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Kanalku and Sitkoh Lakes Subsistence Sockeye Salmon Project: 2006 Annual Report

by

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and

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June 2008

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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June 2008

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ABSTRACT

In 2006, we continued series of annual estimates of escapement of sockeye salmon (*Oncorhynchus nerka*) started in 2001 for Kanalku Lake and in 1996 for Sitkoh Lake. In each lake, we used mark-recapture methods and visual surveys to estimate sockeye escapement, and we estimated the age, sex, and length composition of the escapement from samples collected on the spawning grounds. Some very low escapements into Kanalku Lake in recent years, after several years of high subsistence harvests in the 1990s, raised concerns about the future productivity of Kanalku Lake sockeye stocks. Nevertheless, the estimated escapement into Kanalku Lake in 2006 was 1,300 sockeye salmon, making this the third consecutive year with sockeye escapements over 1,000 fish, an encouraging change after the extremely low escapements in 2001 and 2003. Most of the returning sockeye salmon (97%) were age-1.2 from the 2002 brood year. In 2006, the Alaska Department of Fish and Game (ADF&G) and the Angoon community agreed to no longer attempt the voluntary fishing moratorium proposed by some community members in 2002. Instead, subsistence fishing for sockeye salmon in Kanalku Bay continued under a shortened season. In Sitkoh Lake the estimated escapement of 14,800 sockeye salmon was the third largest in that system since 1996. Due to its apparently healthy sockeye runs, Sitkoh Bay continues to be a good alternative for subsistence fishing for residents Angoon who are able to cross Chatham Strait to fish. Because of its close proximity to Angoon, Kanalku Bay is still the preferred subsistence fishing area for most Angoon residents. However, considering the average annual subsistence harvest reported by Kanalku permit-holders in 1994–2001 was over 1,500 sockeye salmon, current sockeye escapement levels are probably not yet high enough to support a subsistence fishery at those former harvest levels.

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

INTRODUCTION

Sitkoh and Kanalku Lakes support populations of sockeye salmon (*Oncorhychus nerka*) with long histories of subsistence harvest by the residents of Angoon. In former years, Angoon people moved among numerous productive fishing areas and summer camps, according to traditional clan affiliation, to obtain their sockeye salmon. The use of both Sitkoh and Kanalku Bays by Angoon clans for harvesting sockeye salmon can be seen in the archaeological and historical record (de Laguna 1960; Moss 1989; Thornton et al. 1990; Goldschmidt et al. 1998).

With the arrival of the commercial fishing industry in Southeast Alaska, Native families were displaced, often forcibly, from their traditional fishing areas, as was the case in Sitkoh Bay (Thornton et al. 1990). Other changes, including compulsory government schools, new federal fishery laws, and Native participation in the commercial fishing industry led to further changes in traditional fishing practices among Natives of Angoon and other Southeast Alaska villages (Thornton et al. 1990; Betts and Wolfe 1992; Turek et al. 2006). After Alaska statehood, a non-commercial, subsistence fishery was defined and put under a permit system (Turkek et al. 2006). Angoon residents can obtain subsistence permits for Kanalku, Sitkoh, and Basket Bays and other areas, but most people prefer to fish in Kanalku Bay because of its proximity to Angoon and accessibility via sheltered waterways. However, some residents began noticing a decline in abundance of Kanalku sockeye salmon in the 1990s and suggested that community members "slow down" in harvesting that stock (A. Zuboff, Angoon Community Association, personal communication 2007).

