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Smolt Production, Adult Harvest, and Spawning Escapement of Coho Salmon from the Nakwasina River in Southeast Alaska, 2000-2001

by

Troy Tydingco

September 2003

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

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	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	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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SMOLT PRODUCTION, ADULT HARVEST, AND SPAWNING ESCAPEMENT OF COHO SALMON FROM THE NAKWASINA RIVER IN SOUTHEAST ALASKA, 2000–2001

by

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ABSTRACT

In 1998, a coded wire tag (CWT) project was begun for coho salmon in the Nakwasina River near Sitka, Alaska, to supplement a continuing regionwide effort to assess the status of key coho salmon *Oncorhynchus kisutch* stocks in Southeast Alaska. This was the third season of a continuing project, in which we estimated abundance of coho salmon smolt in 2000 and harvest of returning adults in 2001, using Chapman's modification of a two-event Petersen closed population estimator. During spring 2000, 10,335 coho salmon smolt ≥70 mm fork length (FL) were captured in minnow traps, marked with an adipose finclip, given a coded wire tag, and released. Smolt abundance in 2000 was an estimated 46,575 (SE = 2,722). During fall 2001, 93 (of 532,762 sampled) adult coho salmon bearing CWTs with a Nakwasina River code were recovered in random sampling of marine fisheries, and 22.1% of 1,001 adults examined inriver carried CWTs, as evidenced by adipose finclips. An estimated 1,439 (SE = 155) coho salmon of Nakwasina River origin were harvested in Southeast Alaska marine fisheries in 2001. The sport fishery harvested an estimated 222 fish, or 15.4% of the total harvest of Nakwasina River coho salmon, while the commercial troll and net fisheries, respectively, contributed the remaining 81.8% and 2.7%.

An open-population mark-recapture experiment was also conducted to estimate the abundance of coho salmon in the Nakwasina River during fall 2001. An estimated 2,992 (SE = 510) adults escaped into the Nakwasina River. This represents a factor of 4.0 times greater than the peak visual count of 753 adult coho salmon observed during foot surveys of the main river in 2001. The total run (i.e., escapement plus harvest) for all coho salmon bound for the Nakwasina River was 4,431, the marine survival rate was 9.5%, and the marine fishery exploitation was 32.5%.

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, spawning escapement, smolt abundance

INTRODUCTION

Coho salmon *Oncorhynchus kisutch* produced by the Nakwasina River and thousands of other coastal river systems in Southeast Alaska collectively support the region's mixed stock commercial troll and net fisheries and freshwater and marine sport fisheries. Fishing pressure on coho salmon in Southeast Alaska, particularly along the outer coast of Baranof Island near Sitka, has increased as a direct result of growth in the region's sport fisheries. Fishing pressure on coho has also increased because of increased hatchery productions of coho salmon and reductions in the commercial troll fishery for chinook salmon *Oncorhynchus tshawytscha* (Schmidt 1996). The Alaska Department of Fish and Game (ADF&G) has conducted comprehensive coded wire tag (CWT) assessment projects on a long-term basis to evaluate the effects of Southeast Alaska fisheries on specific coho stocks native to streams in northern and inside areas of Southeast Alaska (Yanusz et al. 1999), but stock-specific information is more limited in outside, central, and southern areas. To bridge geographic areas, projects have been implemented more recently for specific stocks, including the Unuk River in southern Southeast (Jones et al. 1999) and Slippery Creek in central Southeast (Beers 1999). Along the outer coast, the first comprehensive CWT program began at Ford Arm in 1982 and continued through 2001 (Shaul and Crabtree 1998; Leon Shaul, Alaska Department of Fish and Game, Commercial Fisheries Division, Douglas, personal communication). The Division of Sport Fish also conducted a CWT project to assess fishery impacts to Salmon Lake coho salmon from 1983 to 1990 and again in 1994–1995 (Schmidt 1996).

In 1998 and 1999, Sport Fish Division conducted a CWT project for coho salmon in the Nakwasina River (Figure 1) to supplement the regionwide effort to assess the status of key coho salmon stocks in central Southeast Alaska (Brookover et al. 2001). Estimated smolt abundance in 1998 from the Nakwasina River was 102,794 (SE = 15,255) and 47,571 (SE = 6,402) in 1999. Estimated harvests of returning adults in 1999 and 2000 were 1,983 (SE = 605) and 1,439 (SE = 155).

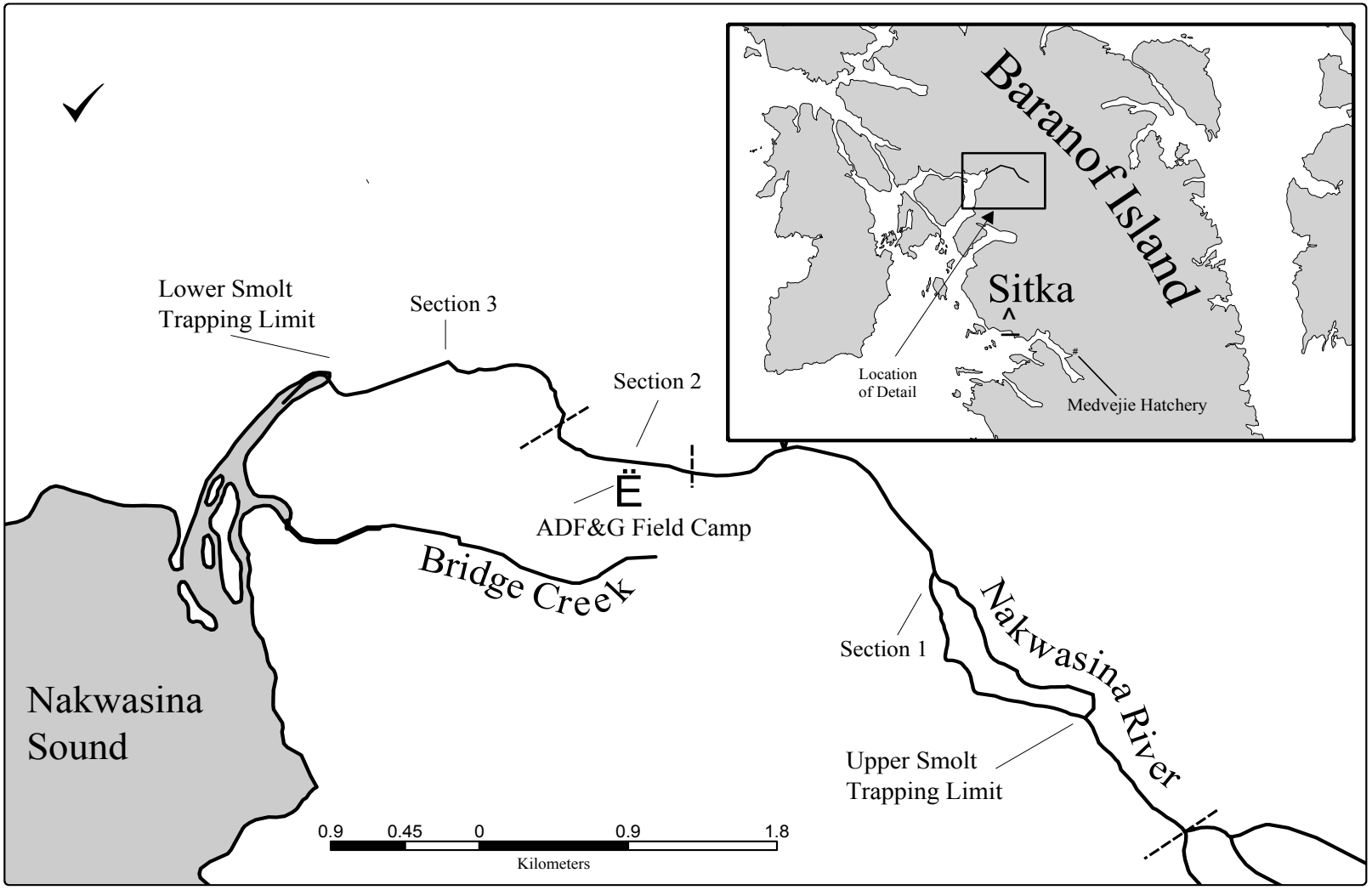

Figure 1.–Nakwasina River area, major tributaries, and location of ADF&G research sites and stream sections.

The three objectives of our study were: (1) estimate the number of coho salmon smolt leaving the Nakwasina River in 2000, (2) estimate the marine harvest of coho salmon from Nakwasina River in 2001 via recovery of CWTs applied in 2000, and (3) estimate spawning escapement in 2001. Sampling and tagging of smolt in the Nakwasina River in 2000 and regionwide adult recapture in 2001 allowed us to estimate smolt abundance in 2000 and harvest in 2001, whereas sampling and tagging in the Nakwasina River during 2001 allowed us to estimate spawning abundance.

