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Smolt Production and Adult Harvest of Coho Salmon from the Nakwasina River in Southeast Alaska, 1998-1999

by

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and

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November 2001

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

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

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

General

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

Mathematics, statistics, fisheries

Alternate hypothesis	H_A
Base of natural logarithm	e
Catch per unit effort	CPUE
Coefficient of variation	CV
Common test statistics	F, t, χ^2, etc.
Confidence interval	C.I.
Correlation coefficient	R (multiple)
Correlation coefficient	r (simple)
Covariance	cov
Degree (angular or temperature)	°
Degrees of freedom	df
Divided by	÷ or / (in equations)
Equals	=
Expected value	E
Fork length	FL
Greater than	>
Greater than or equal to	≥
Harvest per unit effort	HPUE
Less than	<
Less than or equal to	≤
Logarithm (natural)	ln
Logarithm (base 10)	log
Logarithm (specify base)	$\log_2$, etc.
Mideye-to-fork	MEF
Minute (angular)	'
Multiplied by	x
Not significant	NS
Null hypothesis	H_O
Percent	%
Probability	P
Probability of a type I error (rejection of the null hypothesis when true)	α
Probability of a type II error (acceptance of the null hypothesis when false)	β
Second (angular)	"
Standard deviation	SD
Standard error	SE
Standard length	SL
Total length	TL
Variance	Var

FISHERY DATA SERIES NO. 01-16

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by

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ABSTRACT

Recovery of coded wire tags from adult coho salmon *Oncorhynchus kisutch* in 1999 were used to estimate smolt abundance and harvest of coho salmon originating from the Nakwasina River, near Sitka, Alaska. From April 15 through May 20, 1998, 9,980 coho salmon smolt ≥70 mm fork length were captured in minnow traps, marked with an adipose fin clip, given a coded wire tag of codes 04-46-29 or 04-46-30 and released. Smolt averaged 83mm fork length (SE = 0.32) and 5.8g (SE = 0.08) in weight. In 1999, 49 adult coho salmon bearing coded wire tags of the Nakwasina River codes were recovered in random sampling of marine fisheries. This corresponds to an estimated harvest of 1,983 (SE = 605) in the sampled fisheries. The sport fishery harvested an estimated 105 fish representing 5.3% of total harvest of Nakwasina River coho salmon. Estimated smolt abundance in 1998 from the Nakwasina River was 102,794 (SE = 15,255). This estimate was obtained by using a modified Peterson estimator.

Key words: coho salmon, *Oncorhynchus kisutch*, Nakwasina River, harvest, troll fishery, sport fishery, migratory timing, return, exploitation rate, marine survival, coded wire tag, mark-recapture experiment

INTRODUCTION

The Nakwasina River is one of thousands of coastal river systems that produce natural runs of coho salmon in Southeast Alaska. Collectively, coho salmon produced by these systems support the regions mixed stock commercial troll and net fisheries as well as freshwater and marine sport fisheries. Fishing pressure on Southeast Alaska coho stocks has increased as a direct result of growth of the region's sport fisheries and as an indirect result of increased hatchery production and reductions in the commercial troll fishery for chinook salmon. Much of the growth in commercial and sport fisheries has occurred along the outside coast of Baranof and Prince of Wales islands, including the Sitka Management Area. Growth in the Sitka Management Area has occurred predominantly near Sitka, on the outside coast of Baranof Island.

Evaluation of the effects of Southeast Alaska fisheries on coho salmon stocks requires annual estimates of harvest distribution patterns, marine survival, and fishery exploitation rates for specific stocks. The Alaska Department of Fish and Game (ADF&G) conducts comprehensive coded-wire-tagging (CWT) and escapement projects on a long-term basis to assess these fishery parameters on specific coho stocks native to streams in northern and inside areas of Southeast Alaska (Yanusz et al. 1999). Stock-specific information is more limited in outside, central and southern areas, though projects have been started in the last four years on specific stocks to bridge geographic areas, including the Unuk River in the southern end (Jones et al. 1999) and Slippery Creek in the central area (Beers 1999). In the Sitka Management Area, ADF&G has conducted a CWT program to assess fishery impacts on coho salmon native to Ford Arm, on Chichagof Island, since 1982 (Shaul and Crabtree 1998). Ford Arm is the only system in the Sitka Management Area with an ongoing comprehensive coho salmon stock assessment program. On Baranof Island, the Division of Sport Fish conducted a CWT project to assess fishery impacts to Salmon Lake coho salmon from 1983 to 1990 and again in 1994–1995. Schmidt (1996) reported an increase in exploitation rates from 35% in 1985 to 72% in 1989, and a decrease in spawning escapements from 1,514 in 1984 to 204 in 1990 for Salmon Lake coho salmon.

In 1998, Sport Fish Division staff began a CWT project for coho salmon in the Nakwasina River. This project was initiated to supplement a regionwide effort to assess the status of key coho salmon stocks in Southeast Alaska. Recoveries in fall 1999 provided the first estimate of harvest and smolt abundance for this stock. The specific objectives of this study were to estimate the marine harvest of coho salmon from Nakwasina River in 1999 via recovery of coded wire tags (CWTs) applied in 1998, and estimate of the number of coho salmon leaving the Nakwasina River in 1998.

STUDY AREA

The Nakwasina drainage is one of the larger riverine systems on Baranof Island (Figure 1). The anadromous reach includes about 5 miles upstream from the mouth and empties into Nakwasina Sound about 15 miles north of Sitka.

Since 1988, foot surveys have been conducted on the Nakwasina River to provide an index of annual coho escapement abundance trends. Aerial and foot surveys conducted from 1988 to 1997 have documented 104 (1988) to 654 (1993) coho salmon spawners in the Nakwasina River (Integrated Fisheries Database, Commercial Fisheries Division, Douglas). Average survey counts in the Nakwasina River represent the third largest of seven systems surveyed annually in the Sitka area.

The Nakwasina River is important to the area's sport fisheries because it supports a significant population of coho salmon, is easily accessed from Sitka, and is one of the few rivers in Sitka Sound that attract freshwater sport fishing effort for coho salmon. From 1984 to 1997, annual harvests of coho salmon in Nakwasina Sound, including the Nakwasina River, ranged from 0 to 182 fish (Howe et al. 1997; A.L. Howe, Division of Sport Fish, Anchorage, personal communication). Estimated angler effort expended in Nakwasina Sound and River (for all fish species) ranged from 31 to 891 angler-days.

In the 1960s, the majority of riparian area in the anadromous portion of the Nakwasina River valley was clear-cut to the stream bank (Greg Killinger, Sitka Ranger District, U.S. Forest Service, Sitka). Nakwasina River coho salmon are of special concern because of the potential risk of excessive exploitation in combination with likely impacts to the stock from habitat damage.

METHODS

SMOLT CAPTURE, CODED-WIRE-TAGGING, AND SAMPLING

Between 50 and 100 G-40 minnow traps were baited with salmon roe and fished daily from April 15 to May 20, 1998, in the Nakwasina River. Traps were set along mainstem banks in backwater areas of the lower river between the estuary and approximately river mile 3. Traps were fished for 24 hours per day approximately 6 days per week and checked at least once each day.

Coho salmon smolt and fry were removed from minnow traps, transported to holding pens at camp, and processed every 2 to 3 days. Other species (primarily Dolly Varden *Salvelinus malma*) were counted and released on site. All live coho salmon smolt ≥70 mm fork length (FL) were tranquilized with a solution of tricane-methane sulfonate (MS222), injected with a coded wire tag, and marked externally by the excision of their adipose fin, following methods in Koerner (1977). All tagged fish were held overnight in a net pen to test for mortality and tag retention and released. To test for tag retention, 100 fish were randomly selected and passed through a Northwest Marine Portable Sampling Detector™. If tag retention was 98/100 or greater, all fish were counted, mortalities recorded, and released. If tag retention was 97/100 or less, all fish were reprocessed. The number of fish tagged, number of tagging-related mortalities, and number of fish that had shed their tags were compiled and recorded on *ADF&G Tagging Summary and Release Information Forms* which were submitted to ADF&G Commercial Fisheries Division (CF) Tag Lab in Juneau when field work ended. The tag codes used in 1998 were 04-46-29 and 04-46-30.

