Fishery Data Series No. 97-25

Relationship Between Observer Counts and Abundance of Coho Salmon in Steep Creek, Northern Southeast Alaska in 1996

by

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and

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October 1997

Alaska Department of Fish and Game

Division of Sport Fish

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
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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October 1997

This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-12, Job No. S-1-3.

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This document should be cited as:
Jones III, Edgar L. and Scott A. McPherson. 1997. Relationship between observer counts and abundance of coho salmon in Steep Creek, Northern Southeast Alaska in 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-25, Anchorage.

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ABSTRACT

A mark-recapture experiment was used to estimate total escapement of coho salmon *Oncorhynchus kisutch* returning to Steep Creek, a tributary of Mendenhall Lake located in the upper Mendenhall River drainage near Juneau, Alaska during the fall of 1996. Three-hundred and forty-four unique coho salmon were captured in beach seines and dipnets between 30 September and 15 November. All were marked with uniquely numbered anchor tags and given a secondary mark consisting of an opercle punch. Between 6 October and 23 November, 637 fish were inspected for marks, many of which having already been captured, and of these, 342 (50%) had a primary or secondary mark present. The Jolly-Seber model was used to estimate a total escapement of 477 (SE=37) coho salmon. In addition, 5 weekly estimates of abundance were calculated as 201, 170, 176, 230, and 135 coho salmon corresponding to weeks 2-6 (6-12 October through 3-9 November). As part of regular escapement monitoring activities, three foot surveys were conducted between 8 October and 31 October to count the number of coho salmon observed in a single day at Steep Creek. The peak observer count was 134 on 8 October, representing 28% of the estimated total escapement. In addition to these counts, other ADF&G personnel made foot counts and from these, the highest observer count was 151 (29 October), representing 32% of the total escapement. On average, observers underestimated the weekly abundance of fish by a mean relative bias of -50%.

INTRODUCTION

Most of the coho salmon *Oncorhynchus kisutch* harvested by recreational fisheries in the Juneau area are produced by streams on the Juneau road system, along with the Taku River and Gastineau Hatchery stocks. In 1995, anglers in Juneau spent 161,241 days to harvest an estimated 30,396 coho salmon (Howe et al. 1996), and the highest recorded sport catch in Juneau was approximately 60,000 in 1994 (Howe et al. 1995). To aid in the management of these fisheries, indices of observer counts which count a fraction of coho salmon escapement have been made annually since 1980 in five Juneau roadside streams: Jordan, Montana, Peterson, Switzer, and Steep creeks (Figure 1). Because these indices have not been correlated with total escapement (i.e., the total number of fish that successfully reach the stream to spawn over the entire season), managers have been unsure what magnitude of escapement truly occurs in these streams. The current escapement goals (in observer counts) for coho salmon in the five Juneau roadside streams are listed along with the index observer counts in Table 1. In recent years, peak escapement counts for these streams have been relatively high (Figure 2).

Salmon runs are dynamic, as fish continually move into and out of streams, spawn, and die. Thus, observer counts are inherently biased low for the actual total escapement across a season. It is also true that observers usually count only a fraction of the actual abundance present on any given day (Bevan 1961; Cousins et al. 1982; Dangle and Jones 1988; Sharr et al. 1993; Jones 1995). The stream type and the observer's perceptual ability affect observer counts. Furthermore, the visibility of spawning salmon depends on factors such as water clarity, stream morphology, and the ecology, behavior, size, and color of salmon (Bevan 1961; Neilson and Geen 1981; Cousins et al. 1982; Jones 1995).

A mark-recapture experiment was conducted in conjunction with regular foot surveys at Steep Creek in Southeast Alaska to estimate the accuracy and precision of observer counts in a small Southeast Alaska stream, one of the five in the Juneau area where peak observer counts are conducted annually for spawning escapement along the Juneau roadside.

Our objectives in 1996 were:

1) to estimate the total escapement of adult (1-ocean-age) coho salmon spawning in Steep Creek in 1996 such that the estimates are within ±20 percentage points of the true value 95% of the time;
2) to estimate observer counting efficiency by week across the immigration of adult coho salmon in Steep Creek in 1996;

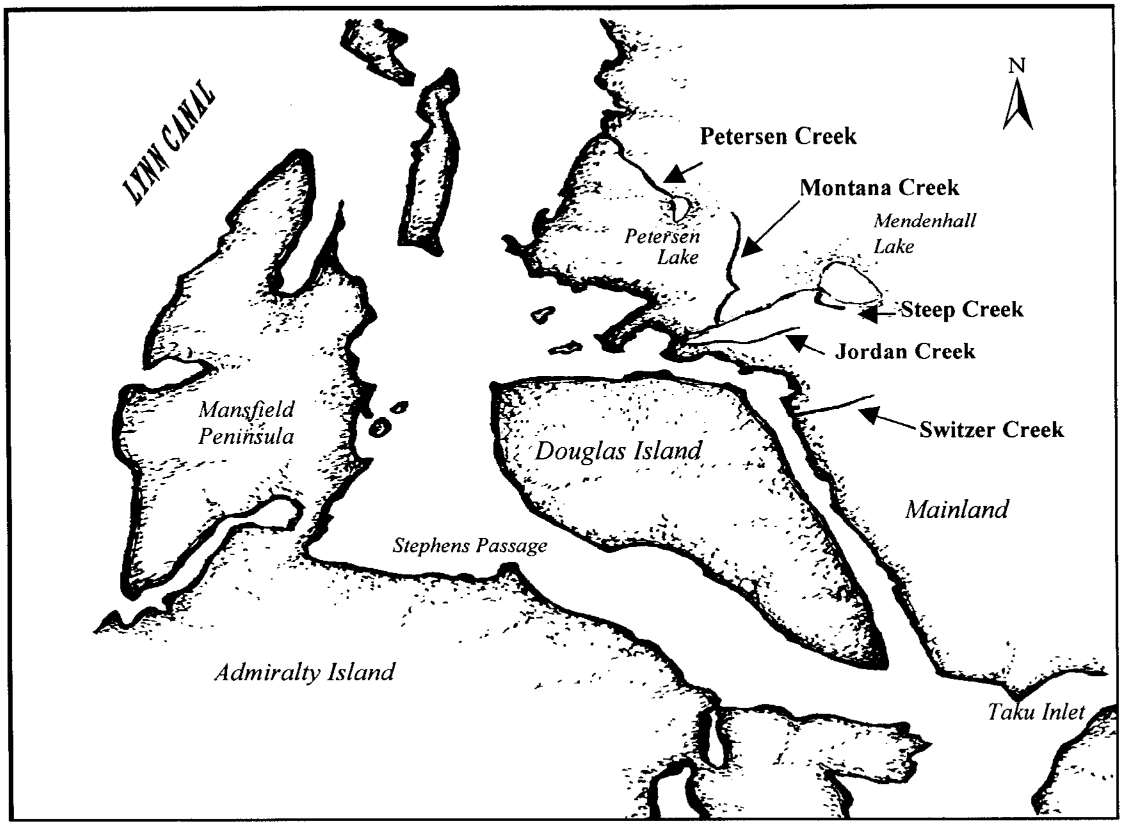

Figure 1.–Location of the five coho salmon producing streams enumerated annually for spawning escapement using foot survey methods along the Juneau roadside.

3) to estimate the highest fraction of total escapement counted on a single day by an observer in 1996; and
4) to estimate age and length composition of adult coho salmon in Steep Creek in 1996 such that each multinomial proportion is within ±5 percentage points of the true value 95% of the time.

METHODS

ESCAPEMENT ESTIMATE

A mark-recapture experiment was used to estimate the total escapement of coho salmon to Steep Creek in 1996. As in a previous study (McPherson et al. 1996), the study area was divided into four locations (Figure 3). A 60-ft-long by 10-ft-deep beach seine was used to capture fish in the two large pools (locations 2 and 4) of Steep Creek. The lowermost portion of the study section was used primarily as a milling site for fish that eventually spawned farther upstream. Large dipnets (about 3 ft by 3 ft), commonly used in everyday sport fishing, were used to capture salmon in the riffle areas (locations 1 and 3) of Steep Creek.

Fish were marked with uniquely numbered Floy T-bar anchor tags at eight regular (weekly) intervals between September 30 and November 15 (Table 2). We made a secondary mark, consisting of any of various combinations of opercle punch (a ¼-in.-diameter hole made with a common paper punch), as a safeguard in the event of primary tag loss.

The eight weekly sampling events occurred between Monday through Friday of each workweek. Sampling effort on each occasion consisted of one

Table 1.–Peak escapement counts and escapement goals for coho salmon in Montana, Jordan, Peterson, Switzer, and Steep creeks 1980–1996.

Year	Jordan Creek	Montana Creek	Peterson Creek	Steep Creek	Switzer Creek	Total
1980	31	-	-	147	7	62
1981	482	227	171	515	109	301
1982	368	545	320	232	80	309
1983	184	636	219	171	80	258
1984	250	581	189	168	123	262
1985	72	810	276	186	122	293
1986	163	60	363	250	54	178
1987	251	314	204	128	48	189
1988	215	164	542	155	51	225
1989	133	566	242	222	78	248
1990	216	1711	324	185	82	504
1991	322	1415	410	267	227	528
1992	785	2512	403	612	93	881
1993	322	1352	112	471	94	470
1994	371	1829	318	200	198	583
1995	77	600	280	409	42	282
Mean	265	888	292	270	93	348
SD	185	714	110	148	56	200
CV	0.70	0.80	0.38	0.55	0.60	0.57
Min	31	60	112	128	7	62
Max	785	2512	542	612	227	881
1996	54	798	263	134	42	258
Escapement goal[a] range (peak count):						
Upper	200	500	350	300	75	
Lower	75	200	100	100	25	

[a] Escapement goals adopted by ADF&G, 9/15/94.

one seine haul at locations 2 and 4 and dip-netting at locations 1 and 3. Each recovery location was sampled as thoroughly as possible with nearly consistent effort throughout the study and effort was made to capture every fish encountered. Locations 1 and 3 were always sampled on the same day. However, pond ice prevented the use of the beach seine at location 4 on November 11–22, and at location 2 on November 18–22.

