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Klag Lake Sockeye Salmon (*Oncorhynchus nerka*) Stock Assessment 2004 Annual Report

by

Jennifer P. Stahl

Jan M. Conitz

Margaret A. Cartwright

Zachary Penney

and

Jack Lorrigan

March 2007

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

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

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

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Jennifer P. Stahl, Jan M. Conitz and Margaret A. Cartwright

Alaska Department of Fish and Game, Division of Commercial Fisheries, Douglas

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Zachary Penney and Jack Lorrigan

Sitka Tribe of Alaska, Natural Resources, Sitka

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

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Jennifer P. Stahl, Jan M. Conitz, and Margaret A. Cartwright
Alaska Department of Fish and Game, Division of Commercial Fisheries,
P.O. Box 240020, Douglas, Alaska, USA,
and
Zachary Penney and Jack Lorrigan
Sitka Tribe of Alaska, Division of Natural Resources
456 Katlian St., Sitka, Alaska, USA

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ABSTRACT

In 2004, we estimated the sockeye escapement into Klag Lake and the number of sockeye salmon (*Oncorhynchus nerka*) harvested in the subsistence and sport fisheries at the head of Klag Bay. We counted salmon through a weir and used mark-recapture methods to verify the sockeye weir count. The weir count, of 17,369, led to our official escapement estimate, of 17,400 sockeye salmon. We chose this estimate because were unable to produce an unbiased mark-recapture estimate of escapement, and the weir count was very different from the mark-recapture estimate. The largest age class was the age-1.2 category, with a mean fork length of 491 mm, composing 51% of the escapement sample. The next largest was the age-1.3 category, with a mean fork length of 548 mm, composing 26% of the escapement sample. The subsistence and sport fishers harvested 14% of the adults sockeye salmon returning to the marine terminal area of Klag Bay in 2004. Disproportional numbers of sockeye salmon were harvested by the subsistence fishery from the beginning of the sockeye run; consequently, we are concerned that continued fishing pressure on the early part of the run could lower the stock's productivity by altering the genetic make-up of the stock. Compared to the size of the escapements the subsistence and sport harvest rates on this system appear to be small and sustainable.

Key words: Sockeye salmon, *Oncorhynchus nerka*, subsistence, Chichagof Island, Klag Lake, Sitka, escapement, mark-recapture, weir, harvest survey.

INTRODUCTION

The Sitka Tlingit clans historically claimed ownership of Klag Bay, located near Sitka, and its abundant sockeye salmon (*Oncorhynchus nerka*) resources (Figure 1). Two villages were located in Klag Bay, prior to the late 1800s; after their disappearance, a few clan members continued to have houses or smokehouses in the area. In the early 1900s, Sitka Tlingits demonstrated their historical rights to the area by posting signs to keep commercial fishermen and other newcomers out of the area (Goldschmidt et al. 1998).

The subsistence harvest of sockeye salmon from Klag Bay has been recorded on Alaska Department of Fish and Game (ADF&G) permits continuously from 1985 to 2004, with estimated annual harvests ranging from 23 to 40,065 sockeye salmon (ADF&G database). In 2001, the reported harvest was underestimated by about 300 sockeye salmon compared to our on-site survey (Conitz et al. 2005). Underreporting of subsistence harvest is typical in other systems in Southeast Alaska (Conitz and Cartwright 2003; Lewis and Cartwright 2004; Lorrigan et al. 2004). However, in 2002, the reported harvest was about 32% larger than our on-site estimate of harvest. These discrepancies are impossible study at this point. The interviewed boat-parties may not have been representative of the eight missed boat-parties; therefore, the expansion of the observed harvest to all boats observed may have been inaccurate. Perhaps, the crew may not have observed all boat parties (Conitz et al. 2005), or subsistence fishers did not report catch correctly during on-site interviews, but accurately reported the catch on subsistence permits after counting their catch during cleaning. In 2003, the on-site survey and the reported harvest were about the same (Conitz et al. 2005). Because the differences in the number of sockeye reported on permits and reported to on-site survey interviewers were small, and most likely due to problems with on-site survey data collection, we believe that the ADF&G permits are a reasonable proxy for the number of salmon harvested in Klag Bay by subsistence fishers.

Subsistence pressure in Klag Bay has increased over the last twenty years. In the last 10 years (1995–2004), the average number of subsistence permits fished annually has doubled, and the number of sockeye salmon harvested annually has tripled, compared to 1985–1994 (ADF&G database; Appendix A).

In addition to harvest by the subsistence fishery, sockeye salmon from the Klag Lake system are harvested by sport and commercial fishermen. A small sport fishery in Klag Bay harvested about

100 sockeye salmon annually from 2001 to 2003 (Conitz et al. 2005). Currently there is no directed commercial fishery in the Klag Bay terminal area. However, a small number of sockeye salmon (0–218) were harvested in recent years (1990–2005) in a commercial purse seine fishery in nearby Khaz Bay (sub-district 113-71; ADF&G database); some of these fish may be from the Klag Lake population.

Most subsistence fish were harvested in Klag Bay at the beginning of the sockeye run. In 2002 and 2003, these large harvests contributed to low early season escapements with only 16–182 sockeye salmon passing through the Klag weir before the end of July. As a result, the subsistence and sport fisheries were closed by emergency order at the end of July in 2002 and 2003. Although, a large number of fish were harvested before the fishery closure, very few fish were harvested after the reopening of the fishery. Overall, only 9–15% of the terminal sockeye returns were harvested by the sport and subsistence fisheries in 2002 and 2003, respectively (Conitz et al. 2005).

From 2001 to 2003 the weir counts were within the 95% confidence interval for the mark-recapture estimate of escapement (Conitz et al. 2005). The 2001 and 2002 weir counts were higher than the mark-recapture estimates, and our 2003 weir count was very close to the mark-recapture estimate. Consequently, we can assume that all fish were counted through the weir in the first three years of our project (2001–2003).

