Fishery Data Series No. 05-57

Kanalku, Sitkoh, and Kook Lakes Subsistence Sockeye Salmon Project: 2003 Annual Report and 2001–2003 Final Report

by

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and

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November 2005

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

FISHERY DATA SERIES NO. 05-57

KANALKU, SITKOH, AND KOOK LAKES SUBSISTENCE SOCKEYE SALMON PROJECT: 2003 ANNUAL REPORT AND 2001–2003 FINAL REPORT

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The Kanalku, Kook, and Sitkoh Subsistence Sockeye Salmon Project (Study Number FIS01-126-1) was approved by the Federal Subsistence Board, managed by US Fish and Wildlife Service — Office of Subsistence Management, funded by the U.S. Forest Service, and is a cooperative project between the U.S. Forest Service (USFS), the Alaska Department of Fish and Game (ADF&G), and the Angoon Community Association (ACA). This annual and final report completes contract obligations for Sikes Act Contract (43-0109-1-0154 for ACA and 53-0109-2-61100 for ADF&G).

The Division of Sport Fish Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Since 2004, the Division of Commercial Fisheries has also used the Fishery Data Series. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

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ABSTRACT

Residents of Angoon expressed concerns about apparent declines in sockeye salmon subsistence harvest and escapement to Kanalku, Sitkoh and Kook lakes in recent years. We used mark-recapture methods in designated "study areas" and visual surveys on the spawning grounds to estimate sockeye escapement into each lake. We also estimated the sockeye fry population, zooplankton abundance and biomass standing crop and other limnological characteristics of these lakes. In Kanalku, we observed a very low escapement of about 250 sockeye salmon in 2001. A voluntary agreement with the Angoon subsistence fishers to not harvest sockeye salmon from this system allowed an estimated 1,600 fish to escape into the lake in 2002. Several parties harvested sockeye salmon in Kanalku Bay in 2003 and less than 300 sockeye salmon spawned in Kanalku Lake. These low escapements appear to be linked to high subsistence harvest rates in this easily accessible system near Angoon. In Sitkoh Lake, current escapement levels appear to be supporting stable returns to this system and escapement estimates from our "study area" in this lake were similar in 1997 and 1998. For Kook Lake, we obtained only an early-season survey count and partial mark-recapture estimate for the inlet stream, due to a shift in project priorities in 2003. Due to technical difficulties in sampling, and changing priorities in the contracting agency, study of the Kook Lake system was minimal in 2003; therefore the authors present the information collected in 2003 the third year of this study in Chapter 1 and synthesize three years of information in Chapter 2. Escapement levels, as far as we have been able to estimate them, have been very low in recent years in Kook Lake. This may be a result of debris jams that formed a partial barrier to migration before they were removed in 2001. Overall, zooplankton abundance and biomass estimates indicate that all three lakes are capable of supporting higher numbers of sockeye fry than the numbers we estimated in 2001 and 2002. We concluded that the production of sockeye salmon in these three lakes is currently limited by escapement.

Key words: sockeye salmon, *Oncorhynchus nerka*, subsistence, Kanalku Lake, Sitkoh Lake, Kook Lake, Basket Bay, escapement, fry, smolt, mark-recapture, zooplankton.

CHAPTER 1—2003 ANNUAL REPORT

INTRODUCTION

Kanalku Lake (ADF&G stream no.112-67-58/60), Sitkoh Lake (ADF&G stream no. 113-59-005), and Kook Lake (ADF&G stream no. 112-12-026), have supplied salmon to the people of Angoon and nearby villages as far back as the oldest traditions recount, and continue to be important subsistence systems for Angoon residents (George and Bosworth 1988; Goldschmidt et al. 1998; Conitz and Cartwright 2002a, 2002b; Figure 1). In the Kanalku, Sitkoh, and Kook Lakes Subsistence Sockeye Salmon Project (which we will subsequently refer to as the “Angoon Sockeye Project” or simply “the project”) we studied the demographics of sockeye salmon (*Oncorhynchus nerka*) that return to these three systems; our purpose is to sustain escapements and provide subsistence harvest opportunities in these systems. The project was initiated in 2001 and is a cooperative project between Alaska Department of Fish and Game (ADF&G), the Angoon Community Association (ACA), and the U.S. Forest Service. Data collection began in the 2001 field season.

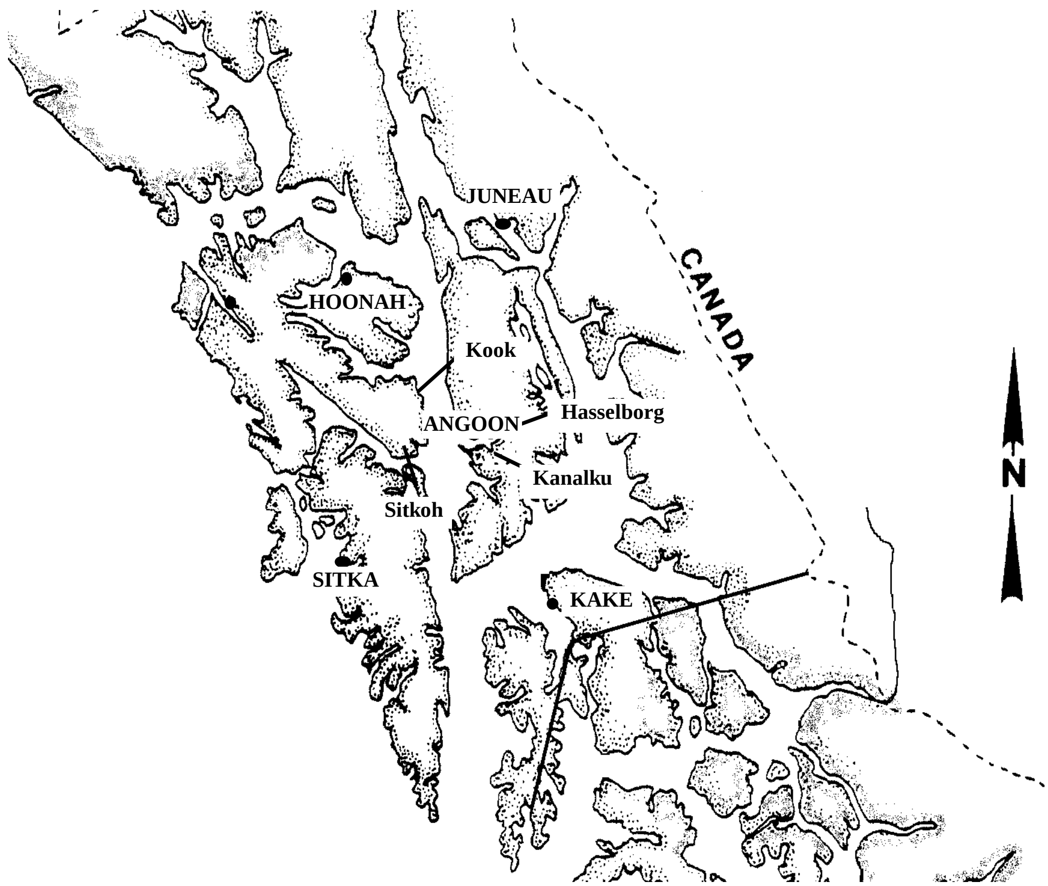

Figure 1.–Map of Southeast Alaska showing location of Kanalku, Kook, and Sitkoh Lakes, and the village of Angoon.

Kanalku Bay and Lake, Basket Bay and Kook Lake, and Sitkoh Bay and Lake each have a well-documented history of traditional clan ownership and fishing rights according to the rules of Tlingit society (de Laguna 1960; George and Bosworth 1988; Moss 1989; Thornton et al. 1990; Goldschmidt et al. 1998). Angoon residents still refer to these ownership rights and rules today.

Sockeye salmon from these systems continue to be an important subsistence resource for most Angoon residents (Conitz and Cartwright 2003a). Community members share salmon widely within the community; fishing households give salmon to households that are unable to harvest their own salmon. Household survey interviews were conducted by ADF&G Division of Subsistence in Angoon in the winter of 2002 and will provide updated information on subsistence harvest and use patterns in the community when published in the Subsistence Division database (A. Paige ADF&G, personal communication 2004).

The ADF&G Division of Commercial Fisheries compiles effort and harvest data reported by permit-holders in its regional database. In the past decade, reported sockeye harvests from Kanalku increased rapidly to a peak of nearly 3,000 fish in 1998, but have fallen off dramatically since the voluntary moratorium began in 2002 (Appendix A). Harvests from Basket Bay (Kook Lake) decreased through the 1990s but have been higher in 2002–2003, possibly as Angoon fishers have shifted their effort away from Kanalku. Likewise, reported sockeye harvests were very low (zero to less than 100) in Sitkoh throughout the 1990s but were substantially higher in 2001–2003. Angoon residents have provided anecdotal information and fishery managers and the field crew have made observations that confirm these recent trends in subsistence harvests (M. Kookesh ADF&G, personal communication 2003; K. Monagle ADF&G, personal communication, 2004).

Sport and subsistence fishers compete directly for salmon in the terminal areas, so high sport catches or the perception thereof is of concern to Angoon subsistence fishers. Some records of sport catches of sockeye salmon in the freshwater and terminal areas of Kanalku, Sitkoh, and Kook Lakes are available (ADF&G Division of Sport Fish Database). These have ranged from zero in most years to several hundred in a few years, between the early 1980s and 2001 (Conitz and Cartwright 2003a; Table 4). Sockeye salmon are generally not targeted in the sport fisheries, but are instead caught incidentally and released.

Little or no commercial salmon fishing has occurred in the terminal areas of the sockeye-producing systems in Chatham Strait since conservation closures were first initiated in 1925 (Conitz and Cartwright 2003a; Rich and Ball 1933). No commercial salmon harvest has occurred inside of Mitchell Bay since before 1960, and very little commercial salmon harvest takes place inside of Sitkoh Bay or the other bays along the west shore of Admiralty Island. Outside of the terminal areas, however, the commercial purse seine fleet has been harvesting increasing numbers of sockeye salmon incidentally. The overall average annual sockeye harvest in northern Chatham Strait, Peril Strait, and Tenakee Inlet (Figure 2) has nearly doubled since the 1970s (Appendix B). It is likely that high hatchery chum production has led to an overall increase in commercial fishing effort and harvest (Larson 2001). These fisheries undoubtedly harvest some of sockeye salmon returning to the Kanalku, Sitkoh, and Kook systems, but it is impossible to distinguish specific runs in these mixed-stock fisheries.