Our sockeye stock assessment program was implemented in 2001, partly in response to concerns about declining run sizes, and that year and again in 2003, we estimated escapements of less than 275 adult sockeye salmon (Conitz and Cartwright 2005). These low numbers prompted the Alaska Department of Fish and Game (ADF&G) fisheries managers to consider an emergency closure or other conservation measures, but some members of the Angoon community proposed instead that they would voluntarily refrain from fishing in Kanalku Bay to allow sockeye runs to rebuild. The Angoon community and ADF&G fisheries managers agreed by consensus that the community would voluntarily curtail fishing in Kanalku Bay during at least the first half of the run (defined as through 14 July) for the 2002 season (letter from Craig Farrington, ADF&G Division of Commercial Fisheries, to Walter Jack, ACA President, and Floyd Kookesh, Mayor of Angoon, 3 June 2002). In subsequent seasons, support for this agreement began to erode in the Angoon community. After several years of misunderstanding and confusion over the matter, ADF&G managers decided to continue the regular permitted subsistence fishery with a restricted season in 2006 (K. Monagle, ADF&G Division of Commercial Fisheries, personal communication 2006). The fishery opened on 21 July 2006, just after the average peak harvest date, according to returned subsistence permits for Kanalku from 1985 to 2005 (ADF&G Division of Commercial Fisheries database, 2006). In the meantime, sockeye escapements of over 1,000 fish were estimated in Kanalku Lake in 2002 and 2004 (Conitz and Cartwright 2003, 2007).

Reported subsistence sockeye harvests from Sitkoh Bay, which were comparable to reported harvests from Kanalku Bay in the 1980s, dropped to very low levels in the 1990s, but rebounded substantially in the 2000s (Appendix A in Conitz and Cartwright 2005). We don't know if these changes were due to changes in access or sockeye abundance or both. Most commercial fishermen in the Southeast Alaska villages used part of their harvest for household needs and sharing within the community, and also used their fishing boats to travel to more distant subsistence harvesting areas. But, like most other Southeast Alaska communities, Angoon experienced a loss of commercial salmon permit holders through the 1980s and 1990s (Betts and Wolfe 1992; Turek et al. 2006). The effects of clear-cut logging in the Sitkoh Lake watershed from 1969 to 1974, were suggested as contributing to an apparent decline in Sitkoh sockeye runs at the end of the 1980s (Thornton et al. 1990). However, a weir count of over 16,000 sockeye salmon in 1996, followed by eight years of escapement estimates between 6,000 and 17,000 sockeye salmon (Conitz and Cartwright 2005), alleviated most concerns that this stock was in trouble. The lowest escapement estimate in the recent time series was less than 4,000 sockeye salmon in 2004. That low escapement was probably attributable, in part, to a warm, dry summer and very low water in the lake outlet in August (Conitz and Cartwright 2007). The 2005 escapement estimate for Sitkoh Lake was about 13,000 sockeye salmon (Burril and Conitz 2007), indicating that the low escapement in 2004 did not signal a downward trend.

Our primary objective in 2006 was to continue estimating sockeye escapement into Sitkoh and Kanalku Lakes. As in 2001–2005, we used mark-recapture studies and visual surveys on the spawning grounds to estimate the escapement, or spawning population, in each lake. Biological data were also collected from both populations to estimate age, sex, and length compositions. Escapement has previously been estimated using consistent methods in Sitkoh Lake for ten consecutive years (1996 to 2005) and in Kanalku Lake for five consecutive years (2001 to 2005). We lack total sockeye harvest estimates for these stocks and cannot fully quantify or analyze returns from each brood year. Nevertheless, the accumulating years of escapement estimates at least allow us to monitor relative spawner abundance from year to year, in comparison with subsistence needs and reported harvests.

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 spawning population at each lake, based on a sample size of 600 fish.

METHODS

STUDY SITES

Kanalku Lake

Kanalku Lake (ADF&G stream no. 112-67-58/60; lat 57^{o} 29.22'N long 134^{o} 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 (*O. gorbuscha*) spawn in the lower part of the outlet creek and intertidal area. A few coho (*O. kisutch*) and chum salmon (*O. keta*) 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.

Sitkoh Lake

Sitkoh Lake (ADF&G stream no. 113-59-005; lat 57^{o}30.89'N, long 135^{o}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 Straits, 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, 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 1.–Map of Southeast Alaska showing location of Kanalku and Sitkoh Lakes, and the village of Angoon.

