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Estimates of Harvest, Escapement, Exploitation Rate, Smolt Production and Marine Survival for Coho Salmon Stocks in the Situk-Ahrnklin Lagoon, 2004–2006

by

Leon D. Shaul,

Kent F. Crabtree

Douglas M. Eggers

Michael Tracy

And

John H. Clark

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

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

FISHERY DATA REPORT NO. 10-11

STUDIES TO ESTIMATE HARVEST, ESCAPEMENT, EXPLOITATION RATE, SMOLT PRODUCTION AND MARINE SURVIVAL OF COHO SALMON STOCKS IN THE SITUK-AHRNKLIN LAGOON, 2004–2006

By
Leon D. Shaul, Kent F. Crabtree, Douglas M. Eggers
Alaska Department of Fish and Game, Division of Commercial Fisheries, Douglas, AK

Michael Tracy
Alaska Department of Fish and Game, Division of Commercial Fisheries, Yakutat, AK

and

John H. Clark
Alaska Department of Fish and Game, Office of the Commissioner, Helena, MT

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

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Leon D. Shaul, Kent F. Crabtree, Douglas M. Eggers
Alaska Department of Fish and Game, Division of Commercial Fisheries
802 Third Street, Douglas, AK 99824 USA

Michael Tracy
Alaska Department of Fish and Game, Division of Commercial Fisheries
P.O. Box 49, Yakutat, AK 99689-0049 USA

And

John H. Clark
Alaska Department of Fish and Game, Office of the Commissioner
4240 Jimtown Road, Helena, MT 59602 USA

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ABSTRACT

The Alaska Department of Fish and Game conducted a study from 2004 to 2006 to estimate the fishery contribution, exploitation rate, smolt production and survival rate of coho salmon stocks in the Situk-Ahrnklin Lagoon near Yakutat, Alaska. Smolt production was relatively equal for the Situk (847,305–1,057,275 smolts) and Ahrnklin Rivers (724,633–1,021,685 smolts), and substantially lower for the Lost River (302,226–514,402 smolts). A dry summer in 2004 was a likely cause of reduced smolt production in 2005 compared with 2004 (estimated 28% lower; range 20–41%). Marine survival rates for Situk River coho salmon returns in 2005 (5.4%; SE = 1.2%) and 2006 (4.9%; SE = 1.4%) were substantially lower than for other Southeast Alaska coho stocks. All-gear fishery exploitation rates on the Situk River stock were similar in 2005 (41.0%; SE = 8.8%) and 2006 (43.8%; SE = 9.3%). Mixed-stock marine fisheries outside the lagoon harvested about 5–6% of the Situk River stock in both years, with the majority taken by the troll fishery. Exploitation rate ranges for the lagoon set gillnet fishery and the Situk River sport fishery were 24–27% and 10–11%, respectively, subsistence fishery exploitation was about 1%. Maximum likelihood estimates generated for Lost and Ahrnklin River escapements were based on an assumption of survival and exploitation rates equal to the Situk River stock. Coho stock productivity estimates from the literature were applied to average Situk River smolt abundance and produced an optimum escapement range of 20,400 to 41,700 spawners, slightly lower than the present goal of 23,000 to 68,300 spawners (derived from a visual survey goal of 3,300 to 9,800 spawners multiplied by an expansion factor of 6.97). Given uncertainty in several parameters including the survey expansion factor and stock productivity, we recommend the current goal be retained.

Key words: coho salmon, *Oncorhynchus kisutch*, exploitation rate, marine survival, escapement goal, Situk River, Ahrnklin River, Lost River, Yakutat, Southeast Alaska

INTRODUCTION

The Situk River is a small river located approximately 14 km southeast of the city of Yakutat, Alaska (Figure 1). The river is approximately 20 km in length and flows from Situk and Mountain Lakes to the Situk-Ahrnklin lagoon before entering the Gulf of Alaska. The Ahrnklin River empties into the southeast portion of the lagoon. The Lost River, a third small stream located to the northwest of the Situk River has also drained into the Situk-Ahrnklin lagoon since a shift in its mouth in the winter of 1999–2000. Returning salmon migrate through the common lagoon to these 3 river systems and numerous smaller streams that flow directly into the lagoon.

Coho salmon (*Oncorhynchus kisutch*) returning to these systems are harvested by a variety of commercial, sport and subsistence fisheries. In marine waters, they are harvested by the Southeast Alaska commercial troll fishery, the Yakutat marine sport fishery and the Yakutat Bay set gillnet fishery (Subdistrict 183-10) conducted primarily on Khantaak Island and the north side of Ocean Cape. After entering the lagoon, the stocks are harvested by the Situk-Ahrnklin set gillnet fishery (Subdistrict 182-70) and by subsistence gillnet fishery and freshwater and estuarine sport fisheries.

Management policy is designed to regulate the fisheries to achieve escapement objectives on an in-season basis. Most of the active in-season management is done in the set gillnet fisheries by adjusting the amount of time fished each week based on information on catch, fishing effort, aerial escapement survey results and weather conditions. Current escapement objectives are based on peak annual survey counts of 3,300 to 9,800 coho spawners in the Situk River and 2,200 to 6,500 coho spawners in the Lost River (Clark and Clark 1994). A weir on the lower Situk River is operated to enumerate salmon and steelhead from April to August, but cannot be effectively operated through the fall coho salmon migration when extreme flows are common. Sporadic escapement surveys have been conducted on the Ahrnklin River and its tributary, the Antlen River. However, no escapement goal has been established for survey counts in the Ahrnklin system because poor visibility has limited the effectiveness of aerial and boat surveys.

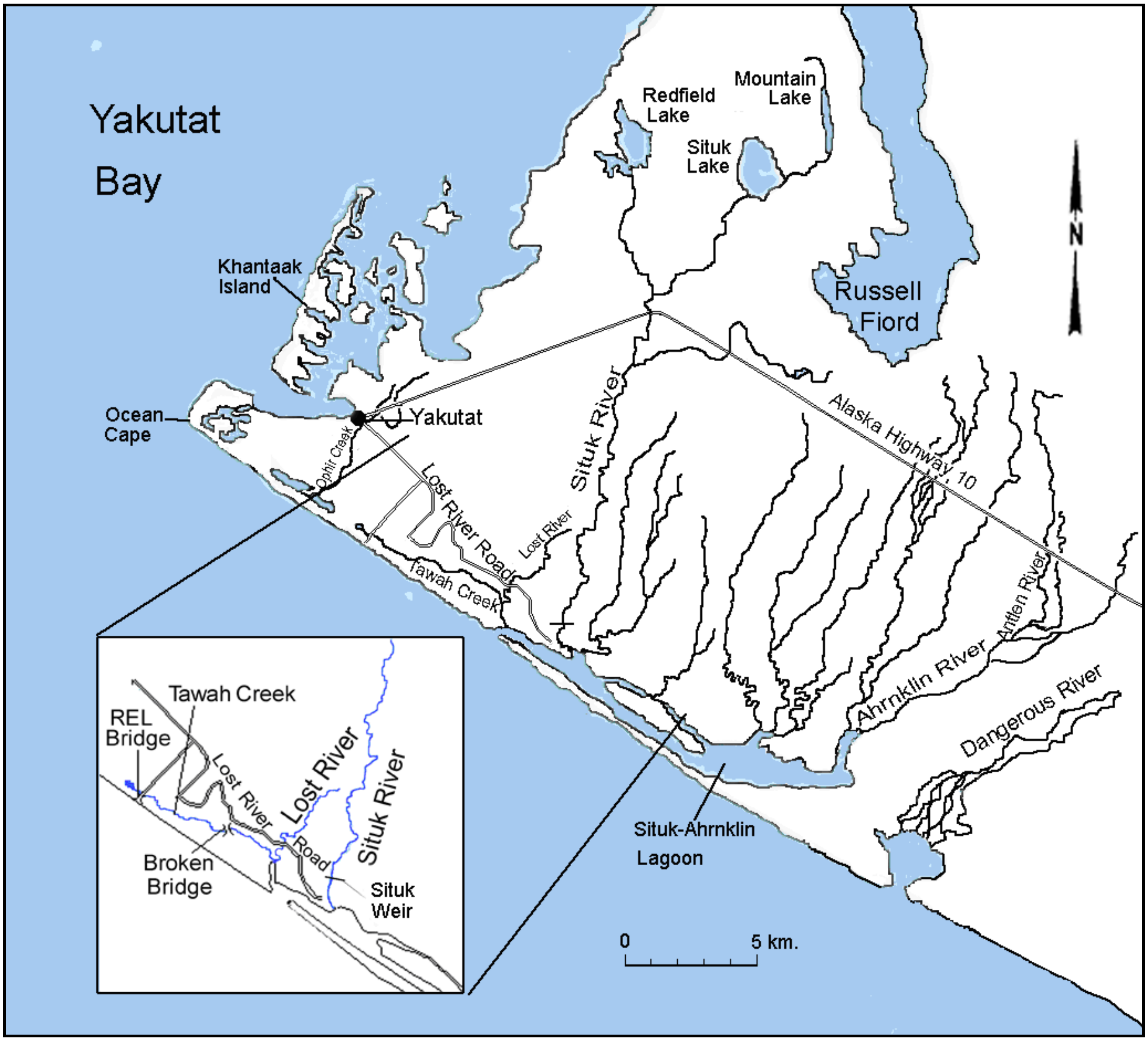

Figure 1.–Map of the Lost, Situk and Ahrnklin River drainages near Yakutat, Alaska.

Despite their substantial economic importance, the existing stock assessment program for Situk-Ahrnklin Lagoon coho salmon stocks is rudimentary and the escapement goals currently in use were based upon a wide array of untested assumptions. Total escapement of coho salmon in these rivers has been largely unknown, with un-calibrated survey counts being the only available measure of spawner abundance. Since 2003, however, several mark-recapture studies have been conducted to estimate total escapement to the Lost and Situk River systems. Estimated spawner abundance in the Lost River in 2003 was about 23,685 fish (SE = 7,835), which represented 3.70 times the peak survey count of 6,396 spawners (Clark et al 2006). A 2004 estimate of 47,566 spawners (SE = 18,560) was 9.42 times the peak survey count of 5,047 spawners (Clark et al 2005). Estimated abundance of coho salmon in the Situk River in 2004 was about 54,014 fish (SE = 17,000; Waltemeyer et al. 2005). After subtracting an estimated sport catch of 4,432 coho salmon upstream from the marking site near the weir site, the estimated 2004 spawning escapement was 49,582 spawners, or 4.82 times the peak survey count of 10,284 spawners. Eggers and Tracy (2007) estimated the 2005 and 2006 Situk River escapements above the Situk Weir at 35,080 fish (SE = 12,310) in 2005 and 24,805 fish (SE = 8,582) in 2006, respectively. Subtraction of the estimated sport catch above the tagging site (1,436 fish in 2005 and 1,636 fish in 2006) results in net escapement estimates of 33,644 spawners in 2005 and 23,169 spawners in 2006. These respective estimates are 13.38 times the peak count of 2,514 spawners in 2005 and 2.71 times the peak count of 8,553 spawners in 2006.

