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Abundance of Coho Salmon in the Lost River System, Yakutat, Alaska, 2004

by

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and

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

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

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

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ABSTRACT

This was the second year of a planned multi-year study to estimate the abundance of coho salmon *Oncorhynchus kisutch* in the Lost River located near Yakutat, Alaska. The abundance of coho salmon in 2004 was estimated using a two-event mark–recapture experiment. Biological data were collected during both sampling events. Fish were captured during event one at the mouth of the Lost River where it empties into the Situk-Ahrnklin Lagoon using a beach seine from August 25 through September 22. Each fish was marked by removal of the adipose fin and given a secondary batch mark; either a single or two holes placed in the left or right operculum with a paper punch. A total of 767 coho salmon were captured, marked, and released during event one. In event two, live fish were caught using a beach seine. Carcasses were also collected and sampled. Event two sampling took place in Tawah Creek, Ophir Creek and other portions of the Lost River system from September 28 through November 17. A total of 772 coho salmon were sampled during event two and of these, 8 had been previously marked in event one. Abundance was estimated using a modification of the Petersen estimator. The total abundance of coho salmon in the Lost River in 2004 was estimated to have been 47,566 fish (SE=18,560; CV=39%). The peak survey count of coho salmon in the Lost River in 2004 was 5,047 fish. The expansion factor calculated from dividing the estimated abundance by the peak survey count was 9.42 (SE=3.68).

Key Words: coho salmon, *Oncorhynchus kisutch*, spawning abundance, Lost River, mark–recapture, peak survey count, expansion factor, Yakutat, Alaska

INTRODUCTION

The Lost River is a small stream located on the Yakutat Forelands near Yakutat, Alaska (Figure 1) and coho salmon *Oncorhynchus kisutch* return each year to this stream and spawn. Alaska Department of Fish and Game (ADF&G) staff annually count spawning and/or migrating coho salmon in the Lost River system during foot and boat based escapement surveys in Ophir Creek, in Tawah Creek, and in various drainage ditches that are tributary to the Lost River. The annual peak survey counts of coho salmon in these tributary systems are used as indices of the annual escapement strength for this stock of coho salmon. A capture recapture experiment conducted in the Lost River in 2003 estimated coho salmon abundance at about 24,000 fish and estimated that the peak survey count represented about 27% of the estimate (Clark et al. *In prep*).

The Lost River system drained into its own lagoon before entering the Gulf of Alaska prior to the winter of 1999–2000. In that winter, the Lost River changed channels and migrated into the Situk-Ahrnklin lagoon. A commercial set gill net fishery took place in the Lost River lagoon prior to the year 2000. Prior to 2000, it is believed that virtually all of the salmon harvested in the Lost River lagoon were fish of Lost River origin. The abundance of coho salmon in 2004 in the Situk River was estimated to have been about 54,000 fish (Waltemyer et al. 2005). Abundance of the Ahrnklin stock of coho salmon has not been estimated but is assumed to be of a similar magnitude. The Situk-Ahrnklin lagoon fishery primarily targets Situk and Ahrnklin origin fish. Although there is no scientific based catch allocation methodology in place for that fishery, it is assumed that some Lost River origin coho salmon have been harvested in the Situk-Ahrnklin lagoon fishery since the channel change.

Coho salmon harvests in the Lost River commercial set gill fishery averaged about 6,000 fish per year from 1972–1999. Lost River origin coho salmon are also harvested in the commercial troll fishery. Clark and Clark (1994) estimated the harvest of Lost River origin coho salmon by the commercial troll fishery at about 6,000 fish per year. The Lost River harvest of coho salmon by sport fishermen has averaged about 1,000 fish per year over the past 15 years and a few coho salmon are also harvested in a subsistence fishery. Peak counts of spawning coho salmon in the Lost River since 1972 have averaged about 4,500 fish. In 1994, ADF&G adopted an escapement goal range of 2,200 to 6,500 coho salmon counted during a peak survey of the Lost River based upon the technical recommendations of Clark and Clark (1994).