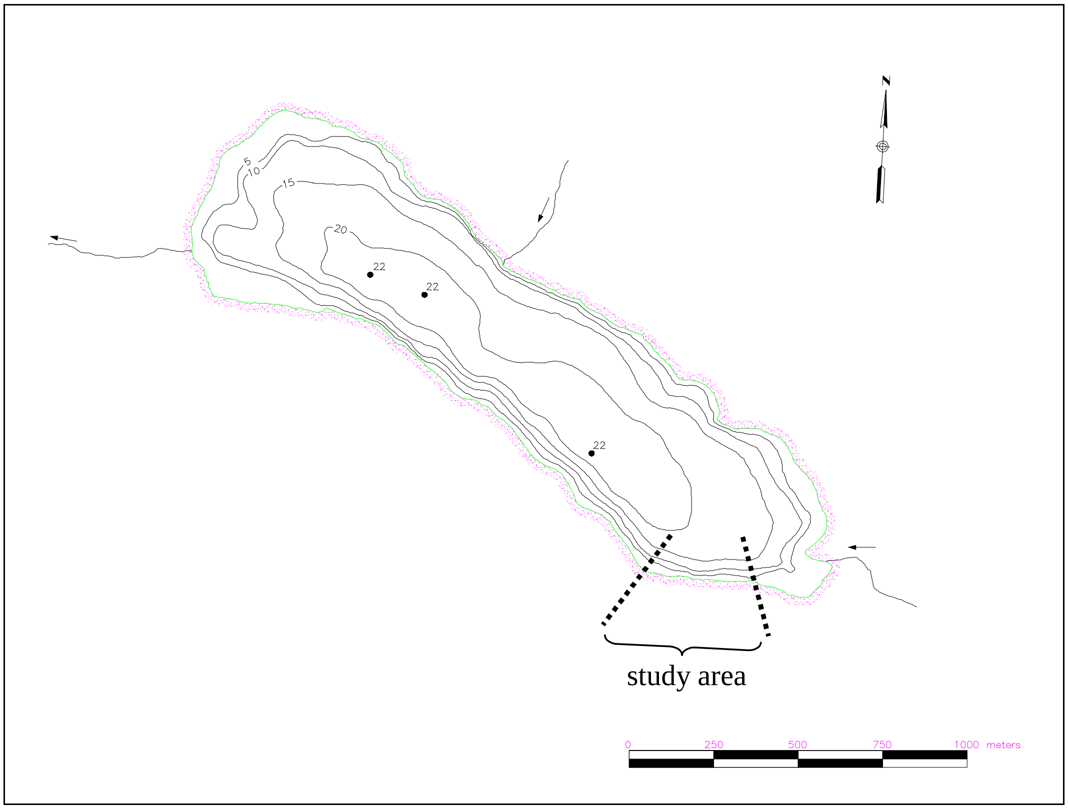

Figure 2.–Bathymetric map of Kanalku Lake, showing 5 m depth contours and the mark-recapture study area. Arrows indicate direction of stream flow.