Exploitation rates in offshore troll and inshore fisheries are largely unknown. The existing understanding of the distribution of these offshore versus inshore harvests is limited to coded-wire tag results obtained for the Lost River in 1986 and the Situk River in 1985 (Shaul et al. 1991) and for the Situk River in 1993 (Ericksen and McPherson 1997). The annual harvest by the set gillnet fishery in the Situk-Ahrnklin Lagoon over the 20-year period from 1987 to 2006 has been substantial (average 112,500 fish; range 29,900 to 217,100), however, the stock composition of the catch has been largely unknown. Improved information on the harvest contribution of these stocks and their exploitation rate in both offshore and onshore fisheries is needed for development of appropriate escapement goals. Another impetus for improved information concerning these stocks is the potential for the Hubbard Glacier to block Russell Fiord, forming a lake that may eventually direct flow of glacial water into the Situk River or another nearby stream.

The primary focus of this study was to estimate the fishery contribution, marine survival rate and exploitation rate by fishery for Situk River coho salmon in 2005 and 2006. Estimates for the latter 2 parameters employ escapement estimates for the Situk River developed by Eggers and Tracy (2007). Additional objectives were to estimate coho salmon smolt production from 3 rivers (Situk, Ahrnklin and Lost) in 2004 and 2005 and the contribution to fisheries by the Ahrnklin and Lost River stocks in 2005 and 2006. A final objective was to develop maximum likelihood escapement estimates for the Lost and Ahrnklin Rivers based on their smolt production and fishery contribution estimates with assumed equal marine survival and mixed-stock exploitation rates compared with the Situk River.

METHODS

SMOLT CAPTURE AND TAGGING

In Spring 2004 and 2005, coho salmon smolts were captured and coded-wire tagged in 3 Yakutat area river systems that drain into the Situk-Ahrnklin Lagoon with an objective of marking 30,000 smolts per system per year. Capture methods used included a beach seine (Situk and Ahrnklin Rivers, a smolt weir (Lost River), a rotary screw trap (Situk River) and minnow traps (all 3 rivers) from late-April to mid-June. Captured smolts were adipose clipped and implanted with a coded-wire tag of a distinctive code for each river using methods described by Koerner (1977).

Beginning in the last week of April in 2004 and first week of May in 2005, minnow traps baited with salmon roe treated with a 5% beta dyne solution were deployed from the stream bank and by boat in Tawah Creek, the main coho salmon rearing area in the Lost River system. The minnow traps were fished in sections upstream and downstream of the REL Bridge near Cannon Beach, and on lower Tawah Creek in the vicinity of Broken Bridge (Figure 1). Once suitable locations were found, the traps were usually checked twice daily and were seldom moved. In 2004, most trapping was done with standard Gee minnow traps produced by the Cuba Manufacturing Company, in addition to 4 large custom-made minnow traps. In 2005, all trapping was done using large custom-made traps designed by Kent Crabtree and shown and described in Magnus et al. (2006). Shortly after trapping commenced, a smolt weir was installed at Broken Bridge and operated throughout most of the smolt migration. A crew of 4 technicians conducted the work, checking traps, collecting fish, and delivering them to the tagging site. After capture, all smolts were transported to Broken Bridge where they were coded-wire tagged, adipose-clipped, sub-sampled for age and length, and released.

When the tagging objective was completed at Tawah Creek in 2004, the crew from that system moved to the lower Situk River where they operated an 8 ft. diameter rotary screw trap near a camp site on the west bank approximately 1.5 km upstream from the adult salmon weir. The screw trap was installed and operated in the same area and using the same methods employed successfully in the Situk River by Thedinga et al. (1994) and Ericksen and McPherson (1997). It was fished in a location with adequate depth where the main current passed next to the west bank. The trap was held offshore by a boom log fixed to the bank and tied off by a tag line fixed to the front pontoons. Wing panels of ¼" Vexar were installed on both sides of the trap to improve capture efficiency by directing smolts toward the cone.

Standard small minnow traps and large custom-made minnow traps were deployed in the lower Situk River in a section about 1 to 2 km above the weir in 2004 and 2005. The traps were checked and smolts removed 3 times daily, with the crew tagging fish between checks. A small-mesh beach seine was also used to capture smolts in open areas of the lower Situk River below the weir site in both years. In some cases, treated salmon bait was used to attract smolts into suitable areas for seining. The rotary screw trap was not operated in 2005 due to poor catch rates in 2004 relative to other methods of capture, including minnow trapping and seining.

A second crew of 3 technicians set up camp on the lower Ahrnklin River and began capturing and tagging smolts beginning in early-May 2004 and mid-May 2005. They deployed large and small minnow traps in suitable habitat and used a small-mesh beach seine to capture smolts from pools in the lower river. Smolts were transported to camp, tagged and released.

At all tagging locations, coho salmon measuring 80 mm or longer (snout-fork length) were sorted from the catch and other species and smaller coho salmon were released. Coho salmon intended for tagging were sorted into 3 size classes (80–99 mm; 101–130 mm; and >130 mm), and tagged at different machine settings, with different head molds for optimum tag placement. The fish were anesthetized and their adipose fins removed before tagging. A sample of 100 tagged fish was held overnight to evaluate tagging mortality and tag retention. A weekly total of 80 smolts were sampled for age and length with a total season target of 400 samples per system.

ESTIMATION OF SMOLT PRODUCTION AND HARVEST

In Fall 2005 and 2006, beach seines were employed in the Situk, Lost and Ahrnklin Rivers to sample returning adults for coded-wire tags in order to generate a Chapman estimate of the smolt migration from each system and to estimate the proportion of each population that carried coded-wire tags implanted in that system (Θ). All adult coho salmon captured in beach seines were examined for an adipose clip and if one existed, the head was taken and sent to the ADF&G Coded Wire Tag and Otolith Laboratory in Juneau for tag removal and decoding. The estimated harvest of coded-wire tagged fish was divided by $\hat{\theta}$ to estimate the total contribution of each stock by area, time and gear type.

Smolt Abundance Estimation

Abundance of coho salmon smolts (N_S) was estimated using Chapman's modification of Petersen's estimator for closed populations in equation 1 (Seber 1982, p. 60). A sample of smolts was marked and tagged and a sample of adults was inspected for marks in the following year. During the year at sea the population was open to mortality, but because of the species' life history, was assumed closed to recruitment.

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

where M is the number of smolts marked and released in a year and R is the number of adipose clip marks in a sample of C adults inspected in the escapement for marks a year later.

In this equation, R is the random variable, and C and M are assumed to be constants. In mark-recapture sampling, R follows a hyper geometric distribution by definition, which can be approximated with the Poisson distribution (Thompson 1992). By simplifying the Petersen mark-recapture equation, we have

$$\frac{1}{\hat{N}_S} \approx \frac{R}{CM}. \qquad (2)$$

In the Poisson approximation for R, the mean and variance are the same, so that the variance (var), standard error (SE), and coefficient of variation (CV) of $\frac{1}{\hat{N}}$ are calculated as follows:

$$\text{var}(\frac{1}{\hat{N}_S}) \approx \frac{R}{(CM)^2}; \qquad (3)$$

$$\text{SE}(\frac{1}{\hat{N}_S}) = \frac{\sqrt{R}}{CM}\text{; and,} \qquad (4)$$

$$\text{CV}(\frac{1}{\hat{N}_S}) = \frac{1}{\sqrt{R}} \cdot 100. \qquad (5)$$

If the numbers of mark-recoveries are moderate or large, the pooled Petersen estimate should meet the criteria outlined above. The distribution for R can then be approximated with the normal distribution. Under these circumstances, we will assume $\frac{1}{\hat{N}_S}$ is approximately normally distributed, and we will generate 95% confidence intervals for $\frac{1}{N_S}$ as,

$$\frac{1}{\hat{N}_S} \pm 1.96 \cdot \text{SE}(\frac{1}{\hat{N}_S}). \qquad (6)$$

Finally, 95% confidence intervals for N_S were generated by inverting the confidence intervals for $\frac{1}{N_S}$.

In cases in which adipose clipped fish were recovered that carried tags from other systems, it was necessary to substitute an estimate of R by multiplying the number of adipose clips in the escapement sample by the proportion of tags recovered in the inriver sample that were from the local system (T_L) compared with recoveries from other systems (T_O):

$$\hat{R} = R\left(\frac{T_L}{T_L + T_O}\right) \quad (7)$$

M represents the number of adipose clipped fish released without an adjustment for estimated tag loss at the time of release. Tag loss was estimated based on the proportion of fish in the escapement that registered no signal with the field detector and were found not to contain a tag upon further examination at the tag lab under an inherent assumption of no natural incidence of adipose clips. Tag loss was assumed to be equal among all tagged groups. In cases where tags from other systems were recovered in the escapement sample, confidence bounds for $\hat{N}_S$ were generated from 1,000 simulations with R and T_L as binomially distributed random variables.

Estimation of Harvest

Stock-specific harvest estimates in mixed-stock fisheries were made using coded-wire tags. Data on recovery of tags were obtained from a computer database maintained by the ADF&G Mark, Tag, and Age Lab located in Juneau. Methods described in Bernard and Clark (1996) were used to estimate the commercial and marine sport harvest of coho salmon from the Situk, Lost and Ahrnklin Rivers using information from stratified catch sampling programs. For 2005, commercial catch and sample data for the set gillnet fisheries in Yakutat Bay (Subdistrict 183-10) and the Situk-Ahrnklin Lagoon (Subdistrict 182-70) in 2005 were summarized by ADF&G statistical week and subdistrict. In 2006, however, 3 broader groupings of statistical weeks (25–36, 37–38, 39–42), each encompassing approximately a third of the season catch, were used to stratify set gillnet recoveries because the weekly sampling effort was less stable. Tag recoveries from the commercial troll fishery were expanded by period and quadrant. Tag recoveries from random dockside sampling of the Yakutat marine sport harvest were expanded by a total season catch estimate for the fishery based on an annual mail-out survey. Resultant estimates of the harvest of coded-wire tags were divided by $\hat{\theta}$ to estimate fishery contribution.

Annual sport harvests in freshwater streams and in the marine fishery in the Yakutat area were estimated from expanded mail-out surveys returned by anglers in 2005 and 2006 (Jennings et al. 2009*a-b*. In-river sport and subsistence harvests were assumed to originate entirely from stocks in the system from which they were reported. Subsistence harvest estimates were compiled from mandatory permit reports by subsistence fishermen and were downloaded from the ALEX catch and escapement database maintained by the ADF&G, Commercial Fisheries Division in Douglas.

Situk River Escapement Estimates

Eggers and Tracy (2007) estimated the number of fish entering the Situk River in 2005 and 2006 based on Chapman's modification of the Peterson estimator described above. Event 1 marking was conducted near where the Situk adult salmon weir was operated in the spring and summer. The estimated harvest based on the mail-out survey was attributed to sections above and below the weir, with a small proportion unspecified in both years. We assigned the unspecified portion of the harvest proportionately based on the harvest estimates specific to areas above and below the weir. The resulting estimate of harvest above the weir was subtracted from the Chapman estimate to arrive at an estimate of the number of spawners.

