Stock Assessment of Salmon Lake Sockeye and Coho Salmon 2001

by

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Alaska Department of Fish and Game **Division of Sport Fish**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

Weights and measures (metric)

Centimeter	cm
Deciliter	dL
Gram	g
Hectare	ha
Kilogram	kg
Kilometer	km
Liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd
Spell out acre and ton.	

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s
Spell out year, month, and week.	

Physics and chemistry

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

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	Etc.
exempli gratia (for example)	e.g.,
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
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	Use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

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	C.I.
Correlation coefficient	R (multiple)
Correlation coefficient	r (simple)
Covariance	cov
Degree (angular or temperature)	°
Degrees of freedom	df
Divided by	÷ or / (in equations)
Equals	=
Expected value	E
Fork length	FL
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.
Mideye-to-fork	MEF
Minute (angular)	'
Multiplied by	x
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
Standard length	SL
Total length	TL
Variance	Var

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ABSTRACT

A stock assessment of sockeye (*Oncorhynchus nerka)* and coho (*Oncorhynchus kisut*ch) salmon at Salmon Lake was begun in 2001. A floating weir and field camp were established at the outlet of the lake to enumerate and sample returning sockeye and coho between June 1 and October 31, 2001. In addition to the floating weir, mark-recapture experiments were done to estimate total escapements into the lake. We estimate that 1,941 adult sockeye (SE = 103) and 588 jack sockeye (SE = 103) for a total of 2,529 (SE = 282) sockeye (both adults and jacks) entered Salmon Lake and 1,424 adult coho (SE = 48) and 293 jack coho (SE = 82) for a total of 1,717 (SE = 94) coho (both adults and jacks) entered Salmon Lake in 2001. Underwater snorkel counts represented approximately 2.7% of the estimated sockeye escapement and 4.8% of the coho escapement.

A total lake population of 44,000 sockeye salmon fry and 1,000 sticklebacks were estimated from hydroacoustic analysis and the estimated density of sockeye salmon fry in Salmon Lake is 0.140 fry $\cdot$ m^{-2}. This population of sockeye salmon fry is expected to produce approximately 31,000 smolt in spring 2002, based on 70% overwinter survival.

In October 2001 4,985 coho presmolt ≥85 mm were tagged with coded-wire tags and released in Salmon Lake. The mean weight of tagged coho salmon pre-smolt was 12.1 g (SE = 0.24). Mean length was 103.3 mm (SE = 0.060).

INTRODUCTION

Information from a past study (Schmidt 1996) describes a declining trend in coho escapement in Salmon Lake and an increasing trend in exploitation for this stock, and suggests that the sustainability of Salmon Lake coho salmon may be at risk from overharvest. Alternatively, the declining trend in escapement may have been due to poor marine survival. In March 2000, the Southeast Alaska Regional Advisory Council (SERAC) identified Sitka Sound coho (*Oncorhynchus kisutch*) and sockeye (*Oncorhynchus nerka*) salmon assessment as a subsistence fisheries monitoring issue. Fishing pressure on coho salmon has grown throughout Southeast Alaska and particularly in the vicinity of Sitka Sound. Of the coho salmon stocks produced in Sitka Sound, Salmon Lake coho are of particular concern due to the stock's proximity to concentrated commercial effort on hatchery stocks, increasing sport fishing effort, and a newly established federal coho subsistence fishery. In October 2000, the SERAC recommended that subsistence-fishing opportunity be provided for coho salmon in Southeast Alaska. Expanded subsistence opportunity for coho salmon had heightened the existing concern for Salmon Lake coho and increased the need to assess the status of this stock.

Sockeye returning to Redoubt and Salmon Lakes support the only two sockeye salmon subsistence fisheries in Sitka Sound. Both lakes are important to local subsistence fishers because they support significant populations of sockeye salmon and are easily accessed from Sitka. Since 1982, Redoubt Lake sockeye escapement has been counted using a weir operated at the outlet of the lake. In 2000 and 2001, the Redoubt Lake sockeye subsistence fishery was closed early by federal and state agencies in response to low escapements. Similar closures by the state occurred in 1992, 1995, and 1996. Such closures raise the concern of a shift in fishing effort to the smaller stock at Salmon Lake, where no program was in place for estimating and managing for escapements needed to sustain subsistence harvests. Local reports of declining abundance of sockeye salmon and potential shifts in subsistence and sport fishing effort to Salmon Lake present a need to assess the status of this sockeye stock.

Fishing pressure on Southeast Alaska coho salmon has increased as a direct result of growth in the region's sport fisheries, reductions in the commercial troll fishery for chinook salmon, and the development of terminal area fisheries targeting hatchery-released chum salmon. Much of the growth in commercial and sport fisheries has occurred along the outer coast of Prince of Wales and Baranof Island. Of the coho salmon stocks produced along the outer coast, Salmon Lake coho salmon are of particular concern due to the proximity of increased commercial effort on hatchery stocks and sport fishing effort near Salmon Lake.

From 1983 to 1990, the Alaska Department of Fish and Game (ADF&G) conducted a coded-wire tag mark-recapture project at Salmon Lake to estimate annual smolt abundance, harvest, and escapement of coho salmon. Schmidt (1996) reported exploitation rates for Salmon Lake coho increased from 35% in 1985 to 72% in 1989, and spawning escapements decreased from 1,514 in 1984 to 204 in 1990. In 1994, ADF&G repeated the project to assess fishery impacts to Salmon Lake coho salmon. In 1995, Salmon Lake contributed 1,740 coho salmon to commercial troll (73%), marine sport (14%), Deep Inlet terminal area commercial seine and gillnet (9%), and commercial seine (4%) fisheries.

Since 1998, ADF&G and the Northern Southeast Regional Aquaculture Association (NSRAA) have conducted foot and snorkel surveys of Salmon Lake inlet streams to provide a low-cost indication of abundance for sockeye and coho salmon in that system. Since salmon runs are dynamic as fish continually move into and out of streams, spawn, and die, observer counts are inherently biased low for the actual total escapement across a season and usually underestimate the actual escapement on any given day (Jones and McPherson 1997; Dangel and Jones 1988; Sharr et al. 1993). Furthermore, the visibility of spawning salmon depends on many factors such as water clarity, stream morphology, and the ecology, behavior, size, and color of salmon (Bevan 1961; Neilson and Geen 1981; Jones and McPherson 1997). Without comparable estimates of escapement, it is not known whether foot or snorkel surveys of Salmon Lake inlet streams can be used as an index of trends in spawning abundance.

