Fishery Data Series No. 06-51

Hugh Smith Lake Sockeye Salmon Adult and Juvenile Studies, 2003 to 2005

by

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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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The Division of Sport Fish Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Since 2004, the Division of Commercial Fisheries has also used the Fishery Data Series. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

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ABSTRACT

In 2003, the Alaska Board of Fisheries formally classified Hugh Smith Lake sockeye salmon as a *management stock of concern* and adopted an action plan to rebuild the sockeye salmon run. Since the 2003 Alaska Board of Fisheries meeting we continued weir operations at the lake and implemented additional studies designed to provide information important for evaluating the rehabilitation efforts ongoing 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 escapement have shown an increasing trend since 1998. Estimates of juvenile abundance in 2004 and 2005 suggest that many of the stocked fish returning to Hugh Smith Lake 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.

Since the 2003 Alaska Board of Fisheries meeting, we continued weir operations at the lake and implemented additional studies designed to evaluate the rehabilitation efforts ongoing at the lake. With the Hugh Smith Lake Juvenile Sockeye Salmon Study 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 with these studies was to identify factors limiting the productivity of sockeye salmon at various stages of their life history within Hugh Smith Lake.

In 2004 and 2005, we conducted monthly hydroacoustic surveys, from early summer through fall, and again in early spring, to estimate the abundance of rearing juvenile sockeye salmon. These surveys also allowed us to determine the approximate survival rates of fry throughout the year. We also attempted to improve the methods we have used for species apportionment in past hydroacoustic surveys: both our capture methods and the statistical methods used in the analysis of trawl catches.

Information on the timing of fry emigration is important for the interpretation of hydroacoustic survey data collected during spring and early summer. Fry emigration into Hugh Smith Lake from Buschmann and Cobb creeks 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).

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. 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 there have been no past 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. In light of the recent declines of this stock, we felt that it was important to gather some baseline information that would allow us to monitor these changes in the future. It is possible that modifications to the stream that took place during hatchery operations in the early 1900s contribute to some of the recent stream shifts.

A private hatchery operated at the head of Hugh Smith Lake from 1901 to 1903, and from 1908 to 1935 (Roppel 1982). The hatchery was originally located on Cobb Creek, but was moved to Buschmann Creek after the first season. When the hatchery was first moved to its Buschmann Creek location, the hatchery operators took advantage of a tiny, one-eighth mile long creek that rose out of a spring, to provide water for hatchery operations (Roppel 1982). Sockeye salmon started spawning in this creek, which was named Hatchery Creek, and by 1934–1935 adult returns to Buschmann Creek and Hatchery Creek were about equal (Roppel 1982). Hatchery operations resulted in modifications to Hatchery Creek, including, the creation of a small 100 × 25 foot reservoir to hold water from the spring, the excavation of nine additional, slightly smaller ponds for rearing fry, and the diversion of water from Buschmann Creek into Hatchery Creek to provide adequate flow for a trap that was built to capture the fish that now entered Hatchery Creek (Roppel 1982).

In response to the stock of concern designation, we also made changes to the sampling program at the adult salmon counting weir. The focus of these changes was on reducing our handling of adult sockeye salmon when they returned to the lake in order to minimize the chances of handling induced stress and mortality. Our primary means of accomplishing this goal was a reduction in the marking rate for our mark-recapture study. In addition, during the first half of the season we began counting fish as they swam freely through the weir at a counting station, which reduced the number of fish that had to be dipnetted out of the weir trap. We also experimented with video camera equipment, which we hope might one day allow us to pass the majority of the fish, throughout the season, into the lake without any handling.

Here, we summarize the information collected over the past three years 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 also has a meromictic layer located below the 60 m depth level. Water below this layer does not interact with the upper freshwater layer of the lake.

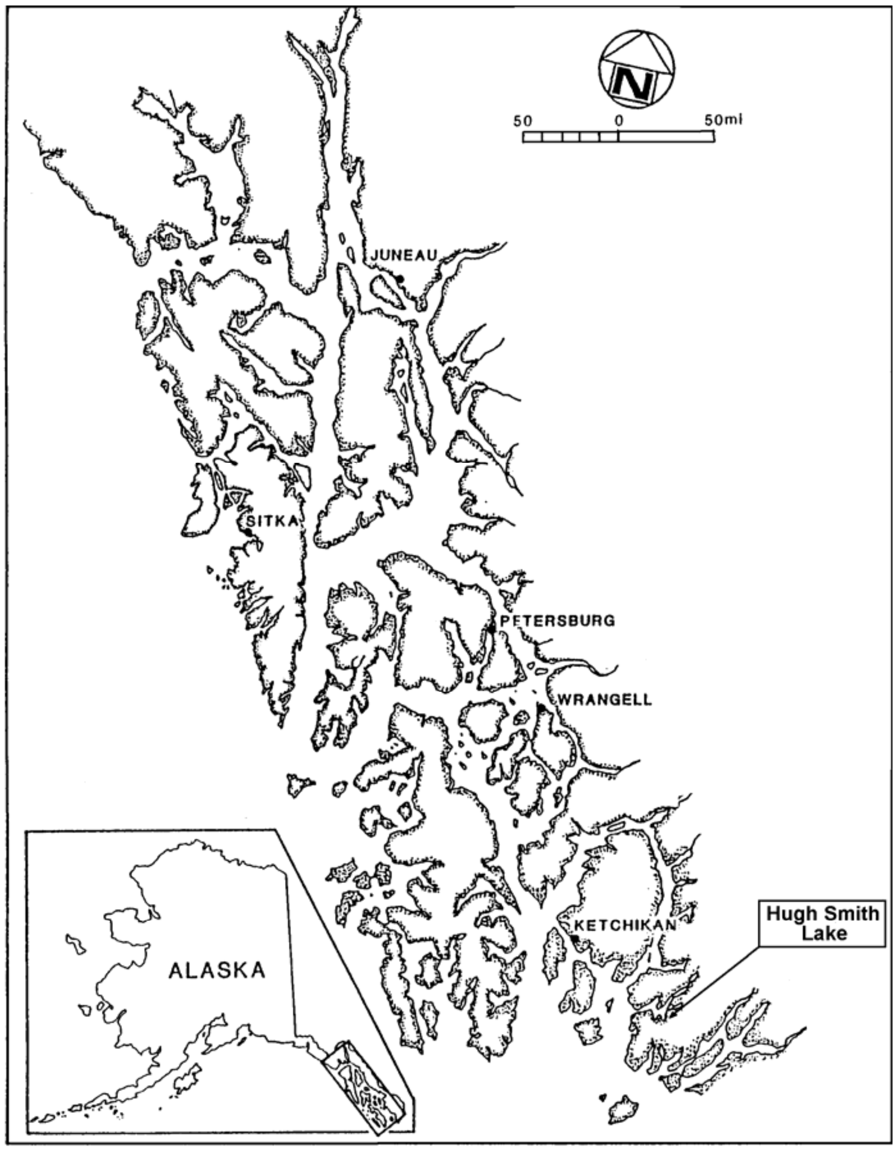

Figure 1.–The location of Hugh Smith Lake in Southeast Alaska.

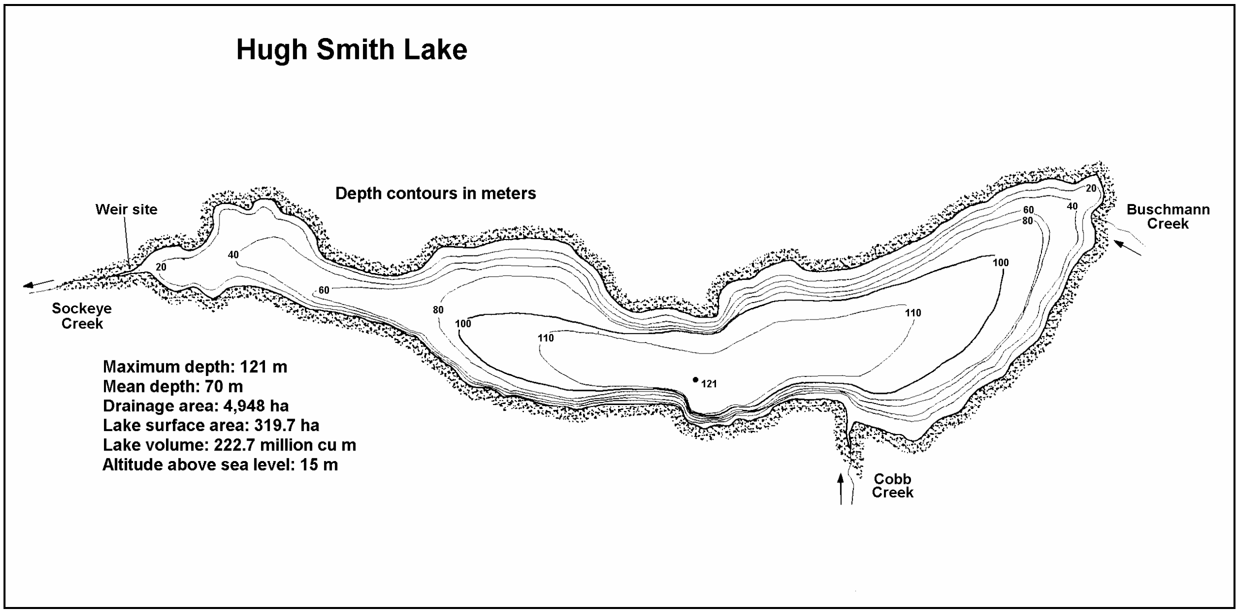

Figure 2.–Bathymetric map of Hugh Smith Lake, Southeast Alaska, showing the location of the weir site, location of inlet streams and other features of the lake system.