Situk River Run Size, Exploitation and Marine Survival

Estimates of run size (N_A) of coho salmon returning to the Situk River and the associated exploitation rates (U) in commercial and sport fisheries are based on the sum of estimates of harvest (H) and escapement (E):

$$\hat{N}_A = \hat{H} + \hat{E} \tag{8}$$

$$\text{var}(\hat{N}_A) = \text{var}(\hat{H}) + \text{var}(\hat{E}) \tag{9}$$

$$\hat{U} = \frac{\hat{H}}{\hat{H} + \hat{E}} \tag{10}$$

Variance for equation (10) was approximated with the delta method (Seber 1982, p. 8) to be:

$$\text{var}(\hat{U}) \cong \frac{\text{var}(\hat{H})\hat{E}^2}{\hat{N}_A^4} + \frac{\text{var}(\hat{E})\hat{H}^2}{\hat{N}_A^4} \tag{11}$$

Survival rate of smolts to adults (μ) was estimated as:

$$\hat{\mu} = \frac{\hat{N}_A}{\hat{N}_S} \tag{12}$$

Variance for equation (12) was approximated with the delta method to be:

$$\text{var}(\hat{\mu}) \cong \hat{\mu}^2 \left[\frac{\text{var}(\hat{N}_A)}{\hat{N}_A^2} + \frac{\text{var}(\hat{N}_S)}{\hat{N}_S^2} \right] \tag{13}$$

Lost River and Ahrnklin River Escapement Estimates

Estimates of coho salmon escapement for the Lost and Ahrnklin Rivers were developed assuming the following: (1) marine survival is equal among the respective streams for Situk, Lost, and Ahrnklin River smolts; (2) troll fishery exploitation rates are identical among the respective runs to the Situk, Lost, and Ahrnklin Rivers; (3) marine sport fishery exploitation rates are identical for the 3 respective runs; and, (4) freshwater sport exploitation rates are identical for respective coho salmon runs to the Situk and Lost Rivers (note that freshwater sport harvest for Ahrnklin River coho salmon is nil).

Estimates of coho salmon escapement for the Lost and Ahrnklin Rivers were based on fitting the following model to respective annual estimated catches of Situk, Lost, and Ahrnklin River coho salmon in the troll, Situk Lagoon commercial gillnet (Subdistrict 182-70), Yakutat area marine sport, and Situk and Lost River freshwater sport fisheries.

Define the following: There are 4 coho salmon fisheries [troll (i = 1), Situk Lagoon gill net (i = 2), Yakutat area marine sport (i = 3), freshwater sport and subsistence (i = 4)] and 3 coho salmon stocks (Situk River (i = 1), Lost River (i = 2), and Ahrnklin River (i = 3)). H_i^j = harvest of coho salmon of stock i and fishery j; E_j = escapement coho salmon of stock j; N_j = total coho salmon run (catch + escapement) of stock j; S_j = coho salmon smolt abundance of stock j; U_j^i = exploitation rate of coho salmon of stock j in fishery i; and μ = marine survival (smolts to adult) of coho salmon.

The harvest of coho salmon in various fisheries and stocks is modeled in 2 ways. The first predicts harvest from estimated smolts (HS_j^i):

$$HS_j^i = \mu S_j U_j^i \tag{14}$$

while the second predicts harvest from the estimated terminal run (HT_j^i).

$$HT_j^i = U_j^i (H_j^i + E_j) \tag{15}$$

In the model, known quantities include: Situk River coho salmon escapement (E_1), smolt abundances for Situk, Lost, and Ahrnklin Rivers (S_j,s). Model parameters estimated include, exploitation rates for 4 fisheries (U_j^i,s), marine survival (μ), and the coho salmon escapement to the Lost and Ahrnklin Rivers (E_2 and E_3). The estimated quantities were estimated using the method of maximum likelihood. Here the likelihood, $L((E_1, E_2, U_j^i, \mu) \big| data(H_j^i, S_j E_1))$, was determined based on the normal probability distribution with the alternative models for harvest weighted equally.

$$L = L(E_2, E_3, U_j^i, \mu \,|\, H_j^i, S_j, E_1) = \prod_{i=1}^{4}\prod_{j=1}^{3} \left(1 \Big/ \sqrt{2\pi\sigma^2} \right) \exp\left(\frac{-(HS_j^i - \hat{H}S_j^i)}{2\sigma^2} \right) \exp\left(\frac{-(HT_j^i - \hat{H}T_j^i)}{2\sigma^2} \right) \tag{16}$$

The estimated parameters were estimated by maximizing $-\log(L)$ by searching over parameter space using EXCEL solver. Confidence intervals for estimated parameters were estimated based on likelihood profiles. Here the likelihood profile for a parameter, is the profile of maximum likelihoods (over the possible range of other parameters values) constrained to the specific parameter value in the profile.

RESULTS

SMOLT TAGGING

The objective of tagging 30,000 smolts in each system in each year was largely met. In 2004, the total number of smolts tagged and released per system was Lost River 30,258, Ahrnklin River 28,265, and Situk River 31,303 (Table 1 and Appendix A). In 2005, the number of smolts tagged by system was as follows: Lost River 30,950, Ahrnklin 30,800, and Situk River 30,057.

Substantial variation was found in the average size and timing of smolts captured in the 3 systems. The average length of smolts sampled in the Lost River was 95.4 mm (SE = 1.2) in 2004 and 98.9 mm (SE = 0.5) in 2005 (Table 1). Situk River smolts were largest in both years, averaging 99.9 mm (SE = 1.2) in 2004 and 104.8 mm (SE = 0.5) in 2005. Ahrnklin River smolts were smaller than those from the other systems in both years, averaging 84.8 mm (SE = 0.9) in 2004 and 97.1 mm (SE 0.4) in 2005. Average smolt length estimates for the 3 systems were 3.7% to 14.5% greater (average 7.7%) in 2005, compared with 2004.

Although the timing of smolt capture was influenced to some extent by the relative timing of capture effort on each system, major differences in the migratory timing of smolts were evident, particularly between the Lost and Situk Rivers (Appendix A). These differences made it possible to concentrate first on capturing smolts in Tawah Creek in the Lost River system before targeting the much later Situk River smolt run. In 2004, smolts were captured in Tawah Creek from April 29 through May 24 with 90% caught during May 5 to May 22. Based on 2004 results, trapping effort in Tawah Creek in 2005 was focused during May 3 to May 19, with 90% of the catch occurring during May 4 to May 19. In the Situk River, smolts were tagged during May 29 to June 17, 2004 and May 24 to June 12, 2005, with 90% of the catch occurring during June 3 to June 16 in 2004, and during May 27 to June 11 in 2005. The timing of capture in the Ahrnklin River was intermediate between the Lost and Situk Rivers, with tagging occurring during May 7 to June 4, 2004 and May 20 to June 9, 2005. In the Ahrnklin River, 90% of smolts were tagged during May 10 to June 2 in 2004, and during May 22 to June 9 in 2005. The later smolt capture timing in that system in 2005 was due in part to later initiation of field work, derived from timing information gained in 2004.

TAG RECOVERIES

In 2005, a total of 66 adipose-clipped fish were recovered from escapement samples from the 3 rivers. Among 35 adipose clips from the Situk River, 32 contained tags implanted locally in the Situk River while 1 contained at tag from the Lost River and 2 contained no tag (Table 1). All 21 adipose clipped fish from the Ahrnklin River had tags, but one was implanted on the Situk River while the remaining 20 were from Ahrnklin River tagging. Ten adipose clipped fish were recovered from the Lost River of which all contained tags implanted in smolts there in 2004. Estimates of the proportion of returning adults marked with local tags (Θ) were 2.627% in the Situk River, 2.639% in the Ahrnklin River and 5.376% in the Lost River.

In 2006, a total of 87 adipose-clipped fish were recovered from escapement samples from the 3 rivers. Among 36 adipose clips from the Situk River, 35 were sent to the tag lab and successfully processed. Of those, 34 contained tags implanted locally in the Situk River while 1 contained a tag from the Ahrnklin River (Table 1). Of 18 adipose clipped fish recovered from the Ahrnklin River in 2006, 17 had tags implanted in smolts there in 2005 while one fish contained no tag. In the Lost River, 33 adipose clipped fish were recovered in 2006 of which 32 contained tags implanted there in 2005 while one did not contain a tag. In 2006, the marked fraction of fish returning to all 3 systems was substantially higher than in 2005. Estimates of the proportion of returning adults marked with local tags (Θ) in 2006 were 3.452% in the Situk River, 3.812% in the Ahrnklin River and 9.668% in the Lost River.

Estimated overall tag retention between the smolt and adult stages was 97.4% with only 4 heads without tags identified in a total sample of 152 heads from all 3 rivers in both years. This estimate may be conservative if there was any natural absence of adipose fins.

SMOLT ESTIMATES

Smolt production from the Situk and Ahrnklin Rivers was similar in magnitude while the Lost River produced substantially fewer smolts in both years. In 2004, total smolt abundance estimates (with 95% confidence bounds in parentheses), by river were as follows: Situk River, 1,057,275 smolts (761,502–1,491,275); Ahrnklin River, 1,021,685 smolts (668,428–1,569,588); and Lost River, 514,402 smolts (328,375–1,186,645) (Table 1). Smolt abundance estimates were lower for all 3 systems in 2005: Situk River 847,305 (608,860–1,183,112) smolts, Ahrnklin River, 724,633 smolts (503,687–1,290,891); and Lost River, 302,226 smolts (226,868–452,547). The combined smolt production estimate for 2005 (1,874,164 smolts; SE = 223,699) was 28% lower than the estimated 2004 smolt migration of 2,596,654 fish (SE = 336,109). Estimates for individual systems ranged from 20 to 41% (average 30%) lower in 2005, compared with 2004.

Recovery of 3 tagged fish (2.0%) that returned to a system different from the one in which they were tagged (out of a total of 148 escapement tag recoveries) suggests that the Chapman estimator’s implicit assumption of a closed population was to some extent violated.

HARVEST ESTIMATES

Catch, sample and recovery data used to expand coded-wire tag recoveries to estimates of fishery harvest by stock, fishery and time period are shown in Appendixes C to G, with definitions of notation found in Appendix B.

The Situk River was the largest fishery contributor of the 3 stocks in both years, with an estimated total catch of 23,363 fish (SE = 1,949) in 2005 (Table 2) and 18,075 fish (SE = 2,158) in 2006 (Table 3). The Lost River was the smallest contributor at 6,113 fish (SE = 951) in 2005 and 6,568 fish (SE = 925) in 2006 while the harvest of Ahrnklin River fish was intermediate at 13,911 fish (SE = 2,078) in 2005 and 9,450 fish (SE = 1,826) in 2006.

The freshwater sport harvest in the Ahrnklin River was nearly negligible, owing to its glacial coloration and more difficult access. In contrast, the freshwater sport fishery accounted for 25% of the total all-gear harvest for the Situk River stock in both years and 35 to 36% of total harvest for the Lost River stock (Table 4). The subsistence harvest of only 657 fish in 2005 and 358 fish in 2006 was reported entirely from the Situk River and assumed to have originated from that system, accounting for 2 to 3% of the total harvest of that stock in both years.