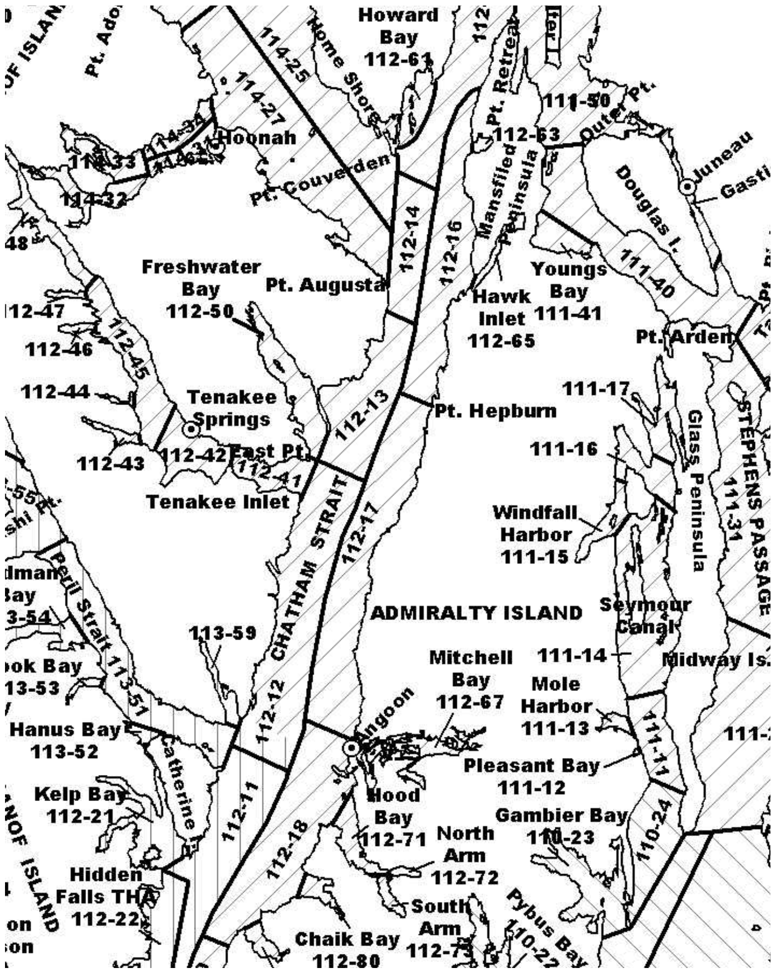

Figure 2.–Commercial fishing districts in northern Chatham Strait; including areas inside and adjacent to Kootznahoo Inlet/Mitchell Bay (112-67 inside, 112-17 and–18 adjacent), Sitkoh Bay (113-59 inside, 113-51, 112-11 and–12 adjacent), and Basket Bay (112-12 adjacent).

We had no estimates of sockeye escapement into Kanalku Lake prior to 2001. The limnology section of ADF&G Division of Commercial Fisheries produced estimates of the sockeye fry and zooplankton populations in Kanalku Lake in 1995 (Barto and Cook 1996). ADF&G operated a sockeye weir on the outlet of Sitkoh Lake in 1996 and estimated the escapement to be about 16,000 (Cook 1998). In subsequent years, and ADF&G crew conducted mark-recapture studies in Sitkoh Lake; resulting sockeye escapement estimates ranged from about 6,000 in 1997 to about 17,000 in 2000 (Cook 1998; Crabtree 2000, 2001). ADF&G also has estimates of age, sex, and length distributions for those and some prior years, and a zooplankton population estimate for 1982 (compiled in Conitz and Cartwright 2002a; Appendix B). ADF&G Division of Sport Fish has conducted studies of the steelhead, cutthroat, and Dolly Varden runs in the outlet of Sitkoh Lake (Brookover et al. 1999; Yanusz 1997). ADF&G and the U.S. Forest Service operated an adult and a smolt weir at the outlet of Kook Lake in 1994 and 1995, and also estimated sockeye fry using hydroacoustic surveys. In 1994, the researchers counted about 12,000 smolt and about 1,800 adults through the respective weirs and estimated a population of 86,000 fry in the lake in fall. In 1995, they counted about 8,000 smolt and 5,800 adults and estimated 50,000 fry (ADF&G Division of Commercial Fisheries database and unpublished data; summarized in Conitz and Cartwright 2002b). Additionally, ADF&G has some estimates of limnological parameters in Kook Lake from 1992, 1994, and 1995, and estimates of adult sockeye age, sex, and length compositions from some years between 1983 and 1995 (Conitz and Cartwright 2002b).

We collected data on sockeye escapements, age and size structure, fry populations, zooplankton prey populations, and light and temperature profiles from 2001 to 2003 in the Kanalku, Sitkoh, and Kook Lake systems. Angoon residents have by far the greatest interest in and concern for the Kanalku system, because of its proximity to the village and the recent declines in escapement and harvest opportunity. The Angoon Sockeye Project crew conducted boat and foot surveys of Kanalku Bay and the lake outlet creek when sockeye salmon began to appear and move into this system in July, continuing until mid-August, in 2003, to keep ADF&G biologists informed about the progress of the run and see if any bottlenecks to escapement were apparent. For the third year since 2001, a crew of U.S. Forest Service and Angoon Community Association employees cleared deadfall and other woody debris from the outlet stream of Kook Lake in June 2003. A large amount of woody debris was blocking cave entrances through which the stream passes prior to the first effort in 2001, but there was very little debris in 2003. A debris barrier may have impeded sockeye salmon migration into Kook Lake for some time, but it appears this is no longer a problem. Due to technical difficulties in sampling, and changing priorities in the contracting agency, study of the Kook Lake system was minimal in 2003. The authors present the information collected in 2003 the third year of this study in Chapter 1 and synthesize three years of information in Chapter 2.

OBJECTIVES

1. Estimate the annual sockeye escapement into Kanalku, Kook, and Sitkoh Lakes, using mark-recapture methods and observer counts on the spawning grounds, so that the estimated coefficient of variation is less than 15%.
2. Describe the age, length, and sex composition of the sockeye salmon in the escapement at each lake.
3. Estimate the productivity of each lake using established ADF&G limnological sampling procedures.

METHODS

STUDY SITES

Kanalku Lake

Kanalku Lake (N 57^o 29.22' W 134^o 21.02') is about 20 km southeast of Angoon and lies in a steep mountainous valley within the Hood-Gambier Bay carbonates ecological subsection (Nowacki et al. 2001). Carbonate bedrock and soils built up on rounded mountainsides and in U-shaped valleys support a highly productive spruce forest in the watershed, especially where there are 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, and has a 1.7 km outlet stream that drains into the east end of Kanalku Bay. The lake surface area is about 113 hectares, the mean depth is 15 m and the maximum depth is 22 m (Figure 3). In addition to the sockeye salmon run (*Oncorhynhcus nerka*), 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. clarki* spp.), 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. The U.S. Forest Service considered constructing a fishpass over the falls in the 1960s but finally recommended against it due to cost. 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.

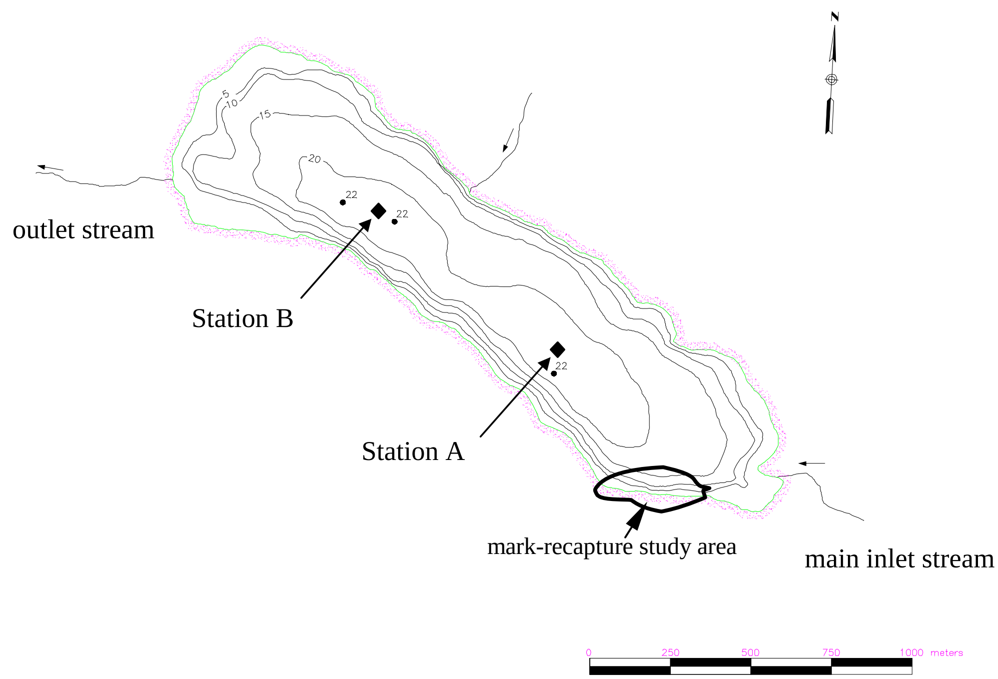

Figure 3.–Bathymetric map of Kanalku Lake, showing 5 m depth contours, mark-recapture study area, and two permanent limnology sampling stations (A and B).

Kook Lake

Kook Lake (N 57° 39.86', W 134° 57.25') is across Chatham Strait from Angoon, about 26 km to the northeast, and on the east side of Chichagof Island. Its watershed lies within the Kook Lake carbonates ecological subsection (Nowacki et al. 2001). Past glaciations over the entire area has rounded the mountains and created cirque basins such as the one containing Kook Lake. The total drainage area is about 54 km^2 and there are two main inlet streams entering the southwest end of the lake. Kook Lake has a surface area of about 240 ha, a mean depth of 30 m, and a maximum depth of 44 m (Figure 4). The lake lies at an elevation of about 123 m, and has a 2 km outlet stream, Kook Creek, that flows into Basket Bay on Chatham Strait. Three natural caves, each about 150–300 m long, have formed in the carbonate bedrock along the Kook Creek channel, and salmon swim through these on their way up to the lake to spawn. In addition to sockeye salmon, the lake supports runs of coho, chum, and pink salmon; resident fish include Dolly Varden char, cutthroat trout, threespine stickleback (*Gasterosteus aculeatus*), and sculpin. The Kook Lake watershed is extensively clear-cut and crossed by a logging road system, which connects with the Corner Bay logging camp in Tenakee Inlet.

