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Hugh Smith Lake Sockeye Salmon Adult and Juvenile Studies, 2006

by

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and

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October 2007

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

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

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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 2006, 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. Currently, 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. High harvest rates appear to be the principle cause of past declines in this stock. Smolt weir counts have increased from the very low levels recorded during the 1990s, and estimates of wild adult sockeye salmon escapements have shown an increasing trend since 1998. Stocked fish returning to Hugh Smith Lake continued to show abnormal behavior and distribution in the lake and likely experienced poor spawning success.

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

INTRODUCTION

In 2003, the Alaska Board of Fisheries (BOF) 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 BOF 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. This stocking of pen-reared fry occurred from 1999 to 2003, and all released fry had thermal otolith marks.

Escapements of adult sockeye salmon at Hugh Smith Lake have improved steadily since reaching a low of 1,100 in 1998 (Piston et al. 2006). From 2003 to 2005, escapements surpassed the upper end of the escapement goal range of 8,000 to 18,000 adult sockeye salmon. 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). Estimates for the wild portion of the spawning escapement have also shown improvement in recent years. In 2005, over 10,000 wild sockeye salmon returned to the system, which was the first time since 1997 that the wild portion of the escapement had reached the escapement goal (Piston et al. 2006). Because of these positive trends at the lake, the Hugh Smith Lake sockeye salmon stock was de-listed as a management stock of concern at the 2006 BOF meeting.

In 2006, we continued weir operations and studies designed to evaluate the rehabilitation efforts at the lake. We looked at a variety of factors that are important for assessing rehabilitation efforts, including 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. These studies also allowed us to monitor returning stocked fish and assess their spawning productivity.

In 2006, we conducted monthly hydroacoustic surveys, from early summer through fall, to estimate the abundance of rearing juvenile sockeye salmon. These surveys, along with a planned spring survey in 2007, will allow us to determine the approximate survival rates of fry throughout the year. The first survey of the summer is timed to coincide with the conclusion of fry emigration from the tributary streams so that the rest of the series of survey results reflect fry survival in the lake.

To determine when sockeye salmon fry had ceased entering the lake from the tributary streams we continued sampling sockeye salmon fry emigrating from Buschmann and Cobb creeks using fyke nets. Fry emigration into Hugh Smith Lake appears to be variable and protracted. Fry studies conducted in the early 1980s documented sockeye salmon fry emigration between 17 March (1983) and 7 July (1982; ADF&G unpublished data). On 16 March 1983, three age-0 sockeye salmon fry were captured in the lake using tow net gear, indicating fry emigration had begun prior to mid-March (ADF&G unpublished data). Larry Peltz, formerly with ADF&G, noted that few sockeye fry were captured leaving Buschmann Creek after May in 1983; however, they were still being captured in early July in 1982 (ADF&G unpublished report). Information we collected in 2004 and 2005 showed that fry emigration tends to be more protracted in Buschmann Creek than Cobb Creek, possibly due to the varied temperature regimes between the primary channels of Buschmann Creek (Piston et al. 2006).

We also continued monitoring the distribution of stocked fish within the system. Generally, it appears that over half of the Hugh Smith Lake sockeye escapement spawns in Buschmann Creek, although we do not have total escapement estimates for the two tributaries. In recent years, a higher proportion of stocked fish have entered Cobb Creek than Buschmann Creek (Geiger et al. 2005), so the proportion of the escapement spawning in Cobb Creek has probably been unusually high since pen-reared fish began returning in 2002. Another pattern we have observed since 2002 is large numbers of stocked fish milling about at the outlet of the lake until death (Geiger et al. 2005). This milling behavior was likely a result of the fact that the holding pens for the stocked fish were located near the outlet of the lake due to concerns with IHN virus. Stocked fish homed to their rearing site at the outlet of the lake, rather than Buschmann Creek, the site of all the egg takes for the stocking program. When these stocked fish move up the lake looking for a place to spawn, Cobb Creek would be the first stream they encounter.

In 2004, we conducted a habitat inventory of the lower 0.75 km of Buschmann Creek (Piston et al. 2006). The Buschmann Creek drainage, especially the lower reaches, is flat, unstable, and prone to frequent changes to its stream channel. Buschmann Creek has experienced stream channel shifts in its lower reaches over at least the last 20 years (Jerry F. Koerner and Tim P. Zadina, formerly ADF&G fisheries biologists, personal communication), but prior to 2004 there had been no efforts to determine the effects of these shifts on the overall productivity of this stock. Detailed information on the extent, duration, and frequency of these changes is lacking. The baseline information we collected in 2004 and continued monitoring will allow us to track these changes and determine if they are significantly affecting sockeye salmon productivity in the system.

Here, we summarize the information collected in 2006 concerning the Hugh Smith Lake sockeye salmon stock.

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.

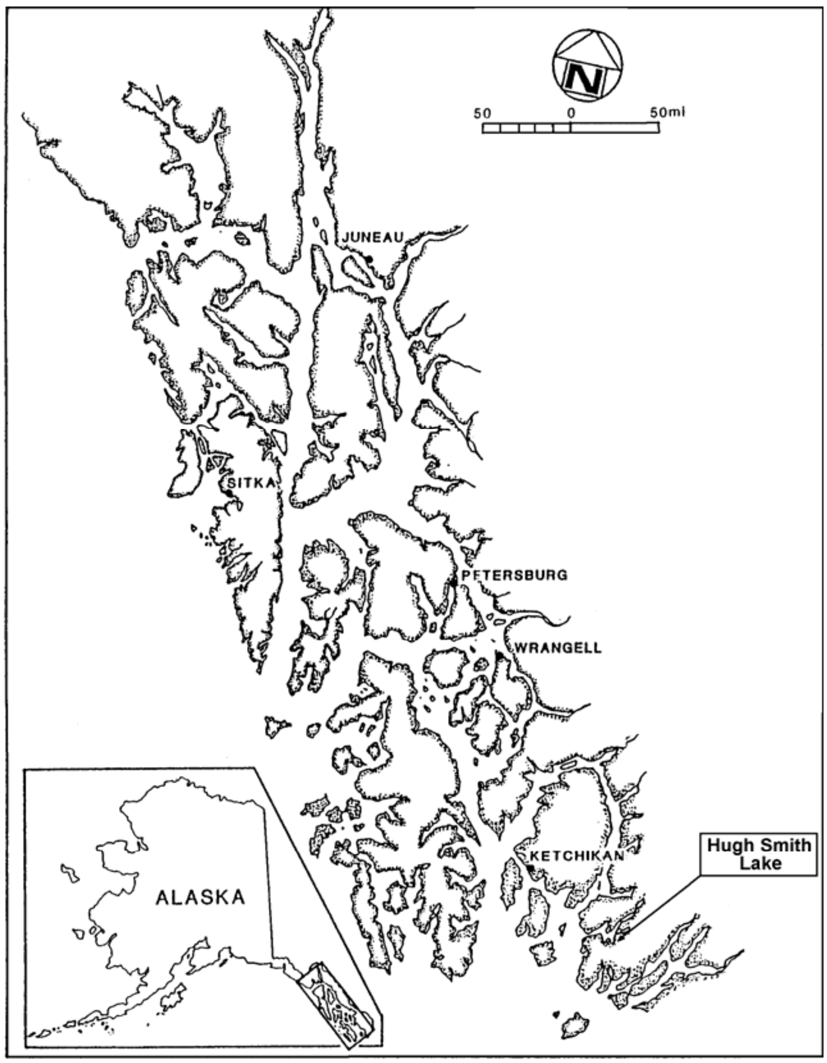

Figure 1.–The location of Hugh Smith Lake in Southeast Alaska.

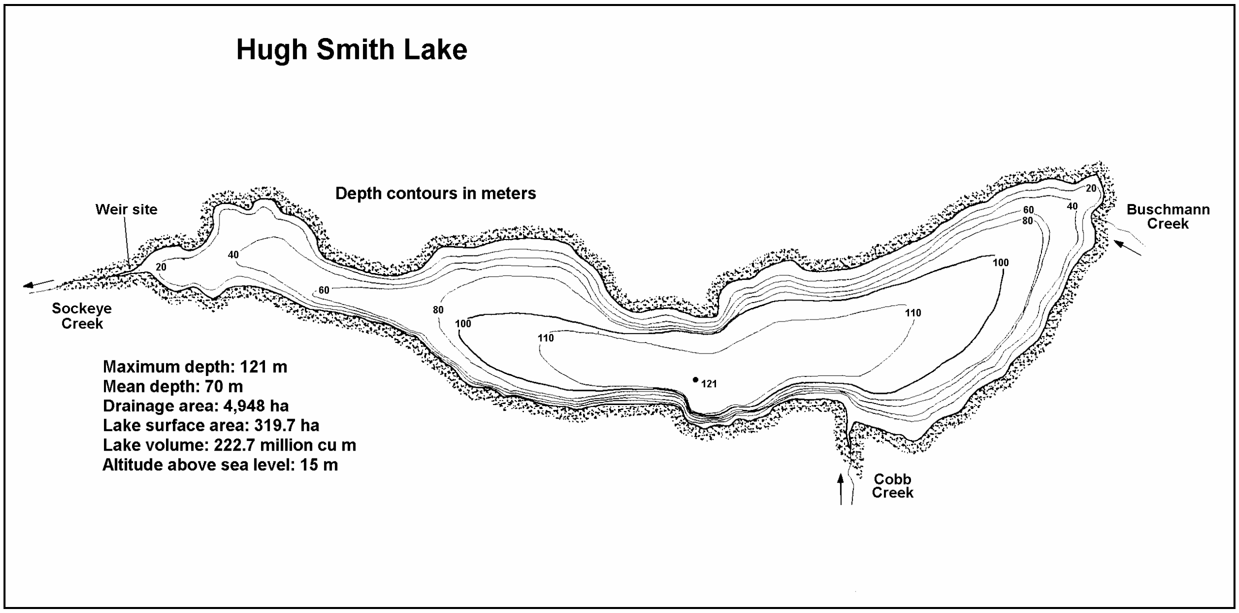

Figure 2.–Bathymetric map of Hugh Smith Lake, Southeast Alaska, showing the location of the weir site, location of inlet streams and other features of the lake system.

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 $0.5 \text{ m} \cdot \text{sec}^{-1}$. 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 March, June, and August of 2005. In 2006, samples were collected in June, August, September, and October, but analysis of these samples is not completed at this time.

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).