Each coho salmon captured in the study area was inspected for T-bar anchor tags and secondary marks, measured to the nearest 5 mm from mid-eye to the fork of the tail (MEF), tagged with a uniquely numbered T-bar anchor tag if untagged, given the appropriate secondary mark, sampled for scales, sex, and condition, allowed to recover, and released. Any fish that had lost a tag was retagged. Definitions for the condition of individual fish were:

Alive: (B) *Bright*—a fish that was ocean bright or nearly ocean bright; (SB) *Semi-bright*—some color (primarily blush red), but not completely dark; (D) *Dark*—very dark color (primarily red); (R) *Ragged*—a fish with worn fins or rough texture, but not yet spawned; and (S) *Spawn*—fish spawned out, but not yet dead.

Carcass (spawned or prespawn mortality):

(F) *Fresh*—carcass with clear eyes and firm flesh.

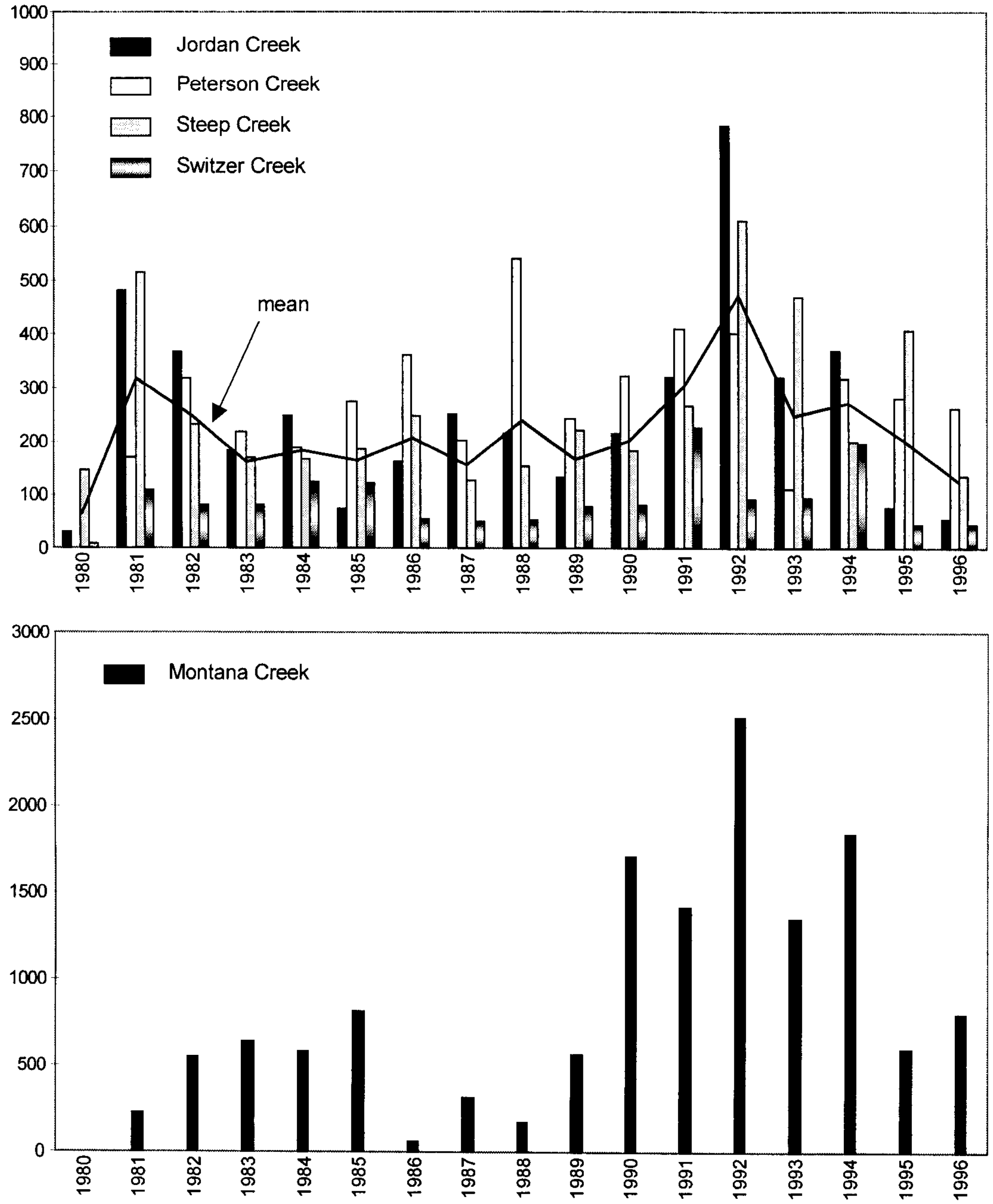

Figure 2.–Peak escapement counts for the five coho salmon producing streams enumerated annually for spawning escapement using foot survey methods along the Juneau roadside.

Definitions were partially adopted from definitions described in Sykes and Botsford (1986).

Calculations of abundance and total escapement were performed using the Jolly-Seber model (Pollock et al. 1990). This model is designed for use with open populations yet has rarely been used for Pacific salmon because it does not provide a direct estimate of escapement (Schwartz et al. 1993). Escapement (*E*) is instead

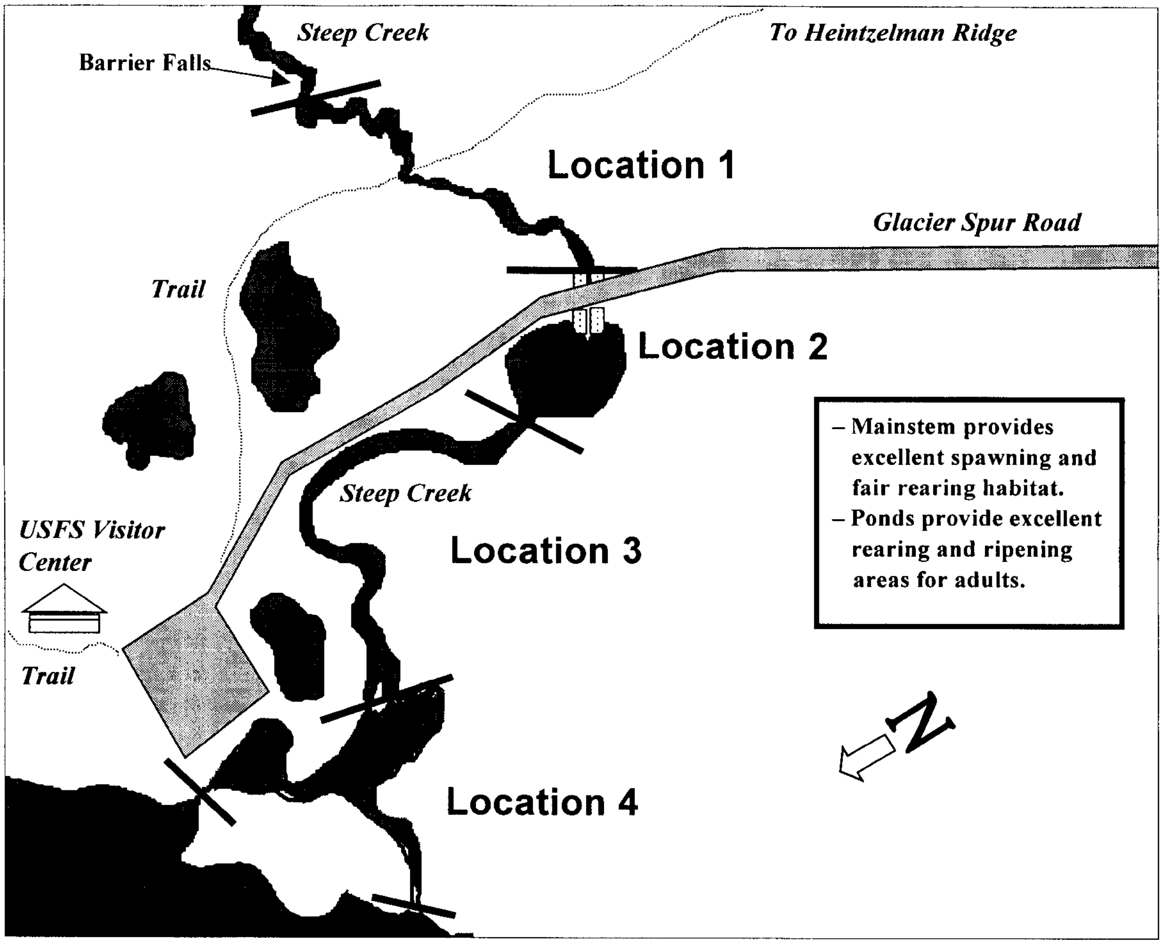

Figure 3.–Steep Creek study area, showing the four study locations and certain key stream characteristics.

the total number of fish immigrating (B) between the first and last sampling occasion, including those fish that enter the system and die between any two sampling occasions, and the number of fish that entered before the first sampling occasion (B_0) and after the last sampling occasion (B_s):

$$\hat{E} = \hat{B}_0 + \ldots + \hat{B}_{s-2} + \hat{B}_{s-1} + \hat{B}_s \quad (1)$$

Sykes and Botsford (1986) estimated the spawning escapement of chinook salmon *O. tshawytscha* by tagging and recovering carcasses using the Jolly-Seber, Manly-Parr, and a modified Jolly-Seber estimator (Pollock 1981). The modified Jolly-Seber estimator ignored recaptures of any carcasses "captured" in a decayed condition. They calculated escapement as the number present during the first sampling event, plus the number of individuals immigrating prior to each subsequent event $i = 2,\ldots,s$:

$$\hat{E} = n_1 + \left(\hat{N}_2 - R_1 * \hat{\phi}_1\right)\left(\frac{1}{\sqrt{\hat{\phi}_1}}\right) + \sum_{i=2}^{s-2} \hat{D}_i + \hat{D}_{s-1} \quad (2)$$

where

n_1 = the number sampled in the first sample event;

R_1 = the number tagged and released during the first sample event;

$\hat{N}_2$ = the estimated population size at sample time two;

$$\hat{D}_i = \frac{\hat{B}_i}{\sqrt{\hat{\phi}_i}}, 2 \leq i \leq s\text{-}2$$

$\hat{\phi}_i$ = the survival rate from i to $i+1$;

$\hat{B}_i$ = the estimated number of fish still present at the sample time $i+1$ which immigrated between i and $i+1$; and

$\hat{D}_{s-1}$ = an estimate of immigration during the last sample period (s-1 to s) made as for D_i, but where B_i and ϕ_i are obtained with survival and capture probabilities estimated using assumptions not provided in the standard Jolly-Seber analysis.