Tagged smolt were sampled for fork length, sampled for scales, and weighed to the nearest 0.1g. Each fish was measured to the nearest 1mm fork length. Twelve to 15 scales were removed from the preferred area (Scarnecchia 1979) on the left side of the coho salmon smolt. Scales were sandwiched between two 1-in. × 3-in. microscope slides and the slides taped together. Scales were numbered consecutively for each fish. In addition, the number of each fish was written on the frosted portion of the bottom slide according to scale position on the slide. Although the sampling goal was 1 in every 15 fish (6.7%), the actual sampling rate varied between 3.2% to 12.6%. Average daily sampling rate for the duration of tagging was 8.4%.

Estimates of mean length and weight at age and their variances were calculated with standard normal procedures.

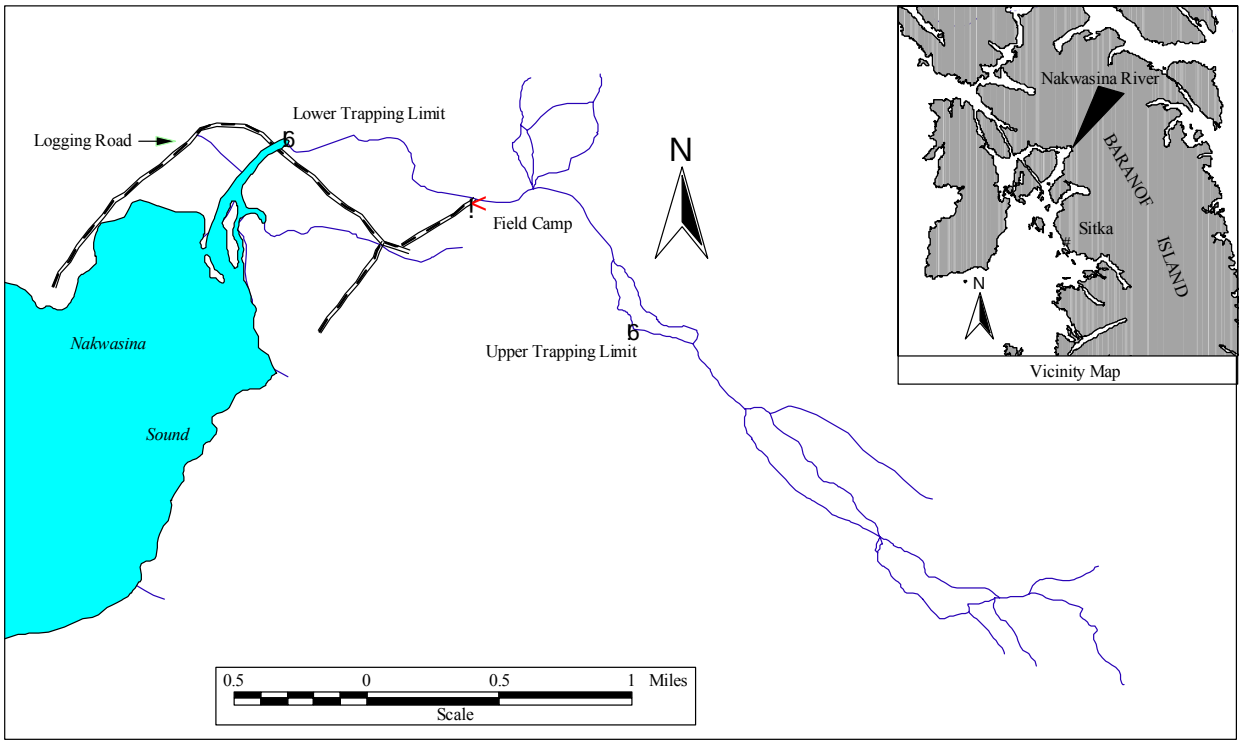

Figure 1.– Nakwasina River study area, major tributaries, and location of ADF&G research site.

ESCAPEMENT SAMPLING

Adult coho salmon were sampled in the Nakwasina River from September 27 through December 9, 1999, to estimate the fraction of tagged adults carrying CWTs. The salmon were captured by hook and line gear and a 3-in. mesh, 8' × 75' beach seine. Weekly field trips to the river began the first week of September, but no adults were observed until the end of September. Sampling began September 27, one to two days per week, and continued until October 26, when high, turbid water conditions precluded efforts. When weather conditions improved, a field camp was established and 5 days of fishing (November 9, 10, 11, 15 and 16) commenced. The last day of sampling occurred December 9.

Sampling effort occurred between river mile 0 and 5. Most sampling took place at two pools just upstream of river mile 1. Efforts were concentrated at this location because most of the fish in the river seemed to be in these two holes, and use of the beach seine was possible. Accordingly, most fish sampled were captured at this location.

Captured coho salmon were examined for presence or absence of their adipose fin, measured to the nearest mm FL, and given a secondary clip to prevent duplicate sampling. Secondary marks included a lower left operculum punch (between September 27 and October 26) and an upper left operculum punch (between November 9 and December 9). No fish were captured between October 26 and November 9. Sex was determined and scale samples were collected for each fish captured.

For all fish missing adipose fins, CWT presence was verified with a portable tag detector. Any fish with a missing adipose fin and a negative detection signal was sacrificed and its head sent to the tag lab for verification of CWT absence or decoding, if actually present. For all other fish with a CWT detected, tag location was assumed to be the Nakwasina River.

Scale samples consisted of 4 scales from the preferred area near the lateral line on an imaginary line from the posterior dorsal fin to the anterior anal fin (Scarnecchia 1979). Scales were affixed

to a gummed card in the field. Ages were determined by examining the impressions under a microscope. Criteria used to assign ages were similar to those of Moser (1968).

ESTIMATE OF SMOLT ABUNDANCE

The mark-recapture experiment based on coho salmon smolts and returning adults was Chapman's modification of the Petersen Method (Seber 1982). To estimate abundance of smolts and its variance we used:

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

$$V[\hat{S}] = \frac{\hat{S}(M-R)(C-R)}{(R+1)(R+2)} \qquad (2)$$

where

$\hat{S}$ = estimated abundance of smolts in 1998,

M = number of marked smolts released alive into the population in 1998,

C = number of adults inspected for marks in 1999,

and

R = number of adults with missing adipose fins in samples taken in 1999.

ESTIMATE OF HARVEST

Harvest in 1999 of coho salmon originating from the Nakwasina River was estimated from fish sampled from catches in commercial and recreational fisheries. Because several fisheries exploited coho salmon over several months in 1999, harvest was estimated over several strata, each a combination of time, area, and type of fishery. Statistics from the commercial troll fishery were stratified by fishing period and by fishing quadrant. Statistics from the recreational fishery were stratified by fortnight. Estimates of harvest $(\hat{r}_i)$ were calculated for each stratum, and then summed across strata and across fisheries to obtain an estimate of the total harvest $(\hat{T})$ (Appendix A2):

$$\hat{T} = \sum_i \hat{r}_i \qquad (3)$$

$$v[\hat{T}] = \sum_i v[\hat{r}_i] \qquad (4)$$

A subset n_i of the catch in each stratum was counted and inspected to find recaptured fish. Of those a_i salmon in this sample without the adipose fin, heads were retrieved from a subset, marked, and sent to Juneau for dissection. Of the a_i' heads that arrived in Juneau, all were passed through a magnetometer to detect a CWT. Of the t_i tags detected, t_i' were successfully decoded under a microscope, after dissection of which m_{ci} had come from the Nakwasina River. Oliver (1990) and Hubartt et al. (1998) present details of sampling commercial and recreational fisheries, respectively. The fraction of the return to the Nakwasina River with tags was estimated as the fraction of the return sample of adults with valid, decoded CWTs $(\theta_h = m_e / n_e)$. Information from catch and field sampling programs was expanded to estimate harvest and the associated variance of coho salmon bound for the Nakwasina River for each stratum, using methods and equations from Bernard and Clark (1996: Table 2).