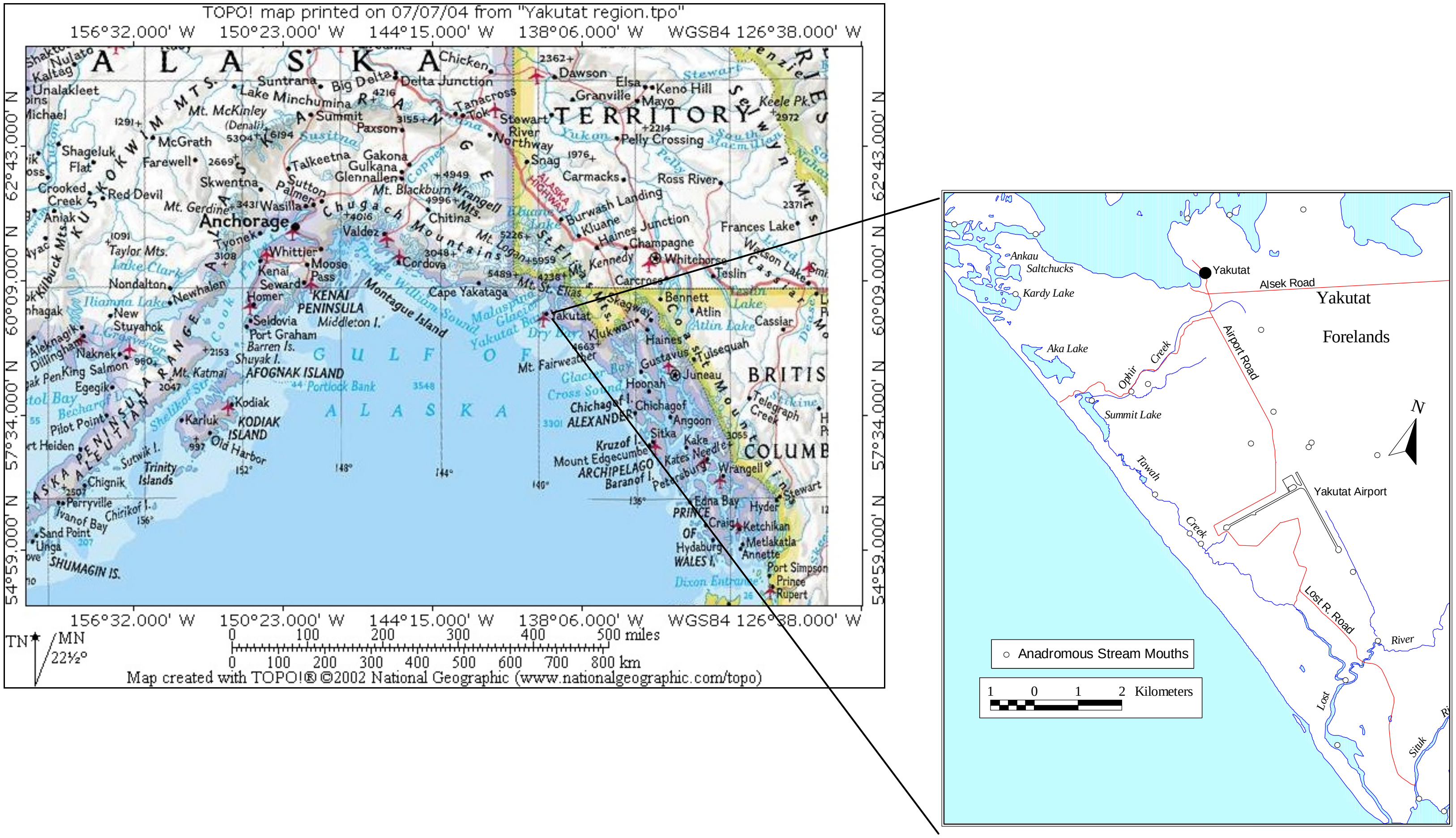

Figure 1.–Map depicting Alaska and showing location of the Lost River southeast of Yakutat, Alaska.

Recommendations concerning coho salmon stock assessments in the Clark and Clark (1994) report include:

"One of the major limitations in this analysis is the lack of any total escapement estimates for coho salmon in the Yakutat Area. Because of high water conditions typically present during the fall coho salmon migration period, the likelihood of maintaining a weir in a fish tight manner is low. However, we believe that fairly good estimates of total escapement could be obtained through mark–recapture experiments at a relatively low cost."

Thus, improvements in the annual stock assessments for Lost River coho salmon have been recommended in past technical reports. The 2003 abundance estimate (Clark et al. *In prep*) was stratified by gender, resulting in estimates of 9,010 males (SE=2,565), 14,675 females (SE=7,255), and total abundance of 23,685 coho salmon (SE=7,835). This specific stock assessment study was planned to provide a direct estimate of total abundance of coho salmon in the Lost River in 2004. We wanted to estimate the annual average and inter-annual variance for the relationship between peak survey counts and total escapements. The stock assessment objectives for this study in 2004 were as follows:

1. To estimate the total abundance of coho salmon in the Lost River in 2004 such that the estimate is within ±37.5% of the true value 95% of the time.
2. To estimate the expansion factor, the coho salmon abundance estimate divided by the peak survey count, in 2004 in the Lost River such that the estimate is within ±37.5% of the true value 95% of the time.

METHODS

A two-event mark–recapture experiment for a closed population (Seber 1982) was conducted to estimate abundance of coho salmon in the Lost River in 2004.

CAPTURE AND MARKING

Immigrating coho salmon were caught in the Lost River immediately upstream of its confluence with the Situk-Ahrnklin Lagoon. A 30 m × 4 m (mesh 2.2 cm) beach seine was used to capture fish during event one from August 25 to September 22. The time of day, tidal stage, and catch for each beach seine set were recorded on field data forms.

Upon retrieval of the beach seine, coho salmon were carefully removed from the net for sampling. Coho salmon captured and in good condition were measured from mid-eye to fork of tail (MEF) to the nearest 5 mm, sexed by visual examination, and doubly marked, and released. The primary mark was an adipose fin clip. The secondary mark was one of three mutilations: 1) a paper punch in the left upper opercle, 2) a paper punch in the right upper opercle, or 3) a double paper punch in the left upper opercle. The secondary marks were used to ensure that when a fish was examined on the spawning grounds, anywhere from a few days to two months later, the time period when the fish was marked and released could be determined. Further, this ensured that we could conduct appropriate tests of these data when calculating the mark–recapture estimate. The condition of each fish was assessed, noted, and recorded.

A subset of fish captured over the course of event one were fitted with radio transmitter tags and then released. The radio transmitters used were manufactured by Advanced Telemetry Systems (ATS). The tags were 51 mm long and necked from a diameter of 19 to 15 mm. The tag was positioned in the mouth and manually inserted through the esophagus into the stomach with a tag plunger. Prior to deploying each radio transmitter tag, the frequency was checked and verified and the frequency noted on the field data form. Once the radio transmitter was in place and measures taken to insure that the tag wouldn't be regurgitated, the fish was released. The radio transmitter tags were used to examine conditions necessary for unbiased estimation with the mark–recapture experiment and to verify that marked fish moved into the event two sampling area rather than dying or moving elsewhere. This information enabled us to later adjust the number of marks used in the abundance estimation process. Tracking of the radio transmitter tagged fish occurred weekly through ground surveys and/or aerial surveys using fixed wing aircraft.