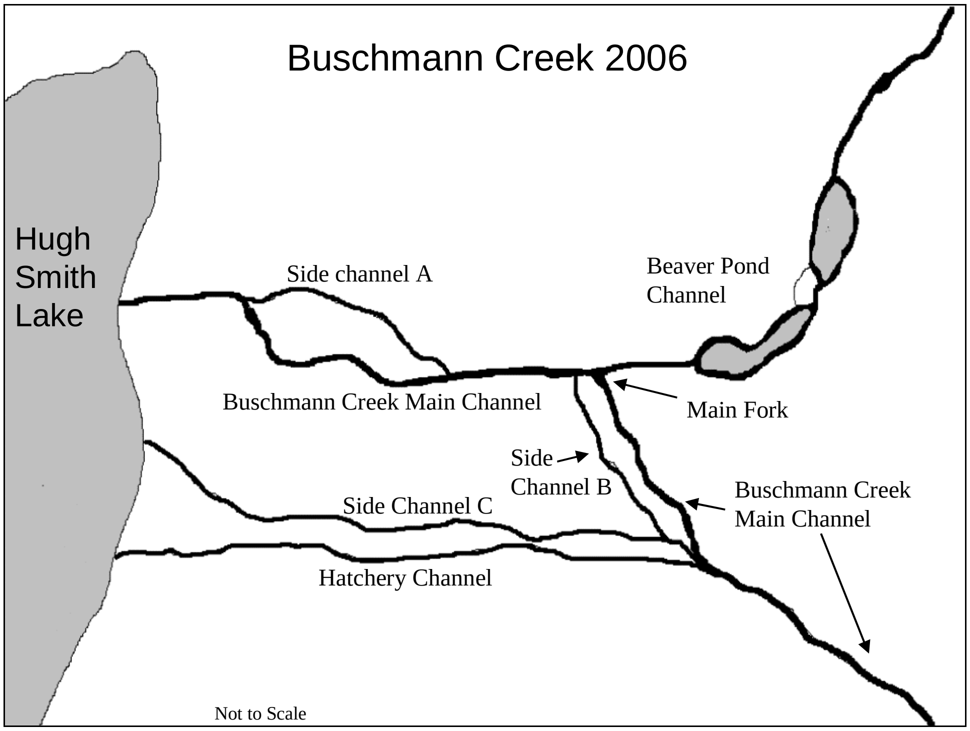

Figure 3.–Schematic diagram of the main channels of lower Buschmann Creek, as of 27 September 2006.

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 2006, we conducted foot surveys of the various channels in Buschmann Creek to determine if any significant changes occurred since the 2005 season. Because only very 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]). Data from these temperature loggers were used to assist in determining if stream channel shifts occurred over the winter, and we used these measurements for assessing potential losses of eggs and alevins. These measurements also provided us with comparative temperature profiles between the two major tributaries of the lake. Four 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 most cases, pairs of temperature loggers were set approximately 10 cm under the gravel with one logger secured in place near the deepest part of the stream channel, and the second one secured in place adjacent to the water's edge under low stream flow conditions. In addition, two thermographs were set in Cobb Creek, approximately 150 meters 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 2006, 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 ($targets{\cdot}m^2$) 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 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-degree of freedom sample

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

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 operated from late April until sockeye fry had ceased entering the lake in early July. Fyke nets were set at least once per week, or more often when the crew was conducting other work near the inlet streams. 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 2006 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 smolts (L. Shaul, ADF&G, personal communication).

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 2006. 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 2006. 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 clips, 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) and our sockeye salmon studies operated in conjunction with coho salmon studies that were conducted annually at the lake. After 1 August, all sockeye salmon that were not selected for scale sampling or for marking for weir-verification studies were dip-netted out of the trap and released. However, due to a large influx of sockeye salmon we again resorted to counting fish freely through the pickets from 8–10 August in 2006.

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 2006 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 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). However, the marking fraction in the mark-recapture estimate was greatly reduced, as noted above. 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 (mid-eye-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).

Otolith sampling on the spawning grounds

From 2002 to 2006, we 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 2005. In 2005, samples were collected in March, June, and August. The sample collected in March 2005 was not directly comparable to samples collected in previous years, which were generally collected after mid-April. Analysis of the 2006 samples has not been completed at this time and will be included in a future report.

In June and August of 2005, the densities of copepods and cladocerans were similar to 2004 levels (Figure 4). The seasonal mean density of *Bosmina*, the numerically dominant cladoceran in Hugh Smith Lake, was 87 thousand per m^2, which represents an increase from 2004 and is above the long term average of 80 thousand per m^2, from 1981–2005 (Figure 5). The seasonal mean density of *Cyclops*, the numerically dominant copepod in Hugh Smith Lake, was 232 thousand per m^2, which represents an increase from 2004 and is above the long term average of 201 thousand per m^2, from 1981–2005. The mean weighted length of *Cyclops*, *Bosmina*, and *Daphnia l*. all showed a slight decrease from 2004 (Figure 6), continuing a slow downward trend that is probably related to the increasing numbers of rearing juvenile sockeye salmon in the lake since the mid-1990s (Piston et al. 2006).

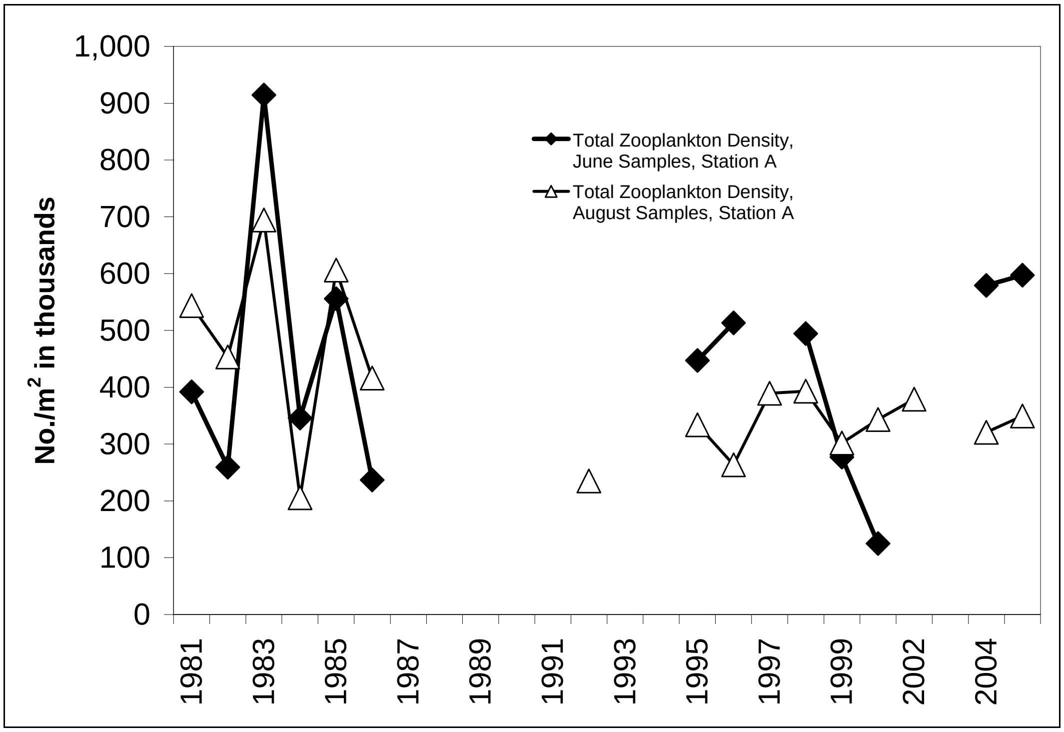

Figure 4.–Density of copepods and cladocerans in Hugh Smith Lake at Station A, June and August samples, from 1981–2005.

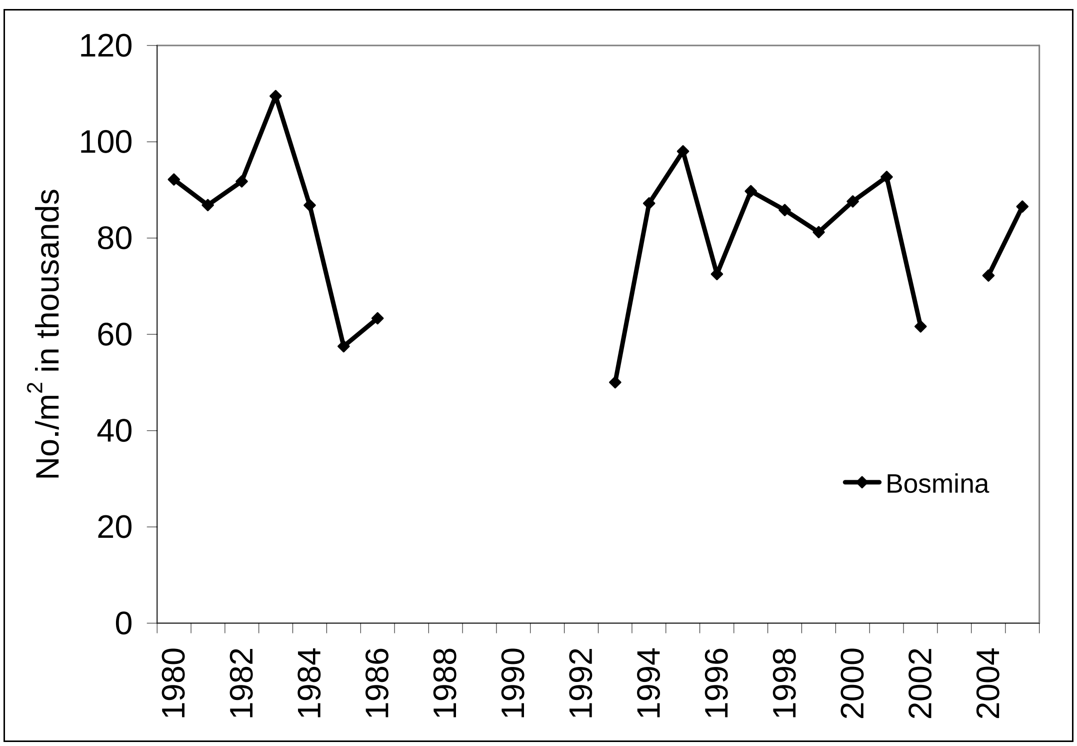

Figure 5.–Mean seasonal density of *Bosmina* in Hugh Smith Lake at Station A, from 1980–2005.