While immigration prior to i = 1 in Sykes and Botsford's estimator was assumed to be the sample size at i = 1. The number immigrating during the second period was taken to be the estimated population at time period 2, minus the estimated number of tagged fish remaining from the first sample which were still alive. Immigration during all subsequent periods except the last were standard Jolly-Seber (immigration/birth) estimates. To account for fish that entered the population and left between sampling periods, and thus were never sampled, each immigration rate was divided by the square root of the survival rate (the survival rate for half the sample period). This adjustment factor assumes that all recruitment takes place at the midpoint between sampling occasions (Sykes and Botsford 1986).

Schwartz et al. (1993) consider the use of six adjustment factors in their study of coho salmon escapement to a small river, and suggest the adjustment factor $\log(\phi_i)/(\phi_i - 1)$ for recruitment that is uniformly distributed between sampling occasions. Although the choice of adjustment factors cannot be verified with the experimental data, differences between factors are small when survival rates are high but should be judiciously selected when this is not true (Schwartz et al. 1993). Sykes and Botsford (1986)

Table 2.–Opercle punches and counting dates used for the mark-recapture experiment, by week (sampling event).

Mark-recapture event (i)	Sampling dates	Secondary mark (opercle punch)	Observers count date
1	9/30–10/4	left, upper	–
2	10/7–11	left, lower	10/7–11
3	10/14–18	right, upper	10/14–18
4	10/21–25	right, lower	10/21–25
5	10/28–11/1	left, upper, upper	10/28–11/1
6	11/4–8	left, lower, lower	11/ 4–8
7	11/11–15	right, upper, upper	11/11–15
8	11/18–22	right, lower, lower	–

(1986) found the three Jolly-Seber and Manly-Parr estimators based on carcass sampling compared very well to weir counts (the known escapement) at the high (≈50%) sampling intensities used in Bogus Creek. They also found declining size and condition of carcasses (i.e., "aged" as fresh, decayed, very decayed) upon capture were associated with declining probability of recapture. The differential catchability/survival did not have a significant (positive) effect (bias) on their survival and population estimates for chinook salmon in Bogus Creek. They found through simulation that as sampling intensity decreases, the modified Jolly-Seber estimator was more robust to age-dependent catchability than were the Jolly-Seber or Manly-Parr estimators. The result was attributed to compensating biases in succeeding immigration estimates due to increasing catchability of marked carcasses relative to population size over time. They also reasoned that the modified Jolly-Seber estimator employed would provide (at relatively higher sampling intensities) robust estimates if differential catchabilities occur for different age-classes (e.g., fresh vs. decayed) of carcasses.

Schwartz et al. (1993) proposed a variation of Sykes and Botsford's (1986) estimator, including closed form asymptotic variance and covariance terms for their recommended (albeit biased low) estimator:

$$\hat{E} = \hat{N}_2\left(\frac{\log\hat{\phi}_1}{\hat{\phi}_1 - 1}\right) + \hat{B}_2\left(\frac{\log\hat{\phi}_2}{\hat{\phi}_2 - 1}\right) + \ldots + \hat{B}_{s-2}\left(\frac{\log\hat{\phi}_{s-2}}{\hat{\phi}_{s-2} - 1}\right) \quad (3)$$

with estimated variance calculated using the delta method (Seber 1982, p.7–9)

$$\hat{V}(\hat{E}(x)) \approx \sum_{i=1}^{s-2} V(x_i)\left(\frac{\delta E}{\delta x_i}\right)^2 + 2\sum_{i<j}\sum \text{cov}(x_i, x_j)\left(\frac{\delta E}{\delta x_i}\right)\left(\frac{\delta E}{\delta x_j}\right) \quad (4)$$

where $\text{cov}(x_i,x_j)$ are derived for the net recruitment estimates in Appendix D of Schwartz et al. (1993).

If the mark-recapture studies are extended until recruitment has virtually ended, Schwartz et al. (1993) suggest B_{s-1} (as in equations 1–2) be set to zero with little effect. Similarly, they note that whereas $N_2 = B_0\phi_1 + B_1$ underestimates $B_0 + B_1$, this bias will be small if immigration is low prior to the first sampling event.

Parameters for the escapement model at Steep Creek were estimated by standard likelihood equations (Arnason et al. 1995; Buckland 1980; Schwartz et al. 1993; Seber 1982) using iterative constrained solutions to force realistic results $\phi \le \phi_i \le 1$, $B_i \ge 0$ if needed, as recommended by Schwartz et al. (1993) and Buckland (1980). Multiple recaptures in a week (a single sampling event) were ignored. Dead fish were removed as losses-on-capture to further satisfy the equal catchability and survival assumptions. Since sample sizes were relatively large ($\bar{p} \ge 0.2$; m_i, $r_i > 3$) and the unconstrained estimates were "reasonable," the variance in equation 4, $v(\hat{E})$, was computed using the delta method (Seber 1982) and the asymptotic variance and covariances in Schwartz et al. (1993).

The Jolly-Seber model (Seber 1982) and the program RECAP (Buckland 1980) were used to estimate parameters $\{M_i, N_i, p_i, \phi_i, B_i\}$. The conditions for accurate use of this methodology are shown in Seber (1982, p. 196) and are as follows:

1. every fish has the same probability of being captured in the i^{th} sampling event;
2. every marked fish has the same probability of survival from the i^{th} to the $(i+1)^{th}$ sampling event;
3. every fish captured in the i^{th} sample has the same probability of being returned alive to the population;
4. marks are not lost and all marks are recognized upon capture; and all samples are instantaneous (i.e., sampling time is negligible).

Three contingency table chi-square tests developed by Pollock et al. (1985) to evaluate the goodness-of-fit of the Jolly-Seber model were implemented using the program JOLLY (Pollock et al. 1990). Test 1 is the first portion of the Pollock et al. (1985) two-component test equivalent to the Robson (1969) test for short-term mortality related to the tagging procedure, and helps detect lowered survival rates due to the attachment of tags or the trapping and handling process (Arnason and Mills 1987). Test 2 detects whether heterogeneity exists in survival and capture probabilities, and test 3 is simply a summation of the X^2 values from tests 1 and 2 that forms an omnibus test of assumptions 1–2 of the Jolly-Seber model (Seber 1982, p. 196).

OBSERVER COUNTS

Foot counts of adult (1-ocean age) coho salmon abundance in Steep Creek were made during the same week as the weekly mark-recapture sampling events $i = 2,\ldots,7$. To an extent, observers were trained prior to counting by being told where, when, and what to count. In addition, observers were told to wear polarized lenses, to differentiate between live and dead fish, to make multiple counts on the same day, and to record counts by location (i.e., location

1–4). The major uncontrolled variables in the experiment were individual methods/abilities, weather condition, etc. The treatment variable, the focus of this study, was the observer. Several trained observers from within the Department of Fish and Game participated in the study. These included personnel from both the Divisions of Sport Fish and Commercial Fisheries Management and Development.

Percent relative bias, a measure of the relative accuracy of the foot observer t's mean count on event i, was calculated as

$$RB_{it} = \left(\frac{\overline{X}_{it} - \hat{N}_t}{\hat{N}_t}\right) = \left(\frac{\overline{X}_{it}}{\hat{N}_t} - 1\right) \qquad (5)$$

with estimated variance calculated using the delta method (Seber 1982, p.7-9)

$$\hat{V}(RB_{it}) = \left(\frac{\overline{X}_{it}}{\hat{N}_t}\right)^2 \left(\frac{\hat{\sigma}^2_{\overline{X}_{it}}}{\overline{X}^2_{it}} + \frac{\hat{\sigma}^2_{\hat{N}_t}}{\hat{N}_t^{\,2}}\right) \qquad (6)$$

where $\overline{X}_{it}$ is the mean count of observer t's counts on event i (i.e., when multiple counts are made) and $\hat{N}_i$ is the estimated population size on event i as determined from the mark-recapture experiment. These equations were also used to calculate the relationship between the peak observer count and the estimated total escapement across the season.

To define the relationships between the observer count and estimates of abundance, the allometric model with multiplicative error structure

$$X_i = \alpha N_i^{\beta} e^{\varepsilon_i} \qquad (7)$$

was used, where ε_i is a random error term with a mean of 0 and constant variance σ^2, X_i is the observer count, and N_i is the estimated population size. We assumed lognormal distribution to model variation as a function of population abundance. Estimation was performed by taking logarithms and using simple linear regression.

AGE, SEX, AND SIZE

Of the 344 unique fish sampled during the 1996 Steep Creek study, all were sampled for sex, 311 (91%) were sampled for length, and 160 (47%) were sampled for scales. Five scales were removed from the preferred area on the left side of the fish (Scarnecchia 1979). Three scales were taken from 2 or 3 rows above the lateral line (1″ apart), and two scales were taken from 4 or 5 rows above the lateral line (1″ apart). All scales were mounted on gum cards as described in ADF&G (1993). Prior to taking a scale sample, each fish was wiped with the blunt side of the knife to remove excess mucus. Lengths were measured from mid-eye to the fork of the tail (MEF) to ±5 mm, and sex was estimated from secondary maturation characteristics. Proportions by age or by sex in samples were estimated by

$$\hat{p}_i = \frac{n_i}{n} \qquad (8)$$

$$V(\hat{p}_i) = \left(1 - \frac{n}{\hat{E}}\right)\left(\frac{\hat{p}_i(1-\hat{p}_i)}{n-1}\right)$$

where $\hat{p}_i$ is the estimated proportion in age group I, n_i is the number in age group I, n is the number successfully aged, and $\hat{E}$ is the estimated total escapement.

RESULTS

ESCAPEMENT ESTIMATE

Three hundred forty-two (342) healthy coho salmon were captured, marked, and then released throughout the study section between 30 September and 15 November in seven weekly marking events (Table 3).

Of the 686 fish captured during the experiment, 3 previously tagged and 2 untagged fish were dead when captured. Details of the marking and recovery by location are shown in Table 4.

In total, 54% of the fish inspected for marks during weeks 2–7 had at least a secondary mark present. Nineteen percent of the sample were captured at location 1, 30% at location 2, 9% at location 3, and 42% at location 4.

Table 3.–Summarized mark-recapture data for Steep Creek coho salmon, 1996. Notation follows that in Seber (1982).

