Fishery Data Series No. 08-27

Stock Assessment of Salmon Lake Coho Salmon, 2004–2005

by

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and

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May 2008

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

Measures (fisheries)

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

Mathematics, statistics

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

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ABSTRACT

A stock assessment of coho salmon *Oncorhynchus kisutch* at Salmon Lake was conducted in 2004 and 2005. A floating weir was installed at the outlet of the lake to count and sample returning coho salmon between early June and late October each year. In addition to the floating weir, in-lake mark–recapture experiments were conducted to estimate total escapements into the lake. The estimated adult coho salmon escapements in 2004 and 2005 were 2,211 (SE = 229) and 2,843 (SE = 307) respectively.

In October 2002 and 2003, 5,047 and 4,981 coho salmon presmolt ≥85 mm FL were injected with coded wire tags and released in Salmon Lake. Harvest of Salmon Lake coho salmon in 2004 and 2005 was estimated at 3,640 (SE = 734) and 3,070 (SE = 485) in the combined sport and commercial fisheries. Exploitation of this stock was 62.2% (SE = 5.3%) in 2004 and 51.9% (SE = 4.8%) in 2005. Presmolt abundance was estimated at 77,071 (SE = 12,376) in 2002 and 75,544 (SE = 10,174) in 2003. Presmolt to adult survival was 7.6% (SE = 1.6%) in 2004 and 7.8% (SE = 1.3%) in 2005.

Key words: Salmon Lake, coho salmon, *Oncorhynchus kisutch*, floating weir, coded wire tag, mark–recapture.

INTRODUCTION

Information from past studies beginning in 1983 and continuing through 1995 (Elliott et al. 1989; Schmidt 1984-1988, 1990, 1996; Schmidt and DerHovanisian 1991) described a declining trend in coho salmon *Oncorhynchus kisutch* escapement in Salmon Lake and an increasing trend in exploitation for this stock, and suggested that the sustainability of Salmon Lake coho salmon was at risk from overharvest. In March 2000, the Southeast Alaska Regional Advisory Council (SERAC) identified Sitka Sound coho salmon assessment as a subsistence fisheries monitoring priority. 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 because of the stock's proximity to concentrated commercial effort on hatchery stocks, increased sportfishing effort, and newly established state and federal coho subsistence fisheries. In October 2001, the SERAC recommended that subsistence fishing opportunity be provided for coho salmon in Southeast Alaska. In 2002, the Federal Subsistence Board implemented this fishery. The State of Alaska also implemented a subsistence fishery for coho in Southeast Alaska in 2002, including the Sitka area and Salmon Lake stocks.

From 1983 to 1990, the Alaska Department of Fish and Game (ADF&G) conducted a coded wire tag (CWT) mark–recapture project at Salmon Lake to estimate annual smolt abundance, harvest, and escapement of coho salmon. Schmidt (1996) reported that exploitation rates for Salmon Lake coho increased from 35% in 1985 to 72% in 1989 and estimated spawning escapements decreased from 1,514 in 1984 to 204 in 1990. In 1994, ADF&G repeated the CWT portion of this 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.

This multi-year study was designed to assess the status of coho salmon in Salmon Lake. The objectives of this study were:

1. Estimate the escapements of coho salmon into Salmon Lake in 2004, and 2005.
2. Estimate the age, length, and sex composition of adult coho salmon in Salmon Lake in 2004 and 2005.
3. Estimate the abundance of coho salmon presmolt abundance in 2002 and 2003.
4. Estimate the age, length, and weight composition of coho salmon presmolt in Salmon Lake in 2002 and 2003.
5. Estimate the marine harvest of coho salmon from Salmon Lake in 2004 and 2005.

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

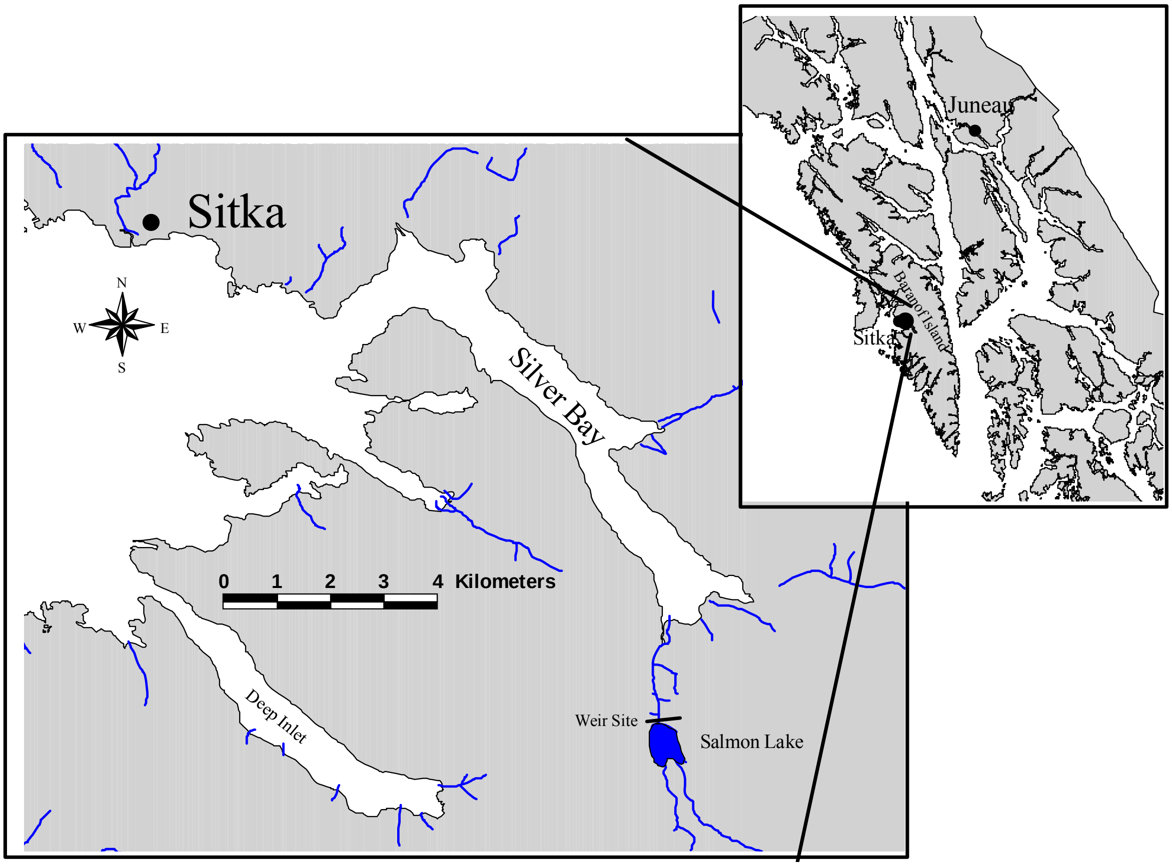

Figure 1.–Study area showing Salmon Lake, weir site and major tributaries.

and is fed primarily by two main inlet streams and several smaller tributaries 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 *O. nerka*, pink *O. gorbuscha*, chum *O. keta*, and coho salmon, Dolly Varden *Salvelinus malma*, cutthroat trout *O. clarki*, stickleback *Gasterosteus aculeatus*, sculpin *Cottus sp*.; resident rainbow trout and steelhead *O. mykiss.*

METHODS

Coho Salmon Escapement Weir Counts and Tagging

The Sitka Tribe of Alaska installed and operated the weir between early June and August 15 each year, and ADF&G ran it through October 31. The floating weir was installed in early June 2004–2005 to capture, count and tag immigrating coho and sockeye salmon. Sitka Tribe's primary focus was sockeye enumeration, but staff at the weir sampled and tagged all coho that passed through the weir prior to August 16. Coho were tagged to provide the means to estimate escapement with mark–recapture methods in the event of weir failure. The weir, located at the outlet of Salmon Lake, was fashioned after a weir described in Tobin (1994). It consisted of hollow high-density polyethylene (HDPE) 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 HDPE was used as the weir pickets. In 2001 the picket spacing was 18 pickets per 4-ft panel that were 20 ft long. In 2004 and 2005, 19 pickets per 4-ft panel were used. A rigid weir was established on either side of the 40 ft of floating weir. The rigid weir was supported by bipods and consisted of 3-in aluminum channel with a hole spacing of 49 per 8 ft. The pickets used for the rigid weir were ¾-in galvanized conduit. The interface between the floating weir and rigid weir was 1½ in nylon mesh netting.

All fish captured in the live box were enumerated. Sockeye and coho salmon 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™[1] tag. Coho salmon were given sequentially numbered tags that were inserted immediately below the middle of the dorsal fin on the left side. In addition to the tag, each fish was given a combination of operculum punches based on the week the fish was captured. The tagging guns, nets, gloves, scale tweezers, and hole punches were rinsed with a solution of 1-part Betadine™ to 10 parts water between sampling each fish. Each fish was allowed to safely recover in a holding box before release on the upstream side of the weir.

RECAPTURE EVENTS

Recapture events were scheduled on a biweekly basis. Coho salmon were captured in the lake and two inlet streams using a 5 m by 40 m beach seine modified for use in the inlet streams. Carcasses were sampled opportunistically and were included in the recapture events. During the recapture events, the lake perimeter was also surveyed by boat to locate areas where coho were present. Each fish captured was examined for tags, operculum punch, and adipose finclips. Date, tag numbers, and location were recorded for each fish. Fish captured in the lake without tags were measured, sampled for scales and sex, and given an individually numbered Floy™ tag.

2004–2005 ESCAPEMENT ESTIMATION

The escapements of coho salmon were estimated through mark–recapture experiments because untagged fish were found above the weir.