Two thousand one was the first year of a multi-year study designed to assess the status of both sockeye and coho salmon. The long-term objectives of this study are:

1. Estimate the escapements of sockeye and coho salmon into Salmon Lake in 2001 such that the estimates are within 10 percentage points of the true value 90% of the time.
2. Estimate the age, length, and sex composition of adult sockeye and coho salmon in Salmon Lake in 2001 such that each multinomial proportion is within 5 percentage points of the true value 95% of the time.
3. Count the number of sockeye and coho salmon in Salmon Lake inlet streams in 2001 using underwater (snorkel) stream surveys.
4. Estimate the abundance of coho salmon presmolt in October 2001, leaving Salmon Lake the following spring such that the estimate is within 20 percentage points of the true value 95% of the time.
5. Estimate the age, length, and weight composition of coho salmon presmolt in Salmon Lake in 2001 such that each multinomial proportion is within 5 percentage points of the true value 95% of the time.
6. Estimate the commercial gillnet harvest of coho salmon in the Deep Inlet terminal harvest area in 2003 such that the estimate is within 15 percentage points of the true value 95% of the time.
7. Estimate the marine harvest of coho salmon from Salmon Lake in 2003 such that the estimate is within 25 percentage points of the true value 90% of the time.
8. Estimate the age, length, and weight composition of sockeye fry in Salmon Lake in 2001 such that each multinomial proportion is within 5 percentage points of the true value 95% of the time.
9. Estimate the in-lake productivity of Salmon Lake in 2001 using established ADF&G limnological sampling procedures.
10. Provide an index of sockeye fry biomass in 2001 through hydroacoustic and trapping methods.

During 2001, a weir and field camp were established at the outlet of Salmon Lake to achieve these objectives. Objectives 1-3, 5, 8-10 were realized during 2001 while objectives 4, 6, and 7 will be accomplished through the sampling of the marine harvests and adult returns to Salmon Lake and through coded-wire tag recoveries of Salmon Lake coho salmon in 2003.

STUDY AREA

Salmon Lake is located 15.2 km southeast of Sitka at the terminus of Silver Bay in eastern Sitka Sound (Figure 1). The lake lies at 17 m elevation and is fed by two inlet streams opposite the 1.4 km outlet stream. The lake is accessible by floatplane or by boat and foot. The U.S. Forest Service maintains a recreational use cabin on the lake and a foot trail that provides access to Salmon and Redoubt Lakes from Silver Bay. The lake supports populations of sockeye, pink (*Oncorhynchus gorbuscha*); chum (*Oncorhynchus keta*); and coho salmon; Dolly Varden (*Salvelinus malma*); cutthroat trout (*Oncorhynchus clarki*); stickleback (*Gasterosteus aculeatus*); sculpin; and steelhead (*Oncorhynchus mykiss*).

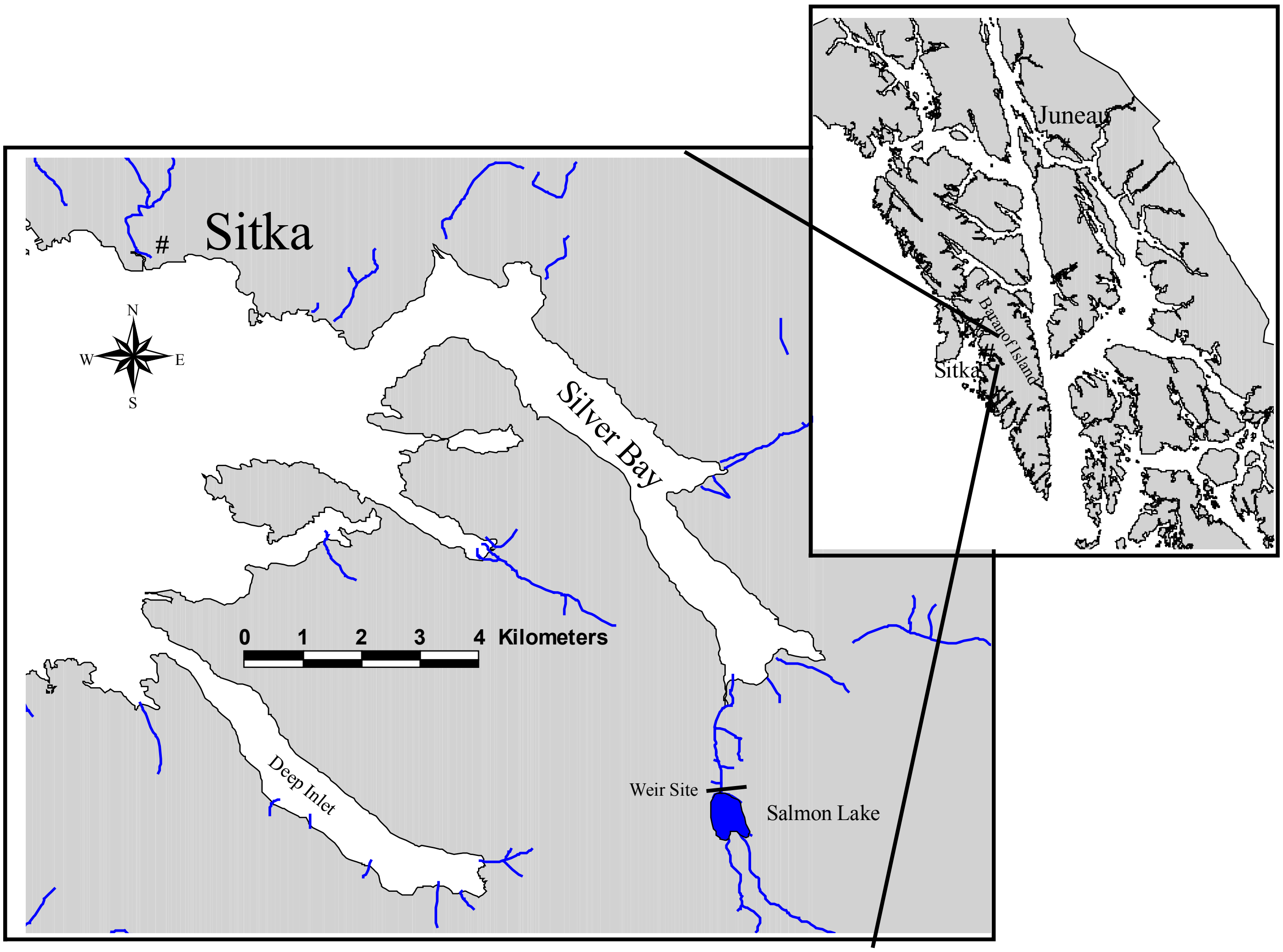

Figure 1. Study area showing Salmon Lake, weir site and major tributaries.