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 nearly annually at Hugh Smith Lake since 1980. Unfortunately, few samples comparable to the rest of the data set were collected from 1987 through 1992, during which time a high percentage of the fry stocking occurred. 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 $\cdot$ 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 Soldotna Limnology Lab (samples through 2003) and the ADF&G Kodiak Limnology Lab (2004–2005 samples), 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).

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).

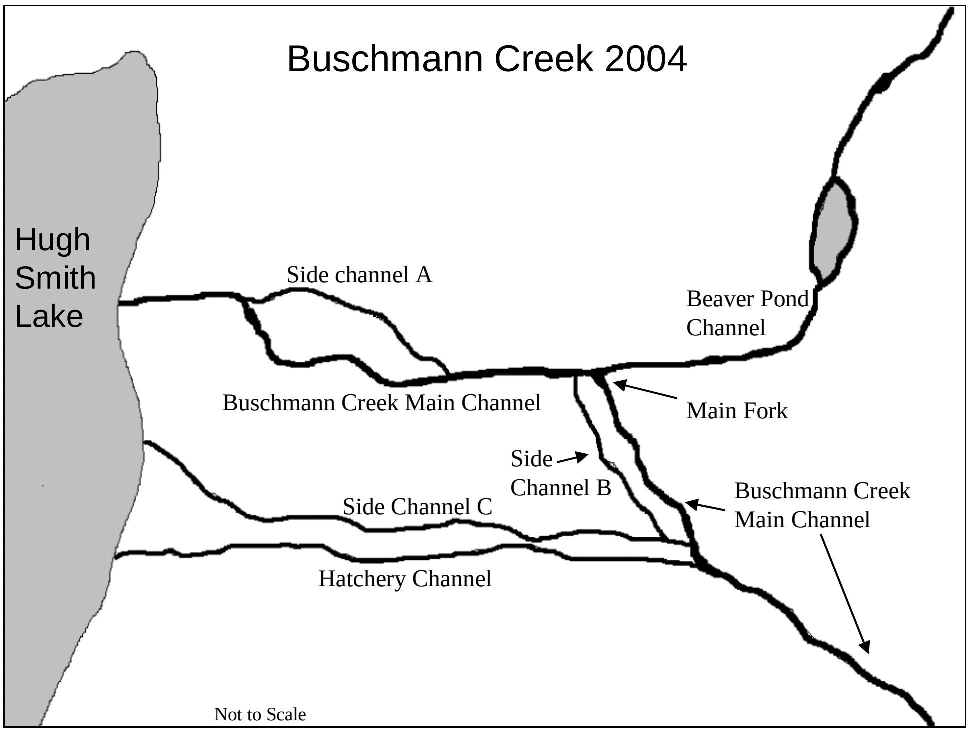

Figure 3.–Schematic diagram of the main channels of lower Buschmann Creek, as of 20 June 2004.

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. The habitat inventory was conducted in early summer, during a period of average stream levels, based on past experience with Buschmann Creek. Stream discharge measurements were conducted at several locations to allow us to conduct future surveys at similar stream levels. Future habitat surveys will be conducted at stream levels within 10% of the first survey's level, if possible.

Each stream channel was divided into sections based on three basic units of stream channel morphology: riffles, runs, and pools. Each section consisted of one continuous unit, e.g., Section

1 would be the first run, Section 2 might be the first riffle, etc. We estimated the area in m^2 of each section as follows. For regular-shaped sections, a wetted width measurement (Schuett-Hames et al. 1999) was taken near the beginning, middle, and end of the section. For sections with highly variable widths, measurements were taken at 2-meter intervals. The length of each section was measured down the middle of the stream channel. The area for each section was calculated by multiplying the section length by the average channel width. Using a digital camera, a series of images for each section was obtained: a view from the downstream end looking upstream, a view from the upstream end looking downstream, and images of any unusual or important features of the section. In the upstream and downstream views, one crewmember stood at the far end of the transect to aid in identifying the boundaries used for future surveyors.

For each section, substrate composition was broken into six classifications based on average substrate diameter that we developed from Wetzel and Likens (2000), and Schuett-Hames et al. (1999; Table 1). We generally characterized the substrate in each section, although we did not follow a rigorous method because of time constraints. Following approximately the same transects used for width measurements, a non-selective grab sample of substrate was taken at points 1 m from each stream bank, and at the middle of the stream channel. At each point the first 25 rocks grabbed from the streambed surface were measured along their intermediate axis (Schuett-Hames et al. 1999), and we calculated the average size of the substrate for each section. In many sections with fairly uniform substrate, the crew used their best judgment, and a smaller number of measurements, in determining substrate type. After the major substrate types were determined, the percentage of each type of substrate in the section was estimated and recorded. Habitat features in each section, such as logs, root-wads, large boulders, etc., were also recorded and described.

Table 1.–Substrate classifications used in the 2004 Buschmann Creek habitat inventory.

Substrate	Size (mm)
Silt/clay/sand	0–2
Fine gravel	2–8
Small spawning gravel	9–64
Large spawning gravel	65–128
Large cobble/small boulder	129–512
Medium boulder/very large boulder	513+

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,

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

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. The undergravel depth of the thermographs was quickly modified by the movement of gravel by spawning salmon so that the actual undergravel depth ranged from about 20 cm to the gravel surface. 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 2004, we conducted hydroacoustic surveys of Hugh Smith Lake to estimate the number of rearing sockeye salmon fry present during the months of August, September, and October. In 2005, surveys were conducted in March, June, July, August, September, and October. 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-6000™ scientific echosounder (430 kHz, 6.8° split-beam transducer) with Biosonics Visual Acquisition © version 4.0.2 software was used to collect the data. Ping rate was set at 5 pings sec^{-1}, pulse width at 0.4 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·m^2) was estimated using Biosonics software (User Guide, Visual Analyser™ 4, BioSonics, Inc.), using the echo integration technique as described in MacLennand 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 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. We developed a Bayesian hierarchical model to apportion the population estimates by species based on our trawl samples (Appendix A). We conducted 6–10 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.

In our previous experience with the 2 m × 2 m trawl net, we have found its catch to be highly selective for size (biased towards small fish), and ineffective at capturing pelagic fish when fish densities were very low (Piston 2004). As currently designed, our trawl net has been limited to fishing the top 12.5 m of the water column. Previous hydroacoustic surveys at Hugh Smith Lake have shown that at night the vast majority of pelagic fish are found from 5–20 m deep. In 2004, we also deployed a modified 40 m × 30 m seine net, with 1/8th inch mesh, in an effort to catch a more representative sample of the pelagic fish in Hugh Smith Lake. We sought to determine if a seine net would prove to be a more effective means of capturing a representative sample of fish from throughout the occupied water column, providing us with improved species apportionment and age class estimates. The seine net was used only during the 2004 season. Seined fish were sampled following the same protocol as was used for trawl net catches.

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, generally by 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 2005 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, otolith 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. From 1998 to 2004, up to 450 sockeye smolts were collected for otolith samples. Samples were collected on a weekly schedule in proportion with historic smolt timing, under the assumption that sampling began the last week of April. Otolith samples were taken from smolts that were also sampled for scales. The smolt were frozen whole in plastic bags, labeled with the date and location, and sent to the ADF&G Mark Lab, where the otoliths were removed, aged, and identified as thermally marked (artificially spawned and stocked) or not (wild). 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 2005. 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 2003–2005. 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.

Mark Recapture

A two-sample mark-recapture population study was conducted annually, in conjunction with weir operations, to estimate the total spawning population of sockeye and coho salmon at Hugh Smith Lake. 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. Fish were marked 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.

Starting in 2003, in order to reduce our handling of fish, we lowered the marking rate to 10% of the adult run (down from 50% over the previous two years). We wanted to confidently conclude that the sockeye salmon escapement was below the lower end of the escapement goal range if the actual escapement was 5,000 or less, even if the weir had failed (allowing a large number of fish to pass undetected). From Figure 3.5 in Seber (1982), we noted that for a population size of 5,000, with a 10% mark rate, and with a recapture sample size of near 600 fish, the probability would be nearly 0.95 that the mark-recapture estimate would be within 25% of the true value, assuming no non-sampling errors. To reach our precision objectives, we examined at least 600 sockeye salmon for fin clips on the spawning grounds in Buschmann and Cobb creeks, with sampling distributed over the length of the spawning season. We expected a sample size of 600 fish in the second sampling event to have yielded a Petersen population estimate with a coefficient of variation less than 15%, when a population size of nearly 5,000 was marked at a rate of 10% (Robson and Regier 1964).

For completeness, we have included the following outline of our reasoning on the mark-recapture sample sizes. Note that if μ denotes the expected number of recaptures, then the approximate coefficient of variation is given by $1/\sqrt{\mu}$ (Seber 1982). We know from experience in this system, as the escapement decreases, the probability of reaching our objective of 600 fish in the recapture sample will also decrease. For example, if the actual escapement was only 1,000 fish, and the mark rate was 10%, we might only be able to find about 100 fish for the second recapture sample. In this scenario, the coefficient of variation would be expected to be nearly 30%, but there would be very little question that the escapement goal was missed. With a 10% mark rate and an attempt to get a second-event sample of about 8% to 10% of the population, the results should clearly indicate whether the escapement was very low (less than 2,000 with a coefficient of variation expected to be near 20% or larger), a low value (such as 4,000 with a coefficient of variation expected to be near but slightly greater than 15%), or a value near the lower end of the escapement goal (with a coefficient of variation expected to be less than 15%).

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-square 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-square 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 each 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. If needed, we adjusted our scale sampling inseason, to ensure that we reach 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).

