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Kanalku and Sitkoh Lakes Subsistence Sockeye Salmon Project: 2005 Annual Report

by

Sean E. Burril

and

Jan M. Conitz

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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

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by
Sean E. Burril
and
Jan M. Conitz
Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau, Alaska

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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Sean E. Burril and Jan M. Conitz
Alaska Department of Fish and Game, Division of Commercial Fisheries,
P.O. Box 110024, Juneau, AK 99811-0024, USA

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ABSTRACT

In 2005, we estimated escapement of sockeye salmon (*Oncorhynchus nerka*) in two systems with important subsistence fisheries for the village of Angoon. These estimates extended a series of annual estimates starting in 2001 for Kanalku Lake and 1996 for Sitkoh Lake. We used mark-recapture methods, visual surveys, and age, sex, and length sampling on the spawning grounds to estimate sockeye escapement and age composition in each lake. Estimated escapement in Kanalku Lake in 2005 was about 1,100 sockeye salmon, marking the first year since the study began in 2001 that escapement levels in Kanalku Lake have been above 1,000 fish for consecutive years. The 2001 brood year consisted of only 200–300 spawning adults; however, the offspring of the 2001 brood year, age-1.2 sockeye salmon, were the dominant age class in the 2005 escapement. The 2005 season was the final season under the voluntary subsistence closure agreement for Kanalku Lake. In Sitkoh Lake the estimated escapement of about 13,400 sockeye salmon was a substantial increase from the 2004 escapement. Sitkoh Lake escapements continue to fluctuate and appear to be following a five year cycle typical of many sockeye salmon populations. Age-1.3 fish were the dominant age class (67.8% of escapement) in 2005, whereas age-1.2 sockeye salmon were the dominant age class in 2004. In Sitkoh Lake, the dominant sockeye age class seems to alternate between 1.2 and 1.3. Kanalku Bay is still the preferred subsistence fishery for most Angoon residents and we expect higher harvest rates following the ending of the voluntary closure. Since Angoon residents prefer Kanalku over Sitkoh Bay for subsistence fishing, future monitoring of Kanalku Lake stocks is a priority, given the changes in management of this system and our lack of knowledge as to how fishers will respond to these changes.

Key words: sockeye salmon, *Oncorhynchus nerka*, subsistence, Kanalku Lake, Sitkoh Lake, escapement, mark-recapture

INTRODUCTION

Sitkoh and Kanalku Lakes support spawning populations of sockeye salmon with long histories of subsistence harvest by the residents of Angoon. Kanalku Lake is preferred over Sitkoh Lake by fishers due to proximity to Angoon and accessibility. Annual sockeye escapement has been estimated since 1996 in Sitkoh Lake and since 2001 in Kanalku Lake.

Alarmingly low escapement estimates of less than 275 adult spawners in Kanalku Lake in 2001 (Conitz and Cartwright 2005) led to concern among users and managers about stock abundance. In response, the community of Angoon proposed a voluntary subsistence closure, which they implemented in cooperation with Alaska Department of Fish and Game (ADF&G) during each of the next four years. Estimates of escapement for Kanalku Lake sockeye salmon have been variable for the past four years (Appendix C in Conitz and Cartwright 2005; Conitz and Cartwright 2007). Subsequent to the voluntary closure, escapement increased in 2002 but dropped again in 2003 to nearly the same low size observed in 2001 (Conitz and Cartwright 2005; Conitz and Cartwright 2007). Subsistence use of the Kanalku sockeye run has continued at low levels in spite of the closure, leading managers to consider different management options for this fishery in 2006 (D. Harris, Division of Commercial Fisheries, personal communication 2005). One option is to delay the subsistence opening until after the peak sockeye spawning migration has passed.

Abundance of Sitkoh Lake sockeye salmon has fluctuated, with highs observed in 1996 and 2000 and a downward trend since 2000 (Appendix C in Conitz and Cartwright 2005; Conitz and Cartwright 2007). Since the mid 1990s, Sitkoh Lake has had both higher escapement and lower harvests of sockeye salmon than Kanalku Lake (Conitz and Cartwright 2005). Our studies combined with previous studies have indicated that sockeye runs are stable and consistent in this system (Cook 1998). With the closure of the Kanalku Bay subsistence fishery in 2002, some users shifted their subsistence efforts to the Sitkoh Lake sockeye run, following a decade of minimal reported harvests on this run (Table 1).

The only quantitative record of subsistence harvest available for specific streams or marine terminal areas in the Angoon area is data collected from subsistence fishing permits returned to ADF&G, dating back only to 1985. After the fishing season users must return their subsistence permit with catch and area information to ADF&G before obtaining their permits for the subsequent year. Self-reported harvests should be considered a minimum estimate of actual harvest. These reported harvests of Kanalku Lake sockeye salmon averaged almost 1,300 fish annually during the 1990s, with a peak of almost 1,700 fish in 1999 (Table 1; Conitz and Cartwright 2005). Reported subsistence harvest levels at Kanalku Lake dropped dramatically in 2002 with the implementation of the voluntary closure, and remained low (<90 fish per year) through 2004. Concurrent with the voluntary closure at Kanalku Lake the subsistence harvest of Sitkoh Lake sockeye salmon reached a recorded high of 1,055 fish in 2004. Overall, reported annual subsistence harvest of Sitkoh Lake sockeye salmon jumped by ten-fold in the early 2000s from amounts reported in the 1990s.