Under ideal conditions, Chapman's modification of the Petersen Method (Seber 1982) would be used to estimate coho salmon escapement:

$$\hat{N}_e = \frac{(M_e+1)(C_e+1)}{(R_e+1)} - 1 \qquad (1)$$

$$\hat{V}[\hat{N}_e] = \frac{\hat{N}_e(M_e-R_e)(C_e-R_e)}{(R_e+1)(R_e+2)} \qquad (2)$$

where:

$\hat{N}_e$ = estimated abundance;

M_e = number of coho salmon tagged and marked at the weir;

C_e = number of coho salmon inspected for Floy™ tags and marks in the lake and inlet streams, and;

R_e = number of coho salmon inspected that were tagged and/or marked.

The conditions for accurate use of this methodology were:

1. all fish had an equal probability of being marked at the weir; or
2. all fish had an equal probability of being inspected for tags in the lake and inlet streams; or
3. marked fish mixed completely with unmarked fish; and
4. there was no recruitment or mortality in the population between events; and
5. there was no tagging-induced behavior; and
6. fish did not lose their marks and all marks were recognizable and reported; and

double sampling did not occur.

The experiments were designed to ensure these conditions could either be met by field procedures or evaluated with diagnostic testing so the appropriate model for estimating abundance could be selected.

Condition 1 required sampling that was independent of fish size, gender, and timing throughout the run. It is unlikely that condition 1 could be satisfied whenever fish passed the weir undetected; however some minor violations could be offset by fish mixing in the lake. Condition 2 was dependent on uniform efficiency of sampling gear for all size classes of fish and in deployment of sampling gear proportional to occurrence of fish in the lake. There were no obvious experimental limitations that could have resulted in unequal probabilities of inspection between marked and unmarked salmon in the lake. Similarly, there were no obvious experimental

[1] Product names are included in this report for scientific completeness, but do not constitute a product endorsement.

conditions that would have prevented complete mixing (condition 3) of marked and unmarked fish between sampling events. However, mixing was dependent on fish behavior.

Diagnostic testing was conducted to detect significant violations of conditions 1–3. Equal probability of capture was evaluated by size, sex, and time of sampling. The procedures to analyze sex and length data for statistical bias due to gear selectivity are described in Appendix A1, as well as recommended procedures to correct for bias when estimating abundance and composition. To further evaluate conditions 1–3, contingency table analyses, recommended by Seber (1982) and described in Appendix A2, were used to detect significant temporal or geographic violations of assumptions of equal probability of capture. If all of conditions 1–3 were not satisfied due to temporal violations and/or lack of complete mixing, the partially stratified estimator described by Darroch (1961) was used to estimate abundance (see also Seber 1982 and Arnason et al. 1996).

Condition 4 was satisfied because there was no meaningful recruitment added to the populations investigated and because the life history of coho salmon isolates those fish returning to Salmon Lake as a "closed" population.

Trap-induced behavior (condition 5) was unlikely because different sampling gear types were used (weir vs. seine) and it is also unlikely that marking fish affected their catchability in the lake. Though a rare occurrence, marked fish were categorized as handling mortalities and censored from the experiment when tag numbers indicated that a fish had been tagged within the previous 3 days. After accounting for these immediate deaths, it was assumed that mortality rates for marked and unmarked fish were similar.

It is unlikely that any previously marked fish were not detected (condition 6) during second event sampling because operculum punches, which were also given, were visible even if the Floy™ tag was missing. Double sampling (condition 7) was prevented by an additional mark during event 2 (adipose finclip or Floy™ tag).

AGE, LENGTH, AND SEX COMPOSITION OF ADULT COHO SALMON

All coho salmon captured in the weir trap and untagged fish inspected in recapture events were sampled for scales, length, condition, and sex. Each fish was measured to the nearest 5 mm MEF. 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 per 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 post-season to determine ages. Sex was determined from secondary maturation characteristics.

If stratification by size was not necessary, proportions and their variances were estimated according to procedures in Cochran (1977) and Appendix A1.

$$\hat{p}_k = \frac{n_k}{n} \quad (3)$$

$$\hat{V}[\hat{p}_k] = \left(1 - \frac{n}{\hat{N}}\right)\frac{\hat{p}_k(1-\hat{p}_k)}{n-1} \quad (4)$$

where:

$\hat{p}_k$ = the proportion of the population in group *k;*

n_k = the number in the sample in group *k;*

n = the total number sampled; and

$\hat{N}$ = estimated population size.

If stratification by size was required, length and age proportions and their variances were again estimated according to the procedures in Cochran (1977) and Appendix A1.

$$\hat{p}_{jk} = \frac{n_{jk}}{n_j} \quad (5)$$

where:

n_j = The number sampled from size stratum j in the mark–recapture experiment;

n_{jk} = The number sampled from size stratum j that were in group k; and

$\hat{p}_{jk}$ = The estimated proportion of group k fish in size stratum j.

The variance calculation for $\hat{p}_{jk}$ was identical to equation 4 (with appropriate substitutions).

The estimated abundance of fish in size stratum j in the population was then:

$$\hat{N}_k = \sum_{j=1}^{i} \hat{p}_{jk} \hat{N}_j \tag{6}$$

where:

$\hat{N}_j$ = the estimated abundance in size stratum j; and

i = the number of size strata.

The variance for $\hat{N}_k$ in this case was estimated using the formulation for the exact variance of the product of two independent random variables (Goodman 1960):

$$\hat{V}\left[\hat{N}_k\right] = \sum_{j=1}^{s}\left(\hat{V}\left[\hat{p}_{jk}\right]\hat{N}_j^2 + V\left[\hat{N}_j\right]\hat{p}_{jk}^2 - \hat{V}\left[\hat{p}_{jk}\right]V\left[\hat{N}_j\right]\right) \tag{7}$$

The estimated proportion of the population in group k $\left(\hat{p}_k\right)$ was then:

$$\hat{p}_k = \hat{N}_k \big/ \hat{N} \tag{8}$$

where: $\hat{N} = \sum_{j=1}^{i} \hat{N}_j$.

Variance of the estimated proportion was approximated with the delta method (Seber 1982):

$$\hat{V}\left[\hat{p}_k\right] \approx \sum_{j=1}^{i}\left\{\left(\frac{\hat{N}_j}{\hat{N}}\right)^2 \hat{V}\left[\hat{p}_{jk}\right]\right\} + \frac{\sum_{j=1}^{s}\left\{V\left[\hat{N}_j\right]\left(\hat{p}_{jk} - \hat{p}_k\right)^2\right\}}{\hat{N}^2} \tag{9}$$

Abundance and Age, Length, and Weight Composition of Coho Salmon Presmolt

Baited minnow traps were deployed in the lake and inlet streams each October in 2002 and 2003. Between 20 and 50 traps were baited with salmon eggs daily, fished continuously, and checked every 12 hours or more often as needed. All captured coho salmon ≥85 mm FL without adipose finclips were tranquilized with the alcohol/clove oil mixture described above, given a CWT following procedures in Koerner (1977), marked with an adipose finclip, and released after 24 hours. Any coho salmon captured with a missing adipose fin was passed through a magnetic tag detector to test for post 24-hour tag retention. Mark IV™ 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 1 in 25 coho salmon juveniles ≥ 85 mm FL was taken to estimate age, length, and weight composition of presmolt. Scales were scraped off a small area on the left side, near the preferred area (Scarnecchia 1979) of each presmolt and placed on slides for age analysis. Lengths were taken to the nearest mm FL and weights to the nearest 0.1 g. Coho presmolt ages were determined postseason.

The abundance of coho presmolt in 2002 and 2003 and the associated variances were estimated using Chapman's modification of the Petersen Method (Seber 1982):

$$\hat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1 \tag{10}$$

$$\hat{V}[\hat{N}] = \frac{\hat{N}(M-R)(C-R)}{(R+1)(R+2)} \tag{11}$$

where:

$\hat{N}$ = estimated presmolt abundance;

M = number of or coho presmolt tagged with coded wire tags in 2002 or 2003;

C = number of adult coho salmon inspected for marks at Salmon Lake in 2004 or 2005; and

R = number of adult coho salmon inspected in 2004 or 2005 that contained a valid CWT.

The conditions for accurate use of this methodology were:

1. all presmolts had an equal probability of being marked in 2002 and 2003; or
2. adults had an equal probability of being inspected for marks in 2004 and 2005; or
3. marked fish mixed completely with unmarked fish in the population between years; and
4. there was no recruitment to the population between years; and
5. there was no tagging induced behavior or mortality; and
6. fish did not lose their marks and all marks were recognizable.

There were no anticipated conditions that resulted in unequal probabilities of inspection between marked and unmarked returning adult salmon at the weir. While the potential existed to detect size, gender, or temporal variability in probability of capture tagging of adults at the weir to estimate escapement (as described above), these potential biases did not imply differential probability of capture between adults with and without coded wire tags. Additionally, no anticipated conditions would have prevented complete mixing of marked and unmarked fish between sampling events. Because almost all surviving salmon return to their natal stream as adults to spawn, there was no meaningful recruitment added to the population of "presmolt" while they were at sea. Trap-induced behavior was unlikely because different sampling gear types were used to capture smolt and adults. Results from other studies (Elliott and Sterritt 1990; Vincent-Lang 1993) indicate that excising adipose fins and implanting CWTs does not increase the mortality of marked salmon. When mortality occurs between sampling events during a mark–recapture experiment and all other conditions are satisfied, the estimate of abundance is germane to the timing of the first sampling event, in this experiment when presmolt were tagged.

In most cases where first or second event sampling data for individual fish was incompletely or ambiguously recorded, individual observations were removed when censoring did not clearly bias the abundance estimate. Where censoring may have resulted in bias, bootstrap estimation procedures (Efron and Tibshirani 1993) similar to those described by Buckland and Garthwaite (1991) were used in place of equations (10) and (11) to estimate abundance and variance so that uncertainty in *M*, *C*, and/or *R* could be modeled correctly.