RESULTS

Zooplankton Productivity

The seasonal mean density and biomass of copepods at Hugh Smith Lake fluctuated widely between 1980 and 1986 (Figure 4 and 5; Table 2). The density and biomass of copepods present in samples obtained prior to the start of lake fertilization in July of 1980 (Peltz and Koenings 1989) were extremely high. Three samples collected between early June and mid-July 1980 had an average *Cyclops* density of 1.25 million per m^2—a level far higher than any observed since that time. It is unclear whether this anomaly was related to the lake fertilization project that ran from 1980 to 1984, as we have no pre-fertilization data for comparison, other than the samples collected between May and mid-July of 1980. When regular sampling resumed in 1993, copepod densities were at their third highest level of the data series (315,000 per m^2), but quickly dropped to below average levels (151,000 per m^2). It is impossible to say if this represents a continuation of the wide fluctuations of the early 1980s because of the six-year gap in the data series. From 1995 to 2004 copepod densities were relatively stable at slightly below average densities (Figure 4; Table 2). The mean seasonal biomass of copepods showed what appeared to be a declining trend from 1995 to 2004 (Figure 5).

Densities of cladocerans were relatively stable throughout the entire period, 1980–2004 (Figure 4). The biomass of cladocerans showed an apparent increasing trend up to 1994, followed by what appears to be a decreasing trend through 2004. The mean weighted length of *Cyclops*, *Bosmina*, and *Daphnia l*. exhibited similar trends to biomass over the 24-year data set (Figure 6). These trends in biomass can be explained to some degree as simply a function of the size of the zooplankton.

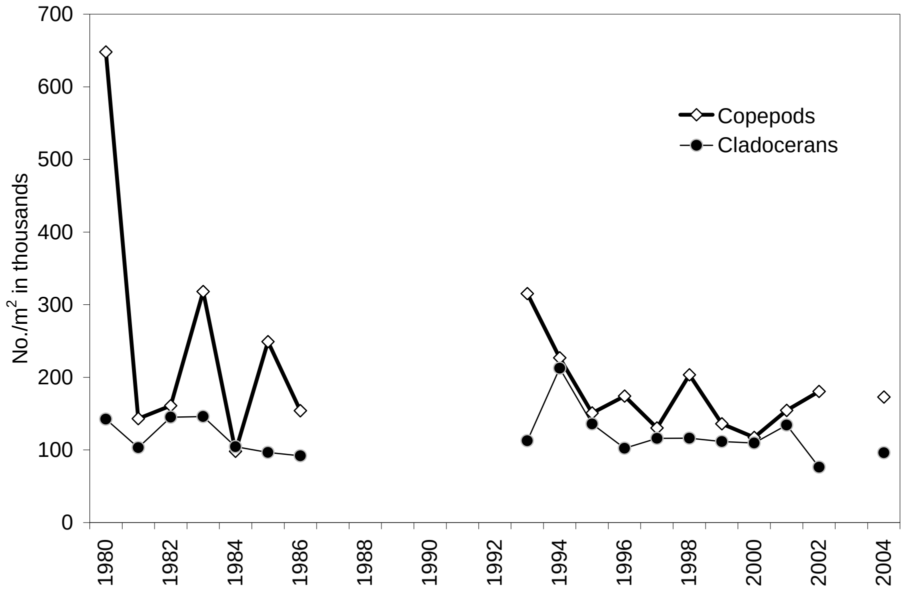

Figure 4.–Seasonal mean density of copepods and cladocerans in Hugh Smith Lake, from 1980 to 2004.

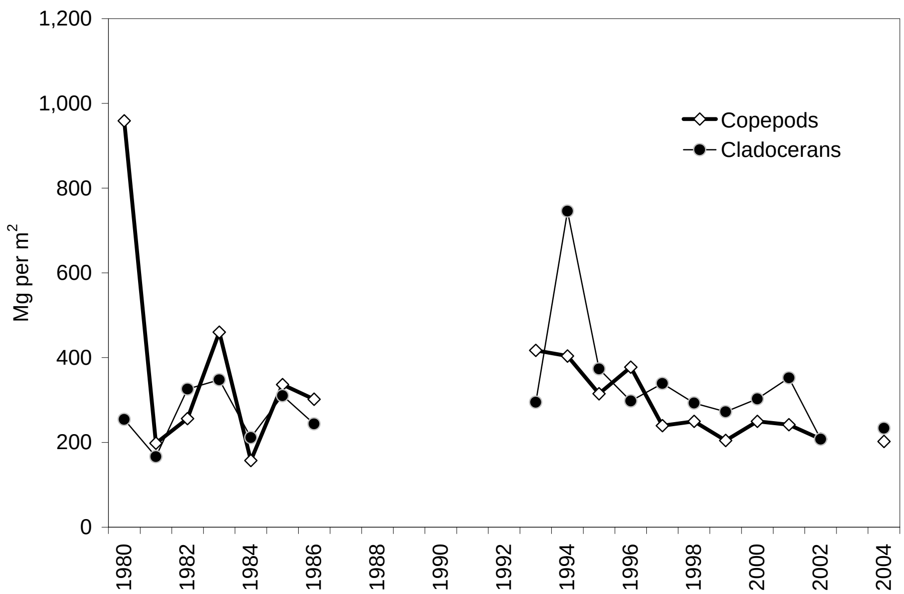

Figure 5.–Seasonal mean biomass of copepods and cladocerans in Hugh Smith Lake, from 1980 to 2004.

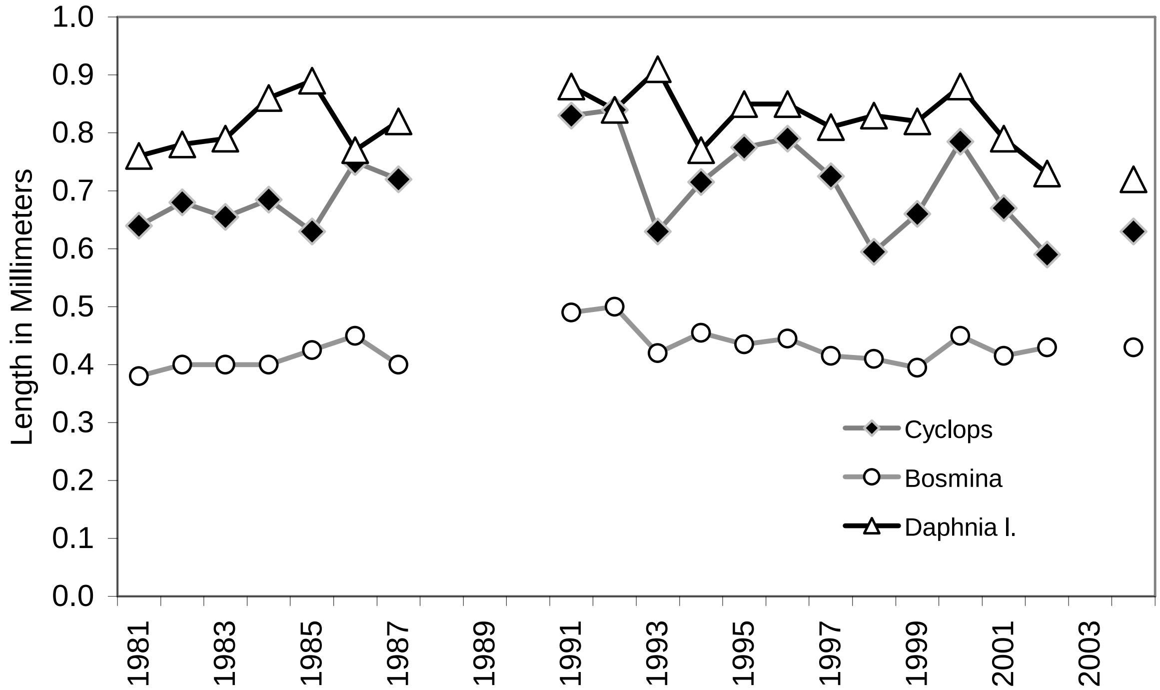

Figure 6.–Seasonal mean weighted length of 3 primary macrozooplankton species at Hugh Smith Lake, 1981–2004.

Table 2.–Zooplankton densities and biomass, by order, for Hugh Smith Lake, from 1980 to 2004.