In 2000, the Sitka Tribe of Alaska, the U.S. Forest Service, and ADF&G initiated this project to monitor the subsistence fishery in Klag Bay and the escapement into Klag Lake as a response to concerns by fishermen and biologists of possible over-harvest of the sockeye stock. Our primary objectives with this project were to estimate sockeye escapement, including age, sex, and length composition, into Klag Lake using a weir and to estimate subsistence and sport harvests in Klag Bay using on-site surveys. The study included a mark-recapture estimate of escapement to detect weir failure.

OBJECTIVES

1. Count sockeye salmon and other fish species escapement into Klag Lake by use of a weir.
2. Estimate sockeye escapement with a mark-recapture study on the spawning grounds so that the coefficient of variation is less than 10%.
3. Estimate subsistence and sport harvest of sockeye salmon from Klag Bay on-site surveys so that the estimated coefficient of variation is less than 15%.
4. Estimate the age composition of the sockeye escapement so that the coefficient of variation is 10% or less for the two major age classes.

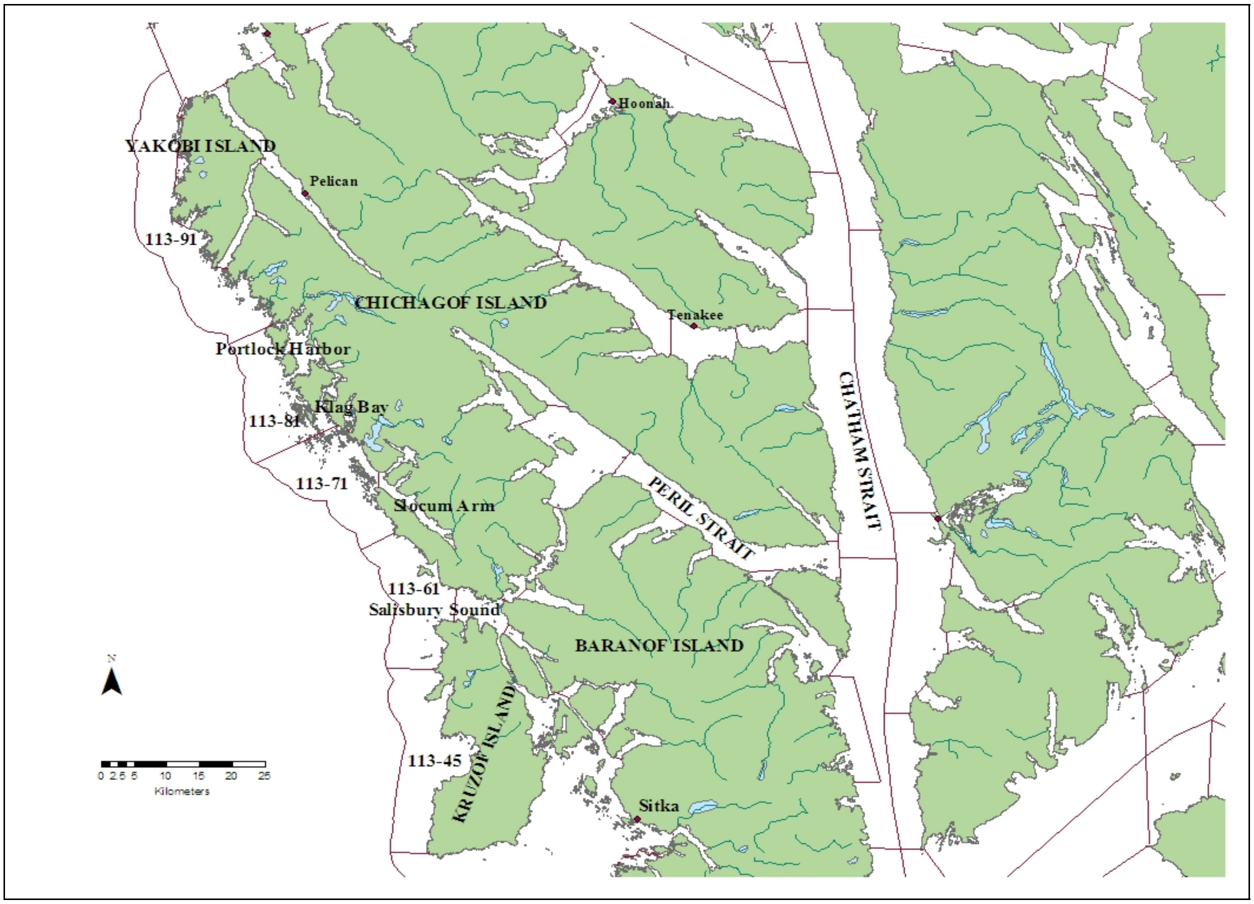

Figure 1.–Location of Klag Bay on Chichagof Island. The town of Sitka and commercial fishing districts along the outside coast of Chichagof Island are also shown.

METHODS

STUDY SITE

Klag Lake (ADF&G stream no. 113-72-007; lat 57^o 39'N, long 136^o 4'W) is located on the southwest side of Chichagof Island. This lake has a surface area of 83 ha, an elevation of about 12 m, and a maximum depth of 43 m (Figure 2). The Klag Lake drainage consists of approximately 7 km^2 of sparsely wooded low hills, large areas of muskeg, and numerous small shallow lakes and ponds. The lake drains to the south via an outlet that flows through a series of three large ponds before emptying into the east side of Klag Bay. In Klag Lake, sockeye salmon have been observed spawning in the first 500 m of the main inlet stream. A 1.3 m high barrier falls blocks further upstream migration in low to moderate water flow; however, sockeye salmon may be able to pass the falls during high water, as observed for coho salmon (*O. kisutch*; Terry Suminski, U.S. Forest Service, personal communication). In addition, small groups of sockeye salmon have been observed spawning on beaches in the northeast end of the lake (Conitz and Cartwright 2002). The spawning habitat is not typical and is comprised mainly of large immovable angular cobble and bedrock. In addition, to sockeye and coho salmon, this drainage supports small populations of pink (*O. gorbuscha*) and chum salmon (*O. keta*), steelhead (*O. mykiss*) and cutthroat trout (*O. clarki*), Dolly Varden char (*Salvelinus malma*), and threespine stickleback (*Gasterosteus aculeatus*).