Table 1.–Subsistence effort and harvest of sockeye salmon reported on permits from 1985 to 2004 at Kanalku and Sitkoh Bays (ADF&G Division of Commercial Fisheries database 2006).

	Kanalku		Sitkoh	
Year	Number of permits	Total reported harvest	Number of permits	Total reported harvest
1985	22	473	40	313
1986	37	931	48	677
1987	20	645	36	636
1988	10	258	25	322
1989	16	425	16	248
1990	30	762	18	181
1991	22	556	0	0
1992	21	571	1	90
1993	32	901	0	0
1994	42	1,282	2	36
1995	39	936	1	10
1996	59	1,627	3	50
1997	56	1,538	6	60
1998	53	1,482	2	16
1999	57	1,666	6	36
2000	50	1,443	8	75
2001	39	951	17	276
2002	1	14	7	184
2003	3	90	20	647
2004	2	60	32	1,055
average, 1980s	21	546	33	439
average, 1990s	46	1,280	4	48
average, 2000s	19	512	17	447

In addition to subsistence harvest, sockeye escapement in Sitkoh and Kanalku Lakes may be affected to an unknown extent by commercial fisheries in Chatham Strait. Sockeye salmon in northern Chatham Strait are primarily taken as incidental catch in purse seine fisheries targeting pink (*Oncorhynchus gorbuscha*) and chum salmon (*O. keta*). We emphasize that the proportion of the total catch, if any, from Sitkoh and Kanalku Lake sockeye stocks is unknown.

The main objective of this study was to obtain escapement estimates of sockeye salmon in Sitkoh and Kanalku Lakes, using mark-recapture methodology on the spawning grounds. Biological data was also collected from both populations to estimate age, sex, and length compositions, and eventually enable us to reconstruct returning population sizes by brood year. Continued monitoring of both systems will allow fisheries biologists and managers to use run size estimates to aid in developing subsistence fishing management strategies, with the goal of maintaining future sockeye run strength and ensuring sustainable harvest opportunities.

OBJECTIVES

1. Estimate annual sockeye escapement into Kanalku and Sitkoh Lakes, using mark-recapture methods and observer counts on the spawning grounds, so the estimated coefficient of variation is less than 15%.
2. Estimate the age, length, and sex composition of the sockeye salmon in the escapement at each lake, based on a sample size of 600 fish, with a coefficient of variation no greater than 10% for the two major age classes.

METHODS

STUDY SITES

Kanalku Lake

Kanalku Lake (ADF&G stream no. 112-67-58/60; lat 57° 29.22'N long 134° 21.02'W) is about 20 km southeast of Angoon (Figure 1) and lies in a steep mountainous valley within the Hood-Gambier Bay carbonates ecological subsection (Nowacki et al. 2001). The U-shaped valley and rounded mountainsides are characterized by underlying carbonate bedrock and built up soil layers supporting a highly productive spruce forest, especially over major colluvial and alluvial fans. The watershed area is approximately 32 km^2, with one major inlet stream draining into the east end of the lake. The lake elevation is about 28 m. The lake surface area is about 113 hectares, with mean depth of 15 m, and maximum depth of 22 m (Figure 2). The outlet stream, Kanalku Creek, is 1.7 km long and drains into the east end of Kanalku Bay. In addition to sockeye salmon returning to the lake, large numbers of pink salmon spawn in the lower part of the outlet creek and intertidal area. A few coho (*O. kisutch*) and chum salmon spawn in the Kanalku system, and resident populations of cutthroat trout (*O. clarkii*) Dolly Varden char (*Salvelinus malma*), and sculpin (*Cottus* sp.) are found in Kanalku Lake. A waterfall, approximately 8–10 m high and about 0.8 km upstream from the tidewater, forms a partial barrier to migrating sockeye salmon. In 1970, ADF&G, working with the U.S. Forest Service, blasted resting pools and a small channel in the falls bedrock to assist the migrating salmon.