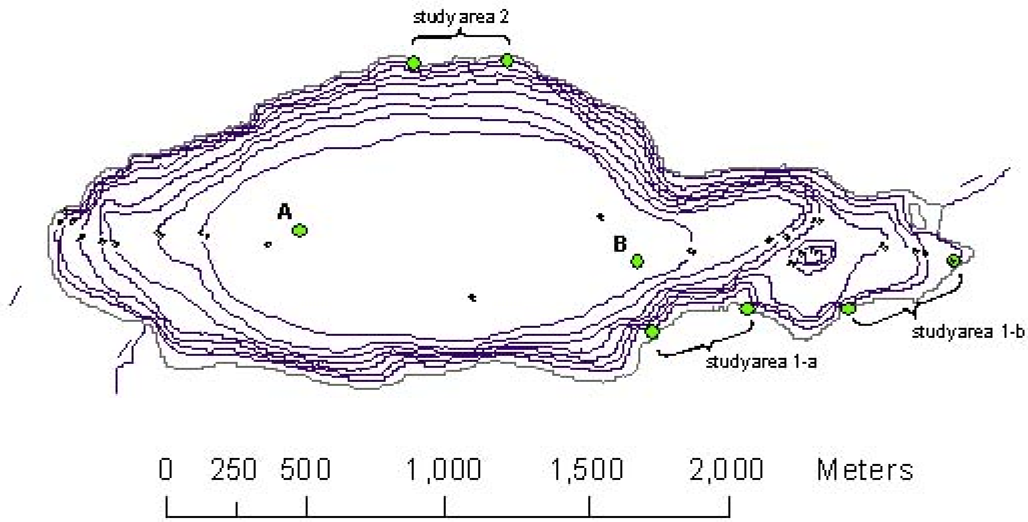

Figure 4.–Bathymetric map of Kook Lake, showing 5 m depth contours, two permanent limnology sampling stations (A, B), and three mark-recapture study areas (1a, 1b, 2).

Sitkoh Lake

Sitkoh Lake (N 57^{o} 30.89', W 135^{o} 2.52') is located on the southeastern tip of Chichagof Island, about 30 km from Angoon, and drains east into Sitkoh Bay. 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 5). 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 at around 500–1100 fish, (Yanusz 1997; Jones and Yanusz 1998; Cook 1998; Brookover et al. 1999). The Sitkoh drainage was extensively clear-cut between 1969 and 1974.

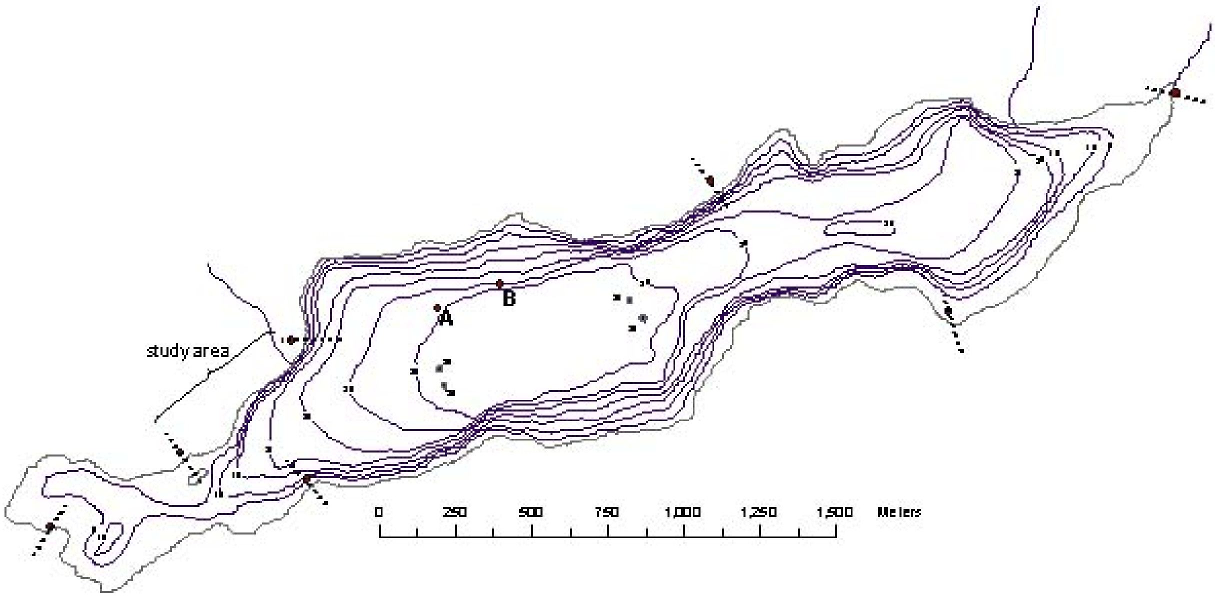

Figure 5.–Bathymetric map of Sitkoh Lake, showing two permanent limnology sampling stations (A, B), mark-recapture study area, and boundaries of lake survey areas.

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, Kook, and Sitkoh Lakes. We designated study areas in the beach spawning areas of Kanalku and Sitkoh Lakes in 2001, and conducted all mark-recapture sampling strictly within these study areas. The crew counted sockeye salmon in visual surveys around the shoreline of each lake. They recorded separate counts within the study area, to provide a rough estimate of the proportion of escapement included within the mark-recapture study areas. In the Kanalku and Sitkoh systems, escapement estimates include only those sockeye salmon spawning along beach or shoreline areas of the lake, and exclude any sockeye salmon spawning in inlet or outlet streams. Observations in this and previous seasons indicate that there are few, if any, stream spawners in any of these systems. In Kanalku Lake, most of the sockeye salmon spawn along a section of the shoreline near the inlet stream, but we have observed no sockeye salmon in the inlet stream itself. In Sitkoh Lake, biologists have observed only beach-spawning sockeye salmon. In Kook Lake, the crew conducted surveys and mark-recapture sampling only in the main inlet stream during August. Kook Lake is known to have both an inlet stream-spawning population and a beach-spawning population (A. McGregor ADF&G, personal communication 2002). In 2003, only the inlet-stream population, which arrives on the spawning grounds earlier and was missed in 2001 and 2002, was estimated.

ADF&G biologists have modified the methods described in Schwarz et al. (1993) for estimating salmon escapements in beach spawning systems (Cook 1998). Specifically, we used a two-sample Petersen estimate for each trip and a multiple-trip estimate using a modified Jolly-Seber method to estimate the number of spawners returning across all trips (Seber 1982; Schwarz et al. 1993; Cook 1998; J. Blick former ADF&G, personal communication 1998). We give details in the Data Analysis section below.

Visual Survey Counts of Sockeye Spawners

Prior to each mark-recapture event, crew members recorded visual counts of sockeye spawners in defined areas around the entire lakeshore and in any inlet stream where spawners were present. A separate count was made within the "study area" or areas designated for the mark-recapture study. Any inlet stream with sockeye spawners present was defined as a separate area for counting, and it was designated as a "study area" if mark-recapture sampling was conducted in the stream. We attempted to have at least three observers for each survey. Each crew member recorded his or her own counts separately. The counts gave a rough indication of the proportion of sockeye spawners within the defined study area at each sampling event.

Mark-Recapture Methods for Beach Spawning Populations

The study design consisted of two stages: 1) a two-sample Petersen estimate for each trip (Seber 1982) and 2) a multiple-trip estimate using a modified form of the Jolly-Seber method for multiple mark-recaptures in an open population (Seber 1982; Schwarz et al. 1993; Cook 1998). In the first stage, fish were marked on one day and examined for marks the next day. In the second stage, fish caught on both days of a given trip were given a unique mark for that trip. Then on subsequent trips, recaptures of these marks were recorded. In the second stage we used the number of recaptures from each previous trip, together with the first-stage Petersen estimates of abundance from each trip, to generate an estimate of fish that spawned within the study area over the entire season.

The crew used a 20 m long x 4 m deep beach seine, pulled by hand with the aid of a small skiff with outboard motor, to capture sockeye salmon on the spawning grounds. They first inspected all sockeye salmon for previous marks, then marked each fish with an opercular punch or pattern of punches indicating the trip and day number 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. Right opercular punches were the primary mark for each trip as follows: trip 1– round, trip 2– triangle, trip 3– square, trip 4– two round. A left opercular punch (any shape) was given each fish caught on the second day of each trip to indicate the fish had already been caught and should not be recounted on that trip.

Data Analysis

Chapman's form of the Petersen mark-recapture estimate was used for the first-stage, "instantaneous" population estimates within the study area (Seber 1982, p. 60). 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 at a later time, and let R denote the number of fish in the second sample with a mark. Then the estimated number of fish in the entire population, $\hat{N}$, is given by $\hat{N} = \dfrac{(K+1)(C+1)}{(R+1)} - 1$.

In this equation, R is a random variable, and it can be assumed to follow a Poisson, binomial, hypergeometric, or normal distribution, depending on the circumstances of the sampling. When R is large compared with the size of the second sample, C, its distribution can be assumed to be approximately normal (a practical check is to ensure R is at least 30 before using the normal approximation). Let $\hat{p}$ be an estimate of the proportion of marked fish in the population such that: $\hat{p} = \frac{R}{C}$. We used approximate confidence interval bounds for $\hat{p}$ based on the assumption that R follows some sampling distribution. We defined the confidence bounds for $\hat{p}$ as ($a_{0.025}$, $a_{0.975}$). Then the 95% confidence interval bounds for the Petersen population estimate, N^*, were found by taking reciprocals of the confidence interval bounds for $\hat{p}$, and multiplying by K. That is, the confidence bounds for the Petersen estimate are given by:

$$\left(K \cdot 1/a_{0.975},\ K \cdot 1/a_{0.025}\right).$$

If $\hat{p} \geq 0.1$, and the size of the second sample C is at least the minimum given in Table 1, a 95% confidence interval for $\hat{p}$ is given by:

$$\hat{p} \pm \left[1.96\sqrt{\left(1-\frac{C}{\hat{N}}\right)\cdot \hat{p}(1-\hat{p})/(C-1)} + \frac{1}{2C}\right] \text{; (Seber 1982, eq. 3.4).}$$

Table 1.–Sample size criteria for using Seber's (1982) eq. 3.4 to find 95% confidence interval for $\hat{p}$. For given $\hat{p}$, minimum sizes for the second sample C are indicated.

$\hat{p}$ (or 1- $\hat{p}$)	0.5	0.4	0.3	0.2	0.1
minimum C	30	50	80	200	600

Seber's (1982) eq. 3.4 was also used when $\hat{p} < 0.1$ if $R > 50$. If these criteria were not met, the confidence interval bounds for $\hat{p}$ were found from Table 41 in Pearson and Hartley (1966).

In the second-stage estimation process, the first-stage Petersen estimates were used to estimate the total spawning population within the study area, N^*. Given s sampling occasions, we let $\hat{N}_i$ denote the first-stage Petersen population estimate from each sampling occasion i. The $\hat{N}_i$ values were used in place of the Jolly-Seber-derived parameter estimates of the number of animals alive in the system at each sampling occasion (J. Blick ADF&G, personal communication 1998; Cook 1998). We let n_i represent the number of unmarked fish and fish marked on previous trips, caught at sampling occasion i, and we let m_i represent the number of fish marked on previous trips, caught at sampling occasion i.

We also defined the following parameters (Schwarz et al. 1993; J. Blick ADF&G, personal communication, 1998; Cook 1998):

M_i = number of marked fish alive at time i,

ϕ_i = probability that a fish alive at time i is also alive at time i+1 (*i.e.* the survival rate)

B_i = number of fish that enter the system after occasion i and are still alive at time i+1 (*i.e.* immigration).