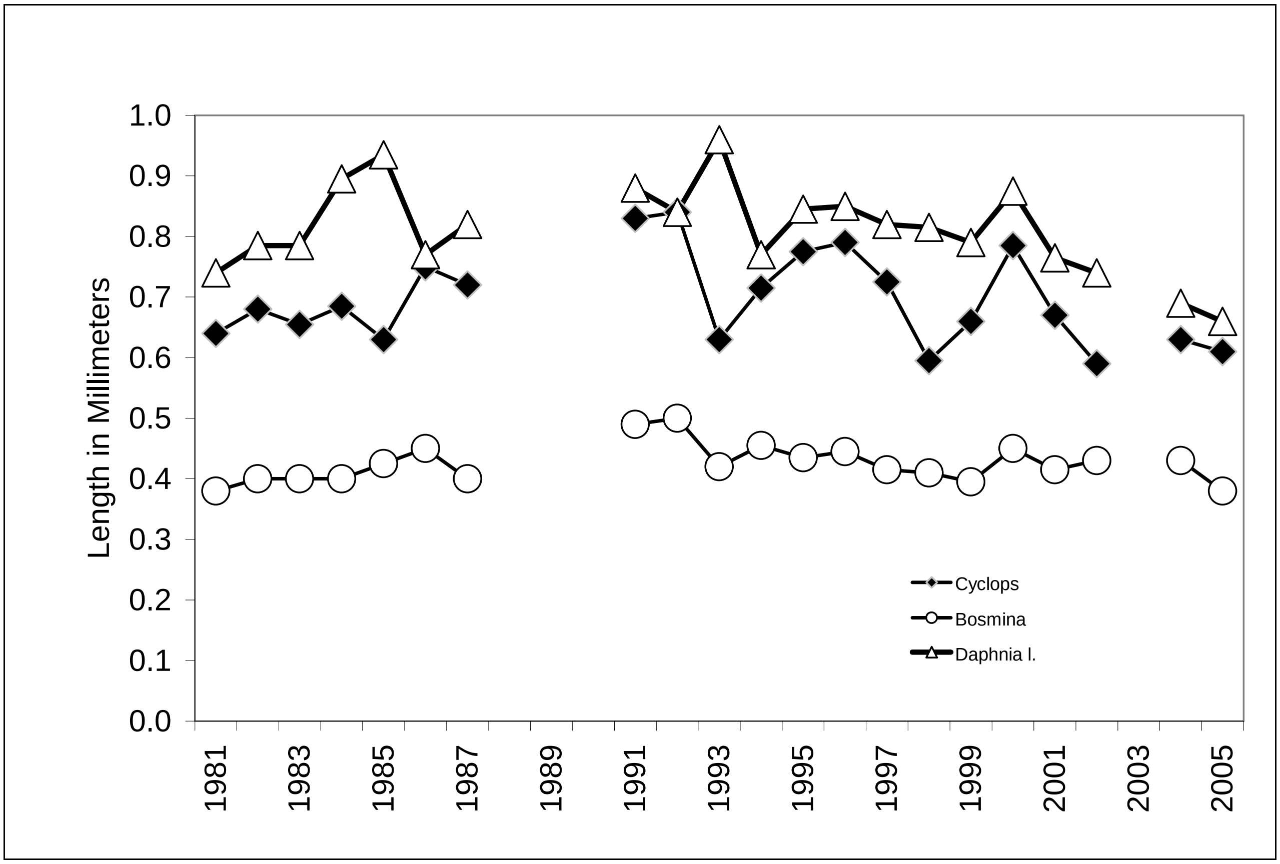

Figure 6.–Seasonal mean weighted length of three primary macrozooplankton species at Hugh Smith Lake, 1981–2005.

BUSCHMANN CREEK HABITAT EVALUATION

The system appeared to be fairly stable between 2005 and 2006. Beavers continued to maintain a new dam in the beaver pond channel, a short distance above the main fork. As in 2005, fish were observed above this dam, as well as a second dam located another 100 meters upstream. On a survey conducted on 27 September, water was flowing around both of these dams, allowing for relatively easy fish passage under slightly above average flow conditions. The area immediately above the second dam has been a beaver pond complex since at least the mid-1990s, and this particular channel has had various beaver dams along its length since ADF&G began studies there in 1980.

The main channel of Buschmann Creek showed very little change since the 2005 season. It appeared that the Hatchery Channel and Side Channel C (Figure 3) may have had slightly less flow than in 2005, but flows were still adequate for spawning sockeye salmon. The only other change noted was an increase in the braiding of Buschmann Creek's Main Channel at the confluence with the top of the Hatchery Channel and Side Channel C (Figure 3). This braiding appeared to slightly increase the amount of water flowing into the Main Channel. In 2006, we documented the presence of adult sockeye salmon in all of the channels outlined in Figure 3 (Table 1).

We also attempted to determine the upper reaches of spawning by sockeye salmon in Buschmann Creek. On 27 September, we conducted a foot survey of the Main Channel up to a point where sockeye salmon were no longer present. Sockeye salmon were observed approximately 0.75 km above the point where the top of the Hatchery Channel meets with the Main Channel (Figure 3). Although there were no complete barriers to fish passage encountered, the substrate gradually turns to one dominated by large cobble and small boulders, as the stream gains elevation. Most fish were observed in the first 0.5 km above the top of the Hatchery Channel (Figure 3), with only sporadic numbers for the remaining 0.25 km. Given the large escapement in 2006, it seems likely that this point (0.75 km above the upstream end of the hatchery channel) is typically the upper limit for spawning sockeye salmon. We surveyed all the channels of Buschmann Creek, except Side Channel C, on this day, and approximately 20% of the fish counted were above the habitat study area surveyed in 2004 (Table 1, Piston et al. 2006).

During the first two weeks of September, the number of sockeye salmon in Buschmann Creek was considerably 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 similar between the two creeks through the remainder of the season. 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, 2006. Blanks indicate that the section was not surveyed on the corresponding date. Surveys conducted in the "Above Beaver Dam" and "Above Hatchery Channel" sections were of varying length and should not be directly compared between dates.

Date	**4-Sep**	**4-Sep**	**14-Sep**	**14-Sep**	**27-Sep**	**27-Sep**	**6-Oct**	**6-Oct**	**13-Oct**	**13-Oct**	**21-Oct**	**21-Oct**	**29-Oct**	**29-Oct**
Condition	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead
Mouth Estimate	1,000	0	300	4	950	0								
Main Channel	700	2	466	50	1,019	21	610	97	187	217	702	37	410	25
Side Channel A			116	14	173	20							67	0
Fork to Beaver Dam	8	0	60	0	50	0	77	15	6	9	15	4	40	0
Above Beaver Dam					22	0	15	0	3	0			9	0
Fork to Hatchery Ch.	394	4	579	41	560	14	487	73	116	125	330	7		
Above Hatchery Ch.	135	2	102	0	471	7	79	10	14	21	7	1		
Side Channel B													12	0
Hatchery Channel	55	0			231	11	109	15	29	13	146	7		
Stream Total	1,292	8	1,323	105	2,526	73	1,377	210	355	385	1,200	56	538	25

Table 2.–Counts of adult sockeye salmon in Cobb Creek, 2006. Each survey was conducted from the mouth to the barrier falls and covered all available spawning habitat within the creek.

Date	**5-Sep**	**5-Sep**	**12-Sep**	**12-Sep**	**19-Sep**	**19-Sep**	**1-Oct**	**1-Oct**	**10-Oct**	**10-Oct**	**17-Oct**	**17-Oct**	**28-Oct**	**28-Oct**
Condition	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead
Count	385	0	685	9	2,200	143	3,250	252	1,620	1,380	1,940	850	1,171	103

STREAM TEMPERATURE MONITORING

Temperature data were collected from Buschmann Creek between 28 July 2005 and 24 July 2006 and in Cobb Creek from 7 November 2005 to 24 July 2006. We experienced a significant loss of temperature loggers over the winter of 2005–2006 and we were only able to retrieve data from Cobb Creek, the lower part of the Main Channel in Buschmann Creek, and the Beaver Pond Channel. Due to this loss, the locations of the loggers was modified in 2006 to reduce the chances of having them dug up by spawning salmon or washed away by shifting gravel.

From 7 November 2005 to 24 July 2006, the number of cumulative thermal units (CTUs) between the lower Buschmann Creek Main Channel and Cobb Creek was identical at 1,090. However, temperature profiles show considerable differences between the two streams at specific points in time (Figure 7). From November through April, Cobb Creek experienced 291 CTUs compared to 507 CTUs in the lower Main channel of Buschmann Creek. From 1 May to 24 July 2006, Cobb Creek experienced 799 CTUs compared to 582 CTUs in the lower Main channel of Buschmann Creek. This is similar to temperature comparisons from 2004 to 2005, which showed that Cobb Creek was warmer than Buschmann Creek from 25 August to early November and again from late April through July.

From 28 August 2005 (typical timing of first spawning) to 24 July 2006, the number of cumulative thermal units (CTUs) between the lower Buschmann Creek Main Channel (1,674) and the Beaver Pond Channel (1,922) varied by 13.1% (Figure 8) and the temperature profiles showed a pattern similar to that seen in the comparison between Buschmann and Cobb Creeks. The lower Buschmann Creek Main Channel temperature logger is located below the junction with the Beaver Pond Channel, which means that temperatures in this region are warmer than in the Main Channel above the Main Fork (Figure 3). The more secure locations of the temperature loggers we set in 2006 should allow us to make more detailed temperature comparisons between all of the channels of Buschmann Creek during the winter of 2006–2007.