RECOVERY ON SPAWNING GROUNDS

Event two sampling was conducted by crews of two to four persons seining live fish and collecting carcasses. Sampling occurred in Tawah Creek, in Ophir Creek and in ditches tributary to the Lost River at locations accessible along the Yakutat area road system during the period of September 28 through November 17. Once coho salmon were captured, they were measured from mid-eye to fork of tail (MEF) to the nearest 5 mm, sexed by visual examination, and examined for the presence of a first event mark (missing adipose fin and secondary mutilation mark). Once a carcass was examined, a slash mark was made on the left side of the fish to ensure that these fish were not sampled again (without replacement). Live fish were marked by removing a portion of the dorsal fin prior to release to prevent sampling of the same fish at a later date.

ABUNDANCE ESTIMATION

This experiment was designed to estimate coho salmon abundance using a two-sample mark–recapture experiment. Under ideal conditions, Chapman's modification of the Petersen Method (Seber 1982) would be used to estimate the coho salmon escapement. The conditions for appropriate use of this methodology are:

1. All coho salmon have an equal probability of being marked; or
2. All coho salmon have an equal probability of being inspected for marks; or
3. Marked fish mixed completely with unmarked fish between events; and
4. There is no recruitment to the population between events; and
5. There is no mark-induced mortality; and
6. Fish do not lose their marks and all marks are recognizable.

This experiment was designed so that these conditions could either be ensured by field procedures or the conditions could be evaluated with diagnostic testing, and the appropriate model for estimating abundance could be selected.

Meeting the first condition depended upon entry pattern, how long these fish remained in the area where netting occurred, and the fishing effort that took place during event one. Meeting the second condition depended primarily upon sampling coverage. Meeting the third condition depended primarily upon behavior of fish marked during event one. Further, conditions 1–3 could be violated if length or sex selective sampling occurred. Meeting the three "or" conditions was tested through a series of hypothesis tests. Diagnostic testing confirmed that we met at least one of the "or" conditions when testing for temporal violations as well as for size and gender selective sampling.

The basis for meeting condition number 4 (no recruitment) is based solely on the timing of the tagging and recovery events and information concerning observations of peak survey abundance in the Lost River system. Coho salmon moving into the Lost River were captured from late August through late September and second event sampling occurred until November 17. Since 1964, peak counts of coho salmon in the Lost River occurred prior to October 10 in 30 of the 36 years (83%). Thus, although it is likely that some coho salmon entered the Lost River after the marking event was complete, it is likely that the majority entered during event one and unlikely that very many coho salmon entered the river after the conclusion of the second sampling event. In the presence of some recruitment after event one but not after event two, an unbiased estimate of abundance can still be calculated.

Any time salmon are caught and handled, there is potential for mark-induced mortality (condition number 5). Periodic visual examinations of the area where event one sampling occurred failed to document marked coho salmon that had died. This information provides only limited evidence for the lack of mark-induced mortality. However further testing of condition number 5 was possible through analysis of the tracking information of radio-tagged coho salmon. Adjustments to the number of marked fish were made based on findings from surveys of radio tag fish distribution.

Each marked fish received a primary mark and a secondary mark to insure that marks were recognizable during second-event sampling. Thus, it is highly unlikely that any marked fish inspected during the second event were not accurately identified as marked (condition number 6).

We used Chapman's modification of Petersen's two-event, closed population estimator to estimate spawning abundance of coho salmon in the Lost River system. However, we did not expect all marked fish to fully recruit to the spawning grounds and thus planned this study to make use of results from the radio tagging effort to address this technical concern. Thus, the abundance estimator included an additional feature:

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

where $\hat{N}$ is the abundance estimate, C is the number of fish examined in the second event, R is the number of recaptured fish in the second event, and $\hat{M}$ is the estimated number of marked coho salmon in the experiment available to be recaptured during the second event. Because a fraction of the coho salmon marked at the mouth of the Lost River are likely not available for sampling during the second event (e.g., they are considered mortalities from event one), the number of tagged fish in the experiment was estimated as:

$$\hat{M} = M\ \hat{y} \qquad (2)$$

where $\hat{y}$ was the proportion of marked fish that survived and moved upriver to the spawning grounds as estimated from the radio tagging results. Introduction of radio telemetry adds one more condition for accuracy of the estimate: test subjects fitted with transmitters must be representative of other marked fish. Test subjects were selected systematically from among those salmon captured and marked. Since a fixed number of test subjects were selected during each of three temporal periods during the first sampling event, y for the run was estimated using a weighted procedure:

$$\hat{y} = \sum_{s=1}^{3} w_s \hat{y}_s \qquad (3)$$

where w_s was the weight $(= M_s / M)$ for the statistic from a temporal stratum denoted by s, M_s the number of marked fish released during stratum s, and $\hat{y}_s$ the fraction of test subjects released during stratum, s that subsequently migrated upstream.

Variance and bias for $\hat{N}$ was estimated using a bootstrap procedure with slight modifications from what was described by Buckland and Garthwaite (1991). A stochastic model was used to estimate the actual number of tags in the experiment. A bootstrap sample was drawn with replacement from a sample of size $\hat{N}$ using the empirical distribution defined by capture histories. The simulated frequencies were used to calculate surrogate statistics M'_s, C'_t, and R'_{st} where t denotes a stratum during the second event. Simulated values for $\hat{M}'_s$ were obtained by drawing values for $\hat{y}'_1$, $\hat{y}'_2$, and $\hat{y}'_3$ from $\text{binom}(16, \hat{y}_1)$, $\text{binom}(11, \hat{y}_2)$, and $\text{binom}(3, \hat{y}_3)$ for each bootstrap sample. Simulated statistics were substituted for observed values in estimators to produce a simulated estimate $\hat{N}'$.