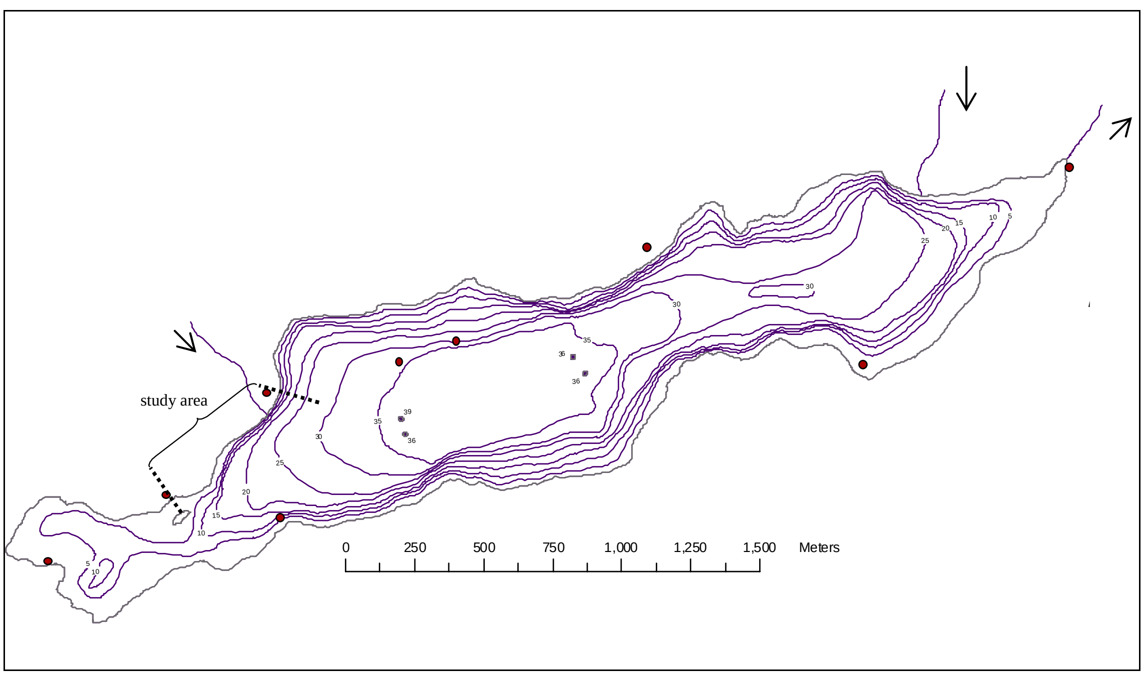

Figure 3.–Bathymetric map of Sitkoh Lake, showing 5 m depth contours and the mark-recapture study area. Arrows indicate direction of stream flow.

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 super population, 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 recorded 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, fifth event—two triangle, sixth event—two square. 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 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 define the parameters relative to the i th sample mark/recapture experiment:

$M^P{}_i$ = number of fish marked in first day of i th sampling event;

$C^P{}_i$ = number of fish caught in second day of i th sampling event;

$R^P{}_i$ = number of fish marked in first day and recovered in second day of i th sampling event.

We also defined the parameters relative to the Jolly-Seber methodology (Schwarz et al. 1993):

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);

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. Note that N_i and M_i were not the usual Jolly-Seber estimates but estimated based on information from the i th sample mark - recapture experiment.

N_i was estimated as $\hat{N}_i = \dfrac{(M_i^P - 1)(C_i^P - 1)}{(R_i^P - 1)}$.

M_i was estimated based on assumption of equivalent proportions of marked and unmarked fish in the i sampling event (i.e, $m_i / M_i = n_i / \hat{N}_i$), so that $\hat{M}_i = m_i \hat{N}_i / n_i$ (M_1=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 ($(s\text{-}1)^{th}$) 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 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. A reasonable estimate of the number of fish that enter the system before the first sampling event and between the first and second sampling events, including those that enter the system and die before and between these sampling events, is,

$$\hat{N}_2 \frac{\log(\hat{\phi}_1)}{\hat{\phi}_1 - 1}$$ (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 estimate for the superpopulation. 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 mideye 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 in each age-sex group was estimated along with its associated standard error, assuming a binominal distribution and using standard statistical techniques as described in common references (e.g. Thompson 1992).

RESULTS

ADULT ESCAPEMENT ESTIMATES

Spawning Grounds Mark-Recapture and Visual Survey

Kanalku Lake

Visual surveys were conducted weekly in Kanalku Lake from 22 August through 6 October 2006. The peak count of sockeye salmon in the study area was on 5 September while the peak count in the whole lake was on 30 August (Table 1).

Table 1.–Visual counts of sockeye spawners in Kanalku Lake, 2006, comparing numbers counted inside designated study area with total counts for the lake.