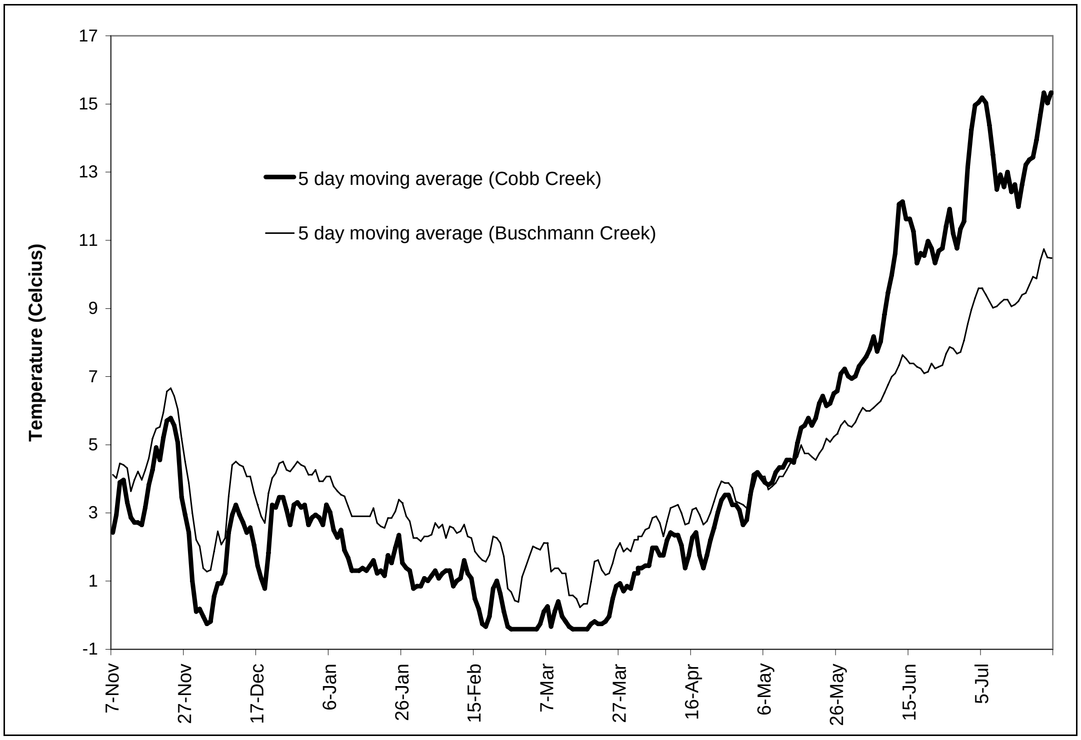

Figure 7.–Stream temperature profile for Buschmann and Cobb Creeks, 7 November 2005 to 24 July 2006.

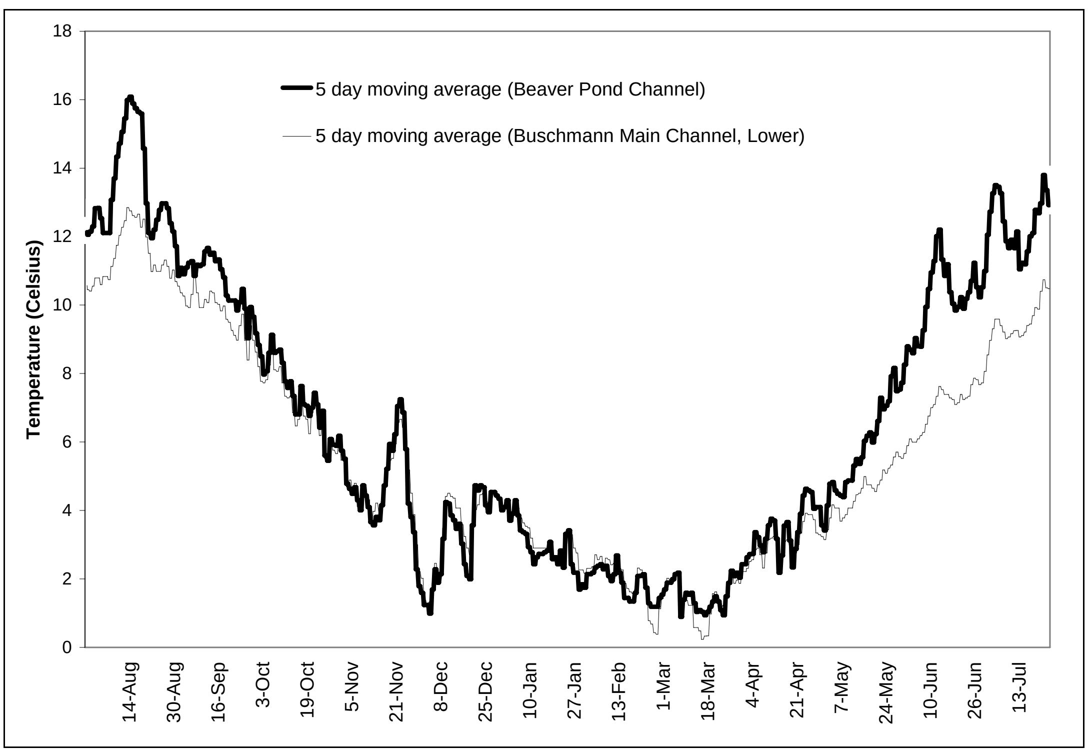

Figure 8.–Stream temperature profile for the Beaver Pond Channel and the lower Buschmann Main Channel, 28 July 2005 to 24 July 2006.

FRY PRODUCTION

Hydroacoustic Surveys

2005

Total pelagic fish estimates for 2005 were reported in Piston et al. (2006), but analysis of trawl samples had not been completed in time for inclusion in the paper. Here we report the final results of our 2005 and 2006 hydroacoustic surveys.

In July, we completed 8 trawls, catching a total of 204 fish, all of which were sockeye fry. The age composition of the sockeye fry was 93.6% age 0 and 5.4% age 1, with the remaining 1.0% un-ageable. The total estimate of sockeye fry in the lake was 475,500, with a 95% credible interval of 356,900 to 595,600.

We completed 8 trawls in August, catching a total of 85 fish, of which 24 were stickleback (28.2%). The age composition of the sockeye fry was 96.7% age 0 and 3.3% age 1. The total estimate of sockeye fry in the lake was 327,300, with a 95% credible interval of 280,100 to 376,200.

In September, we completed 8 trawls, catching a total of 178 fish, of which 10 were stickleback (5.6%). The age composition of the sockeye fry was 96.4% age 0 and 3.6% age 1. The total estimate of sockeye fry in the lake was 263,000, with a 95% credible interval of 216,100 to 280,800.

During our final survey in October, we completed 6 trawls, catching a total of 19 fish, only one of which was a stickleback (5.3%). The age composition of the sockeye fry was 83.3% age 0 and 16.7% age 1. The total estimate of sockeye fry in the lake was 212,000, with a 95% credible interval of 169,700 to 255,600. The survival rate of the sockeye fry between late July and late October was approximately 45%

2006

We were unable to conduct a spring survey in 2006 because ice still covered over half the lake's surface in mid-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 599,000 with a standard error of 78,800 (CV 13.15%). We caught a total of 357 fish in 8 trawls, of which 3 (0.8%) were stickleback. Of the 354 sockeye fry captured, 98.9% were age 0 and 1.1% were age 1. The total estimate of sockeye fry in the lake was 593,800, with a 95% credible interval of 439,400 to 752,900.

The estimate for August increased over the July estimate. The August estimate was probably skewed high by a storm event that left the lake very high and filled with debris that had washed in from the tributary streams. The total pelagic fish estimate for the August survey was 880,000 with a standard error of 114,800 (CV 12.96%). However, we do not feel that these results indicate an increase in fish numbers from the July survey, especially when compared to the September survey results. The lake surface was covered in detritus and drifting foam and similar conditions below the surface made it impossible to analyze the data with confidence.

The total pelagic fish estimate for the September survey was 432,000 with a standard error of 52,200 (CV 12.08%). We caught a total of 103 fish in 8 trawls, of which only 1 was a stickleback. Of the 102 sockeye fry captured, 97% were age 0 and 3% were age 1. The total estimate of sockeye fry in the lake was 426,200, with a 95% credible interval of 325,200 to 526,100.

The total pelagic fish estimate for the October survey was 425,178 with a standard error of 88,600 (CV 20.84%). We caught a total of 23 fish in 7 trawls, all of which were age 0 sockeye fry. The total estimate of sockeye fry in the lake was 420,600, with a 95% credible interval of 249,800 to 593,600. The late July to late October survival rate of rearing fry was approximately 71%, which is considerably higher than 2004 and 2005 results.

Fry Emigration Timing

In 2006, sockeye fry were captured in both creeks on the first set of the fyke nets; 3 May for Buschmann Creek and 6 May at Cobb Creek. Catch rates were high at Buschmann Creek through the last week of June, followed by a rapid decline after the first week of July, while at Cobb Creek the catch rate dropped sharply after late May and few sockeye were captured after early June (Figure 9). This is very similar to the pattern we observed in 2004 (Piston et al. 2006).

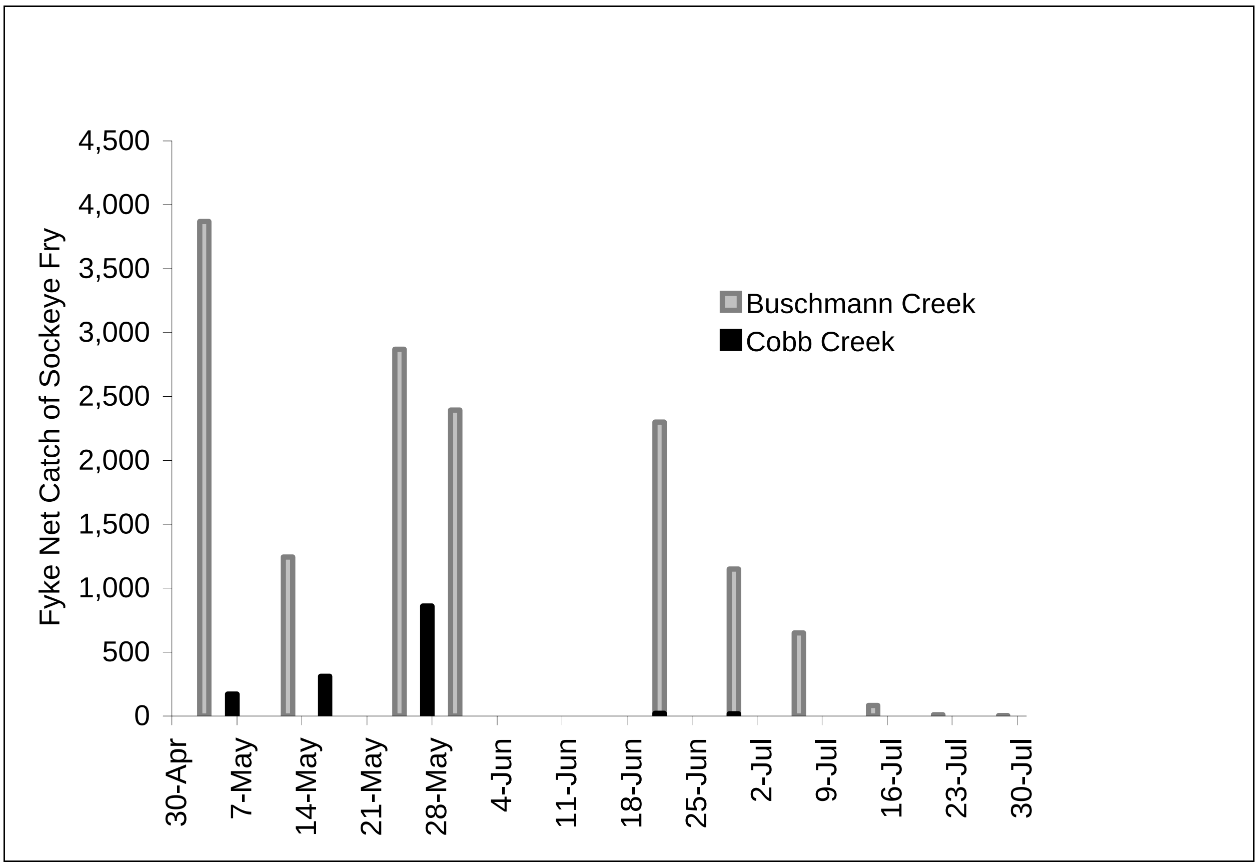

Figure 9.–Sockeye fry emigration timing, Buschmann and Cobb creeks, 2006.