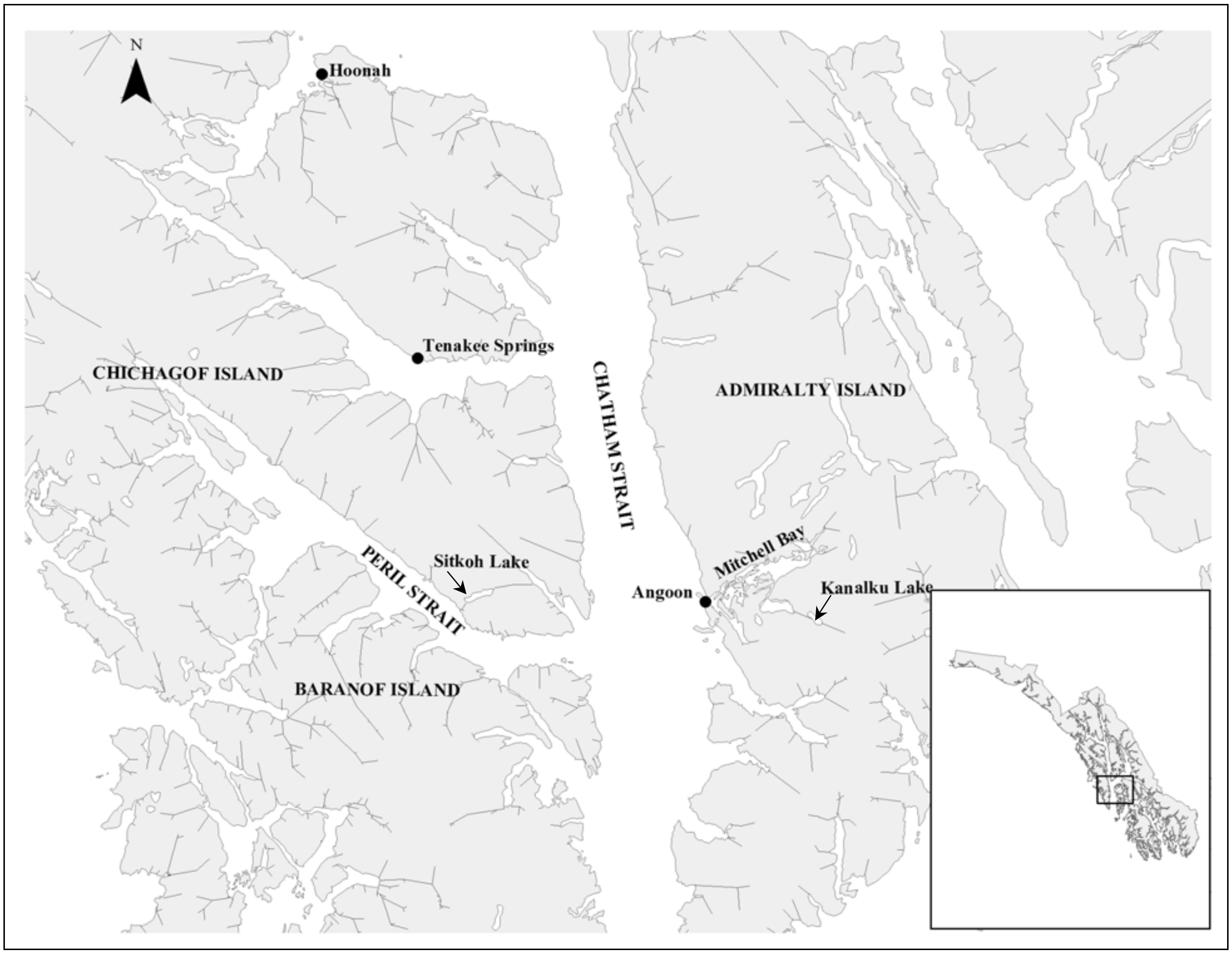

Figure 1.–Map of Angoon area, Southeast Alaska, showing location of Kanalku and Sitkoh Lakes.

Figure 2.–Bathymetric map of Kanalku Lake, showing 5 m depth contours and the mark-recapture study area. Arrows indicate direction of stream flow.

Sitkoh Lake

Sitkoh Lake (ADF&G stream no. 113-59-005; lat 57°30.89'N, long 135°2.52'W) is located on the southeastern tip of Chichagof Island, about 30 km from Angoon, and drains east into Sitkoh Bay (Figure 1). Situated between Chatham and Peril Strait, the Sitkoh Lake drainage lies within the Peril Strait granitics ecological subsection, while the outlet stream and the bay are part of the Kook Lake carbonates subsection to the east (Nowacki et al. 2001). Continental ice sheets covering this area left rounded and heavily scoured mountains. Sitkoh Lake and its outlet stream lie in a broad, U-shaped valley that nearly bisects the peninsula at the tip of Chichagof Island. The Sitkoh Lake watershed area is about 31 km^2; the lake is situated at an elevation of about 59 m. Its surface area is 189 hectares, the average depth is 20 m, and the maximum depth is 39 m (Figure 3). Several steep-gradient inlet streams enter the lake on the north and south sides, ending in productive alluvial fans on the lakeshore; the outlet stream is about 6 km long with at least two tributaries. The lake supports runs of sockeye, coho, pink, and chum salmon. It also supports a run of as many as 50,000 anadromous Dolly Varden char, several thousand sea-run cutthroat trout and a smaller number of summer resident cutthroat trout, and one of the region's largest steelhead (*Oncorhynchus mykiss*) runs (Yanusz 1997; Jones and Yanusz 1998; Cook 1998; Brookover et al. 1999). The Sitkoh drainage was extensively clear-cut between 1969 and 1974.