Date	Average count within study area	Average count for whole lake	Proportion in the study area
22 Aug	133	273	0.49
30 Aug	336	450	0.75
5 Sep	364	366	0.99
11 Sep	212	254	0.83
19 Sep	166	180	0.92
27 Sep	38	38	1.00
6 Oct	2	2	1.00

Mark-recapture sampling was conducted between 22 August and 19 September (Table 2). Sampling was not conducted on 27 September, due to problems with the outboard motor, or on 6 October, because very few live fish remained in the lake. Because so few sockeye salmon were present on the spawning grounds on these final two dates, we felt justified in assuming that immigration had ended. We may have slightly underestimated the total spawning population because a few new spawners may have entered the study area between 19 and 27 September, but the numbers were clearly declining at that point. At the beginning of the season on 22 August, most sockeye salmon had not yet committed to the spawning grounds. Mark-recapture sampling was attempted on that date but no fish were recaptured; therefore, marks from the 22 August and 30 August sampling events were pooled. We assumed mortality was low just prior to and at the beginning of the spawning period, and so pooling two marking events during this period was reasonable. The estimated abundance of sockeye spawners in the study area in 2006 was 1,100 fish (CV=4.4%; 95% CI 1000–1,200). The weighted average proportion of sockeye salmon in the study area compared with the whole lake was 0.86 over the sampling period. Visual survey results from 27 September and 6 October (Table 1) were not used in estimating this proportion since no sampling occurred on these dates. Expanding the mark-recapture estimate for the study area by the estimated proportion of sockeye salmon in the study area, we estimated the total Kanalku Lake spawning population was roughly 1,300 sockeye salmon in 2006.

Table 2.–Sample sizes and numbers of recaptured fish in the Kanalku Lake study area in 2006. For the Petersen (first stage) estimate, we marked and released fish the first day and sampled for marks 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	180	161	50
5 Sep	132	180	65
11 Sep	204	141	57
19 Sep	103	120	37

Second Stage: Jolly-Seber

Trip beginning	Number of marks released	Recaptures from previous marking event		
		5 Sep	11 Sep	19 Sep
30 Aug	291	-	-	-
5 Sep	247	112	-	-
11 Sep	288	44	110	-
19 Sep	186	6	17	26

Sitkoh Lake

In Sitkoh Lake, abundance of sockeye salmon on the spawning grounds was greatest during the latter half of the study period, in early October. Visual surveys were conducted between 25 August and 2 November (Table 3); however, due to crew error, no survey was conducted on 16 October, and on 2 November only the study area was surveyed. To estimate the proportion of sockeye spawners in the study area on 2 November, we used the five-year (2001–2005) average proportion of spawners in the study area for the last sampling trip of the season.

Table 3.–Visual counts of sockeye spawners in Sitkoh Lake, 2006, comparing numbers counted inside designated study areas with total counts for the lake.

Trip beginning	Average count within study area	Average count for whole lake	Proportion in the study area
25 Aug	212	407	0.52
8 Sep	303	886	0.34
20 Sep	452	1,043	0.43
3 Oct	575	1,343	0.43
16 Oct	-	-	-
2 Nov	203	-	0.82[a]

[a] Estimated as the 5-year average of the proportion in the study area for survey dates in November.

Based on mark-recapture sampling between 25 August and 2 November (Table 4), we estimated a total of 6,700 sockeye spawners within the study area (CV= 4.1%; 95% CI 6,400–7,500). The weighted average proportion of sockeye spawners in the study area compared with the whole lake was 0.45 over the sampling period (excluding the missing value for 16 October). Based on this proportion, we expanded the mark-recapture estimate for the study area to a rough estimate of total abundance of 14,800 sockeye spawners in 2006.

Table 4.–Mark and recapture sample sizes and numbers of recaptured fish in the study area of Sitkoh Lake, 2006.