Table 1.–Situk Lagoon coho salmon smolt statistics, 2004–2005.

	Lost River		Ahrnklin River		Situk River	
	2004	**2005**	**2004**	**2005**	**2004**	**2005**
Smolt Tagging						
Number Tagged (Year x)	30,258	30,950	28,265	30,800	31,303	30,057
Snout-fork Length (mm) [Average (SE)]	95.4 (1.2)	98.9 (0.5)	84.8 (0.9)	97.1 (0.4)	99.9 (1.2)	104.8 (0.5)
Escapement Sample						
Adults Sampled (Year x+1)	186	331	758	446	1,218	1,013
Number with Adipose Clips	10	33	21	18	35	36
Heads Recovered	10	33	21	18	35	35
Heads with Local Tags	10	32	20	17	32	34
Heads with Non-local tags (Location Tagged)	0	0	1 (Situk)	0	1 (Lost)	1 (Ahrnklin)
Heads with No Tag	0	1	0	1	2	0
Theta (% with Local Tags)	5.376%	9.668%	2.639%	3.812%	2.627%	3.452%
Smolt Population						
Estimate	514,402	302,226	1,021,685	724,633	1,057,275	847,305
Lower Bound (95% C.I.)	328,375	226,868	668,428	503,687	761,502	608,860
Upper Bound (95% C.I.)	1,186,645	452,547	1,569,588	1,290,891	1,491,275	1,183,112

The majority of the harvest of all 3 stocks occurred in the set gillnet fishery in the Situk-Ahrnklin Lagoon (Subdistrict 182-70) while smaller marine harvests of all 3 stocks were taken in the troll fishery, the Yakutat Bay set gillnet fishery (Subdistrict 183-10) and the Yakutat area marine sport fishery. Of those fisheries, the troll fishery accounted for the greatest share, with the average troll percentage of the total harvest ranging from about 9 to 10% for both the Lost River and Situk River stocks to 15% for the Ahrnklin River stock. Nearly all of the estimated troll catch was taken in regulatory districts in the Yakutat area (Districts 181-191). Only 2 tags out of 75 random recoveries from the 3 stocks in the troll fishery were reported caught in districts south of the Yakutat Area. One Situk River tag (expanded to 125 fish caught) was recovered in 2006 in District 114 and one tag (expanded to 148 fish caught) from the Ahrnklin River was recovered in 2005 in District 116, south of the Yakutat area. After subtracting the fish taken outside of the Yakutat Area, the total contribution by the 3 stocks to the Yakutat troll fishery in 2005 was estimated at 6,127 fish or 8.9% of the total troll catch of 68,855 fish. In 2006, the combined contribution was estimated at 2,746 fish or 11.4% of the 2006 Yakutat troll catch of 24,067 fish. Contribution estimates to the Yakutat area troll catch by the Situk River stock alone were 2,708 fish (3.9%) in 2005 and 1,383 fish (5.7%) in 2006.

In 2005, the combined contribution estimate by the 3 stocks accounted for only 26,832 fish or 52.7% (SE = 5.3%) of the total harvest of 50,933 coho salmon by the Situk-Ahrnklin set gillnet fishery. The result was similar in 2006, with the 3 systems contributing only 22,713 fish or 46.0% (SE = 5.4%) of a season total catch of 49,336 fish.

For 2005, the estimated total harvest of 23,363 Situk River coho salmon added to the estimated escapement of 33,644 spawners, results in a total return estimate of 57,007 fish (Table 2; Figure 2). Both harvest and escapement were lower in 2006 when the total run estimate of 41,244 fish included an all-gear catch of 18,075 fish and an escapement of 23,169 spawners (Table 3; Figure 2).

SITUK RIVER EXPLOITATION RATE

Total all-gear exploitation rate estimates for the Situk River stock as a percent of the total run were similar in the 2 years at 41.0% (SE = 8.8%) in 2005 (Table 2) and 43.8% (SE = 9.3%) in 2006 (Table 3), and were similarly distributed among the fisheries in both years. The highest exploitation rate occurred in the set gillnet fishery in the Situk-Ahrnklin Lagoon (Subdistrict 182-70) at 23.8% in 2005 and 27.3% in 2006. The freshwater sport fishery also had a substantial effect, with an exploitation rate estimate of 10.1% in 2005 and 10.9% in 2006. The subsistence fishery removed a relatively small proportion of the run, estimated at about 1% in both years. Exploitation rates outside the lagoon were relatively low at 3.3 to 4.7% in the troll fishery, 0.3 to 0.6% in the Yakutat marine sport fishery, and 0.6 to 1.1% in the Yakutat Bay set gillnet fishery, for a total of 4.8 to 5.9%.

SITUK RIVER MARINE SURVIVAL

The marine survival rate for Situk River smolts entering the sea in 2004 and returning to the fisheries and escapement in 2005 was estimated at 5.4% (SE = 1.2%; Tables 2 and 3). The survival rate for Situk River smolts entering the sea in 2005 and returning in 2006 was similar at 4.9% (SE = 1.4%).

HARVEST TIMING

In 2005, tagged fish from the Ahrnklin River displayed the earliest cumulative catch timing in the set gillnet fishery in the lagoon, while tagged Situk River fish were present in the catch in about equal proportions throughout the season (Figure 3). The Lost River stock displayed the latest timing. In 2006, a similar comparison of timing in the set gillnet fishery across 3 groups of statistical weeks, corresponding to August/early September, mid-September, and late September/early October, shows the Lost River stock to have had later timing in both years, compared with the other stocks (Figure 4). The Situk River displayed the earliest timing in 2006.

Table 2.–Situk Lagoon adult coho salmon abundance estimates, 2005.

			River System (Number of Fish)				% of Run
Fishery	**Area**		**Lost**	**Ahrnklin**	**Situk**	**Total**	**Situk River**
Troll	NW Quad.	Estimate	843	2,576	2,708	6,127	4.7
		(SE)	(357)	(724)	(691)	(1,063)	(1.0)
Set Gillnet	183-10	Estimate	334	195	334	863	0.6
		(SE)	(204)	(195)	(171)	(330)	(0.1)
	182-70	Estimate	2,689	10,575	13,568	26,832	23.8
		(SE)	(683)	(1,922)	(1,788)	(2,712)	(5.1)
	Subtotal	Estimate	3,023	10,770	13,902	27,695	24.4
		(SE)	(713)	(1,932)	(1,796)	(2,733)	(5.3)
Sport	Marine	Estimate	124	507	340	971	0.6
		(SE)	(89)	(248)	(184)	(322)	(0.1)
	Freshwater	Estimate	2,123	58	5,756	7,937	10.1
		(SE)	(511)	(21)	(241)	(565)	(2.2)
	Subtotal	Estimate	2,247	565	6,096	8,908	10.7
		(SE)	(519)	(249)	(303)	(650)	(2.3)
Subsistence	Situk R.	Estimate	0	0	657	657	1.2
		(SE)	(0)	(0)	(0)	(0)	(0.3)
All-Gear	Total	Estimate	6,113	13,911	23,363	43,387	41.0
		(SE)	(951)	(2,078)	(1,949)	(3,003)	(8.8)
Escapement		Estimate	N/A	N/A	33,644	N/A	59.0
		(SE)			(12,310)		(2.0)
Total Run		Estimate	N/A	N/A	57,007	N/A	100.0
		(SE)			(12,463)		
No. of Smolts (2004)		Estimate	514,402	1,021,613	1,057,275	2,596,654	
		(SE)	(144,035)	(236,157)	(190,927)	(336,109)	
Survival Rate (%)		Estimate	N/A	N/A	5.4%	N/A	
		(SE)			(1.2%)		

Table 3.–Situk Lagoon adult coho salmon abundance estimates, 2006.

			River System (Number of Fish)				% of Run
Fishery	**Area**		**Lost**	**Ahrnklin**	**Situk**	**Total**	**Situk River**
Troll	NW Quad.	Estimate	224	1,139	1,383	2,746	3.3
		(SE)	(106)	(476)	(484)	(687)	(0.7)
Set Gillnet	183-10	Estimate	322	408	451	1,181	1.1
		(SE)	(231)	(408)	(450)	(650)	(0.2)
	182-70	Estimate	3,663	7,789	11,261	22,713	27.3
		(SE)	(620)	(1,711)	(1,945)	(2,663)	(5.7)
	Subtotal	Estimate	3,985	8,197	11,712	23,894	28.4
		(SE)	(662)	(1,759)	(1,996)	(2,742)	(5.9)
Sport	Marine	Estimate	0	114	126	240	0.3
		(SE)	(0)	(114)	(126)	(170)	(0.1)
	Freshwater	Estimate	2,359	0	4,496	6,855	10.9
		(SE)	(638)	(0)	(650)	(911)	(2.3)
	Subtotal	Estimate	2,359	114	4,622	7,095	11.2
		(SE)	(638)	(116)	(662)	(927)	(2.4)
Subsistence	Situk R.	Estimate	0	0	358	358	0.9
		(SE)	(0)	(0)	(0)	(0)	(0.2)
All-Gear	Total	Estimate	6,568	9,450	18,075	34,093	43.8
		(SE)	(925)	(1,826)	(2,158)	(2,974)	(9.3)
Escapement		Estimate	N/A	N/A	23,169	N/A	56.2
		(SE)			(8,582)		(2.9)
Total Run		Estimate	N/A	N/A	41,244	N/A	100.0
		(SE)			(8,849)		
No. of Smolts (2005)		Estimate	302,226	724,633	847,305	1,874,164	
		(SE)	(48,373)	(158,503)	(150,260)	(223,699)	
Survival Rate (%)		Estimate	N/A	N/A	4.9%	N/A	
		(SE)			(1.4%)		

Table 4.–Estimated harvest distribution of Situk-Ahrnklin Lagoon coho salmon stocks, 2005 and 2006.