Year	Mean seasonal density of all species	Mean weighted biomass of all species	Seasonal mean density of copepods	Percent of total density in copepods	Mean weighted biomass of copepods	Percent of total biomass in copepods	Seasonal mean density of cladocerans	Percent of total density in cladocerans	Mean weighted biomass of cladocerans	Percent of total biomass in cladocerans
1980	790,619	1,212.8	648,041	82.0%	958.8	79.1%	142,578	18.0%	254.0	20.9%
1981	246,393	364.2	143,136	58.1%	198.0	54.4%	103,257	41.9%	166.2	45.6%
1982	305,927	581.6	160,830	52.6%	255.9	44.0%	145,097	47.4%	325.7	56.0%
1983	464,146	808.2	318,115	68.5%	460.4	57.0%	146,031	31.5%	347.8	43.0%
1984	202,620	368.5	98,052	48.4%	157.1	42.6%	104,568	51.6%	211.4	57.4%
1985	345,965	646.7	249,317	72.1%	336.3	52.0%	96,648	27.9%	310.4	48.0%
1986	245,769	545.7	153,917	62.6%	302.0	55.3%	91,852	37.4%	243.7	44.7%
1987	Incomplete data									
1988	No data collected these years									
1989	No data collected these years									
1990	No data collected these years									
1991	Incomplete data, only one sample taken for year in April									
1992	Incomplete data, only one sample taken for year in August									
1993	428,129	712.0	315,348	73.7%	417.2	58.6%	112,781	26.3%	294.8	41.4%
1994	439,489	1,149.5	226,964	51.6%	403.6	35.1%	212,525	48.4%	745.8	64.9%
1995	286,709	688.0	150,842	52.6%	314.7	45.7%	135,867	47.4%	373.3	54.3%
1996	276,408	675.2	174,091	63.0%	377.5	55.9%	102,317	37.0%	297.7	44.1%
1997	246,341	578.5	130,349	52.9%	239.6	41.4%	115,992	47.1%	339.0	58.6%
1998	319,833	542.7	203,557	63.6%	249.7	46.0%	116,276	36.4%	293.0	54.0%
1999	247,665	476.9	136,188	55.0%	204.6	42.9%	111,478	45.0%	272.2	57.1%
2000	226,986	552.3	117,353	51.7%	249.7	45.2%	109,632	48.3%	302.6	54.8%
2001	288,930	594.0	154,497	53.5%	241.8	40.7%	134,432	46.5%	352.2	59.3%
2002	256,794	415.5	180,517	70.3%	208.0	50.1%	76,277	29.7%	207.5	49.9%
2003										
2004	268,955	435.6	172,811	64.3%	202.3	46.4%	96,144	35.7%	233.4	53.6%
Mean	327,093	630	207,440	61%	321	49.6%	119,653	39.3%	309	50.4%

BUSCHMANN CREEK HABITAT EVALUATION

In late June of 2004, we completed the habitat inventory of lower Buschmann Creek. We determined the approximate area of spawning habitat in each of the main channels of lower Buschmann Creek (Figure 3; Appendix C). The habitat survey was conducted from the main mouth of Buschmann Creek to the old beaver ponds, from the main fork to the break with the top of the hatchery channel, down the hatchery channel, and down the main side channels in between (Figure 5). Stream discharge measured above the hatchery channel was 0.68 cubic meters/second. Stream discharge measured in the Buschmann Creek main channel near the mouth of the creek was 0.40 cubic meters/second. In 2004 and 2005, the flow of Buschmann Creek was divided into three channels (Main Channel, Hatchery Channel, and Side Channel C) in its lower 0.7 kilometer. As water levels in Buschmann Creek rise, water flows into many small channels between the Main Channel and the Hatchery Channel (Figure 3). This area of the creek is dynamic, with small changes certain to occur on a yearly basis. It was not possible to map the myriad of tiny overflow channels running through this brushy and difficult-to-access area. Prior to the survey we did not realize Side Channel C was a separate channel all the way from its top to its mouth at Hugh Smith Lake (Figure 3).

We documented the presence of adult sockeye salmon in all of the channels outlined in Figure 3. The Hatchery Channel and Side Channel C, which have apparently had variable flow in the past, contain quality spawning habitat and some excellent coho salmon rearing habitat when flows are sufficient. In years when the flow in lower Buschmann Creek was divided into several channels, severe drought conditions may have increased chances of redds in these locations drying out or freezing in the winter.

The system appeared to be fairly stable between 2004 and 2005. The most noticeable change occurred in the upper part of the Hatchery Channel. Buschmann Creek stopped flowing directly into the Hatchery Channel and instead was divided between its primary channel and Side Channel C. However, flow from Side Channel C entered the hatchery channel about 50 meters below its junction with Buschmann Creek, so very little spawning habitat was actually left dry and adequate flow remained in all of the major channels of the lower creek. Beavers constructed a new dam in the beaver pond channel, a short distance above the main fork. Fish were observed above this new dam early in the season, and the dam washed out in high water later in the fall. Beaver dams have been present in this branch of the creek since ADF&G began studies there in 1980.

STREAM TEMPERATURE MONITORING

Temperature data collected from Buschmann and Cobb creeks, between 26 July 2004 and 30 July 2005, revealed that there are different temperature regimes between the two tributaries (Figure 7). There also appears to be a fair amount of temperature variation between different regions of Buschmann Creek. Temperatures were warmest in the beaver pond channel, with temperatures similar to Cobb Creek, while water in Buschmann Creek was considerably cooler. Temperatures below the main fork in Buschmann Creek, where waters from the two previously mentioned branches mix, were intermediate in temperature and were used in the following analysis. The number of cumulative thermal units (CTUs) between the two streams varied by approximately 12% (2,218 in Cobb, 1,954 in Buschmann) over the entire time period that eggs and juvenile sockeye salmon are found within the spawning tributaries, approximately 25 August to 25 July.

The spawn timing of adult sockeye salmon in Buschmann and Cobb creeks determines how different the thermal regime experienced by developing eggs and alevins will be between the two streams. Temperatures were warmer in Cobb Creek than Buschmann Creek from mid-April through early November. Temperatures were similar, or slightly warmer, in Buschmann Creek, from mid-November to mid-April (Figure 7). Eggs deposited in Cobb Creek on 25 August would have been exposed to 683 CTUs by November, compared to 610 CTUs for eggs deposited in Buschmann Creek. From 1 November through 31 March, eggs would have been exposed to 384 CTUs in Cobb Creek and 424 CTUs in Buschmann Creek. During the final stages of development leading to emergence, 1 April through 1 July, alevins would be exposed to 835 CTUs in Cobb Creek and only 660 CTUs in Buschmann Creek.

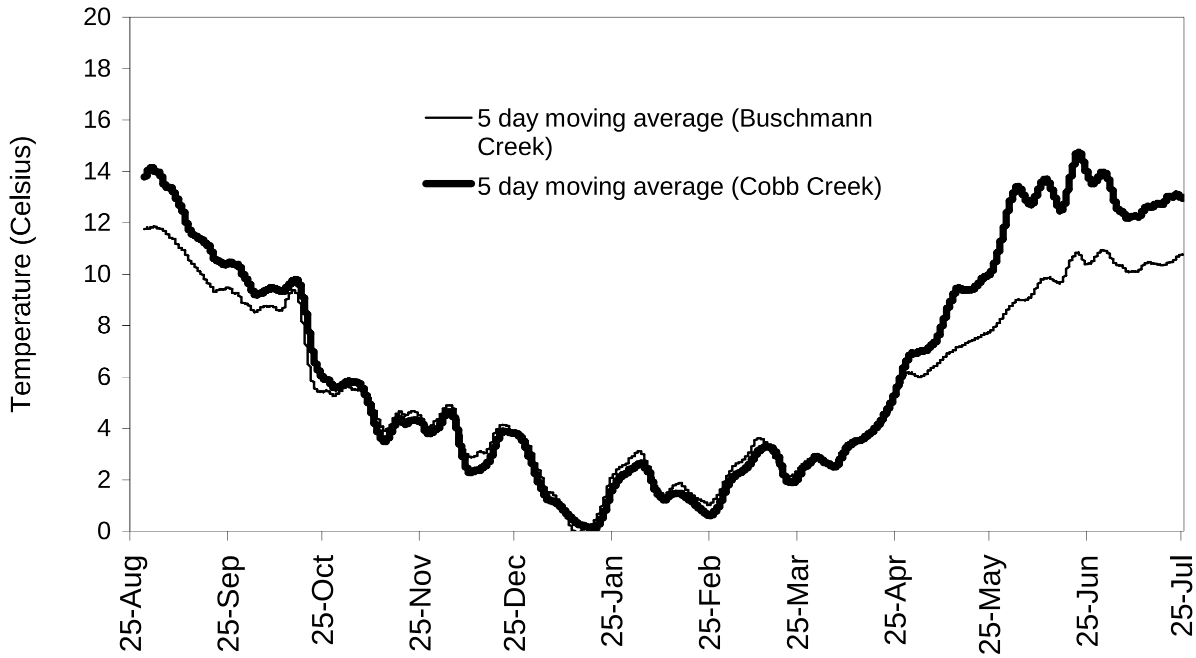

Figure 7.–Stream temperature profile for Buschmann and Cobb Creeks, 25 August 2004 to 25 July 2005.

FRY PRODUCTION

Hydroacoustic Surveys

2004

In 2004, the total pelagic fish estimate for the August survey was 686,000, with a standard error of 110,000 (CV 16%). We performed six trawls for a catch of 293 total fish, 35 of which were sticklebacks (11.9%). The age composition of the sockeye fry was 98.1% age 0 and 1.9% age 1. Three seine sets produced 34 fish of which 14.7% were stickleback. All of the sockeye fry in the seine catch were age 0. Due to extremely inconsistent results between various trawls, we were not able to reliably apportion the estimate by species using the Bayesian hierarchical model. We were able to apply the model to the seine catches. Using the seine net data we estimated the sockeye fry population to be 563,000, with a 95% credible interval of 369,000 to 769,000.

The September total pelagic fish estimate was 317,000, with a standard error of 77,000 (CV 24%). We completed 10 trawls, catching a total of 296 fish, 28 of which were stickleback (9.5%). The age composition of the sockeye fry was 93.7% age 0 and 6.0% age 1, with the remaining 0.3% un-ageable. Six seine sets produced 65 fish, of which 3 (4.6%) were stickleback and 2 (3.1%) were cutthroat trout. The age composition of the sockeye fry was 98.3% age 0 and 1.7% age 1. The total estimate of sockeye fry in the lake was 260,000, with a 95% credible interval of 133,200 to 393,000.

The October total pelagic fish estimate was 302,000, with a standard error of 25,000 (CV 8%). The October trawl net sampling produced 151 fish in nine trawls. Eleven stickleback were captured (7.3%) and the age composition of the sockeye fry was 94.3% age 0 and 5.0% age 1, with a few unreadable scale samples making up the rest. The total estimate of sockeye fry in the lake was 251,000, with a 95% credible interval of 199,000 to 303,000. The survival rate of the sockeye fry between late August and late October was roughly 45%.