STUDY DESIGN

This project has been proposed as a long-term, comprehensive assessment of Salmon Lake sockeye and coho salmon stocks. The primary components of this study consist of:

1. An adult weir and mark-recapture experiment to estimate escapement of sockeye and coho salmon in Salmon Lake;
2. Biweekly observer counts of sockeye and coho salmon in Salmon Lake inlet streams for comparison with escapement estimates;
3. A coded-wire tag mark-recapture experiment to estimate presmolt abundance, adult harvest, and harvest distribution for Salmon Lake coho salmon;
4. A fall hydroacoustic assessment of sockeye fry rearing biomass;
5. An independent on-site survey to estimate commercial coho salmon harvest and CWT fraction in the Deep Inlet terminal harvest area gillnet fishery;
6. In-lake limnological sampling.

METHODS

Estimate of escapement of sockeye and coho salmon

A floating weir was used to capture, tag, and enumerate coho and sockeye salmon migrating upstream. The weir, located 10 m downstream of the outlet of Salmon Lake, was fashioned after a weir described in Tobin (1994). It consisted of hollow PVC panels attached to an anchored cable laid across the stream channel, with a fixed live box attached on the upstream side. One-inch diameter schedule 40 PVC was used as the weir pickets. They were spaced at 18 pickets per 4 ft panel that were 20 ft long. A rigid weir was established on either side of the 96 ft of floating weir. The rigid weir was supported by bipods and consisted of 3inch aluminum channel with a hole spacing of 49 per 8 ft. The pickets used for the rigid weir were ¾ in galvanized conduit.

All fish captured in the live box were enumerated and passed upstream using dip nets except for adult sockeye and coho which were anesthetized with a mixture of clove oil and Everclear™ alcohol (12 ml clove oil to 108 ml alcohol) in 15 gal of water prior to being tagged with a uniquely numbered t-bar anchor Floy™ Tag. Each fish was tagged immediately below the middle of the dorsal fin on its left side. Sockeye were tagged with blue sequentially numbered tags and coho were tagged with gray sequentially numbered tags. In addition to the tag, each fish was given an operculum punch on its left side. The tagging gun, scale tweezers, and hole punch were rinsed with a solution of 1-part Betadine™ to 10 parts water between sampling each fish. Upon sampling, each fish was allowed to safely recover in a holding box before release on the upstream side of the weir.

Age, length, and sex composition of adult sockeye and coho salmon

All sockeye and coho salmon taken from the weir trap were sampled for scales, length and sex. Each fish was measured from mid eye to tail fork to the nearest 5 mm. Four to five scales were removed from the preferred area (one row up from the lateral line on an imaginary line between the posterior base of the dorsal fin and the anterior portion of the ventral fin (Scarnecchia 1979)) on the left side of the fish. Scales were mounted on gum cards and numbered consecutively. Scale impressions were transferred to acetate and read to determine ages post-season. Sex was determined from secondary maturation characteristics.

Recapture events

Some fish passed through the weir undetected so recapture events were scheduled on a biweekly basis to estimate total escapement. Coho and sockeye were captured from the lake and two inlet streams using a 5 by 30 m beach seine modified for use in the inlet streams. In addition to the beach seine, hook and line gear was used in the inlet streams. During the recapture events, the lake perimeter was surveyed by boat to locate areas where sockeye or coho were present. Each fish captured was examined for tags, operculum punch, and other marks and recorded by date, tag number, gear type used for capture, and location. Any untagged fish were sexed, measured, and its adipose fin removed to identify it as a previously observed fish.

Snorkel counts of sockeye and coho salmon in Salmon Lake inlet streams using underwater stream surveys

Snorkel counts of sockeye and coho salmon were conducted biweekly when possible in the two inlet streams using mask, snorkel, and a dry suit. Counts began at fixed points of each of the two inlet streams approximately 2 km upstream of the inlet of the lake and ended at the inlet of the lake. Adult fish were counted and recorded by species for each inlet stream.

Habitat variables recorded at the beginning of each survey included: surface water temperature in degrees Celsius, and weather conditions (cloud cover, wind, precipitation). Additionally, the visibility was given a subjective rating of very poor, poor, good, or excellent.

A permanent benchmark for water levels was established prior to the first survey. On each survey, the water level was recorded. Rain, wind, high water, and turbidity occasionally obscured subsurface visibility and prevented the surveys.

Abundance of coho salmon presmolt and age, length, and weight composition of coho salmon presmolt

A mark-recapture experiment was begun in 2001 to estimate presmolt abundance by marking and tagging presmolts with CWT's. We will inspect adult coho for these marks as they return at adults. We anticipate that most of these fish will return in 2003.

Three technicians implanted microwire tags in coho salmon presmolt during the fall of 2001. Baited minnow traps were deployed in Salmon Lake and lake inlet streams during October to capture coho salmon presmolt. Between 20 and 50 traps were baited with salmon eggs daily, fished continuously, and checked every 12 hrs or more often as needed. All captured coho salmon ≥85 mm FL without adipose clips were tranquilized with the alcohol/clove oil mixture described above, given a CWT following procedures in Koerner (1977), their adipose fins removed, and released. Any coho salmon captured with a missing adipose fin was passed through a magnetic tag detector to test for post 24 hr tag retention. Mark IV (primary) tagging machines produced by Northwest Marine Technology, Inc. were used to apply the CWTs. All tagged fish were held overnight in a net pen to test for mortality and tag retention. To minimize recaptures and the potential for predation, tagged presmolt were released just prior to the onset of darkness each evening in locations of cover near their capture site.

A systematically drawn sample of 490 coho salmon juveniles ≥ 85 mm FL were taken to estimate age, length, and weight composition of presmolt. Scales were scraped off a small area on the side of each pre-smolt and placed on slides for age analysis. Lengths were taken to the nearest mm and weights to the nearest tenth gram.

Sockeye fry rearing density within Salmon Lake

Hydroacoustic and midwater trawl sampling estimated the distribution and abundance of rearing sockeye salmon fry. Salmon Lake was divided into seven sampling areas based on surface area. Sample design consisted of a series of seven stratified, randomly chosen transects across the lake, one from each sampling area. Transect sampling was conducted during post-sunset darkness in one night. A constant boat speed of about 2.0 m sec-1 was attempted for all transects. A Biosonics DT-4000™ scientific echosounder (420 kHz, 6° single beam transducer) with Biosonics Visual Acquisition © version 4.0.2 software was used to collect data. Ping rate was set at 5 pings sec-1 and pulse width at 0.4 ms. Data were analyzed using Biosonics Visual Analyzer © version 4.0.2 software after returning to the office.