Fisheries personnel with the ADF&G CF port sampling program examined commercially caught fish at processing locations and recovered coho with missing adipose fins. Similarly, the Division of Sport Fish employed a creel survey program to examine fish caught in the sport fishery. When possible, the heads of fish without an adipose were removed and sent to the ADF&G Coded Wire Tag and Otolith Processing Laboratory for tag detection and decoding.

AGE AND SEX COMPOSITION:

$$\hat{p}_j = \frac{n_j}{n} \qquad (5)$$

$$Var(\hat{p}_j) = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1} \qquad (6)$$

where

p_j = the proportion in the population in group j,

n_j = the number in the sample of group j,

and

n = sample size.

Systematic selection of samples promoted proportional sampling and reduced bias from any inseason changes in age composition.

RESULTS

SMOLT TAGGING, AGE, LENGTH AND WEIGHT IN 1998

From April 15 through May 20, 1998, 9,985 coho salmon smolt ≥70 mm FL were captured and tagged (Table 1). Five died within 24 h of tagging, leaving a total release of 9,980 marked smolts. Tag retention measured 24 h after tagging was 100%.

Age-1. fish, those rearing for one year in freshwater, constituted 95% of sampled smolt and averaged 82 mm FL (SE = 0.30) and 5.6 g (SE = 0.07) in weight (Table 2). Age-2. coho smolt averaged 98 mm FL (SE = 1.77) and 9.2 g (SE = 0.52). The combined catch averaged 83 mm FL (SE = 0.32) and 5.8 g (SE = 0.08) (Figure 2). Average size of captured coho remained about the same throughout the tagging effort.

Numbers of coho caught per trap checked remained approximately the same throughout the duration of the tagging effort (Figure 3).

CODED WIRE TAG RECOVERY

In 1999, 55 CWTs from the Nakwasina River were recovered from coho salmon in the sampled fisheries. Of these, 49 were random recoveries (Table 3). Detailed capture and release information for each recovered tag is provided in Appendix A1.

Forty-six (46) CWT fish from the Nakwasina River were recovered from Southeast Alaska's commercial troll fisheries. Of these, all but one were caught in the Northwest Quadrant (Figure 4) of Southeast Alaska between July 8 and September 20, 1999 (Table 4). One fish was caught in the Southeast Quadrant. Three (3) Nakwasina River coho were recovered in the 1999 sport fishery. Of these, all were recovered in the Sitka area between July 13 and August 12. No fish were recovered in the commercial gillnet or seine fisheries. Fish recovered in the commercial and sport fisheries averaged 602 mm FL (SE = 6.07).

ESTIMATED SMOLT ABUNDANCE

The estimate of smolt abundance for the Nakwasina River in 1998 was 102,794 (SE = 15,255). Of 411 adult coho salmon examined in the Nakwasina River during 1999, 39 had adipose finclips and coded wire tags (Table 5). The tagging fraction (θ) for the Nakwasina River in 1998 was 0.095 (SE = 0.014). No tag was detected in the field for 4 of the 39 finclipped fish. All four were sacrificed, sent to the tag lab to search for CWTs, and found to contain tags implanted at the Nakwasina River in 1998.

The proportion of age-1. fish was not significantly different ($\chi^2 = 0.91$, P = 0.34) between the smolt sampled in 1998 and the adult coho sampled inriver during 1999 (Table 6). Both groups were predominately (>95%) age-1. fish. Similarly, there was no difference in age composition between tagged and non-tagged adults sampled inriver ($\chi^2 = 0.10$, P = 0.75). The size of captured adults did not change over time (F = 1.82, P = 0.18) or between gear types (F = 2.05, P = 0.15).

The proportion of tagged adults sampled inriver did not change significantly over time ($\chi^2 = 2.86$, P = 0.24) or between gear types ($\chi^2 = 2.06$, P = 0.15). Therefore, it is unlikely that differences occurred in the return rate of tagged fish or that gear was selective for or against fish with tags.

Most (251) adults examined were sampled during November; 78 were sampled December 9, and the remainder (82) were sampled in September and October (Figure 5). Most (338) fish were captured with beach seine, and the remainder (73) were captured with hook and line. Spinning and snagging gear was used to capture fish in September and October, before large numbers of fish were observed in holes. Spinning and snagging gear was moderately effective at capturing fish, but only when water conditions were good enough to see fish. In November, the use of a beach seine, which was more effective in tangling, as opposed to seining fish, seemed to be the most effective means of capture. Most fish sampled in October were very bright. Fish were still entering the river in the middle of November,

Table 1.–Daily fishing effort, catch, CPUE and mean size of coho salmon smolt ≥70 mm FL caught in minnow traps in Nakwasina River, 1998. Estimated catch includes recaptured fish and fish <70 mm FL.

Date	Water temperature	Estimated catch	Number of traps checked	Fish per trap check	Average smolt size (mm)	Number of fish tagged
4/19/1998	6	65	26	3		
4/20/1998	6	544	68	8		
4/21/1998	6	379	55	7		
4/22/1998	6.5	430	71	6		
4/23/1998	6.5	320	70	5		
4/24/1998	6.5		no trapping effort		81.2	1,076
4/25/1998	5	276	65	4		812
4/26/1998	5		no trapping effort			
4/27/1998	.	384	69	6		
4/28/1998	5	420	85	5	80.4	649
4/29/1998	5.5	584	106	6	84.7	
4/30/1998	5	78	19	4		1,010
5/1/1998	5	439	87	5	84	
5/2/1998	5	259	57	5		
5/3/1998	5		no trapping effort			
5/4/1998	5	218	52	4	83	929
5/5/1998	5	533	124	4	85.9	
5/6/1998	5	377	84	4		
5/7/1998	5	278	54	5	83.4	818
5/8/1998	5.5	649	100	6		
5/9/1998	5.5	713	117	6		
5/10/1998	5.5		no trapping effort		82.6	1,569
5/11/1998	5.5	497	56	9	83.4	
5/12/1998	6	796	121	7		
5/13/1998	6	250	42	6	83.6	1,441
5/14/1998	5.5	644	101	6		
5/15/1998	5.5	283	64	4	85.2	795
5/16/1998	.		no trapping effort			
5/17/1998	.		no trapping effort			
5/18/1998	5	545	81	7		
5/19/1998	5	439	89	5		
5/20/1998	5	218	61	4	82.7	886
Total		10,618	1,924	6		9,985

Table 2.–Estimated length (mm), weight (g), and age of coho salmon smolt in the Nakwasina River, 1998.