First Stage: Petersen			
Trip beginning	Number marked (1st day)	Number sampled (2nd day)	Number recaptured
25 Aug	108	115	71
8 Sep	329	316	207
20 Sep	467	383	268
3 Oct	442	675	287
16 Oct	376	421	221
2 Nov	206	205	182

Second Stage: Jolly-Seber						
Trip beginning	Number of marks released	Recaptures from previous marking event				
		8 Sep	21 Sep	3 Oct	16 Oct	2 Nov
25 Aug	152	-	-	-	-	-
8 Sep	438	67	-	-	-	-
20 Sep	582	1	164	-	-	-
3 Oct	830	0	1	56	-	-
16 Oct	576	0	0	0	55	-
2 Nov	229	0	0	0	3	2

Adult Sockeye Salmon Population Age and Size Composition

Kanalku Lake

During the 2006 season, 426 sockeye salmon were sampled for scales, sex, and length on the spawning grounds at Kanalku Lake, and of these age was determined for 309 fish. Only two age classes were found. Age-1.2 sockeye salmon, from the 2002 brood year, comprised an estimated 97% (CV=1%) of the spawning population (Table 5). The other 3% of the population was age-1.3 fish, of which all sampled individuals were male.

Table 5.–Age composition of adult sockeye salmon sampled in the Kanalku Lake escapement by sex, 2006.

Brood Year	2002	2001	
Age	**1.2**	**1.3**	**All Aged**
Male			
Sample size	170	10	180
Percent	55%	3%	58%
Female			
Sample size	129	0	129
Percent	42%	0.0%	42%
All Fish			
Sample size	299	10	309
Percent	97%	3%	100%
Std. error (%)	1.0%	5.9%	

The average length of age-1.2 sockeye salmon in the Kanalku Lake spawning population was 492 mm, mideye to fork length. Age-1.3 fish, with an additional year in saltwater, were larger at 559 mm, but this average length was based on a very small sample, comprising only males (Table 6).

Table 6.–Mean fork length (mm) of adult sockeye salmon in the Kanalku Lake escapement by sex and age class, 2006.

Brood Year	2002	2001	
Age	**1.2**	**1.3**	**All Aged**
Male			
Sample size	170	10	180
Avg. length (mm)	498	559	497
Std. error	1.7	2.5	1.6
Female			
Sample size	129	0	129
Avg. length (mm)	485	-	495
Std. error	1.9		1.9
All Fish			
Sample size	299	10	309
Avg. length (mm)	492	559	497
Std. error	1.3	2.5	1.2

Sitkoh Lake

From Sitkoh Lake, 595 sockeye spawners were sampled for scales, sex, and length, and age was determined in 508 scale samples (Table 7). Most of this population were age-1.2 sockeye salmon, comprising an estimated 67% (CV=3%), and age-1.3 sockeye salmon, comprising an estimated 32% (CV=6%) of the total. Thus, about 99% of the population was made up of sockeye salmon with one freshwater year. The average length of the age-1.2 spawners was 497 mm and the average length of the age-1.3 spawners was 544 mm (Table 8).

Table 7.–Age composition of adult sockeye salmon sampled in the Sitkoh Lake escapement by sex, 2006.

Brood year	**2002**	**2001**	**2001**	**2000**	
Age	1.2	1.3	2.2	2.3	**All aged**
Male					
Sample size	163	99	1	0	263
Percent	32%	20%	0.2%	0%	52%
Female					
Sample size	177	62	5	1	245
Percent	35%	12%	1%	0.2%	48%
All fish					
Sample size	341	161	6	1	508
Percent	67%	32%	1%	0.2%	100%
Std. error	2.1%	2.1%	0.5%	0.2%	

Table 8.–Mean fork length (mm) of adult sockeye salmon in the Sitkoh Lake escapement by sex and age class, 2006.