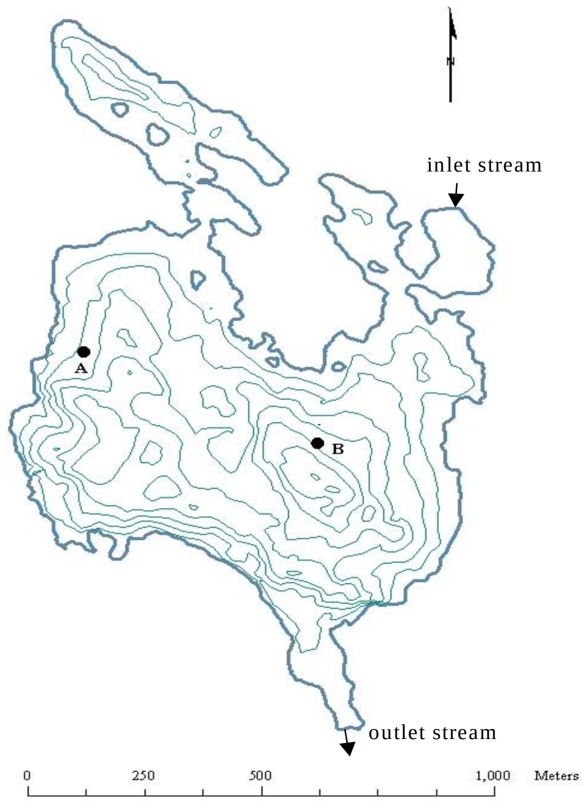

Figure 2.–Bathymetric map of Klag Lake, showing 5 m depth contours and two permanent limnology sampling stations (A and B).

SOCKEYE ESCAPEMENT ESTIMATE

Weir Count

Salmon were counted by species daily through a wooden picket and channel type weir on the outlet stream of Klag Lake. The weir was operated from 6 July to 6 September. The location and dimensions of the weir are described in Lorrigan et al. (2004).

Mark Recapture Estimate

To test the integrity of the weir and provide an independent estimate of sockeye escapement into Klag Lake, we also estimated escapement using a closed, stratified, two-sample mark-recapture model. The first sample was the marking phase, conducted at the weir, and the second sample the recovery phase, was performed on the spawning grounds.

The crew sampled 19% of the fish passed through the weir for marking; each sampled sockeye salmon was given a primary mark of an adipose fin clip. Samples were stratified over time by the following secondary marks: a left axillary clip (6 July–4 August), a right axillary clip (5 August–23 August), and a pelvic fin clip (24 August–6 September). Marked fish were handled quickly so as to minimize stress and were released upstream from the weir.

Mark-recovery sampling was conducted on the spawning grounds in the main inlet stream after the end of weir operation. Prior to the recovery sampling event on 11 September, the crew conducted a visual survey and counted the number of sockeye spawners in the main inlet stream. All captured fish during recovery phase sampling were examined for marks and further marked with an opercular punch to prevent duplicate sampling in future trips (sampling without replacement). Fish spawned within a concentrated period of time and area, around large irregular-shaped boulders, and died quickly afterwards. Consequently, it was difficult to sample live fish. The crew was able to sample a large number of salmon carcasses.

Data Analysis

The two-sample Petersen method is a simple model for estimating total escapement based on the total number of fish marked as they move into the spawning grounds (first sample), the total number of fish subsequently sampled for marks (second sample), and the number of marks recovered in the second sample (Seber 1982, p. 59; Pollock et al. 1990). Stratified mark-recapture models extend the two-sample Petersen method over two or more sampling trips or events in both the marking (first) and mark-recovery (second) samples. Stratified models are widely used for estimating escapement of salmonids as they migrate into the spawning grounds (Arnason et al. 1996). Spawning migrations may last for a month or more, during which there can be substantial variation in biological parameters such as daily immigration or mortality rates. A fundamental assumption of the Petersen and related mark-recapture models is that capture probabilities for individual animals are equal (Pollock et al. 1990). The natural variation typical of salmon escapements presents many possibilities for individual capture probabilities to vary, but if the assumptions of equal probability of capture required by the Petersen model are met, then a simplified model can be used. Briefly stated, the three assumptions of equal probability of capture are: 1) all fish have an equal probability of capture in the first sample (marking), 2) all fish have an equal probability of capture in the second sample (mark-recovery), and 3) fish mix completely between the first and second sample. Generally, if one or more of these assumptions is met, data from all marking and all mark-recovery samples can be pooled, thereby providing the most precise estimate. However, if none of the assumptions are met, the pooled estimate can be badly biased (Arnason et al. 1996).

We used the Stratified Population Analysis System (SPAS) software to aid in analyzing and interpreting mark-recapture results (Arnason et al. 1996; for details, refer to www.cs.umanitoba.ca/~popan/). SPAS calculates Darroch and "pooled Petersen" estimates and provides two goodness-of-fit tests to compare observed and expected capture probabilities in the marking (first) and mark-recovery (second) samples (Arnason et al. 1996). The test of the assumption of complete mixing is incorporated into the test for equal probability of capture in the second sample. We considered a goodness-of-fit test with a p-value ≤ 0.05 to be statistically significant—providing evidence that the necessary assumptions were not met. However, following the guidance of Arnason et al. (1996), if at least one goodness-of-fit test was not significant, we considered the pooled Petersen estimate valid. In addition, if SPAS failed to converge on a solution for the Darroch estimate, if the Darroch estimate was very different from the pooled estimate, or if both goodness-of-fit tests failed, then we searched for a partial pooling scheme that closely fit actual sampling conditions. We followed the guidelines and suggestions in Arnason et al. (1996) to help decide between the pooled Petersen and Darroch estimates.