	Age 1		Age 2		Combined	
	Length	Weight	Length	Weight	Length	Weight
Mean	82.54	5.66	97.84	9.21	83.31	5.85
Sample variance	64.24	2.76	118.89	9.18	78.04	3.73
Standard error	0.30	0.07	1.77	0.52	0.32	0.08
Count	717	601	38	34	755	635
Minimum	69	3.1	79	4.9	69	3.1
Maximum	111	12.5	120	17.1	120	17.1

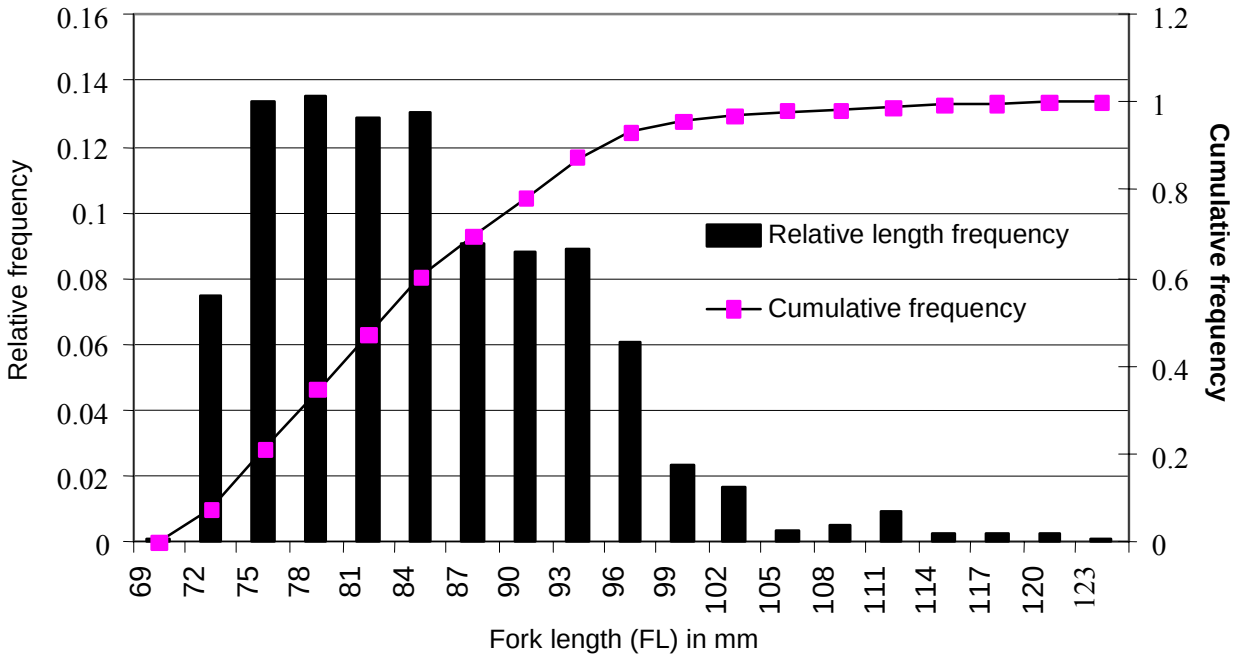

Figure 2.–Relative length frequency of coho salmon smolt ≥70 mm FL captured and measured at Nakwasina River, 1998.

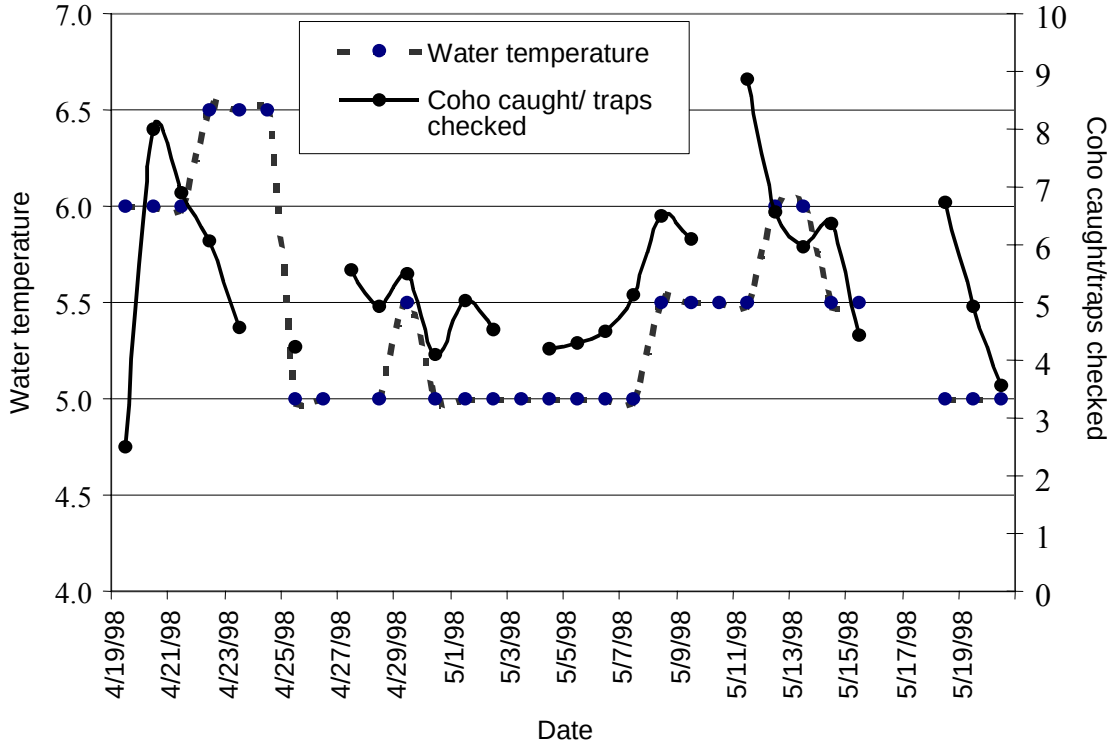

Figure 3.–Daily coho captures per trap checked and water temperature in the Nakwasina River, 1998.

Table 3.–Estimated harvest of adult Nakwasina River coho (tag codes 04-46-29 and 04-46-30) in sampled sport and commercial fisheries in 1999.

TROLL FISHERY										
Quadrant	Dates	N	n	a	a'	t	t'	m	r_1	SE
NW	6/27–8/14	934,245	239,684	4,776	4,695	3,947	3,941	28	1,172	287
NW	8/15–10/9	547,199	144,191	3,606	3,564	3,093	3,088	17	688	197
SE	6/27–8/14	121,202	65,626	1,172	1,159	871	869	1	20	19
Subtotal		1,602,646	449,501					46	1,880	503
SPORT FISHERY										
Bi-week	Dates	N	n	a	a'	t	t'	m	r_1	SE
14	7/5–7/18	8417	2,835	42	41	35	35	1	32	32
15	7/19–8/1	13,467	4,159	87	84	81	81	1	35	35
16	8/2–8/15	17,932	5,582	154	146	131	131	1	36	35
Subtotal		39,816	12,576					3	103	102
Total 1999 harvest		1,642,462						49	1,983	605

as evidenced by the presence of sea lice. The last sampling occurred December 9 when, although most of the fish were dark or ripe, some bright fish were observed.