STUDY AREA

The Nakwasina River (ADF&G Anadromous Stream Catalog No. 113-43-01) is located on the outer coast of Baranof Island in Southeast Alaska (Figure 1). It is about 13 km long, 6 to 30 m wide, and up to 3 m deep, and empties into Nakwasina Sound (57°15′16.8″ W, 135°20′41.5″ N) about 15 miles north of Sitka. The Nakwasina River drains approximately 8,600 square hectares and is one of the larger river systems on Baranof Island.

The Nakwasina River is known locally for its freshwater sport fisheries for Dolly Varden and coho salmon. Because the Nakwasina River is easily accessed by boat and it supports one of the largest populations of coho salmon in Sitka Sound, it is one of the few rivers near Sitka that attracts freshwater sport fishing effort for coho salmon. From 1984 to 2000, annual harvests of coho salmon in Nakwasina Sound, including the Nakwasina River, ranged from 0 to 182 fish (Mills 1985–1994, Howe et al. 1995–1996, 2001a-d). 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, personal communication, 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 the potential negative impacts to the stock from habitat damage by logging.

Since 1988, visual surveys have been conducted by foot on the Nakwasina River to provide an indication of trends in the annual abundance of coho escapement. Annual peak counts in the Nakwasina River represent the largest of five systems surveyed annually in the Sitka area. Surveys conducted from 1980 to 2001 have documented 104 (1988) to 753 (2001) adult coho salmon spawners in the Nakwasina River (Table 1).

METHODS

There were three major components of this study. A 2-event mark-recapture experiment for a closed population was used to estimate the abundance of coho salmon smolt ≥ 70mm FL in the Nakwasina River during spring 2000. For this component, coho salmon smolt were sampled and tagged with coded wire tags during spring 2000 (event 1) and recaptured as returning adults in the Nakwasina River during fall 2001 to estimate the fraction carrying CWTs (event 2). The second component was sampling the marine harvest. Marine harvests were sampled during the summer and fall of 2001 to estimate the tagged fraction and origin of coho captured through commercial fisheries port sampling and recreational fisheries creel survey programs. The final component of this study was an open-population mark-recapture experiment conducted fall of 2001 in the Nakwasina River to estimate the spawning escapement of adult coho. Instream mark and recapture events were integrated with coded-wire tag recovery efforts. In addition to the three major parts of this study, we also conducted biweekly foot surveys to compare with our escapement estimate.

SMOLT TAGGING AND SAMPLING

From April 9 to May 22, 2000, between 50 and 100 G-40 minnow traps were baited with salmon roe and fished daily in the Nakwasina River. Traps were fished for 24 hours per day approximately 6 days per week and checked at least once each day. Traps were set along mainstem banks and in backwater areas of the lower river between the estuary and approximately 6 km upstream. Traps were distributed and redistributed opportunistically to maximize catch by targeting areas of likely rearing habitat, unfished areas, and areas known to produce relatively high catch rates. Coho salmon smolt

Table 1.–Peak coho escapement counts for rivers in the Sitka area, by date and stream, 1980–2001.

	Sinitsin Creek			St. John Baptist Bay Creek			Starrigavan River			Eagle River			Nakwasina River		
Year	Survey type	Peak survey date	No. of coho	Survey type	Peak survey date	No. of coho	Survey type	Peak survey date	No. of coho	Survey type	Peak survey date	No. of coho	Survey type	Peak survey date	No. of coho
1980	Foot	30-Sep	39	Foot	9-Oct	26	Foot						Foot	29-Oct	70
1981	Foot	6-Oct	85	Foot	14-Oct	51	Foot	20-Oct	170	Foot	22-Sep	27	Foot	7-Oct	780
1982	Foot	20-Oct	46	Foot			Foot	21-Oct	317						
1983	Foot	27-Sep	31	Foot	13-Oct	12	Foot	6-Oct	45				Foot	14-Oct	217
1984	Foot	10-Oct	160	Foot	10-Oct	154	Foot	10-Oct	385				Foot	17-Oct	715
1985	Foot	15-Oct	144	Foot	8-Oct	109	Foot	11-Oct	193				Foot	7-Oct	408
1986	Foot	30-Sep	4	Foot	10-Oct	9	Foot	10-Oct	57	Foot	26-Sep	245	Foot	28-Oct	275
1987	Foot	23-Sep	32	Foot	23-Sep	9	Foot	9-Oct	36	Foot	24-Sep	167	Foot	30-Oct	47
1988	Foot	3-Oct	56	Foot	3-Oct	71	Foot	12-Oct	45	Foot	2-Sep	10	Foot	27-Oct	104
1989	Foot	5-Oct	76	Foot	5-Oct	89	Foot	13-Oct	101	Foot	2-Oct	130	Foot	19-Oct	129
1990	Foot	1-Oct	80	Foot	1-Oct	35	Foot	17-Oct	39	Snorkel	2-Oct	214	Foot	31-Oct	195
1991	Foot	1-Oct	186	Foot	10-Oct	107	Foot	2-Oct	142	Snorkel	17-Oct	454	Foot	25-Oct	621
1992	Foot	23-Sep	265	Foot	14-Oct	110	Foot	12-Oct	241	Snorkel	6-Oct	629	Foot	30-Oct	654
1993	Foot	7-Oct	213	Foot	6-Oct	90	Foot	13-Oct	256	Snorkel	13-Oct	513			
1994	Foot	30-Sep	313	Foot	30-Sep	227	Foot	11-Oct	304	Snorkel	1-Oct	717	Foot	14-Oct	404
1995	Foot	26-Sep	152	Foot	5-Oct	99	Foot	6-Oct	272	Snorkel	5-Oct	336	Foot	29-Sep	626
1996	Foot	2-Oct	150	Snorkel	2-Oct	201	Foot	17-Oct	59	Snorkel	30-Sep	488	Foot	30-Oct	553
1997	Foot	29-Sep	90	Snorkel	30-Sep	68	Foot	27-Oct	55	Snorkel	30-Sep	296	Foot	14-Nov	239
1998	Foot	1-Oct	109	Snorkel	9-Oct	57	Foot	8-Oct	123	Snorkel	9-Oct	300	Foot	2-Nov	653
1999	Snorkel	11-Oct	48	Snorkel	29-Oct	25	Snorkel	8-Oct	166				Snorkel	12-Nov	291
2000	Foot	26-Sep	62	Snorkel	26-Oct	32	Snorkel	8-Oct	144	Snorkel	29-Sep	108	Foot	8-Nov	419
2001	Foot	5-Oct	132	Snorkel	4-Oct	80	Snorkel	3-Oct	130	Snorkel	4-Oct	417	Foot	14-Nov	753
Mean (1980–2000)			111			79			158			299			389
5-yr mean (1996–2000)			92			77			109			298			431

≥70 mm were removed from minnow traps and transported to holding pens at the campsite each day. Other species (primarily Dolly Varden *Salvelinus malma*) and coho fry <70 mm were counted and released onsite.

Every 2–3 days, all live coho salmon smolt ≥70 mm FL were tranquilized with a solution of tricane methane-sulfonate (MS222) and injected with a CWT with one of the following codes: 04-04-16; 04-04-17; or 04-04-18. Fish were then marked externally by excising the adipose fin following methods in Koerner (1977). All tagged fish were held overnight in a net pen to test for mortality, tag retention, and adipose finclip status 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% or greater, all fish were counted, mortalities recorded, and released. If tag retention was 97% or less, all fish were retagged. The number of fish tagged, number of tagging-related mortalities, and number of fish that had shed their tags were 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 fieldwork ended.

In 2000, three separate tag codes were used to identify three components of the smolting run. Fish from the Nakwasina that were ≥70 mm but <85 mm were tagged with code 04-04-16, while fish ≥85 mm were tagged with code 04-04-17. These two tag codes were used to identify differential survival based on size at smolting. A third tag code (04-04-18) was used for all fish ≥70 mm captured in an unnamed tributary to the Nakwasina (Figure 1) that is connected only intermittently. This tributary, referred to as "Bridge Creek," empties into salt water approximately ½ km from the outlet of the Nakwasina River, except at high tide, when the two appear to be connected by a small freshwater passage. This third tag code was used to determine if fish originating from this tributary spawn in the mainstem of the Nakwasina.

One in every 15 tagged smolt was measured to the nearest 1 mm FL, weighed to the nearest 0.1 g, and sampled for scales. 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 × 3" microscope slides and numbered consecutively for each fish. Slides were taped together and the number and length of each fish was written on the frosted portion of the bottom slide according to scale position on the slide.

INSTREAM MARK-RECAPTURE SAMPLING, CODED WIRE TAG RECOVERY, AND MARINE HARVEST SAMPLING

An instream sampling program was designed to conduct external Floy™ tagging, recovery, and sampling efforts required for the open-population mark-recapture estimate of adults instream in conjunction with CWT recovery efforts necessary for the closed population estimate of smolt in 1999. Requirements of the open-population experiment demanded the most intensive sampling efforts; sampling methods were therefore designed for the open population experiment, and sampling for CWT recovery became incidental.