B_i^* = number of fish that enter the system after occasion i, but before occasion i+1,

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

M_i was estimated as $\hat{M}_i = m_i \hat{N}_i / n_i$, for $i = 1,\ldots,s$;

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

B_i was estimated as $\hat{B}_i = \hat{N}_{i+1} - \hat{\phi}_i \hat{N}_i$, for $i = 1,\ldots,s$-1;

B_i^* was estimated as $\hat{B}_i^* = \hat{B}_i \log(\hat{\phi}) / (\hat{\phi} - 1)$, for $i = 2,\ldots..,s$-1, and

N^* was estimated as $\hat{N}^* = \sum_{i=0}^{s-1} \hat{B}_i^*$.

Recruitment and mortality were assumed to be uniform between times i and i+1. Because B_0^* and B_1^* are not uniquely estimable, $\hat{B}_0^* + \hat{B}_1^*$ was estimated by $\hat{N}_2 \log(\hat{\phi}) / (\hat{\phi} - 1)$.

A parametric bootstrap method (Buckland 1985 and 1984) was used to construct confidence intervals for the parameter estimates in both stages. 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 C_i, K_i, and $\hat{N}_i$ at each sampling event i. At each step $\hat{N}_i(j)$ is developed as previously described. Denote each bootstrap observation in the first estimation stage as the pair of $r_i(j)$ and $\hat{N}_i(j)$, for j = 1...G. Before proceeding on to the simulation of the second stage (the Jolly-Seber portion), the variance of the number of recaptures across all bootstrap replicates was calculated and denoted sb_i, for each trip i (*i.e.*, $\text{Var}_j(r_i(j)) = sb_i$). Note that this standard deviation is calculated from the bootstrap distribution of just the recaptures from the previous-day's marking 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 given by sb_i. Because this standard deviation is based on the simulated variability in just the previous-day's marking, it may tend to understate the sampling variability of m_i, which is the number of recaptures from all previous marking events. Even so, this assumption should provide a sensible approximation. We condition on the sample size, which we assume to be fixed and not a random variable, so that $n_i = n_i(j)$, for all j bootstrap observations. We then estimate $\hat{M}_i(j)$, $\hat{\phi}_i(j)$, and so on, as previously described, for all j = 1, ...G. The confidence interval for each parameter estimate is found from the quantiles of the bootstrap distribution (Rice 1995) for that estimate.

Adult Sockeye Salmon Population Age and Size Distribution

Scales, matched with sex and length data, were collected from adult sockeye salmon on the spawning grounds in Kanalku and Sitkoh Lakes to describe the age and size structure of each population. The sampling goal for each lake was 600 fish. All unmarked sockeye salmon were sampled on the first day of each sampling trip, until the trip goal of 200 samples was reached. 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 and length data were paired for each fish sample. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period (e.g. 1.3 denotes 1-year freshwater and 3-years saltwater) (Koo 1962). Brood year tables were compiled by sex and brood year to describe the age structure of the returning adult sockeye salmon population. The length of each fish was measured from mideye-to-tail-fork to the nearest millimeter (mm).

The proportion p_k of each age-sex group k was estimated as $\hat{p}_k$ by the standard binomial formula, with associated standard error (SE), where n_k is the number of samples in age-sex group k and n is the total number of samples aged:

$$\hat{p}_k = \frac{n_k}{n} \text{ and } SE(\hat{p}_k) = \sqrt{\frac{\hat{p}_k(1-\hat{p}_k)}{n-1}} \text{ (Thompson 1992, p. 35–36).}$$

The mean length and associated standard error for age-sex group k were calculated by standard normal methods:

$$\bar{y}_k = \frac{1}{n_k}\sum_{i=1}^{n_k} y_{ki} \text{ and } SE(\bar{y}_k) = \sqrt{\frac{1}{n_k}} \cdot \sqrt{\left(\frac{1}{n_k - 1}\right)\sum_{i=1}^{n_k}(y_{ki} - \bar{y}_i)^2} \text{ (Thompson 1992, p. 42–43).}$$

LIMNOLOGY

Limnology sampling was conducted only in Kanalku Lake in 2003, due to the funding shortage for this project. Sampling was conducted on 10 July, 25 Aug, and 30 Sept; zooplankton was sampled at two stations on each date, and light, temperature and dissolved oxygen were measured only at station A.

Light, Temperature, and Dissolved Oxygen Profiles

Underwater light intensity was recorded from just below the surface to the depth where measured intensity was one percent of the surface light reading, at 0.5 m intervals, using an electronic light sensor and meter (Protomatic). The vertical light extinction coefficients (K_d) were calculated as the slope of the light intensity (natural log of percent subsurface light) versus depth. The euphotic zone depth (EZD) was defined as the depth to which one percent of the subsurface light [photosynthetically available radiation (400–700nm)] penetrates the lake surface (Schindler 1971), and is calculated from the equation: EZD = 4.6205/ K_d (Kirk 1994). The euphotic zone depth multiplied by the surface area of the lake defined the volume of the lake where photosynthesis is possible.

Temperature and dissolved oxygen (DO) profiles were measured with a Yellow Springs Instruments (YSI) Model 58 DO meter and probe, in relative (percent saturation) and absolute (mg L^{-1}) values for DO and in ºC for temperature. Measurements were made at 1 m intervals to the first 10 m or the lower boundary of the thermocline (defined as the depth at which the change in temperature decreased to less than 1ºC per meter), and thereafter at 5 m intervals to within 2 m of the bottom (or 50 m). The dissolved oxygen meter reading at 1 m was calibrated at the beginning of a sampling trip using the value from a 60 ml Winkler field titration (Koenings et al. 1987). The DO profile for Kanalku Lake was measured only on the first sampling trip, in July.

Secondary Production

Zooplankton samples were collected at two stations using a 0.5 m diameter, 153 um mesh, 1:3 conical net. Vertical zooplankton tows were pulled from a maximum depth of 50 m, or 2 m from the bottom of the lake if shallower than 50 m, at a constant speed of 0.5 m sec^{-1}. The net was rinsed prior to removing the organisms, and all specimens were preserved in neutralized 10% formalin (Koenings et al. 1987). Zooplankton samples were analyzed at the ADF&G Commercial Fisheries Limnology Laboratory in Soldotna, Alaska. Identification to genus or species, enumeration, and density and biomass estimates were performed as in 2001 and 2002 (Conitz and Cartwright 2002a, 2003; Koenings et al. 1987). Zooplankton density (individuals per m^2 surface area) and biomass (weight per m^2 surface area) were estimated by species and by the sum of all species (referred to as total zooplankton density or biomass).

RESULTS

ADULT ESCAPEMENT ESTIMATES

Mark-Recapture and Visual Survey

Kanalku Lake

Three surveys were conducted at Kanalku Lake between 2–21 September 2003 (Table 2). On an earlier trip to the lake on 25 August, no sockeye spawners were seen in the lake. Mark and recapture sampling was conducted on the same dates as the surveys. By 21 September, there were so few spawners that a fourth mark-recapture event was not scheduled.

Table 2.–Visual counts of sockeye spawners in Kanalku Lake in 2003, listed individually by date and observer (3 observers). Shoreline areas were surveyed by boat. The study area was a designated area within the total lake shoreline area.

	Sockeye Counts	
Date	**Study Area**	**Entire Lake Shore**
9/02	169, 183, 189	169, 183, 190
9/13	85, 94, 97	87, 96, 100
9/21	32, 31, 28	32, 31, 31

Due to very low numbers of sockeye salmon on the spawning grounds, sample sizes were small throughout the short spawning period (Table 3). Nevertheless, sufficient numbers of recaptures were obtained, and an estimate of escapement was possible that met our objective for precision. Within the study area, we estimated about 270 sockeye spawners (95% CI 250– 300) in the 2003 season; the coefficient of variation for this estimate was 5%. Overall, 98% of sockeye salmon counted in the visual surveys were within the study area, indicating that the study area estimate was close to the total escapement for 2003.

Table 3.–Sample sizes and numbers of recaptured fish in the Kanalku Lake study area in 2003. In the first-stage sampling, fish were marked on one day and examined for marks the following day, assuming the population to be closed over this short time period. In the second-stage sampling, fish caught on both days of an event were given a unique mark for that event, and were also examined for marks given on previous events. The second stage allowed for an open population estimate.

	First Stage		
Event Dates	**No. Marked (day 1)**	**No. Sampled (day 2)**	**No. Recaps from day 1**
9/02–03	91	62	34
9/13–14	77	70	33
9/21–22	35	34	24
	Second Stage		
		Recaps from previous marking event:	
	No. Sampled and Released with Marks	**1**	**2**
9/02–03	119	-	-
9/13–14	114	39	-
9/21–22	45	0	22

Sitkoh Lake

The crew conducted six visual surveys at Sitkoh Lake between 27 August and 4 November, but no sockeye salmon were seen on the last trip, 4 November (Table 4). Only the shoreline areas of the lake were surveyed, as historically, no sockeye spawners have been observed in the inlet streams. The peak count of sockeye salmon was on 10 September.

Table 4.–Visual counts of sockeye spawners in Sitkoh Lake in 2003, listed individually by date and observer (3–4 observers). Shoreline areas were surveyed by boat. The study area was a designated area within the total lake shoreline area.

	Sockeye Counts	
Date	**Study Area**	**Entire Lake Shore**
08/27	92, 123, 89	138, 173, 122
09/10	395, 446, 370	986, 1036, 937
09/25	441, 476, 209, 408	669, 705, 444, 591
10/08	240, 238, 225	378, 395, 366
10/22	43, 42, 35	53, 50, 42
11/04	0	0

The crew conducted five mark and recapture events in Sitkoh Lake in 2003 (Table 5). The escapement estimate for the study area was 5,100 (95% CI 4,700–5,700) sockeye salmon, and the estimated coefficient of variation was 5%, meeting our objective for precision. Overall, the study area included about 60% of all sockeye spawners counted in visual surveys.

Table 5.–Mark and recapture sample sizes and numbers of recaptured fish in the study area of Sitkoh Lake, 2003.

First Stage			
Event Dates	**No. Marked (day 1)**	**No. Sampled (day 2)**	**No. Recaps from day 1**
08/28–29	131	190	59
09/11–12	434	412	254
09/26–27	472	321	188
10/09–10	248	248	115
10/22–23	45	32	16

Second Stage					
		Recaps from previous marking event:			
Dates	**No. Sampled and Released with Marks**	**1**	**2**	**3**	**4**
08/28–29	262	-	-	-	-
09/11–12	592	25	-	-	-
09/26–27	605	5	37	-	-
10/09–10	381	0	1	40	-
10/22–23	61	0	0	0	10

Kook Lake

Three sampling events were conducted at Kook Lake between 7–21 August 2003. On the first two trips, visual surveys were conducted in conjunction with mark-recapture sampling on both days (Table 6).