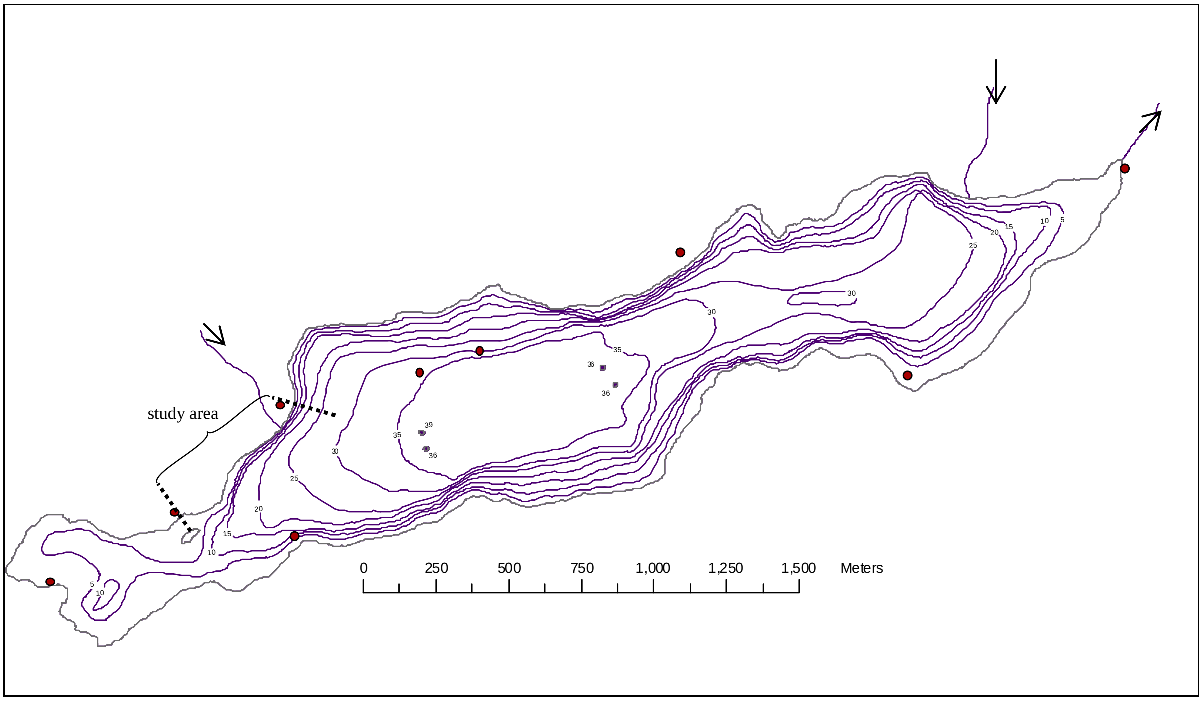

Figure 3.–Bathymetric map of Sitkoh Lake, showing 5 m depth contours and the mark-recapture study area. Arrows indicate direction of stream flow.

ADULT ESCAPEMENT ESTIMATES

Spawning Grounds Mark-Recapture and Visual Survey

Mark-recapture methods were used to estimate portions of the sockeye salmon spawning populations in Kanalku and Sitkoh Lakes. Mark-recapture sampling was conducted only within designated study areas, established in 2001, in the beach spawning areas of Kanalku and Sitkoh Lakes (Figures 2 and 3). We used a study design based on the methods described in Schwarz et al. (1993) for estimating salmon escapements and further modified for estimating spawning populations in beach spawning sockeye systems (Cook 1998). Specifically, we used a simple Petersen estimator (Seber 1982) to estimate the number of spawners present at each sampling event, and a modified Jolly-Seber model to estimate the superpopulation, or total number of fish entering the spawning area throughout the season (Seber 1982; Schwarz et al. 1993; Cook 1998). We give details in the data analysis section below.

Visual Survey Counts of Sockeye Spawners

Mark-recapture sampling was conducted in the most highly concentrated spawning areas, designated as the study area in each lake (Figures 2 and 3). Consequently, mark-recapture estimates applied only to those fish, out of the total spawning population, within these designated study areas. To determine the proportion of the total spawning population that we were able to sample in the study area, we estimated the total number of sockeye spawners in the lake and the number of spawners within the study area using visual survey counts. Just before each sampling event, at least three observers counted sockeye spawners from a skiff motoring slowly around the lake perimeter. Each crew member reported a total count of all sockeye salmon observed in the lake system, and a separate count of sockeye salmon within the designated study area. The main inlet stream in Kanalku Lake was checked for presence of fish, but we have never observed sockeye spawners in this stream. Sitkoh Lake has no spawning tributaries. After each survey, we divided the mean count (between all observers) for the study area by the mean total count for the whole lake, to estimate the proportion of fish within the study area at that sampling event. A rough approximation of the proportion of fish in the study area over the entire season was estimated by taking the mean of proportions in the study area at each sampling event, weighted by the estimated spawning population size at each event.

Mark-Recapture Methods for Beach Spawning Populations

Each sampling event consisted of two consecutive days of sampling. On each day, the crew captured sockeye salmon on the spawning grounds with a beach seine. They first inspected each sockeye salmon for previous marks, then marked the fish with an opercular punch or pattern of punches identifying the sampling event and day, and released it with a minimum of stress. The crew leader recorded the total sample size, the number of new fish marked, and the number of recaptured fish with each type of mark. Sampling in these small populations continued until the number of same-day recaptures exceeded the number of new fish caught. Left opercular punches used to identify each sampling event were: first event—round, second event—triangle, third event—square, fourth event—two round. A right opercular punch was given each fish caught on the second day of each event to indicate the fish had already been caught and should not be recounted during that event. In order to generate a simple Petersen estimate for each event, fish were marked on one day and examined for marks the next day. For the superpopulation estimate, fish marked on both days of a given event were counted, and on subsequent sampling events, recaptures of these marks were recorded. We used the number of recaptures from each previous event and the Petersen estimates of abundance from each event to generate the superpopulation estimate.