Week	Number captured n_i	Number marked caught in n_i m_i	Losses on capture[a]	Released after marking R_i	Subsequently recaptured r_i	Seen before i and after i, not at i z_i
1	49	0	0	49	32	14
2	95	18	0	95	66	8
3	147	72	0	147	109	37
4	89	80	2 (1)	87	31	14
5	142	54	3(2)	139	58	18
6	84	54	0	84	46	0
7	80	64	0	80	0	0
Total	686	342	5(3)	681	342	91

[a] Number in parentheses indicates number of marked fish lost on capture.

The probability of capturing a marked fish in a riffle versus a pool was significantly different (X^2 = 6.75, df = 1, P <0.01). This may be a result of the tendency of fish to mill downstream in pools for prolonged periods of time before actually moving upstream to spawn. Thus, a fish would have a greater chance of actually being marked once it finally moved into the spawning area (i.e., locations 1 and 3). The results of the various chi-squared tests performed are shown below:

Test	m_i/n_i	Unmarked n_i-m_i	Marked m_i	X^2 value	P
Loc. 1 vs.	62%	49	80	***13.03***	***< 0.01***
loc. 2	42%	120	86		significant
Loc. 3 vs.	49%	32	31	0.03	0.87
loc. 4	50%	143	145		NS
Locs. 1&2	50%	169	166	0.02	0.88
vs. 3&4	50%	175	176		NS
Loc. 1 vs.	62%	49	80	2.85	0.09
loc. 3	49%	32	31		NS
Loc. 2 vs.	42%	120	86	3.57	0.06
loc. 4	50%	143	145		NS
Locs. 1&3	58%	81	111	***6.75***	***< 0.01***
vs. 2&4	47%	263	231		significant

The contingency table chi-square test results developed by Pollock et al. (1985) to evaluate the goodness-of-fit of the Jolly-Seber model are as follows:

Test	Week (i)	X^2 value	df	P	Comment
1	2	**9.80**	1	**< 0.01**	significant
1	3	0.08	1	0.37	NS
1	4	0.43	1	0.51	NS
1	5	**9.56**	1	**< 0.01**	significant
1	6	0.07	1	0.79	NS
3	Sum =	**20.67**	5	**< 0.01**	significant
2	2	0.00	0	1.00	NS
2	3	0.87	1	0.35	NS
2	4	0.20	2	0.91	NS
2	5	0.00	1	1.00	NS
2	6	3.37	2	0.19	NS
3	Sum =	4.43	6	0.62	NS

The results of test 1 were significant for weeks 2 (X^2 = 9.80, df = 1, P <0.01) and 5 (X^2 = 9.56, df = 1, P <0.01) indicating that the survival of fish was affected by the tagging or handling process in these weeks. In both cases, a large influx of new fish had just arrived at Steep Creek and this likely explains the significance of the tests for these weeks. Regarding test 2, in no case was the result significant; therefore, significant differences in the survival and capture probabilities did not exist. For test 3, the results were significant (X^2 = 20.67, df = 5, P <0.01) for the summation of test 1 and not significant (X^2 = 4.43, df = 6, P = 0.62) for the summation of test 2. This suggests that violations of assumptions 1–2 of the Jolly-Seber model (Seber 1982, p. 196) occurred, and not every fish had the

Table 4.–Marking and recovery data from the Steep Creek coho salmon mark-recapture study, 1996, by area and period.

Date of sampling event	Area	Number captured (n_i)	Number caught in n_i (m_i)	Number unmarked caught in n_i *	m_i/n_i
Sept. 30-Oct. 5	Location 1	4	0	4	0.00
Mark period #1	Location 2	26	0	26	0.00
	Location 3	1	0	1	0.00
	Location 4	18	0	18	0.00
	TOTAL	49	0	49	0.00
	Cumulative	49	0	49	0.00
Oct. 6-Oct. 12	Location 1	16	7	9	0.44
Mark period #2	Location 2	27	5	22	0.19
Recovery period #1	Location 3	7	0	7	0.00
	Location 4	45	6	39	0.13
	TOTAL	95	18	77	0.19
	Cumulative	144	18	126	0.13
Oct. 13-Oct. 19	Location 1	6	3	3	0.50
Mark period #3	Location 2	33	12	21	0.36
Recovery period #2	Location 3	0	0	0	-
	Location 4	108	57	51	0.53
	TOTAL	147	72	75	0.49
	Cumulative	291	90	201	0.31
Oct. 20-Oct. 26	Location 1	8	7	1	0.88
Mark period #4	Location 2	26	23	3	0.88
Recovery period #3	Location 3	8	4	4	0.50
	Location 4	47	46	1	0.98
	TOTAL	89	80	9	0.90
	Cumulative	380	170	210	0.45
Oct. 27-Nov. 2	Location 1	38	21	17	0.55
Mark period #5	Location 2	39	8	31	0.21
Recovery period #4	Location 3	27	9	18	0.33
	Location 4	38	16	22	0.42
	TOTAL	142	54	88	0.38
	Cumulative	522	224	298	0.43
Nov. 3-Nov. 9	Location 1	6	4	2	0.67
Mark period #6	Location 2	46	30	16	0.65
Recovery period #5	Location 3	0	0	0	-
	Location 4	32	20	12	0.63
	TOTAL	84	54	30	0.64
	Cumulative	606	278	328	0.46
Nov. 10-Nov. 15	Location 1	51	38	13	0.75
Mark period #7	Location 2	9	8	1	0.89
Recovery period #6	Location 3	20	18	2	0.90
	Location 4	0	0	0	-
	TOTAL	80	64	16	0.80
	Cumulative	686	342	344	0.50
Totals by location	Location 1	129	80	49	0.62
	Location 2	206	86	120	0.42
	Location 3	63	31	32	0.49
	Location 4	288	145	143	0.50
	TOTAL	686	342	344	0.50

* Without regard for deaths on capture (Table 3).

the same probability of being captured in the i^{th} sampling event and not every marked fish had the same probability of survival from the i^{th} to the $(i+1)^{th}$ sampling event. The mark-recapture data sorted by individual tag number are summarized in Appendix A1.

The estimates of abundance, growth, survival, and standard errors obtained from the program RECAP (Buckland 1980) and the estimates of escapement and standard errors obtained from equations 3 and 4 are shown below:

	Abundance		Growth		Survival		Adjust-ment	Escape-ment
Wk	N	SE	B	SE	ϕ_i	SE	$(\log\phi_i)/(\phi_i-1)$	E
1	-	-	-	-	0.779	0.089	1.130	227
2	201	30	24	20	0.723	0.052	1.171	28
3	170	13	6	6	1.000	0.014	1.000	6
4	176	13	138	22	0.530	0.063	1.351	186
5	230	28	21	13	0.503	0.055	1.382	29
6	135	15	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-
							Total escapement =	477
							SE =	37

OBSERVER COUNTS

Observer counts and summary statistics for the various analyses performed are contained in Table 5.

In 1996, ten observers made foot counts starting in week 2 (Oct. 6–12) and ending in week 7 (Nov. 10–16). Not every observer made a count each week, and a total of 28 distinct counts were made over the 6 week period. Multiple counts were made on 11 of 18 (39%) separate counting occasions.

Seven observers made more than one count during the study and in a comparison of their counts to the weekly abundance estimates, relative bias ranged from -36% (SE = 8%, $\hat{N} = 230$) to -82% (SE = 2%, $\hat{N} = 176$). In general, relative bias was high, and observers underestimated the actual weekly abundance on average -58% (SE = 12%):

	WEEK				
Observer	**2**	**3**	**4**	**5**	**6**
A				-79%	
B				-50%	
C	-33%	-60%		-60%	
D			-79%	-36%	
E			-53%		
F			-80%		
G			-81%		-60%
H			-81%		-77%
I			-71%	-57%	
J			-82%		-57%
Abundance	201	170	176	230	135
Mean	-33%	-60%	-75%	-56%	-64%
SD	–	–	10%	15%	11%
CV	–	–	-14%	-28%	-17%

The mean weekly counts for each observer compared to the weekly abundance estimates are shown in Figure 4. Included in the figure is a dark line depicting no bias (i.e., $\beta = 1$) and a dotted line, which is the allometric fit from equation 3.

The allometric relationship provides a convenient summary of the trend in observer bias. When $\beta > 1$, the fit is concave upwards and concave downwards when $\beta < 1$. At values of $\beta = 0$, the fit has a zero slope and the y-intercept can be found by exponentiating the parameter $\ln \alpha$. Results from a previous study performed by Jones (1995) suggest that the intercept $\ln \alpha$ is a parameter directly related to the size and acuity characteristics of the objects being counted. Thus, as the size of objects differs, the intercepts using the allometric fit should differ.

The parameter estimates for the allometric fit in Figure 4 are -4.42 (SE = 2.42) for $\ln \alpha$ and 1.63 (SE = 0.47) for β. In this case, β is marginally, but not statistically, different from 1 ($t_{25} = 1.37$, P = 0.09), and observer bias is not a nonlinear function of population abundance.

For those observers who performed more than one count during the study, a comparison of the peak observer count to the actual escapement provided high values of relative bias ranging from -68% (SE = 7%) to -91% (SE = 1%), and observers underestimated the actual escapement on average -82% (SE = 9%). The peak observer

Table 5.–Observer foot counts of Steep Creek coho salmon, 1996.

	WEEK																	
	2		3		4		5		6		7							
Observer	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down	Peak	SD	CV	SE	RB	SE
A							51	47					51	3	0.06	1	-89%	1%
B								116					116	-	-	-	-76%	-
C		134		68				93					134	33	0.25	17	-72%	4%
D					39	34	151	142					151	64	0.42	32	-68%	7%
E						82							82	-	-	-	-83%	-
F					36								36	-	-	-	-92%	-
G					37	31				54			54	12	0.22	6	-89%	1%
H					38	29			34	29	43	37	43	5	0.13	3	-91%	1%
I					54	49	96	104					104	28	0.27	14	-78%	3%
J					33	29			58	59			59	16	0.27	8	-88%	2%
Abundance	201	201	170	170	176	176	230	230	135	135	-	-						
Sum	-	134	-	68	237	254	298	502	92	142	43	37	830					
Mean	-	134	-	68	40	42	99	100	46	47	43	37	83				-83%	9%
SD	-	-	-	-	7	21	50	35	17	16	-	-		41				
CV	-	-	-	-	0.19	0.49	0.50	0.35	0.37	0.34	-	-			0.49			

RB = relative bias.

counts compared to the actual escapement estimate are shown in Figure 5. Included in the figure are the maximum and minimum counts for each observer (provided that multiple counts were performed) and the upper and lower 95% confidence intervals for the escapement estimate.