A 2 m by 2 m elongated trawl net was used for pelagic fish sampling. Trawl depths and duration were determined by fish densities and distributions throughout the lake based on observations during the hydroacoustic survey. Fish were euthanized with MS-222, preserved in 10% alcohol, and transported to the ADF&G laboratory in Ketchikan. Mean fork length was measured to the nearest mm and weight was measured to the nearest gram. All sockeye salmon fry under 50 mm fork length were assumed to be age 0. Scales were collected from fish over 50 mm fork length for aging. Sockeye fry scale aging was conducted through the microscopic examination and interpretation of scale growth patterns per Mosher (1968). Two trained technicians using a Carton microscope with a video monitor independently aged fry. The results of each independent scale ageing were compared. In instances of discrepancy between the two age determinations, a third independent examination was conducted.

Age, length and weight composition of sockeye fry in Salmon Lake

All sockeye captured in the midwater tow net were sampled for scales, length, and weight, as described for coho salmon pre-smolt.

In-lake productivity of Salmon Lake using established ADF&G limnological sampling procedures.

Limnology sampling was conducted by the weir crew opportunistically from July through October using established ADF&G limnological sampling procedures. Physical, chemical, and biological production data was collected at two fixed sampling sites within Salmon Lake for the duration of the project.

Light penetration, temperature, dissolved oxygen, and conductivity vertical profiles were measured and recorded monthly at varying depth intervals at two sampling sites within the lake. Bulk (~5 L) water samples were collected from the 1 m and mid-hypolimnion depths at two sites within the lake to characterize general and nutrient water chemistry of the epilimnion and hypolimnion. Primary production (algal standing crop) samples were collected from the two sampling sites on the same sampling interval as the vertical profiles. Water samples were collected at 1 m, mid-euphotic zone, and at the compensation depth defined as the depth penetrated by 1% of subsurface sunlight. These samples were analyzed for chlorophyll and phaeophytin pigment analysis. Vertical zooplankton tows were collected from a standard depth of 1 m less than the sampling site depth. These tows were collected using a 0.5m diameter, 153 u-mesh, 1:3 conical zooplankton net. The net was retrieved at a constant rate of 1 m/sec. rinsed with lake water to remove all of the organisms collected and preserved in a solution of 10% neutralized formalin. Samples were analyzed for genus abundance, density, body length, and biomass.

DATA ANALYSIS

Escapement of sockeye and coho salmon into Salmon Lake

All captured adult sockeye and coho salmon were marked and counted as they entered Salmon Lake through the weir and live box. Surveys above the weir indicated salmon were passing the weir without being marked and counted, so a mark-recapture experiment was used to estimate the abundance of adult salmon above the weir. Chapman's modification to the Petersen estimator or a time-stratified Darroch (1961) estimator was used to estimate escapement.

Relationship between observer counts and estimated escapement

The snorkel counts were compared to the actual weekly escapement estimates of coho and sockeye. The counts were compared to the weekly escapement estimate as a proportion or percentage of the total estimated escapement. The peak snorkel count was also compared to the total escapement estimate.

Age, length, and sex composition of adult sockeye and coho salmon

All composition estimates and the associated variances were calculated as:

$$\hat{p}_i = \frac{n_i}{n} \quad \text{and} \quad \hat{V}[\hat{p}_i] = \left(1 - \frac{n}{N}\right)\frac{\hat{p}_i(1-\hat{p}_i)}{n-1} \qquad \text{(1) and (2)}$$

where:

$\hat{p}_i =$	the proportion of the population in group *i*;
$n_i =$	the number in the sample in group *i*,
$n =$	the total number sampled.
$N =$	population size

Length and weight at age estimates for juvenile and adult coho and sockeye salmon
Estimates of mean length and weight at age and their variance were calculated with standard normal procedures (Cochran 1977).

Age composition of juvenile sockeye and coho salmon:
Proportions by age of sockeye fry and coho pre-smolt were estimated by:

$$\hat{p}_j = \frac{n_j}{n} \quad and \quad var[\hat{p}_j] = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1} \qquad \text{(3) and (4)}$$

where p_j is the proportion in the population in group j, n is sample size, and n_j *is* the subset of n that belong to group j. The systematic selection of samples and uniformity of procedures provides for sampling proportional to abundance between sampling sites resulting in little potential for bias from any in-season changes in age composition.

RESULTS

Estimate of escapement of sockeye and coho salmon
The floating weir was operational on June 1. The first sockeye was captured in the upstream trap on June 10 (Appendix A1). The sockeye migration into Salmon Lake continued through October 1 (Appendix A1, Figure 2) by which time 1,132 (718 adult and 414 jack) sockeye had been counted through the weir. Observations of sockeye above the weir and in the lake revealed that not all sockeye had been marked at the weir. It is likely that sockeye and coho had passed through the weir undetected during periodic high water events that breached the weir and through holes in the weir that were not detected until well into the migration. Several recapture events were conducted in the lake and inlet streams to estimate the total escapement. Of the 1,132 sockeye marked at the weir 317 individual sockeye were recaptured at least once during subsequent recapture events. Another 306 previously unmarked sockeye were also captured. Escapements of jacks and adults were estimated separately.

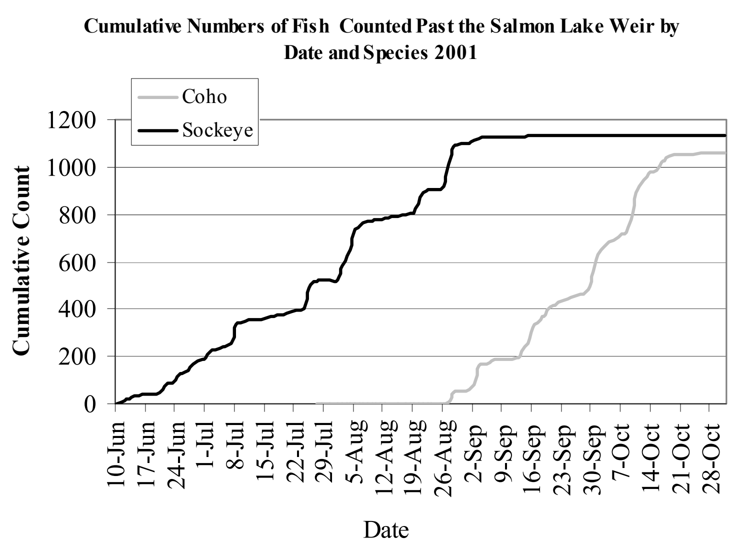

Figure 2. Cumulative numbers of fish counted past the Salmon Lake weir in 2001.

We estimate that 1,941 adult sockeye (SE = 103) and 588 jack sockeye (SE = 103) for a total of 2,529 (SE = 282) sockeye (both adults and jacks) entered Salmon Lake in 2001.