Table 6.–Visual counts of sockeye spawners in Kook Lake in 2003, conducted on both days of first two sampling events. Counts were recorded individually by 2–4 observers during mark-recapture sampling in the stream.

	Sockeye Counts	
Dates	**First Day**	**Second Day**
8/7–8	95, 59, 69	115, 100, 72, 112
8/14–15	74, 93	84, 34, 66

Numbers of sockeye salmon were low in Kook Creek during the sampling period (Table 7). The number of sampling events was limited by budget constraints, so we don't know whether we adequately sampled the entire spawning run in this stream. For the period of 7– 21 Aug, in Kook Creek only, we estimated an escapement of 180 (95% CI 160–220) sockeye salmon; the coefficient of variation for this estimate was 9%. This mark-recapture estimate should be considered only a partial estimate of escapement in Kook Creek, and does not provide any information about beach-spawning escapement in Kook Lake.

Table 7.–Sample sizes and numbers of recaptured fish in Kook Creek between 7– 21 August 2003.

	First Stage		
Event Dates	**No. Marked (day 1)**	**No. Sampled (day 2)**	**No. Recaps from day 1**
8/07–08	92	84	44
8/14–15	55	33	11
8/21–22	56	43	17
		Second Stage	
		Recaps from previous marking event:	
	No. Sampled and Released with Marks	**1**	**2**
8/07–08	132	-	-
8/14–15	77	53	-
8/21–22	82	22	43

Adult Sockeye Salmon Population Age and Size Distribution

Kanalku Lake

At Kanalku Lake, 217 sockeye salmon were sampled, of which 119 were males and 98 were females (Table 8). Ages could not be determined for 61 fish. Given the very low escapement it was not possible to meet the sampling goal of 600. The majority of the sockeye salmon in the sample were age 1.2 (87%), and the only other age classes represented were age 1.3 and age 2.2.

Table 8.–Age composition of adult sockeye salmon sampled in the Kanalku Lake escapement by sex, 2003.

Brood Year:	**1999**	**1998**	**1998**			
Age:	**1.2**	**1.3**	**2.2**	**All Aged**	**Not Aged**	**All Fish**
Male						
Sample size	71	17	1	89	30	119
Percent	45.5	10.9	0.6	57.1		54.8
Standard Error	4.0	2.5	0.6	4.0		
Female						
Sample size	65	1	1	67	31	98
Percent	41.7	0.6	0.6	42.9		45.2
Standard Error	4.0	0.6	0.6	4.0		
All Fish						
Sample size	136	18	2	156	61	217
Percent	87.2	11.5	1.3	100.0		
Standard Error	2.7	2.6	0.9			

The Kanalku sockeye salmon sampled in the escapement were small, averaging 489 mm in mideye-to-fork length due to the high number of age-1.2 fish (Table 9). The age-1.3 fish were larger at 554 mm on average, but only represented about 11% of the sample.

Table 9.–Mean fork length (mm) of adult sockeye salmon in the Kanalku Lake escapement by sex and age class, 2003.

Brood Year:	1999	1998	1998		
Age:	**1.2**	**1.3**	**2.2**	**Not Aged**	**All Fish**
Male					
Av. Length (mm)	487	555	525	499	500
SE (av. length)	2.3	3.3		5.2	2.9
Sample Size	71	17	1	30	119
Female					
Av. Length (mm)	476	540	470	473	476
SE (av. length)	2.3			3.8	2.0
Sample Size	65	1	1	31	98
All Fish					
Av. Length (mm)	482	554	498	486	489
SE (av. length)	1.7	3.2	27.5	3.6	2.0
Sample Size	136	18	2	61	217

Sitkoh Lake

At Sitkoh Lake, 599 sockeye salmon were sampled, of which 377 were males and 222 were females. Age could not be determined for 133 fish (Table 10). Of the 466 samples that were aged, 79% were age 1.2 and 18% were age 1.3. The only other age classes present in the sample were one fish, age 2.2, and 11 age-1.1 jacks.

Table 10.–Age composition of adult sockeye salmon sampled in the Sitkoh Lake escapement by sex, 2003.

Brood Year:	2000	1999	1998	1998			
Age:	**1.1**	**1.2**	**1.3**	**2.2**	**All Aged**	**Not Aged**	**All Fish**
Male							
Sample size	11	227	47		285	92	377
Percent	2.4	48.7	10.1		61.2		62.9
Standard Error	0.7	2.3	1.4		2.3		
Female							
Sample size		142	38	1	181	41	222
Percent		30.5	8.2	0.2	38.8		37.1
Standard Error		2.1	1.3	0.2	2.3		
All Fish							
Sample size	11	369	85	1	466	133	599
Percent	2.4	79.2	18.2	0.2			
Standard Error	0.7	1.9	1.8	0.2			

The overall average mideye-to-fork length was 495 mm, reflecting the high proportion of smaller age-1.2 fish in Sitkoh Lake samples. Age-1.3 fish averaged 543 mm (Table 11).

Table 11.–Mean fork length (mm) of adult sockeye salmon in the Sitkoh Lake escapement by sex and age class, 2003.

Brood Year:	**2000**	**1999**	**1998**	**1998**		
Age:	**1.1**	**1.2**	**1.3**	**2.2**	**Not Aged**	**All Fish**
Male						
Av. Length (mm)	351	495	551		494	498
SE (av. length)	5.8	1.3	1.7		4.7	2.2
Sample Size	11	227	47		92	377
Female						
Av. Length (mm)		478	532	530	493	491
SE (av. length)		1.6	2.1		5.0	2.0
Sample Size		142	38	1	41	222
All Fish						
Av. Length (mm)	351	489	543	530	494	495
SE (av. length)	5.8	1.1	1.7		3.6	1.5
Sample Size	11	369	85	1	133	599

LIMNOLOGY

Light, Temperature, and Dissolved Oxygen Profiles

The mean euphotic zone depth (EZD) in Kanalku Lake in 2003 was about 13 m on 10 July and about 14.5 m on 25 Aug, averaging 13.8 m for the summer season. A thermocline had begun to form by 10 July, and was present at about 10–11 m on 25 Aug (Figure 6). The temperature near the surface reached 16.4^{o}C in early July. Dissolved oxygen (DO) levels were between 8.7– 9.8 mg·L^{-1} throughout the water column on 10 July. The 10 July dissolved oxygen saturation was between 89–90% in the upper 5 m, between 80–86% between from 6–10 m, and between 71–79% below 11 m.

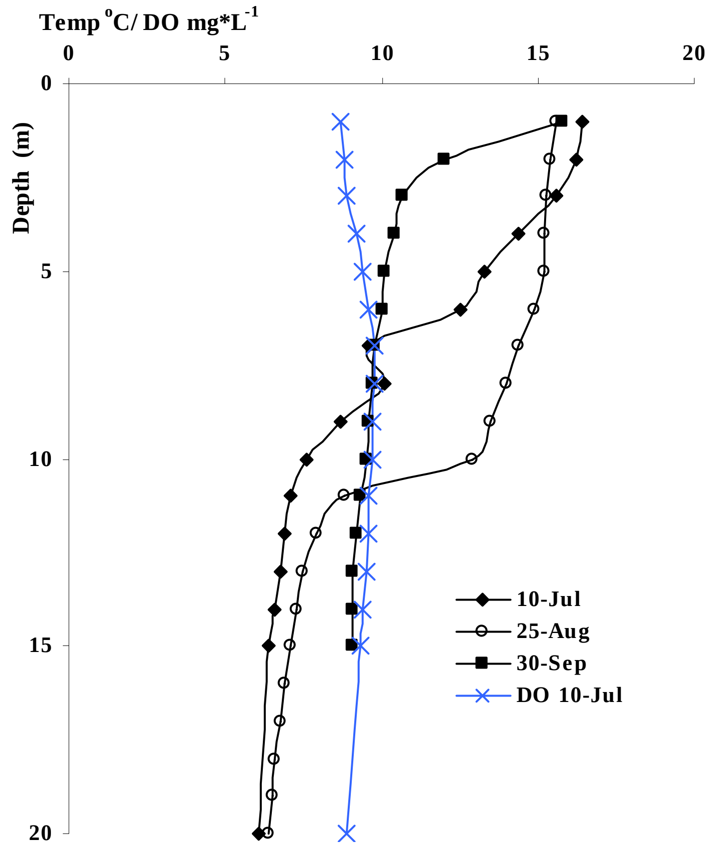

Figure 6.–Summer and fall water temperature vertical profiles, and July Dissolved Oxygen (DO) profile, for Kanalku Lake in 2003.

Secondary Production

Macro-zooplankton identified in water samples from Kanalku Lake included four cladoceran taxa-*Bosmina* sp., *Daphnia longiremis*, *Holopedium* sp., and *Sidadae*-and three copepod taxa-*Cyclops* sp., *Diaptomus* sp., and *Epischura* sp. Zooplankton total seasonal mean biomass was about 370 mg·m^{-2} in Kanalku Lake in 2003 (Table 12). *Bosmina* sp., with weighted mean lengths of about 0.5 mm, comprised about 40% of total biomass, and the larger *Daphnia longiremis*, weighted mean length 0.7–1.2 mm, comprised about 22% of total biomass (ovigerous and non-ovigerous forms combined).

Table 12.–Estimates of size and biomass of macrozooplankton in Kanalku Lake for July–September 2003, averaged between Stations A and B. Mean lengths are weighted by density (numbers · m^{-2}) at each sampling date and seasonal mean biomass is based on the weighted mean length. Ovigorous (egg-bearing) individuals in each taxa were measured separately.

	Average length (mm)			Weighted mean length (mm)	Seasonal mean biomass (mg·m^{-2})	Percent of total biomass
	10-Jul	25-Aug	30-Sep			
Bosmina	0.50	0.47	0.52	0.49	146.9	39.4%
Ovig *Bosmina*	0.74	0.63	0.62	0.61	1.5	0.4%
Daphnia l.	0.74	0.69	0.76	0.74	50.2	13.5%
Ovig *Daphnia l.*	1.23	1.03	1.05	1.19	33.1	8.9%
Holopedium	1.01			1.01	8.9	2.4%
Ovig *Holopedium*	1.03			1.00	1.0	0.1%
Sidadae		1.52	1.82	1.76	12.0	3.2%
Cyclops	1.12	0.84	0.50	0.59	16.0	4.3%
Ovig *Cyclops*	1.17	1.11		1.17	9.4	2.5%
Diaptomus	1.22	1.19	1.21	1.22	20.8	5.6%
Ovig *Diaptomus*	1.27			1.27	0.7	0.2%
Epischura	1.77	1.18	1.32	1.25	72.8	19.6%
				Total Seasonal Mean Biomass	**372.5**	

The total seasonal mean density was about 146,000 zooplankters $\cdot m^{-2}$ (Table 13). Cladocerans were dominant in numbers; *Bosmina* sp. were the most numerous zooplankters comprising 44% of the samples. Excluding the copepod nauplii, the second most numerous taxon was *Daphnia longiremis*, with combined ovigerous and non-ovigerous individuals comprising nearly 18% of the samples.