MARINE HARVEST OF COHO SALMON FROM SALMON LAKE IN 2004 AND 2005

Harvest in 2004 and 2005 of coho salmon originating from Salmon Lake was estimated from fish sampled in commercial and marine sport fisheries. Fisheries personnel with the ADF&G, Division of Commercial Fisheries (CFD) port-sampling program examined commercially caught fish at processing locations and recovered coho with missing adipose fins (ADF&G *Unpublished*). Similarly, the Division of Sport Fish (SFD) employed a creel survey program to examine fish caught in the sport fishery (e.g., Hubartt et al. 2001). When possible, heads of fish without an adipose fin were removed and sent to the ADF&G Mark, Tag and Age Laboratory (Tag Lab) in Juneau for tag detection and decoding. Because multiple fisheries exploited coho salmon over several months in 2004 and 2005, harvest was estimated over several strata, each a combination of time, area, and type of fishery. Statistics from the commercial troll fishery were stratified by fishing period and by fishing quadrant, from the purse seine fishery by week and fishing district, and the marine sport fishery bi-weekly by area.

A simulated data set, based on actual fishery data from past years, average survival, and anticipated sampling of sport and commercial harvests were used to anticipate precision for the harvest contribution estimate in 2004 and 2005, using methodology outlined in Bernard et al. (1998).

The contribution (r_{ij}) of a release group (j) to a fishery stratum (i) was estimated as (Bernard and Clark 1996):

$$\hat{r}_{ij} = N_i \left[\frac{m_{ij}}{\lambda_i n_i} \right] \theta_j^{-1}; \qquad \lambda_i = \frac{a_i' t_i'}{a_i t_i} \qquad (12)$$

where:

N_i = total harvest in the fishery;

n_i = number of fish inspected (the sample); and

a_i = number of fish which were missing an adipose fin;

a_i' = number of heads that arrived at the lab;

t_i = number of heads with CWTs detected;

t_i' = number of CWTs that were dissected from heads and decoded;

m_{ij} = number of CWTs with code(s) of interest; and

θ_j = fraction of the cohort tagged with code(s) of interest.

When N_i and θ_j are known without error, an unbiased estimate of the variance of $\hat{r}_{ij}$ can be calculated as shown by Clark and Bernard (1987). However, N_i is estimated with error in sport fisheries, and θ_j was estimated with error because wild stocks were tagged. Because of these circumstances, unbiased estimates of the variance of $\hat{r}_{ij}$ were obtained using the appropriate equations in Table 2 of Bernard and Clark (1996), which show the formulations for large samples. The total harvest for a cohort was the sum of the $\hat{r}_{ij}$ terms.

Commercial catch data for the analysis was summarized by ADF&G statistical week and district (seine fisheries) or by period and quadrant for troll fisheries (e.g., see Clark et al. 1985). Sport fish CWT recovery data were obtained from Tag Lab reports and summarized by biweek and fishery (e.g., biweek 16 during the Sitka Marine Creel Survey). Harvest estimates were obtained from ADF&G reports (e.g., Suchanek and Bingham 1992) and ADF&G computer summaries.

RESULTS

COHO SALMON ESCAPEMENT

The floating weir was operational by the first week of June each year. Coho runs began on July 28 in 2004 and August 7 in 2005 and continued through late October each year (Figure 2). The weir was dismantled on October 31 each year.

2004

In 2004 the first coho were passed at the weir on July 28 and the run proceeded through October 28. In total 432 coho (315 classified as adults and 117 as jacks) were handled and released (Table 1, Appendix A3). Of the 432 coho captured at the weir, 5 died shortly after tagging, so 427 were used for analysis. Estimated coho escapement in 2004 was 2,211 (SE = 229).

When comparing the length frequency distributions of all marked fish (M) and all recaptured fish (R), the null hypothesis that size-selective sampling did not occur during the second event was accepted (D = 0.082, P = 0.696). Also, the length frequency distributions of all fish inspected during the second event (C) and all recaptured fish (R) were not significantly different (D = 0.110, P = 0.320), so the null hypothesis that size selectivity did not occur during the first event sampling was accepted. Therefore, a Case I experiment (Appendix A1) with respect to size bias sampling was evident. When comparing the sex ratios of all fish captured in the second event (C) versus all recaptured fish (R), the null hypothesis that sex-selective sampling did not occur during the first event was accepted ($\chi2$ = 1.539, P = 0.215). Neither were differences detected when comparing fish marked at the weir (M) and all recaptured fish (R) ($\chi2$ = 0.093, P = 0.760). Therefore, a Case I experiment with respect to gender bias was also realized. No size or gender stratification was necessary prior to estimating abundance.

A flood event occurred on September 23 that moved the trap and allowed fish to move upstream freely for five full days before the trap could be repaired and replaced. Because of this, diagnostic testing for temporal violations was done with contingency table analysis to evaluate equal

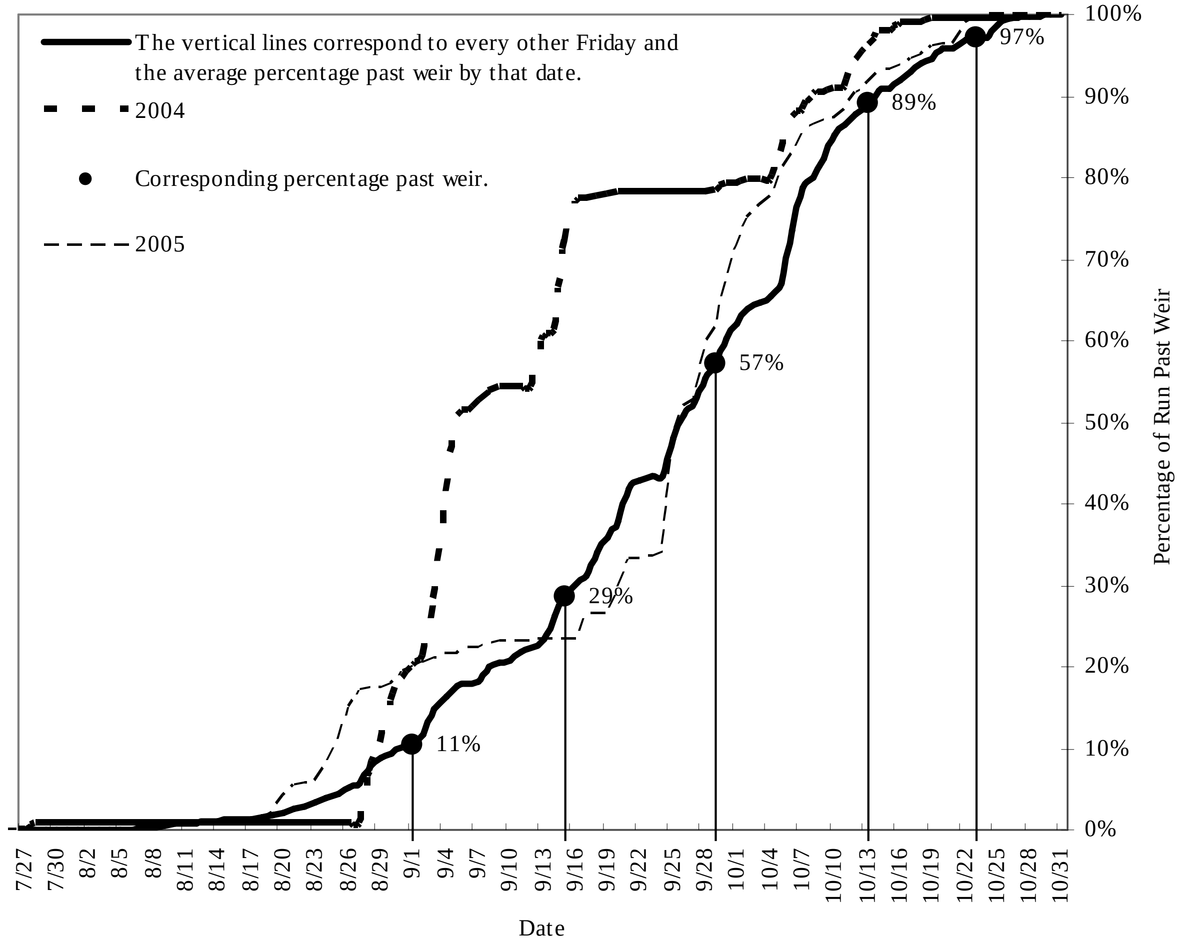

Figure 2.–Cumulative coho salmon counts at Salmon Lake weir, 2004–2005.

Table 1.–Salmon Lake weir counts and corresponding escapement estimates with standard error, 2004–2005**.**

	Weir counts		Mark–recapture events			Escapement estimates		Escapement estimate			
Year	Adults	Jacks	Marked	Examined	Recaptured	Adults SW-age-1	Jacks SW-age-0	Jacks and adults	SE	Date of first capture	Date of last capture
2004	315	117	427	440	90	1,478	733	2,211	229	28-Jul	28-Oct
2005	532	205	731	423	99	2,003	840	2,843	307	7-Aug	24-Oct
Averages	424	161	579	432	95	1,741	786	2,527	255	1-Aug	26-Oct

probability of sampling conditions. Marked to unmarked ratios in recapture events prior to the flood event were compared to marked to unmarked ratios after the flood event resulting in rejection of the hypothesis that fish had the same probability of sampling before and after the flood event ($\chi2$ = 29.619, P < 0.001). To test the probability that all fish sampled during the second event (recapture) had an equal chance of being seen, contingency table analysis was done on the marked to unmarked recovery rate over time (approximately weekly basis). This resulted in less than conclusive results ($\chi2$ = 6.910 P = 0.212). When weeks were pooled to increase sample sizes and the flood event was used as a stratification point the probability of a marked fish being recovered during the second event was not independent of when it was marked, and fish marked prior to the flood had a higher probability of being sampled during the second event than those marked after the flood ($\chi2$ = 4.805 P = 0.0284). To test for complete mixing between sampling events, contingency table analysis was again used to test the hypothesis that final second event capture histories for marked fish (as recaptured before the flood, recaptured after the flood, or never seen again) was independent of when the fish were marked. The null hypothesis that capture history was independent of time marked was rejected ($\chi2$ = 6.320, P = 0.0424). Because significant evidence existed that the equal probability of capture condition was violated during both sampling events, and significant evidence existed that complete mixing did not occur between events, a partially (temporally) stratified estimator described by Darroch (1961) was attempted to estimate abundance.