HARVEST CONTRIBUTION

The estimated harvest of Nakwasina River coho salmon in sampled commercial and sport fisheries in 1999 was 1,983 (SE = 605) (Table 3). Nakwasina coho contributed less than 1% of the coho salmon harvested in the combined sport and commercial troll fisheries (1,642,462 fish) for the areas in which Nakwasina River fish were recovered. The total contribution to the sport fishery by Nakwasina coho was estimated at 103 fish. Sport-caught Nakwasina coho constituted

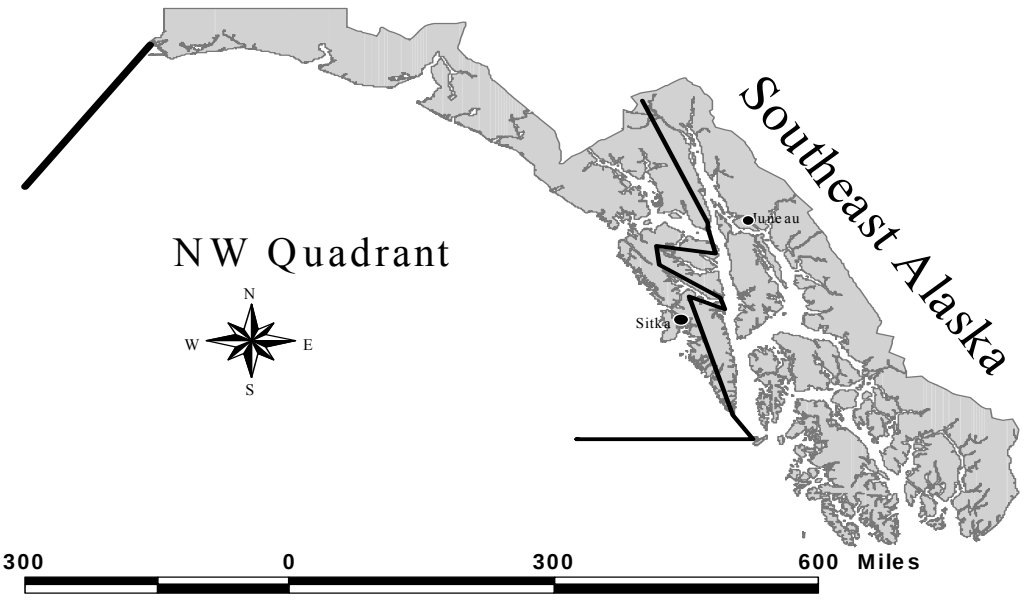

Figure 4.–Boundary of Northwest quadrant in Southeast Alaska.

Table 4.–Sampled troll fisheries in 1999 that contained coho salmon, and numbers of random CWT recoveries from smolt marked at Nakwasina River in 1998.

Time period	Dates	Quadrant	Tag code 04-46-29	Tag code 04-46-30	Sampled harvest	Total harvest	Percent sampled
2	5/2–6/26	NE			128	2,105	0.06
2	5/2–6/27	NW			1,980	4,636	0.43
2	5/2–6/28	SE			475	1,214	0.39
3	6/27–8/17	NE			1	110	0.01
3	6/27–8/18	NW			1,191	3,844	0.31
3	6/27–8/14	NE			72,468	205,680	0.35
3	6/27–8/15	NW	15	13	239,684	934,245	0.26
3	6/27–8/16	SE		1	65,626	121,202	0.54
3	6/27–8/17	SW			85,717	217,193	0.39
4	8/15–10/9	NE			36,415	100,892	0.36
4	8/15–10/10	NW	10	7	144,191	547,199	0.26
4	8/15–10/11	SE			35,346	91,203	0.39
4	8/15–10/12	SW			17,534	42,754	0.41
Total			25	21	700,756	2,272,277	0.31

about 5.3% of the harvest of that stock in the sampled marine fisheries, but relative contributions were higher for the sport harvest (0.3%) than for the troll harvest (0.1%). Freshwater harvest of coho salmon in the Nakwasina River will not be available until the Division of Sport Fish publishes the results of its annual mailout angler survey in September 2000.

DISCUSSION

Several assumptions were required in the design of this study:

1. all smolts had an equal probability of being marked in 1998, or

   all adults had an equal probability of being inspected for marks in 1999, or

   marked fish mixed completely with unmarked fish in the population between years, and
2. there was no recruitment, immigration or emigration to the population between years, and
3. there was no tagging induced behavior or mortality, and
4. fish did not lose their marks and all marks were recognizable.

We believe that most of these assumptions were met; the first was the most difficult. It assumes that all smolt had the same probability of capture regardless of time of smolting, location in the river, or size. Smolt capture and tagging occurred throughout the emigration, within most of the available smolt habitat, and was also accomplished with minnow traps that would capture a wide range of smolt sizes encompassing the entire geographic range of smolt observed in the river. Because approximately equal effort occurred throughout the emigration, later running smolt may have had a higher probability of capture. Similarly, recovery effort was expended throughout most of the run of returning adults, but not in exact proportion to fish abundance, and a small number of fish probably returned earlier or later than the tag recovery sampling.

Although the assumption about mixing cannot be tested, coho salmon mix within or across stocks during their extended time (14 months) at sea. This should provide adequate mixing of the population. In catches in the Nakwasina River, the fraction of adult coho salmon with marks (missing an adipose fin) did not vary significantly over time. This indicates that one, two, or all of the conditions in assumption 1 were satisfied.

Table 5.–Number of adult salmon captured and examined in the Nakwasina River to estimate tagged ratio (θ), 1999.

Date	Total captured	Number tagged	Proportion tagged	Cumulative total	Cumulative number. tagged	Cumulative tagged proportion	Gear used	
							Hook and line	Seine
1-Oct	7	2	0.29	7	2	0.28	7	
1-Oct	18	1	0.06	25	3	0.12	18	
5-Oct	22	4	0.18	47	7	0.14	22	
9-Oct	8	2	0.25	55	9	0.16	8	
26-Oct	23	3	0.13	78	12	0.15	14	9
26-Oct	4	0	0	82	12	0.14	4	
9-Nov	38	5	0.13	120	17	0.14		38
9-Nov	23	2	0.09	143	19	0.13		23
10-Nov	38	4	0.11	181	23	0.12		38
10-Nov	38	5	0.13	219	28	0.12		38
10-Nov	3	1	0.33	222	29	0.13		3
11-Nov	38	4	0.11	260	33	0.12		38
15-Nov	6	0	0	266	33	0.12		6
16-Nov	29	0	0	295	33	0.11		29
15-Nov	38	1	0.03	333	34	0.10		38
9-Dec	34	1	0.03	367	35	0.10		34
9-Dec	44	4	0.09	411	39	0.10		44
Total	411	39	0.09				73	338

The next assumption required for this study was that there was no recruitment to the population between years. Because almost all salmon return to their natal streams and sampling for θ only occurred in the river, there was probably no appreciable recruitment to the stock between marking and recovery. The results from analysis of four heads sacrificed inriver showed each fish originated in the Nakwasina River. We believe the presence of stray coho salmon reared at Medvejie hatchery is possible but unlikely given the geographical distance between the two sites.

Marine survival rates for Nakwasina River coho salmon can only be guessed because escapement abundance was not known. Other studies (McPherson et al. 1996; Jones and McPherson 1997) have shown that visual peak survey counts of coho salmon represent approximately 20% of mark-recapture (total escapement) estimates. If a factor of five is applied to the 1999 survey count (290 fish), escapement may be approximated at 1,500 fish. Combining this with the harvest estimate of 1,983 fish results in an estimated adult return of 4,000 fish. Given our estimate of smolt abundance, marine survival would be approximately 3.4%.

If marine survival for Nakwasina coho salmon was as low as it appears, it represents less than 50% of the lowest survival rate estimated for wild-stock returns in Southeast Alaska in 1999.

On the Taku River, the 1998–99 marine survival was 9.9%, (Richard Yanusz, Alaska Department of Fish and Game, Douglas, personal communication) and on the Unuk River, it was 9.2% (Ed Jones, Alaska Department of Fish and Game, Douglas, personal communication). Smolt to return survival rates (1998–1999) for coho salmon in Auke Lake, Berners River, and Hugh Smith Lake were 20%, 13%, and 14%, respectively, and in Ford Arm Lake, pre-smolts tagged in the fall preceding emigration averaged 12% survival for the same period (Stopha 2000).

Factors that may potentially influence estimates of survival include incomplete fishery sampling (underestimating harvest), post-24-h tagging

Table 6.–Number of coho salmon smolt examined in 1998 in the Nakwasina River and adults examined in 1999, by freshwater age class.