Table 13.–Density (number $\cdot$ m^{-2}) of macrozooplankton by taxa in Kanalku Lake, 2003, averaged between Stations A and B.

	Density (number $\cdot$ m^{-2})				
	10-Jul	**25-Aug**	**30-Sep**	**Seasonal Mean**	**% of Total Numbers**
Bosmina	84,400	79,000	30,000	64,000	44.0%
Ovig Bosmina	0	200	1,100	400	0.3%
Daphnia l.	50,900	7,900	4,400	21,100	14.4%
Ovig Daphnia l.	11,300	2,700	900	4,900	3.4%
Holopedium	2,400	0	0	800	0.5%
Ovig Holopedium	100	0	0	0	0.0%
Sidadae	0	100	600	200	0.2%
Ovig Sidadae	0	0	0	0	0.0%
Cyclops	4,900	800	37,000	14,000	9.7%
Ovig Cyclops	5,400	100	0	1,900	1.3%
Diaptomus	6,600	800	800	2,800	1.9%
Ovig Diaptomus	300	0	0	100	0.1%
Epischura	1,400	18,400	7,000	8,900	6.1%
Copepod nauplii	0	10,100	69,000	26,500	18.1%
	Seasonal Mean Density, All Taxa			**146,300**	

DISCUSSION

The third year of study in the three systems comprising the Angoon sockeye salmon project was successfully completed. Limnology sampling was reduced to one lake only, due to a shift in the priorities of the contracting agency. As in the previous years, the most important results of this project were the escapement estimates for Kanalku and Sitkoh Lakes. We once again documented a very low sockeye escapement into Kanalku Lake, and we added another year's estimate to a continuing time series of sockeye escapements in Sitkoh Lake. The estimate of stream-spawning escapement into Kook Creek demonstrated the presence of a distinct, early run spawning in the inlet stream.

The extremely small escapement into Kanalku Lake of less than 300 sockeye salmon in 2003 was troubling, after the larger escapement and the voluntary fishing closure in 2002. Visual survey observations provided further evidence of very low spawning numbers; very few fish were seen anywhere in the lake outside of the study area. Prior to the spawning period, the crew also surveyed the Kanalku outlet stream on a weekly basis and documented low numbers of sockeye salmon reaching the top of the falls. Many people in Angoon were not aware of whether the voluntary closure would continue in 2003. Some residents claimed they saw people fishing at Kanalku, but the crew observed few or no fishing parties during surveys conducted in July and August. It is clear that more than one or two years of reduced fishing in the Kanalku terminal area will be needed in order to see whether these sockeye runs will rebound. We did not estimate the sockeye fry population in 2003, but the zooplankton populations look similar to those in 2002, an indication that the predator population (sockeye fry) did not increase enough to make a difference. The warm and dry weather in July and early August of 2003 may have had an effect on both the adult and juvenile sockeye populations. Low water and warm temperatures possibly inhibited the migration of sockeye salmon upstream during the critical period in mid-July; the low water certainly made the fish more vulnerable to bears and any humans that may have been fishing then. Warm epilimnetic temperatures in the lake, combined with reduced oxygen levels in mid-summer, may stress fry, although without any fry population data, we cannot show any evidence of such effects.

The estimated sockeye escapement into Sitkoh Lake was somewhat lower in 2003 than in the two previous years of this study. The spawning period extended from late August through the end of October. This run has extended into early November in previous years, and has one of the latest spawning periods of the sockeye systems we are studying in northern Southeast Alaska. The strong numbers in mark-recapture samples from late August through early October suggest that there may be at least two overlapping runs spawning in Sitkoh Lake. There was some successful subsistence fishing for sockeye salmon in the Sitkoh terminal area, but the area appears to be less popular with Angoon residents than either Kanalku or Basket Bay (M. Kookesh ADF&G, personal communication 2003). We have no estimates of juvenile or prey populations in 2003, so we cannot speculate about whether the Sitkoh sockeye escapement was at an optimum size.

Study at Kook Lake was designated as lower-priority and was minimal in 2003. Kook Lake was known to have an inlet stream-spawning population, arriving on the spawning grounds earlier than the beach-spawning population, but it had not been observed in aerial surveys for at least 10 years (A. McGregor ADF&G, personal communication 2002). The August mark-recapture sampling in Kook Creek confirmed presence of a stream-spawning sockeye population there for the second consecutive year. The U.S. Forest Service and the ACA crew cleared debris from the Kook Lake outlet for the third consecutive year. It is likely that this effort has reduced or eliminated a migration barrier that had been in place for a number of years. Some Angoon residents reported fishing for subsistence sockeye salmon at Basket Bay in 2003, with good catches (M. Kookesh ADF&G, personal communication 2003). However, the distance across Chatham Strait from Angoon is a deterrent to many Angoon residents who travel and fish in small skiffs.

CHAPTER 2—THREE-YEAR FINAL REPORT

PROJECT BACKGROUND

Kanalku, Kook, and Sitkoh Lakes were selected for study because of their high-use subsistence fisheries and the lack of available information on their sockeye salmon populations. Angoon subsistence users identified these systems as among their highest priority resources. Of the three systems, Kanalku is of greatest interest and concern to Angoon residents and subsistence users. It is close to the village and accessible via the sheltered waters of Mitchell Bay. Remains of a weir and other artifacts found at the head of Kanalku Bay provide physical evidence for a history of at least 1,000 years of continuous use of salmon resources there (Moss 1989). Another sockeye-producing system located at the head of Mitchell Bay, Hasselborg River/Salt Lake, has also sustained a traditional fishery in the area for many generations (Moss 1989; George and Kookesh 1982). This system was included in the study during the first year, but was subsequently dropped due to lack of success in sampling sockeye spawners in the deep stream channel and because there are no particular concerns about this run (Conitz and Cartwright 2002a). Across Chatham Strait from Angoon, Kook Lake/Basket Bay and Sitkoh Lake have sockeye salmon runs that are fished by some Angoon residents. Oral tradition and other evidence also point to long, continuous use of salmon from these systems by Angoon people (de Laguna 1960; George and Bosworth 1988; Moss 1989; Thornton et al. 1990; Goldschmidt et al. 1998).

This project was initiated in 2001, and our goal was to provide information about sockeye populations in these systems to support management for sustainable escapements and harvest opportunities. Prior to this project, there was little if any information specific to these systems on which to base management decisions. Some preliminary limnology studies and assessments of juvenile and adult sockeye populations had been conducted in Kanalku, Kook, and Sitkoh Lakes during the 1990s, but there were no long-term or continuing assessments (Conitz and Cartwright 2002a, 2002b, 2003a). In the first three years of study at Kanalku, Kook, and Sitkoh Lakes, our objectives included estimation of adult sockeye escapements and size and age distributions, populations of sockeye fry and other small pelagic fish, secondary production (zooplankton, focusing on sockeye prey species), and physical characteristics of each lake.

We succeeded in estimating sockeye escapements in each year of the project, from 2001-2003, for Kanalku and Sitkoh Lakes. Escapement estimates for Sitkoh Lake built upon several previous years of study. We were less successful in producing escapement estimates for Kook Lake because the spawning areas were physically difficult to sample; nevertheless we obtained visual counts and partial estimates of escapement in all three years. We estimated distributions of size and age classes of sockeye escapements in these three systems, adding to estimates made in previous years. We completed hydroacoustic population estimates of small pelagic fish in each lake in 2001 and 2002, but a persistent difficulty in estimating species apportionment from mid-water trawl samples prevented estimation of the sockeye fry populations separately. Lack of a practical solution to this problem, combined with changing project priorities in 2003, forced us to drop this part of the study in the third year. We estimated zooplankton prey populations and profiled water column light, temperature, and dissolved oxygen in each lake in 2001 and 2002, and for a third year in Kanalku Lake. This successful three-year study is a good start on the multi-year data collection effort needed to determine the status of these sockeye-producing systems, and to use the information to manage their sockeye runs for sustainable escapements and harvest opportunities.

OVERVIEW OF PROJECT OBJECTIVES AND METHODS

Project objectives are listed in Chapter 1. Objectives 1 and 2, covering escapement estimation and age-length-sex distributions, have remained the same throughout the first three years of the project. Objective 3, covering lake productivity, has included zooplankton sampling and measurement of light, temperature, and dissolved oxygen profiles in all three years. We discontinued hydroacoustic and trawl sampling to assess sockeye fry rearing densities in 2003, listed as Objective 4 (Conitz and Cartwright 2003a) due to technical difficulties and changing priorities. We conducted project activities in all three lakes, Kanalku, Kook, and Sitkoh, in all three years. However, Kook Lake was part of a different project in 2001, and was largely eliminated from this project in 2003 due to reorganization of priorities after funds were reduced. In 2003, we estimated only one part of the escapement, and conducted no other sampling, in Kook Lake. We conducted limnology sampling only in Kanalku Lake in 2003.

We used the same methods for the study design, with only slight modifications, throughout the first three years of the project. We changed the fry sampling design in 2002 to allow for true replicate hydroacoustic transects in each lake section and replicate trawl samples at depths and areas with the highest concentrations of fish, making it possible to calculate a coefficient of variation for the target distribution in each sample section. (Conitz and Cartwright 2003a). We successfully adapted other sampling methods, including those for adult mark-recapture and age-sex-length, zooplankton, and water column physical parameters, to the unique environment of each lake without any significant changes. We had trouble selecting a suitable study area in Kook Lake because of steep dropoffs, submerged snags, and sparse spawning aggregations that appeared in different locations in 2001 and 2002. We sampled parts of the beach spawning population in 2001 and 2002, but in 2003, we sampled only the stream spawning population.

We used the same statistical methods for data analysis without major changes throughout the first three years of the project, although some minor modifications and improvements were made in 2003 after a thorough review by biometrics staff. Estimates of sockeye fry populations are an exception, and modification of our methods is ongoing. The trawl samples used to apportion the acoustic targets by species were very small in lakes with low fish density, such as Kanalku. The sampling error associated with the species apportionment estimates is unknown and can be large because of the clumped distribution of small pelagic fish in the lake potentially unequal catchability of species, and small sample sizes. Our first approach was to increase the number of trawl samples, but this greatly increased the time needed for each survey. Consequently, we had to reduce the number of lakes surveyed each season. We eliminated surveys in Kook and Kanalku Lakes because their fish densities were so low that no amount of towing would give us an adequate sample. A survey of Sitkoh Lake was not completed in 2003 due to weather delays. Our biometrician at ADF&G has been developing Bayesian methods to describe the sampling error associated with the trawl samples that would enable us to reconstruct a range of abundance for each pelagic species in previous surveys with limited trawl samples. This approach is still in the developmental stages and results were not available at the time this report was published.