		River System and Year (Percent of Total Catch)								
		Lost River			Ahrnklin River			Situk River		
Gear Type	Area	2005	2006	Avg.	2005	2006	Avg.	2005	2006	Avg.
Troll	Subtotal	13.8	3.4	8.6	18.5	12.1	15.3	11.6	7.6	9.6
Setnet	183-10	5.5	4.9	5.2	1.4	4.3	2.9	1.4	2.5	2.0
	182-70	44.0	55.8	49.9	76.0	82.4	79.2	58.1	62.3	60.2
	Subtotal	49.5	60.7	55.1	77.4	86.7	82.1	59.5	64.8	62.2
Sport	Marine	2.0	0.0	1.0	3.7	1.2	2.5	1.5	0.7	1.1
	Freshwater	34.7	35.9	35.3	0.4	0.0	0.2	24.6	24.9	24.8
	Subtotal	36.7	35.9	36.3	4.1	1.2	2.6	26.1	25.6	25.8
Subsistence		0.0	0.0	0.0	0.0	0.0	0.0	2.8	2.0	2.4
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

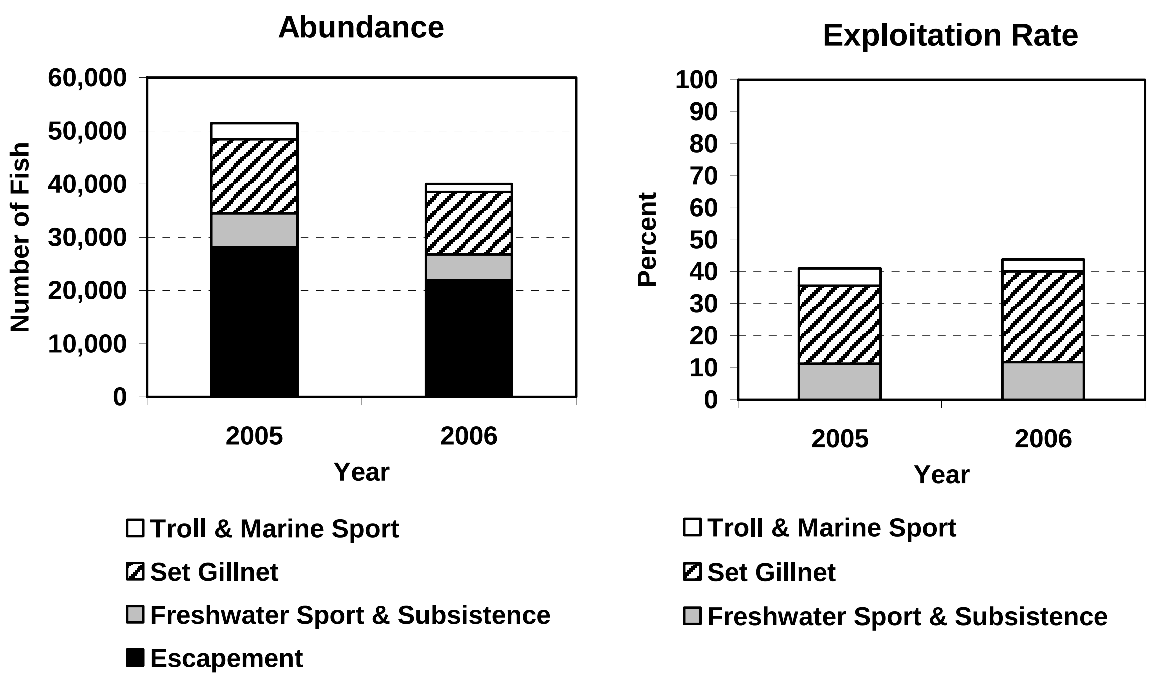

Figure 2.–Estimated harvest and escapement (left graph) and exploitation rate (right graph) for returning Situk River coho salmon, 2005–2006.

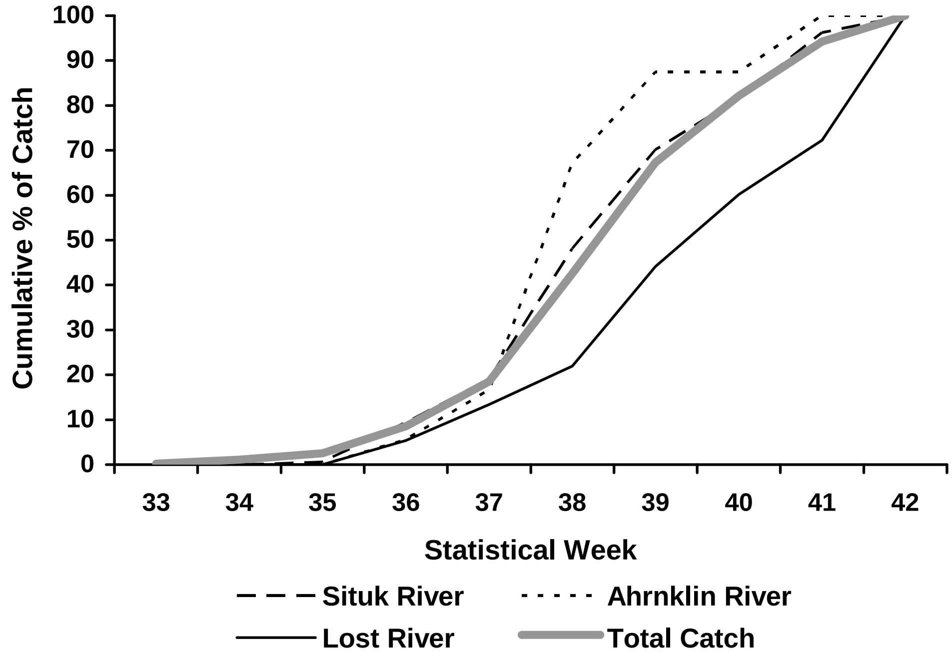

Figure 3.–Cumulative percent of the total season catch by statistical week for 3 coho salmon stocks and all coho salmon caught in the set gillnet fishery in the Situk-Ahrnklin Lagoon (Subdistrict 182-70), 2005.

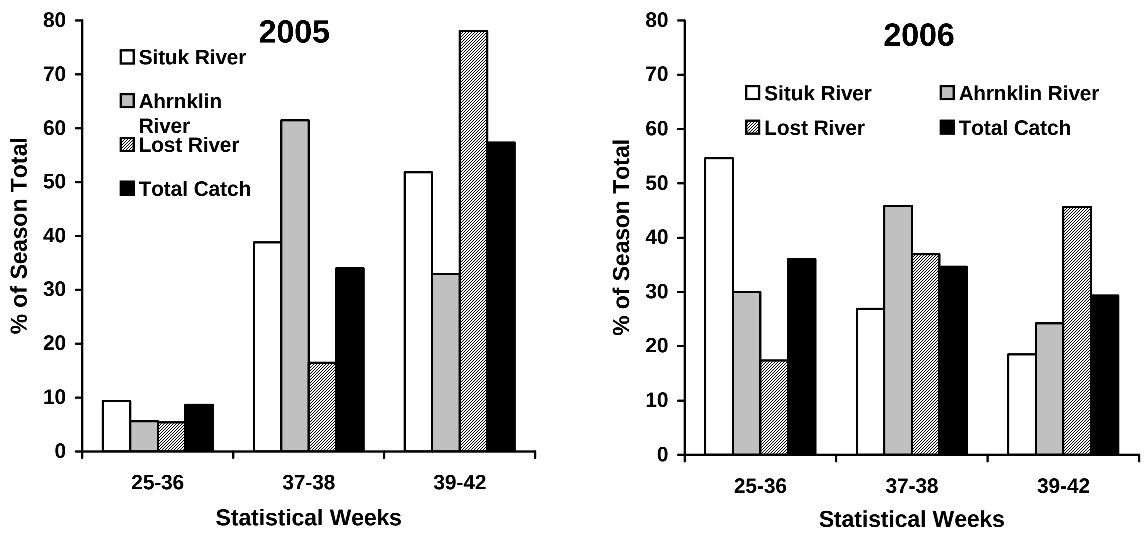

Figure 4.–Percent of the total season catch by period for 3 coho salmon stock and all coho salmon caught in the set gillnet fishery in the Situk-Ahrnklin Lagoon (Subdistrict 182-70), 2005 and 2006.

LOST RIVER AND AHRNKLIN RIVER ESCAPEMENT ESTIMATES

Estimates of model parameters based on maximum likelihood fit to 2005 and 2006 estimated catch by stock are shown in Table 5. The 2005 Ahrnklin River coho salmon escapement estimate is 31,261 fish (90% C.I. 18,000–47,000 fish). The 2005 Lost River escapement estimate is 6,712 fish (90% C.I. 200–11,600 fish). Likelihood profiles for 2005 model parameters are shown in Figure 5. The uncertainty is highest for the Lost River coho salmon escapement and the marine sport harvest rate (Figure 5). The other parameters were well defined in the model (Figure 5). The 2006 Ahrnklin River coho salmon escapement is 19,655 fish (90% C.I. 11,000–31,000 fish). The 2006 Lost River coho salmon escapement estimate is 7,444 fish (90% C.I. 500–11,600). Likelihood profiles for 2006 model parameters are shown in Figure 6. The uncertainty is highest for the Lost River coho salmon escapement and the marine sport harvest rate (Figure 6). The other parameters were well defined in the model (Figure 6).

Table 5.–Model parameter estimates based on maximum likelihood fit to 2005 and 2006 data.

	Parameter Values by Year	
Parameter	**2005**	**2006**
Marine Survival	0.047	0.045
Troll Harvest Rate	0.052	0.034
Lagoon Harvest Rate	0.24	0.282
Freshwater Sport Harvest Rate	0.119	0.122
Marine Sport Harvest Rate	0.006	0.002
Ahrnklin River Escapement	31,261	19,655
Lost River Escapement	6,712	7,444

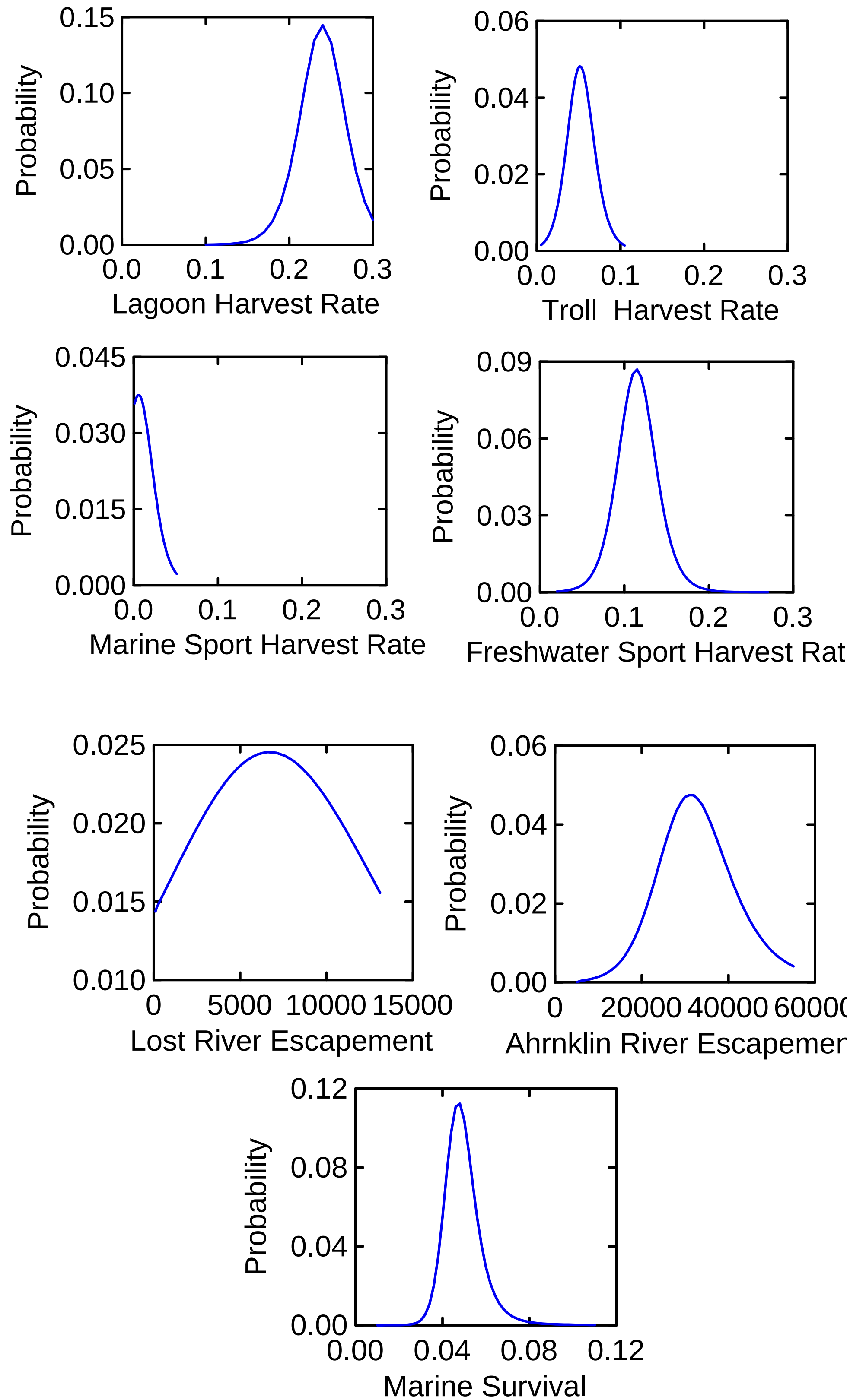

Figure 5.–Likelihood profiles for parameters estimated for 2005.