Smolt 1998			Adults 1999		
Date	Age-1	Age-2	Date	Age-1	Age-2
4/24	58	1	9/26	1	
4/28	32		9/27	6	
4/29	26	3	10/1	13	2
5/1	112	10	10/5	18	1
5/4	71	5	10/9	7	
5/5	33	6	10/26	24	
5/7	98	4	11/9	46	1
5/10	55	1	11/10	61	4
5/11	47		11/11	30	2
5/13	90	3	11/15	34	2
5/15	50	2	11/16	20	
5/20	49	3	12/9	78	
Total	721	38		338	12

	Smolt	Adults
Proportion of age-1 fish	0.95	0.97
SE	0.0079	0.0097

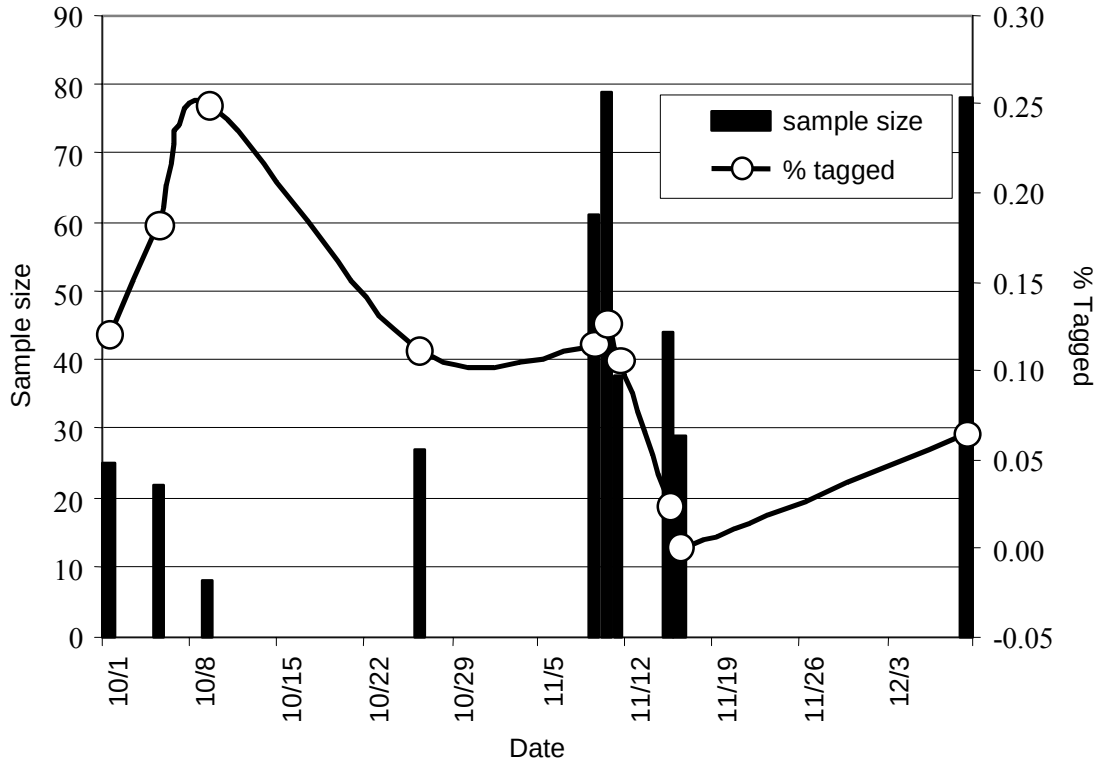

Figure 5.–Marked fraction (of CWTs) and sample size of examined adult coho in the Nakwasina River in 1999.

mortality (overestimating smolt abundance), relatively inefficient escapement surveys, and fish holding over in fresh water (after tagging) to emigrate as age-2. smolt. To assess the adequacy of sampling rates in the purse seine and gillnet fisheries, we examined purse seine and gillnet harvests that occurred within the Northwest Quadrant where all but one Nakwasina River coho salmon recovery occurred (Table 7). Sampling rates in the purse seine fisheries within the Northwest Quadrant ranged from 2% (Districts 105 and 114) to 6% (District 113, traditional and terminal area harvest combined). The likelihood was therefore increased that Nakwasina River coho salmon carrying CWTs were missed and harvest underestimated in the net fisheries. Of 33 tags recovered from the Northwest Quadrant troll fishery and identified by District, 26 (79%) were recovered in District 113. As 12,671 coho salmon were harvested in the District 113 purse seine fisheries, the potential harvest of Nakwasina River coho is probably small relative to the purse seine harvest, but it may be significant relative to the estimated harvest of Nakwasina River coho.

The coho salmon harvest in the District 113 drift gillnet fishery was underreported and sampled at a very low rate. The only gillnet fishery within District 113 targets hatchery-produced chum salmon in the Deep Inlet Terminal Harvest Area. This fishery was sampled for coho salmon CWT recovery September 21, when 13 coho salmon were examined from only four vessels observed fishing. Fishers interviewed on each vessel reported similar or greater catches per boat-day during previous openings when fishing effort was higher. Fishers also reported that most coho were kept for home use and not recorded on fish tickets. For these reasons, the reported harvest of 112 coho salmon probably represents only a fraction of the actual harvest and the harvest of Nakwasina River coho salmon in this fishery was likely underestimated. In a similar study, Schmidt (1996) estimated that the Deep Inlet gillnet fishery harvested 7% of the total harvest of another Sitka Sound coho salmon stock, but considered that estimate biased low due to underreporting and sampling problems similar to those experienced during 1999.

Although we have no direct evidence, it is possible that the capture and tagging procedures caused fish to emigrate the system prematurely. This premature emigration may increase the mortality rate of tagged fish and subsequently bias the estimate of abundance high and the estimate of marine survival low. The observed recapture rate of previously marked smolt was 4.8%, not unexpected given the smolt estimate and number of fish tagged.

Based on the age composition observed for 1998 smolt, it is also possible that some fish tagged in 1998 remained in fresh water an additional year to smolt and emigrate in 1999. However, very few recaptures were observed during smolt capture and tagging operations in 1999, suggesting that few fish remained in fresh water.

In future tagging events, extra care should be taken to ensure that effects of tagging are minimized. Recommendations for future tagging include: 1) releasing fish in side tributaries with extensive available rearing habitat as opposed to mainstem areas with higher velocities; 2) minimizing transport distances by centralizing the tagging and holding site; and 3) tagging and sampling all fish within 48 hours of capture to ensure fish are not held for periods longer than 72 hours, including overnight mortality testing. Future study design should also address the problems encountered in sampling the 1999 commercial purse seine and gillnet fisheries, to ensure accurate harvest estimates and adequate CWT sampling rates—particularly for fisheries in District 113.

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Table 7.–Numbers of fish harvested and sampled for CWT recovery for districts in which Nakwasina River coho were recovered.

District	Gear type	Fish harvested	Fish sampled	Proportion sampled
105	Purse	3,211	55	0.02
	Troll	106,230	34,239	0.32
113	Drift	112	16	0.14
	not reported	12		0.00
	Purse	12,671	806	0.06
	Troll	823,637	172,911	0.21
114	Purse	32,987	639	0.02
	Troll	266,306	47,911	0.18
116	Troll	226,686	43,746	0.19
156	Troll	5,668		0.00
183	Set	9,029		0.00
	Troll	29,613	1,511	0.05
Total		1,516,162	301,834	0.20

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APPENDIX A

Appendix A1–Recoveries of coded wire tags from Nakwasina River coho salmon during 1999.