Mark-recapture estimates and a 95% confidence interval were made using a modified version of the Jolly-Seber method as outlined in Schwarz et al. (1993) and further modified by ADF&G biometrics staff for small populations of sockeye salmon in beach-spawning areas (Conitz and Cartwright 2003a; Cook 1998). In each lake, we sampled only a portion of the spawning population, within a study area defined by physical features of the lake shoreline and the tendency of sockeye spawners to aggregate within specific locations. A whole-lake estimate of escapement could be obtained by estimating the proportion of sockeye spawners in each lake that were available for sampling within the study area and expanding the study-area estimate by this proportion. We have attempted to do this by using observer counts of fish in the study area and in other parts of the lake. The only variation in observer counts that we can quantify is the difference in counts between individual observers, yet other factors, such as water depth and clarity, weather, and behavior of fish, could be more significant sources of observational error. Therefore, the proportion of sockeye spawners available for sampling within the study area is considered a rough estimate, allowing us to re-scale the study-area estimate for comparison purposes and to indicate trends. No attempt was made to estimate the non-sampling (between observer) error or the magnitude of the observational error of this proportion, and the whole-lake extrapolation.

THREE-YEAR RESULTS AND DISCUSSION

Kanalku Lake

Angoon residents point out that Kanalku sockeye salmon runs have sustained their traditional fishery for an unbroken period of over one thousand years. Quantitative data on sockeye harvests in the Kanalku system are only available for the most recent twenty years, and these data are limited to harvest totals reported to ADF&G by permit holders on a voluntary basis. Permit holders must return a permit for one year, with harvest information entered, before they can receive a permit in the following year. However, there is no independent check on the harvest numbers reported by permit holders. Nevertheless, these data serve as an indicator of minimum effort and harvest, as well as trends over time. The harvest totals reported by Kanalku permit holders show an increase in fishing pressure on the Kanalku sockeye runs during the years since this reporting system began (1985). Comparing the reported subsistence harvests with recent escapements, it is obvious that demand exceeds recent productivity at Kanalku. The highest reported annual harvest on record was about 3,000 sockeye salmon in 1998 (Appendix A). The annual harvests for the two years prior to and the two years after 1998 were each about 1,500 sockeye salmon. These high levels of harvest are five to ten times higher than the escapements we observed in 2001 and 2003 (Appendix C). The actual harvest was very likely even higher than this. Evidence from the few subsistence sockeye systems in which on-site harvest surveys have been conducted shows that harvest is typically, but not always, under-reported; the degree of under-reporting appears to be highly variable (Conitz and Cartwright 2003a; Cartwright and Lewis 2004; Lorrigan et al. 2004). The voluntary subsistence fishing moratorium in 2002 appeared to have a positive effect on escapement into Kanalku Lake, but in 2003 the moratorium was still in place and the escapement was once again very low. Clearly, many more than two years are needed to allow the Kanalku stock to rebuild and produce sustainable returns.

We estimated a sockeye fry population in Kanalku Lake of only one-tenth in 2001 and about one-sixth in 2002 of that estimated in 1995 (Table 14). The 2002 fry estimates are not exactly comparable with the 2001 estimates, because sampling areas and selection of transects were changed in the sampling design, but should be close enough to show broad relationships. (Table 14). The very low fry density was evident from the extremely sparse pattern of targets in the hydroacoustic surveys and the very small numbers of fish caught in the trawl tows (Conitz and Cartwright 2002a, 2002b, 2003). Although their numbers were low, sockeye fry rearing in Kanalku Lake were large compared with fry in other lakes in Southeast Alaska (Appendix D). Density and biomass of *Daphnia* sp., the preferred prey for sockeye fry, increased between two- and four-fold during this same time period (Table 14). *Daphnia* sp. biomass exceeded that in most other sockeye-producing lakes studied in 2001–2003 (Appendix E). The populations of *Daphnia* have probably responded positively to a reduced predator population. The average length of *Daphnia* sp. individuals was about 0.1 mm (roughly 10%) less in 2002 and 2003 than in 1995 and 2001. Reduced size in the absence of grazing pressure could indicate other limiting factors for *Daphnia* populations, but this is outside the scope of our study. Total zooplankton biomass and density, and euphotic zone depth remained at roughly the same levels between 1995 and 2001–2003 (Table 14). Escapement samples showed most of the sockeye salmon in the Kanalku escapement left freshwater at age 1 (Appendix F). The stable zooplankton populations and evidence that most sockeye fry remain only one year in freshwater are further indications that sockeye productivity is not being limited by food availability in Kanalku Lake.

Table 14.–Summary of lake habitat, sockeye prey and sockeye fry population information from Kanalku Lake.

		Zooplankton seasonal means					
Year	**Seasonal mean euphotic zone depth (m)**	**Total biomass (mg ·m^2)**	**Density, all species (no ·m^2)**	***Daphnia* biomass (mg ·m^2)**	***Daphnia* density (no ·m^2)**	***Daphnia* length (mm)**	**Estimated sockeye fry population**
1995	14.6	370	102,000	50	12,000	0.93	119,000
2001	11.6	370	133,000	120	27,000	0.96	11,700
2002	12.5	420	127,000	140	45,000	0.81	21,500
2003	13.8	370	146,000	80	26,000	0.83	ns

Sitkoh Lake

We now have a five-year time series of consistent escapement estimates for Sitkoh Lake using the same study area and mark-recapture methods, and there are three previous years for which an estimate of escapement using other methods is available (Appendix C). Escapements have fluctuated between about 6,000– 17,000 sockeye salmon. The Sitkoh escapements may follow a five-year cycle between successive high (or low) numbers, but there are not yet enough years in the time series to show this. Comparing the reported subsistence harvests with recent escapements, it appears likely that very little of the Sitkoh sockeye returns are being harvested (Appendix A). Again, as pointed out for the Kanalku subsistence harvest, the true subsistence harvest totals are unknown due to the voluntary reporting system for subsistence users. By contrast, numbers of sockeye salmon were harvested in the commercial fishing sub-districts closest to Sitkoh Bay (112-11,–12, 113–51) increased dramatically during the 1990s, and reached a peak in 1993–1994; numbers since 2000 have been comparable to the non-peak years in the 1990s (Appendix B). We think the increase may be due to greater fishing effort near the Hidden Falls hatchery as a result of increased chum production (Larson 2001).

The sockeye fry population in Sitkoh Lake was about the same in 2001 and 2002. The 2001 fry estimates are not exactly comparable with the 2002 estimates, because sampling areas and selection of transects were changed in the sampling design, but should be close enough to show broad relationships (Table 15). Fry density in Sitkoh Lake appeared to be moderate, in comparison with other sockeye rearing lakes studied in 2002 (Appendix D). Since there are no previous fry estimates for Sitkoh Lake, we have no evidence for any trend in population size.

However, the larger prey populations in 2001 and 2002 compared with 1992 suggests Sitkoh sockeye production is not limited by food and in fact the lake may be capable of producing more sockeye fry. The total zooplankton biomass and density have more than doubled, as have the *Daphnia* biomass and density between 1992 and 2002 (Table 15). Because we don't know the range of potential escapements in Sitkoh Lake, it is difficult to speculate as to whether escapement is currently limiting production. No sticklebacks, and only a single sculpin, were caught in mid-water trawl tows in Sitkoh Lake. Sitkoh Lake also has significant populations of cutthroat trout, Dolly Varden char, and steelhead trout (Brookover 1999, Jones and Yanusz 1998, Yanusz 1997). Inter-specific competition is probably not a factor affecting sockeye production in Sitkoh Lake, but predation may be. Escapement samples showed over 90% of the sockeye salmon in Sitkoh escapements, in years sampled since 1982, left freshwater at age 1 (Appendix F), another indicator that rearing habitat is not limiting sockeye production in this lake.

Table 15.–Summary of lake habitat, sockeye prey and sockeye fry population information from Sitkoh Lake.

		Zooplankton seasonal means					
Year	**Seasonal mean euphotic zone depth (m)**	**Total biomass (mg ·m²)**	**Density, all species (no ·m²)**	***Daphnia* biomass (mg ·m²)**	***Daphnia* density (no ·m²)**	***Daphnia* length (mm)**	**Estimated sockeye fry population**
1992[a]	6.1	291	109,000	87	25,500	0.85	ns
2001	6.7	647	359,000	91	35,900	0.75	177,000
2002	6.1	569	296,000	187	68,500	0.79	148,000

[a] Estimates for 1992 are from unpublished data, ADF&G Division of Commercial Fisheries.

We have a continuous series of escapement estimates and age-sex-length samples from 1996–2003 (Appendix F). We can thus estimate the number of each fish of each age class in the offspring of the 1996 and 1997 brood years that returned to spawn in Sitkoh Lake (Table 16). Since we have no information on the size and age composition of the harvest, we cannot estimate the total number of recruits per spawner. However we can examine the relationship between number of parents in each year and the number of their offspring that escaped to spawn in Sitkoh Lake. The parents in 1996 just replaced themselves with offspring escaping into Sitkoh Lake from 1999–2002. Each parent in the 1997 brood year produced about 1.4 adults that escaped into Sitkoh Lake from 2000–2002. The reason for the difference between these two brood years, or even whether it is significant, is unknown given the large number of variables affecting survival and the limited amount of information available. However, because the subsistence harvest of sockeye salmon in Sitkoh Bay was small from 1999–2002 (Appendix A), when the offspring of these two brood years were returning to spawn, it is apparent that terminal area harvest had little effect on survival and escapement.

Table 16.–Numbers of sockeye salmon returning to spawn in Sitkoh Lake (escapement only) from the 1996 and 1997 brood years, by age class.

		Number of offspring returning to spawn, and age class (return year shown in parentheses)									
Brood year	**Number of parents**	**0.2**	**1.1**	**0.3**	**1.2**	**2.1**	**1.3**	**2.2**	**1.4**	**2.3**	**Number of offspring**
1996	16,300		130		2,980		13,070			80	16,300
			(1999)		(2000)		(2001)			(2002)	
1997	6,000	68	187		763		7,268	155			8,442
		(2000)	(2000)		(2001)		(2002)	(2002)			

Taking the voluntary reports of subsistence harvests at Sitkoh Bay as a rough indicator of the trend and magnitude of the true subsistence harvest in this system, it appears terminal area harvests may be relatively small but perhaps on the increase (Appendix A and M. Kookesh ADF&G, personal communication 2004). Recent high catches of sockeye salmon in the nearby commercial seine fisheries, contrasted with restricted subsistence fishing opportunities near Angoon, have already begun to cause concern among Angoon subsistence users. With consistent escapement estimates for an unbroken period of over five years, and supporting lake habitat information for some of those years, we are beginning to accumulate the long time series of demographic information needed to manage Sitkoh sockeye stocks for sustainable harvests and escapements.