The modified seine net that we used in 2004 did not appear to be any more effective than our trawl net at capturing the larger age-1 sockeye fry, and in fact caught a smaller percentage of these fish in the two surveys where the seine was used extensively. The net proved to be extremely difficult to set, requiring a minimum of four people and two boats for deployment. The large amount of web required to construct a net 30 m deep made the net difficult to feed smoothly out of a small skiff. During the 2005 season we did not have enough crew members at the lake to make using the seine net feasible and the net was not used.

2005

The total pelagic fish estimate for the March survey was 355,000 with a standard error of 105,000 (CV 29.5%). We caught a total of 151 fish in 8 trawls, of which 4 (2.6%) were stickleback. Of the 146 sockeye fry captured, 42.5% were age 0, 48.6% were age 1, and 6.8% were age 2, with a few unreadable scale samples making up the remainder. The total estimate of sockeye fry in the lake was 330,000, with a 95% credible interval of 141,000 to 522,000. The estimate of 180,000 age-1 and age-2 sockeye fry gives an overwinter survival, from October 2004 to March 2005, of approximately 72%.

We conducted our next hydroacoustic survey in late June, 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 in June was 475,000, with a standard error of 98,000 (CV 20.62%). Total pelagic fish estimates for the remaining surveys decreased through October (225,000, standard error 22,400, CV 9.97%). At this time we do not have an analysis of the age structure of the associated samples, and so we do not have the total pelagic fish targets apportioned into species and age categories. However, based on the total pelagic fish estimates, it appears that the late August to late October survival rate will be about 50%, which is similar to 2004 results.

Fry Emigration Timing

In 2004, sockeye fry were captured in both creeks on the first set of the fyke nets; 30 April at Cobb Creek, and 4 May for Buschmann Creek. Trawl net catches from late April, however, showed that sockeye fry had already begun migrating into the lake prior to those dates. Catch rates remained high at Buschmann Creek through the first week of July before declining quickly, while at Cobb Creek the catch rate dropped sharply in late May and few sockeye were captured after early June (Figure 8).

In 2005, large numbers of fry had entered the lake by late March. Hydroacoustic and trawl net data, collected on March 22 and 23, gave an estimate of about 140,000 age-0 sockeye fry in the lake. The lake had only been ice free for about 1.5 weeks prior to the survey. The fyke nets were again deployed in late April. Emigration from Cobb Creek was steady from the initial deployment to mid May, then quickly dropped to single digit captures each day by the end of the month. Catches in Buschmann Creek were high initially, began dropping steadily in early June, and few fish were caught after mid June. In 2005, emigration timing was similar between the two creeks, with Buschmann Creek fish moving only slightly later than those in Cobb (Figure 9).

SMOLT PRODUCTION

In 2003, the total estimate of sockeye salmon smolt passing through the smolt weir at the outlet of the lake was approximately 260,000, of which 71% were stocked fish (185,000, SE=4,500), and 29% were wild fish (Table 3). Nearly all of the stocked fish were from the 2002 release of 465,000 pre-smolt; the only exception being a single smolt that had held over a second year from the 2001 release.

In 2004, the smolt weir estimate was approximately 360,000, of which 47% were stocked (170,000 smolt, SE=8,000), and 53% were wild. Nearly all of the stocked fish were from the 2003 release of 420,000 pre-smolt. The estimate of 190,000 wild sockeye smolt was larger than all smolt weir estimates from 1989 to 2001 (Table 3).

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 2005 smolt weir count was 77,000.

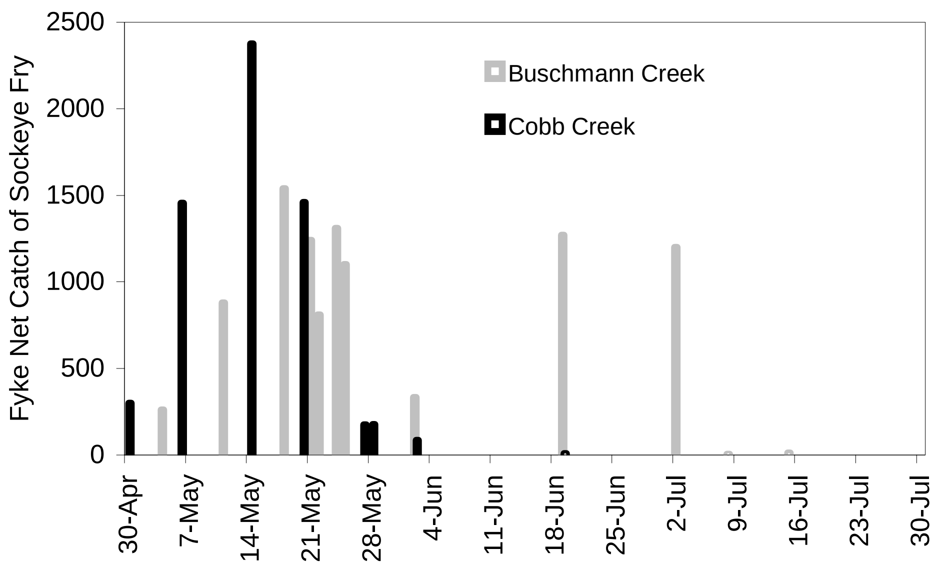

Figure 8.–Sockeye fry emigration timing, Buschmann and Cobb Creeks, 2004.

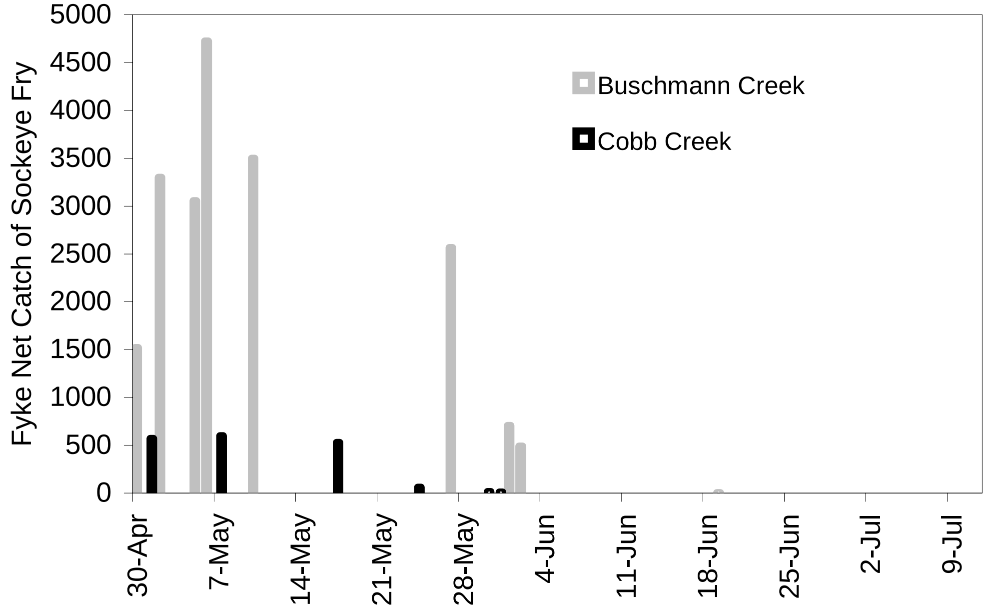

Figure 9.–Sockeye fry emigration timing, Buschmann and Cobb Creeks, 2005.

Table 3.–Hugh Smith Lake weir counts of sockeye smolt by smolt year, and stocked fry and pre-smolt releases by year of release, 1981–2004. 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	644,586	Unfed Fry	1995	19,212			
1995	417,678	Unfed Fry	1996	16,355			
1996	357,956		1997	44,257			
1997	572,547	Unfed Fry/ Pre-smolt[a]	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	

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

ADULT ESCAPEMENT

2003

In 2003, the adult weir was fish-tight from 17 June to 7 November, and we passed 19,568 adult sockeye salmon, and 1,356 jacks. The adult escapement exceeded the upper end of the new escapement goal range of 8,000–18,000 sockeye salmon (Figure 10). Also of interest, is the fact that age-1.2 fish comprised over 50% of the escapement in 2003 (Figure 11).

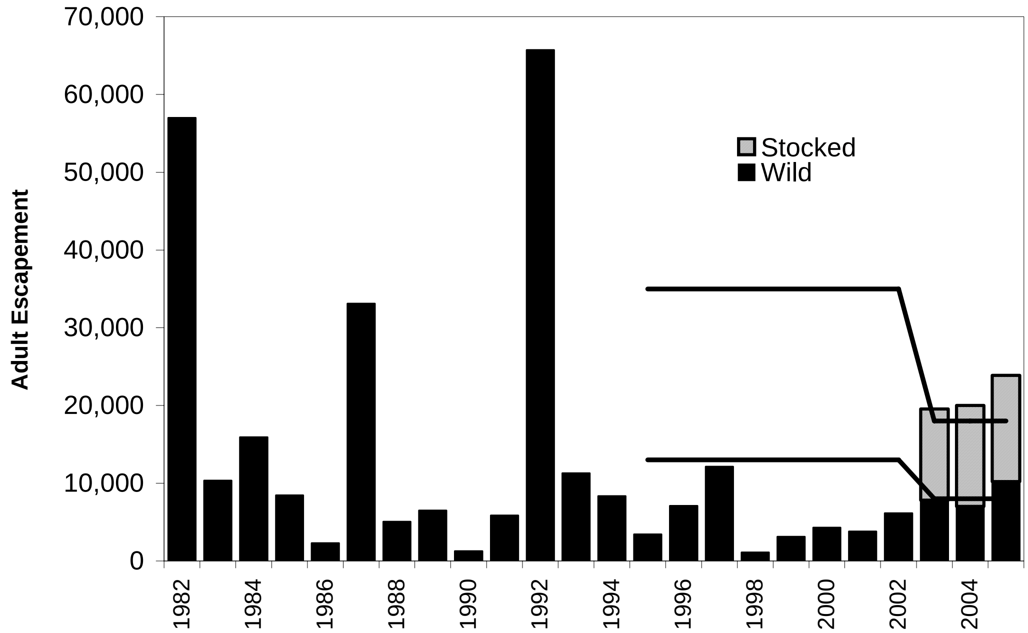

Figure 10.–Annual sockeye salmon escapement at Hugh Smith Lake, 1982–2005. The two black horizontal lines show the escapement goal range, by year. The escapement goal range of 8,000 to 18,000 adult sockeye salmon that was adopted in 2003 includes both wild and hatchery stocked fish and replaced the previous goal of 15,000–35,000. From 2003 to 2005, the bars are divided to show our estimate of wild (black) and stocked fish (gray).

