian posterior distribution for the number of sockeye fry in the lake was found by simulation: by repeatedly drawing an observation from the posterior distribution of the proportion of sockeye fry and by repeatedly sampling the posterior distribution of the total targets in the lake.

Suppose there were a total of *I* total trawl samples from different parts of the lake, and that *i* indexes one possible trawl sample. First, the specimens from the i^{th} trawl sample were divided into y_i sockeye fry, and n_i-y_i non-sockeye targets, for a total sample size of n_i. Let p_i denote the underlying (parameter) mean proportion of sockeye targets associated with the *i*th trawl sample in the lake. Conditioned on this parameter (p_i) and on the total number of fish caught in the *i*th trawl sample the number of sockeye fry in the sample could be modeled with a binominal sampling law. The unknown parameter p_i, denoted the underlying proportion of sockeye salmon that the *i*th trawl sample was sampling. Each trawl sample had its own underlying proportion of sockeye salmon, depending on schooling or clustering of either sockeye salmon or else schooling or clustering of other kinds of sonar targets within the lake. Next, we supposed that p_i was itself drawn from a beta probability distribution with hyperparameters α and β, such that the hyperparameters α and β are the same for each transect in the lake at the occasion of the trawl sampling. These hyperparameters can be re-expressed as an overall mean, given by *p*, which represents the overall proportion of sockeye juveniles within the whole lake:

$$p = \frac{\alpha}{\alpha + \beta}\,.$$

We chose a uniform distribution between 0 and 10 for both the α and β parameters. These distributions limited the influence of the prior distributions on the posterior distributions, once a large sample size was achieved, and this ensured that once a large sample was collected the data had adequate influence. We noted that as posterior probability built up on larger and larger values of α and β, the posterior means of each p_i became more alike, and the posterior variance of the overall *p* declined. Limiting the maximum values of both α and β to 10 seemed to provide a compromise between allowing the posterior means of the individual p_i's to be either alike or unalike, while still allowing the data (likelihood) to dominate the posterior distribution.

Then the properties of *p* were studied through its Bayesian posterior distribution (Appendix A1). Note that the total sample size was 97, and that in four trawl samples a total of 43 sockeye were caught, for a sample proportion of 0.443 sockeye salmon. This number differs only slightly from the Bayesian posterior mean of 0.432. The usual binominal sample standard error for this estimate

-continued-

was 0.050. In this particular case, by inspection, the individual samples look like they could have come from binominal distributions with a common proportion parameter. Even so, our Bayesian standard error was 76% larger than the usual sampling-based binominal standard error.

Summary of the Markov Chain Monte Carlo simulations of the posterior distributions of the proportion of sockeye fry sampled in the four trawl passes and the posterior distribution for the proportion of sockeye fry in the whole lake. Each trawl pass was assumed to have a specific rate of sockeye acquisition, denoted p_i, and the overall rate for the whole lake is denoted p. Each individual p_i was assumed to follow a beta distribution with the same hyperparameters α and β, such that the mean for the whole lake is given by $p= \alpha/(\alpha+\beta)$. In turn, α and β were assumed to follow uniform distribution on the interval 0 to 10.

Parameter	Posterior Mean	Posterior Standard Error	2.50 Percentile	Median	97.50 Percentile	Sample Size	Sockeye in Sample
p_1	0.468	0.055	0.361	0.467	0.578	74	34
p_2	0.467	0.109	0.256	0.467	0.682	12	6
p_3	0.431	0.123	0.201	0.427	0.679	7	3
p_4	0.320	0.136	0.063	0.319	0.593	4	0
p	0.432	0.089	0.248	0.437	0.596	97	43

Now let S denote the number of sockeye fry that were within the lake. Recalling that T denoted the total targets within the lake and p denoted the proportion of the targets that are sockeye fry, obviously $S = pT$. The estimate of total targets developed above is in the sampling-based frame of reference, and we need to discuss both the estimates of p and T in the same frames of reference, either Bayesian or sampling based. To do that, we assumed that the Bayesian posterior distribution of T was adequately approximated by a t-distribution with a very few degrees of freedom (such as 5).

We used a Markov Chain Monte Carlo method to numerically approximate all posterior distributions. The analysis was performed with the Winbugs software. At each simulation step, a value of p and a value of T were drawn from their posterior distributions, and a value of S was generated by multiplication. At least 5,000 observations of each posterior distribution were generated for the estimation of the posterior mean and standard deviation. The interval from the 2.5th percentile to the 97.5th percentile of the posterior distribution of the overall S was reported as the 95% *credible interval*, which is similar to a 95% confidence interval, but with a more direct probability statement (i.e., the probability is 95% that the parameter is within the credible interval). Naturally, the trawl-sampling tool may be biased, so that there may be a substantial difference between the true proportion of sockeye salmon that could be caught with a trawl in the lake in question and the true proportion of sonar targets that are made up of sockeye salmon.

APPENDIX B.
ESCAPEMENT SAMPLING DATA ANALYSIS

Appendix B1.–Escapement sampling data analysis.

The weekly age-sex distribution, the seasonal age-sex distribution weighted by week, and the mean length by age and sex weighted by week, for smolt and adults, were calculated using equations from Cochran (1977; pages 52, 107-108, and 142-144).

Let

h = index of the stratum (week),

j = index of the age class,

p_{hj} = proportion of the sample taken during stratum h that is age j,

n_h = number of fish sampled in week h, and

n_{hj} = number observed in class j, week h.

Then the age distribution was estimated for each week of the escapement in the usual manner:

$$\hat{p}_{hj} = n_{hj} \big/ n_h \ . \tag{1}$$

If N_h equals the number of fish in the escapement in week h, standard errors of the weekly age class proportions are calculated in the usual manner (Cochran 1977, page 52, equation 3.12):

$$SE\left(\hat{p}_{hj}\right) = \sqrt{\left[\frac{\left(\hat{p}_{hj}\right)\left(1-\hat{p}_{hj}\right)}{n_h - 1}\right]\left[1 - n_h/N_h\right]} \ . \tag{2}$$

The age distributions for the total escapement were estimated as a weighted sum (by stratum size) of the weekly proportions. That is,

$$\hat{p}_j = \sum_h p_{hj}\left(N_h/N\right), \tag{3}$$

such that N equals the total escapement. The standard error of a seasonal proportion is the square root of the weighted sum of the weekly variances (Cochran 1977, pages 107–108):

$$SE\left(\hat{p}_j\right) = \sqrt{\sum_j^h \left[SE\left(\hat{p}_{hj}\right)\right]^2 \left(N_h/N\right)^2} \ . \tag{4}$$

The mean length, by sex and age class (weighted by week of escapement), and the variance of the weighted mean length, were calculated using the following equations from Cochran (1977, pages 142-144) for estimating means over subpopulations. That is, let i equal the index of the individual fish in the age-sex class j, and y_{hij} equal the length of the ith fish in class j, week h, so that,

$$\hat{\bar{Y}}_j = \frac{\sum_h \left(N_h/n_h\right) \sum_i y_{hij}}{\sum_h \left(N_h/n_h\right) n_{hj}} \text{, and} \tag{5}$$

$$\hat{V}\left(\hat{\bar{Y}}_j\right) = \frac{1}{\hat{N}_j^2} \sum_h \frac{N_h^2\left(1 - n_h/N_h\right)}{n_h\left(n_h - 1\right)} \left[\sum_i \left(y_{hij} - \bar{y}_{hj}\right)^2 + n_{hj}\left(1 - \frac{n_{hj}}{n_h}\right)\left(\bar{y}_{hj} - \hat{\bar{Y}}_j\right)^2\right].$$