SMOLT PRODUCTION

Because escapements were above the upper end of the escapement goal range from 2003 to 2005, no egg takes and subsequent stocking of Hugh Smith Lake occurred, and starting in 2005 the smolt emigration was 100% wild. The 2006 smolt weir count was 119,000 (Table 3). We sampled 1,033 sockeye smolt for scales and determined that the age composition of the smolt, weighted by week, was 63% age 1, 36% age 2, and 1% age 3 (Figure 10).

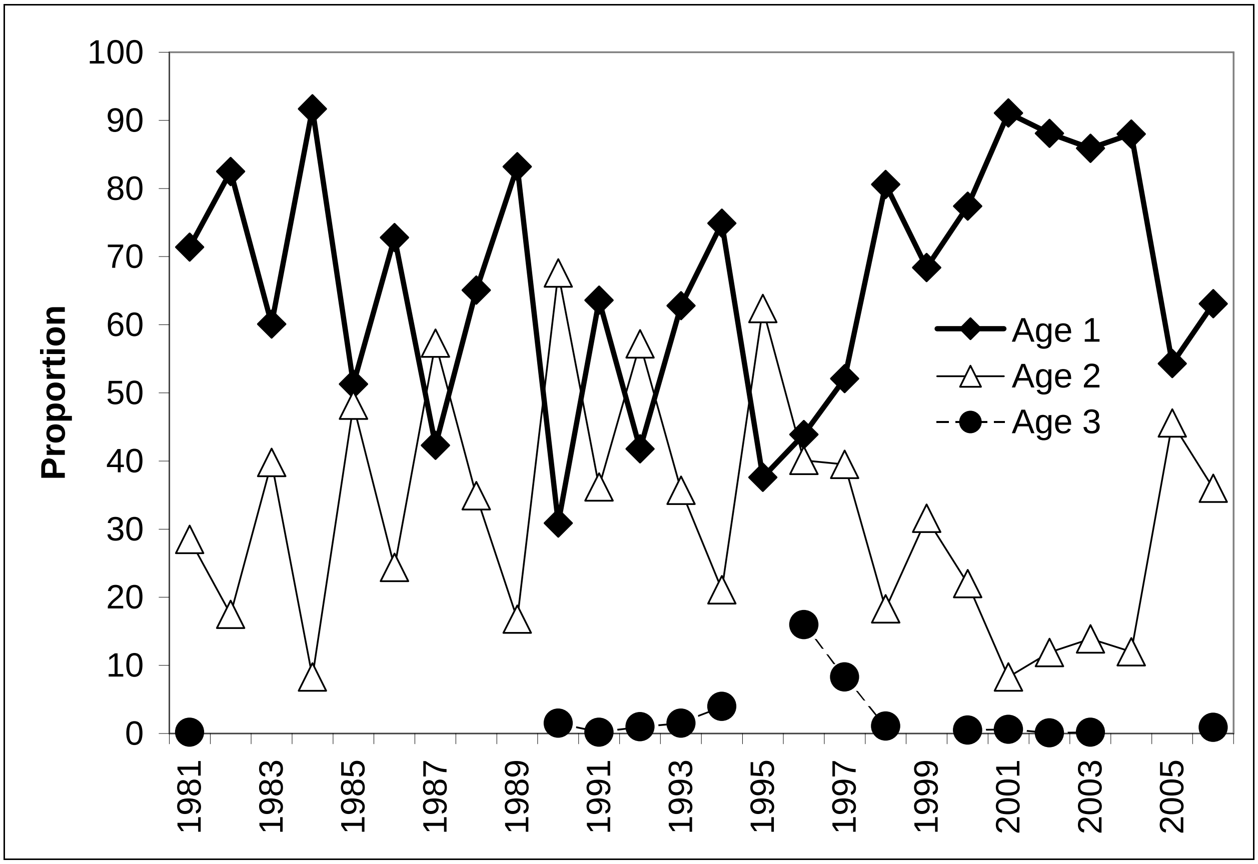

Figure 10.–Age composition of sockeye salmon smolt at Hugh Smith Lake, 1981–2006.

Table 3.–Hugh Smith Lake weir counts of sockeye smolt by smolt year, and stocked fry and pre-smolt releases by year of release, 1981–2006. Proportions of stocked and wild smolt were determined from otolith samples.

Release Year	Hatchery Release Numbers	Release Type	Smolt Year	Total Smolt Counted	Stocked Smolt Counted	Wild Smolt Counted	Percent Stocked Smolt
			1981	318,857			
			1982	90,325			
			1983	77,096			
			1984	330,442			
			1985	39,692			
			1986	373,450			
1986	273,000	Unfed Fry	1987	104,776			
1987	250,000	Unfed Fry	1988	54,421			
1988	1,206,000	Unfed Fry	1989	427,366			
1989	532,800	Unfed Fry	1990	137,092			
1990	1,480,800	Unfed Fry	1991	74,655			
1991			1992	14,912			
1992	477,500	Fed Fry	1993	35,737			
1993			1994	43,056			
1994	645,000	Unfed Fry	1995	19,212			
1995	418,000	Unfed Fry	1996	16,355			
1996	358,000	Unfed Fry/ Pre-Smolt[a]	1997	44,257			
1997	573,000	Unfed Fry	1998	64,667	30,456	34,211	47%
1998	0		1999	42,397	3,485	38,912	4%
1999	202,000	Pre-smolt[b]	2000	71,849		---No data---	
2000	380,000	Pre-smolt[b]	2001	189,323	145,160	44,163	77%
2001	445,000	Pre-smolt[b]	2002	296,203	163,321	134,091	55%
2002	465,000	Pre-smolt[b]	2003	260,740	185,176	75,564	71%
2003	420,000	Pre-smolt[b]	2004	363,687	170,010	193,677	47%
2004	0		2005	77,000		77,000	
2005	0		2006	119,000		119,000	

[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, early August. All fish from those releases were otolith marked.

ADULT ESCAPEMENT

In 2006, the adult weir was fish-tight from 17 June to 7 November, and we passed 42,112 adult sockeye salmon, and 4 jacks. The adult escapement exceeded the upper end of the escapement goal range of 8,000–18,000 sockeye salmon (Figure 11) for the fourth consecutive year. Approximately 65% of the escapement was comprised of stocked fish (Heinl et al. *In prep*), which gives an estimated wild escapement of nearly 15,000. This is the largest wild sockeye salmon escapement at Hugh Smith Lake since 1992 and is the second consecutive wild escapement within the escapement goal range of 8 to 18 thousand.

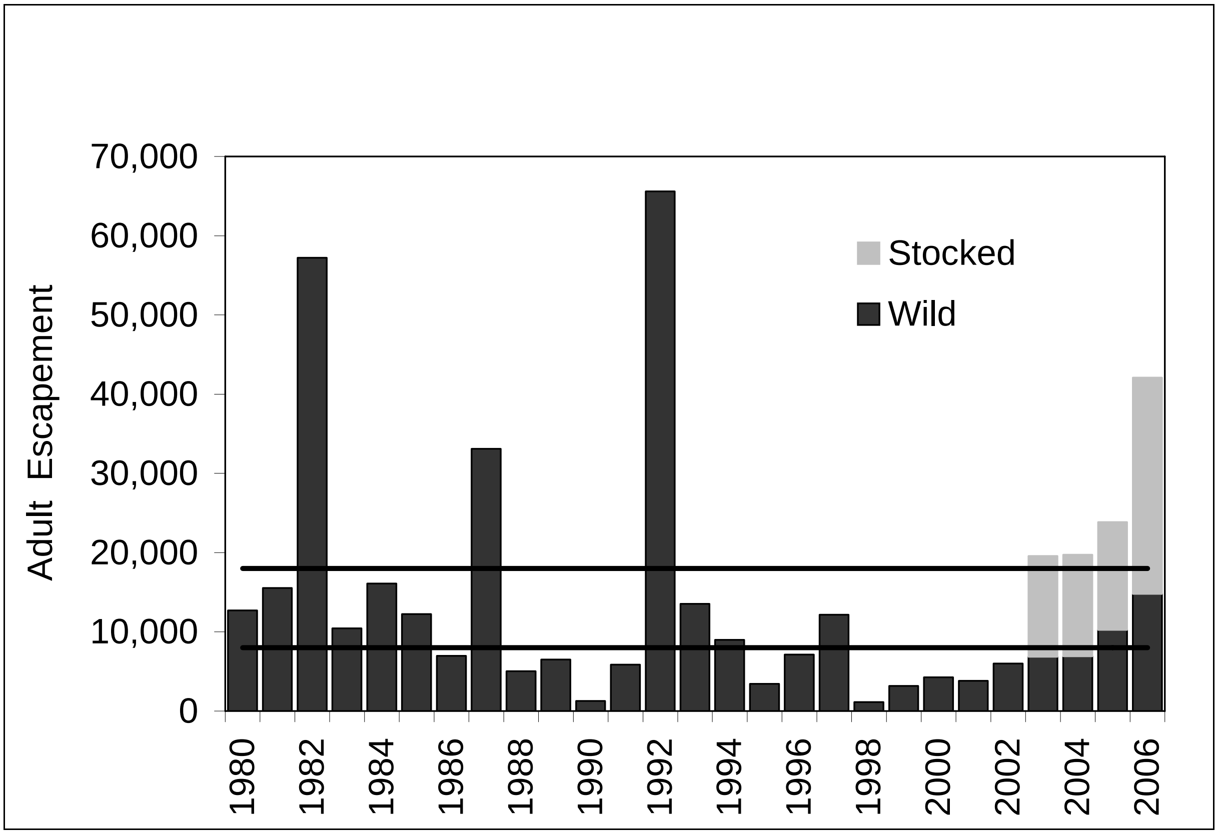

Figure 11.–Annual sockeye salmon escapement at Hugh Smith Lake, 1982–2006. The two black horizontal lines show the escapement goal range of 8,000 to 18,000 adult sockeye salmon that was adopted in 2003. This escapement goal range includes both wild and hatchery stocked fish. From 2003 to 2006, the bars are divided to show our estimate of wild (black) and stocked fish (gray).