From September 25 through December 18, 2001, sampling occurred for 2- or 3-day periods once each week except during the week of November 25 when high, turbid water conditions prevented capture. Adult coho salmon were captured using a 3.6 × 22.5-m, 3.75-cm mesh beach seine and a 3.0 × 35-m, 7.5-cm mesh gillnet. Hook and line gear was also used to supplement net captures.

We divided the stream into three sections (Figure 1). Section 1 extended from river kilometer (rkm) 7.75 downstream to rkm 4.1. The portion of the river upstream of rkm 7.75 was not included because few fish have been observed in this area and the presence of excessive amounts of woody debris and undercut banks were not conducive to capturing fish. Section 2 extended from rkm 4.1 downstream to 3.7 and section 3 extended from rkm 3.7 to rkm 3.4. Sampling was concentrated in section 2 most heavily because a large pool contained a majority of adult coho salmon visible in the river at any one time and enabled use of the more effective beach seine. Relatively little sampling occurred below rkm 3.4 because we wished to avoid potential mortality associated with capturing coho salmon that had recently entered fresh water (Vincent-Lang et al. 1993).

All coho captured were examined for presence or absence of their adipose fin. Between September 25 and November 6 all coho missing adipose fins were sacrificed, their heads removed, and sent to the CFD tag and age lab for dissection and decoding. After November 6, every fish missing an adipose fin in section 1 was sacrificed, but only one of every three fish in sections 2 and 3 were sacrificed because sample size goals had been met for these sections. All captured coho salmon were also examined for an anchor tag and opercle punch combination. All coho salmon absent this combination were measured to the nearest millimeter fork length, tagged with uniquely numbered Floy™ T-Bar anchor tag, given a secondary mark to permit estimation of tag loss, sampled to determine sex and condition, and sampled to collect scales for aging. Tags were inserted just posterior of and 1 cm below the dorsal fin on the left side of the fish. Secondary marks included various combinations of opercle punches that consisted of 0.6 cm diameter holes. The condition of each fish was determined from external characteristics using the following convention:

Bright:	Ocean bright or nearly ocean bright;
Blush:	Some color (primarily blush red);
Dark:	Dark color (primarily red);
LPS:	(live post-spawner), spawned out but not yet dead;
Carcass:	Dead spawned fish;
Mortality:	Dead unspawned fish.

For fish captured with an anchor tag, the location, gear used, tag number, and condition of the fish were recorded and the fish was released. If an opercle punch but no anchor tag was present, the fish was recorded as a valid tag recovery (indicating the tag was shed), retagged, and examined for condition. All carcasses that could be retrieved were also inspected for marks, recorded, and removed from the experiment by slashing the left side of the fish. These fish were not counted in subsequent observations.

Sex was determined from external characteristics. Scale samples, consisting of 4 scales from the preferred area near the lateral line on an imaginary line from the insertion of the posterior dorsal fin to the anterior origin of the anal fin (Scarneccia 1979), were collected and affixed to a gum card in the field. Post-season, scale images were impressed on acetate and ages were determined by examining the impressions under a microscope. Criteria used to assign ages were similar to those of Moser (1968).

Harvest in 2001 of coho salmon originating from the Nakwasina River was estimated from fish sampled in commercial and recreational fisheries. Fisheries personnel with the ADF&G CFD port-sampling program examined commercially caught fish at processing locations and recovered coho with missing adipose fins (Alaska Department of Fish and Game Coded Wire Tag Sampling Program 2002). Similarly, the Division of Sport Fish employed a creel survey program to examine fish caught in the sport fishery (Hubartt et al. 2001). When possible, heads of fish without an adipose fin were removed and sent to the ADF&G Coded Wire Tag and Otolith Processing Laboratory for tag detection and decoding. Because multiple fisheries exploited coho salmon over several months in 2001, 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.

FOOT SURVEY COUNTS

Adult coho salmon in the Nakwasina River were counted visually once every two weeks from October 31 to November 30, 2001. Visual counts were conducted by two or three experienced observers wearing polarized lenses during or one day after instream sampling efforts. Only fish positively identified as coho salmon were counted. In braided areas, one observer would walk one braid and the other observer, the adjacent braid. Counts were conducted between the uppermost portion of the survey area (river kilometer 7.75) and a pool near the high tide mark at river kilometer 0.25. This survey area included the portion of river below the lower most point of the mark-recapture study area (river kilometer 3.4) to provide consistency with past counts. Uncontrolled variables included observer abilities, weather conditions, and water clarity.

"Bridge Creek," the unnamed tributary of the Nakwasina, was examined opportunistically about every other week during the course of sampling in an attempt to determine if coho used it for spawning as well as rearing.

ESTIMATE OF SMOLT ABUNDANCE AND SIZE

The mark-recapture experiment used to estimate smolt abundance was Chapman's modification of the Petersen method (Seber 1982). To estimate abundance of smolts and its variance we used:

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

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

where

$\hat{N}_S$ = estimated abundance of smolts in 2000,

M = number of marked smolts released alive into the population in 2000,

C = number of adults inspected for marks in 2001, and

R = number of adults with missing adipose fins in samples taken in 2001.

Estimates of mean length and weight-at-age and their variances were calculated with standard procedures assuming lengths and weights were normally distributed.

ESTIMATE OF HARVEST

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

$$\hat{r}_{ij} = N_i \left[\frac{m_{ij}}{\lambda_i n_i} \right] \theta_j^{-1}; \qquad \lambda_i = \frac{a_i' t_i'}{a_i t_i} \qquad (3)$$

where

N_i = total harvest in fishery stratum i,

n_i = number of fish inspected in fishery stratum i (the sample),

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

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

t_i = number of heads with CWTs detected,

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

m_i = number of CWTs with code(s) of interest, and

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

When N_i and θ_j are known without error, an unbiased estimate of the variance of (1) can be calculated as shown by Clark and Bernard (1987). However, N_i is estimated with error in our sport fisheries, and θ_j is estimated with error on the Nakwasina River since wild stocks are tagged. Because of these circumstances, unbiased estimates of the variance of $\hat{r}_{ij}$ were obtained by using the appropriate equations in Table 2 of Bernard and Clark (1996), which show the formulations for large samples.

The total harvest for a cohort was calculated as the sum of strata estimates:

$$\hat{H} = \sum_i \sum_j \hat{r}_{ij} \qquad (4)$$

$$v[\hat{H}] = \sum_i \sum_j v[\hat{r}_{ij}] \qquad (5)$$

SPAWNING ESCAPEMENT

The escapement of adult (1-ocean age) coho salmon in the Nakwasina River was estimated from a Jolly-Seber (JS) experiment (Seber 1982) using the model described by Schwartz et al. (1993). Sub-adult (0-ocean age) coho salmon were rarely encountered and were much smaller than adults, and were ignored. Weekly sampling trips spanning the breadth of the river and time of immigration were conducted to mark and recapture adults. Following the work of Sykes and Botsford (1986), we did not include repeated recaptures of carcasses "captured" in a decayed condition.

In general, escapement (E) is the total number of immigrants (Bi) between the first and last sampling occasion, including fish that enter the system and die between any two sampling occasions (i) and fish that enter before the first sampling occasion (B0) and after the last sampling occasion (Bs): $\hat{E} = \hat{B}_0 + \ldots + \hat{B}_{s-2} + \hat{B}_{s-1} + B_s$. Because we began

sampling while immigration was low and continued it until recruitment was virtually over, we estimated $B_0 + B_1$ from an estimate of abundance just before the second JS sampling event (N2) and ignored any small immigration B_{s-1} and beyond as suggested by Schwarz et al (1993). The resulting (albeit biased low) estimator is thus

$$\hat{E} = \hat{N}_2\left(\frac{\log\hat{\phi}_1}{\hat{\phi}_1 - 1}\right) + \hat{B}_2\left(\frac{\log\hat{\phi}_2}{\hat{\phi}_2 - 1}\right) + \ldots + \hat{B}_{s-2}\left(\frac{\log\hat{\phi}_{s-2}}{\hat{\phi}_{s-2} - 1}\right) \quad (6)$$

where $\hat{B}_i$ are JS estimates of the number of fish present at the sample time i+1 which immigrated between i and i+1, $\hat{\phi}_i$ is the survival rate from i to i+1, and the factors $\frac{\log(\phi_i)}{\phi_i - 1}$ account for fish that enter and die between samples under the assumption that recruitment is uniformly distributed between samples. The computer program POPAN (Arnason and Schwarz 1995) was used to estimate the JS parameters, and out-of-bounds estimates were constrained to admissible values (Schwarz et al. 1993, Schwarz and Arnason 1996). Variance of escapement was estimated using the delta method and the asymptotic variance and covariances in Schwarz et al. (1993), and expected values of the sampling statistics from POPAN.

Assumptions of the standard (full) JS model (Seber 1982) include:

1. every fish in the population has the same probability of capture in the ith sample;
2. every marked fish has the same probability of surviving from the ith to the (i+1)th sample and being in the population at the time of the (i+1)th sample;
3. every fish caught in the ith sample has the same probability of being returned to the population;
4. marked fish do not lose their marks between sampling events and all marks are reported on recovery; and
5. all samples are instantaneous (sampling time is negligible).