A valid abundance estimate using the Darroch estimator was not possible using this experimental data. The most logical and optimum stratification (at the flood for both events) allowed for a maximum likelihood and moment estimator to be computed, but the estimate was not plausible because it computed a negative probability of capture for fish during the second event prior to the flood. Several other stratification strategies were attempted, but none of these strategies where fish with dissimilar capture probabilities were kept in separate temporal strata provided plausible estimates. In some cases, no estimate could be computed, and in those cases where the estimate could be computed, it contained implausible components so the Darroch estimator was of no utility.

Without an unbiased estimator, only biased estimators were possible. Biased estimators, where the nature of the bias is known and describable based on diagnostics, were the only possibility to describe the abundance of coho salmon escaping into Salmon Lake in 2004.

A subset of the data collected was used to calculate an estimate using the Chapman model. The subset was selected after reviewing diagnostic tests described above and with consideration of the timing of weir failure (flood event) during the experiment. The estimate was computed using:

M2: Where the marked sample consisted of those coho salmon marked at the weir prior to and following the flood event up to and including October 13 (*M2* = 411).

The 14 fish marked at the weir after October 14 were treated the same as handling mortalities in that they were excluded from consideration when calculating the abundance estimate and were later added to the estimate. Components of diagnostic testing for the overall experiment indicated that fish marked during this time period had similar probabilities of being recovered during the second sampling event ($\chi2$ = 1.602, P = 0.206).

C2: The catch sample consisted of those coho salmon inspected for marks during October 14–26 (*C2* = 329).

Marked:unmarked ratios did not vary significantly for fish inspected during this time period ($\chi2$ = 2.395, P = 0.302). Only one of the 14 fish marked during October 14–19 was recaptured during this period, and that fish was not included as part of *C2* or *R2*.

R2: those fish observed in *C2* that were part of *M2* (*R2* = 61).

Complete mixing was also evaluated, and no significant evidence was detected to indicate that fish did not mix completely prior to second event sampling ($\chi2$ = 8.717, P = 0.190). The estimated abundance using the subset of data as described above is 2,192, and after adding handling mortalities and fish passed through the weir after October 13, the total estimated escapement of coho salmon was 2,211 (SE = 229). This estimate is germane to the first sampling event because some mortality or loss due to emigration (up spawning tributaries) was expected during the experiment and, under normal conditions these losses would affect similar proportions of both marked and unmarked fish. The population was effectively closed to immigration after the beginning of the second sampling event, in that no or very few fish were able to enter the population undetected after October 13. However, due to heterogeneity in probability of capture during both sampling events, this unstratified Chapman estimator may be biased high, overestimating true abundance.

The lack of significance in the temporal diagnostic tests suggests that the potential for bias was not severe. However, it is known that equal probability of capture did not occur during the first event and the majority of coho salmon escaping into Salmon Lake entered the lake during the flood event when the weir was not operational. Based on previous years' experience, a very high proportion of the fish that entered the lake before and after the flood event were marked. It is likely that a higher proportion of fish that entered the lake prior to September 23 had "left" the system due to mortality or emigration up spawning tributaries prior to second event sampling, than fish entering during or after the flood. As a result, the marked:unmarked ratio during second event sampling would be lower than expected, producing an overestimate of abundance.

2005

Coho salmon were first captured at the weir on August 7 in 2005 and the run proceeded through October 24. At the weir, 737 fish (532 classified as adults and 205 as jacks) were captured. One fish was sacrificed for coded wire tag analysis and 5 fish died shortly after tagging. Of the 737 fish captured, 731 were released above the weir with an individually numbered Floy™ tag (Table 1, Appendix A3).

When comparing the length frequency distributions of all marked fish (*M*) and all recaptured fish (*R*), the null hypothesis that size-selective sampling did not occur during the second event was rejected (D = 0.159, P = 0.024). However, the null hypothesis that size-selective sampling did not occur during first event sampling was not rejected (D = 0.100, P = 0.374), resulting in a Case II experiment (Appendix A1) so size stratification was not required prior to estimating abundance. When evaluating gender bias, there was no evidence of bias during second event sampling ($\chi 2$ = 0.456, P = 0.500), but some potential that gender biased sampling may have occurred during first event sampling ($\chi 2$ = 3.248, P = 0.072). Because gender bias was not detected concurrently with size bias, which is commonly the case with coho because jack salmon may have a lower probability of being sampled, it was concluded that the apparent potential gender bias was most likely the result of gender misclassification during first event sampling. A Case I experiment with respect to gender bias with no stratification required prior to abundance estimation was therefore used.

Tests for temporal bias for coho salmon clearly indicated that capture probabilities were not uniform throughout either the first event ($\chi 2$ = 4.238, P = 0.040) or the second event ($\chi 2$ = 10.967, P = 0.001). Also, the null hypothesis that complete mixing occurred between sampling events was rejected ($\chi 2$ = 15.931, P < 0.001), so the partially stratified model described by Darroch (1961) was necessary to estimate abundance. The most parsimonious legitimate model indicated by the diagnostics tests did not yield an admissible estimate using Darroch's model. Further stratification of the first event into four strata with two second event strata did yield an admissible abundance estimate with acceptable goodness-of-fit test statistics (P = 0.09). Further attempts with different legitimate but less parsimonious stratifications were attempted to try to identify a model providing an admissible estimate with better goodness-of-fit statistics, but no better model was found.

Coho salmon escapement into Salmon Lake in 2005 was estimated to be 2,843 (SE = 307; Table 1) after adding on handling mortalities.

Age, Length, and Sex Composition of Adult Coho Salmon

Based on sampling at the weir, coho salmon were predominately saltwater-age-1 fish in 2004 (72.9%). After aging scales taken during both sampling events (weir and recapture), the estimated proportion of saltwater-age-1 fish was 70.9% (SE = 1.7%; Table 2). In 2005, 72.2% of the coho captured at the weir were classified as adult (saltwater-age-1) fish based on fish length. After aging scales taken during the first (weir)

Table 2.–Age distribution of the coho salmon escapement at Salmon Lake, 2004–2005.

Year	Saltwater-age-1	Saltwater-age-0	% Saltwater-age-1 (SE)
2004	494	203	70.9 (1.7)
2005	522	205	71.8 (1.7)

sampling event, the estimated proportion of saltwater-age-1 fish was 71.8% (SE =1.7%). The mean lengths of adult coho examined at the weir ranged from 588 mm MEF in 2004 to 571 mm MEF in 2005 (Table 3). The mean length of jacks ranged between 365 mm MEF in 2004 and 366 mm MEF in 2005. The cutoff length for jack coho (age-0) was established at <410 mm MEF (Table 4, Figure 3) in 2004 and 2005.

Table 3.–Mean lengths (mm MEF) of coho salmon adults and jacks examined at the Salmon Lake weir, 2004–2005[a].

	2004		2005	
	Jacks	Adults	Jacks	Adults
Mean	365	588	366	571
Standard Error	2.3	5.2	2.8	3.9
Standard Deviation	25.2	91.2	89.8	41.1
Count	119	307	204	521

[a] The coho jack cut-off was <410 mm MEF in 2004 and 2005.

ABUNDANCE AND AGE, LENGTH, AND WEIGHT COMPOSITION OF COHO SALMON PRESMOLT

2002

In October 2002, 5,047 coho presmolt ≥85 mm were successfully captured, adipose-finclipped and tagged with coded wire tag 04-07-80. Two overnight mortalities resulted in a valid release of 5,042. The same month, 338 presmolt were adipose fin clipped and not tagged. Overnight tag retention was 99.6%, leading to a valid tagged release of 4,704. The mean weight of freshwater-age-1 tagged coho salmon presmolt was 14.9 g (SE = 0.50) and their mean length was 108.9 mm FL (SE = 1.09, Table 5). The mean weight of freshwater-age-0 tagged coho salmon presmolt was 10.3 g (SE = 0.81) and their mean length was 98.2 mm FL (SE = 2.22). Most presmolt were freshwater-age-1 (92.9%).

In 2004, 534 individual adult coho were examined for presence or absence of an adipose fin clip at the weir and again in recapture events. Of these, 34 were found to have a clipped fin, indicating the presence of a coded wire tag. The resulting tagged fraction was 6.4%. Estimated presmolt abundance in 2002 was 77,071 (SE = 12,376). Estimated presmolt to adult survival was 7.6% (SE = 1.6%).

2003

In October 2003, 4,981 coho presmolt ≥85 mm were captured, adipose-finclipped and tagged with coded wire tag 04-08-44. There were no overnight mortalities. Tag retention was 99.5%, which resulted in a valid tagged released of 4,956. The mean length of tagged coho salmon presmolt was 100.7 mm FL (SE = 0.27). Neither weights nor scale samples were taken during fall presmolt tagging in 2003.

In 2005, 761 individual adult coho were examined for presence or absence of an adipose finclip at the weir and again in recapture events. Of these, 49 were found to have a clipped fin, indicating the presence of a coded wire tag. The resulting tagged fraction was 6.4%. Estimated presmolt abundance in 2003 was 75,544 (SE = 10,174). Estimated presmolt to adult survival was 7.8% (SE = 1.3%).