Brood year	**2002**	**2001**	**2001**	**2000**	
Age	1.2	1.3	2.2	2.3	**All aged**
Male					
Sample size	163	99	1	0	263
Avg. length (mm)	501	550	500	-	519
Std. error	1.6	1.7	-	-	1.2
Female					
Sample size	177	61	5	1	243
Avg. length (mm)	493	534	509	550	504
Std. error	1.7	2.2	11.9	-	1.3
All fish					
Sample size	340	160	6	1	506
Avg. length (mm)	497	544	508	550	512
Std. error	1.2	1.3	9.7	-	0.9

DISCUSSION

The estimated escapement of 1,300 sockeye salmon in Kanalku Lake in 2006 was similar in size to the escapements of 1,200 and 1,100 estimated in 2004 and 2005. Thus, for the third consecutive year since assessment began in 2001, the estimated escapement was greater than 1,000 fish, a marked improvement from the estimated escapements of less than 300 sockeye salmon in 2001 and 2003. As observed in previous years, the spawning period was very short, only about four weeks starting at the end of August. The spawning area was limited to a very small section of the lake along the shoreline near the mouth of the main inlet stream, an area which appears to be associated with a steep drainage and perhaps some upwelling. However, sockeye salmon have reduced even further the size of their spawning area; in the most recent two or three years they were absent in the easternmost portion, which was covered with a milfoil-like aquatic plant. As in previous years, no sockeye spawners were found in the main inlet stream. This is very puzzling since the stream appears to provide suitable depth, substrate, and flow levels for sockeye spawning and egg incubation, and is similar to other sockeye spawning streams in the region, such as the inlets of Kook and Hoktaheen Lakes (Conitz and Cartwright 2002, 2003).

In 2006, we observed a further reduction in an already limited age class diversity: only two age classes (1.2 and 1.3) were found in a sample of just over 300 fish, with age-1.2 fish comprising an estimated 97% of the escapement. In comparison, escapements in 2001–2005 had a third class (age 2.2) with an estimated 1–3% of escapement, and in 2005, three additional age classes were observed (1.1, 2.1, and 2.3). Furthermore, in 2001–2005 the age-1.3 class made up a substantially larger proportion (11–44%) of the escapement than in 2006. The near absence of age-1.3 fish and the apparent total absence of age-2.2 fish in the 2006 is alarming, and may be a consequence of the extremely small parental population of just 240 spawners in 2001. However, the return of age-1.2 fish in 2005 from the same small parent population showed a substantial rebound in the first generation (Burril and Conitz 2007). In all, estimated returns from the 2001 brood year included about 930 age-1.2 fish (returned in 2005), 40 age-1.3 fish (returned in 2006), and 10 age-2.1 fish (returned in 2005). Thus an estimated 980 sockeye salmon from the 2001 brood year returned to spawn in Kanalku Lake, about four returning spawners for every parent in the 2001 spawning population. These returns do not include any age-2.3 fish which might return in 2007, but age 2.3 appears to be a very small category in Kanalku spawning populations. These estimates do not include fish harvested in the subsistence or commercial fisheries. The apparent rebound in total numbers of sockeye salmon returning to Kanalku Lake, after reduced harvest during a single generation, is encouraging. Nevertheless, the absence or extremely small numbers in some age classes in returns from the 2001 brood year could indicate a loss of genetic diversity in this heritable trait (Burgner 1991).

The 2006 season was the first since 2002 that ADF&G fisheries managers did not rely on voluntary measures within the Angoon community to reduce sockeye harvest in Kanalku Bay. Instead, the opening date was set late in the season, just past the date of peak reported harvests for 1985–2001. ADF&G managers conducted a few aerial surveys over Kanalku Bay during the 2006 season and observed very minimal fishing effort, and they received no complaints from community members about the season or the fishing in Kanalku Bay. One enforcement action was reported due to an alleged harvest over the limit (K. Monagle, ADF&G Division of Commercial Fisheries, personal communication 2007). Four permit holders reported a total harvest of 78 sockeye salmon in 2006, compared to reports of 50 fish harvested on three permits the previous year (ADF&G Division of Commercial Fisheries database, 2008).