Sampling type	Head no.	Tag code	Survey site	Source	Date (CWT)	Stat week (CWT)	Quad	District		Length (mm)	Expansion factor	Contribution
Random	69612	44630	SITKA	SPORT	13-Jul-99	29	NW	113	41	590	3.04	3.04
Random	69524	44629	SITKA	SPORT	30-Jul-99	31	NW	113	61	645	3.35	3.35
Random	69953	44629	SITKA	SPORT	12-Aug-99	33	NW	113	41	610	3.39	3.39
Random	142013	44630	ELFIN COVE	TROLL	12-Jul-99	29	NW	114	21	540	3.97	3.97
Random	142195	44629	ELFIN COVE	TROLL	9-Aug-99	33	NW	114		730	3.97	3.97
Random	28794	44630	EXCURSION	TROLL	28-Jul-99	31	NW			571	3.97	3.97
Random	53611	44629	HOONAH	TROLL	27-Jul-99	31	NW	116	11	625	3.97	3.97
Random	53603	44630	HOONAH	TROLL	27-Jul-99	31	NW	116	11	610	3.97	3.97
Random	53612	44630	HOONAH	TROLL	27-Jul-99	31	NW	116	11	620	3.97	3.97
Random	55128	44629	HOONAH	TROLL	9-Aug-99	33	NW	113		590	3.97	3.97
Random	55106	44630	HOONAH	TROLL	11-Aug-99	33	NW	113	93	600	3.97	3.97
Random	55617	44630	JUNEAU	TROLL	13-Aug-99	33	NW	113	91	631	3.97	3.97
Random	90289	44630	PELICAN	TROLL	9-Aug-99	33	NW	116	12	627	3.97	3.97
Random	91029	44629	PELICAN	TROLL	22-Aug-99	35	NW			605	3.84	3.84
Random	91037	44629	PELICAN	TROLL	22-Aug-99	35	NW			605	3.84	3.84
Random	91076	44629	PELICAN	TROLL	23-Aug-99	35	NW	113	91	607	3.84	3.84
Random	91782	44629	PELICAN	TROLL	7-Sep-99	37	NW	113	91	593	3.84	3.84
Random	68013	44630	PETERSBURG	TROLL	12-Aug-99	33	SE	105	50	570	1.87	1.87
Random	128063	44629	SITKA	TROLL	8-Jul-99	28	NW	113	31	576	3.97	3.97
Random	138002	44630	SITKA	TROLL	17-Jul-99	29	NW	113	91	556	3.97	3.97
Random	133661	44630	SITKA	TROLL	19-Jul-99	30	NW			577	3.97	3.97
Random	133725	44629	SITKA	TROLL	20-Jul-99	30	NW	113	41	576	3.97	3.97
Random	138248	44630	SITKA	TROLL	22-Jul-99	30	NW			582	3.97	3.97
Random	138511	44629	SITKA	TROLL	25-Jul-99	31	NW	113	45	633	3.97	3.97
Random	138138	44629	SITKA	TROLL	26-Jul-99	31	NW			608	3.97	3.97
Random	137083	44630	SITKA	TROLL	29-Jul-99	31	NW	113	41	598	3.97	3.97
Random	137306	44630	SITKA	TROLL	1-Aug-99	32	NW			570	3.97	3.97
Random	137616	44629	SITKA	TROLL	3-Aug-99	32	NW	113	31	631	3.97	3.97
Random	137336	44629	SITKA	TROLL	5-Aug-99	32	NW			550	3.97	3.97
Random	138331	44629	SITKA	TROLL	6-Aug-99	32	NW	113	41	578	3.97	3.97
Random	137577	44629	SITKA	TROLL	10-Aug-99	33	NW	113	41	589	3.97	3.97
Random	136906	44629	SITKA	TROLL	11-Aug-99	33	NW	113	91	586	3.97	3.97
Random	137786	44629	SITKA	TROLL	11-Aug-99	33	NW	113		558	3.97	3.97
Random	136944	44629	SITKA	TROLL	12-Aug-99	33	NW	113	41	613	3.97	3.97
Random	136632	44629	SITKA	TROLL	12-Aug-99	33	NW	113	45	632	3.97	3.97
Random	136600	44630	SITKA	TROLL	12-Aug-99	33	NW			606	3.97	3.97
Random	141354	44629	SITKA	TROLL	21-Aug-99	34	NW	113	45	652	3.84	3.84
Random	137891	44629	SITKA	TROLL	22-Aug-99	35	NW			456	3.84	3.84
Random	136806	44629	SITKA	TROLL	23-Aug-99	35	NW	113	41	615	3.84	3.84
Random	136492	44630	SITKA	TROLL	23-Aug-99	35	NW	113	41	504	3.84	3.84
Random	141732	44629	SITKA	TROLL	2-Sep-99	36	NW	116	11	607	3.84	3.84
Random	141654	44630	SITKA	TROLL	2-Sep-99	36	NW	113	41	619	3.84	3.84
Random	141635	44630	SITKA	TROLL	2-Sep-99	36	NW	113	41	638	3.84	3.84
Random	141611	44630	SITKA	TROLL	2-Sep-99	36	NW	113	41	660	3.84	3.84
Random	141786	44630	SITKA	TROLL	3-Sep-99	36	NW	113	41	630	3.84	3.84
Random	138643	44630	SITKA	TROLL	6-Sep-99	37	NW			643	3.84	3.84
Random	133812	44629	SITKA	TROLL	9-Sep-99	37	NW			630	3.84	3.84
Random	140000	44630	SITKA	TROLL	14-Sep-99	38	NW	113	41	650	3.84	3.84
Random	139572	44629	SITKA	TROLL	20-Sep-99	39	NW	113	91	644	3.84	3.84
Select	133085	44629	SITKA	TROLL	9-Jul-99	28	NW	183				
Select	137022	44629	SITKA	TROLL	26-Jul-99	31	NW					
Select	136752	44629	SITKA	TROLL	11-Aug-99	33	NW	156				
Select	141066	44630	SITKA	TROLL	12-Aug-99	33	NW					
Select	45880	44629	YAKUTAT	TROLL	23-Jul-99	30	NW	116				
Select	69777	44630	SITKA	SPORT	16-Aug-99	34	NW	113	31			

Appendix A2.–Equations for estimating harvests in coded-wire-tagging experiments (Bernard and Clark 1996).

Equations for estimating harvests in coded-wire-tagging experiments (Bernard and Clark 1996) were employed to estimate the fraction of a cohort that must be tagged (θ) to yield a given relative precision in a contribution estimate. When large samples are available from the fisheries and both the catch and fraction marked (θ) are known without error, variance in stratum i is:

$$V[\hat{r}_i] = \frac{\hat{r}_i}{\lambda_i \phi_i \theta}(1 - \lambda_i \phi_i \theta) \tag{A1}$$

where Table A.1 below explains the notation. Since harvests for a cohort are estimated by stratum, relative precision for all harvests is calculated by summing statistics across strata:

$$RP_{\alpha/2}[\hat{r}_i] = Z_{\alpha/2}\frac{\sqrt{\sum_i V[\hat{r}_i]}}{\sum_i \hat{r}_i} \tag{A2}$$

Whenever N and θ are known, Equations A1 and A2 can be used directly to determine the value of θ that will produce an estimate of the harvest from each cohort. However, θ is estimated for coho salmon from the Nakwasina River, and some fish are caught in recreational fisheries in which N is estimated.