MARINE HARVEST OF COHO SALMON FROM SALMON LAKE

In 2004, 34 CWTs from Salmon Lake were randomly recovered from 290,688 coho salmon sampled in commercial and sport fisheries (Table 6). Three additional CWTs were recovered incidentally as volunteered samples. Twenty-five coho salmon bearing CWTs with a Salmon Lake code were recovered randomly from Southeast Alaska's commercial troll fisheries, and one was recovered from commercial purse seine fisheries, which combined could be used to estimate commercial harvest. All but one of these fish was caught in the Northwest Quadrant (Figure 4) of Southeast Alaska between July 1 and August 17, 2004. Eight salmon bearing CWTs with a Salmon Lake code were randomly recovered in the Sitka sport fishery between June 7 and September 12, 2004. Coho salmon bearing CWTs with a Salmon Lake code recovered in the commercial and sport fisheries in 2004 averaged 678.4 mm FL (SE = 7.0).

The estimated harvest of Salmon Lake coho salmon in sampled marine fisheries in 2004 was 3,640 (SE = 734; Table 6) or less than 0.3% of the combined sport and commercial troll harvest. The total contribution to the sport fishery by Salmon Lake coho was estimated at 888 fish. The total contribution to the commercial fishery was estimated at 2,352. Sport-caught Salmon Lake

Table 4.–Adult/jack cutoff lengths (mm MEF) for coho salmon at Salmon Lake, 2004–2005.

Cut off sizes for jack coho salmon in Salmon Lake 2004–2005						
	Saltwater-age-1		Saltwater-age-0			
Year	<410 mm MEF	≥410 mm MEF	<410 mm MEF	≥410 mm MEF	% saltwater-age-0 coho <410 MEF	% saltwater-age-1 coho ≥410 MEF
2004	8	299	116	3	97.5%	97.4%
2005	21	501	199	6	97.1%	96.0%

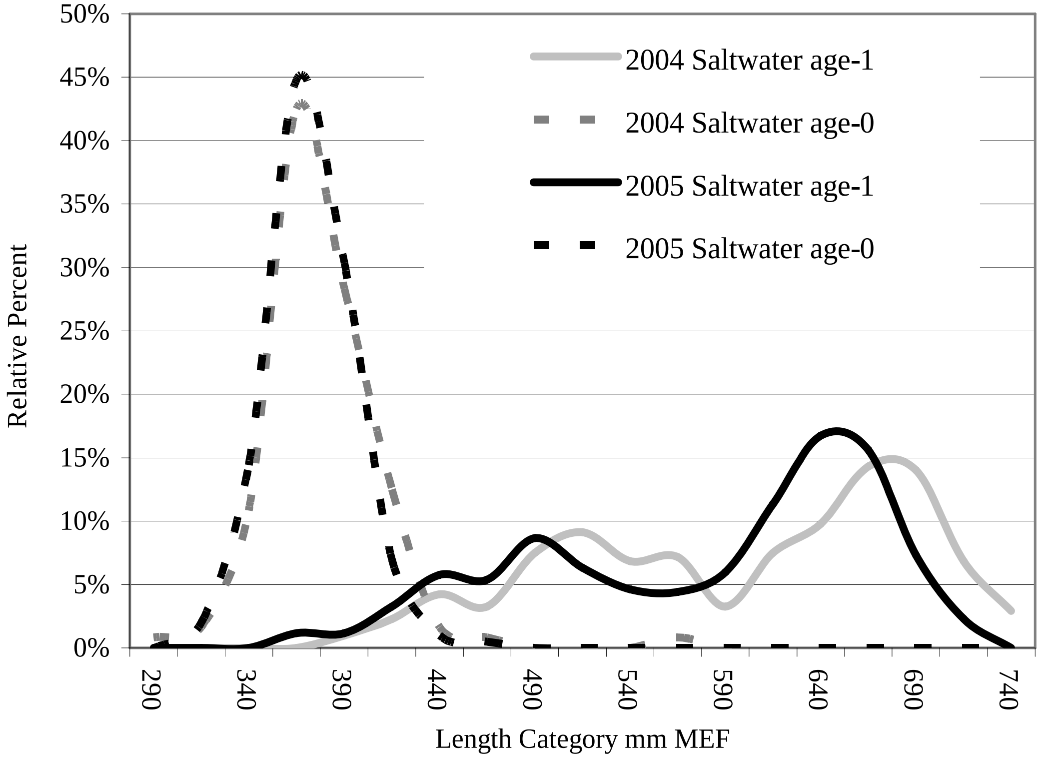

Figure 3.–Length frequency distributions of adult (saltwater age-1) and jack (saltwater age-0) coho salmon measured at the Salmon Lake weir, 2004–2005.

Table 5.–Mean weight and length (mm FL) of tagged coho salmon presmolt in Salmon Lake, 2002.

	Freshwater-age-0	
	Length (mm FL)	Weight (g)
Mean	98.2	10.3
Standard error	2.22	0.81
Sample variance	64.31	8.50
Count	13	13
	Freshwater-age-1	
	Length (mm FL)	Weight (g)
Mean	108.9	14.9
Standard error	1.09	0.50
Sample variance	203.73	42.94
Count	171	169

coho comprised 24.4% of the harvest of that stock in the sampled marine fisheries, and relative contributions were higher for the sport harvest (2.4%) than the troll harvest (0.18%). Estimates of freshwater harvest of coho salmon in Salmon Lake are not available because of the low number of respondents in the Statewide Harvest Survey (Jennings et al. 2007). This is indicative of low effort and negligible harvest.

Given an estimated escapement in 2004 of 2,211 (SE = 229) and a marine harvest of 3,640, the estimated total return of Salmon Lake coho salmon was 5,851 (SE = 768). Total exploitation was estimated to be 62.2% (SE = 5.3%).

Table 6.–Estimated marine harvest of adult Salmon Lake coho salmon (tag codes 04-07-80 and 04-08-44) in sampled sport and commercial fisheries, 2004 and 2005.

					2004						
					TROLL FISHERY						
Period	Dates	Quadrant	Harvest	Inspected	a	a'a	t	t't	m	r	SE{r}
3	7/1–8/9	NW	576,159	118,686	1,587	1,560	1,230	1,229	15	1,438	423
4	8/12–9/30	NW	661,464	149,828	2,760	2,710	2,229	2,228	9	785	282
3	7/1–8/9	NE	97,303	15,163	195	190	145	145	1	128	127
Subtotal troll fishery			1,334,926	283,677	4,542	4,460	3,604	3,602	25	2,352	
					SPORT FISHERY						
Biweek	Dates	Area	Harvest	Inspected	a	a'a	t	t't	m	r	SE{r}
12	6/7–6/20	SITKA	479	85	3	3	3	3	1	109	109
14	7/5–7/18	SITKA	11,105	2,297	18	18	16	16	1	94	93
15	7/19–8/1	SITKA	8,126	1,465	18	18	15	15	1	108	107
16	8/2–8/15	SITKA	11,438	2,200	33	32	29	29	4	416	214
18	8/30–9/12	SITKA	6,413	770	23	23	16	16	1	162	161
Subtotal sport fishery			37,561	6,817	95	94	79	79	8	888	
					SEINE FISHERY						
Biweek	Dates	Area	Harvest	Inspected	a	a'a	t	t't	m	r	SE{r}
31	7/25–7/31	NW	4,003	194	9	9	8	8	1	400	400
Subtotal seine fishery			4,003	194	9	9	8	8	1	400	
Total all fisheries			1,376,490	290,688	4,646	4,563	3,691	3,689	34	3,640	734
					2005						
					TROLL FISHERY						
Period	Dates	Quadrant	Harvest	Inspected	a	a'a	t	t't	m	r	SE{r}
3	7/1–8/9	NW	643,680	181,111	2,238	2,194	1,614	1,609	28	1,581	375
4	8/14–9/20	NE	71,657	16,812	238	238	185	185	1	66	66
4	8/14–9/20	NW	395,975	102,640	1,420	1,404	1,131	1,128	8	486	183
5	10/11–12/31	NW	139,380	39,415	737	729	571	571	1	56	55
Subtotal troll fishery			1,250,692	339,978	4,633	4,565	3,501	3,493	38	2,189	
					SPORT FISHERY						
Biweek	Dates	Area	Harvest	Inspected	a	a'a	t	t't	m	r	SE{r}
14	7/4–7/17	SITKA	5,237	2,101	24	24	20	20	3	116	68
15	7/18–7/31	SITKA	17,199	3,848	46	46	37	37	4	278	142
16	8/1–8/14	SITKA	17,411	4,973	101	100	85	85	7	384	153
17	8/15–8/28	SITKA	16,823	5,161	66	65	61	61	2	103	73
Subtotal sport fishery			56,670	16,083	237	235	203	203	16	881	
Total all fisheries			1,307,362	356,061	4,870	4,800	3,704	3,696	54	3,070	485