One million (n_b) such bootstrap samples were drawn, creating the empirical distribution $\hat{F}(\hat{N}')$, which is an estimate of $\hat{F}(\hat{N})$. The difference between the average of bootstrap estimates and $\hat{N}$ is an estimate of statistical bias in the latter statistic (Efron and Tibshirani 1993, Section 10.2). Variance was estimated as:

$$var(\hat{N}) = (n_b - 1)^{-1} \sum_{b=1}^{n_b} (\hat{N}'_b - \overline{\hat{N}'})^2 \qquad (4)$$

EXPANSION FACTOR

The expansion factor for the peak count of coho salmon from the survey in 2004 and its variance was estimated as follows:

$$\hat{\pi}_{2004} = \hat{N} / I_{2004} \qquad (5)$$

$$var(\hat{\pi}_{2004}) = var(\hat{N}) I_{2004}^{-2} \qquad (6)$$

where π was the expansion factor for 2004 and I the peak count of several surveys conducted in 2004. The variance in equation 6 represents sampling-induced variation from the mark–recapture experiment, and accordingly represents the same precision attained with the estimate of abundance from that experiment.

RESULTS

MARKING EVENT

A total of 767 coho salmon were captured, marked and released at the mouth of the Lost River in 2004 from August 25 through September 22. In the 29-day period of August 25 through

September 22, fishing occurred on 21 of those days (72%) and from one to three seine sets were made on these sampling days (Figure 2). A total of 424 of these fish were females and a total of 343 were males. Three secondary marks were applied as the sampling effort progressed through time (Table 1). From August 25 through September 7, a total of 441 coho salmon were given a left upper opercula punch (LUOP) as a secondary mark. From September 8 through September 18, a total of 271 coho salmon were given a right upper opercula punch (RUOP) as a secondary mark, however an additional seven fish on September 16 and two fish on September 18 were mistakenly marked with LUOP rather than RUOP prior to release. From September 20 through September 22, a total of 46 coho salmon were given secondary marks consisting of a double left opercula punch (DLUOP). A total of 30 of these first event fish were also fitted with a radio tags; details concerning dates when these fish were radio-tagged, radio frequency, and other pertinent information is provided in Appendix Table 1.

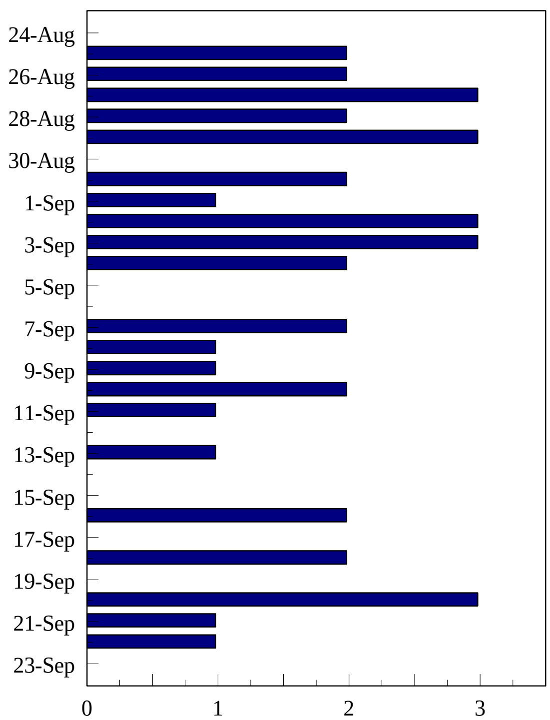

Figure 2.–Fishing effort expended during the first event of the 2004 mark–recapture experiment for coho salmon in the Lost River.

We had intended that event one sampling continue until about October 8, and that first event sample sizes be at least 1,500 coho salmon with 50 being radio-tagged. Unfortunately, very heavy rains in mid-September with flood events lasting into early October prevented additional first event sampling after September 22. These inclement weather conditions significantly shortened our first event sampling effort and prevented our desired sample sizes for first event marked fish from being achieved (both total first event marked fish and radio-tagged fish).

Table 1.–Summary of the number of coho salmon released with marks during the first event of the Lost River mark–recapture experiment in 2004. Mark abbreviations are as follows: LUOP=single hole punch through the upper left opercle, RUOP=single hole punch through the right upper opercle, and DLUOP=two hole punches in the left upper opercle.

Date Released	Number Released	Cumulative Number Released	Type of Mark
25-Aug	17	17	LUOP
26-Aug	43	60	LUOP
27-Aug	19	79	LUOP
28-Aug	40	119	LUOP
29-Aug	95	214	LUOP
31-Aug	25	239	LUOP
01-Sep	110	349	LUOP
02-Sep	20	369	LUOP
03-Sep	26	395	LUOP
04-Sep	11	406	LUOP
07-Sep	35	441	LUOP
08-Sep	67	508	RUOP
09-Sep	44	552	RUOP
10-Sep	38	590	RUOP
11-Sep	2	592	RUOP
13-Sep	54	646	RUOP
16-Sep	54	700	RUOP
16-Sep	7	707	LUOP
18- Sep	12	719	RUOP
18- Sep	2	721	LUOP
20- Sep	28	749	DLUOP
21- Sep	12	761	DLUOP
22- Sep	6	767	DLUOP

RECOVERY EVENT

A total of 772 coho salmon were captured and examined for the presence of marks during the second event of the 2004 Lost River mark–recapture experiment (Table 2). Of these 772 coho salmon, 430 were females and 342 were males. The second event took place during 12 sampling dates that started on September 28 and ended on November 17 (Figure 3). A total of 8 coho salmon were recaptured during second event sampling, three of which had been marked with LUOP, four with RUOP, and one with DLUOP. Of the eight recaptures, five were females and three were males. Second event sampling was hampered by high water conditions during September and October and desired samples sizes were not achieved (a minimum of 1,000 being coho examined). The inclement weather resulted in sampling during fewer days than was desired and catches per day were less than expected due to fishing in high water conditions being less effective than anticipated.