Chi-square goodness-of-fit tests were used to test for homogeneous capture and survival probabilities by tagged status (results from program JOLLY, Pollock et al. 1990). The first test is equivalent to the Robson (1969) test for short-term mortality. The second test is reported to be better at detecting heterogeneous survival probabilities (Pollock et al. 1990:24). The sum of the chi-squares from each test is an overall test statistic for violations of the first three assumptions above (equal probability of capture, survival, and return to the population).

The equal probability of capture assumption can also be violated if sampling is size or sex selective. Although differences in the size of adult coho salmon are small, a hypothesis that fish of different sizes were captured with equal probabilities was tested by using Kolmogorov-Smirnov (K-S) 2-sample tests (Appendix A3). Sex selective sampling was investigated using a χ^2 test comparing the number of males and females marked with those recaptured. Assumptions 3, 4, and 5 were thought to be robust in this experiment.

AGE AND SEX COMPOSITION

The proportion of the spawning population composed of a given age or sex was estimated as:

$$\hat{p}_j = \frac{n_j}{n} \quad (7)$$

$$Var(\hat{p}_j) = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1} \quad (8)$$

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.

To reduce bias caused by inseason changes in age composition, samples were obtained systematically.

ESTIMATES OF TOTAL RUN, EXPLOITATION, AND MARINE SURVIVAL

Estimates of total run (i.e., harvest and escapement) for coho salmon returning to the Nakwasina River in 2001 and the associated exploitation rate in commercial and sport fisheries are based on the sum of the estimated harvest and escapement

$$\hat{N}_R = \hat{H} + \hat{E} \tag{9}$$

The variance of the estimated run was calculated as the sum of the variances for estimated escapement and harvest

$$var[\hat{N}_R] = var[\hat{H}] + var[\hat{E}] \tag{10}$$

The estimate of exploitation rate was calculated as:

$$\hat{U} = \frac{\hat{H}}{\hat{N}_R} \tag{11}$$

$$var\left[\hat{U}\right] \approx \frac{var[\hat{H}]\,\hat{E}^2}{\hat{N}_R^4} + \frac{var[\hat{E}]\,\hat{H}^2}{\hat{N}_R^4} \tag{12}$$

The estimated survival rate of smolt to adults was calculated as:

$$\hat{S} = \frac{\hat{N}_R}{\hat{N}_s} \tag{13}$$

$$\text{var}[\hat{S}] \approx \hat{S}^2 \left[\frac{\text{var}[\hat{N}_R]}{\hat{N}_R^2} + \frac{\text{var}[\hat{N}_s]}{\hat{N}_s^2} \right] \tag{14}$$

RESULTS

SMOLT TAGGING, SAMPLING, AND ABUNDANCE IN 2000

Between April 9 and May 22, 2000, we captured, tagged, and removed adipose fins from 10,137 coho smolt out of the Nakwasina River and its tributary. Tag retention was 99.8% with 7 over-night mortalities, leaving 10,120 valid tag releases. Of these smolt, 5,440 (54%) were captured in the mainstem of the Nakwasina River and were ≥70 mm but <85 mm. Eighteen percent (18%) were >85mm and 28% were fish ≥70mm from "Bridge Creek," the unnamed tributary of the Nakwasina River.

Smolt captured in the mainstem of the Nakwasina that were age-1 fish (those rearing for one year in fresh water) composed 96% of sampled smolt and averaged 81.7 mm FL (SE = 0.49) and 5.8 g (SE = 0.10) (Table 2). Age-2 coho smolt from the mainstem Nakwasina averaged 99.7 mm FL (SE = 2.77) and 9.7 g (SE = 0.76). The combined catch averaged 82.5mm FL (SE = 0.53) and 6.0 g (SE = 0.11). Average length and weight of captured coho remained approximately the same throughout the tagging effort. Trap catches ranged from 1.7 fish per trap to 7.4 fish per trap but did not appear to increase or decrease throughout the trapping effort.

From Bridge Creek, age-1 fish composed 99% of sampled smolt and averaged 81.4 mm FL (SE = 0.73) and 5.6 g (SE = 0.14) (Table 2). Only one age-2 coho smolt was sampled from Bridge Creek. It was 87 mm FL and 6.9 g.

The proportions of smolt tagged in 2000 with each of three tag codes was not significantly different than that observed in the spawning escapement in 2001 ($\chi^2 = 0.011$ p = 0.99). Because fish tagged in Bridge Creek were found to spawn in the mainstem of the Nakwasina and no fish were found to spawn in Bridge Creek, Bridge Creek was assumed to be a part of the Nakwasina and were grouped together for analysis of harvest contribution, escapement, and the estimate of smolt abundance.

An estimated 45,677 (SE = 2,669) coho smolt emigrated from the Nakwasina River in 2000.

INSTREAM MARK-RECAPTURE SAMPLING AND CODED WIRE TAG RECOVERY

The tagged fraction of adult coho salmon sampled in the Nakwasina River during 2001 was 0.221. Of the 1,001 coho salmon examined, 221 had an adipose finclip.

The proportion of freshwater age-1 fish was not significantly different ($\chi^2 = 0.27$, P = 0.6) between smolt sampled in 2000 and adults sampled inriver during 2001 (Table 3). Both groups were predominately (>95%) freshwater age-1. fish.

Table 2.–Estimated length, weight and age of coho salmon smolt from the Nakwasina River and Bridge Creek in 2000. Length measured to the nearest mm and weight to the nearest 0.1 g.

	Nakwasina River						Bridge Creek			
	Age-1		Age-2		Combined		Age-1		Age-2	
Statistic	Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Weight
Mean	81.7	5.8	99.7	9.7	82.5	6.0	81.4	5.6	87.0	6.9
SE	0.49	0.10	2.77	0.76	0.53	0.11	0.73	0.14	N/A	N/A
Sample size	258	260	12	12	270	270	125	125	1	1
% age-1 fish in the Nakwasina = 96%							% age-1 fish in Bridge Creek = 99%			

Table 3.–Number of freshwater age-1 and freshwater age-2 coho salmon smolt in 2000 versus 2001 adult samples.

	Age		Proportion	χ^2	
	1.1	2.1	age-2	test	P-value
Adult in 2001	701	19	0.026	0.27	0.6
Smolt in 2000	397	13	0.032		

Length distributions of adult coho salmon captured in 2001 in the Nakwasina River were not different between sex or time of capture (K-S tests, Figure 2). Hook and line gear caught significantly smaller fish [586 mm (SE = 8.9)] than did the seine [mean length 627 mm (SE = 1.7)]. A higher proportion of males were captured in section 1 (51%) than section 3 (34%) (Table 4). Additionally, the recapture rate was higher for males than females (χ^2 tests, P = 0.01 Table 4). No difference in sex composition was detected between gear types (χ^2 tests, P = 0.91, Table 4).

Most (948) adult coho captured in the Nakwasina River in 2001 were captured with the beach seine, while 51 were captured with hook and line. Two carcasses were found. Hook and line gear was moderately effective at capturing fish but only when water conditions allowed for sighting fish. The use of a beach seine seemed to be the most effective means of capture.

CONTRIBUTION OF SMOLT TAGGED IN 2000 TO HARVEST IN 2001

In 2001, 100 CWTs from the Nakwasina River were recovered from about 532,000 coho salmon sampled in commercial and sport fisheries. Of these, 93 were random recoveries (Appendix A1). Seventy-six coho salmon bearing CWTs with a Nakwasina River code were recovered randomly from Southeast Alaska's commercial troll fisheries. Of these, all but seven were caught in the Northwest Quadrant (Figure 3) of Southeast Alaska between July 11 and September 30, 2001. Fifteen coho salmon bearing CWTs with a Nakwasina River code were recovered in the sport fishery; fourteen were recovered near Sitka between July 12 and August 25. One coho was recovered in the Craig sport fishery. Two fish were recovered in the commercial seine fishery but no fish were recovered in the commercial gillnet fisheries. Detailed information is provided for each recovered tag in Appendix A1.