Data Analysis

We used Chapman's form of the Petersen mark-recapture estimator to estimate the number of sockeye spawners within the study area at each sampling event (Seber 1982, p. 60). Then we used the Petersen estimates of spawner abundance at each event, and the number of recaptures from previous events, to estimate the superpopulation, or total spawning population within the study area, N^*. Given s sampling events, we let $\hat{N}_i$ denote the Petersen estimate from each sampling event i ($i=1,...,s$). The $\hat{N}_i$ values were used in place of the usual Jolly-Seber derived parameter estimates of the number of animals alive in the system at each sampling event (Cook 1998). We let n_i represent the number of unmarked fish and fish marked in previous events, caught at sampling event i, and we let m_i represent the number of fish marked in previous events, caught at sampling event i.

We also defined the parameters (Schwarz et al. 1993; Cook 1998):

> M_i = number of marked fish alive at time i (i=1,…,s; M_1=0);
>
> ϕ_i = probability that a fish alive at time i is also alive at time i+1 (i=1,…,s-1; *i.e.* the survival rate);

B_i = number of fish that enter the system after event i and are still alive at event i+1 (i=1,…,s-1; *i.e.* immigration), and B_0 = number of fish that entered the population before the first sample and are still alive at the time of the first sample;

N^* = total number of animals that enter the system before the last sampling event.

We used the following parameter estimates:

M_i was estimated as $\hat{M}_i = m_i \hat{N}_i / n_i$ and $\hat{M}_i = 0$;

ϕ_i was estimated as $\hat{\phi}_i = \hat{M}_{i+1} / (\hat{M}_i - m_i + n_i)$;

B_i was estimated as $\hat{B}_i = \hat{N}_{i+1} - \hat{\phi}_i \hat{N}_i$.

Seber (1982, p. 204) recommended that m_i should be greater than 10 for satisfactory performance of these bias-adjusted estimators.

We assumed the interval between the last (s^{th}) sampling event, and the next-to-last (s-1^{th}) sampling event was so short that the number of fish entering the population during this interval was negligible. Furthermore, we assumed that sampling extended to a time when immigration had ended, and the number of fish entering the population was negligible. Escapement can be estimated as the sum of the $\hat{B}_i$, estimated numbers of fish that entered the population between sampling events. However, the $\hat{B}_i$ are numbers of fish that entered the population after sampling event i and were alive at sampling event i+1. These estimates exclude those fish in the escapement that entered after sampling event i but died before sampling event i+1. Consequently, Jolly-Seber estimates of B_i underestimate spawning recruitment, except when all fish are known to survive from their entry to the next sampling event. To account for those fish that entered the system after sampling event i but died before sampling event i+1, we adjusted $\hat{B}_i$ by a probability distribution approach (Schwarz et al. 1993). Let B_i^* denote the total number of new fish entering the population between sampling events (including those that die before the next sampling event). When recruitment and mortality are assumed to occur uniformly between sampling events, the maximum likelihood estimator (MLE) for B_i^* is

$$\hat{B}_i^* = \hat{B}_i \frac{\log(\hat{\phi}_i)}{\hat{\phi}_i - 1}.$$

$\hat{B}_0$, $\hat{B}_1$, and $\hat{B}_{s-1}$ are confounded parameters and cannot be estimated without further assumptions (Schwarz et al. 1993). However, we assumed recruitment had virtually ended before the last sampling event, so we set $\hat{B}_{s-1}$ to zero. The number of fish alive in the population on the second sampling event, N_2, was estimated as,

$$\hat{N}_2 = \hat{B}_0 \phi_1 + \hat{B}_1.$$

So a reasonable estimate of the number of fish that entered the system before the first sampling event and between the first and second sampling events, including those that entered the system and die before and between these sampling events, was,

$\hat{N}_2 \frac{\log(\hat{\phi}_1)}{\hat{\phi}_1 - 1}$ (Schwarz et al. 1993).

We then estimated the superpopulation, or total escapement, as

$$N^* = \hat{N}_2 \frac{\log(\hat{\phi}_1)}{\hat{\phi}_1 - 1} + \sum_{i=2}^{k-1} \hat{B}_i^* .$$

A parametric bootstrap method (Buckland 1984, 1985) was used to construct a confidence interval for the population estimate. Let each bootstrap step be indexed by j (j=1...G; for our purposes G=1,000). The parametric bootstrap distribution for $\hat{N}_i$ was developed by drawing G bootstrap observations of a hypergeometrically distributed random variable (that is, r_i) using parameters based on the observed values of the first and second sample sizes and Peterson estimate $\hat{N}_i$ at each sampling event i. At each step the Petersen estimate $\hat{N}_i(j)$ was calculated using the Chapman estimator (Seber 1982, p. 60). Denote each bootstrap observation in the Petersen estimation process as the pair of $r_i(j)$ and $\hat{N}_i(j)$, for j=1...G. Before proceeding on to simulation of the modified Jolly-Seber estimation process, the sample variance and standard deviation of the number of recaptures, r_i, across all bootstrap replicates, were estimated for each sampling event i. Note that the variance and standard deviation estimates were derived from the bootstrap distribution of the first-stage (second day) recaptures only, for each sampling event. To simulate the Jolly-Seber portion, for each bootstrap step, a bootstrap observation, $m_i(j)$, was drawn from a normal distribution with the mean determined from the actual observed value of m_i, and the standard deviation estimated from the bootstrap sample of r_i. Because this standard deviation was based on the simulated variability only from first-stage recaptures in a given sampling event, it may have tended to understate the sampling variability of m_i, which is the number of recaptures from all previous marking events. Even so, we think this assumption provides a sensible approximation. We conditioned on the sample size, which we assumed to be fixed and not a random variable, so that $n_i = n_i(j)$, for all j bootstrap observations. We then estimated $\hat{M}_i(j)$, $\hat{\phi}_i(j)$, and so on, as previously described, for all j=1, ...G. The confidence interval for each parameter was found from the quantiles of the bootstrap distribution (Rice 1995) for that estimate.