In 2006, a total of 4,208 adults were marked with different fin clips over three marking strata. Between 16 June and 15 July, 124 adult sockeye salmon were marked with a right ventral fin clip. From 16 July to 15 August, 3,131 adult sockeye salmon were marked with a left ventral fin clip and from 16 August to 3 November, 953 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 4 September to 1 November (Table 4). We also sampled all dead fish that washed up on the weir. A total of 2,187 fish were sampled for fin clips, of which 229 were marked (Table 4). Results of a X^2 test of complete mixing was significant ($p<0.01$); however, a test for equal proportions of marked fish on the spawning grounds was not significantly different ($p=0.22$), which allowed us to use a pooled Petersen estimate. Our final estimate was 40,000 (SE=2,400: 95% CI=35,000 to 45,000) adult Sockeye salmon. The weir count of 42,112 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 6% easily met our objective of a coefficient of variation of no greater than 15%. Due to the extremely small numbers of jacks (four fish) passed through the weir we were not able to generate a mark-recapture estimate.

Table 4.–Recapture results for the adult sockeye salmon mark-recapture study, 2006.

		Number of Marked Fish			Number	Total Number
Date	Sampling Area	Left Ventral	Right Ventral	Dorsal	Unmarked	Sampled
4-Sep	Buschmann Creek	8	9	0	125	142
9-Sep	Buschmann Creek	8	3	0	120	131
11-Sep	Buschmann Creek	6	1	0	52	59
14-Sep	Buschmann Creek	13	2	0	167	182
27-Sep	Buschmann Creek	7	1	0	40	48
2-Oct	Buschmann Creek	1	1	0	12	14
3-Oct	Buschmann Creek	5	1	1	24	31
6-Oct	Buschmann Creek	0	0	0	8	8
10-Oct	Buschmann Creek	2	0	1	18	21
11-Oct	Buschmann Creek	0	0	1	25	26
19-Oct	Buschmann Creek	1	0	0	4	5
21-Oct	Buschmann Creek	0	0	0	8	8
29-Oct	Buschmann Creek	1	0	0	20	21
1-Nov	Buschmann Creek	2	0	3	15	20
5-Sep	Cobb Creek	3	0	0	42	45
8-Sep	Cobb Creek	1	0	0	31	32
12-Sep	Cobb Creek	1	0	0	6	7
19-Sep	Cobb Creek	7	0	0	108	115
21-Sep	Cobb Creek	2	0	0	53	55
1-Oct	Cobb Creek	11	1	1	136	149
2-Oct	Cobb Creek	1	1	2	18	22
9-Oct	Cobb Creek	6	0	0	46	52
10-Oct	Cobb Creek	9	0	1	90	100
16-Oct	Cobb Creek	7	0	3	41	51
28-Oct	Cobb Creek	0	0	0	40	40
1-Nov	Cobb Creek	1	0	1	8	10
21-Sep	Weir	0	0	0	2	2
23-Sep	Weir	2	1	0	3	6
24-Sep	Weir	0	0	0	4	4
25-Sep	Weir	1	0	0	3	4
26-Sep	Weir	0	0	0	6	6
28-Sep	Weir	0	0	0	4	4
29-Sep	Weir	2	0	0	4	6
30-Sep	Weir	0	0	0	5	5
1-Oct	Weir	2	1	0	7	10
2-Oct	Weir	2	0	0	3	5
3-Oct	Weir	0	0	0	12	12
4-Oct	Weir	1	0	2	17	20
5-Oct	Weir	3	0	0	14	17
6-Oct	Weir	2	0	1	16	19
7-Oct	Weir	0	0	0	6	6
8-Oct	Weir	0	0	0	13	13
9-Oct	Weir	2	0	0	12	14
11-Oct	Weir	1	0	1	17	19
12-Oct	Weir	2	0	1	11	14
13-Oct	Weir	4	0	0	12	16
14-Oct	Weir	1	0	0	14	15
15-Oct	Weir	1	0	0	24	25
16-Oct	Weir	1	0	3	25	29
17-Oct	Weir	0	0	0	26	26
18-Oct	Weir	3	0	0	26	29
19-Oct	Weir	1	0	1	33	35
20-Oct	Weir	3	0	0	24	27
21-Oct	Weir	3	0	0	28	31
22-Oct	Weir	3	0	0	27	30
23-Oct	Weir	4	0	0	49	53
24-Oct	Weir	4	0	3	71	78
25-Oct	Weir	6	1	2	41	50
26-Oct	Weir	7	1	2	55	65
27-Oct	Weir	3	0	1	28	32
28-Oct	Weir	3	0	0	24	27
29-Oct	Weir	2	0	0	11	13
30-Oct	Weir	1	0	0	6	7
31-Oct	Weir	0	0	0	9	9
1-4 Nov	Weir	1	0	0	9	10
	Total	174	24	31	1,958	2,187

The age composition of the adult sockeye salmon was 57.1% 2-ocean and 42.9% 3-ocean fish, with age-1.2 fish being the dominant age class (Figure 12, Table 5). 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. In 2006, we estimate that there were over 24,000 2-ocean fish in the escapement, which is a new high count for that age class, and continued the pattern of early age at return we have observed at Hugh Smith Lake since pen-reared fish began returning in 2002 (Figure 13, Piston et al. 2006).

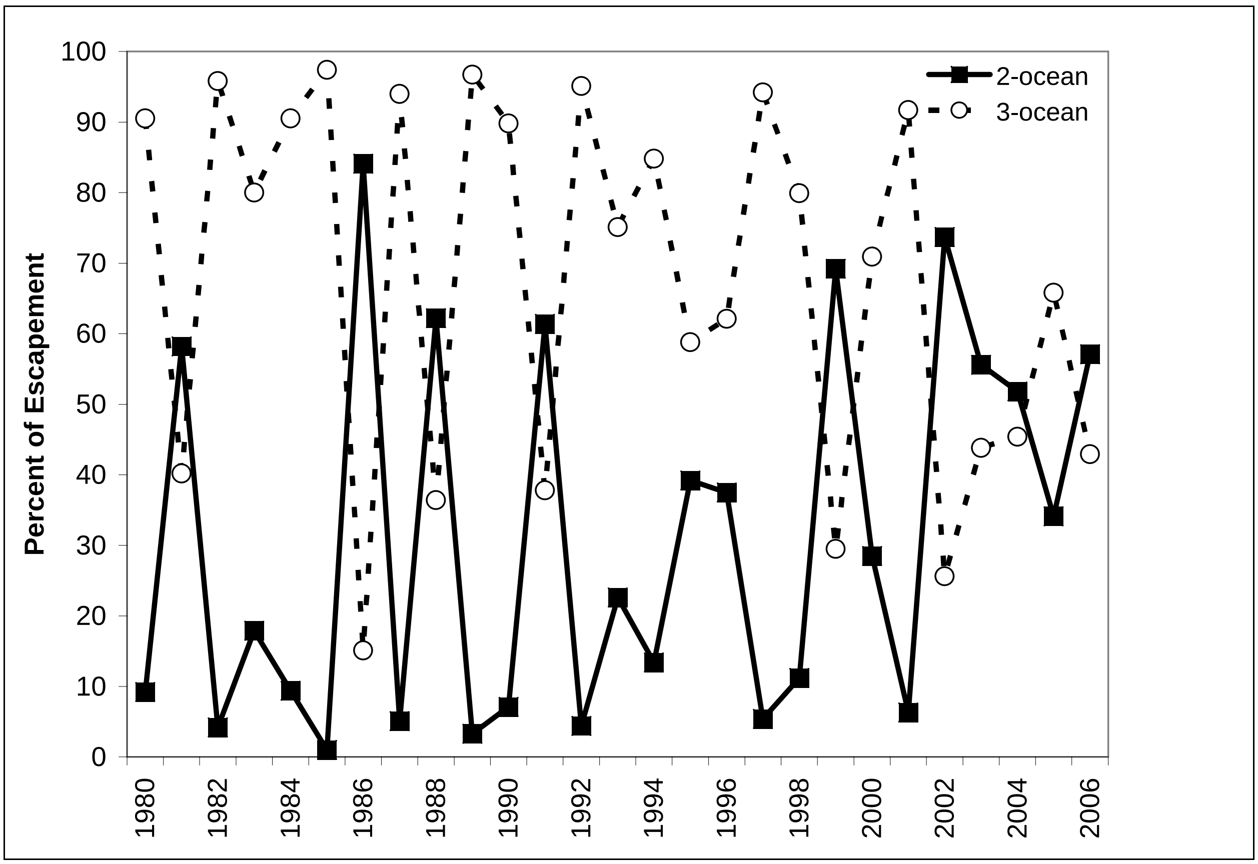

Figure 12.–Annual proportions of 2-ocean and 3-ocean aged sockeye salmon in the Hugh Smith Lake escapement, 1982–2006.

Table 5.–Age composition of the 2006 adult sockeye salmon escapement at Hugh Smith Lake, weighted by statistical week.