AGE, SEX, AND SIZE

One hundred sixty (160) fish were sampled for scales, sex, and length (one of these did not have a length taken), and of these, 148 were aged, equating to an aged fraction of 93%. In general, the majority of the coho salmon sampled were age 1.1 fish, and very little difference occurred between sexes. In all cases, the mean length at age was smallest for age 1.1 fish versus age 2.1 fish. Interestingly, the mean length at age for age 1.1 females was 38 mm larger than age 1.1 males. This difference decreased considerably for age 2.1 fish, as shown in the following data (where n_a is the number sampled for age successfully and n_l is the number sampled for length):

	Brood year			
	1993		1992	
Females	1.1	2.0	2.1	Total
n_a	34	0	14	48
%	70	0	30	100
SE	7.3%	0.0%	7.3%	
n_l	77	0	33	110
Length	612	–	633	618
SD	71.6	–	62.6	77.0
SE	12.5	–	17.4	11.2
	Brood year			
	1993		1992	
Males	1.1	2.0	2.1	Total
n_a	74	2	24	100
%	74	2	24	100
SE	4.4%	1.4%	4.3%	
n_l	173	5	56	234
Length	574	281	621	579
SD	90.4	–	70.6	140.4
SE	10.6	–	14.7	14.1
	Brood year			
	1993		1992	
Both	1.1	2.0	2.1	Total
n_a	108	2	38	148
%	73	1	26	100
SE	3.7%	1.0%	3.7%	
n_l	250	5	89	344
Length	586	281	626	590
SD	97.7	–	67.4	127.7
SE	9.4	–	11.1	10.5

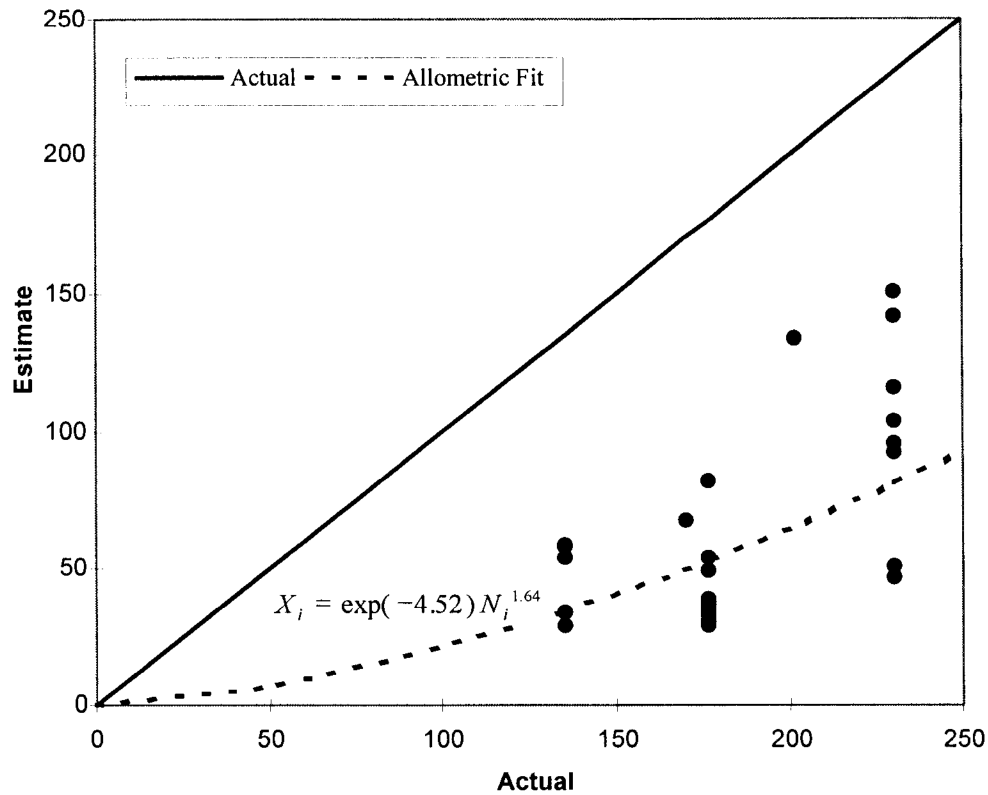

Figure 4.–Mean weekly observer foot counts compared to weekly abundance estimates of coho salmon in Steep Creek, 1996.

Sex compositions gathered were 44% (SE = 6%) females in locations 1 and 3 (i.e., primarily riffles) and 28% (SE = 4%) females in locations 2 and 4 (i.e., primarily pools). The age-length composition was further broken down by location, and in a comparison of locations 1 and 3 versus locations 2 and 4 (riffles vs. pools) no obvious differences were seen. Similarly, a comparison was made of the sex composition of the aged sample versus the total sample, and no differences were seen:

Percent by sex of total sampled:			
Sex	Total (SE)	1&3 (SE)	2&4 (SE)
female	32 (4)	44 (6)	28 (4)
male	68 (2)	56 (5)	72 (2)
Percent by sex of aged sample:			
Sex	Total (SE)	1&3 (SE)	2&4 (SE)
female	32 (6)	43 (10)	29 (7)
male	68 (3)	57 (7)	71 (3)

DISCUSSION

In general, the results of this study suggest that observers tend to underestimate actual abundance and escapement of coho salmon in the stream on the day and for the season. Further studies to identify observer-specific counting rates are necessary for unbiased, more realistic estimates of salmon escapement. Biased escapement estimates produce biased estimates of optimum harvest rate and escapement in stock-recruitment analyses (Walters 1981; Walters and Ludwig 1981).

During this study, we attempted to keep extraneous factors constant by having observers count in similar fashion; however, differences in the accuracy of their counts occurred, and the numbers of salmon alone may not be the only reasons for these differences. Eicher (1953), in

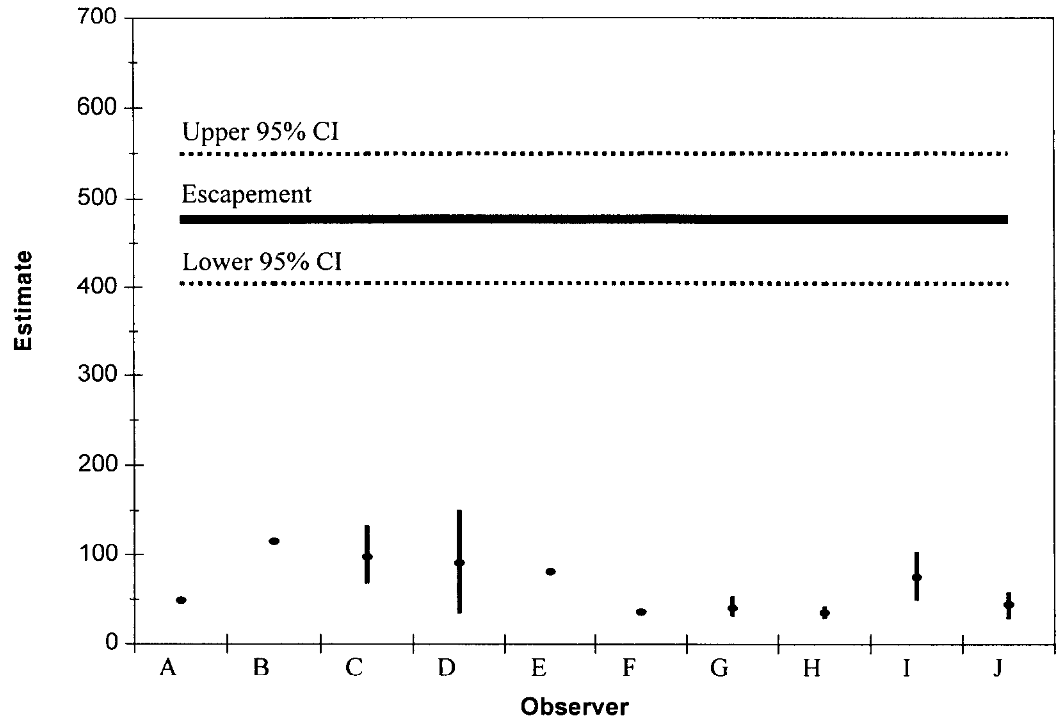

Figure 5.–The actual escapement estimate of 477 (SE = 37) coho salmon in the study section of Steep Creek compared to the mean of foot counts performed by observer 8 October through 13 November 1996. Bars represent high and low counts.

work performed in Bristol Bay, Alaska, suggested that the density of fish may be the underlying factor affecting the accuracy of an observer's count. Unlike other studies (Jones 1995), our results do not necessarily indicate that the observer accuracy decreases nonlinearly with an increase in the number of salmon. A likely explanation is that the density of coho salmon is low in Steep Creek, a small shallow stream system. Perhaps at higher abundances (i.e., increased densities), the nonlinear relationship between observer accuracy and abundance may become significant.

Studies have shown prior knowledge of the stream to be advantageous as far as observer accuracy goes (ADF&G 1964). Our results agree with this theory, as the one observer most familiar with the study section had the second highest peak observer count seen resulting in an accuracy of 28% (SE = 4%) for the season.

In the 1994 Steep Creek study, 21% of the total escapement was counted during a single peak observer count. In comparison, the most accurate observer in the 1996 Steep Creek study estimated 32% (SE = 7%) of the total escapement in a single peak count, and on average, observer peak counts were 17% (SE = 9%) of the total escapement. Observers greatly underestimated the actual abundance of fish during any given week counting on average 42% (SE = 15%) of the actual weekly abundance.

During the study, we found that only three fish (<1%) out of the 342 fish recaptured with a secondary mark, had lost their primary mark (T-bar anchor tag). Marking did not appear to affect the behavior or movement of fish and, from the observer's point of view, marked and unmarked fish seemed indifferent. Marked and unmarked fish were seen spawning together throughout the duration of the study.