The estimated escapement of nearly 15,000 sockeye salmon into Sitkoh Lake in 2006 was exceeded in only two other years during eleven years of escapement monitoring (1996–2006; Appendix C in Conitz and Cartwright 2005). The relatively high escapement in 2006 followed a slightly smaller escapement, about 13,000 sockeye salmon, the previous year (Burril and Conitz 2007). We feel reasonably confident in assuming that our escapement estimates express a normal range of sockeye spawning population sizes for Sitkoh Lake, of a few thousand to about twenty thousand fish. The sockeye spawning period in Sitkoh Lake, as we have observed in previous years, was prolonged compared to Kanalku Lake and other sockeye lakes in the area. Sockeye salmon occupied the spawning ground from the first sampling event in late August until the last event at the beginning of November, when some fish were still actively spawning. In 2006, returns from the 2000 brood year were complete with the return of six-year-old (age-2.3) fish (Table 9). The number of offspring from the 2000 brood year returning to the spawning grounds appeared to be smaller, in relation to the number of parents, than from the four previous brood years for which we have information. However, the 1996–2000 escapements were point estimates only, and therefore we don't know the extent to which differences between them are meaningful. Furthermore, without estimates of the number and age of Sitkoh Lake sockeye salmon harvested in commercial fisheries, we cannot estimate the true number of recruits per spawner for this stock. We would expect unpredictable variation in the timing and location of incidental sockeye catches in the commercial fishery, and some further variation in the size of the annual subsistence sockeye harvest in Sitkoh Bay. Therefore, we cannot assume the fish escaping to spawn, from each brood year, to be a consistent proportion of the total return.

Table 9.–Returns from the 1996–2000 brood years estimated from Sitkoh Lake escapements and age compositions, 1999–2006. Numbers do not include fish from any subsistence, sport, or commercial harvest.

Brood Year	Number of parents	Number in escapement, by age class							Total offspring[a]	Offspring per parent[a]
		0.2	1.1	1.2	1.3	2.1	2.2	2.3		
1996	16,300	0	126	2,975	13,043	0	0	83	16,227	1.00
1997	6,000	68	187	761	7,259	0	155	0	8,430	1.41
1998	6,600	0	212	4,272	1,583	0	17	0	6,084	0.92
1999	10,500	0	131	6,890	1,480	0	118	54	8,673	0.83
2000	17,000	0	209	2,031	9,085	7	94	30	11,456	0.67

[a] Total number of offspring (i.e. recruitment) and number of offspring per parent, from each brood year, include only fish in the Sitkoh Lake spawning escapement.

Estimating annual sockeye escapement into Kanalku Lake continues to be a priority for the management of Angoon area subsistence sockeye fisheries. With the end of voluntary restrictions on harvest in Kanalku Bay, we expect effort to gradually increase, and therefore, monitoring is essential to ensure adequate spawning escapement past the fishery. As has been noted previously, average annual subsistence harvest reported by permit-holders from 1994 through 2001 was at least 1,500 sockeye salmon (Appendix A in Conitz and Cartwright 2005). With apparently fewer than this number of sockeye salmon returning to spawn in Kanalku Lake in recent years, annual harvests this large would leave few fish in the escapement. The relationship between the number of sockeye salmon returning to Kanalku Bay and the ultimate size of the spawning population in the lake, however, could also be restricted by natural mortality due to the impediment at the falls. We expect that the use a weir and additional tagging studies over the next few seasons will give interested parties more confidence in the escapement estimates and possibly help us answer questions such as that of natural mortality at the falls. Sitkoh Lake appears to be producing adequate sockeye returns to support subsistence, sport, and commercial harvest, and these sockeye runs provide an alternate source of subsistence fish for Angoon residents who are able to travel across Chatham Strait. We recommend continuing at least a minimal level of harvest and escapement monitoring on the Sitkoh Lake sockeye run, so that any changes to the apparently stable pattern might be detected early.

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