When N and θ are estimated with significant error, the intuitive estimator can be restructured to isolate statistics generated from the sampling programs to estimate harvest, sample catch for tags, and estimate the fraction of the cohort with marks (Bernard & Clark 1996):

$$\hat{r}_i = \hat{N}_i\left(\frac{t_i a_i m_i}{t'_i a'_i n_i}\right)\hat{\theta}^{-1} = \hat{N}_i\left(\frac{m_i}{\lambda_i n_i}\right)\hat{\theta}^{-1} = \hat{N}_i \hat{p}_i \hat{\theta}^{-1} \tag{A3}$$

Because N and θ are fixed, $\hat{p}$ is an unbiased estimate of the fraction of the catch composed of the subset of a cohort that had been tagged ($[p \equiv x_1/N)$ because $E[\hat{p}_i] = E[\hat{r}_i]\theta N_i^{-1} = \hat{r}_i \theta N_i^{-1} = p_i$. Under these circumstances, $CV[\hat{p}_i] = CV[\hat{r}_i]$. Dividing both sides of Equation A1 by r_i^2 produces:

$$G(\hat{p}_i) = CV^2[\hat{p}_i] = \frac{V[\hat{p}_i]}{\hat{p}_i^2} = \frac{V[\hat{r}_i]}{\hat{r}_i^2} = \frac{1 - \lambda_i \phi_i \theta}{m_i} \tag{A4}$$

The relationship between $G(\hat{p}_i)$ and $v[\hat{r}_i]$ can be derived from the exact variance of the product of two or three means as described in Goodman (1960). If the harvest of fish from Nakwasina River is known and θ is estimated:

$$V[\hat{r}_i] = \hat{r}_i^2\left[G(\hat{p}_i) + G(\overline{\theta^{-1}}) - G(\hat{p}_i)G(\overline{\theta^{-1}})\right] \tag{A5}$$

If the harvest and θ are estimated:

$$\begin{aligned} V[\hat{r}_i] = \hat{r}_i^2 [&G(\hat{p}_i) + G(\hat{N}_i) + G(\overline{\theta^{-1}}) - G(\hat{p}_i)G(\hat{N}_i) - G(\hat{p}_i)G(\overline{\theta^{-1}}) - G(\hat{N}_i)G(\overline{\theta^{-1}}) \\ &+ G(\hat{p}_i)G(\hat{N}_i)G(\overline{\theta^{-1}})] \end{aligned} \tag{A6}$$

-continued-

The squared coefficients of variation, $G(\hat{N}_i)$ and $G(\overline{\theta^{-1}})$, are obtained from creel surveys and field sampling programs, respectively. As before, statistics were summed across strata to obtain the relative precision as per equation 2.

Equations 4-6 and 2 were used to determine how many smolt to tag with CWTs and how many adults to inspect in the Nakwasina River to estimate harvest with the desired relative precision. Expected values for the statistics $G(\hat{N}_i)$, λ_i, ϕ_i, and $\hat{r}_i$ were obtained from creel surveys and catch sampling programs from earlier years, then adjusted for our anticipation of events. Once determined, these statistics were considered fixed. An expected number of smolt was likewise determined (the denominator defining θ). The number of smolt to be tagged (R, the numerator defining θ) and the number of returning adults in later year(s) that were inspected to estimate θ (s) were treated as variables. Relationships among θ, s, and $G(\overline{\theta^{-1}})$ were determined from Figure A2. Combinations of {R,s} that met our desired relative precision were determined through trial and error with the equations.

Table A2.–Notation used to describe the parameters involved in estimators of harvest from a cohort of salmon when only some members of that cohort carry coded wire tags (CWTs). See Bernard and Clark (1996) for additional details.

a_i	= Number of fish in the sample recognized as missing an adipose fin
a'_i	= Number of heads that arrive at the lab
G(x)	= Coefficient of variation squared for variable x
i	= Subscript denoting a specific stratum
R	= Number of smolt tagged with CWTs
s	= Number of adults in the Nakwasina River inspected for CWTs
λ_t	= Product of the fraction of heads that reach the lab and the fraction of detected CWTs that are decoded
t_i	= Number of heads with CWTs detected magnetically
t'_i	= Number of CWTs that are found through dissection and decoded
m_i	= Number of decoded CWTs from a specific cohort
r_i	= Number of fish harvested from a specific cohort
n_i	= Number of fish in the catch inspected (the sample)
N_i	= Number of fish in the catch
p_i	= Probability a fish in the catch has a CWT from a specific cohort
ϕ_t	= Fraction of the catch inspected (sampled)
RP[x]	= Relative precision of variable x
θ	= Fraction of a cohort with CWTs

-continued-

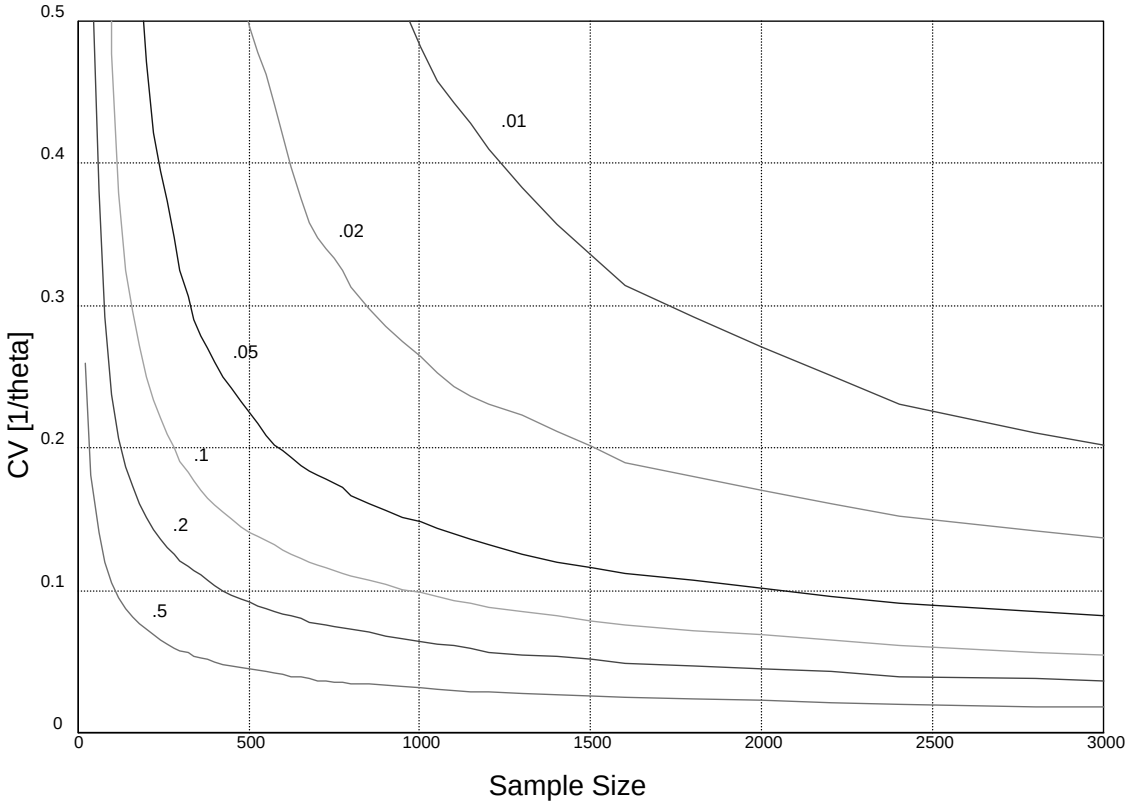

Figure A2.–Coefficient of variation of θ vs. sample size (adults inspected) at five levels of θ.

Appendix A3.–Computer data files on 1998 Nakwasina River coho salmon smolt and subsequent estimates of 1999 Nakwasina River adult coho salmon run parameters.

File name	Description
99 CWTs Nakawasina.XLS	Spreadsheet containing coded wire tag recoveries in 1999 from smolt tagged in 1998 from Nakwasina River coho salmon.
99 Harvest Estimates.XLS	Spreadsheet containing the estimated harvests of Nakwasina coho salmon in 1999, with algorithms for harvest estimation and associated variance.
Smolt & Adult Data.XLS	Spreadsheet with raw sampling data for smolt in 1998 and adults in 1999, for Nakwasina coho salmon.