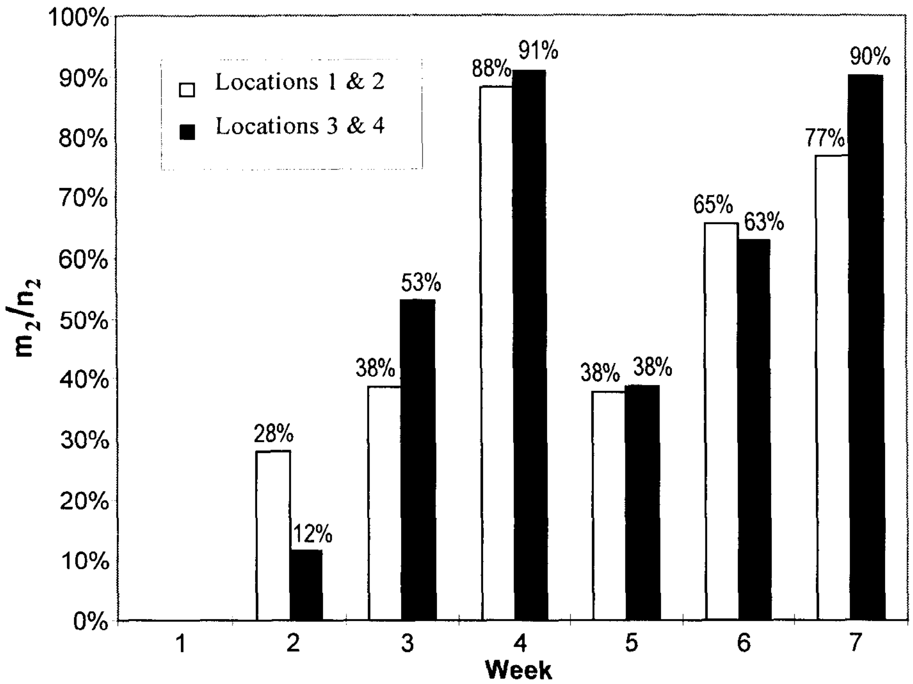

Figure 6.–Ratio of m_i/n_i by location (1 and 2 vs. 3 and 4) over seven weekly mark-recapture occasions in Steep Creek, 1996.

The ratio of m_i/n_i in the two upper locations (50%) was identical to that seen in the lower two locations for the entire study, and this ratio increased as the season progressed throughout the study section (Figure 6). The number of unique fish sampled appeared bimodal in both the lower and upper locations (Figure 7). This suggests that two separate influxes of fish occurred in Steep Creek in 1996. Similar trends exist when the data are analyzed by sex (Figures 8 and 9).

The fractions of marked fish (m_i/n_i) at the upstream locations (locations 1 and 2) were 0.62 and 0.42, respectively, values which were significantly different (X^2 = 13.03, df = 1, P <0.01). The fractions of marked fish at downstream locations (locations 3 and 4) were 0.49 and 0.50, respectively, which were not significantly different (X^2 = 0.03, df = 1, P = 0.87). However, when data from the upstream locations were combined and compared to the combined data from downstream locations, fractions were not significantly different (X^2 = 0.02, df = 1, P = 0.88). These findings suggest that the probability of finding a marked fish versus an unmarked fish in location 1 was much higher than in the lower locations. A likely explanation for this is that location 1 is the farthest upstream location, and thus, fish had to run the gauntlet of sampling effort to reach this area.

The age composition summary revealed an increased proportion of males to females in pools (locations 2 and 4) versus riffles (locations 1 and 3). This may suggest that females tend to remain in the spawning areas after spawning (i.e., die on redds) while males have the behavior of swimming downstream out of the spawning areas, a phenomenon also observed for chinook salmon *O. tshawytscha* (Kissner 1985). These results are not unlike those found in the 1994

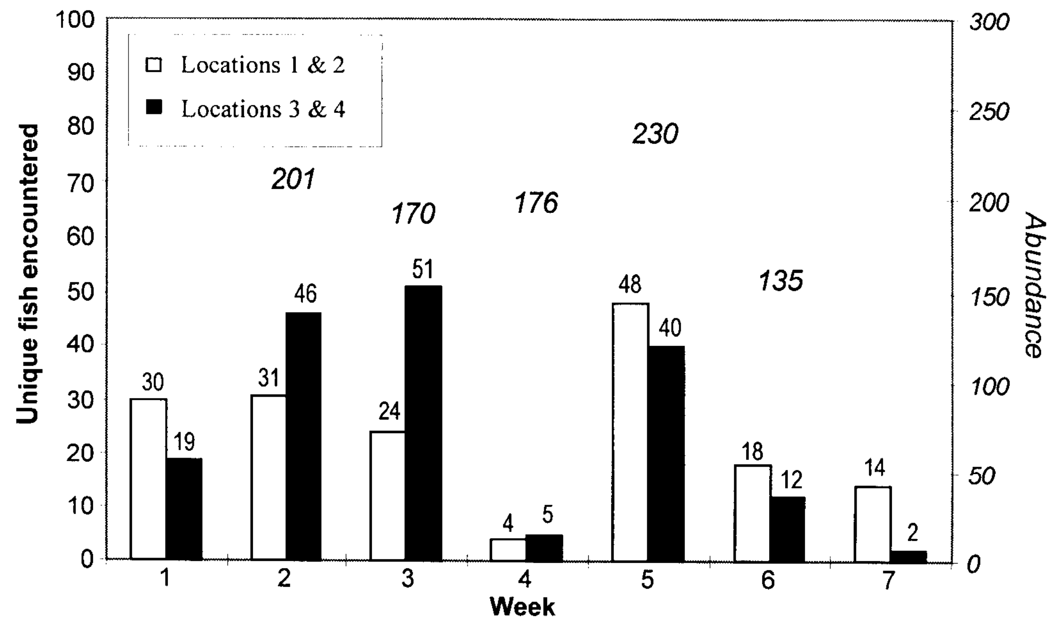

Figure 7.–Number of unique coho salmon encountered in locations 1 and 2 versus locations 3 and 4 over seven weekly mark-recapture occasions in Steep Creek, 1996. The italicized number is the weekly mark-recapture abundance estimate.

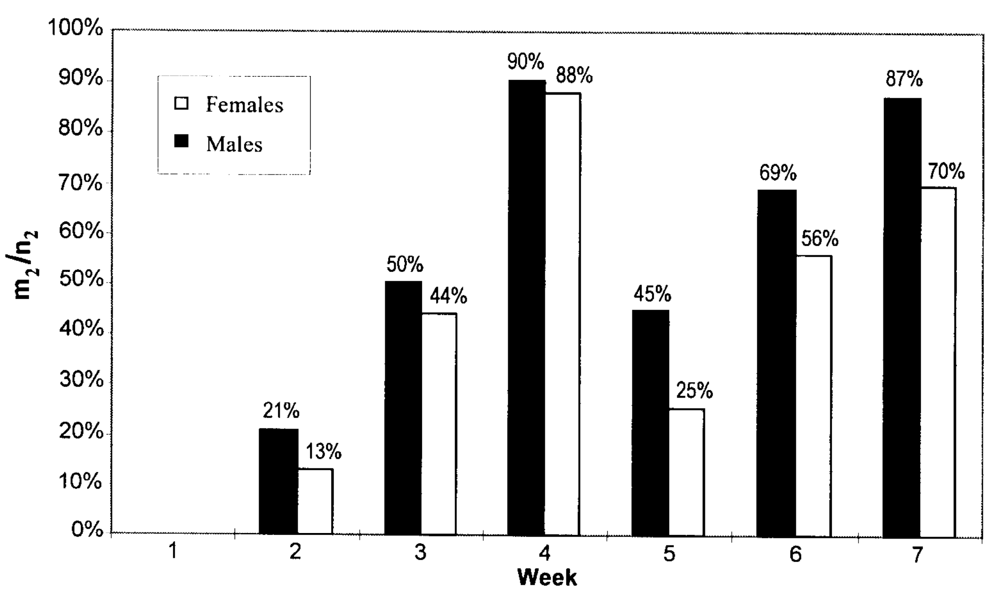

Figure 8.–Ratio of m_i/n_i by sex over seven weekly mark-recapture occasions in Steep Creek, 1996.

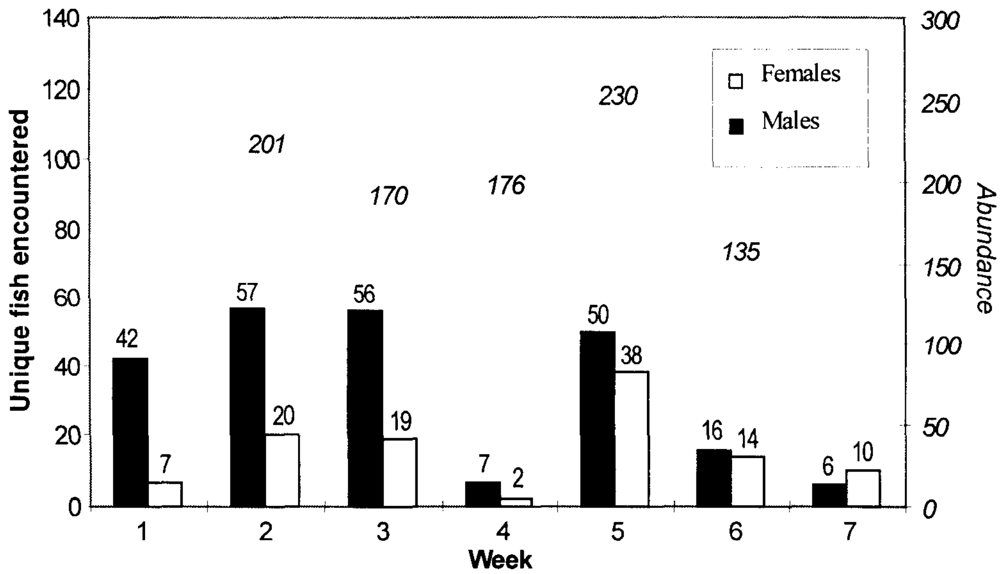

Figure 9.–Number of unique coho salmon encountered by sex over seven weekly mark-recapture occasions in Steep Creek, 1996. Italicized numbers are weekly mark-recapture abundance estimates.