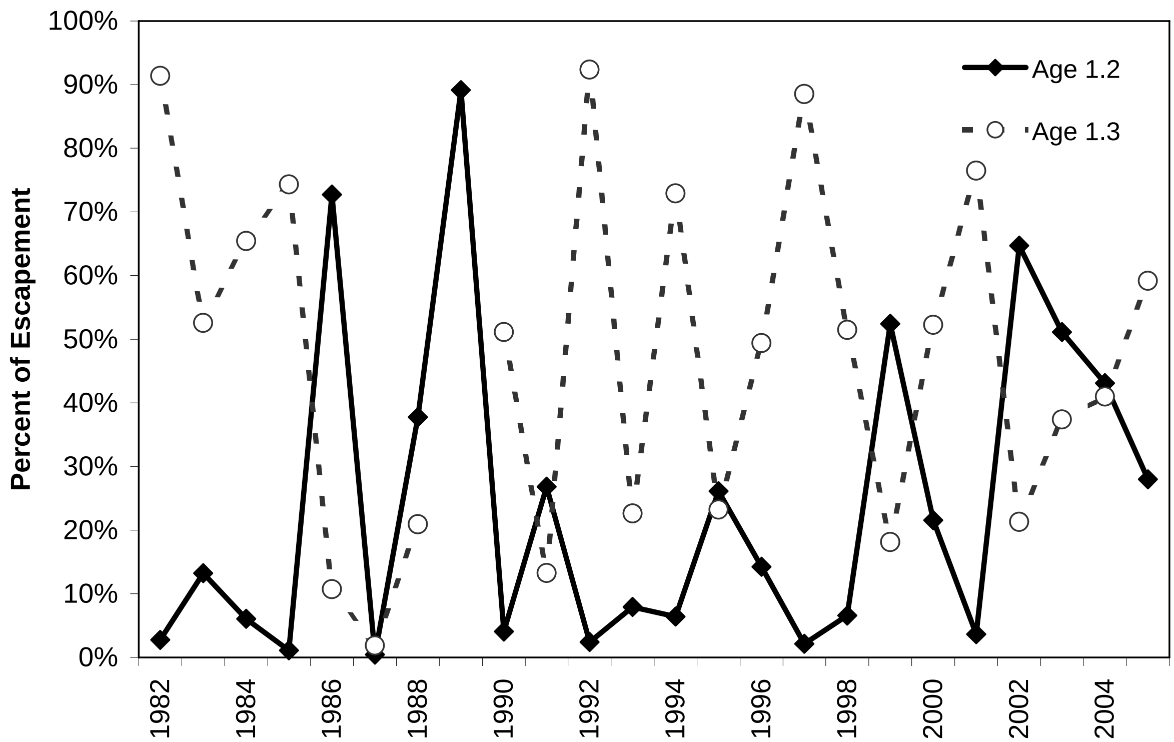

Figure 11.–Hugh Smith Lake sockeye salmon escapement by proportion of age class, 1982–2005.

In 2003, a total of 1,945 adults were marked with different fin clips over three marking strata. Recapture sampling on the spawning grounds was spread out over the course of the spawning season, from 29 August to 3 November. We also sampled all dead fish that washed up on the weir. A total of 2,057 fish were sampled for fin clips, of which 194 were marked. From these data we generated a Darroch estimate of the adult population of 20,000 (SE=1,500; 95% CI=17,000 to 23,000). Thus, the weir count of 19,568 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 7.7% easily met our objective of a coefficient of variation of no greater than 15%, likely because our recovery sample was very large. In addition, we marked and released 1,070 jacks at the weir. We sampled 496 jacks in our recapture strata, of which only 25 were marked. The Darroch estimate of 19,000 jacks (SE=4,300) was not as precise as the adult estimate (CV=22.1%), because we were not able to recover as many marked jacks. We felt all season that the weir crew passed more than the average number of jacks at the weir, and the Darroch estimate of the jack population corroborates this to some degree (e.g., an "extraordinary number of sockeye jacks this year"—Nick Olmstead and Molly Kemp, ADF&G, personal communication).

2004

In 2004, the adult weir was fish-tight from 17 June to 7 November, and we passed 19,734 adult sockeye salmon and 147 jacks. The adult escapement exceeded the new escapement goal of 8,000–18,000 sockeye salmon for the second year in a row (Figure 10). Age-1.2 fish again comprised over 40% of the escapement (Figure 11), continuing the general trend of increasing numbers of age-1.2 fish returning to Hugh Smith Lake.

In 2004, a total of 1,979 adults were marked with different fin clips over three marking strata. Recapture sampling on the spawning grounds was conducted over the course of the spawning season, from 30 August to 2 November. We again sampled all dead fish that washed up on the weir. A total of 1,547 fish were sampled for fin clips, of which 136 were marked. From these data we generated a Darroch estimate of the adult population of 22,000 (SE=2,000; 95% CI=18,000 to 26,000). Thus, the weir count of 19,734 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 9.1% easily met our objective of a coefficient of variation of no greater than 15%.

In addition, we marked and released 102 jacks at the weir. We sampled 48 jacks in our recapture strata, of which only 2 were marked. Thus, we were unable to generate a population estimate on jacks for 2004. We saw far fewer jacks at the weir and on the spawning grounds than we did in 2003.

2005

In 2005, the final escapement number was once again above the upper end of the escapement goal range. The weir was fish-tight from 17 June to 4 November, and we passed a total of 23,872 adult sockeye salmon and 331 jacks through the weir. Age-1.3 fish made up 60% of the adult escapement in 2005 (Figure 11), but the number of 2-ocean fish (8,200) was far above levels observed in any year prior to the onset of the pre-smolt stocking program.

In 2005, we marked a total of 2,278 adult sockeye salmon at a 10% marking rate over three marking strata. Recapture sampling was conducted throughout the spawning season, with sampling taking place at both tributary streams and at the weir, as in 2004. A total of 1,244 fish were sampled for fin clips, of which 115 were marked. Results of X^2-square tests of complete mixing of marked fish between release and recovery strata, and tests of equal proportions of marked fish in the recovery strata were non-significant ($p>0.05$); therefore, we used a pooled Petersen estimate of 24,500 (SE=2,098; 95% CI=20,400 to 28,600) adult sockeye salmon. The weir count of 23,872 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 9% easily met our objective of a coefficient of variation of no greater than 15%. As in 2004, we were not able to generate a population estimate for jacks.

DISCUSSION

Overall, the Hugh Smith Lake system appears to be healthy. The entire drainage is located within the pristine wilderness of Misty Fjords National Monument and there does not appear to be any productivity problems within the lake itself. The increases we have seen in wild escapements at Hugh Smith Lake have occurred at a time when we are also seeing corresponding decreases in fishing effort in the District 101 seine and gillnet fisheries near the mouth of Boca de Quadra inlet (S. C. Heinl unpublished data). We presume that the Canadian harvest of Hugh Smith Lake sockeye salmon has dropped below historical levels due to changes in Canadian management strategy and associated reductions in fishing effort in British Columbia Area 3, which is immediately adjacent to the Alaska border in eastern Dixon Entrance. Between 1983 and 1998, the Alaskan harvest rate on Hugh Smith Lake sockeye salmon averaged 60.2% and reached a high of 94.3% in 1990 (Geiger et al. 2003). The Alaskan harvest rate of Hugh Smith Lake sockeye salmon was approximately 70% in 2004 (S. C. Heinl unpublished data). These harvest rate estimates do not reflect all fishery removals, because Canadian fisheries were not sampled for coded wire tagged sockeye salmon and only Southeast Alaskan fisheries were represented in the estimates (Geiger et al. 2003). High harvest rates appear to be the principal cause of past declines of this stock.

The estimates of densities and biomass of the major groups of zooplankton in Hugh Smith Lake do not give us any reason to suspect the past declines in escapement at Hugh Smith Lake were related to lake productivity problems. Peltz and Koenings (1989) concluded that the numbers of rearing sockeye salmon fry in the lake during the early 1980s were not taxing the sockeye salmon food base even without fertilization. The mean seasonal density of all zooplankton at Hugh Smith Lake averaged 330,000 per m^2, from 1980 to 2004 (Table 2). It is interesting to note that seasonal mean densities of zooplankton at McDonald Lake (Johnson et al. 2005), one of the largest sockeye salmon producers in southern southeast Alaska, averaged only about one-third of what we found at Hugh Smith Lake, and densities of cladocerans averaged about 65% of the levels found in Hugh Smith Lake. The lowest mean seasonal density of zooplankton recorded at Hugh Smith Lake (1984) was higher than the highest value recorded at McDonald Lake (2003).