Adult Sockeye Salmon Population Age and Size Composition

At each lake, about 600 length, sex, and scale samples were collected during mark-recapture sampling of adult sockeye salmon to describe the size and age structure of the population, by sex. Length of each fish was measured from mid eye to tail fork, to the nearest millimeter (mm). Sex of the fish was decided by length and shape of the kype or jaw. Three scales were taken from the preferred area of each fish (INPFC 1963), and prepared for analysis as described by Clutter and Whitesel (1956). Scale samples were analyzed at the ADF&G salmon aging laboratory in Douglas, Alaska. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period (e.g. 1.3 denotes a five-year-old fish with one freshwater and three ocean years; Koo 1962). The proportion of each age-sex group was estimated along with its associated standard error, using standard statistical techniques assuming a binominal distribution, described in common references, such as Thompson (1992).

RESULTS

ADULT ESCAPEMENT ESTIMATES

Spawning Grounds Mark-Recapture and Visual Survey

Kanalku Lake

Visual surveys were conducted weekly in Kanalku Lake between 23 August and 22 September 2005. The greatest abundance of sockeye salmon in the study area and in the lake was on 8 September (Table 2). The surveys were well timed to encompass peak abundance on the spawning grounds.

Table 2.–Visual counts of sockeye spawners in Kanalku Lake, 2005, comparing numbers counted inside designated study area with total counts for the lake.

Trip beginning	Average count within study area	Average count for whole lake	Proportion in the study area
23 Aug	36	236	0.15
30 Aug	207	235	0.88
8 Sep	345	371	0.93
15 Sep	171	198	0.86
22 Sep	55	59	0.93

Sockeye salmon were not yet committed to their spawning areas and were unavailable for capture with a beach seine on the first trip to the lake, 23 August. Therefore, mark-recapture sampling was conducted between 30 August and 22 September (Table 3). The estimated abundance of sockeye spawners in the study area over the entire 2005 season was about 950 fish (CV=2.5%; 95% CI 900–1,000). Excluding 23 August, when no sampling occurred, the weighted average proportion of sockeye salmon observed in the study area compared with the whole lake was 0.90 over the whole season. Assuming this proportion adequately represents the true proportion of the population sampled in the mark-recapture study, the rough estimate of total spawning population size for 2005 was then about 1,100 sockeye salmon.

Table 3.–Sample sizes and numbers of recaptured fish in the Kanalku Lake study area in 2005. For the Petersen (first stage) estimate, we marked and released fish the first day and conducted recapture sampling on the second day of each sampling event, to estimate spawner abundance at that date. For the Jolly-Seber (second stage) estimate, we counted all fish released with marks denoting the event on both days of a given sampling event, and also counted all recaptures of fish with marks from previous events.

First Stage: Petersen

Trip beginning	Number marked (1st day)	Number sampled (2nd day)	Number recaps from 1st day
30 Aug	154	93	27
8 Sep	261	147	137
15 Sep	150	38	61
22 Sep	50	10	27

Second Stage: Jolly-Seber

Trip beginning	Number of marks released	Recaptures from previous marking event		
		1 Sep	15 Sep	23 Sep
30 Aug	247	-	-	-
8 Sep	408	133	-	-
15 Sep	188	8	84	-
22 Sep	60	0	5	11

Sitkoh Lake

Visual surveys were conducted in Sitkoh Lake between 2 September and 2 November. Sockeye salmon were present in the lake on all sampling dates and peak abundance on the spawning grounds was near the midpoint of the study period (Table 4).

Table 4.–Visual counts of sockeye spawners in Sitkoh Lake, 2005, comparing numbers counted inside designated study areas with total counts for the lake.

Date	Average count within study area	Average count for whole lake	Proportion in the study area
2 Sep	267	608	0.44
14 Sep	384	857	0.45
22 Sep	461	1,096	0.42
5 Oct	388	896	0.43
18 Oct	275	509	0.54
2 Nov	116	116	1.00

Based on mark-recapture sampling between 2 September and 2 November (Table 5), we estimated a total of about 6,400 sockeye spawners (CV=3%; 95% CI 6,100–6,800) within the study area. The weighted average proportion of fish observed in the study area, for the entire season, was 0.48. Expanding the study area estimate by this proportion, we judged the total population in Sitkoh Lake to be about 13,400 sockeye spawners over the course of the season.

Table 5.–Mark and recapture sample sizes and numbers of recaptured fish in the study area of Sitkoh Lake, 2005.