The estimated harvest of Nakwasina River coho salmon in sampled marine fisheries in 2001 was 1, 439 (SE = 155; Table 5). Nakwasina coho contributed less than 1% of the combined sport and commercial troll harvest (1,650,838) for the areas in which Nakwasina River fish were recovered. The total contribution to the sport fishery by Nakwasina coho was estimated at 222 fish. Sport caught Nakwasina coho comprised 15.4% of the harvest of that stock in the sampled marine fisheries, but relative contributions were higher for the sport harvest (0.3%) than the troll harvest (0.1%). Freshwater harvest of coho

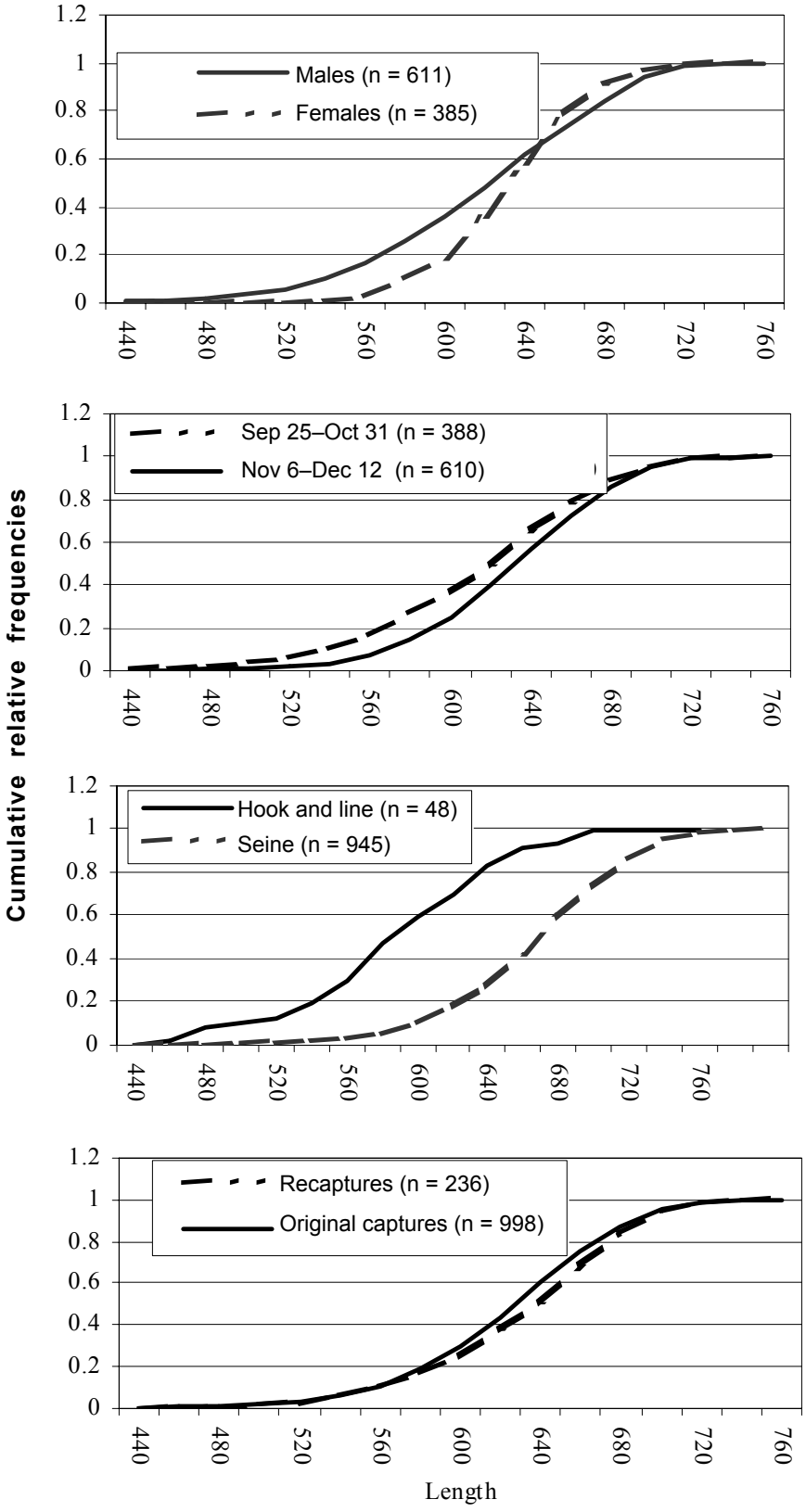

Figure 2.–Cumulative length frequency distributions to test for differences in lengths of captured coho by sex, time, gear, and capture or recapture.

Table 4.–Differences in sex composition between capture type, gear, and location.

Capture	Males	Females	% males	χ^2	p-value
Marked	385	615	0.39	3.3596	0.010
Recaptured	105	215	0.33		
Gear					
Hook and line	18	31	0.37	0.1789	0.914
Seine	365	581	0.39		
Location					
Section 1	60	57	0.51	15.959	0.001
Section 2	34	59	0.37		
Section 3	206	394	0.34		
Section –3 (tidewater)	85	104	0.45		

salmon in the Nakwasina River will not be available until the Division of Sport Fish publishes the results of its annual mailout angler survey.

Coho salmon bearing CWTs with a Nakwasina River code recovered in the commercial and sport fisheries averaged 631 mm FL (SE = 5.6).

ESTIMATED SPAWNING ESCAPEMENT, TOTAL RUN, AND MARINE SURVIVAL

Coho salmon were marked and recaptured in all 13 weeks of the study, save week 10 when water conditions were high. Altogether, 1,001 individual adults were captured and examined, of which 835 were marked and released alive and 322 were subsequently recaptured (Table 6). Only 2 recaptured fish had lost their numbered tag

Table 5.–Estimated harvest of adult Nakwasina River coho salmon (tag codes 04-04-16, 04-04-17, and 04-04-18) **in sampled in sport and commercial fisheries in 2001.**

TROLL FISHERY

Stat. week period	Dates	Quadrant	Est. harvest H	Inspected n	a	a'a	t	t'	m	r	SE[r]
4	8/12–10/6	NE	73,563	24,190	445	443	379	379	1	14	13
3	7/01–8/11	NW	828,146	201,968	3,821	3,801	3,198	3,191	33	617	111
4	8/12–10/6	NW	432,752	144,857	3,368	3,338	2,926	2,923	37	506	85
3	7/01–8/11	SW	198,715	114,056	1,456	1,405	1,113	1,108	4	33	15
4	8/12–10/6	SW	36,381	20,201	313	309	256	256	1	8	8
	Subtotal troll fishery		1,569,557	505,272	9,403	9,296	7,872	7,857	76	1,178	

SEINE FISHERY

Stat. week	Dates	Quadrant	H	n	a	a'a	t	t'	m	r	SE[r]
32	8/05–8/11	NW	38	10	1	1	1	1	1	17	17
30	8/22–8/28	NE	17,776	3,702	50	50	44	44	1	22	21
	Subtotal seine fishery		17,814	3,712	51	51	45	45	2	39	

SPORT FISHERY

Biweek	Dates	Area	H	n	a	a'a	t	t'	m	r	SE[r]
15	7/15–7/28	Craig	14,307	2,761	45	45	37	37	1	23	23
14	7/01–7/14	Sitka	10,816	2,947	43	41	38	37	1	18	17
15	7/15–7/28	Sitka	21,656	6,344	76	75	66	66	3	47	26
16	7/29–8/11	Sitka	17,822	6,386	120	120	105	105	5	63	27
17	8/12–8/25	Sitka	16,680	5,340	90	90	81	81	5	71	31
	Subtotal sport fishery		81,281	23,778	374	371	327	326	15	222	
	TOTAL ALL FISHERIES		1,668,652	532,762	9,828	9,718	8,244	8,228	93	1,439	155