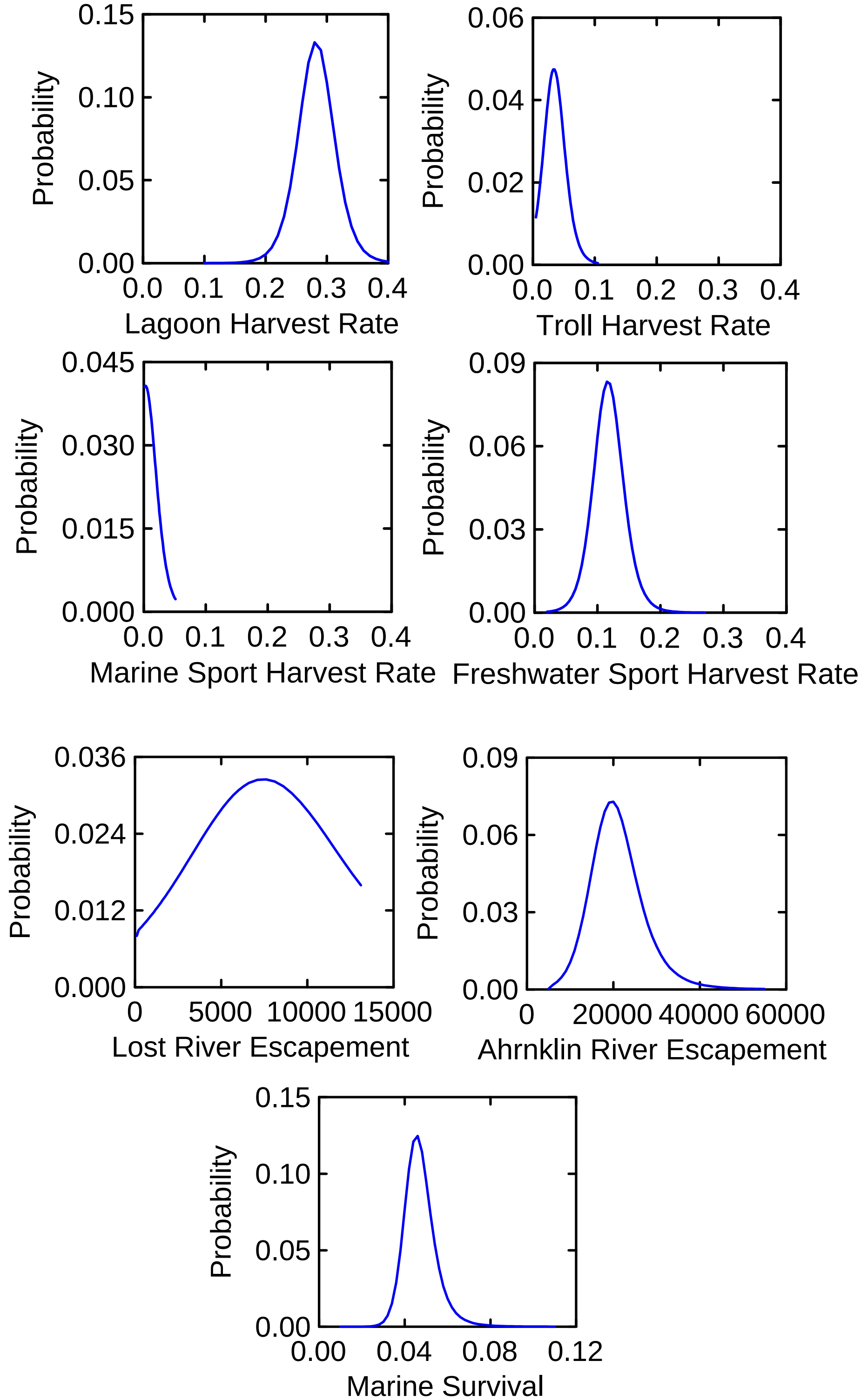

Figure 6.–Likelihood profiles for parameters estimated for 2006.

DISCUSSION

Our smolt estimates based on marking of smolts and recovery of adults were higher than prior real-time estimates of Situk River smolt production generated by marking and recovering smolts within the system. Our estimates of 1,057,275 smolts (SE = 190,927) in 2004 and 847,305 smolts (SE = 150,260) in 2005 were substantially higher than a 1990 estimate of only 213,000 smolts (95% C.I. 187,000–238,000) by Thedinga et al. (1994) who captured fish for both marking and sampling in a rotary screw trap located in the lower river and released newly-marked fish back into the population above the trap. However, they also estimated a migration of 127,000 parr (95% C.I. 116,000–142,000), of which they surmised many may have migrated to sea that spring, for a total estimated migration of 340,000 smolts and parr. Ericksen and McPherson (1997) estimated the 1992 downstream migration at only 612,034 smolts (SE = 43,927) based on caudal fin marking at a rotary screw trap where Highway 10 crosses the upper Situk River (Figure 1) and recovery sampling at a similar trap fished on the lower river. That number, based on a Darroch estimator (Darroch 1961), was substantially lower than their Chapman estimate of 1,197,298 smolts (SE = 186,212) based on coded-wire tagging of smolts and sampling of returning adults in the escapement. They discussed potential biases with both methods and concluded that the smolt-adult method provided the best estimate of abundance. We agree with their conclusion, because that method provides the best potential for intermixing of marks within the population. However, we suspect there may be some upward bias inherent in the smolt-adult method because of evidence of intersystem movement of fish in violation of the assumption of a closed population.

Perhaps the most perplexing question raised in the study is the origin of coho salmon harvested by the Situk-Ahrnklin Lagoon set gillnet fishery that were not accounted for by the 3 study systems that have been thought to contribute the vast majority of the catch in the lagoon. The combined contribution estimate by each system to the set gillnet fishery in Subdistrict 182-70 was based on coded-wire tag recoveries collected in random samples expanded by both the appropriate sampling fraction and the proportion marked in escapement samples in each respective system (including only tags implanted in that system). The sum of the contribution estimates by the 3 systems divided by the reported total catch of all coho salmon in the fishery resulted in estimates of only a 53% contribution rate in 2005 and a 46% contribution rate in 2006.

These estimates are particularly surprising in view of observed movement of fish among the study streams between tagging and recovery that suggests the populations were not entirely closed. Such movement potentially resulted in under-estimates of the marked fraction of the 3 tagged smolt populations due to returns of tagged fish to other systems where escapement sampling was not conducted and to dilution by untagged fish from those systems into the study streams. This intersystem movement and any resulting under-estimates of the marked fraction in the smolt populations would result in over-estimates of the contribution by the 3 tagged populations to the Situk-Ahrnklin set gillnet fishery, as well as other fisheries. This suggests that the set gillnet fishery catch included a significant number of coho salmon not represented by the coded-wire tagging of smolts in the 3 study systems.

Potentially significant sources of unrepresented coho salmon in the set gillnet fishery are limited to either streams that enter directly into the lagoon or passing stocks from neighboring systems such as the Italio and Akwe Rivers, as well as more distant streams and hatcheries, that may intrude into the fishery. The fan of streams that enters the lagoon between the Ahrnklin and Situk Rivers shown in Figure 1 contains extensive rearing habitat that likely produces thousands of adult coho salmon that may contribute a substantial proportion of the unaccounted catch. Relatively little is known about the contribution by passing stocks. Many tagged fish from Southeast Alaska have been recovered from landings by the troll fishery in the Yakutat area but coded-wire tag sampling in the set gillnet fishery has been limited to years when tagged returns were expected for local stocks. No non-local tags were recovered in the fishery in this study but a search of the coded-wire tag database indicates a tagged Akwe River coho salmon was recovered in the lagoon (Subdistrict 182-70) in 1986 and a tagged fish from the Berners River in northern Southeast Alaska was recovered there in 1993.

The maximum likelihood estimates of escapement in the Lost River and Ahrnklin River were highly variable. Estimates for the Lost River escapement in 2005 and 2006 based on that method were low compared with 2003 and 2004 mark-recapture estimates. The maximum likelihood estimates of Lost River escapement in 2005 and 2006 had 90% confidence limits of 200–11,600 spawners and 500–11,600 spawners, respectively, that were well below the 95% confidence ranges for mark-recapture estimates in 2003 (15,290–45,760; Clark et al. 2006) and 2004 (26,400–97,970; Clark et al. 2005). While mark-recapture estimates for the Situk River escapement in 2005 and 2006 were 68% and 47% of the 2004 Situk River estimate, respectively, the maximum likelihood estimates for the Lost River in 2005 and 2006 were 28% and 16%, respectively, of the 2004 Lost River estimate. There are no comparable mark-recapture escapement estimates for the Ahrnklin River where maximum likelihood estimates were 7 to 15% lower, compared with the Situk River.

In addition to statistical uncertainty expressed in the confidence bounds, there is also some uncertainty in the assumption of equal marine survival among the populations because of variation in average size and run timing of smolts from the 3 streams. The assumption of equal exploitation rates is also uncertain, in part because of later migratory timing of adults returning to the Lost River. Lost River smolts may have experienced lower marine survival than Situk River smolts because they were smaller, on average, and departed the system earlier and returned later, implying a longer time at sea. However, this probably does not account for the presumed low bias in the maximum likelihood estimates of Lost River escapement. A potentially more important source of error is the assumption of equal exploitation rates on the stocks among the fisheries. Lost River adults returned later, on average, while sport and commercial fishing effort tends to decline later in the season. Also, Lost River adults can transit less distance across the fishing area in the Situk-Ahrnklin Lagoon to enter their natal stream compared with adults returning to the Situk River. Therefore, they may be exploited at a lower rate than returning Situk River fish, which would result in an under-estimate of the Lost River escapement.