However, Geiger et al. (2003) noted that due to warm winter temperatures from 1987 to 1989 fry emerged early in the hatchery and were stocked into Hugh Smith Lake, possibly before the plankton production was sufficient to handle the increased predation. It is difficult to assess the impact of the 1987 to 1989 plants because regular zooplankton samples were not collected from 1987 through 1992. The few samples that were collected during this period raise the possibility that the stocking caused a steep reduction in zooplankton density and biomass in Hugh Smith Lake. A zooplankton sample collected on 25 April 1987 had the lowest total zooplankton density (20% of average) for samples collected between mid-April and mid-May, from 1980 to 2004.

Similarly, a sample collected 15 July 1987 was only 45% of the average zooplankton density observed in comparable samples between 1980 and 2004. When regular zooplankton sampling resumed in 1993 densities and biomass were at above average levels (Figures 4 and 5), suggesting that any declines in zooplankton abundance brought about by early fry stocking were temporary.

The trend towards a higher biomass of the dominant macrozooplankton in the early to mid 1990s followed by decreases through 2004 is the inverse of the trend we see in smolt weir counts at the lake. It is possible that the increased size of zooplankton in the early 1990s was a result of reduced predation due to very low densities of rearing juvenile sockeye salmon. Smolt weir estimates reached lows in the early to mid 1990s, and were generally much higher in the 1980s and since 2000. Food habit studies conducted in the early 1980s at Hugh Smith Lake showed that *Cyclops*, *Bosmina*, and *Daphnia* were the dominant macrozooplankton in the diet of the lake's juvenile sockeye salmon (ADF&G unpublished data). These three groups also represent the vast majority of the macrozooplankton density and biomass in Hugh Smith Lake.

In 2004, we made our first effort to inventory spawning habitat at Buschmann Creek. This inventory, while not technically sophisticated, should provide us with a baseline with which we can assess the scope of future changes in the habitat of lower Buschmann Creek, and certainly the ability to detect gross changes in habitat that may reduce the available spawning area or negatively effect rearing conditions. Currently, we have no reason to believe that habitat changes have played a role in declining escapements at Hugh Smith Lake. It is likely that small shifts in stream flow have always occurred in the lower 0.7 kilometer of Buschmann Creek, due to the dynamic nature of the lower valley. The small changes we observed between the 2004 and 2005 seasons affected very little spawning habitat. In a worst-case scenario, such as the Hatchery Channel and Side Channel C drying up completely, the effect should still be minimal because these two channels represent only a small fraction of the available spawning habitat in the system and the increased flow in the main channel would likely make more spawning habitat available in that area. We know that sockeye salmon spawn above our habitat study area in the main channel of Buschmann Creek and in the Upper Beaver Pond channel. Habitat in Cobb Creek, which has a well-defined stream channel that is largely framed with bedrock, has been stable for at least the past 10 years, and probably longer. The temperature differences we recorded between Buschmann and Cobb creeks probably explain much of the difference in fry emigration timing we have observed and is an important consideration for the stocking program, which has inadvertently mixed fish from these two creeks (Geiger et al. 2005). We do not know what effect, if any, local adaptations to each particular stream may have on fry emigration timing, and whether the stocking program has altered the dynamics in any way.

Smolt weir counts increased in recent years from the very low levels recorded during the 1990s (Table 3). A high proportion of the smolt in these most recent years have been from the releases of pre-smolt that were pen-reared and stocked into the lake at the outlet from late-May to late-July, but numbers of wild smolt appear to have increased in recent years as well. From 2001 to 2005, estimates of wild smolt averaged 105,000 (range: 44,000–194,000). This is more than double the average smolt weir count of the 1990s. Although this is an improvement, the magnitude of the wild smolt emigration is of concern because smolt production at this level may not allow future adult returns to consistently reach the lower end of the escapement goal range given current levels of harvest. Coded wire tagging studies, from 1991 to 1996, showed that tagged Hugh Smith Lake sockeye salmon had an average marine survival rate of about 8%

(Geiger et al. 2003). If marine survival continues to be approximately 8%, and harvest rates remain close to 60%, it will require approximately 250,000 smolt annually to consistently reach the lower end of the escapement goal range. Typically, the majority of adult sockeye salmon returning to Hugh Smith Lake are 3-ocean fish. If we look at the seven years between 1984 and 2002 in which we reached the lower end of the escapement goal range of 8,000 fish, we see that the average smolt weir count three years prior was slightly over 200,000 fish, and as previously noted these smolt weir estimates have tended to be low.

We find the relatively low smolt count of 77,000 in 2005 alarming, and we interpret this finding to mean that large numbers of stocked fish returning to Hugh Smith Lake in 2003 may have had poor spawning success. Hydroacoustic surveys conducted during the summer and fall of 2005 showed lower rearing fry abundance than in 2004, suggesting that the 2006 smolt weir count, as in 2005, will likely be below 100,000. Fish spawning in poor substrate near the weir, or along the lake shore near the release site, probably added little or nothing to the overall production, and it seems likely that this was the fate of many of the stocked sockeye salmon (Geiger et al. 2005). Although the smolt numbers produced by the large escapement of 2003 are disappointing, the results of our monthly hydroacoustic surveys suggest that mortality of fry in the lake was not unusually high. We estimated that the overwinter survival rate of juvenile sockeye salmon in the lake to be approximately 72%. This is similar to the 70% general assumption for overwinter survival that has been used by ADF&G biologists in the past (e.g., Geiger and Koenings 1991). Survival rates from mid-summer through fall have been close to 50%.

In addition, we feel that the comparison of our 2004 and 2005 hydroacoustic surveys and the 2005 smolt weir count show that the hydroacoustic estimates provided reliable estimates of juvenile abundance. We assume that the number of smolt that left the lake in the spring of 2005 was lower than the 180,000 hydroacoustic estimate of age-1 and age-2 sockeye fry, due to an unknown number of age-1 holdovers and mortality during the April through May emigration period. On a brood year basis, age-2 smolt accounted for an average of 33% of the total smolt emigration between 1980 and 2001 (Geiger et al. 2003). Assuming a 33% figure for age-1 holdovers in 2005, the smolt emigration would be roughly 128,000. Mortality associated with emigration from the lake would also reduce this number, bringing it closer in line with the smolt weir estimate of 77,000. Again, we know that the smolt weir efficiency averaged about 70% for coho salmon smolts. If we assume a 70% capture rate on sockeye salmon smolt in 2005 we would estimate approximately 110,000 sockeye smolt left the lake. Although any comparison between our hydroacoustic surveys and our smolt weir counts requires us to make several questionable assumptions, we feel that these results indicate that the hydroacoustic surveys provided a reliable measure of juvenile abundance.

The similarities between our spring hydroacoustic survey estimate and our smolt weir count reflected our efforts to improve these estimates by increasing our trawl effort and developing improved analysis methods for determining species apportionment (Appendix A). Prior to the 2004 season, the majority of hydroacoustic surveys conducted in the Ketchikan area included very little trawl effort, and most of the estimates should be viewed as total pelagic fish estimates (Piston 2004). We boosted our trawl sampling effort to include six to ten trawls at various depths (prior to 2004 surveys often included only one trawl) and in 2004 we experimented with the use of a seine net for capturing pelagic fish. We found that incorporating a seine net into our sampling procedure may be impractical in a remote lake with small boats and limited numbers of personnel. Although we designed the net to be as small and light as possible, given the need to reach depths of 20 to 30 meters while encircling a reasonable volume of water, it proved to be extremely difficult to set and the results we obtained from its use did not indicate that it gave us more reliable estimates of species composition or age sockeye salmon age class proportions than we achieved with our trawl net.

Since the Hugh Smith Lake sockeye salmon stock was declared a *management stock of concern* in winter 2003, adult sockeye salmon escapements were above the escapement goal range of 8,000–18,000 for three consecutive seasons: 2003–2005. The pen-rearing program that was implemented in 1999 greatly improved the survival rate of stocked fish and was successful at increasing adult sockeye salmon escapements at Hugh Smith Lake. However, the behavior and distribution of the stocked fish returning to the lake indicated that large numbers of these fish did not spawn successfully and likely contributed little to overall natural production (Geiger et al. 2005). Also of interest, is the fact that age-1.2 fish comprised over 40% of the escapement in 2003 and 2004. Although it is unusual for the age-1.2 fish to make up such a large component, it has happened in the past, particularly when a stronger brood class is returning with a weak brood class of 3-ocean fish. More unusual, however, was the number of age-1.2 fish in the escapement. There were about 8,500 in 2003 and 8,800 in 2004—more than any other year at Hugh Smith Lake. In 2005, the percentage of 2-ocean fish dropped to 34%, but the number of age 1.2 fish (6,700) was still higher than all but one year (1981) prior to the onset of the pre-smolt stocking program. The stocked fish returning to Hugh Smith Lake have also exhibited later run timing than the wild fish, which has complicated efforts to assess the fisheries closures that are part of the rehabilitation plan.

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 (Figure 9). In 2005, the wild portion of the escapement was estimated (based on otolith samples) to be over 10,000 fish, which is the first time in the past eight years the lower end of the escapement goal range was met by the wild portion of the escapement. Due to three consecutive years of escapements over the upper end of the escapement goal range, and the increasing trend in wild escapement previously noted, the Hugh Smith Lake sockeye salmon stock was de-listed as a *management stock of concern* at the 2006 Board of Fisheries meeting. We will continue our detailed monitoring of Hugh Smith Lake to see if current trends in escapement continue, and to assess the final two years of stocked fish returns to the lake.