Table 2.–Summary of the number of coho salmon captured during the second event of the Lost River mark–recapture experiment in 2004 with the number of those captured fish that were marked during the first event. Mark abbreviation: LUOP = upper left opercle punch, RUOP = upper right opercle punch, DLUOP = upper left opercle double punch.

Date	Catch	LUOP-Recap.	RUOP-Recap.	DLUOP Recap.
28-Sep	49	0	2	0
29-Sep	94	1	0	0
07-Oct	116	0	1	0
13-Oct	54	0	0	0
14-Oct	70	1	0	0
25-Oct	37	0	0	0
28-Oct	24	0	0	0
01-Nov	48	1	1	0
02-Nov	32	0	0	0
12-Nov	40	0	0	1
14-Nov	175	0	0	0
17-Nov	33	0	0	0
Total	772	3	4	1

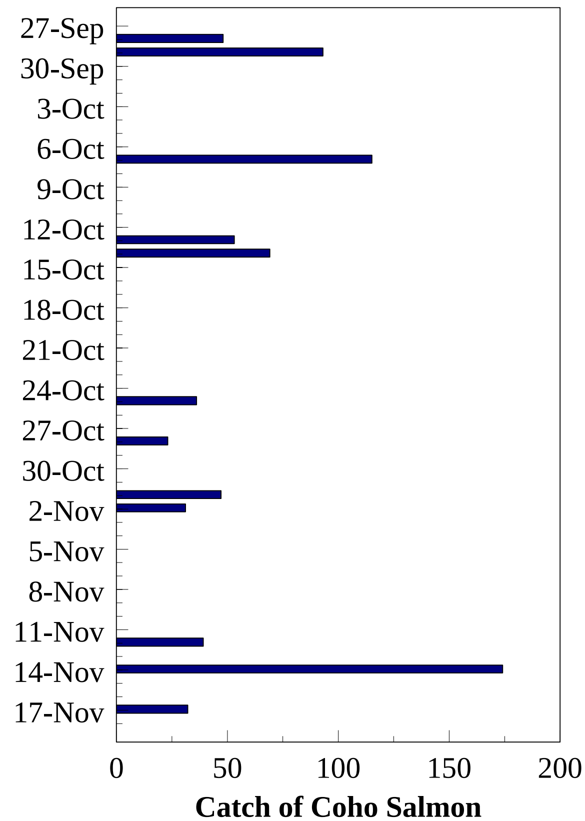

Figure 3.–Temporal pattern of sampling and daily catch of coho salmon during the second event of the 2004 mark–recapture experiment for coho salmon in the Lost River.

A total of 22 of the 30 coho salmon that were radio-tagged moved upstream into the Lost River system and remained there when they were last located (Table 3). Four of the radio tagged fish were never located after release, and four migrated to the Situk River system.

Table 3.–Distribution of last known locations of coho salmon caught at the mouth of the Lost River in 2004 and fitted with radio tags. See Appendix Table 1 for additional details.

Final Tracked Location	Number	Percent
Remained in Lost River	22	73
Never Relocated	4	13
Moved to Situk River	4	13
Total Radio-Tagged Coho	30	100

DIAGNOSTIC TESTING OF MARK-RECAPTURE DATA

The first diagnostic tests of the mark–recapture data were directed at evaluation of the three "or" conditions associated with the experiment:

1. All coho salmon had an equal probability of being marked; or
2. All coho salmon had an equal probability of being inspected for marks; or
3. Marked fish mixed completely with unmarked fish in the population between events.

The first diagnostic was temporal; we tested the null hypothesis that the probability of a fish being inspected for marks was independent of the time during the run when it was marked. We failed to reject the null hypothesis (Table 4), the Chi-square test statistic was 1.68 with a *P*-value of 0.432. The power of this test, which relies on secondary marks, was compromised slightly by the erroneous application of the LUOP mark, rather than RUOP, to nine coho salmon late in the middle time period. Because of this source of error and because of the small number of recaptured fish, we elected to conduct a second test. The second test was a temporal test where the null hypothesis was that the probability that a second event fish was marked was independent of the time during the second event when the fish was caught and inspected. Due to the small number of recaptured fish, second event recapture data were pooled into three temporal strata by calendar month. The Chi-square test statistic was 2.02 with a *P*-value of 0.363, hence we failed to reject the null hypothesis (Table 5). As a result of these two statistical tests, we have found no evidence that we failed to satisfy at least one of the "or" conditions due to temporal or geographic bias.

Table 4.–Contingency table for hypothesis test: H_O: probability of a coho salmon being inspected for marks was independent of the time during the run that it was marked. Chi-squared value = 1.68, 2 df, *P*-value = 0.432; failed to reject H_O.