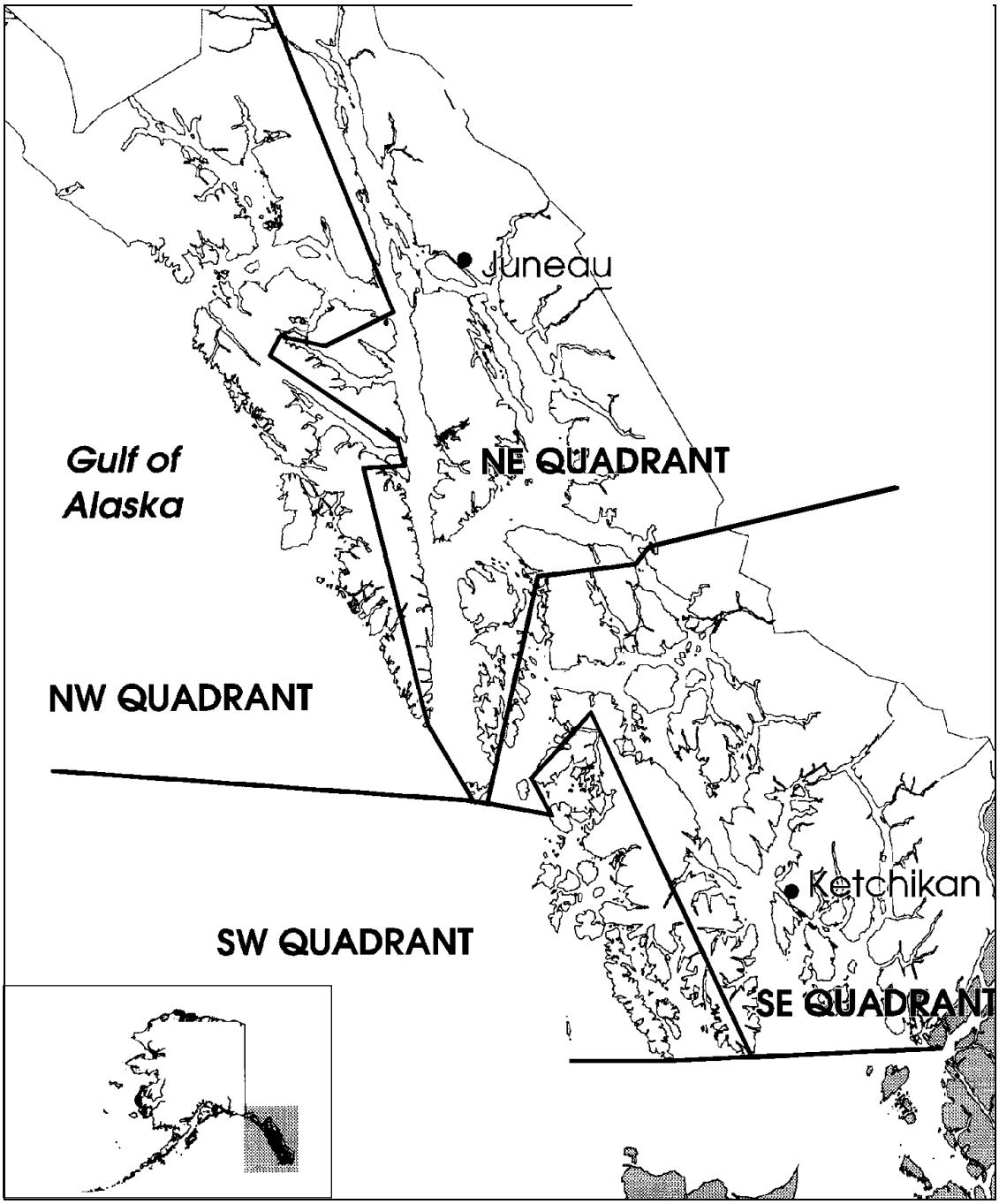

Figure 3.–Boundaries of CWT quadrants in Southeast Alaska.

as evidenced by the operculum punches. A total of 166 fish were sacrificed for their CWTs or died upon capture, and 239 tagged fish were recaptured more than once during one sampling period. No recaptured fish died upon recapture or were killed. These measures should have prevented any duplicate samplings. Details of the marking and recovery by location are shown in Appendix A2.

Table 6.–Summarized mark-recapture data for Nakwasina River coho salmon 2001. Notation follows that in Seber (1982).

Week	Number captured n_i	Number marked caught in m_i	Losses on capture	Released after marking R_i	Subsequently recaptured r_i
1	8	0	3	8	6
2	55	1	3	55	31
3	35	18	8	35	2
4	30	2	8	30	4
5	118	3	32	118	58
6	142	21	30	142	78
7	148	53	27	148	42
8	150	47	23	150	58
9	115	82	10	115	28
11	135	56	17	135	14
12	9	9		9	1
13	56	30	4	56	
Total	1,001	322	165	1,001	322

Small sample sizes in 3 weeks led us to pool data (weeks 0 and 1; 3 and 4; and 10 and 11) for the data analysis. In-stream abundance peaked at 1,320 adults in sample-period 3 and declined to 695 fish in sample-period 7 (Table 7). Period-to-period survival rates varied from 1.0 to 0.42 (Table 7).

The estimated spawning escapement of coho salmon in the Nakwasina River was 2,992 fish (SE = 510). Goodness-of fit-tests (Table 8) suggested the JS model fit the data well. Two estimates of survival and two recruitment estimates were constrained to yield admissible (realistic) values during the estimation procedure (Table 7).

Ten percent (10%) of the sample was captured or recovered in section 1, 62% at location 2, and 28% at location 3 or below (Table 9); in total, 24.3% of the fish inspected for Floy™ tags had either a Floy™ tag or a secondary mark. The probability of capturing a tagged fish was not significantly different between sections 1-3 (Table 9).

Based on an escapement estimate of 2,992, a coho salmon marine harvest of 1,439 fish, and smolt abundance of 45,677, we estimated the total run in 2001 to be 4,431 (SE = 533) and ocean survival to be 9.7% (SE = 0.4%). Total exploitation was estimated to be 32.5% (SE = 4.42%).

VISUAL COUNTS

Visual counts were conducted on the Nakwasina River on 3 occasions in 2001 (Table 10). The peak count (753) occurred November 13 (Table 10) and represented 25.2% of the estimated total

Table 7.–Jolly-Seber estimates of abundance (N), survival (ϕ)**, and recruitment** (B) **of adult coho salmon at Nakwasina River, 2001.**

Period	Dates	$\hat{N}$	SE($\hat{N}$)	$\hat{\phi}$	SE($\hat{\phi}$)	$\hat{B}$	SE($\hat{B}$)
1 (weeks 0–1)	09/25–10/06	–	–	1.00*	0	–	–
2 (week 2)	10/07–10/13	174	29	0.42	0.11	1,249	260
3 (weeks 3–4)	10/14–10/27	1,320	265	0.71	0.1	0*	0
4 (week 5)	10/28–11/03	903	201	1.00*	0	28	206
5 (week 6)	11/04–11/10	901	115	0.6	0.08	373	90
6 (week 7)	11/11–11/17	896	98	0.8	0.14	0*	0
7 (week 8)	11/18–11/24	695	119	0.59	0.16	351	118
8 (week 9)	11/25–12/01	754	196	–	–	–	–
9 (week 10–11)	12/16–12/22	–	–	–	–	–	–

Table 8.–Summary of goodness-of-fit tests for homogeneous capture/survival probabilities by tag group. Asterisks denote tests which contained one or more cells with an expected value of less than 2. Overall chi-squares are the sum of the individual test statistics.

	Component 1			Component 2		
Period	χ^2 stat	df	P-value	χ^2 stat	df	P-value
2	2.30	1	0.13	na	0	*
3	na	0	*	na	2	*
4	2.21	1	0.14	1.01	1	0.31
5	0.03	1	0.86	1.38	2	0.50
6	0.02	1	0.90	0.30	2	0.86
7	1.97	1	0.16	1.02	2	0.60
8	0.05	1	0.82	1.43	2	0.49
Overall	6.58	6	0.36	5.15	9	0.82

Table 9.–Results of χ^2 tests for differences in tagged rate between sections.

Location	Tagged	Untagged	Total	% of total captures by area
1	43	94	137	10
2	217	600	817	62
3	53	190	243	18
–3	9	117	126	10
Totals	322	1,001	1,323	
Sections 1–3		$\chi^2 = 4.39$	$P < 0.11$	

Table 10.–Stream counts in 2001, including number of coho counted, date, survey conditions, and percentage of total escapement estimate represented by daily count.

Date	Count	Conditions	% of total escapement abundance
10/31/01	703	Ideal: low, clear water	23.5
11/13/01	753	Ideal: low, clear water	25.2
11/30/01	657	Ideal: low, clear water	22.0

escapement. The area between river kilometer 7.75 (the upper end of the sampling area) and river kilometer 13.0 was inspected for coho salmon in November, but few fish were seen.

DISCUSSION

SMOLT ABUNDANCE AND ADULT HARVEST

To estimate smolt abundance and adult harvest we assumed:

(1) all smolts had an equal probability of being marked in 2000; or all adults had an equal probability of being inspected for CWT marks in 2001; or marked fish mixed completely with unmarked fish in the population between years;

(2) there was no recruitment, immigration, or emigration to the population between years;

(3) there was no tagging induced behavior or mortality;

(4) fish did not lose their marks and all marks were recognizable;

(5) tag code and release locations were correctly determined for all fish observed with a missing adipose fin;

(6) smolt emigrating from the unnamed tributary mix completely and spawn with the mainstem Nakwasina fish; and

(7) marked fish at the Nakwasina River were smolt.

We believe that most of these assumptions were satisfied. The first assumption required 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 most likely mixed within or across stocks during their extended time (14 months) at sea. This should provide adequate mixing of the population. In Nakwasina River catches, the fraction of adult coho salmon with marks (missing an adipose fin) did not vary significantly over time (Table 11). This indicates that at least one of the conditions in assumption 1 was satisfied.

Assumption 2 required that there was no recruitment to the population between years. Because almost all salmon return to their natal streams and sampling only occurred in the river, there was probably no appreciable recruitment to the stock between marking and recovery. We believe the presence of stray coho salmon reared at Medvejie Hatchery is possible but unlikely given the geographical distance between the two sites.

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 would likely increase the mortality rate of tagged fish and subsequently bias the estimate of abundance high and the estimate of marine survival low. Based on the age composition observed for 2000 smolt, it is also possible that some fish tagged in 2000 remained in fresh water an additional year to smolt and emigrate in 2001. This would also bias the abundance estimate high and the survival estimate low.