The first coho was captured on July 27, but no additional coho were captured again until August 27. A total of 1,060 coho (1,002 adults, 58 jacks) were captured and marked at the weir. Recapture events for coho revealed that some coho had passed through the weir undetected. During the recapture events two hundred thirty seven (237) previously marked coho were recaptured and 128 unmarked coho were captured.

We estimate that 1,424 adult coho (SE = 48) and 293 jack coho (SE = 82) for a total of 1,717 (SE = 94) coho (both adults and jacks) entered Salmon Lake in 2001.

Age, length, and sex composition of adult sockeye and coho salmon

Sockeye were predominately one of six age classes (Figure 3). A strong bimodal length distribution was also evident (Figure 4). This appears to be due to the predominate presence of two strong saltwater year classes; 1 year and 3 years (Figure 5). The cut-off length for jack sockeye (the fish that returned after only one year at saltwater) was established at 446mm (Table 1).

Coho were predominately age 1.0 fish. The average lengths of coho examined at the weir were 598 mm (adults) and 398 mm (jacks) (Table 5). The cut-off length for Jack coho (those fish that returned after only one summer at saltwater) was established to be 399 mm (Table 2, Figure 6).

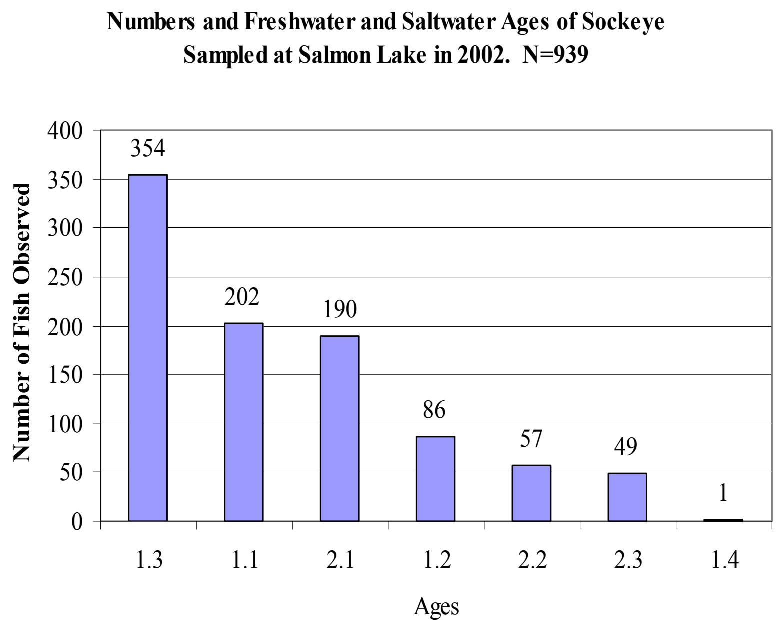

Figure 3. Number of sockeye by age class observed at Salmon Lake weir in 2001.

Snorkel counts of sockeye and coho salmon in Salmon Lake inlet streams using underwater stream surveys.

Underwater snorkel counts were done on 5 occasions beginning on August 22 (Table 3). Peak snorkel counts represented approximately 2.7% of the sockeye run and 4.8% of the coho run. Counts were not possible every week primarily due to high water conditions.

Abundance of coho salmon presmolt and age, length, and weight composition of coho salmon presmolt

In October 2001 4,985 coho presmolt ≥85mm were captured and tagged with coded-wire tags, then released in Salmon Lake. Tag retention was 99.9% leaving a valid tag release of 4,888. The mean weight of tagged coho salmon presmolt was 12.1g (SE = 0.24). Mean length was 103.3mm (SE = 0.060) (Table 4). Abundance of coho salmon presmolt will be determined through examination of returning adult coho in 2003 for presence or absence of adipose fins, indicating that the coho had been tagged with a coded wire tag.

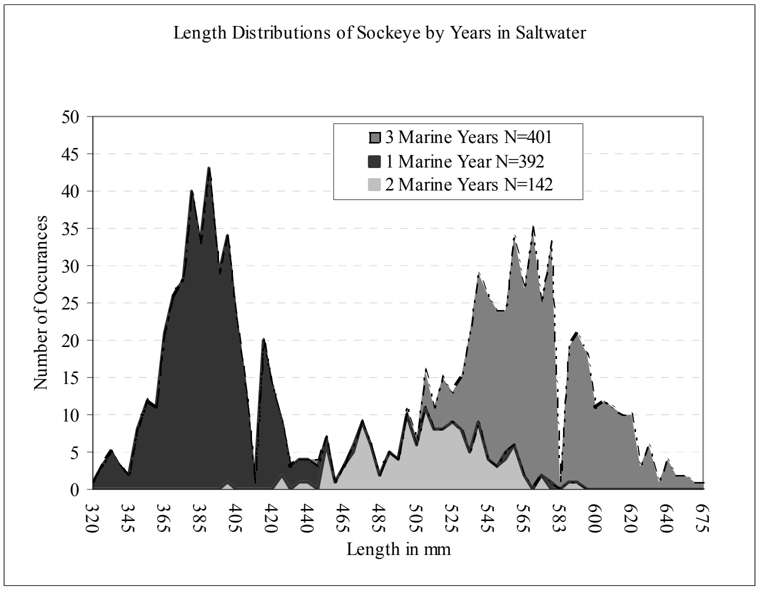

Figure 4. Length distributions of sockeye captured at the Salmon Lake weir in 2001 based on number of years spent in saltwater.

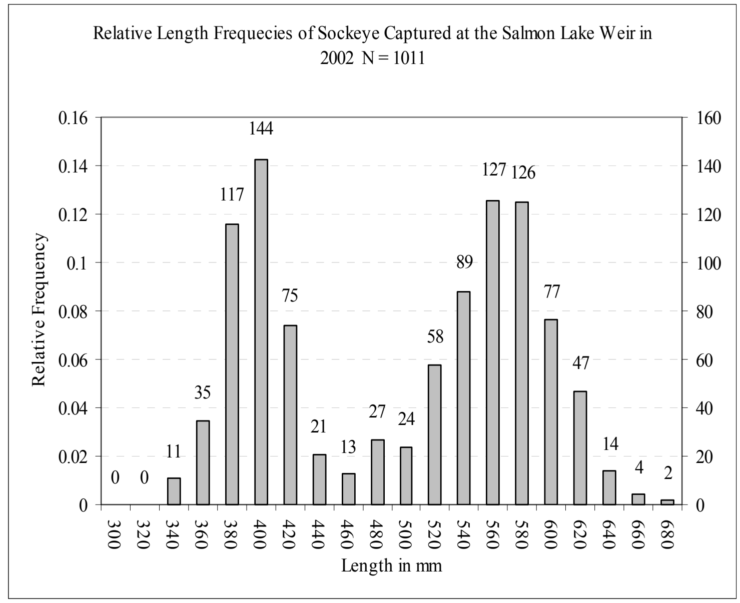

Figure 5. Length distribution of all measured sockeye at the Salmon Lake Weir in 2001.