Although the Situk River run was reconstructed for only 2 years, the similarity in magnitude and distribution of exploitation rates in those years, combined with 3 available mark-recapture estimates and 3 smolt abundance estimates, provides a basis for re-examining some aspects of the existing escapement goals developed by Clark and Clark (1994). They recommended a peak survey goal of 3,300 to 9,800 spawners, but were concerned that their estimates of escapement at MSY may have been biased low. They therefore favored the upper portion of the range above 6,500 spawners.

Marine survival estimates of about 5% for Situk River smolts in both years were relatively low compared with estimates for the main portion of Southeast Alaska (Shaul et al. 2005). Comparable marine survival estimates for 2004 and 2005 smolts from ongoing studies of selected Southeast Alaska stocks were 7 to 9% for Hugh Smith Lake, 8 to 13% for the Berners River, 8 to 10% for the Taku River, and 16 to 20% for Auke Creek (Lynch and Skannes 2007). If the observed survival rates in 2004 and 2005 are indicative of the Yakutat area, stock productivity may be lower than for most Southeast Alaska stocks. Smolts leaving the Situk-Ahrnklin Lagoon enter directly into ocean waters whereas smolts in most other areas of Southeast Alaska begin their marine residence in inlets and passages that have different physical and ecological conditions. Similar differences in marine survival rates of wild smolts entering directly into oceanic waters compared with inside marine waters are evident in Washington State where typical wild coho salmon survival rates above 12% for Puget Sound stocks have contrasted sharply with rates of 4 to 6% for stocks on the nearby Washington Coast (Shaul et al. 2007).

On the other hand, the estimated all-gear exploitation rates of 41 to 44% for the Situk River stock are relatively conservative compared with average rates for many Southeast Alaska stocks. During the 1990s, the Hugh Smith Lake stock was exploited at an average rate of 75% while the Ford Arm Lake stock has been exploited at an average rate of about 61%, with recent rates as high as 75% (Shaul et al. 2005). The total exploitation rate estimates from this study are far below the average of 69% (range 53–90%) estimated by Clark and Clark (1994) for the 1972 to 1993 Situk River returns, based on a number of assumptions about harvest and their highest assumed peak survey count expansion of 4.00. They also assumed peak count expansions of 1.00, 1.33, and 2.00 that corresponded to average exploitation rates ranging from 81 to 90%.

Exploitation rates by combined marine fisheries (troll, marine sport, Yakutat Bay set gillnet) of only about 6% in 2005 and 5% in 2006 were lower than the average of 25% (range 8–43%) for commercial trollers only assumed by Clark and Clark (1994). However, the recent troll harvest in Yakutat districts (181-191) was somewhat lower at 68,900 fish in 2005 and 24,100 fish in 2006 compared with the 1972 to 1993 average of 74,200 fish (range 300–272,000) for the return years they analyzed. The Yakutat area has traditionally provided an opportunity for superior catch rates that has attracted many trollers in September, after fishing has declined south of Cape Fairweather. However, fewer boats have traveled to the area in recent years, because of higher fuel prices, combined with increasing opportunity on late-migrating hatchery fish in other areas of Southeast Alaska. On the other hand, the Yakutat sport charter fishery has expanded substantially since the mid-1990s, with catches estimated at 8,641 fish in 2005 and 3,333 fish in 2006. However, the effect of the marine sport fishery on Situk-Ahrnklin Lagoon stocks still appears to be minimal, with an exploitation rate on the Situk River run lower than 1% in both years.

There are now 3 available estimates of coho salmon smolt production from the Situk River arrived at using a consistent method (i.e. Chapman estimate based on coded-wire tagging of smolts and sampling of returning spawners). We estimated recent migrations at 1,057,275 smolts (SE = 190,927) in 2004 and 847,305 smolts (SE = 150,260) in 2005 while Ericksen and McPherson (1997) estimated the 1992 smolt migration at 1,197,298 smolts (SE = 186,212). Assuming that the average of the 3 estimates (1,033,959 smolts) represents the average habitat capability of the system and applying a range of 25.4 to 50.8 smolts per spawner recommended by Shaul and Tydingco (2006) based on a literature survey of coho salmon productivity estimates, would result in a recommended range of about 20,400 to 41,700 spawners. The 3 available mark-recapture estimates of total escapement to the Situk River of 49,582 spawners in 2004, 33,644 spawners in 2005 and 23,169 spawners in 2006 all fall within or above that range.

Unfortunately, variable fall weather often has a detrimental effect on visibility conditions for escapement surveys in the Situk River system. Expansion factors for survey counts based on the 3 mark-recapture experiments (with sport catch above the marking site subtracted) are highly variable (4.82 in 2004, 13.38 in 2005 and 2.71 in 2006) around an average of 6.97. The current peak survey goal (3,300–9,800 spawners) expanded by 6.97 translates to about 23,000 to 68,300 total spawners, which is a higher and considerably broader range than the 20,400 to 41,700 spawner range based on assumed spawner productivity and average smolt production. However, we note that the average survey expansion factor is heavily influenced by the high value for 2005. If the median expansion (4.82) is used instead of the average (6.97) the current index goal would expand to a total escapement goal of 15,900 to 47,200 spawners, which encompasses the range of 20,400 to 41,700 spawners based on smolt production and assumed productivity.

For the Situk River, therefore, we recommend that the current goal of 3,300 to 9,800 spawners based on the peak survey count be retained until substantial additional information is available on the productivity of the stock and habitat capability of the system. However, our findings tend to alleviate the concern expressed by Clark and Clark (1994) that the current goal may be biased low.

For the Lost River, the current goal for the survey count is 2,200 to 6,500 spawners. The 2 estimated expansion factors for the peak survey count were substantially different at 3.70 in 2003 and 9.42 in 2004 (average 6.56) which would correspond to a current goal range of 14,400 to 42,600 spawners. Use of the smaller expansion ratio (3.70) would correspond to a goal range of approximately 8,100 to 24,000 spawners. A range of 25.4 to 50.8 smolts/spawner, applied to the average Lost River smolt production estimates for 2004 and 2005 (408,314 smolts) results in a target range of approximately 8,000 to 16,100 spawners, which is lower than the current goal based on the average index expansion ratio, but nearly within the range based on the lower expansion ratio. An expanded current goal based on the higher expansion ratio (9.42) would be 20,700 to 61,200 spawners. Escapement estimates of 23,685 spawners in 2003 (Clark et al. 2006) and 47,566 spawners in 2004 (Clark et al. 2005) fall within or above all of these ranges.

The current escapement goal for the Lost River may be higher than optimum over most if its range, assuming that the average smolt production estimate for 2004 and 2005 is indicative of average potential production at full seeding by spawners and that stock productivity is similar to other coho salmon populations that have been studied. For coho salmon populations, there appears to be little or no risk to smolt production and future returns from escapement levels well above MSY (Bradford et al. 2000). Given current uncertainty about an appropriate survey expansion factor, we recommend that the current relatively broad escapement goal range be retained for the Lost River.

Unfortunately, biological goals and expectations for Yakutat area coho salmon stocks may need to be revised downward in the future, as rearing habitat is transformed and becomes less productive, due to geological change. Gordie Woods, a fishery manager and observer of Yakutat salmon and their habitat since 1975, has observed a substantial decrease in surface flow and rearing area in streams and sloughs around the Situk-Ahrnklin Lagoon (Gordie Woods, Fishery Management Technician, ADF&G, Commercial Fisheries Division, Yakutat; *personal* *communication*). The 28% overall decrease in estimated smolt production (range of 20 to 41% for individual systems) observed in this study following a dry summer in 2004, suggests that survival of rearing coho salmon is very sensitive to dry conditions and will likely decline if small streams and wetlands continue to dry up in response to glacial rebounding.

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APPENDICES

Appendix A.–Daily number of coho salmon smolts captured and coded-wire tagged in Tawah Creek (Lost River), the Situk River and the Ahrnklin River in 2004 and 2005.

	2004			2005		
Date	**Tawah Cr. (Lost River)**	**Ahrnklin River**	**Situk River**	**Tawah Cr. (Lost River)**	**Ahrnklin River**	**Situk River**
29-April	55	—	—	—	—	—
30-April	223	—	—	—	—	—
1-May	459	—	—	—	—	—
2-May	658	—	—	—	—	—
3-May	303	—	—	1,450	—	—
4-May	64	—	—	1,562	—	—
5-May	1,409	—	—	2,061	—	—
6-May	674	—	—	1,178	—	—
7-May	1,514	56	—	1,284	—	—
8-May	1,000	206	—	1,997	—	—
9-May	940	357	—	2,470	—	—
10-May	875	461	—	2,405	—	—
11-May	884	653	—	1,855	—	—
12-May	2,315	859	—	2,856	—	—
13-May	1,901	610	—	2,654	—	—
14-May	2,554	1,033	—	2,178	—	—
15-May	2,374	922	—	0	—	—
16-May	0	1,031	—	739	—	—
17-May	0	0	—	1,868	—	—
18-May	1,846	1,633	—	1,582	—	—
19-May	2,674	1,273	—	2,811	—	—
20-May	2,589	0	—	—	1,630	—
21-May	1,913	2,226	—	—	1,316	—
22-May	2,190	986	—	—	2,395	—
23-May	0	0	—	—	338	—
24-May	844	2,080	—	—	1,765	430
25-May	—	1,115	—	—	1,560	0
26-May	—	1,397	—	—	600	915
27-May	—	0	—	—	2,069	917
28-May	—	2,892	—	—	0	2,638
29-May	—	0	420	—	1,551	985
30-May	—	707	0	—	0	869
31-May	—	2,658	0	—	0	1,557

–Continued–

Appendix A.–Continued (page 2 of 2)

Date	2004			2005		
	Tawah Cr. (Lost River)	**Ahrnklin River**	**Situk River**	**Tawah Cr. (Lost River)**	**Ahrnklin River**	**Situk River**
1-June	—	0	1,084	—	2,026	1,608
2-June	—	3,014	0	—	902	2,447
3-June	—	0	994	—	3,788	1,131
4-June	—	2,096	682	—	2,600	622
5-June	—	—	2,048	—	0	1,913
6-June	—	—	1,114	—	2,263	2,211
7-June	—	—	942	—	1,993	2,304
8-June	—	—	920	—	2,355	1,488
9-June	—	—	1,139	—	1,649	2,059
10-June	—	—	3,419	—	—	2,978
11-June	—	—	2,040	—	—	2,178
12-June	—	—	3,836	—	—	807
13-June	—	—	2,248	—	—	—
14-June	—	—	3,528	—	—	—
15-June	—	—	2,201	—	—	—
16-June	—	—	2,159	—	—	—
17-June	—	—	1,529	—	—	—
Total	30,258	28,265	30,303	30,950	30,800	30,057

Appendix B.–Definitions of notation used to label coded-wire tag recovery statistics in Appendixes C through G. Calculations follow equations in Table 2 of Bernard and Clark (1996).