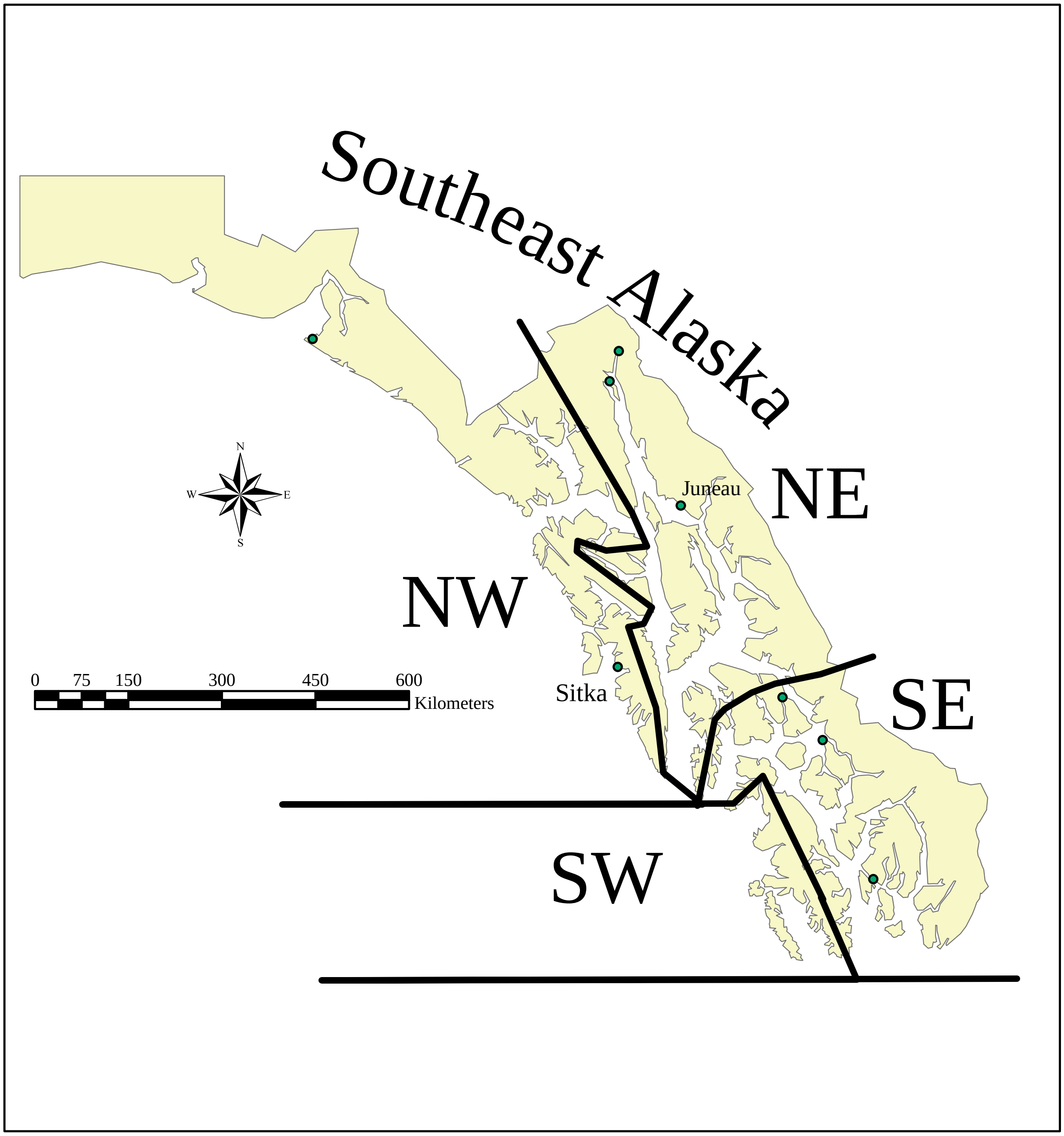

Figure 4.–Map of Southeast Alaska showing the troll quadrant boundaries.

In 2005, 54 CWTs from Salmon Lake were randomly recovered from 356,061 coho salmon sampled in commercial and sport fisheries. One additional CWT was recovered incidentally as a volunteered sample. Thirty-eight coho salmon bearing CWTs with a Salmon Lake code were recovered randomly from Southeast Alaska's commercial troll fisheries, which could be used to estimate commercial harvest. All but one of these fish was caught in the Northwest Quadrant (Figure 4) of Southeast Alaska between July 2 and September 11, 2005. Sixteen salmon bearing CWTs with a Salmon Lake code were recovered in the Sitka sport fishery between July 3 and August 24, 2005. Coho salmon bearing CWTs with a Salmon Lake code recovered in the commercial and sport fisheries in 2005 averaged 629 mm FL (SE = 5.87).

Sampling rates in the troll fisheries in the Northeast and Northwest Quadrants in 2004 and 2005 ranged from 4.6% to 22% (average 17.2%). The estimated harvest of Salmon Lake coho salmon in sampled marine fisheries in 2005 was 3,070 (SE = 485; Table 6) or less than 0.23% of the combined sport and commercial troll harvest. The total contribution to the sport fishery by Salmon Lake coho was estimated at 881 fish. The total contribution to the commercial fishery was estimated at 2,189. Sport-caught Salmon Lake coho comprised 5.4% of the harvest of that stock in the sampled marine fisheries, and relative contributions were higher for the sport harvest (1.6%) than the troll harvest (0.18%). Estimates of freshwater harvest of coho salmon in Salmon Lake are not available because of the low number of respondents. This is indicative of low effort and negligible harvest.

Given an estimated escapement in 2005 of 2,843 (SE = 307) and a marine harvest of 3,070, the estimated total return of Salmon Lake coho salmon was 5,913 (SE = 574). Total exploitation was estimated to be 51.9% (SE = 4.8%).

DISCUSSION

COHO ESCAPEMENT IN 2004–2005

The study design provided adequate opportunities to investigate size related and/or temporal violations of the three components of the first assumption. Diagnostic tests and criteria for choosing the correct model of estimating abundance have been described in Appendices A1 and A2.

Floy™ tag loss was low and sampling rates were high. Additionally, 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 study. Because fish were given a uniquely numbered Floy™ tag and fin clipped, double sampling was largely prevented in the recapture events. The use of a secondary mark (operculum punch) during the first event sampling ensured that the week of marking could be identified for any fish sampled during the second event, even if the Floy™ tag was lost. One (1%) of the 90 marked fish recaptured with a secondary mark in 2004 had actually lost their primary (Floy™ tag) mark. None of the 99 marked fish recaptured in 2005 lost their primary mark. Additionally, handling effects were minor. Pre-spawn live fish recaptured in the lake appeared to be in good condition. Many tagged fish were recaptured in good condition more than a month after initial tagging.

Each year the number of fish captured at the weir only represented a portion of the total escapement, as some fish were able to pass over the weir undetected during high water events. Because the proportion of fish captured at the weir varied in relation to estimated escapement, weir counts should be viewed as a minimum escapement count rather than an index of escapement. The floating weir was designed to allow water to pass over it without damage. Experience has shown that although the periodic high water events are short and infrequent, a 100-fold increase in discharge can occur. In addition to high water events that provide an opportunity for fish to pass, picket spacing allows smaller resident fish to swim through the weir unimpeded.

Estimating abundance in 2004 was problematic due to temporal variation of probabilities of capture during both sampling events. We were unable to identify an appropriate model to estimate abundance using the entire data set. The subset of the data used to estimate abundance was arrived at after careful inspection of diagnostic results. The estimate of 2,211 (SE = 229) has the least potential for bias of different alternatives considered.

Temporal variation in probabilities of capture was also detected during both sampling events in 2005. However, a suitable partially stratified Darroch (1961) model was identified, providing an estimated escapement of 2,843 (SE = 307), which has minimal potential for bias.

COHO PRESMOLT ABUNDANCE IN 2002 AND 2003 AND ADULT HARVEST IN 2004 AND 2005

All presmolt had the same probability of capture regardless of location in the lake or size. Presmolt capture and tagging occurred throughout the lake and tributaries, within most of the available habitat, and was also accomplished with minnow traps that capture a wide range of presmolt sizes.

Although the assumption about mixing couldn't be tested, coho salmon most likely mixed within or across stocks during their extended time (14 months) at sea. This should have provided adequate mixing of the population of tagged and untagged fish.

Another assumption requires that there was no recruitment to the population between years. Because almost all wild coho salmon return to their natal streams and sampling only occurred in the river, there was probably no appreciable recruitment to the stock between marking and recovery. The presence of stray coho salmon reared at Medvejie hatchery is possible but unlikely because no coho from Medvejie hatchery were recovered in Salmon Lake 2001 and 2002.

It is unlikely that presmolt regenerated the clipped adipose fin that identified the fish as containing a tag. In conjunction with tag retention and overnight mortality tests, adipose finclips on presmolt were examined. All presmolt examined appeared to have good finclips. Also, all adult coho examined had well defined or a complete absence of an adipose fin.

The results of an instream sampling event that occurred in spring 2003 suggest a need for caution when interpreting many of the statistics for Salmon Lake coho salmon harvested in 2004. In May 2003, Northern Southeast Regional Aquaculture Association (NSRAA) staff sampled coho salmon smolt during the outmigration. Smolt were captured using an incline plane trap. Of 446 smolt observed, 61 had missing adipose fins. Using these data to calculate the abundance of fall 2002 presmolts yields an estimate of 35,918 (SE = 4,147), which is much smaller than the estimate of 77,116 that was based on the proportion of marked adults observed at the weir. This smaller number, when used in calculations of marine harvest in sport and commercial fisheries, provides an estimated harvest of 1,445 (SE = 316), compared to the estimate of 3,640. Subsequently, the smaller harvest estimate produces a total return size of 4,288 (SE = 280) with an estimated exploitation rate of 33.7% (SE = 5.4%), which is smaller than our estimates, respectively, of 5,851 and 62.2%.

The contrast in these results is dramatic and if one (if not both) set of results is inaccurate, most likely it is a result of an unidentified source of bias during sampling. It is unlikely that presmolt-to-smolt survival of tagged fish was significantly lower than that of untagged fish because results from other studies (Elliott and Sterritt 1990; Vander Haegen et al. 2005; Vincent-Lang 1993) indicate that excising adipose fins and implanting CWTs does not increase the mortality of marked salmon. It is also unlikely that tagged fish were more susceptible to being captured and sampled during spring 2003, again because the tagging event occurred several months earlier and used different capture gear.

It is likely that the proportion of marked fish observed at the weir was more representative of the proportion of marked fish available during outmigration. The spring sample was a discrete sample that did not encompass the entire outmigration and may have been biased toward marked fish. The statistics calculated based on escapement data (as presented in the Results) should be used to guide fishery management.