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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,

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

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

APPENDIX C. BUSCHMANN CREEK HABITAT SURVEY

Appendix C1.–Observation records from the Buschmann Creek habitat survey.

Branch	Section	Length (m)	Wetted Width (m)	Area m²	Percent silt	Percent fine gravel	Percent small spawning gravel	Percent large spawning gravel	Percent large cobble
Buschmann Main Channel	Mouth								
Buschmann Main Channel	1R	36	14.17	510.12	50%			50%	
Buschmann Main Channel	2p	29.2	6.97	203.52	50%		50%		
Buschmann Main Channel	3R	10	4.73	47.30			100%		
Buschmann Main Channel	4p	12.2	8.9	108.58	50%		50%		
Buschmann Main Channel	5R	22.2	6.17	136.97			60%	40%	
Buschmann Main Channel	6r	28.5	5.67	161.60	10%		60%	30%	
Buschmann Main Channel	7R	4.8	6.53	31.34			50%		50%
Buschmann Main Channel	8p	16.2	5.67	91.85	60%		20%	20%	
Buschmann Main Channel	9p	11.2	4.77	53.42	80%		20%		
Buschmann Main Channel	10R	7	3.7	25.90			90%	10%	
Buschmann Main Channel	11r	7.8	5.2	40.56	50%		30%	20%	
Buschmann Main Channel	12p	8.1	21	170.10	40%		60%		
Buschmann Main Channel	13R	24.2	5.07	122.69			70%	30%	
Buschmann Main Channel	14p	13	4.37	56.81	30%	20%	30%	20%	
Buschmann Main Channel	15R	4.6	5.25	24.15			90%	10%	
Buschmann Main Channel	16p	6.3	4.55	28.67	40%			20%	20%
Buschmann Main Channel	17R,r	56	8.73	488.88	10%		10%	80%	
Buschmann Main Channel	18r	47.7	7.88	375.88	15%		60%	25%	
Buschmann Main Channel	19p	16.7	9.6	160.32	40%	25%	20%	15%	
Total for Main Channel		361.7		2,838.67					
Side Channel A		125	3.26	407.50	10%		75%	15%	
Fork to Beaver Ponds	1pr	24.5	6.9	169.05	40%	30%	30%		
Fork to Beaver Ponds	2Rrp	26.9	11	295.90	60%	20%	20%		
Fork to Beaver Ponds	3p	29.5	9.6	283.20	85%	5%	10%		
Fork to Beaver Ponds	4R	10.1	8.1	81.81	35%	40%	25%		
Fork to Beaver Ponds	5Rr	20.9	10.7	223.63	40%	10%	50%		
Fork to Beaver Ponds	6R	9.8	5	49.00	60%		40%		
Fork to Beaver Ponds	7p	16.7	9.6	160.32	80%		20%		
Fork to Beaver Ponds	8Rr	20.5	4	82.00	20%	20%	60%		
Fork to Beaver Ponds	9p	17.1	7	119.70	50%	10%	40%		
Fork to Beaver Ponds	10p	24.8	12.6	312.48	70%	15%	15%		
Fork to Beaver Ponds	11R	9.1	5.6	50.96	40%	30%	30%		
Fork to Beaver Ponds	12p	11.4	17.2	196.08	30%		70%		
Total for Section		221.3		2,024.13					

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Branch	Section	Length (m)	Wetted Width (m)	Area m^2	Percent silt	Percent fine gravel	Percent small spawning gravel	Percent large spawning gravel	Percent large cobble
Fork-Top of Hatchery Channel	1R	21.5	4.9	105.35			50%	30%	20%
Fork-Top of Hatchery Channel	2r	10	7.4	74.00	30%	20%	25%	25%	
Fork-Top of Hatchery Channel	3R	18.9	6.2	117.18	10%		40%	25%	25%
Fork-Top of Hatchery Channel	4r	6.6	5.4	35.64			50%	35%	15%
Fork-Top of Hatchery Channel	5R	18.9	6.4	120.96	10%		40%	30%	20%
Fork-Top of Hatchery Channel	6R	28.6	4.8	137.28	10%		20%	50%	20%
Fork-Top of Hatchery Channel	7r	4.9	4.8	23.52	60%		20%	10%	10%
Fork-Top of Hatchery Channel	8R	17.3	4.5	77.85		10%	50%	20%	20%
Fork-Top of Hatchery Channel	9Rr	19.8	5.3	104.94		10%	30%	30%	30%
Fork-Top of Hatchery Channel	10Rrp	17.9	4.8	85.92		10%	30%	30%	30%
Fork-Top of Hatchery Channel	11R	21.9	5.4	118.26			15%	40%	55%
Fork-Top of Hatchery Channel	12r	16.5	7	115.50		35%	20%	20%	25%
Fork-Top of Hatchery Channel	13Rr	20	5.3	106.00		25%	25%	25%	25%
Fork-Top of Hatchery Channel	14p	3.4	4.6	15.64		60%	10%	10%	20%
Fork-Top of Hatchery Channel	15rR	9.2	3.4	31.28		30%	30%	30%	10%
Fork-Top of Hatchery Channel	16rR	22.1	4.7	103.87		30%	30%	30%	10%
Fork-Top of Hatchery Channel	17p	3.6	3.3	11.88		70%	10%		20%
Fork-Top of Hatchery Channel	18R	19	4.7	89.30		10%	30%	30%	30%
Fork-Top of Hatchery Channel	19Rr	59.4	4	237.60			35%	35%	30%
Fork-Top of Hatchery Channel	20r	9.2	4.8	44.16		25%	25%	25%	25%
Fork-Top of Hatchery Channel	21R	22.4	4.2	94.08			30%	30%	40%
Fork-Top of Hatchery Channel	22r	28.9	7.7	222.53			30%	30%	40%
Total for Section		400		2,072.74					
Side Channel B		247	2.62	647.14			25%	50%	25%
Hatchery Channel	1R	24.5	3.1	75.95		25%	25%	25%	25%
Hatchery Channel	2r	16.1	5.4	86.94		25%	25%	25%	25%
Hatchery Channel	3R	20.2	5.4	109.08			10%	45%	45%
Hatchery Channel	4R	37	2.7	99.90			10%	45%	45%
Hatchery Channel	5R	27	2	54.00		40%	30%	30%	
Hatchery Channel	6r	54	3.3	178.20		25%	25%	25%	25%
Hatchery Channel	7	20	braided			25%	25%	25%	25%
Hatchery Channel	8	18.7	3.1	57.97			10%	80%	10%
Hatchery Channel	9Rrp	11.1	3.2	35.52	15%	30%	25%	30%	
Hatchery Channel	10	11.1	3	33.30		30%	40%	30%	
Hatchery Channel	11r	11.4	3.3	37.62		30%	40%	30%	
Hatchery Channel	12Rrp	20.3	2.2	44.66		35%	35%	30%	
Hatchery Channel	13r	15.2	3	45.60	30%	30%	30%	10%	
Hatchery Channel	14R	10.9	2.9	31.61	30%	30%	30%	10%	
Hatchery Channel	15Rr	11.4	2.7	30.78		50%	50%		
Hatchery Channel	16p	9	4.1	36.90		50%	50%		
Hatchery Channel	17p	32.4	5.4	174.96	25%	25%	25%	25%	

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Branch	Section	Length (m)	Wetted Width (m)	Area m^2	Percent silt	Percent fine gravel	Percent small spawning gravel	Percent large spawning gravel	Percent large cobble
Hatchery Channel	18r	8.7	3.1	26.97	20%	30%	30%	20%	
Hatchery Channel	19p	5.3	3.2	16.96	20%	30%	30%	20%	
Hatchery Channel	20R	4	3.4	13.60		20%	20%	60%	
Hatchery Channel	21p	7.1	3	21.30	80%			20%	
Hatchery Channel	22R	3.4	2	6.80	80%			20%	
Hatchery Channel	23r	9	2.2	19.80	90%			10%	
Hatchery Channel	24R	4.3	2.4	10.32	20%			60%	20%
Hatchery Channel	25p	14.2	3	42.60	90%	10%			
Hatchery Channel	26r	6	4.2	25.20	100%				
Hatchery Channel	27Rrp	22.6	5.6	126.56	90%			10%	
Hatchery Channel	28p	11.6	3.3	38.28	90%			10%	
Hatchery Channel	29R	4.2	3.1	13.02	20%	20%	40%	20%	
Hatchery Channel	30p	22.5	3.1	69.75	90%		10%		
Hatchery Channel	31r	12.3	4.5	55.35	70%		30%		
Hatchery Channel	32Rr	15.4	4.1	63.14	50%		35%	15%	
Hatchery Channel	33Rr	22.7	4.3	97.61		20%	40%	40%	
Hatchery Channel	34Rr	12.2	3.2	39.04		20%	40%	40%	
Hatchery Channel	35p	15.1	2.6	39.26	70%		20%	10%	
Hatchery Channel	36rp	13.2	2.1	27.72	100%				
Hatchery Channel	37r	12.5	3	37.50	30%	20%		20%	30%
Hatchery Channel	38p	6.1	2.6	15.86	80%		20%		
Hatchery Channel	39R	4	6.3	25.20		20%	80%		
Hatchery Channel	40p	12.2	3.3	40.26	80%		20%		
		598.9		2,005.09					
Side Channel C		~598.9	~ 2	1,197.8	Good spawning gravel in upper half, poor spawning gravel in lower half, but excellent coho rearing habitat.				
All sections combined		19,53.9		11,193.07					
All sections with at least 50% spawning gravel				7,329.00					