Table 3. Count of sockeye and coho in the inlet streams of Salmon Lake in 2001. Counts were done with the use of a snorkel and dry suit.

Date	Sockeye Observed	Coho Observed
8/22/2001	69	
8/31/2001	53	
10/3/2001		13
10/20/2001		83
10/30/2001		48

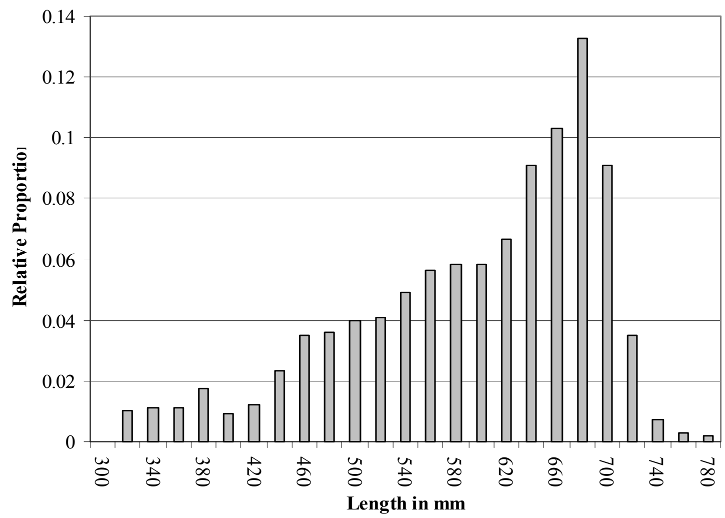

Figure 6. Relative length frequency distribution of Salmon Lake coho salmon captured and measured at the Salmon Lake weir in 2001.

Table 1. Cut off size for jack sockeye salmon in Salmon Lake 2001.

Age one sockeye <446mm	Age one sockeye >446mm	Sockeye older than age one <446mm	Sockeye older than age one >446mm	% age one sockeye <446mm	% older than age one sockeye >446mm
388	4	5	540	99.0%	99.1%

Table 2. Cut off size for jack coho salmon in Salmon Lake 2001.

Age one coho <399mm	Age one coho >399mm	Age 0 coho <399	Age 0 coho >399	% age zero coho <399mm	% age one coho >399mm
10	924	44	1	97.8%	98.9%

Table 4. Mean weight and length of tagged coho salmon presmolt in Salmon Lake 2001.

	Weight (g)	Length (mm)
Mean	12.1	103.3
Standard Error	0.24	0.60
Sample Variance	28.2	177.1
Count	474	490

Table 5. Mean lengths (mm) of coho salmon adults and jacks examined at the Salmon Lake weir in 2001.

	Adults	Jacks
Mean Length (mm)	598	350
Standard Error	2.76	3.89
Standard Deviation	84.36	26.10
Sample Variance	7116.95	681.24
Count	933	45

Sockeye fry rearing density within Salmon Lake

A total lake population of 44,000 sockeye salmon fry and 1,000 sticklebacks were estimated from the hydroacoustic survey conducted on 16 August 2001. The estimated density of sockeye salmon fry in Salmon Lake is 0.140 fry · m^{-2}. One hundred ten (110) fish (Table 6) were captured between two mid-water trawl tows; 40 sockeye salmon fry from tow 1 which lasted for 10 minutes at a depth of 10 m and 68 sockeye salmon fry and 2 sticklebacks from tow 2 which lasted for 15 minutes at a depth of 7 m. Ninety-five (95) sockeye salmon fry (88%) were smaller than 50 mm fork length and were assumed to be age 0. Thirteen sockeye salmon fry were greater than 50 mm, four (4%) were age 1, and nine (8%) were age 0. The age 0 sockeye salmon had a mean fork length of 40.1 mm and a mean weight of 0.6 g. The age 1 sockeye salmon had a mean fork length of 63.0 mm and a mean weight of 2.5 g. Two sticklebacks (2% of total catch) were caught with a mean fork length of 54.0 mm and a mean weight of 1.7 g. The length frequency (Figure 7.) shows a strong age 0 class and a small age one class. All targets that fell within target strength range of –50 dB to –68 dB during hydroacoustics were assumed to be proportionally represented by 98% sockeye salmon fry and 2% stickleback. This population of sockeye salmon fry is expected to produce approximately 31,000 smolt in spring 2002, based on 70% over-winter survival.

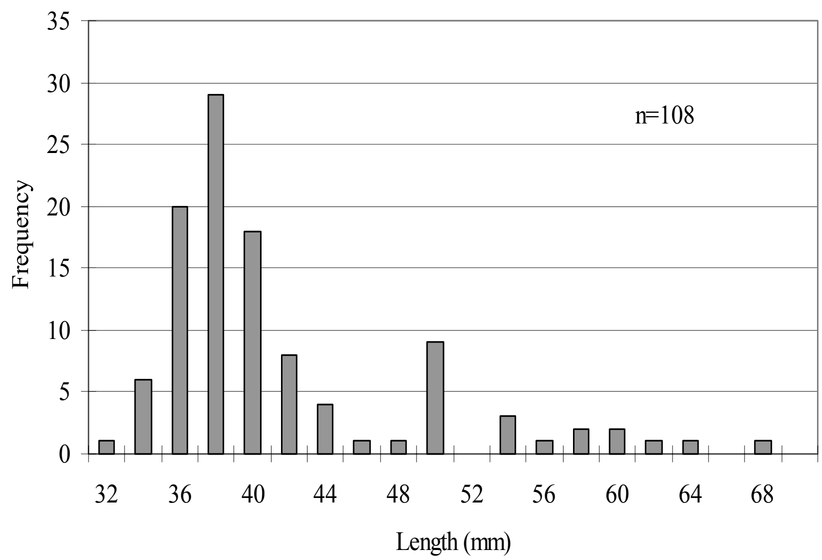

Figure 7. Length frequency distribution of sockeye captured in trawl surveys in Salmon Lake on August 16.

Table 6. Species and age distribution from mid water trawl net on August 16, 2001.