If we concluded that the use of the pooled Petersen method was warranted, then we used the following alternative method to estimate the 95% confidence interval for the number of fish in the escapement, N. The confidence interval estimate provided in the SPAS output is based on an assumption that N is normally distributed. However, normal confidence intervals for N are often badly biased and have poor coverage probability, especially with small sample sizes. Following the usual Petersen method for estimating escapement, we let K denote the number of fish marked in a random sample of a population of size N. We let C denote the number of fish examined for marks in the second sample (recovery phase), and let R denote the number of fish in the second sample with a mark. Then the pooled Petersen estimate of the number of fish in the entire population, $\hat{N}$, is given by $\hat{N} = \frac{(K+1)(C+1)}{(R+1)} - 1$. In this equation, R is the random variable, and C and K are assumed to be constants. In mark-recapture sampling, R follows a hypergeometric distribution by definition, which can be approximated with the Poisson distribution (Thompson 1992). Simplifying the Petersen mark-recapture equation, we have $\frac{1}{\hat{N}} \approx \frac{R}{CK}$. In the Poisson approximation for R, the mean and variance are the same, so

$\text{var}(\frac{1}{\hat{N}}) \approx \frac{R}{(CK)^2}$, $\text{SE}(\frac{1}{\hat{N}}) = \frac{\sqrt{R}}{CK}$, and the coefficient of variation (CV) is $\text{CV}(\frac{1}{\hat{N}}) = \frac{1}{\sqrt{R}} \cdot 100$.

With moderate or large numbers of mark-recoveries, which will generally be the case if the pooled Petersen estimate meets the criteria outlined above, the distribution for R could be approximated with the normal distribution. Therefore we could assume $\frac{1}{\hat{N}}$ is approximately normally distributed, and we generated 95% confidence intervals for $\frac{1}{N}$ as,

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

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

SOCKEYE ESCAPEMENT AGE AND SIZE COMPOSITION

The crew sampled 651 sockeye salmon for scales, length, and sex at the Klag Lake weir to describe the age and size structure of the population, by sex. In the field, we measured the length of each fish from mid eye to tail fork to the nearest millimeter (mm). Three scales were taken from the preferred area of each fish (INPFC 1963) and prepared for analysis (Clutter and Whitesel 1956). Scale and length data were paired for each sample.

Ages were determined by technicians at the ADF&G Age Laboratory in Douglas, Alaska. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period. For example, a fish aged as a 2.3 means the fish spent two years in freshwater after hatching and 3 years in saltwater for a total age of 6 years (Koo 1962). The proportion of each age-sex group was estimated along with its associated standard error, using standard statistical techniques and assuming a binominal distribution (Thompson 1992).

SUBSISTENCE AND SPORT HARVEST ESTIMATES

We interviewed all subsistence and sport fishers in Klag Bay to census the number of sockeye salmon harvested. Boat-party was an appropriate sampling unit because participating boats could be accurately counted. All subsistence and sport fishermen were interviewed after they completed fishing. We conducted interviews during daylight hours and included information on fishing effort (rod or net hours), gear type used, and harvest by species. Because the crew was confident that they interviewed all sport and subsistence users, we simply summed the sockeye harvest across all gear types and days for each type of fishery to obtain the total number of sockeye salmon harvested in Klag Bay, by fishery. The total subsistence sockeye harvest was compared to the reported subsistence harvest on the 2004 ADF&G subsistence permits.

RESULTS

SOCKEYE ESCAPEMENT ESTIMATE

Weir count and Mark-Recapture Estimate

A total of 17,369 sockeye salmon were counted through the Klag weir between 27 July and 6 September in 2004. In addition, 3,940 coho, 5,213 pink, 5 chum salmon and 43 Dolly Varden were counted through the weir during the same time period. Similar to other years, peak sockeye counts coincided with dramatic increases in water levels of the outlet stream to Klag Lake. In 2004, peak sockeye counts occurred on 29 July and 28 August (Figure 3; Appendix B). The water level remained high, for the most part, from the end of August to the end of the weir operation (Figure 3).

The crew performed a visual survey of the inlet stream of Klag Lake on 11 September 2004 and conducted mark-recovery sampling on 11 and 17 September in the main inlet stream. Although an average of 19% of sockeye salmon counted through the weir were marked throughout the run, only 12% of the fish observed on the spawning ground had marks (Table 1). In addition, the percentages of sockeye salmon with marks that were observed on the spawning grounds were different between the two sampling dates of 11 September (11%) and 17 September (16%). The marking rates were different among marking strata: 7% were marked in Stratum One, 39% Stratum Two, and 22% Stratum Three. A larger proportion of Stratum One (24%) secondary marks were observed on the spawning ground compared to the later two strata (10%).

The pooled Petersen estimate was 26,700 sockeye salmon, the 95 % confidence interval for the true population was 24,300–29,500, and the coefficient of variation was 5%. The SPAS software was unable to produce a valid stratified estimator of sockeye abundance using the three marking strata and three recovery strata. We believe the Petersen estimate could be badly biased indicated by failure of both goodness-of-fit tests (i.e. $p < 0.01$; Arnason et al. 1996). The assumptions of equal probability of capture in the first event (i.e. fish marked in a given stratum had an equal probability of recovery in either recapture event) and of complete mixing or equal probability of capture in the second event (i.e. recapture probabilities were different for fish marked in different strata) may have been violated.