The smolt to adult survival rate of 9.7% is low, but comparable to other systems in the region. Average smolt to adult survival rates in other parts of the region range from 13.4% in Hugh Smith Lake (Shaul 1998) and 14% above Canyon Island in the Taku River to as high as 23% in Auke Lake (Yanusz et al. 1999). Because of the low smolt to adult survival rate in the Nakwasina River in 1999–2000 (6.7%) extra care was taken in spring 2000 to insure smolt were given an adequate opportunity to recover and smolt naturally. Because survival remained relatively low in 2000–2001, we assume that the Nakwasina River coho have a naturally lower survival rate.

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

Table 11.–Proportion of recovered Nakwasina River adult coho observed with and without adipose finclips.

Date	No clip	Clip observed	Tagged proportion
25-Sep	6	1	0.14
28-Sep	1		0.00
1-Oct	2	1	0.33
4-Oct	3	1	0.25
5-Oct	45	3	0.06
9-Oct	27	8	0.23
17-Oct	22	8	0.27
23-Oct	61	22	0.27
24-Oct	26	9	0.26
29-Oct	2		0.00
30-Oct	110	30	0.21
6-Nov	66	19	0.22
7-Nov	38	12	0.24
8-Nov	10	3	0.23
13-Nov	40	13	0.25
14-Nov	22	4	0.15
15-Nov	47	24	0.34
19-Nov	16	2	0.11
20-Nov	37	13	0.26
21-Nov	40	7	0.15
4-Dec	50	18	0.26
5-Dec	45	15	0.25
6-Dec	7		0.00
11-Dec	9		0.00
17-Dec	6		0.00
18-Dec	42	8	0.16
Total	780	221	0.22

ADULT ESCAPEMENT IN 2001

There were no indications to suggest problems with the abundance estimate; tag loss was low, sampling rates were high and assumptions of the JS experiment were met, and the JS model fit the

data. Additionally, marking did not appear to affect the behavior or movement of fish, as marked fish were observed spawning with or near unmarked fish throughout the study.

A higher rate of recapture was observed for males than females during the adult escapement. This may have been due to error in determining the sex of fish early in the run. Because the secondary maturation characteristics had not fully developed earlier in the run, it is possible that some fish were misidentified as females. When recaptured, fish previously identified as females may have been identified as males. This would lead to an indication that a higher proportion of males were recaptured .

Some adult coho may not have had the same probability of capture as others because only river kilometers 3.4 to 7.75 were sampled. However, this was unlikely because only small and statistically insignificant ($\chi^2 = 4.39$, $P = 0.11$) differences were found in the fractions of fish carrying marks in upriver (31%) and downriver (22%) locations.

The fact that the JS estimations were constrained to yield admissible values suggests violation of assumptions of some kind were experienced in the experiment, although the escapement estimate is unlikely to be seriously affected by this problem (Schwarz et al. 1993). One explanation for the difficulty is temporary emigration and re-immigration of fish from the study area, perhaps due to stress associated with handling and tagging.

VISUAL COUNTS

The Nakwasina River is similar to other clearwater streams in the area, and the relationship between the peak observer count and the total escapement are typical for similar streams in Southeast Alaska (McPherson 1996; Jones and McPherson 1997). The ability to count spawning salmon depends on many factors, including the observer, weather, water clarity, canopy cover, pool-to-riffle ratio, the density of fish, the amount of undercut banks, and the ecology, behavior, size, and color of salmon (Jones 1995).

HARVEST SAMPLING

To assess the adequacy of sampling rates in the purse seine and gillnet fisheries, we examined purse seine and gillnet harvests that occurred within Southeast Alaska where Nakwasina River coho salmon recovery occurred (Table 12). The overall sampling rate in the troll fishery in the Southwest Quadrant (Districts 103 and 104) was 47%. The sampling rate in the purse seine fishery in district 113 was 9% and 19% in District 109. The troll fisheries in the Northwest Quadrant ranged from 24% (Districts 113) to 18% (District 154). Because not all fisheries were sampled, and not all fish in a sampled fishery were examined, it is likely that Nakwasina River coho salmon carrying a CWT were missed and that harvest was underestimated in some fisheries.

The coho salmon harvest in the District 113 drift gillnet fishery was under reported and not sampled. 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, 1999, 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 692 coho salmon in 2001 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 Salmon Lake coho (another Sitka Sound coho salmon stock) but considered that estimate biased low due to under reporting and sampling problems similar to those experienced during 1999 and 2000.

The smolt abundance estimate in 1999 of 47,571 is similar to that in 2000 (46,575).

In future tagging events, extra care should be taken to ensure that any potential effects of tagging are minimized. Recommendations for future tagging include: (1) releasing smolt into side tribu-

Table 12.–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
103	troll	123,757	51,463	0.42
104	troll	111,123	59,419	0.53
109	purse	59,753	11,352	0.19
109	troll	208,252	52,137	0.25
113	purse	6,797	606	0.09
113	troll	835,319	198,345	0.24
114	troll	251,123	33,077	0.13
116	troll	88,418	15,492	0.18
154	troll	28,167	5,063	0.18
Totals		1,712,709	426,954	0.25

taries with extensive available rearing habitat, as opposed to mainstem areas with higher stream velocities; (2) minimizing transport distances by centralizing the tagging and holding site; (3) returning tagged smolt to locations near their capture site; and (4) 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 designs should also address those problems encountered in sampling the 1999–2001 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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APPENDIX A

Appendix A1.–Recoveries of coded wire tags originating from the Nakwasina River coho salmon during 2001.

Head	Tag Code	Gear Class	Recovery Date	Stat. Week	Quadrant	District	Sub-District	Length	Survey Site	Sample
RANDOM RECOVERIES										
152413	40417	PURSE	8/8/2001	32	NW	113	38	572	SITKA	1030700
504221	40417	PURSE	7/27/2001	30	NE	109	20	573	PETERSBURG	1050580
184853	40418	SPORT	7/12/2001	28	NW	113	45	560	SITKA	1035313
184887	40417	SPORT	7/18/2001	29	NW	113	45	710	SITKA	1035385
169582	40417	SPORT	7/25/2001	30	NW	113	45	655	SITKA	1035407
169587	40417	SPORT	7/26/2001	30	NW	113	45	680	SITKA	1035411
144823	40416	SPORT	7/30/2001	31	NW	113	31	600	SITKA	1035458
144830	40416	SPORT	7/31/2001	31	NW	113	41	640	SITKA	1035463
144848	40418	SPORT	8/1/2001	31	NW	113	31	620	SITKA	1035475
144947	40416	SPORT	8/7/2001	32	NW	113	41	580	SITKA	1035510
144894	40416	SPORT	8/10/2001	32	NW	113	31	620	SITKA	1035540
184980	40418	SPORT	8/13/2001	33	NW	113	45	690	SITKA	1035569
149708	40416	SPORT	8/25/2001	34	NW	113	45	630	SITKA	1035638
149665	40417	SPORT	8/20/2001	34	NW	113	41	480	SITKA	1035639
149680	40418	SPORT	8/21/2001	34	NW	113	45	730	SITKA	1035650
149688	40417	SPORT	8/22/2001	34	NW	113	45	520	SITKA	1035655
53594	40418	SPORT	7/21/2001	29	SW	104	30	590	CRAIG	1075083
192046	40417	TROLL	7/7/2001	27	NW	113	91	778	PELICAN	1010086
192025	40418	TROLL	7/7/2001	27	NW	113	91	641	PELICAN	1010086
192303	40418	TROLL	7/22/2001	30	NW	116	12	698	PELICAN	1010121
192335	40416	TROLL	7/22/2001	30	NW	113	91	637	PELICAN	1010124
192408	40418	TROLL	7/25/2001	30	NW	113	81	645	PELICAN	1010132
192524	44730	TROLL	7/31/2001	31	NW			725	PELICAN	1010150
192718	40418	TROLL	8/12/2001	33	NW	113	81	650	PELICAN	1010179
192901	40416	TROLL	8/21/2001	34	NW	113	91	615	PELICAN	1010218
193179	40416	TROLL	8/26/2001	35	NW			555	PELICAN	1010242
193399	40418	TROLL	9/6/2001	36	NW	114	21	637	PELICAN	1010292
193574	40416	TROLL	9/11/2001	37	NW	113	91	657	PELICAN	1010306
193662	40417	TROLL	9/13/2001	37	NW	113	91	650	PELICAN	1010321
193782	40416	TROLL	9/20/2001	38	NW	113	91	572	PELICAN	1010341
193843	40416	TROLL	9/21/2001	38	NW	113	91	752	PELICAN	1010344
193878	40416	TROLL	9/29/2001	39	NW	113	91	695	PELICAN	1010350
193889	40418	TROLL	9/29/2001	39	NW	113	91	715	PELICAN	1010351
193901	40416	TROLL	9/29/2001	39	NW	113	91	695	PELICAN	1010353
193917	40416	TROLL	9/30/2001	40	NW	113	91	707	PELICAN	1010354
151389	40416	TROLL	7/6/2001	27	NW	113	45	611	SITKA	1030498
153131	40418	TROLL	7/14/2001	28	NW	113	31	665	SITKA	1030593
153140	40417	TROLL	7/14/2001	28	NW	113		610	SITKA	1030594
153137	40418	TROLL	7/14/2001	28	NW	113		605	SITKA	1030594
152713	40418	TROLL	7/21/2001	29	NW	113	45	615	SITKA	1030623
186059	40416	TROLL	7/28/2001	30	NW	113	21	560	SITKA	1030651
186073	40417	TROLL	7/29/2001	31	NW	113	21	675	SITKA	1030652
153287	40416	TROLL	7/31/2001	31	NW	113	45	666	SITKA	1030666
152344	40418	TROLL	8/4/2001	31	NW	113	71	577	SITKA	1030687
152406	40416	TROLL	8/8/2001	32	NW	113	61	641	SITKA	1030699
152360	40418	TROLL	8/8/2001	32	NW	113	45	577	SITKA	1030701
152449	40418	TROLL	8/10/2001	32	NW			586	SITKA	1030707
152450	40418	TROLL	8/10/2001	32	NW			644	SITKA	1030707
152469	40416	TROLL	8/11/2001	32	NW			620	SITKA	1030709
152480	40417	TROLL	8/12/2001	33	NW	113		705	SITKA	1030711
152363	40416	TROLL	8/12/2001	33	NW	113		618	SITKA	1030714
152844	40416	TROLL	8/13/2001	33	NW			577	SITKA	1030731
152900	40416	TROLL	8/21/2001	34	NW	113	45	607	SITKA	1030783
187501	40417	TROLL	8/24/2001	34	NW	113	31	610	SITKA	1030820