Mark	Recaptured	Not Recaptured
LUOP	3	447
RUOP	4	267
DLUOP	1	45

Table 5.–Contingency table for hypothesis test: H_O: probability that a second event coho salmon was marked was independent of the time during the second event that it was caught. Chi-squared value=2.02, 2 df, *P*-value=0.363; failed to reject H_O.

Date	Recaptured	Not Recaptured
Sep	3	140
Oct	2	299
Nov	3	325

We also tested for potential size biased sampling. We used the Kolmogorov-Smirnov (KS) test to test the null hypothesis of no difference in size distributions of all coho salmon marked during the first event with those marked fish recaptured during the second event. The KS test statistic was 0.443 with a *P*-value of 0.087. Due to the small number of lengths from recaptured salmon (eight), we interpreted this result as evidence to reject the null hypothesis (Figure 4). We also used the KS test to compare the size distribution of all coho salmon marked during the first event with those captured during the second event (Figure 5). The KS statistic was 0.239 with a *P*-value of <0.001; so we rejected the null hypothesis and concluded that we had a Case IV experiment (Appendix Table 2), indicating that second event sampling was size-biased and further testing was needed to evaluate size bias during first event sampling. We used the KS test to compare the size distribution of all coho salmon recaptured during the second event with those captured during the second event (Figure 6). The KS statistic was 0.216 with a *P*-value of 0.851; so we failed to reject the null hypothesis and concluded that we had no significant evidence of size-biased sampling during the first event and size stratification was not necessary for estimating abundance or the coho salmon population in the Lost River in 2004.

Potential gender bias sampling was also tested. We tested the null hypothesis that the probability of recovery during the second event was independent of gender. The Chi-square test statistic was 0.11 with a *P*-value of 0.742, hence we failed to reject the null hypothesis (Table 6). We then tested the null hypothesis that male to female ratios were similar during both sampling events; the Chi-square test statistic was 0.17 with

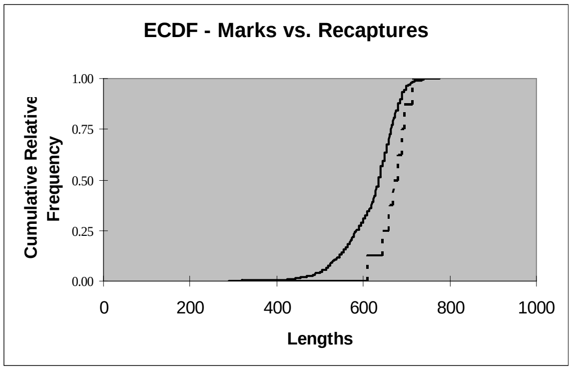

Figure 4.–Cumulative frequency distribution of lengths of coho salmon marked during event one (solid line) versus those recaptured during event two (dotted line), Lost River mark–recapture experiment, 2004.

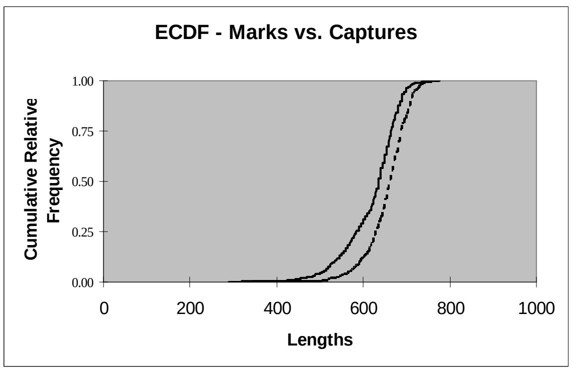

Figure 5.–Cumulative frequency distribution of lengths of coho salmon marked during event one (solid line) versus those captured during event two (dotted line), Lost River mark–recapture experiment, 2004.

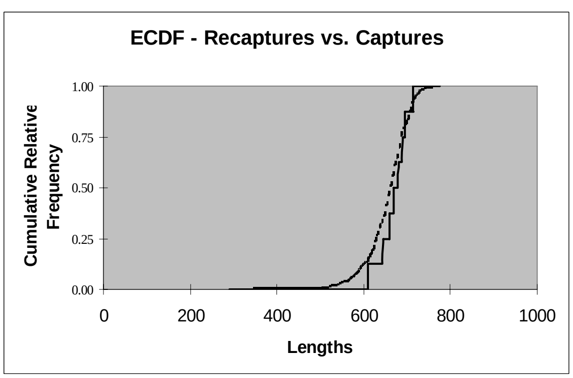

Figure 6.–Cumulative frequency distribution of lengths of coho salmon recaptured during event two (solid line) versus those captured during event two (dotted line), Lost River mark–recapture experiment, 2004.

a *P*-value of 0.677, hence we failed to reject the null hypothesis (Table 7). As a result of these two statistical tests, we found no evidence for gender bias in our sampling.

Table 6.–Contingency table for hypothesis test: H_o: probability of recovery during the second event was independent of gender. Chi-squared value=0.11, 1 df, *P*-value=0.742; accept H_o.

Sex	Captured	Not Recaptured
Males	3	320
Females	5	419

Table 7.–Contingency table for hypothesis test: H_o: male to female ratios were similar during both sampling events. Chi-squared value=0.17, 1 df, *P*-value=0.677; accept H_o.

Sex	Marked	Captured
Males	323	343
Females	424	430

As a result of this series of diagnostic tests, we determined that stratification was unnecessary and a single estimate of abundance could be calculated.