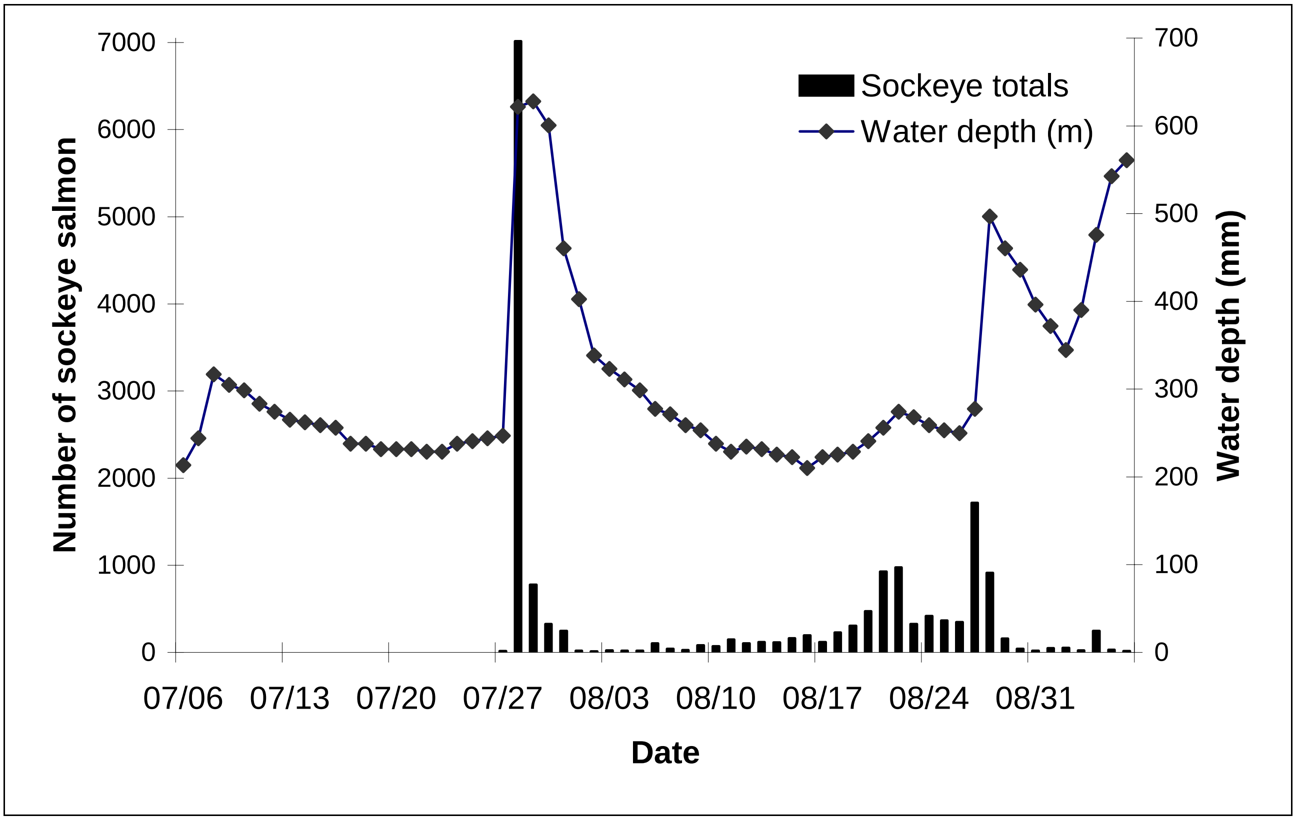

Figure 3.–Daily weir counts in comparison to the water depth of Klag Lake's outlet stream in 2004.

Table 1.–The number of sockeye salmon marked at the weir for each marking period, and number of recoveries of marked fish by recapture event and marking stratum in Klag Lake 2004. The number of fish passed through the weir during each marking period is included for comparison. Recapture sampling occurred on 11 and 17 September.

Marking at weir					Marks recaptured on spawning grounds			
Marking strata	**Marking dates**	**Number counted through weir**	**Number marked**	**Percent marked**	**11-Sep**	**17-Sep**	**All recapture events**	**Percent of marked fish recovered**
1	7/6–8/4	8,450	584	7%	103	36	139	24%
2	8/5–8/23	4,523	1,768	39%	116	57	173	10%
3	8/24–9/6	4,396	973	22%	55	45	100	10%
Total		17,369	3,325	19%	274	138	412	12%
Total sampled					2,464	844	3,308	
Percent marked fish in total sample					11%	16%	12%	

ESCAPEMENT AGE AND SIZE DISTRIBUTION

The largest sockeye age class was age 1.2, comprising 51% of the samples aged (CV=4%). The second largest age class was age 1.3 representing about 26% of the samples (CV=7%). Combining age classes by brood year, we see that this sockeye spawning population was composed of 1% 3-year olds, 54% 4-year olds, 40% 5-year olds, and 5% 6-year olds (Table 2). Similar to 2001, about 82% of the returning sockeye escapement had spent one year in freshwater as juveniles, however in 2002 only 72% had one freshwater year and in 2003 only 63% had only one freshwater year. Sockeye salmon that spent three years in the ocean before returning to Klag Lake had a greater average length than those that spent only two years in the ocean (Table 2); the mean fork length was 491 mm for age-1.2 fish and 548 mm for age-1.3 fish (Table 3). Only 5 jacks were sampled of age class 1.1 (mean length = 338 mm) and of age class 2.1 (mean length = 354 mm). Stratifying the age composition in the escapement by week showed that the age classes, other than age-1.1 and -2.1 jacks, returned to Klag Lake distributed fairly evenly throughout the run (Table 4).

Table 2.–Age composition of sockeye salmon in Klag Lake escapement by sex, brood year, and age class, sampled 28 July–3 September, 2004. Std. error represents the standard error of the percent estimated in each age class. The percentage for each age class was weighted by the weekly weir count. The escapement estimate per age class for the entire season was calculated using the weighted percent per age class and the total weir count (17,369 fish).