		Age Class				
Stat Week		**1.2**	**2.2**	**1.3**	**2.3**	**Total**
25-26	Sample Size	7	1	5	1	14
	Esc. Age Class	86	12	61	12	172
	Proportion	50%	7%	36%	7%	
	SE of %	13%	7%	13%	7%	
27	Sample Size	19	13	31	6	69
	Esc. Age Class	266	182	434	84	966
	Proportion	28%	19%	45%	9%	
	SE of %	5%	5%	6%	3%	
28	Sample Size	1		4		5
	Esc. Age Class	13		50		63
	Proportion	20%		80%		
	SE of %	19%		19%		
29	Sample Size	14	14	32	7	67
	Esc. Age Class	182	182	416	91	871
	Proportion	21%	21%	48%	10%	
	SE of %	5%	5%	6%	4%	
30	Sample Size	9	21	29	4	63
	Esc. Age Class	113	263	363	50	789
	Proportion	14%	33%	46%	6%	
	SE of %	4%	6%	6%	3%	
31	Sample Size	151	41	184	20	396
	Esc. Age Class	4,369	1,186	5,324	579	11,459
	Proportion	38%	10%	46%	5%	
	SE of %	2%	2%	2%	1%	
32	Sample Size	74	3	42	2	121
	Esc. Age Class	10,076	408	5,719	272	16,476
	Proportion	61%	2%	35%	2%	
	SE of %	4%	1%	4%	1%	
33	Sample Size	13		11		24
	Esc. Age Class	2,004		1,696		3,700
	Proportion	54%		46%		
	SE of %	10%		10%		
34	Sample Size	5	1	4		10
	Esc. Age Class	1,006	201	805		2,012
	Proportion	50%	10%	40%		
	SE of %	17%	10%	16%		
35	Sample Size	13	6	5		24
	Esc. Age Class	1,800	831	692		3,323
	Proportion	54%	25%	21%		
	SE of %	10%	9%	8%		
36	Sample Size	5	1	8	3	17
	Esc. Age Class	486	97	778	292	1,653
	Proportion	29%	6%	47%	18%	
	SE of %	11%	6%	12%	9%	
37-45	Sample Size	3	1	2	3	9
	Esc. Age Class	209	70	140	209	628
	Proportion	33%	11%	22%	33%	
	SE of %	17%	11%	15%	17%	
Total	Escapement by Age Class	20,611	3,433	16,479	1,589	42,112
	SE of Number	567	83	376	45	
	Proportion by Age Class	49%	8%	39%	4%	
	SE of %	1%	0%	1%	0%	
	Sample Size	314	102	357	46	819

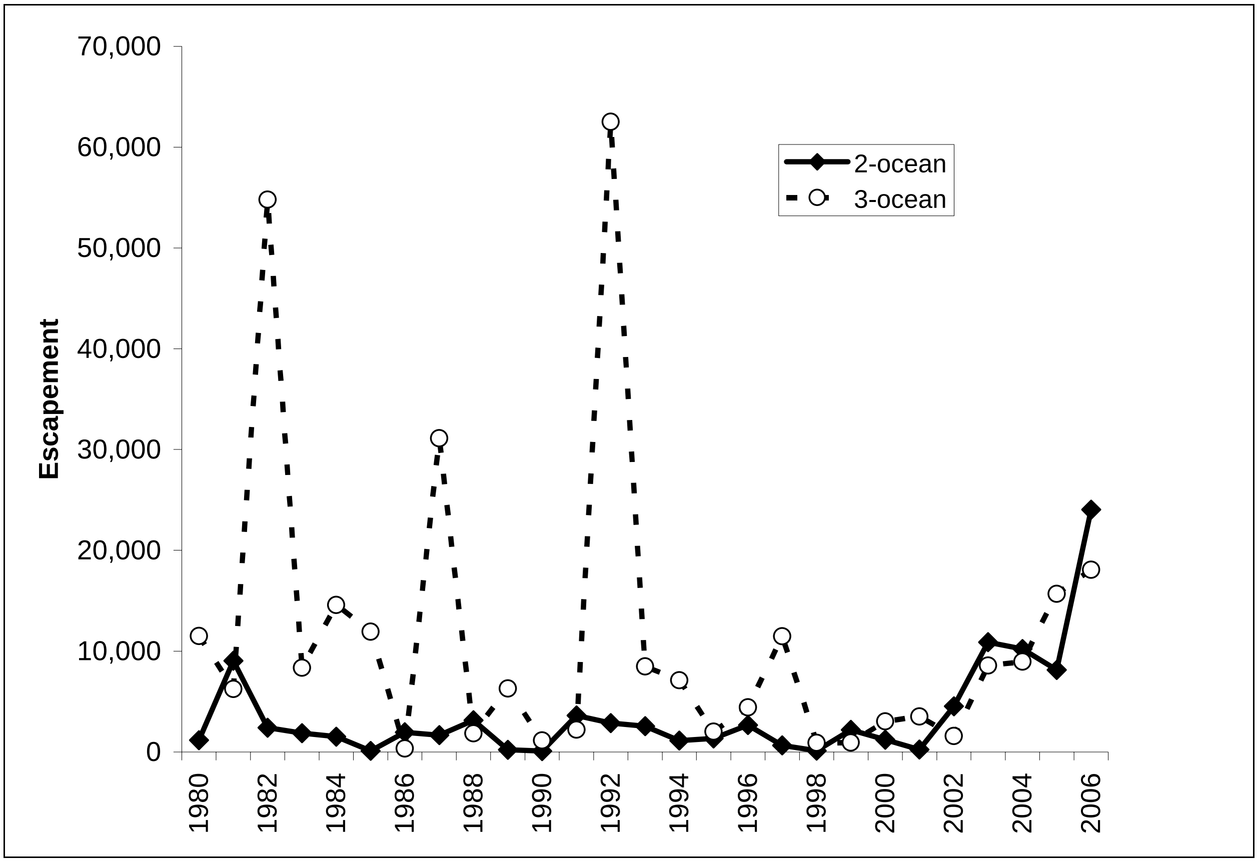

Figure 13.–Annual numbers of 2-ocean and 3-ocean aged sockeye salmon in the Hugh Smith Lake escapement, 1980–2006.

As we have seen in the past four seasons, stocked fish continued to show an unequal spawning distribution within the system in 2006. Nearly all of the fish milling about at the weir and attempting to spawn at the outlet of the lake were otolith marked (98%). Samples from the two primary spawning tributaries showed that approximately 78% of the fish at Cobb Creek and 33% of the fish at Buschmann Creek were otolith marked (Table 6).

Table 6.–Proportion of marked and unmarked otoliths from adult sockeye salmon carcass samples, by recovery location, Hugh Smith Lake, 2002–2006.

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

DISCUSSION

By nearly every measure, things seem to be continuing to improve for the Hugh Smith Lake sockeye salmon stock. The estimated escapement of wild sockeye salmon in 2006 (15,000) was the largest since 1992. This is a continuation of an upward trend in wild sockeye salmon escapement that began at this stock's low point in 1998 (Figure 11). The improvement in wild escapement has corresponded with reductions in fishing effort near the mouth of Boca de Quadra inlet. Fishing effort in the seine fishery near the mouth of Boca de Quadra inlet has declined substantially since the early 1990s (Figure 14) and from 2000 to 2006, the effort levels in the nearby drift gillnet fishery was only about 50% of the effort levels in the preceding 20 years (Figure 15).

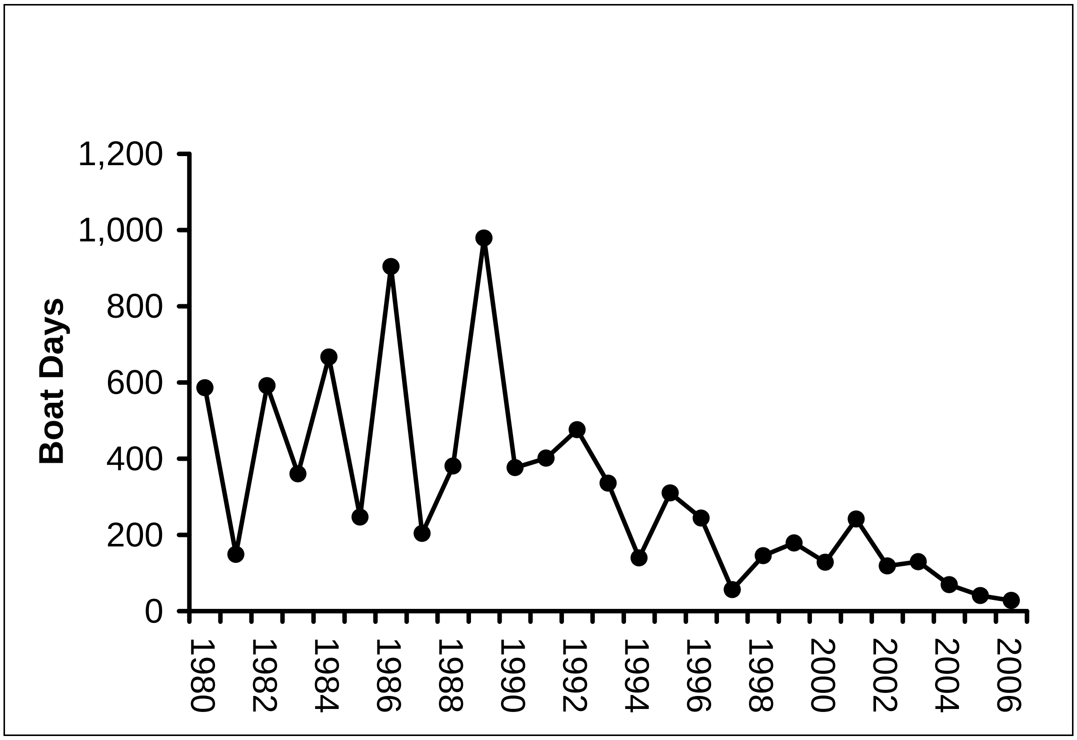

Figure 14.–Fishing effort in boat days for the District 101-23 purse seine fishery, 1980–2006.