Adjustment of the Number of Marks from Event One

The number of fish released during event one had to be adjusted before abundance could be estimated because radio-tagged fish demonstrated that only a portion of the marked population remained in the Lost River and were thus susceptible to event two sampling efforts (Table 3). Based upon radio tag results, the estimated fraction of coho salmon that moved upstream into the Lost River from the first event sampling site was 0.7208. The bootstrap standard error for this statistic was 0.0800 and the 95% confidence interval ranged from 0.5525 to 0.8627. The mean of the bootstraps was 0.7201, indicating negligible bias in the estimate. Thus the adjusted number of marked coho salmon during event one was estimated to have been 553.

Mark-Recapture Abundance Estimates

Total abundance of coho salmon in the Lost River in 2004 was estimated to be 47,566 fish with a standard error of 18,560 (CV=39%). The 95% confidence interval was estimated to have ranged from 26,400 to 97,970 coho salmon. Ignoring the variation associated with the portion of first event fish that moved upstream ($\hat{y}$), the potential computational (small sample size) bias of the point estimate using Chapman's formula (Seber 1982) is about six fish, a negligible amount.

SURVEY EXPANSION FACTOR

Several surveys of the Lost River took place to count coho salmon in 2004 (Table 8). The first coho salmon count took place on 8/31/04 and the last on 11/4/04. Weather conditions in 2004 seriously hampered the ability of ADFG to conduct consistent coho salmon surveys in the Lost River system in 2004. Extensive rainfall in September resulted in flood conditions until early October and high water conditions in October made visual surveys of coho abundance difficult. Because most surveys only covered a portion of the drainage, the peak survey can best be expressed as occurring between 10/31/04 and 11/4/04 when 2,582 coho salmon were counted in Tawah Creek, 2,157 were counted in Ophir Creek, and 308 were counted in ditches tributary to those streams for a total survey of 5,047 coho salmon. We think the actual peak abundance occurred in the Lost River system in 2004 earlier than was observed. The 2004 peak count represented 10.6% of the mark–recapture estimate. The 2004 expansion factor was estimated to be 9.42 with a standard error of 3.68 (CV = 39%).

Table 8.–Survey counts of coho salmon in the Lost River in 2004.

Date	Tawah (Float)	Ophir (Foot)	Ditches (Foot)
8/31/04	882		
9/08/04	1,868		
9/18/04	2,214		
10/06/04	1,114		
10/08/04		877	
10/31/04			308
11/01/04		2,157	
11/04/04	2,582		

DISCUSSION

We designed this experiment so that if all necessary conditions were met, Chapman's modification of the Petersen method could be used to estimate escapement. We collected data such that we could directly evaluate if the three "or" conditions were violated due to size or gender selectivity of sampling gear or if sampling effort over time was inconsistent. Based on the results of the diagnostic tests for gender selectivity, we concluded that gender selective sampling did not occur at detectable levels. However, diagnostic tests revealed that size selection occurred during the second sampling event, while no evidence was detected for size selection during first event sampling. Stratification by neither gender nor size was necessary for unbiased estimation of abundance.

Tests for equal probability of sampling over time for event one and event two indicated that at least one of the three "or" conditions was satisfied. A more rigorous second sampling event would have undoubtedly increased sample sizes, resulted in additional recaptured coho salmon from the first event and improved our estimation of abundance of coho salmon in the Lost River in 2004.

The ability of detecting movement of coho salmon into the Lost River through the use of radio tags was an important part of this experiment. The failure of coho salmon to continue to successfully migrate upstream when captured in the lower portions of streams can easily jeopardize the success of a mark–recapture experiment. In the case of this experiment, we were able to use results from radio-tagged fish to directly adjust the number of marked fish released during the first sampling event. As evidenced by the radio-tag results, some of the fish marked during the first event migrated back to the lagoon and were caught while others migrated into the Situk River system.

We believe that the abundance estimate of about 48,000 coho salmon derived from the mark–recapture experiment in 2004 is a relatively unbiased estimate of the actual abundance that returned to the Lost River in 2004. The project objective of estimating the total coho salmon abundance in the Lost River in 2004 to within

37.5% of the true value 95% of the time was not achieved. The failure was due to imprecision resulting from smaller than necessary sample sizes in both sampling events. The mark-recapture experiment was planned using an anticipated abundance of 24,000 coho salmon, about half of what we estimated. The sample sizes necessary to achieve the precision criteria for a population of 24,000 salmon would not allow us to achieve the criteria for a population of 48,000. Also, we were not successful in achieving our planned sample sizes in either the first or second sampling events. We had previously determined (Robson and Regier 1964) that we would need to handle approximately 2,500 coho salmon divided fairly evenly between the two sampling events assuming a population size of 24,000 and deployment of 50 radio tags to estimate the true number of valid marks. Less than 800 fish were handled during each of the two events. Further, only 30 radio-tags were deployed rather than 50 during the marking event which also reduced the precision of the abundance estimate. Many of these problems occurred because of the torrential rains in late September and resulting flood conditions that made sampling difficult in the Yakutat area in the fall of 2004. Further, the same sampling crew was simultaneously attempting to estimate abundance of sockeye salmon (*Oncorhynchus nerka*) in the Lost River during September and October and was also attempting to complete second event sampling in the East Alsek River in late September and October, thus trying to implement three capture recapture experiments at the same time. The combination of inclement weather conditions and an overly ambitious sampling effort resulted in the sampling crew not achieving desired sample sizes for this study. Less than desired precision of the estimate of abundance is the result of this difficulty.

We conjecture that peak abundance of coho salmon in the Lost River occurred prior to the peak counts being made (earlier than late October-early November). We think it likely that peak abundance of coho actually occurred in early to mid October. Inclement weather resulting in surveys not being conducted in some tributaries during the likely peak abundance period, and surveys conducted prior to the end of October were hampered with poor water visibility. This likely resulted in the peak counts being less than would have occurred under more normal weather conditions as well as making the expansion factor determined for 2004 less applicable to other more normal years.