Species	Age	Sample size	Percent Species	Population	Mean length (mm)	Mean weight (g)
Sockeye	0	104	94%	42,000	40.1	0.6
Sockeye	1	4	4%	2,000	63	2.5
Stickleback	No Age	2	2%	1,000	54	1.7

In-lake productivity of Salmon Lake using established ADF&G limnological sampling procedures. Limnology samples were taken three times during the summer field season (Table 7). Over the course of the three sampling periods, *Bosmina* sp. dominated the species composition numerically (92%) and in biomass (93%). *Cyclops, Holopendium,* and *Chydorinae* were also present in the lake (Table 8). Water temperature was taken only once on July 24.

Table 7. Species length and biomass of macro-zooplankton in Salmon Lake, 2001. Length was measured in mm and biomass (mg • m^2). Seasonal mean values are from two samples for station A, and three values from station B at two permanent sampling stations.

Macrozooplankton Length and Biomass

	Mean Length (mm)					Seasonal Mean							
Station	A		B			A				B			
Species	30-Aug	19-Oct	24-Jul	30-Aug	19-Oct	Mean Length (mm)	Weighted Length (mm)	Biomass (mg/m^2)	Weighted Biomass '(mg/m^2)	Mean Length (mm)	Weighted Length (mm)	Biomass (mg/m^2)	Weighted Biomass '(mg/m^2)
Ergasilus													
Epischura													
Diaptomus													
Cyclops	0.50	0.60	0.47	0.53	0.59	0.55	0.50	5	4	0.53	0.51	1	1
Bosmina	0.31	0.32	0.33	0.31	0.35	0.32	0.32	27	27	0.33	0.31	21	19
Ovig. Bosmina	0.37	0.40	0.35	0.36	0.40	0.39	0.39	21	22	0.37	0.36	4	4
Daphnia l.													
Daphnia g.													
Holopedium	0.44					0.44	0.44	0.10	0.10				
Ovig. Holopedium	0.53					0.53	0.53	0.05	0.05				
Chydorinae	0.27			0.32		0.27	0.27	0.10	0.10	0.32	0.32	0.16	0.16
Polyphemus													
Total	2.42	1.32	1.15	1.52	1.34	Total:		53	53	Total:		27	24

DISCUSSION

This was the first year a weir was placed at the outlet of Salmon Lake to enumerate sockeye. The weir was not "fish tight" throughout the course of the summer. Because of this, some fish were able to pass through the weir undetected. The mark-recapture experiment to estimate the total escapement of coho and sockeye showed that the weir captured approximately 62% of the coho migrating upstream and 45% of the sockeye migrating upstream. The weir has since been modified to increase the probability of capturing all or nearly all fish migrating upstream.

Several assumptions were required to estimate the sockeye and coho abundances using the mark-recapture experiment. Included in these were:

1. Every fish had an equal probability of being marked at the weir, or that every fish had an equal probability of being captured in the mark-recapture sample, or that marked fish mixed completely with unmarked fish;
2. Recruitment and mortality did not occur between samples;
3. Marking did not affect the catchability of fish;
4. Fish did not lose their marks in the time between the initial marking and subsequent recapture
5. All marks were seen on recovery in the recapture events; and
6. Double sampling did not occur.

Chi-square tests were used to determine if assumption (1) was met. The null hypothesis tested was that the fraction of marked fish was constant across the recapture events and that the probability of recovering a fish was independent of its initial strata (time) in the marking event. Two Kolmogorov-Smirnov (K-S) 2-sample tests were used to test the hypothesis that fish of different sizes were captured with equal probability ($\alpha = 0.05$) (Appendix A2). Failure to confirm one of these hypotheses (fish had an equal probability of being marked at the weir) required a stratified (by size) estimate of escapement (Arnason et al. 1996).

We found that only 7 (<1%) of the 611 marked fish recaptured with a secondary mark had actually lost their primary (Floy™ tag) mark. Marking did not appear to affect the behavior or movement of fish, as marked fish were observed spawning with or near unmarked fish throughout the entire project. Because of the low occurrence of tag loss, either an operculum punch or Floy™ tag alone may be sufficient in future tagging efforts.

The population was assumed to be closed to recruitment because sampling covered the entire duration of the immigration of the fish to the river. Marking was assumed to have little effect on behavior of released fish or the catchability of fish in the recapture events since different gear types were used to catch fish (weir vs. seine). The use of multiple marks, (Floy™ tag and operculum punch) inspection of all fish captured in the recapture events, and additional marking of all fish inspected in the recapture events helped to insure that the assumptions in 4, 5, and 6 were met.

Lake surveys of Salmon Lake indicate that many sockeye spawn in the littoral areas of the lake (peak sockeye counts in the inlet streams represented less than 3% of the total estimated escapement). While we suspect that coho use primarily the inlet streams for spawning, only 5% of the estimated escapement was observed during the peak count. Because of this, snorkel surveys may not be useful to provide an index of escapement.

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APPENDICIES

Appendix A1. Daily and cumulative weir counts at the Salmon Lake Weir 2001

Page 1 of 3

	Coho				Sockeye			
Date	Adults	Jacks	Total	Cumulative Total	Adults	Jacks	Total	Cumulative Total
6/10/01					3		3	3
6/11/01					6		6	9
6/12/01					10		10	19
6/13/01					1		1	20
6/14/01					11		11	31
6/15/01					2		2	33
6/17/01					4		4	37
6/18/01					1		1	38
6/19/01					1		1	39
6/20/01					8		8	47
6/21/01					25	2	27	74
6/22/01					10		10	84
6/23/01					2		2	86
6/24/01					25		25	111
6/25/01					16	2	18	129
6/26/01					3	2	5	134
6/27/01					18	1	19	153
6/28/01					13		13	166
6/29/01					14		14	180
6/30/01					6	1	7	187
7/1/01					4	2	6	193
7/2/01					22	5	27	220
7/3/01					6	2	8	228
7/4/01					4	3	7	235
7/5/01					1	5	6	241
7/6/01					3	1	4	245
7/7/01					19	7	26	271
7/8/01					56	6	62	333
7/9/01					8	3	11	344
7/10/01					2		2	346
7/11/01					1	9	10	356
7/12/01						1	1	357
7/13/01					1		1	358
7/15/01					3	4	7	365
7/17/01						1	1	366
7/18/01						10	10	376
7/19/01						1	1	377
7/20/01					1	6	7	384
7/21/01					2	2	4	388
7/22/01						6	6	394
7/23/01					1		1	395
7/24/01					2	7	9	404
7/25/01					29	54	83	487