CONCLUSIONS AND RECOMMENDATIONS

ESCAPEMENT ESTIMATION

To minimize the number of fish passing through the weir undetected, the weir should be closely inspected and reinforced during times of low water in order to prepare the weir for high water events. A picket spacing of 20 pickets per 4-ft panel may also reduce the number of salmon passing through the weir while still allowing smaller resident fish to move through unimpeded.

As an alternative approach to estimating escapement, inlake mark–recapture methods without the use of the weir should be explored. To do this, fish would need to be captured and tagged with individually numbered Floy™ tags in Salmon Lake periodically throughout the escapement migration.

Because such a relatively small number of fish may be present in the inlet streams during stream counts, stream counts were found to be a poor predictor for estimating escapement (Tydingco 2006) and should be discontinued.

SAMPLING

Floy™ tag retention rate was high (99%) between 2004 and 2005. To reduce fish handling, only one mark, either a Floy™ tag or operculum punch, could be used to identify a fish as being previously captured.

Harvest

The reported subsistence harvest of both coho and sockeye salmon are likely underestimated. On July 4, 2001, Sitka Tribe and ADF&G staff observed approximately 400 sockeye taken at the mouth of the Salmon Lake outlet stream in the subsistence fishery. The total reported subsistence harvest for the year was 255 fish. To fully understand the harvest of both sockeye and coho salmon from Salmon Lake, a sampling protocol should be developed and implemented that addresses this harvest.

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APPENDIX A

Appendix A1.–Detection of size and/or sex selective sampling during a two-sample mark–recapture experiment and its effects on estimation of population size and population composition**.**

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first and/or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R) by using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. A third test that compares M and C is then conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling: Contingency table analysis (chi^2-test) is generally used to detect significant evidence that sex selective sampling occurred during the first and/or second sampling events. The counts of observed males to females are compared between M&R, C&R, and M&C using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. If the proportions by gender are estimated for a sample (usually C), rather than observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are then compared between samples using a two-sample test (e.g., Student's t-test).

M vs. R	**C vs. R**	**M vs. C**
Case I:		
Fail to reject H_o	Fail to reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during either sampling event.

Case II:		
Reject H_o	Fail to reject H_o	Reject H_o

There is no size/sex selectivity detected during the first event but there is during the second event sampling.

Case III:		
Fail to reject H_o	Reject H_o	Reject H_o

There is no size/sex selectivity detected during the second event but there is during the first event sampling.

Case IV:		
Reject H_o	Reject H_o	Either result possible

There is size/sex selectivity detected during both the first and second sampling events.

Evaluation Required:		
Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test is likely detecting small differences that have little potential to result in bias during estimation. *Case I* is appropriate.

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B. If a) sample sizes for M vs. R are small, b) the M vs. R p-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R p-value is fairly large (~0.30 or more), then rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the second event, which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

C. If a) sample sizes for C vs. R are small, b) the C vs. R p-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R p-value is fairly large (~0.30 or more), then rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the first event, which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R p-values are not large (~0.20 or less), then rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events, which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

Case I. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

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If stratification by sex or length is necessary prior to estimating composition parameters, then an overall composition parameters (p_k) is estimated by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{j=1}^{i} \frac{\hat{N}_j}{\hat{N}_\Sigma} \hat{p}_{jk} \tag{1}$$

and

$$\hat{V}\left[\hat{p}_k\right] \approx \frac{1}{\hat{N}_\Sigma^2}\left(\sum_{j=1}^{i} \hat{N}_i^2 \hat{V}\left[\hat{p}_{jk}\right] + (\hat{p}_{ik} - \hat{p}_k)^2 \hat{V}\left[\hat{N}_j\right]\right) \tag{2}$$

where: i = the number of sex/size strata;

$\hat{p}_{jk}$ = the estimated proportion of fish that were age or size k among fish in stratum j;

$\hat{N}_j$ = the estimated abundance in stratum j; and,

$\hat{N}_\Sigma$ = sum of the $\hat{N}_j$ across strata.

Appendix A2.-Tests of consistency for the Petersen estimator (from Seber 1982, page 438).

Tests of consistency for Petersen estimator

Of the following conditions, at least one must be fulfilled to meet assumptions of a Petersen estimator:

1. Marked fish mix completely with unmarked fish between events;
2. Every fish has an equal probability of being captured and marked during event 1; or,
3. Every fish has an equal probability of being captured and examined during event 2.

To evaluate these three assumptions, the chi-square statistic was used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis needed to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests were rejected, a geographically stratified estimator (Darroch 1961) was used to estimate abundance.

I.-Test For Complete Mixing[a]

Area Where Marked	Area Where Recaptured				Not Recaptured
	1	**2**	**…**	**t**	$(n_1\text{-}m_2)$
1					
2					
…					
s					

II.-Test For Equal Probability of capture during the first event[b]

	Area Where Examined			
	1	**2**	**…**	**t**
Marked (m_2)				
Unmarked $(n_2\text{-}m_2)$				

III.-Test for equal probability of capture during the second event[c]

	Area Where Marked			
	1	**2**	**…**	**s**
Recaptured (m_2)				
Not Recaptured $(n_1\text{-}m_2)$				

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[a] This tests the hypothesis that movement probabilities (θ) from area *i* (*i* = 1, 2, ...s) to area *j* (*j* = 1, 2, ...t) are the same among areas: H_0: $\theta_{ij} = \theta_j$.

[b] This tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among areas: H_0: $\Sigma_i a_i\theta_{ij} = kU_j$, where *k* = total marks released/total unmarked in the population, U_j = total unmarked fish in stratum *j* at the time of sampling, and a_i = number of marked fish released in stratum *i*.

[c] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among the river areas: H_0: $\Sigma_j\theta_{ij}p_j = d$, where p_j is the probability of capturing a fish in area *j* during the second event, and d is a constant.

Appendix A3.–Daily fish passing and cumulative percent of run for fish captured at the Salmon Lake weir 2001–2005.

	2001		2002		2003		2004		2005		2001–2005 Average
Date	Coho	Cumulative % of Coho Run	Coho	Cumulative % of Coho Run	Coho	Cumulative % of Coho Run	Coho	Cumulative % of Coho Run	Coho	Cumulative % of Coho Run	Cumulative % of Coho Run
27-Jul	1	0.1%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0.0%
28-Jul	0	0.1%	0	0.0%	0	0.0%	3	0.7%	0	0.0%	0.2%
29-Jul	0	0.1%	0	0.0%	0	0.0%	0	0.7%	0	0.0%	0.2%
30-Jul	0	0.1%	0	0.0%	0	0.0%	0	0.7%	0	0.0%	0.2%
31-Jul	0	0.1%	0	0.0%	0	0.0%	0	0.7%	0	0.0%	0.2%
1-Aug	0	0.1%	0	0.0%	0	0.0%	0	0.7%	0	0.0%	0.2%
2-Aug	0	0.1%	1	0.1%	0	0.0%	0	0.7%	0	0.0%	0.2%
3-Aug	0	0.1%	0	0.1%	0	0.0%	0	0.7%	0	0.0%	0.2%
4-Aug	0	0.1%	0	0.1%	0	0.0%	0	0.7%	0	0.0%	0.2%
5-Aug	0	0.1%	0	0.1%	0	0.0%	0	0.7%	0	0.0%	0.2%
6-Aug	0	0.1%	0	0.1%	0	0.0%	0	0.7%	0	0.0%	0.2%
7-Aug	0	0.1%	0	0.1%	0	0.0%	0	0.7%	1	0.1%	0.2%
8-Aug	0	0.1%	8	0.9%	0	0.0%	0	0.7%	0	0.1%	0.4%
9-Aug	0	0.1%	6	1.5%	0	0.0%	0	0.7%	2	0.4%	0.5%
10-Aug	0	0.1%	8	2.3%	0	0.0%	0	0.7%	2	0.7%	0.7%
11-Aug	0	0.1%	1	2.4%	0	0.0%	0	0.7%	0	0.7%	0.8%
12-Aug	0	0.1%	0	2.4%	0	0.0%	0	0.7%	0	0.7%	0.8%
13-Aug	0	0.1%	15	3.8%	0	0.0%	0	0.7%	2	0.9%	1.1%
14-Aug	0	0.1%	1	3.9%	0	0.0%	0	0.7%	0	0.9%	1.1%
15-Aug	0	0.1%	0	3.9%	1	0.1%	0	0.7%	0	0.9%	1.2%
16-Aug	0	0.1%	0	3.9%	2	0.3%	0	0.7%	0	0.9%	1.2%
17-Aug	0	0.1%	0	3.9%	4	0.6%	0	0.7%	0	0.9%	1.3%
18-Aug	0	0.1%	0	3.9%	6	1.1%	0	0.7%	3	1.4%	1.4%
19-Aug	0	0.1%	0	3.9%	2	1.3%	0	0.7%	5	2.0%	1.6%
20-Aug	0	0.1%	0	3.9%	6	1.9%	0	0.7%	15	4.1%	2.1%
21-Aug	0	0.1%	7	4.6%	4	2.2%	0	0.7%	10	5.4%	2.6%
22-Aug	0	0.1%	9	5.5%	0	2.2%	0	0.7%	3	5.8%	2.9%
23-Aug	0	0.1%	20	7.5%	1	2.3%	0	0.7%	1	6.0%	3.3%
24-Aug	0	0.1%	4	7.9%	1	2.4%	0	0.7%	15	8.0%	3.8%
25-Aug	0	0.1%	0	7.9%	1	2.5%	0	0.7%	24	11.3%	4.5%
26-Aug	0	0.1%	1	8.0%	0	2.5%	0	0.7%	28	15.1%	5.3%
27-Aug	8	0.8%	1	8.1%	0	2.5%	0	0.7%	15	17.1%	5.8%
28-Aug	39	4.5%	28	10.8%	0	2.5%	28	7.2%	2	17.4%	8.5%
29-Aug	7	5.2%	14	12.2%	0	2.5%	15	10.6%	1	17.5%	9.6%
30-Aug	0	5.2%	0	12.2%	0	2.5%	23	16.0%	3	17.9%	10.7%
31-Aug	1	5.3%	0	12.2%	5	2.9%	12	18.8%	12	19.5%	11.7%
1-Sep	1	5.4%	1	12.3%	10	3.8%	7	20.4%	3	19.9%	12.4%
2-Sep	25	7.7%	3	12.6%	11	4.8%	4	21.3%	4	20.5%	13.4%
3-Sep	77	15.0%	2	12.8%	26	7.1%	30	28.2%	4	21.0%	16.8%
4-Sep	7	15.7%	0	12.8%	7	7.7%	57	41.4%	3	21.4%	19.8%
5-Sep	4	16.0%	1	12.9%	1	7.8%	41	50.9%	1	21.6%	21.8%
6-Sep	14	17.4%	0	12.9%	0	7.8%	2	51.4%	5	22.3%	22.3%
7-Sep	4	17.7%	1	13.0%	0	7.8%	6	52.8%	0	22.3%	22.7%
8-Sep	2	17.9%	0	13.0%	62	13.3%	4	53.7%	4	22.8%	24.1%
9-Sep	0	17.9%	4	13.4%	21	15.1%	2	54.2%	2	23.1%	24.7%