First Stage: Petersen

Date	Number marked (1st day)	Number sampled (2nd day)	Number recaps from 1st day
2 Sep	240	180	123
13 Sep	419	355	174
22 Sep	452	399	176
5 Oct	498	454	298
18 Oct	388	396	230
2 Nov	58	63	22

Second Stage: Jolly-Seber

Date	Number of marks released	Recaptures from previous marking event				
		13-Sep	22-Sep	5-Oct	18-Oct	2-Nov
2 Sep	297	-	-	-	-	-
13 Sep	600	45	-	-	-	-
22 Sep	675	8	145	-	-	-
5 Oct	654	0	1	80	-	-
18 Oct	554	0	0	0	42	-
2 Nov	99	0	0	0	3	13

Adult Sockeye Salmon Population Age and Size Composition

Kanalku Lake

During the 2005 season, 486 sockeye salmon were sampled for age, sex, and length; of these, age was determined for only 380 fish. Similar to previous years, the age-1.2 (one year freshwater, two years marine) class was dominant, comprising 85% of sampled fish (Table 6). The next largest age class, with 11% of the total, was age-1.3. This age class had a highly skewed sex ratio, with 39 males and only three females sampled, possibly a result of sampling bias. An overall sex ratio of approximately 1.8:1 was observed. Six age classes, including age-1.1 and -2.1 jacks, were represented among sampled males, while only three age classes were observed for females.

Table 6.–Age composition of adult sockeye salmon sampled in the Kanalku Lake escapement by sex, 2005.

Brood year	**2002**	**2001**	**2000**	**2001**	**2000**	**1999**	
Age	1.1	1.2	1.3	2.1	2.2	2.3	**All aged**
Male							
Sample size	1	188	39	3	5	1	237
Percent	0.3%	50%	10%	1%	1%	0%	62.4%
Female							
Sample size	-	134	3	-	6	0	143
Percent	-	35%	1%	-	2%	-	37.6%
All Fish							
Sample size	1	322	42	3	11	1	380
Percent	0%	85%	11%	1%	3%	0%	100%
Std. error	-	2%	2%	1%	1%	-	

Consistent with past years, fish in the most abundant age-1.2 class in Kanalku Lake were small, averaging 479 mm in mid-eye to fork length. Age-1.3 fish which spent an additional year in saltwater were larger, but this group also had a large number of males relative to females in the sample (Table 7). Both males and females of age 1.3 were larger than their five-year-old counterparts that spent an additional year in freshwater (age 2.2), by an average of 49 mm. Four fish under 260 mm were sampled in 2005; although these small sizes suggested the fish might be kokanee, scale aging clearly revealed one year of marine growth, so these fish were assumed to be precocious males (jacks).

Table 7.–Mean fork length (mm) of adult sockeye salmon in the Kanalku Lake escapement by sex and age class, 2005.

Brood year	**2002**	**2001**	**2000**	**2001**	**2000**	**1999**	
Age	1.1	1.2	1.3	2.1	2.2	2.3	**All aged**
Male							
Avg. length (mm)	255	484	533	237	495	525	488
Std. error	-	1.8	3.0	3.3	9.6	-	2.9
Sample size	1	188	39	3	5	1	237
Female							
Avg. length (mm)	-	473	515	-	473	-	474
Std. error	-	1.7	4.0	-	12.1	-	1.7
Sample size	-	134	3	-	6	-	143
All Fish							
Total avg. length (mm)	255	479	532	237	483	525	483
Std. error	-	1.3	2.9	3.3	8.2	-	1.9
Sample size	1	322	42	3	11	1	380

Sitkoh Lake

Most sockeye salmon returning to Sitkoh Lake reared for only one year in freshwater, (ages 1.1, 1.2, and 1.3; Table 8). More males than females spent three in the ocean before returning to spawn; only 27% of the females returned after three years at sea versus 41% of the males. Age composition estimates were based on analysis of scale samples from 544 out of a total sample of 640 fish.

Table 8.–Age composition of adult sockeye salmon sampled in the Sitkoh Lake escapement by sex, 2005.

Brood year	**2002**	**2001**	**2000**	**2000**	**1999**	
Age	1.1	1.2	1.3	2.2	2.3	**All aged**
Male						
Sample size	11	73	222	2	1	309
Percent	2%	13%	41%	0%	0%	57%
Female						
Sample size	-	85	147	2	1	235
Percent	-	16%	27%	0%	0%	43%
All Fish						
Sample size	11	158	369	4	2	544
Percent	2%	29%	68%	1%	0%	100%
Std. error	1%	2%	2%	0%	-	

As observed in past years both male and female sockeye salmon from Sitkoh Lake that spent an additional year in the ocean, e.g. age-1.3 versus age-1.2, were larger in mid-eye to fork length by an average of 53 mm. Sockeye from Sitkoh Lake were longer, across all age classes, than sockeye from Kanalku Lake (Tables 7 and 9).

Table 9.–Mean fork length (mm) of adult sockeye salmon in the Sitkoh Lake escapement by sex and age class, 2005.