	Coho				Sockeye			
Date	Adults	Jacks	Total	Cumulative Total	Adults	Jacks	Total	Cumulative Total
7/26/01					5	16	21	508
7/27/01	1		1	1	5	6	11	519
7/28/01				1		1	1	520
7/30/01				1		1	1	521
8/1/01				1	2	2	4	525
8/2/01				1	16	43	59	584
8/3/01				1	5	35	40	624
8/4/01				1	9	20	29	653
8/5/01				1	32	52	84	737
8/6/01				1	7	10	17	754
8/7/01				1	1	6	7	761
8/8/01				1	6	5	11	772
8/9/01				1		2	2	774
8/10/01				1	4	1	5	779
8/11/01				1		1	1	780
8/12/01				1	1	5	6	786
8/15/01				1		3	3	789
8/17/01				1	2	4	6	795
8/18/01				1	2	6	8	803
8/19/01				1	3		3	806
8/20/01				1	17	20	37	843
8/21/01				1	35	14	49	892
8/22/01				1	9	2	11	903
8/23/01				1	3		3	906
8/25/01				1	1		1	907
8/26/01				1	11	2	13	920
8/27/01	8		8	9	86	7	93	1013
8/28/01	36	3	39	48	73	2	75	1088
8/29/01	6	1	7	55	7	1	8	1096
8/30/01			0	55	4		4	1100
8/31/01	1		1	56				1100
9/1/01	1		1	57		1	1	1101
9/2/01	24	1	25	82	12	1	13	1114
9/3/01	71	6	77	159	6	1	7	1121
9/4/01	6	1	7	166	2		2	1123
9/5/01	4		4	170				1123
9/6/01	14		14	184	1		1	1124
9/7/01	3	1	4	188	1		1	1125
9/8/01	2		2	190				1125
9/10/01	1		1	191				1125
9/12/01	2		2	193		1	1	1126
9/13/01	10		10	203				1126
9/14/01	38	2	40	243				1126
9/15/01	32	3	35	278	4		4	1130
9/16/01	38	4	42	320				1130
9/17/01	17	5	22	342				1130
9/18/01	25	3	28	370				1130

Appendix A1 Continued. Daily and cumulative weir counts at the Salmon Lake Weir 2001

	Coho				Sockeye			
Date	Adults	Jacks	Total	Cumulative Total	Adults	Jacks	Total	Cumulative Total
9/19/01	5	2	7	377				1130
9/20/01	31	2	33	410				1130
9/21/01	6		6	416				1130
9/22/01	11	3	14	430				1130
9/23/01	6	2	8	438				1130
9/24/01	2	3	5	443				1130
9/25/01	6	2	8	451				1130
9/26/01	2		2	453				1130
9/27/01	7	2	9	462				1130
9/28/01	1	1	2	464				1130
9/29/01	14	2	16	480				1130
9/30/01	76	2	78	558				1130
10/1/01	47	3	50	608	2		2	1132
10/2/01	42	1	43	651				1132
10/3/01	20		20	671				1132
10/4/01	12		12	683				1132
10/5/01	9		9	692				1132
10/6/01	14		14	706				1132
10/7/01	11		11	717				1132
10/8/01	4		4	721				1132
10/9/01	57		57	778				1132
10/10/01	116		116	894				1132
10/11/01	25		25	919				1132
10/12/01	24	1	25	944				1132
10/13/01	28	1	29	973				1132
10/14/01	8		8	981				1132
10/15/01	2		2	983				1132
10/16/01	35		35	1018				1132
10/17/01	5		5	1023				1132
10/18/01	20		20	1043				1132
10/19/01	7		7	1050				1132
10/20/01	3		3	1053				1132
10/21/01	1		1	1054				1132
10/22/01		1	1	1055				1132
10/29/01	2		2	1057				1132
10/30/01	2		2	1059				1132
10/31/01	1		1	1060				1132
Grand Total	1002	58	1060		718	414	1132	

Appendix A2.–Detection of size-selectivity in sampling and its effects on estimation of abundance and age and size composition.

Results of hypothesis tests, K-S on lengths of fish

Case I:

Accept H_O Accept H_O

There is no size-selectivity during marking or recapture, gear types, or locations.

Case II:

Accept H_O Reject H_O

There is no size-selectivity during recapture but there is during marking.

Case III:

Reject H_O Accept H_O

There is size-selectivity during both marking and recapture, between all gear types, or all locations.

Case IV:

Reject H_O Reject H_O

There is size-selectivity during recapture; the status of size-selectivity during marking is unknown.

Case I: Calculate one unstratified abundance estimate, and pool lengths, sexes, and ages from both marking and recapture events to improve precision of proportions in estimates of composition.

Case II: Calculate one unstratified abundance estimate, and only use lengths, sexes, and ages from recapture to estimate proportions in compositions.

Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition and apply formulae to correct for size bias to the pooled data (p. 17).

Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Use lengths, ages, and sexes from only recapture to estimate proportions in compositions, and apply formulae to correct for size bias to the data from recapture.

Whenever the results of the hypothesis tests indicate that there has been size-selective sampling (Case III or IV), there is still a chance that the bias in estimates of abundance from this phenomenon is negligible. Produce a second estimate of abundance by not stratifying the data as recommended above. If the two estimates (stratified and unbiased vs. biased and unstratified) are dissimilar, the bias is meaningful, the stratified estimate should be used, and data on compositions should be analyzed as described above for Cases III or IV. However, if the two estimates of abundance are similar, the bias is negligible in the UNSTRATIFIED estimate, and analysis can proceed as if there were no size-selective sampling during Event 2 (Cases I or II).

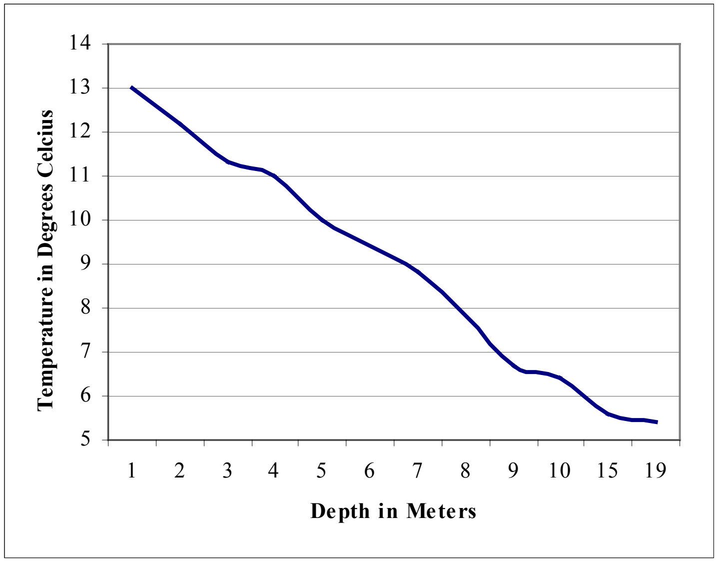

Figure XX. Water temperature at depth in ºC in Salmon Lake on 7/24/01. Temperature was taken at Station B between the surface and bottom of the lake.