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	2001		2002		2003		2004		2005		2001–2005 Average
Date	Coho	Cumulative % of Coho Run	Coho	Cumulative % of Coho Run	Coho	Cumulative % of Coho Run	Coho	Cumulative % of Coho Run	Coho	Cumulative % of Coho Run	Cumulative % of Coho Run
10-Sep	1	18.0%	4	13.8%	0	15.1%	0	54.2%	0	23.1%	24.8%
11-Sep	0	18.0%	2	13.9%	47	19.3%	0	54.2%	0	23.1%	25.7%
12-Sep	2	18.2%	1	14.0%	22	21.2%	1	54.4%	0	23.1%	26.2%
13-Sep	10	19.2%	0	14.0%	2	21.4%	26	60.4%	2	23.3%	27.7%
14-Sep	40	22.9%	1	14.1%	88	29.2%	4	61.3%	0	23.3%	30.2%
15-Sep	35	26.2%	1	14.2%	18	30.7%	47	72.2%	0	23.3%	33.4%
16-Sep	42	30.2%	2	14.4%	1	30.8%	21	77.1%	0	23.3%	35.2%
17-Sep	22	32.3%	3	14.7%	0	30.8%	1	77.3%	23	26.5%	36.3%
18-Sep	28	34.9%	86	23.2%	0	30.8%	2	77.8%	0	26.5%	38.6%
19-Sep	7	35.6%	80	31.0%	1	30.9%	1	78.0%	0	26.5%	40.4%
20-Sep	33	38.7%	6	31.6%	16	32.3%	1	78.2%	24	29.7%	42.1%
21-Sep	6	39.2%	22	33.8%	121	43.0%	0	78.2%	26	33.2%	45.5%
22-Sep	14	40.6%	12	35.0%	20	44.8%	0	78.2%	0	33.2%	46.4%
23-Sep	8	41.3%	0	35.0%	9	45.6%	0	78.2%	1	33.4%	46.7%
24-Sep	5	41.8%	1	35.1%	0	45.6%	0	78.2%	5	34.1%	46.9%
25-Sep	8	42.5%	4	35.5%	78	52.5%	0	78.2%	109	48.8%	51.5%
26-Sep	2	42.7%	0	35.5%	104	61.7%	0	78.2%	22	51.8%	54.0%
27-Sep	9	43.6%	0	35.5%	52	66.3%	0	78.2%	6	52.6%	55.2%
28-Sep	2	43.8%	15	36.9%	61	71.6%	0	78.2%	50	59.4%	58.0%
29-Sep	16	45.3%	0	36.9%	40	75.2%	1	78.5%	17	61.7%	59.5%
30-Sep	78	52.6%	1	37.0%	11	76.1%	3	79.2%	41	67.3%	62.5%
1-Oct	50	57.4%	0	37.0%	5	76.6%	0	79.2%	32	71.6%	64.4%
2-Oct	43	61.4%	0	37.0%	6	77.1%	2	79.6%	25	75.0%	66.0%
3-Oct	20	63.3%	2	37.2%	4	77.5%	0	79.6%	11	76.5%	66.8%
4-Oct	12	64.4%	3	37.5%	4	77.8%	0	79.6%	9	77.7%	67.4%
5-Oct	9	65.3%	19	39.4%	3	78.1%	15	83.1%	22	80.7%	69.3%
6-Oct	14	66.6%	230	62.0%	8	78.8%	19	87.5%	16	82.9%	75.6%
7-Oct	11	67.6%	179	79.6%	20	80.6%	4	88.4%	19	85.5%	80.3%
8-Oct	4	68.0%	23	81.8%	5	81.0%	8	90.3%	7	86.4%	81.5%
9-Oct	57	73.4%	35	85.3%	9	81.8%	0	90.3%	5	87.1%	83.6%
10-Oct	116	84.3%	8	86.1%	1	81.9%	3	91.0%	2	87.4%	86.1%
11-Oct	25	86.7%	16	87.6%	0	81.9%	1	91.2%	7	88.3%	87.1%
12-Oct	25	89.1%	10	88.6%	0	81.9%	14	94.4%	15	90.4%	88.9%
13-Oct	29	91.8%	8	89.4%	0	81.9%	8	96.3%	9	91.6%	90.2%
14-Oct	8	92.5%	1	89.5%	41	85.5%	7	97.9%	10	92.9%	91.7%
15-Oct	2	92.7%	1	89.6%	10	86.4%	0	97.9%	3	93.4%	92.0%
16-Oct	35	96.0%	0	89.6%	1	86.5%	4	98.8%	4	93.9%	93.0%
17-Oct	5	96.5%	36	93.1%	2	86.7%	0	98.8%	5	94.6%	93.9%
18-Oct	20	98.4%	14	94.5%	0	86.7%	0	98.8%	4	95.1%	94.7%
19-Oct	7	99.1%	1	94.6%	10	87.5%	3	99.5%	8	96.2%	95.4%
20-Oct	3	99.3%	27	97.2%	20	89.3%	0	99.5%	2	96.5%	96.4%
21-Oct	1	99.4%	0	97.2%	0	89.3%	0	99.5%	0	96.5%	96.4%
22-Oct	1	99.5%	21	99.3%	3	89.6%	0	99.5%	18	98.9%	97.4%
23-Oct	0	99.5%	5	99.8%	1	89.7%	0	99.5%	6	99.7%	97.7%
24-Oct	0	99.5%	0	99.8%	0	89.7%	0	99.5%	2	100.0%	97.7%
25-Oct	0	99.5%	1	99.9%	71	95.9%	0	99.5%	0	100.0%	99.0%

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	2001		2002		2003		2004		2005		2001–2005 Average
Date	Coho	Cumulative % of Coho Run	Coho	Cumulative % of Coho Run	Coho	Cumulative % of Coho Run	Coho	Cumulative % of Coho Run	Coho	Cumulative % of Coho Run	Cumulative % of Coho Run
26-Oct	0	99.5%	0	99.9%	33	98.9%	0	99.5%	0	100.0%	99.6%
27-Oct	0	99.5%	0	99.9%	7	99.5%	0	99.5%	0	100.0%	99.7%
28-Oct	0	99.5%	0	99.9%	2	99.6%	2	100.0%	0	100.0%	99.8%
29-Oct	2	99.7%	0	99.9%	2	99.8%	0	100.0%	0	100.0%	99.9%
30-Oct	2	99.9%	1	100.0%	1	99.9%	0	100.0%	0	100.0%	100.0%
31-Oct	1	100.0%	0	100.0%	1	100.0%	0	100.0%	0	100.0%	100.0%
Totals	1,060		1,018		1,132		432		737		

Appendix A4.–Computer files used to estimate spawning abundance of sockeye and coho salmon and coho harvest in Salmon Lake 2004–2005.

File Name	Description
2002 Salmon Lake Presmolt AWL.xls	Excel spreadsheets containing presmolt data from Salmon Lake in 2002 including age, weight, and length information
2003 Salmon Lake Presmolt AWL.xls	Excel spreadsheets containing presmolt data from Salmon Lake in 2003 including length information
2004 Salmon Lake Coho Scales.xls	Excel spreadsheet containing coho age, sex and length information from Salmon Lake in 2004
2005 Salmon Lake Coho Scales.xls	Excel spreadsheet containing coho age, sex and length information from Salmon Lake in 2005
2004 Salmon Lake Coho Weir Data.xls	Excel spreadsheet containing Salmon Lake Weir data from 2004; includes recapture event information
2005 Salmon Lake Coho Weir Data.xls	Excel spreadsheet containing Salmon Lake Weir data from 2005; includes recapture event information
2004 Salmon Lake Mark-Recapture-Chapman	Excel spreadsheet estimating escapement abundance in 2004
2005 Salmon Lake Mark-Recapture-Chapman	Excel spreadsheet estimating escapement abundance in 2005
2004 Salmon Lake Harvest Estimate.xls	Excel spreadsheet estimating harvests of Salmon Lake coho in 2004; includes information from recovered salmon lake coho and fishery information in 2004
2005 Salmon Lake Harvest Estimate.xls	Excel spreadsheet estimating harvests of Salmon Lake coho in 2005; includes information from recovered salmon lake coho and fishery information in 2005
2004 Salmon Lake K-S Tests.xls	Excel spreadsheet with Kolmogorov-Smirnov 2-sample tests