Brood year	**2002**	**2001**	**2000**	**2000**	**1999**	
Age	1.1	1.2	1.3	2.2	2.3	**All aged**
Male						
Avg. length (mm)	351	495	551	508	555	530
Std. error	4.7	2.1	1.4	17.5	-	2.6
Sample size	11	73	222	2	1	309
Female						
Avg. length (mm)	-	490	535	485	510	518
Std. error	-	2.5	1.3	5.0	-	1.9
Sample size		85	147	2	1	235
All Fish						
Total avg. length (mm)	351	492	545	496	533	525
Std. error	4.7	1.7	1.0	9.9	22.5	1.7
Sample size	11	158	369	4	2	544

DISCUSSION

The estimated escapement of 1,100 sockeye salmon in Kanalku Lake in 2005 was similar to the escapement of 1,200 observed in 2004. This level of escapement is encouraging given the very low escapements of under 300 fish per year in 2001 and 2003, and marks first time since assessment began in 2001 that escapement was greater than 1,000 fish in two consecutive years. The duration of spawning was approximately four weeks, with sockeye salmon on the spawning grounds from the first to the last visual surveys. Even though escapement was higher in 2004 and 2005, the amount of subsistence harvest was low, so overall returns may still be quite weak, and probably too low to support former harvest levels.

In the absence of scientifically collected subsistence harvest data, we do not have a good estimate of harvest or know what effect the voluntary closure has had on subsistence effort and harvest in Kanalku Bay. Angoon residents reported that some community members harvested sockeye from Kanalku Bay, but those reports were not confirmed, and we do not know how accurate the permit reports are. Considering that 2005 was the last year of the voluntary closure, subsistence harvest should be monitored closely along with escapement levels in an attempt to maintain an acceptable balance between subsistence harvest and escapement levels. An on-site survey of subsistence harvest for Kanalku Bay is warranted given the current stock status, and past uncertainty of subsistence harvest estimates.

Estimated sockeye escapement into Sitkoh Lake in 2005 was the third highest since the project began in 1996 (Appendix C in Conitz and Cartwright 2005; Conitz and Cartwright 2007). Sockeye were present on the spawning beds from 2 September through 2 November. Numbers of spawners were relatively high during the first sampling trip (2 September) indicating that sockeye began entering the spawning grounds around mid to late August. Therefore we may have slightly underestimated the number of sockeye spawners.

For both lakes, we caution that our estimates of the total sockeye spawning population are based on very rough visual survey counts, which were used to expand the study area mark-recapture estimates into a whole lake population estimate. The visual counts are somewhat subjective approximations or guesses, and have no estimate of associated sampling error. Furthermore, we recognize the many possible sources of non-sampling error, including subjective differences between observers in how they count fish, observer inexperience, differences in visibility of fish between counting areas or times, and fish residing below visible depth in the lake. Nevertheless, our visual survey methods have allowed us to roughly quantify our impression of what proportion of the lake's sockeye spawner population has been captured by the mark-recapture estimate, and to roughly account for year-to-year differences in that proportion.

We added another year to our reconstruction of sockeye returns to Sitkoh Lake by brood year. Without data on commercial harvest of Sitkoh lake stocks, the true number of recruits per spawner cannot be estimated. However, we can look at the returns in the escapement per spawner (Table 10). Parents in brood years 1996 and 1998 replaced themselves in the escapement, close to 1:1, and in 1997 there were about 1.4 offspring per parent in the escapement. However, the 1999 brood year had fewer offspring, only about 0.8 per parent. It is interesting to note that age-1.3 sockeye salmon were dominant in returns from the 1996 and 1997 brood years, and then age-1.2 sockeye salmon were dominant in returns from the 1998 and 1999 brood years. The reason for the shift in dominant age classes is unknown, but it could be a result of changing ocean conditions.

Table 10.–Returns from the 1996–1999 brood years estimated from Sitkoh Lake escapements and age compositions, 1999–2005. Numbers do not include fish from any subsistence, sport, or commercial harvest.

Brood Year	Number of parents	Number of offspring returning to spawn, by age class					Number of offspring	Returns per spawner[a]
		0.2	2.3	1.2	1.3	2.2		
1996	16,300	0	83	2,982	13,074	0	16,265	1.0
1997	5,984	68	0	763	7,268	155	8,442	1.4
1998	6,649	0	0	4,277	1,579	17	6,086	0.9
1999	10,500	0	0	6,890	1,480	118	8,619	0.8

[a] Returns per spawner include only fish in the escapement. Sitkoh Lake returns harvested in commercial and subsistence fisheries were not included in this estimate.

Eleven permit holders reported a total subsistence harvest of 275 sockeye in 2005 for Sitkoh Bay. Although this was a drop from the relatively high harvests in 2003 and 2004, the Sitkoh sockeye harvest still remained higher than levels reported in the 1990s. Given relatively high escapement estimates coupled with low recent harvest levels, Sitkoh lake stocks should be able to support current or greater levels of subsistence harvest, assuming escapement levels stay within the range of past estimates.

It is critical that we continue estimating sockeye escapement for Kanalku Lake. Not only has this system experienced alarmingly low spawning populations in 2001 and 2003, but 2005 was the last year of the voluntary subsistence closure. Furthermore, federal fisheries biologists have recently expressed concern about the possible effects of the commercial seine fishery in Chatham Strait on Kanalku sockeye stocks. Given recent advances in genetic determination of salmon stocks it may be feasible to try and estimate the level of commercial harvest on Kanalku stocks. However, this could be difficult or impossible given the extremely small stock size of Kanalku Lake sockeye salmon in relation to the much larger runs that contribute to the overall commercial harvest.

Sitkoh Lake still remains an alternate source for subsistence sockeye salmon for Angoon residents, but access to this system is questionable for some families. Given Sitkoh Lake's history as a popular sport, commercial, and subsistence fishery, future escapement estimates are essential to ensure an acceptable balance between harvest levels and escapement.

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