-continued-

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Head	Tag Code	Gear Class	Recovery Date	Stat. Week	Quadrant	District	Sub-District	Length	Survey Site	Sample
RANDOM RECOVERIES CONTINUED										
187668	40416	TROLL	9/5/2001	36	NW	113		561	SITKA	1030875
187393	40418	TROLL	9/11/2001	37	NW	113	45	667	SITKA	1030904
186239	40417	TROLL	9/14/2001	37	NW	154		690	SITKA	1030929
186438	40416	TROLL	9/22/2001	38	NW	113	41	661	SITKA	1030943
186417	40416	TROLL	9/21/2001	38	NW	113	41	668	SITKA	1030945
186533	40416	TROLL	9/21/2001	38	NW	113	41	630	SITKA	1030951
186537	40416	TROLL	9/21/2001	38	NW	113	41	691	SITKA	1030951
186351	40418	TROLL	9/21/2001	38	NW	113	45	628	SITKA	1030956
152678	40416	TROLL	9/20/2001	38	NW	113	41	605	SITKA	1030961
152674	40418	TROLL	9/20/2001	38	NW	113	41	563	SITKA	1030961
152680	40418	TROLL	9/20/2001	38	NW	113	41	643	SITKA	1030961
186586	40417	TROLL	9/30/2001	40	NW	113		669	SITKA	1030976
505898	40416	TROLL	9/20/2001	38	NE	109	45	665	PETERSBURG	1051169
505679	40416	TROLL	9/22/2001	38	NW	113		723	PETERSBURG	1051176
41997	40416	TROLL	7/18/2001	29	SW	103	50	522	CRAIG	1070137
46182	40416	TROLL	7/19/2001	29	SW	104	40	587	CRAIG	1070153
46188	40416	TROLL	7/20/2001	29	SW			609	CRAIG	1070155
35874	40416	TROLL	8/7/2001	32	SW	103	70	560	CRAIG	1070314
29832	40418	TROLL	8/23/2001	34	SW	103	11	633	CRAIG	1070415
9072	40416	TROLL	7/11/2001	28	NW			634	EXCURSION INLET	1100027
9089	40416	TROLL	7/13/2001	28	NW			599	EXCURSION INLET	1100032
3798	40416	TROLL	7/15/2001	29	NW			594	EXCURSION INLET	1100033
7999	40416	TROLL	7/22/2001	30	NW			550	EXCURSION INLET	1100053
5487	40418	TROLL	7/25/2001	30	NW			609	EXCURSION INLET	1100063
5715	40418	TROLL	8/23/2001	34	NW			627	EXCURSION INLET	1100139
25897	40416	TROLL	9/1/2001	35	NW			661	EXCURSION INLET	1100146
23975	40418	TROLL	9/3/2001	36	NW			624	EXCURSION INLET	1100149
71032	40416	TROLL	9/5/2001	36	NW			635	EXCURSION INLET	1100152
71175	40418	TROLL	9/13/2001	37	NW			692	EXCURSION INLET	1100155
190335	40418	TROLL	7/5/2001	27	NW	113		620	HOONAH	1110211
190610	40417	TROLL	7/18/2001	29	NW	113		680	HOONAH	1110236
190628	40417	TROLL	7/20/2001	29	NW	113		565	HOONAH	1110243
190702	40416	TROLL	7/24/2001	30	NW	114	21	595	HOONAH	1110247
190777	40416	TROLL	7/29/2001	31	NW	113	92	600	HOONAH	1110259
190940	40417	TROLL	8/5/2001	32	NW			670	HOONAH	1110281
191042	40416	TROLL	8/9/2001	32	NW	113		560	HOONAH	1110293
191058	40416	TROLL	8/9/2001	32	NW	113	91	620	HOONAH	1110294
191089	40417	TROLL	8/13/2001	33	NW	114	21	660	HOONAH	1110306
195118	40416	TROLL	9/5/2001	36	NW	189	30	681	YAKUTAT	1140131
SELECT RECOVERIES										
184947	40416	SPORT	7/30/2001	31	NW	113	41		SITKA	1035439
149217	40416	SPORT	8/10/2001	32	NW	113	41		SITKA	1035556
188001	40417	SPORT	10/6/2001	40	NW	113	43		NAKWASINA RIVER	01EG5001
186802	40416	SPORT	10/1/2001	40	NW	113	43		NAKWASINA RIVER	01EG5003
152287	40417	TROLL	7/8/2001	28	NW	113	61		SITKA	1030680
187826	40417	TROLL	8/11/2001	32	NW	154			SITKA	1030737
162132	40418	TROLL	8/13/2001	33	NW	189	40		YAKUTAT	1140053

Appendix A2.–Capture and recovery data from the Nakwasina River coho salmon mark-recapture study, 2001, by area and date.

Week	Location	Original Captures	Recaptured	Total Captures	Proportion Tagged
September 25-September 29	1	1		1	0.00
	2	5		5	0.00
	3	2		2	0.00
		8			0.00
September 30-October 6	-3	4		4	0.00
	2	49	1	50	0.02
	3	2		2	0.00
		55	1		0.02
October 7- October 13	2	24	18	42	0.43
	3	11		11	0.00
		35	18		0.34
October 14-October20	2	30	2	32	0.06
		30	2		0.06
October 21-October 27	1	2		2	0.00
	2	72	3	75	0.04
	3	44		44	0.00
		118	3		0.02
October 28- November 3	1	2		2	0.00
	2	102	21	123	0.17
	3	38		38	0.00
		142	21		0.13
November 4- November 10	1	28	7	35	0.20
	2	85	25	110	0.23
	3	35	21	56	0.38
		148	53		0.26
November 11-November 17	-3	53	4	57	0.07
	1	25	5	30	0.17
	2	72	38	110	0.35
		150	47		0.24
November 18-November 24	-3	38	5	43	0.12
	1	12	12	24	0.50
	2	47	51	98	0.52
	3	18	14	32	0.44
		115	82		0.42
November 25-December 1	-3	22		22	0.00
	1	9	4	13	0.31
	2	68	38	106	0.36
	3	36	14	50	0.28
		135	56		0.29
December 9-December 15	1	9	9	18	0.50
		9	9		0.50
December 16-December 22	1	6	6	12	0.50
	2	46	20	66	0.30
	3	4	4	8	0.50
		56	30		0.35
Grand Total		1001	322	1323	0.24

Appendix A3.–Detection of size-selectivity in sampling and its effects on estimation of abundance and age and size composition.

RESULTS OF HYPOTHESIS TESTS, K-S on lengths of fish

Marked vs. Recaptures	Marks vs. Captures
Case I:	
Accept H_O	Accept H_O

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

Case II:

Accept H_O	Reject H_O

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

Case III:

Reject H_O	Accept H_O

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

Case IV:

Reject H_O	Reject H_O

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

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

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

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

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

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

Appendix A4.–Data files used to estimate parameters of the Nakwasina River coho salmon population, 2000 and 2001. Data files are archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.

Data file	Description
2001_Adult_CWT_Recoveries.xls	Recovery information from 2001 coded wire tag recoveries in Southeast Alaska.
Nakwasina_River_2001_M-R_and_CWT.xls	Mark, recapture, and coded wire tag recovery information from fish captured in the Nakwasina River in 2001.
2001AdultAWL.xls	Age and length information including summary statistics of adult coho captured in the Nakwasina River in 2001.
2000_smolt_AWL_data.xls	2000 smolt raw data including summaries of analyzed data.