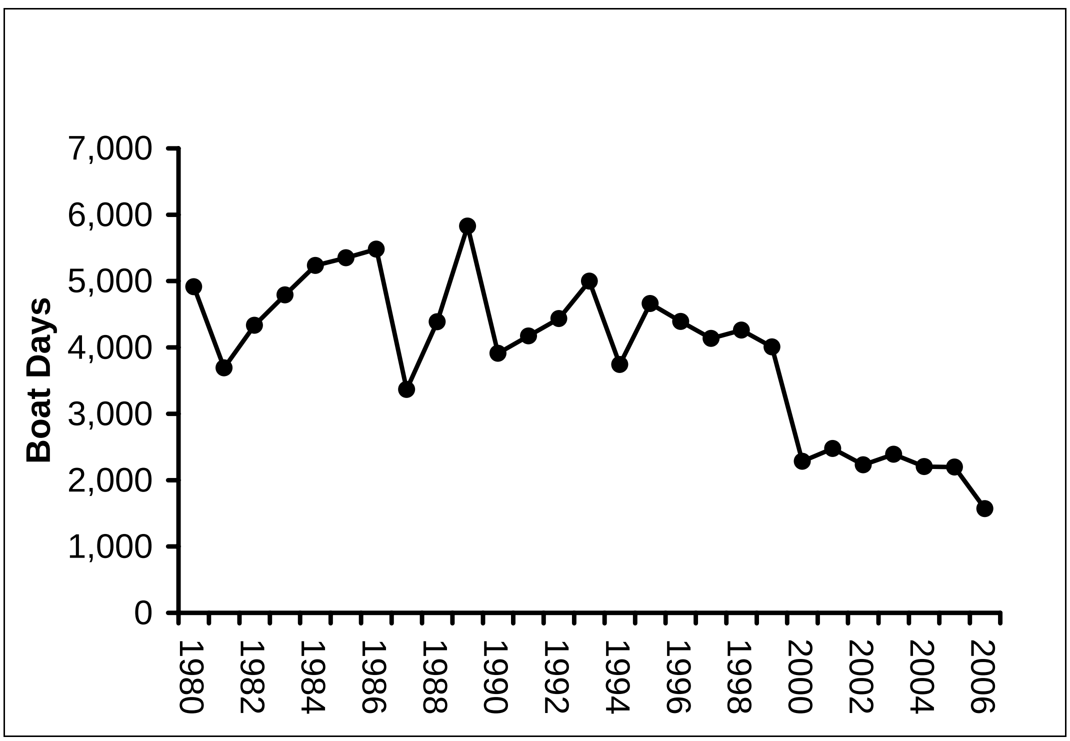

Figure 15.–Fishing effort in boat days for the District 101-11 gillnet fishery, 1980–2006.

Stocked fish from the pen-rearing program returned in large numbers (Figure 11), but as in past years (Geiger et al. 2005, Table 6) large numbers of the stocked fish milled about near the weir and attempted to spawn in unsuitable habitat. In late September, thousands of spawning condition sockeye salmon began backing up to the weir during periods of rising water levels. The number of salmon holding near the weir was difficult to estimate due to the high water levels and the main mass of fish tended to move away from the weir as water receded. From late September to early November, several hundred fish were a constant presence along the front of the weir, attempting to spawn at the lake outlet. The fish milling and dying near the weir were heavily preyed upon by bears and otters, so we do not have precise estimates of the total number of stocked fish that died near the outlet of the lake, but it was clearly in the thousands.

The fish milling about near the weir were not successfully spawning. Our field crew estimated that only about 10% of the carcasses that washed up on the weir looked like a typical spawned out fish (Nick Olmstead and Molly Kemp, ADF&G, personal communication). The majority of these weir wash-ups did not show the typical wear on the skin and fins that one would expect to see on a spawned-out salmon and most had partial to complete loads of ripe eggs or sperm. (Figure 16). While the stocking program successfully increased the sockeye salmon escapement through the weir, it appears that large numbers of these stocked fish did not contribute to juvenile production.

Figure 16.–Variation in the condition of carcasses of stocked sockeye salmon that washed-up on the Hugh Smith Lake adult weir in 2006. The fish on the far left had a full belly of loose eggs, while the two fish on the right had partial loads of eggs. The fish second from the left showed spawning wear and was fully spawned out; a condition exhibited by few of the carcasses that washed up on the weir.

It is unclear what effect the large numbers of stocked fish attempting to spawn in Cobb Creek may be having. From 2002 to 2006, an average of 70% of the sockeye salmon sampled for otoliths in Cobb Creek were stocked fish (Table 6). All of the egg-takes for this program took place at the mouth of Buschmann Creek, but only about 20% of the adult sockeye salmon sampled in Buschmann Creek, from 2002 and 2006, were from the stocking program. The net-pens used for the stocking program were located near the outlet of the lake and it seems clear that most of the stocked fish homed to this site, rather than their stream of origin. Fish wandering down the lake would encounter Cobb Creek first, which probably explains the why there was a higher portion of stocked fish in Cobb Creek than in Buschmann Creek. With the different thermal regimes that exist between Buschmann and Cobb creeks, it is uncertain what the long-term genetic effects of mixing fish from these two streams might be if these stocked fish are successfully spawning to some degree.

Estimates of juvenile sockeye salmon abundance at Hugh Smith Lake have also been trending upwards. Our estimate of 119,000 wild sockeye smolt leaving Hugh Smith Lake in spring of 2006 was well above the very low levels recorded during the 1990s (Table 3). From 2001 to 2006, estimates of wild smolt averaged 107,000 (range: 44,000–194,000). Although smolt-weir estimates in this range may be too low to consistently produce adult returns within the escapement goal range given historical survival and harvest rates, strong wild sockeye salmon escapements in 2005 and 2006 indicate that recent decreases in fishing effort near the mouth of Boca de Quadra (Figures 14 and 15) and corresponding reductions in harvest rate since the early 1990s may allow the stock to reach escapement goals with fewer smolt.

Our hydroacoustic survey results indicate that we should see a continuation of the increasing trend in smolt weir counts in 2007. Our fall fry estimate of 425,000 is approximately double our 2005 fall fry estimate and indicates we should see a corresponding increase in smolt numbers in 2007. The recent increase in smolt numbers seems to be related to increases 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 (Figure 17). Juvenile abundance shows an overall increasing trend, however, we did not see the dramatic increase in smolt production that one would expect given the dramatic four-fold increase in adult escapements that occurred in 2003.

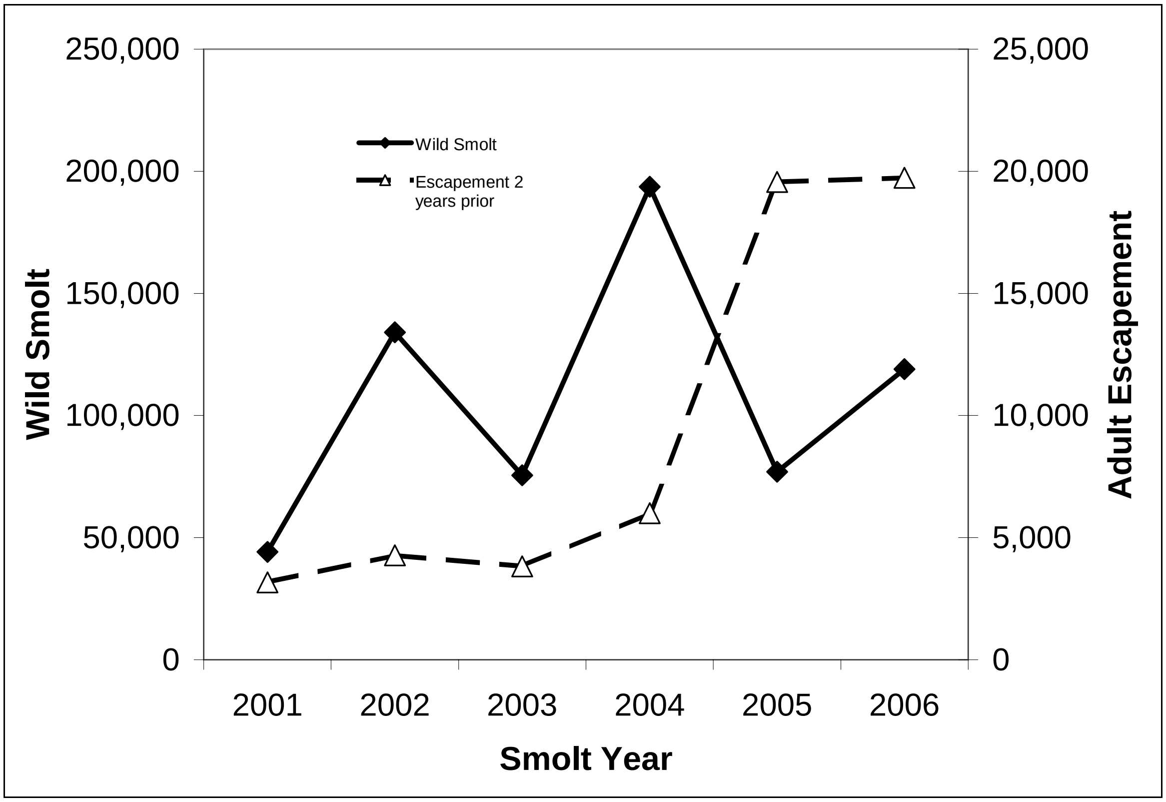

Figure 17.–Smolt weir estimates plotted against adult escapement 2 years prior, 2001–2006.

The results of our monthly hydroacoustic surveys suggest that the mortality rate of fry in the lake was lower during the summer of 2006 than it was in the past two seasons. We estimated that the survival rate of juvenile sockeye salmon from late July to late October was approximately 71%. This is considerably higher than our estimated mid-summer to late fall survival rate of 45% in 2004 and 2005. It is possible that the wet, cool summer in 2006 improved conditions for emerging and rearing fry.

A comparison of our 2005 fall hydroacoustic survey and the 2006 smolt weir count shows that the hydroacoustic estimates provided reliable estimates of juvenile abundance. Unfortunately, late ice cover on the lake prohibited us from conducting a spring hydroacoustic survey, but assuming a 70% overwinter survival rate from our estimated 212,000 fall fry in 2005, we would have expected 148,000 sockeye fry to have survived the winter. 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, mortality during the April through May emigration period, and the smolt weir efficiency. Although any comparison between our hydroacoustic surveys and our smolt weir counts requires us to make several assumptions, we feel that these results indicate that the hydroacoustic surveys provided a reliable measure of juvenile abundance.

Since the spawning escapement reached a low of 1,100 adult sockeye salmon in 1998, we have seen an increasing trend in wild sockeye salmon escapement that has continued into the 2006 season (Figure 11). In both 2005 and 2006, the wild portion of the escapement was estimated (based on otolith samples) to be over 10,000 fish. 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 four consecutive years. If current trends continue, it appears that we should continue to meet escapement goals for this stock.

ACKNOWLEDGEMENTS

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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 2.5^{th} percentile to the 97.5^{th} 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:

$$\hat{p}_{hj} = n_{hj} / n_h \ . \qquad (1)$$

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):

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

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

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

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):

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

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,

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

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