Brood year	**2001**	**2000**	**1999**	**2000**	**1999**	**1998**	
Age	**1.1**	**1.2**	**1.3**	**2.1**	**2.2**	**2.3**	**Total**
Male							
Sample size	5	155	70	1	38	17	286
Percent	0.3%	26.1%	12.2%	0.3%	8.3%	3.5%	50.8%
Std. error	0.2%	1.8%	1.3%	0.2%	1.1%	0.8%	2.1%
Female							
Sample size		163	88		40	12	303
Percent		24.6%	14.2%		8.3%	2.1%	49.2%
Std. error	0.0%	1.8%	1.4%	0.0%	1.1%	0.6%	2.1%
All Fish							
Sample size	5	318	158	1	78	29	589
Percent	0.3%	50.8 %	26.3%	0.3%	16.6%	5.7%	100.0%
Std. error	0.2%	2.1%	1.8%	0.2%	1.5%	1.0%	0.0%
Escapement estimate	56	8,820	4,574	48	2,885	985	17,369

Table 3.–Mean fork length (mm) of sockeye salmon in Klag Lake escapement by brood year, sex, and age class, sampled 28 July–3 September, 2004. Std. error represents the standard error of the length measure in each age class.

Brood year	2001	2000	1999	2000	1999	1998
Age	1.1	1.2	1.3	2.1	2.2	2.3
Male						
Avg. length (mm)	337.6	495.0	559.2	354.0	497.9	547.2
Std. error	22.1	2.0	2.6		4.3	7.0
Sample size	5	155	70	1	38	17
Female						
Avg. length (mm)		486.3	539.2		490.5	541.6
Std. error		1.8	2.6		3.9	8.0
Sample size		163	88		40	12
All Fish						
Avg. length (mm)	337.6	490.5	548.1	354.0	494.1	544.9
Std. error	14.1	1.3	2.0		2.9	5.2
Sample size	5	318	158	1	78	29

Table 4.–The percentage of each age class, by week, from 25 July to 3 September in Klag Lake in 2004. Percentages are based on the percentage in each age class and the number of fish passed through the weir each week. Although fish were passed through the weir after 3 September, scale samples were not taken.

Week	Percentage of weekly weir total, by age class						Weekly
beginning	1.1	1.2	1.3	2.1	2.2	2.3	weir totals
25-Jul	0%	46%	27%	1%	19%	8%	8,382
8-Aug	4%	57%	28%	0%	10%	1%	655
15-Aug	1%	44%	39%	0%	10%	6%	2,403
22-Aug	0%	60%	20%	0%	17%	3%	5,069
29-Aug	1%	68%	22%	0%	6%	4%	586

SUBSISTENCE AND SPORT HARVEST ESTIMATES

All boat parties observed on the fishing grounds were interviewed. Subsistence users participated in the fishery from 7 July to 16 August, and sport users fished in Klag Bay from 9 July through 4 August. With our on-site survey we estimated that a total of 2,800 sockeye salmon were harvested by subsistence fishers using gill nets and beach seines. Beach seines were the most efficient method of harvest with a catch of 45 sockeye salmon per hour for a total harvest of 1,700 sockeye salmon; gill nets caught 37 sockeye salmon per hour for a total harvest of 1,100 sockeye salmon (Table 5). In the sport fishery, only about 3 sockeye salmon were caught per hour fished with a total harvest of 100 sockeye salmon by 25 rods (Table 5). In addition, 11 chum salmon were harvested by gillnets, 4 pink salmon were harvested with seines, and 22 coho salmon were caught with sport and subsistence gear.

Table 5.–Number of salmon harvested in the subsistence and sport fisheries at Klag Bay in 2004, determined from ground surveys.

Fishery type	Boats counted	Missed interviews	Hours fished	Sockeye harvest	Coho harvest	Chum harvest	Pink harvest
Subsistence Gillnet	10	0	30	1,100	5	11	0
Subsistence Seine	10	0	38	1,700	6	0	4
Sport	13	0	40	100	11	0	0
Total	33	0	108	2,900	22	11	4

Similar to 2002 and 2003, the subsistence harvest reported on returned permits was greater than the estimate derived from on-site surveys. The sum of the reported harvest on permits totaled 3,200 sockeye salmon harvested in Klag Bay by 75 permit holders (ADF&G database; Sub-district 113-72).

DISCUSSION

In spite of the uncertainty surrounding the escapement estimate in 2004, we can confidently conclude that the subsistence and sport harvest at Klag Bay were small relative to the breeding escapement for this system. Even so, our 2001–2004 study demonstrated that Klag Lake sustains an important subsistence fishery, with catches of 1,600–2,800 sockeye salmon harvested annually, a very small sport fishery of about 100 sockeye salmon harvested annually, and an estimated escapement of approximately 14,000–25,000 sockeye salmon (Conitz et al. 2005).

Because a Darroch estimate could not be calculated and the Petersen estimate of escapement is likely to be badly biased, we used the weir count as our official estimate of escapement for Klag Lake in 2004. Apparently, the Petersen estimate was unreliable because marks were not applied in proportion to the run or sampling effort on the spawning grounds was inadequate. The crew was only able to mark less than 1% of the large pulse of over 7,000 fish that moved through the weir on 28 July. If these fish spawned at a different time or location than the rest of the run, then the crew may have sampled this group of mostly unmarked fish at a different rate than other fish. Furthermore, secondary marks applied at the weir were not identifiable in 55 fish recaptured on the spawning grounds; we apportioned these marks among marking and recapture strata based on the observed proportions. However, distribution of the unidentifiable marks within strata could have been different from our allocation.