CONCLUSIONS AND RECOMENDATIONS

Estimating total abundance is important information for assessment and management of the Lost River coho salmon stock. Use of a two-event mark–recapture abundance estimator provided an abundance estimate of about 48,000 coho salmon in 2004. The peak annual survey count of about 5,000 fish represented about 10% of the total abundance of coho salmon in the Lost River in 2004. Annual abundance estimates and survey expansion factors for coho salmon in the Lost River have been obtained for both 2003 and 2004. Multiple years are critical to determining annual variation and an appropriate average for application of expansion factors to historic peak surveys for run reconstruction efforts. We suggest obtaining additional years of useable abundance estimates and companion expansion factors will result in valuable information. Such a multi-year data set should provide the information needed to improve historic run reconstructions and improve the scientific information needed relative to better understand productivity and estimation of an appropriate escapement goal for this stock of salmon.

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APPENDIX

Appendix Table 1.–Specifics concerning coho salmon that were captured at the mouth of the Lost River in 2004 and fitted with radio tags. Length is in mm measured as mid-eye to fork of tail (MEF); F indicates females and M indicates males; and secondary mark abbreviations are as follows: RUOP = a paper punch in the right upper opercle, LUOP = a paper punch in the left upper opercle and DLUOP = a double paper punch in the left upper opercle.

Date	Radio-Tag Number	Length (MEF)	Sex	Secondary Mark	Final Radio-Tracked Location
26-Aug	152.041-23	620	m	LUOP	Lost
26-Aug	152.133-23	630	f	LUOP	Old Situk River
28-Aug	152.191-23	680	m	LUOP	Tawah/Ophir
28-Aug	152.223-23	660	m	LUOP	Situk Lake
29-Aug	152.643-23	620	f	LUOP	Tawah/Ophir
29-Aug	152.943-23	675	m	LUOP	Fate unknown
29-Aug	153.003-23	660	f	LUOP	Tawah/Ophir
31-Aug	153.063-23	630	m	LUOP	Lost
01-Sep	152.002-24[a]	595	f	LUOP	Lost
01-Sep	152.163-24	635	m	LUOP	Situk
01-Sep	152.373-23	625	f	LUOP	Tawah/Ophir
02-Sep	152.252-24	675	f	LUOP	Tawah/Ophir
03-Sep	152.764-23	700	m	LUOP	Lost
03-Sep	152.852-23	630	f	LUOP	Tawah/Ophir
04-Sep	152.793-23	645	m	LUOP	Fate unknown
07-Sep	152.822-23	700	f	LUOP	Lost
08-Sep	153.093-24	635	m	RUOP	Lost
08-Sep	152.163-24[a]	670	f	RUOP	Redfield Lakes (Situk)
09-Sep	153.122-24	620	f	RUOP	Tawah/Ophir
09-Sep	153.153-24	680	f	RUOP	Fate unknown
10-Sep	153.213-24	700	f	RUOP	Fate unknown
13-Sep	153.183-24	675	f	RUOP	Lost
13-Sep	153.243-24	655	m	RUOP	Lost
16-Sep	153.273-24	655	f	LUOP[b]	Lost
16-Sep	153.302-24	575	m	RUOP	Lost
16-Sep	153.332-24	690	m	RUOP	Tawah/Ophir
18-Sep	153.362-24	655	f	RUOP	Lost
20-Sep	153.392-24	680	m	DLUOP	Lost
20-Sep	153.423-24	735	m	DLUOP	Lost
21-Sep	153.093.23	625	m	DLUOP	Lost

[a] Radio tag number 152.163-24 was redeployed after being returned from the Situk on 9/4/04.

[b] Of 61 coho salmon marked and released on 16-Sep, seven were incorrectly marked with LUOP rather than RUOP, including the radio-tagged salmon.

Appendix Table 2.–Detection of size-selectivity in sampling and its effects on estimation of size composition.

Results of Hypothesis Tests (K-S) on lengths of fish MARKED during the First Event and RECAPTURED during the Second Event	Results of Hypothesis Tests (K-S) on lengths of fish MARKED during the First Event and CAPTURED during the Second Event
Case I: Fail to reject H_O There is no size-selectivity during either sampling event.	Fail to reject H_O
Case II: Fail to reject H_O There is no size-selectivity during the second sampling event but there is during the first.	Reject H_O
Case III: Reject H_O There is size-selectivity during both sampling events.	Fail to reject H_O
Case IV: Reject H_O There is size-selectivity during the second sampling event; test further for status of size-selectivity during the first event.	Reject H_O

Case I: Calculate 1 unstratified abundance estimate, and pool lengths, sexes, and ages from both sampling events to improve precision of proportions in estimates of composition.

Case II: Calculate 1 unstratified abundance estimate, and only use lengths, sexes, and ages from the second sampling event to estimate proportions in compositions. If second event composition data are not available, completely stratify both sampling events and estimate abundance for each stratum and apply formulae to correct for size bias to stratified first event composition data.

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

Case IV: Conduct hypothesis Tests (K-S) on lengths of fish CAPTURED during the Second Event and RECAPTURED during the Second Event:

Fail to reject H_O: There is no size-selectivity during the first sampling event but there is during the second. Calculate 1 unstratified abundance estimate, and only use lengths, sexes, and ages from the first sampling event to estimate proportions in compositions. If first event composition data are not available, completely stratify both sampling events and estimate abundance for each stratum and apply formulae to correct for size bias to stratified second event composition data.

Reject H_O: There is size selectivity during both sampling events. Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data.