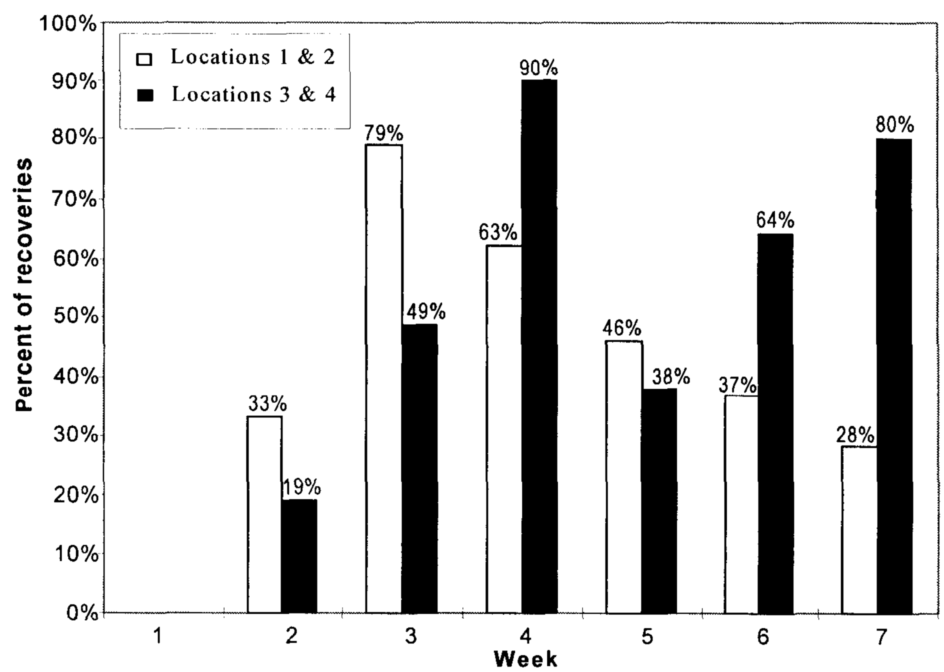

Figure 10.–Percent of recoveries by location (1 and 2 versus 3 and 4) over seven weekly mark-recapture occasions in Steep Creek, 1996.

Steep Creek study, where the sex composition was primarily females (71%) in the riffles and males (78%) in the pools.

The number of tag recoveries in the upper locations decreased after week 3, whereas the number steadily increased after week 5 in the lower locations (Figure 10). This is understandable, considering that water levels dropped later in the season which likely limited the available habitat in the upper locations and thus promoted spawning and milling in the lower locations.

During the week prior to the start of the study (29 September through 5 October), only three salmon (2 coho and 1 sockeye) were counted in the study section in several preliminary surveys. No carcasses were found in the study section until week 4 (20–26 October), and in general, all bright fish sampled were considered in excellent condition. Of a minimum total of 289 trout captured incidentally during the study, 97% were Dolly Varden *Salvelinus malma* and the rest were coastal cutthroat trout *O. clarki*.

Emigration from the study section was considered negligible, and significant recruitment into the study section didn't take place until after the study began. Although the study extended well after the pool locations had frozen over, it is our belief that some persistent coho salmon still managed to evade our sampling efforts by entering Steep Creek after the last sampling date (23 November). Nevertheless, their numbers were undoubtedly small and we can safely say we sampled the vast majority of the run of coho salmon to Steep Creek in 1996.

In 1994, 952 (SE = 68) coho salmon were estimated to have entered Steep Creek. The peak observer count that year was 200 fish, or 21% of the total escapement. The same observer made a peak count of 134 coho salmon in 1996. Assuming a similar counting efficiency as in 1994, a simple expansion of the peak observer count to the total escapement can be made resulting in an estimate of 638 coho salmon: $\left(134/0.21\right)$. Even though this estimate is larger than the estimated 1996 escapement of 477 (SE = 37) coho salmon, it is reassuring that the escapement estimates and observer counts show similar trends. Interestingly, the observer efficiencies of 21% in 1994 and 28% in 1996 support the theory that an increase in the density of fish leads to a decrease in observer efficiency.

In the method used to estimate the total escapement of 477 (SE = 37) coho salmon, 344 unique fish were handled, or 72% of the estimate. The 95% relative precision of the estimate (± 13%) was far better than the 20% level targeted in the operational plan using the methods described by Robson and Regier (1964). This year the study progressed smoothly and without incident.

Steep Creek is a small clearwater stream, and the relationships we have found in the 1994 and 1996 studies may or may not be representative of similar stream types in Southeast Alaska. The visibility of salmon depends on many physical factors (Bevan 1961; Neilson and Geen 1981; Jones 1995). These factors, in various combination, serve to create the many stream types found in Southeast Alaska. Salmon are not a static population, because they continually move into streams and die throughout the season (Sheridan 1962). Thus, observations on a single day will give at best an index, an unknown portion, of the total escapement of salmon (Bevan 1961). In practice, the peak count during a given season has been used as this index of total escapement. This study has shown that peak observer counts greatly underestimate the actual escapement, and at best, this study has gathered a minimum of information necessary to calculate total escapement based on peak observer counts. Future studies should explore the relationship between the observer count and the actual abundance and escapement on multiple stream types.

Southeast Alaska contains more than 2,000 salmon producing streams. Annually, up to 66 of these streams are surveyed by observers for coho escapement. Ideally, when making a choice as to where to perform such studies, importance should be placed on those stream types that lack sufficient survey information and the actual stream/river systems which produce the majority of coho salmon used for sport fishing purposes. Such studies improve fisheries management, which directly relates to larger run sizes (long-term average) and ultimately increased sport fishing opportunities.

RECOMMENDATIONS

For future studies involving mark-recapture estimates of coho salmon escapement, we offer the following recommendations:

1. Investigate the stream or river one (preferably) or two years prior, and determine whether to conduct the study as a multiple mark-recapture experiment for an open population as done in Steep Creek in 1996 or as a two-event single or multiple stratified Petersen estimate.
2. Begin marking early to ensure that the earliest arriving fish are sampled and not missed.
3. If the open-population estimator is used and conditions permit, marking should take place throughout the entire study area.
4. Distinct primary marks should be used, with the addition of secondary marks unique for time and possibly location.
5. AWL data should be collected at all times.
6. Recovery efforts should be made on at least a weekly basis.

ACKNOWLEDGMENTS

The authors thank Bob Marshall for his helpful insight for the planning and implementation of this project, for biometric assistance in the analysis, and for review of the manuscript. Special recognition goes to the members of the field crews who conducted the mark-recapture experiments: namely Dale Brandenburger, Brian Glynn, Richard Yanusz, Sue Millard, Dean Beers, Kurt Kondzela, and Tim Schantz. We thank Sue Millard for her help in aging the scale samples. We appreciate the participation of the foot observers: Dean Beers, Steve Elliot, Brian Glynn, Rodger Harding, Rocky Holmes, Kurt Kondzela, Doug Jones, Andy McGregor, Joe Muir, Keith Pahlke, and Rich Yanusz. We probably will end up thanking Rob Bentz, Steve Elliott, and Rocky Holmes for their review of this manuscript. We also thank Alma Seward for final report layout and preparation.

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APPENDIX A

Appendix A1.–Tagging and recovery of individual tags on coho salmon at Steep Creek, 1996. A value of 1 indicates a fish was captured and released, whereas a value of 2 indicates a fish was captured and not released.

Tag number	Week of capture						
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
1001	Tagged	0	1	0	1	0	0
1002	Tagged	0	1	1	0	0	0
1003	Tagged	1	1	0	2	0	0
1004	Tagged	0	0	0	0	0	0
1005	Tagged	0	1	1	1	0	0
1006	Tagged	1	0	0	0	0	0
1007	Tagged	0	0	0	0	0	0
1009	Tagged	1	0	0	0	0	0
1010	Tagged	0	1	0	0	0	0
1012	Tagged	1	1	1	0	0	0
1013	Tagged	0	1	1	1	0	0
1014	Tagged	0	1	1	0	0	0
1015	Tagged	0	0	0	0	0	0
1016	Tagged	1	1	0	0	0	0
1017	Tagged	0	0	0	0	0	0
1018	Tagged	0	0	0	0	0	0
1019	Tagged	0	1	1	0	0	0
1020	Tagged	1	1	0	0	0	0
1022	Tagged	0	0	0	0	0	0
1023	Tagged	0	0	0	0	0	0
1024	Tagged	0	1	1	0	0	0
1025	Tagged	0	0	0	0	0	0
1026	Tagged	0	1	0	0	0	0
1027	Tagged	1	0	1	0	0	0
1028	Tagged	0	0	0	0	0	0
1029	Tagged	1	0	0	0	0	0
1030	Tagged	1	1	0	1	0	0
1031	Tagged	1	0	0	0	0	0
1032	Tagged	0	1	0	0	0	0
1033	Tagged	0	1	0	0	0	0
1034	Tagged	1	0	0	0	0	0
1035	Tagged	0	1	0	0	0	0
1036	Tagged	1	0	0	0	0	0
1037	Tagged	0	0	0	0	0	0
1038	Tagged	0	1	0	0	0	0
1039	Tagged	0	0	0	0	0	0
1040	Tagged	0	0	0	0	0	0
1041	Tagged	1	0	0	0	0	0
1042	Tagged	0	0	0	0	0	0
1043	Tagged	1	0	0	0	0	0
1044	Tagged	0	1	1	1	0	0
1045	Tagged	1	1	1	1	0	0
1046	Tagged	0	0	0	0	0	0

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Tag number	Week of capture						
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
1047	Tagged	1	0	0	0	0	0
1048	Tagged	0	0	0	0	0	0
1049	Tagged	0	0	0	0	0	0
1051	Tagged	1	0	0	0	0	0
1052	Tagged	1	0	0	0	0	0
1053	Tagged	0	0	0	0	0	0
1054		Tagged	0	0	1	0	0
1055		Tagged	1	0	0	0	1
1056		Tagged	1	0	1	1	2
1057		Tagged	1	1	0	0	0
1058		Tagged	1	1	0	0	0
1060		Tagged	1	1	1	0	0
1061		Tagged	1	1	0	0	0
1062		Tagged	1	0	1	0	0
1063		Tagged	0	0	0	0	0
1064		Tagged	1	1	1	0	0
1065		Tagged	1	1	0	0	1
1066		Tagged	0	0	0	0	0
1067		Tagged	1	0	0	1	1
1068		Tagged	1	0	0	0	0
1069		Tagged	1	0	0	0	0
1070		Tagged	1	1	0	0	0
1071		Tagged	1	1	1	0	0
1072		Tagged	0	0	1	0	0
1073		Tagged	1	0	0	0	0
1074		Tagged	1	0	0	0	0
1075		Tagged	1	1	1	0	0
1076		Tagged	1	0	0	1	0
1077		Tagged	1	0	0	0	0
1079		Tagged	1	0	0	1	1
1080		Tagged	1	1	0	0	0
1081		Tagged	0	0	0	0	0
1082		Tagged	1	1	0	0	0
1083		Tagged	1	1	1	0	1
1084		Tagged	1	0	1	0	0
1087		Tagged	1	0	1	0	0
1088		Tagged	1	1	0	0	0
1089		Tagged	0	0	0	0	0
1090		Tagged	0	0	0	0	0
1091		Tagged	0	1	1	0	0
1092		Tagged	1	0	0	0	0
1093		Tagged	1	0	0	0	0
1094		Tagged	1	0	1	0	0
1095		Tagged	1	1	0	0	0
1096		Tagged	1	0	0	1	1

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Appendix A1.–Page 3 of 8.