The assumption of a closed population may have been violated because sampling on the spawning grounds did not cover the entire spawning period. The crew conducted the recovery phase of sampling on the spawning grounds during just two dates, which were only a week apart. In addition, sampling on the spawning grounds did not begin until a month and a half after the first fish were passed through the weir on 27 July. Some fish may have spawned, died, and decomposed before the first recovery event; consequently, the beginning of the sockeye run may have not been sampled. In addition, the crew only performed one visual survey and sampled one location on the spawning grounds; therefore, they may have missed other spawning locations and violated the assumption that the population was closed in relationship to space.

Our practice at this and other weir projects has been to use mark-recapture estimates to confirm the weir count or to use as an alternative means to estimate escapement in case high water, early weir removal, or human error. An important feature of the Petersen estimate is that a failure of mark-recapture assumptions will usually lead to inflated estimates, as mark loss, mark-induced mortality, failure to detect the mark, and so forth will lead to too few recaptures in the denominator of the Petersen ratio. Although it is possible that the weir leaked during high water events or that fish moved into the system after the weir was removed, we think that the 2004 Petersen estimate is almost certainly biased high. Even so, the weir was removed a week earlier than in previous years, and large numbers of fish passed through the weir only a week before its removal (1,600 fish passed through the weir on 27 and 28 August). However, the weir counts in 2001–2003 were within the confidence bounds and not statistically different than the mark-recapture estimates, demonstrating that both counting tools (weirs and mark-recapture) can be operated in such a way as to produce coordinated estimates.

To produce unbiased mark-recapture escapement estimates in the future, we recommend consistently marking sockeye salmon throughout the run and increasing sampling effort on the spawning grounds. Because sockeye salmon move into Klag Lake in large pulses, it is difficult to consistently mark sockeye salmon. Therefore, we recommend a lower level of marking, perhaps 10%. We also suggest that the secondary mark should be changed immediately after a large pulse of fish moves through the weir in order to isolate the event, more or less, as a separate marking stratum. Visual surveys of the entire lake perimeter and possible spawning streams should begin in early August and be performed before each recovery event, to determine when spawning begins and if other spawning locations exist. Once fish have been observed on the spawning grounds, then the recapture portion of the mark-recapture study should begin immediately and continue until no more new fish appear on the spawning grounds or as many carcasses as possible have been sampled. In addition, five to six sampling trips, spread evenly throughout the season, should be performed in order to consistently sample the entire sockeye run.

In 2003 and 2004, the sockeye harvest in Klag Bay reported by permit holders (3,200 in 2004; ADF&G database) was higher than the harvest estimated in our on-site survey (2,800 in 2004). In 2003, this discrepancy may be because the interviewed boat-parties' harvest did not represent the missed boat-parties' harvest (Conitz et al. 2005). However, in 2004 there were no missed interviews. It is possible the crew did not observe some boat-parties that fished in the area. Alternatively, subsistence fishers may have reported their catch more accurately on permits after returning home and counting their catch. Because the returned-permit estimate of subsistence catch in Klag Bay has been the similar or higher than the harvest estimated by our on-site surveys, it seems reasonable to rely on the returned-permit estimate of harvest as an accurate proxy for Klag Lake subsistence harvest. However, the reported harvest is not available to managers until the following fishing season.

At the current sockeye run size, the Klag Lake system appears to be able to support a larger subsistence fishery; however, we are concerned about the timing of the subsistence harvest. Sport and subsistence users harvested 14% of the total sockeye terminal returns, which is similar to the harvests observed from 2001 to 2003 (9–15%; Conitz et al. 2005). Almost all (more than 96%) of the subsistence harvest occurred at the beginning of the season, before 25 July in all years, 2001–2004. Low water conditions limit escapement of sockeye salmon into Klag Lake at the beginning of the season. For the most part, high escapements into Klag Lake coincide with increasing stream water levels. During low water conditions, spawners stage in the bay; consequently, large schools of sockeye salmon may be vulnerable to fishing gear. In 2004, subsistence fishers harvested over 99% of the year's harvest (2,800 fish) before any fish passed through the weir. By the third week in July in 2002 and 2003, total sockeye harvests greatly exceeded sockeye escapement through the Klag Lake weir. Consequently, the subsistence and sport fisheries were closed by emergency order before the end of July as a precaution. In both years, the fisheries were reopened after the managers were convinced that fish were successfully entering freshwater. Although escapement needs may be met in a season, the early timing of the subsistence fishery could potentially alter the genetic makeup of the stock by disproportionably removing fish at the beginning of the season.

Weir counts and on-site surveys provide managers with the best inseason monitoring tools. For that reason, we suggest that if the Klag Lake weir operation is continued, then on-site harvest surveys should also be continued so that managers can continue to look at the harvest level in the context of the escapement level. This information is important, and managers have used this inseason information to close the subsistence fishery in past years. However, we know now after several years of studying this system that the sockeye returns to Klag Bay are large compared to the terminal harvest. In other words, we don't believe that Klag should be included in the list of systems with the highest priority for monitoring because the harvest rate currently appears to be low. If monitoring resources are scarce, the Klag fishery could be assessed using alternative methods, such as boat or aerial surveys to measure effort in Klag Bay, even though these methods are inadequate for accurate estimation of sockeye escapement into the system.

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APPENDICES

Appendix A.–Number of permits, total annual harvests, and average number of sockeye salmon harvested per permit, reported by Klag Bay subsistence permit holders, 1985–2004 (ADF&G database).

Year	Number of permits	Total sockeye harvest	Average sockeye per permit
1985	29	582	20
1986	46	919	20
1987	42	816	19
1988	26	629	24
1989	5	114	23
1990	5	115	23
1991	1	23	23
1992	11	276	25
1993	59	1,626	28
1994	31	809	26
1995	28	1,098	39
1996	100	3,381	34
1997	42	1,106	26
1998	33	834	25
1999	42	1,048	25
2000	48	1,082	23
2001	65	1,325	20
2002	94	4,065	43
2003	70	2,475	35
2004	75	3,196	43
average 1985–1994	26	591	23
average 1995–2004	60	1,961	31

Appendix B.–The 2004 Klag Lake weir counts by species and sockeye salmon marking schedule, and daily water temperature and depth of Klag Lake's outlet stream.