H	=	Harvest in a stratum
$v(H)$	=	Variance of the harvest in a stratum
a	=	number of adults missing adipose fins in a sample from catch in a stratum
a'	=	number of heads that arrive at Juneau for dissection (subset of a_i) in a stratum
$\hat{r}$	=	number of adults from the stock harvested in a stratum
m	=	number of CWTs with the appropriate code(s) (subset of t') in a stratum
n	=	number of adults caught in a stratum inspected for missing adipose fins
t	=	number of heads with tags detected magnetically (subset of a') in a stratum
t'	=	number of CWTs found through dissection and decoded (subset of t) in a stratum
θ	=	fraction of the stock with CWTs
$G(\theta^{-1})$	=	squared coefficient of variation for the estimate of $1/\theta$
$SE[\hat{r}]$	=	standard error of the estimated number of adults from a stock harvested in a stratum
$RP[\hat{r}]$	=	relative precision (95% confidence) of the estimated number of adults from a stock harvested in a stratum

Appendix C.–Coded-wire tag recovery statistics for the Situk River, 2005. Definitions of notation used to label these and other statistics are shown in Appendix B. The estimate of θ is 0.0263 while the estimate of $G(\theta^{-1})$ is 0.0377. In fishing periods and areas for which no coded-wire tag was recovered with the appropriate code, harvest was assumed to be zero.

Description	Statistical Weeks	Dates	Quadrant/Sub-district./Area	Parameter										
				H	**v[*H*]**	***n***	***a***	***a'***	***t***	***t'***	***m***	$\hat{r}$	$SE[\hat{r}]$	$RP[\hat{r}]$
Troll NW 3	29–33	7/10–8/13	NW	643,680	—	181,111	2,238	2,194	1,614	1,609	3	415	248	117%
Troll NW 4	34–37	8/14–9/10	NW	395,975	—	102,639	1,419	1,403	1,130	1,127	9	1,340	508	74%
Troll NW 5	38–39	9/11–9/24	NW	139,380	—	39,415	737	729	571	571	7	953	398	82%
Sport	23–42	Season	Yakutat	8,641	1,971,216	3,873	29	29	25	25	4	340	184	106%
Set GN	36	8/28–9/3	183-10	134	—	62	1	1	1	1	1	82	82	195%
Set GN	40	9/25–10/1	183-10	546	—	302	2	2	2	2	2	138	98	140%
Set GN	41	10/2–10/8	183-10	968	—	323	9	9	9	9	1	114	114	195%
Set GN	35	8/21–8/27	182-70	724	—	354	3	3	1	1	1	78	77	195%
Set GN	36	8/28–9/3	182-70	3,067	—	440	9	8	7	7	4	1,194	629	103%
Set GN	37	9/4–9/10	182-70	5,084	—	1,323	24	24	20	20	9	1,316	499	74%
Set GN	38	9/11–9/17	182-70	12,239	—	5,003	111	110	104	104	42	3,946	970	48%
Set GN	39	9/18–9/24	182-70	12,580	—	3,531	53	53	47	47	22	2,983	850	56%
Set GN	40	9/25–10/1	182-70	7,537	—	2,655	41	40	38	38	14	1,551	504	64%
Set GN	41	10/2–10/8	182-70	6,160	—	1,110	22	21	18	18	9	1,992	756	74%
Set GN	42	10/9–10/15	182-70	2,919	—	1,093	23	23	20	20	5	508	243	94%
Total				1,239,634	1,971,216	343,234	4,721	4,649	3,607	3,599	133	16,950		

Appendix D.–Coded-wire tag recovery statistics for the Lost River, 2005. Definitions of notation used to label these and other statistics are shown in Appendix B. The estimate of θ is 0.0538 while the estimate of $G(\theta^{-1})$ is 0.2507. In fishing periods and areas for which no coded-wire tag was recovered with the appropriate code, harvest was assumed to be zero.

				Parameter										
Description	**Statistical Weeks**	**Dates**	**Quadrant/Sub-district./Area**	***H***	**v[*H*]**	***n***	***a***	***a'***	***t***	***t'***	***m***	$\hat{r}$	$SE[\hat{r}]$	$RP[\hat{r}]$
Troll NW 3	29–33	7/10–8/13	NW	643,680	—	181,111	2,238	2,194	1,614	1,609	1	68	67	2
Troll NW 4	34–37	8/14–9/10	NW	395,975	—	102,639	1,419	1,403	1,130	1,127	7	509	304	117%
Troll NW 5	38–39	9/11–9/24	NW	139,380	—	39,415	737	729	571	571	4	266	175	129%
Sport	All	0	Yakutat	8,641	1,971,216	3,873	29	29	25	25	3	124	89	140%
Set GN	41	10/2–10/8	183-10	968	—	323	9	9	9	9	6	334	204	120%
Set GN	36	8/28–9/3	182-70	3,067	—	440	9	8	7	7	1	146	145	195%
Set GN	37	9/4–9/10	182-70	5,084	—	1,323	24	24	20	20	3	214	151	138%
Set GN	38	9/11–9/17	182-70	12,239	—	5,003	111	110	104	104	5	230	145	124%
Set GN	39	9/18–9/24	182-70	12,580	—	3,531	53	53	47	47	9	596	344	113%
Set GN	40	9/25–10/1	182-70	7,537	—	2,655	41	40	38	38	8	433	253	115%
Set GN	41	10/2–10/8	182-70	6,160	—	1,110	22	21	18	18	3	324	229	138%
Set GN	42	10/9–10/15	182-70	2,919	—	1,093	23	23	20	20	15	745	408	107%
Total				1,238,230	1,971,216	342,516	4,715	4,643	3,603	3,595	65	3,991		

Appendix E.–Coded-wire tag recovery statistics for the Ahrnklin River, 2005. Definitions of notation used to label these and other statistics are shown in Appendix B. The estimate of θ is 0.0264 while the estimate of $G(\theta^{-1})$ is 0.0647. In fishing periods and areas for which no coded-wire tag was recovered with the appropriate code, harvest was assumed to be zero.

	Statistical		Quadrant/Sub-	Parameter										
Description	**Weeks**	**Dates**	**district./Area**	H	v[H]	n	a	a'	t	t'	m	$\hat{r}$	$SE[\hat{r}]$	$RP[\hat{r}]$
Troll NW 3	29–33	7/10–8/13	NW	643,680	—	181,111	2,238	2,194	1,614	1,609	4	551	300	107%
Troll NW 4	34–37	8/14–9/10	NW	395,975	—	102,639	1,419	1,403	1,130	1,127	10	1,483	589	78%
Troll NW 5	38–39	9/11–9/24	NW	139,380	—	39,415	737	729	571	571	4	542	295	107%
Sport	All	0	Yakutat	8,641	1,971,216	3,873	29	29	25	25	6	507	248	96%
Set GN	37	9/4–9/10	183-10	345	—	67	1	1	1	1	1	195	195	196%
Set GN	41	10/2–10/8	183-10	968	—	323	9	9	9	9	—	—	—	0%
Set GN	36	8/28–9/3	182-70	3,067	—	440	9	8	7	7	2	594	433	143%
Set GN	37	9/4–9/10	182-70	5,084	—	1,323	24	24	20	20	8	1,165	495	83%
Set GN	38	9/11–9/17	182-70	12,239	—	5,003	111	110	104	104	57	5,333	1,518	56%
Set GN	39	9/18–9/24	182-70	12,580	—	3,531	53	53	47	47	16	2,160	757	69%
Set GN	40	9/25–10/1	182-70	7,537	—	2,655	41	40	38	38	16	—	—	0%
Set GN	41	10/2–10/8	182-70	6,160	—	1,110	22	21	18	18	6	1,322	620	92%
Total				1,235,656	1,971,216	41,490	4,693	4,621	3,584	3,576	130	13,853		

Appendix F.–Coded-wire tag recovery statistics for the Situk and Ahrnklin Rivers, 2006. Definitions of notation used to label these and other statistics are shown in Appendix B.

Description	Statistical Weeks	Dates	Quadrant/Sub-district./Area	Parameter										
				H	v[*H*]	*n*	*a*	*a'*	*t*	*t'*	*m*	*r*	SE*[r]*	RP*[r]*
Situk River, 2006 (Θ = 0.0345, $G(\theta^{-1})$ = 0.0356)														
Troll NW 4	33–39	8/13–9/30	NW	405,761	—	96,590	1,568	1,519	1,270	1,269	11	1,383	484	69%
Sport	23–39	6/4–9/30	Yakutat	8,641	1,971,216	3,873	29	29	25	25	4	126	184	106%
Set GN	25–42	6/18–10/21	183-10	3,254	—	251	6	5	4	4	1	451	82	195%
Set GN	25–36	6/18–9/9	182-70	17,762	—	2,594	58	58	53	53	31	6,149	98	140%
Set GN	37–38	9/10–9/23	182-70	17,103	—	3,314	75	74	71	71	20	3,030	114	195%
Set GN	39–42	9/24–10/21	182-70	14,471	—	2,416	57	57	51	51	12	2,082	77	195%
Total					1,971,216	109,038	1,793	1,742	1,474	1,473	79	13,220		
Ahrnklin River, 2006 (Θ = 0.0381, $G(\theta^{-1})$ = 0.0842)														
Troll NW 4	33–39	8/13–9/30	NW	405,761	—	96,590	1,568	1,519	1,270	1,269	10	1,139	476	82%
Sport	23–39	6/4–9/30	Yakutat	3,333	725,904	765	8	8	8	8	1	114	114	195%
Set GN	25–42	6/18–10/21	Troll	3,254	—	251	6	5	4	4	1	408	408	196%
Set GN	25–36	6/18–9/9	182-70	17,762	—	2,594	58	58	53	53	13	2,335	917	77%
Set GN	37–38	9/10–9/23	182-70	17,103	—	3,314	75	74	71	71	26	3,568	1,232	68%
Set GN	39–42	9/24–10/21	182-70	14,471	—	2,416	57	57	51	51	12	1,886	754	78%
Total				440,669	1,971,216	115,755	1,650	1,633	1,341	1,338	33	2,050		

Appendix G.–Coded-wire tag recovery statistics for the Lost River, 2006. Definitions of notation used to label these and other statistics are shown in Appendix B.

Description	Statistical Weeks	Dates	Quadrant/Sub-district./Area	Parameter										
				H	**v[*H*]**	***n***	***a***	***a'***	***t***	***t'***	***m***	***r***	**SE*[r]***	**RP*[r]***
Lost River, 2006 (Θ = 0.0967, $G(\theta^{-1})$ = 0.0345)														
Troll NW 4	33–39	8/13–9/30	183-10	405,761	—	96,590	1,568	1,519	1,270	1,269	5	224	106	93%
Set GN	25–42	6/18–10/21	182-70	3,254	1,971,216	251	6	5	4	4	2	322	231	141%
Set GN	25–36	6/18–9/9	182-70	17,762	—	2,594	58	58	53	53	9	637	239	73%
Set GN	37–38	9/10–9/23	182-70	17,103	—	3,314	75	74	71	71	25	1,353	364	53%
Set GN	39–42	9/24–10/21	182-70	14,471	—	2,416	57	57	51	51	27	1,673	442	52%
Total					1,971,216	105,165	1,764	1,713	1,449	1,448	68	4,209		