Tag number	Week of capture						
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
1098		Tagged	1	1	0	0	0
1099		Tagged	1	1	0	0	0
1100		Tagged	1	1	1	0	0
1101		Tagged	0	1	0	0	0
1102		Tagged	1	0	1	0	0
1103		Tagged	0	0	0	0	0
1104		Tagged	1	1	0	0	0
1105		Tagged	1	0	0	0	0
1106		Tagged	1	1	0	0	0
1107		Tagged	1	0	0	0	0
1108		Tagged	1	1	0	0	0
1109		Tagged	0	1	0	0	0
1110		Tagged	1	0	1	0	0
1111		Tagged	0	0	0	0	0
1112		Tagged	1	1	0	0	0
1113		Tagged	1	1	0	1	1
1114		Tagged	1	1	1	1	1
1115		Tagged	1	0	1	0	0
1116		Tagged	0	0	0	0	0
1117		Tagged	0	1	0	0	0
1118		Tagged	0	0	0	0	0
1119		Tagged	0	0	0	0	0
1123		Tagged	0	1	0	0	0
1124		Tagged	1	1	0	0	0
1125		Tagged	0	0	0	0	0
1127		Tagged	0	0	0	0	0
1128		Tagged	0	0	0	0	0
1129		Tagged	1	1	0	0	0
1133		Tagged	0	0	0	0	0
1134		Tagged	0	0	0	0	0
1135		Tagged	1	0	0	0	0
1136		Tagged	1	0	0	0	0
1137		Tagged	0	0	0	0	0
1138		Tagged	0	0	0	0	0
1139		Tagged	1	0	0	0	0
1140		Tagged	1	0	0	0	0
1141		Tagged	1	1	0	0	0
1143		Tagged	0	0	0	0	0
1144			Tagged	0	2	0	0
1145			Tagged	1	0	0	0
1146			Tagged	0	0	0	0
1147			Tagged	0	0	0	0
1148			Tagged	1	0	0	1
1149			Tagged	0	0	0	0
1150			Tagged	0	0	0	0

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Appendix A1.–Page 4 of 8.

Tag number	Week of capture						
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
1151			Tagged	0	1	0	0
1152			Tagged	1	0	1	1
1153			Tagged	1	0	0	0
1154			Tagged	0	0	0	0
1155			Tagged	1	0	0	1
1158			Tagged	1	1	0	0
1159			Tagged	0	0	0	0
1160			Tagged	1	0	0	0
1162			Tagged	1	1	1	1
1163			Tagged	0	1	0	0
1164			Tagged	0	1	0	0
1165			Tagged	0	1	1	1
1166			Tagged	0	0	1	0
1167			Tagged	0	1	0	1
1168			Tagged	1	1	0	0
1169			Tagged	0	0	0	0
1170			Tagged	1	0	0	0
1171			Tagged	1	0	0	0
1172			Tagged	1	0	0	0
1173			Tagged	0	1	0	0
1174			Tagged	0	0	0	0
1175			Tagged	1	0	0	0
1176			Tagged	0	0	0	0
1177			Tagged	0	0	0	0
1178			Tagged	0	1	0	0
1179			Tagged	0	1	0	0
1180			Tagged	0	0	0	0
1181			Tagged	1	0	0	0
1182			Tagged	0	0	1	0
1183			Tagged	0	1	0	0
1184			Tagged	1	1	0	0
1185			Tagged	0	0	1	0
1186			Tagged	0	1	0	0
1187			Tagged	0	1	0	1
1188			Tagged	1	0	0	0
1189			Tagged	1	1	0	1
1190			Tagged	1	1	0	0
1191			Tagged	1	0	0	0
1192			Tagged	1	0	0	0
1193			Tagged	0	1	1	1
1194			Tagged	0	1	1	1
1195			Tagged	0	1	0	0
1197			Tagged	1	0	0	0
1198			Tagged	1	0	0	0
1199			Tagged	1	0	0	0

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Tag number	Week of capture						
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
1200			Tagged	0	0	0	0
1201			Tagged	2	0	0	0
1203			Tagged	0	1	0	0
1204			Tagged	0	0	0	0
1206			Tagged	1	0	0	0
1207			Tagged	1	0	0	0
1208			Tagged	1	1	0	0
1209			Tagged	1	0	0	0
1210			Tagged	1	1	0	0
1211			Tagged	1	0	0	0
1212			Tagged	1	1	0	1
1213			Tagged	1	0	0	0
1214			Tagged	1	0	0	0
1215			Tagged	0	0	0	0
1216			Tagged	1	1	1	2
1217			Tagged	1	0	0	0
1218			Tagged	1	1	0	0
1219			Tagged	1	0	0	1
1220			Tagged	1	0	0	0
1221			Tagged	1	0	0	0
1222			Tagged	0	0	0	0
1223			Tagged	0	0	0	0
1224			Tagged	0	0	0	0
1226				Tagged	0	0	0
1227				Tagged	0	0	0
1228				Tagged	1	1	0
1230				Tagged	0	0	0
1232					Tagged	1	0
1233					Tagged	0	1
1234					Tagged	0	0
1235					Tagged	0	0
1236					Tagged	1	0
1237					Tagged	1	1
1238					Tagged	1	0
1239					Tagged	0	0
1240					Tagged	0	0
1241					Tagged	0	0
1242					Tagged	0	0
1243					Tagged	0	0
1244					Tagged	0	0
1245					Tagged	0	0
1246					Tagged	0	0
1247					Tagged	1	0
1248					Tagged	0	0
1249					Tagged	0	0

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Tag number	Week of capture						
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
1250					Tagged	1	0
1251				Tagged	0	0	0
1252				Tagged	0	0	0
1253				Tagged	1	0	0
1254				Tagged	0	0	0
Mort				*Tagged	0	0	0
1255					Tagged	1	1
1256					Tagged	0	0
1257					Tagged	1	0
1258					Tagged	0	0
1259					Tagged	1	1
1260					Tagged	1	1
1261					Tagged	0	0
1262					Tagged	0	0
1263					Tagged	1	1
1264					Tagged	0	0
1265					Tagged	1	1
1266					Tagged	0	0
1267					Tagged	0	1
1268					Tagged	0	0
1269					Tagged	0	1
1272					Tagged	0	0
1273					Tagged	0	0
1274					Tagged	1	0
1276					Tagged	1	1
1277					Tagged	1	1
1278					Tagged	1	1
1279					Tagged	1	1
1280					Tagged	0	0
1281					Tagged	1	1
1282					Tagged	1	0
1283					Tagged	0	0
1284					Tagged	0	0
1285					Tagged	1	0
1286					Tagged	1	1
1287					Tagged	1	1
1288					Tagged	0	0
1289					Tagged	0	0
1290					Tagged	0	0
1291					Tagged	0	0
1292					Tagged	1	0
1293					Tagged	1	0
1294					Tagged	0	1
1295					Tagged	0	0
1296					Tagged	0	0

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Tag number	Week of capture						
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
1297					Tagged	0	0
1298					Tagged	0	0
1299					Tagged	0	0
1300					Tagged	0	0
1302					Tagged	0	0
1303					Tagged	1	0
1304					Tagged	0	0
1305					Tagged	0	2
1306					Tagged	0	1
1307					Tagged	1	0
1308					Tagged	0	0
1309					Tagged	1	0
1310					Tagged	1	1
1311					Tagged	1	0
1312					Tagged	0	1
1313					Tagged	1	0
1314					Tagged	0	0
1315					Tagged	0	1
1316					Tagged	0	0
1318					Tagged	1	0
1319					Tagged	1	1
1320					Tagged	0	0
1321					Tagged	1	1
1322					Tagged	1	0
1323					Tagged	0	0
1325					Tagged	1	1
1326					Tagged	0	0
1327					Tagged	1	0
1328					Tagged	1	0
Mort					*Tagged	0	0
1329						Tagged	1
1330						Tagged	1
1332						Tagged	0
1333						Tagged	1
1334						Tagged	0
1335						Tagged	1
1337						Tagged	0
1338						Tagged	1
1340						Tagged	1
1341						Tagged	0
1342						Tagged	0
1343						Tagged	0
1344						Tagged	1
1345						Tagged	1
1347						Tagged	1

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Appendix A1.–Page 8 of 8.

Tag number	Week of capture						
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
1348						Tagged	1
1349						Tagged	1
1351						Tagged	1
1352						Tagged	1
1353						Tagged	1
1354						Tagged	0
1355						Tagged	0
1356						Tagged	1
1357						Tagged	0
1358						Tagged	0
1359						Tagged	0
1360						Tagged	1
1361						Tagged	0
1362						Tagged	1
1363						Tagged	0
1364							Tagged
1366							Tagged
1368							Tagged
1369							Tagged
1370							Tagged
1371							Tagged
1372							Tagged
1373							Tagged
1374							Tagged
1375							Tagged
1376							Tagged
1377							Tagged
1378							Tagged
1379							Tagged
1380							Tagged
1381							Tagged

* These fish were captured as fresh mortalities and therefore not given a tag.

Appendix A2.–Computer data files concerning data from the Steep Creek coho salmon mark-recapture study, 1996.

File name	Description
96_Steep.fds	WORD 6.0 (Windows) file of this FDS report. The manuscript describing the 1996 Steep Creek study is contained in this file.
96_STdat.xls	Excel spreadsheet file containing the mark-recapture data from the 1996 Steep Creek study and the various analyses performed.
96_STcnt.xls	Excel spreadsheet file containing the observer foot counts from the 1996 Steep Creek study and the various analyses performed.
96_STage.xls	Excel spreadsheet file containing the age-composition summary of the age, sex, length data gathered in the 1996 Steep Creek study.
96_STfig.wb1	Quattro Pro (Windows) spreadsheet file containing a single high-low figure describing the relationship between observer counts and the estimated actual weekly abundance during the 1996 Steep Creek study.