Date	Water depth (m)	Water temperature	Number marked	Sockeye daily counts	Sockeye cumulative counts	Daily % marked	Cumulative marked	Coho counted	Pink counted	Chum counted	Dolly Varden counted
6-Jul	0.21	15	0	0	0		0	0	0	0	0
7-Jul	0.24	16	0	0	0		0	0	0	0	0
8-Jul	0.32	16	0	0	0		0	0	0	0	0
9-Jul	0.30	16.5	0	0	0		0	0	0	0	0
10-Jul	0.30	16	0	0	0		0	0	0	0	0
11-Jul	0.28	16.5	0	0	0		0	0	0	0	0
12-Jul	0.27	16.5	0	0	0		0	0	0	0	0
13-Jul	0.27	18	0	0	0		0	0	0	0	0
14-Jul	0.26	19	0	0	0		0	0	0	0	0
15-Jul	0.26	21.5	0	0	0		0	0	0	0	0
16-Jul	0.26	18.5	0	0	0		0	0	0	0	0
17-Jul	0.24	18.5	0	0	0		0	0	0	0	0
18-Jul	0.24	18	0	0	0		0	0	0	0	0
19-Jul	0.23	17.5	0	0	0		0	0	0	0	0
20-Jul	0.23	17.5	0	0	0		0	0	0	0	0
21-Jul	0.23	17.5	0	0	0		0	0	0	0	0
22-Jul	0.23	16.5	0	0	0		0	0	0	0	0
23-Jul	0.23	16	0	0	0		0	0	0	0	0
24-Jul	0.24	16	0	0	0		0	0	0	0	0
25-Jul	0.24	16	0	0	0		0	0	0	0	0
26-Jul	0.24	16.5	0	0	0		0	0	0	0	0
27-Jul	0.25	17	0	16	16	0%	0	67	0	0	0
28-Jul	0.62	16	33	7,015	7,031	0%	33	416	0	0	0
29-Jul	0.63	16	94	779	7,810	12%	127	197	0	0	0
30-Jul	0.6	16.5	215	326	8,136	66%	342	135	0	0	0
31-Jul	0.46	17	180	246	8,382	73%	522	111	0	0	0
1-Aug	0.40	17	18	19	8,401	95%	540	48	0	0	0
2-Aug	0.34	17	10	10	8,411	100%	550	22	0	0	0
3-Aug	0.32	17	18	21	8,432	86%	568	9	0	0	0
4-Aug	0.31	16.5	16	18	8,450	89%	584	4	0	0	0
5-Aug	0.30	17	15	17	8,467	88%	599	10	0	0	0
6-Aug	0.28	18	86	104	8,571	83%	685	0	0	0	0
7-Aug	0.27	17	31	40	8,611	78%	716	15	2	0	0
8-Aug	0.26	17	23	26	8,637	88%	739	1	0	0	0
9-Aug	0.25	17	46	82	8,719	56%	785	3	0	0	0
10-Aug	0.24	18	50	68	8,787	74%	835	0	0	0	0
11-Aug	0.23	18.5	110	147	8,934	75%	945	0	0	0	0

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Appendix B.–Page 2 of 2.

Date	Water depth (m)	Water temperature	Number marked	Sockeye daily counts	Sockeye cumulative counts	Daily % marked	Cumulative marked	Coho counted	Pink counted	Chum counted	Dolly Varden counted
12-Aug	0.23	17.5	77	101	9,035	76%	1,022	0	0	0	0
13-Aug	0.23	17	91	117	9,152	78%	1,113	2	0	0	0
14-Aug	0.23	17	101	114	9,266	89%	1,214	1	3	0	0
15-Aug	0.22	18	136	150	9,416	91%	1,350	2	1	0	0
16-Aug	0.21	18.5	99	193	9,609	51%	1,449	0	3	0	0
17-Aug	0.22	18.5	0	118	9,727	0%	1,449	0	0	0	0
18-Aug	0.23	19	70	229	9,956	31%	1,519	1	2	1	0
19-Aug	0.23	19	0	304	10,260	0%	1,519	7	3	0	0
20-Aug	0.24	18	0	472	10,732	0%	1,519	48	29	0	0
21-Aug	0.26	18.5	60	927	11,659	6%	1,579	78	2	0	0
22-Aug	0.27	18.5	548	796	12,455	69%	2,127	182	6	0	1
23-Aug	0.27	18	225	327	12,782	69%	2,352	78	6	0	1
24-Aug	0.26	17	324	419	13,201	77%	2,676	50	7	0	0
25-Aug	0.25	17	263	368	13,569	71%	2,939	30	13	1	0
26-Aug	0.25	17	117	347	13,916	34%	3,056	15	83	0	1
27-Aug	0.28	17	85	1,716	15,632	5%	3,141	1017	236	1	3
28-Aug	0.50	17	40	915	16,547	4%	3,181	516	1,468	0	5
29-Aug	0.46	17	61	158	16,705	39%	3,242	241	287	0	1
30-Aug	0.44	17	32	42	16,747	76%	3,274	175	94	0	1
31-Aug	0.4	17	12	20	16,767	60%	3,286	98	117	0	4
1-Sep	0.37	17	30	47	16,814	64%	3,316	97	174	0	3
2-Sep	0.34	17.5	0	52	16,866	0%	3,316	45	190	0	9
3-Sep	0.39	16	9	22	16,888	41%	3,325	61	460	0	14
4-Sep	0.48	15.5	0	245	17,133	0%	3,325	65	1,176	0	0
5-Sep	0.54	15.5	0	31	17,164	0%	3,325	54	585	0	0
6-Sep	0.56	15	0	14	17,178	0%	3,325	39	266	2	0