Kook Lake

The relationship between sockeye harvest and production in the Basket Bay/Kook Lake system is uncertain. Our escapement estimates from 2001–2003 were very rough and we had to change our sampling area because of changes in the location of the spawning population and difficulty in sampling at some locations. Our "best educated guess" estimates ranged from only about 250 spawners in 2001 to about 3,500 in 2002. A comparable estimate is not available for 2003 because we only sampled and surveyed one portion of the escapement (Appendix C).

Low numbers of sockeye adults, estimated in Kook Lake, may be a result of 1) missed counts of spawners, due to the early timing of the stream spawners and the late timing of the beach spawners; 2) the inability of sockeye adults to swim past the debris barrier prior to 2001; 3) substantial harvest of sockeye salmon in the subsistence and commercial fisheries, or 4) a combination of the above. We recommend a weir be placed out the outlet of Kook Lake to get an accurate estimate of escapement. We also recommend that the Angoon crew continue to remove the debris from the outlet stream every year. We rely on the reported subsistence harvest on ADF&G permits, and we know from comparative studies (Conitz and Cartwright 2003b and Cartwright and Lewis 2004) that under-reporting can be significant. Unfortunately, we have no way to estimate the number of Kook Lake bound sockeye salmon in the commercial fishery.

Sockeye fry populations were estimated in Kook Lake in 1994 and 1995 as well as in 2001 and 2002 during this study; the numbers have remained similar over that time period. The 2001 fry estimates are not exactly comparable with the 2002 estimates, because sampling areas and selection of transects were changed in the sampling design, but should be close enough to show broad relationships (Table

17). Prey populations have likewise remained about the same, although zooplankton densities were higher in 2002. The moderate numbers (12–24% of total zooplankton) and apparent stability of *Daphnia* sp. biomass and individual sizes over the eleven-year period are an indication that sockeye fry are not limited by prey availability in Kook Lake. It is more likely that sockeye fry populations are well below capacity in this lake, probably because of low spawning escapements. We have no evidence of competition or predation in this lake, with the limited information available. Age distributions of adult sockeye salmon in the Kook Lake escapements sampled between 1983 and 2002 show the great majority (over 95%, on average) had only one freshwater year (Appendix F), which is another indication that freshwater production is not food limited.

Table 17.–Summary of lake habitat, sockeye prey and sockeye fry population information from Kook Lake.

		Zooplankton seasonal means					
Year	**Seasonal mean euphotic zone depth (m)**	**Total biomass (mg ·m^2)**	**Density, all species (no ·m^2)**	***Daphnia* biomass (mg ·m^2)**	***Daphnia* density (no ·m^2)**	***Daphnia* length (mm)**	**Estimated sockeye fry population**
1992	ns	208	69,157	27	9,933	0.80	
1994	ns	269	90,251	50	16,152	0.82	85,629
1995	ns	246	69,244	59	18,512	0.83	59,128
2001	5.8	299	78,034	37	10,630	0.87	84,653
2002	6.4	310	101,242	50	16,843	0.81	49,465

CONCLUSIONS

After three years of study, we think that sockeye escapement is severely limiting production in Kanalku Lake, may be limiting production to an unknown degree in Kook Lake, and may be limiting production to a lesser degree in Sitkoh Lake. We think the subsistence harvests in the Kanalku terminal area were unsustainably high since the 1990s, until the voluntary fishing moratorium began in 2002. Some Angoon residents disagree and feel that the harvest levels during recent years are no greater than past levels over many generations. However, the subsistence harvest reporting system in place since 1985 provides the only numerical evidence we have of sockeye harvests in the Kanalku system. Because the reporting system is voluntary, it may not be altogether accurate or reliable. The actual harvest is generally higher than the reported harvest. Evidence from the few subsistence sockeye systems in which on-site harvest surveys have been conducted shows that harvest is typically, but not always, under-reported; the degree of under-reporting appears to be highly variable (Conitz and Cartwright 2003a; Cartwright and Lewis 2004; Lorrigan et al. 2004). The reported harvest numbers nevertheless reflected a sharply increasing trend for Kanalku sockeye salmon, coinciding with the extremely low escapement first documented in 2001.

Angoon residents reported shifting some fishing effort to Sitkoh and Basket Bays since the Kanalku closure was implemented, and an increased harvest was reported in both systems in 2003. Indications from the voluntary permit reporting are that subsistence harvests in Sitkoh are still small compared with estimated escapements, but harvests in Basket Bay could be equal or greater to the escapements into Kook Lake in some years. We don't have very solid escapement estimates yet for Kook Lake, but we do have evidence of very low escapement in 2001. The blockage in the outlet stream could have depressed the Kook Lake sockeye runs for a number of years, and the recovery time will depend in part on how long the blockage was in place and to what degree it blocked migration.

We want to emphasize the importance of continuing to monitor the sockeye escapements into Kanalku Lake as fishery managers and the Angoon community continue to work on a recovery plan for this run. We also point out the need to continue monitoring escapements into Kook and Sitkoh Lakes, because they provide alternative sources of subsistence sockeye salmon for Angoon residents, especially when fishing is limited at Kanalku. We strongly recommend continued monitoring of the Sitkoh Lake sockeye stock, to provide fishery managers with a long-range time series of escapements and associated estimates, such as sockeye fry and zooplankton populations in the lake, as a basis for setting sustainable escapement levels and managing for sustainable subsistence harvest opportunities. Because of its proximity to commercial fishing sub-districts adjacent to the Hidden Falls hatchery terminal area, Sitkoh Lake sockeye stock may also serve as an indicator of the effects of commercial sockeye harvest on escapement into small, sockeye systems in the northern Chatham area. We recommend that the Kook Lake sockeye stocks be closely watched, and they may need to be allowed to rebuild. The Hasselborg River/Salt Lake system, originally part of this project, provides another alternative for Angoon subsistence users. It is not currently being studied or proposed for study, but additional information or monitoring may be necessary if fishing effort increases there in the future. If escapement levels begin to increase in these systems in the future, biologists should resume assessment of fry and zooplankton populations, to determine whether these could be limiting at higher escapement levels. However, we recommend continuing to place the highest priority on continued monitoring of sockeye escapements in Kanalku, Sitkoh, and Kook Lakes.

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The ACA crew conducted the fieldwork at Kanalku and Sitkoh Lakes almost entirely on their own in 2003, and did an excellent job. This was the third season for Leroy Martin and Peter McCluskey Jr. and the second for Edward Gamble Jr. This crew also conducted weekly boat and foot surveys of Kanalku Bay and the Kanalku outlet stream in conjunction with ADF&G commercial fisheries managers Kevin Monagle and Dave Harris. We thank the pilots of Alaska Seaplanes and Ward Air, who safely transported to crew to and from the field sites.

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APPENDICES

Appendix A.–Subsistence effort and harvest of sockeye salmon reported on permits from 1985–2003 at Kanalku, Basket, and Sitkoh Bays (ADF&G Division of Commercial Fisheries database 2004).

Year	Kanalku			Basket (Kook Lake)			Sitkoh		
	No. of Permits	Total Sockeye	Average Sockeye per Permit	No. of Permits	Total Sockeye	Average Sockeye per Permit	No. of Permits	Total Sockeye	Average Sockeye per Permit
1985	22	473	22	37	450	12	40	313	8
1986	37	931	25	78	1427	18	48	677	14
1987	20	645	32	55	1233	22	36	636	18
1988	10	258	26	30	316	11	25	322	13
1989	16	425	27	35	493	14	16	248	16
1990	30	762	25	32	477	15	18	181	10
1991	22	556	25	28	406	15	0	0	
1992	21	571	27	34	602	18	1	90	90
1993	32	901	28	27	475	18	0	0	
1994	42	1282	31	23	348	15	2	36	18
1995	39	936	24	21	387	18	1	10	10
1996	59	1627	28	20	302	15	3	50	17
1997	56	1538	27	18	187	10	6	60	10
1998	106	2964	28	19	327	17	2	16	8
1999	57	1666	29	23	418	18	6	36	6
2000	50	1443	29	19	252	13	8	75	9
2001	39	951	24	23	279	12	17	276	16
2002	1	14	14	38	645	17	7	184	26
2003	3	90	30	39	941	24	20	647	32
Average 1985–1993:	23	614	26	40	653	16	20	274	24
Average 1994–2003:	45	1251	26	24	409	16	7	139	15
Average 1994–2001[a]:	56	1551	27						

[a] For Kanalku only, to eliminate years 2002–2003, with voluntary fishing closure, from average.

Appendix B.–Commercial harvest of sockeye salmon in northern Chatham Strait, by sub-district (locations of sub-districts shown in Fig. 2). Average annual harvests for years with commercial harvest are shown, by decade, for each sub-district and all sub-districts combined; the three Tenakee Inlet sub-districts showing commercial sockeye harvests are also combined. Average annual sockeye harvests in Whitewater Bay (112-90), Chaik Bay (112-80), Hood Bay (112-71,–72,–73) and Sitkoh Bay (113-59) were less than 100 fish and are not shown (ADF&G Division of Commercial Fisheries database 2004).

	District 112							Tenakee Inlet	Fresh-water Bay	District 113	All Sub-Districts
YEAR	**11**	**12**	**13**	**14**	**16**	**17**	**18**	**41, 42, 45**	**50**	**51**	
1980	0	174	0	0	637	10	51	353	0	0	1,225
1981	0	1,094	71	755	14,562	32	25	649	0	22	17,210
1982	1,427	8,477	435	1,116	10,753	106	26	4,011	0	14	26,365
1983	2,131	9,630	4	454	11,967	0	118	1,549	0	1,022	26,875
1984	1,369	25	0	0	15,326	0	156	4,997	0	1,321	23,194
1985	835	55	223	162	30,128	716	1,067	829	0	1,335	35,350
1986	0	0	0	0	4,730	0	0	537	0	59	5,326
1987	198	115	0	0	39,900	0	0	1,156	0	1,550	42,919
1988	585	289	0	34	320	0	182	894	0	103	2,407
1989	1,197	2,455	0	0	35,956	2,148	1,715	3,232	0	5,016	51,719
1990	2,878	146	0	0	11,426	423	367	1,527	0	910	17,677
1991	2,112	4,057	0	0	23,660	724	2,208	4,003	0	1,233	37,997
1992	1,577	3,685	0	1,067	31,292	53	4,263	5,684	0	2,606	50,227
1993	2,722	5,954	0	616	43,986	4,858	5,782	4,022	0	3,962	71,902
1994	2,678	3,744	0	2,543	46,465	245	2,067	4,315	0	9,415	71,472
1995	0	0	0	2,436	3,839	0	529	2,679	1,576	856	11,915
1996	1,214	1,040	0	5,159	16,923	0	979	4,016	0	1,645	30,976
1997	944	3,611	0	2,066	13,056	0	0	2,295	1,582	637	24,191
1998	648	3,411	0	1,616	16,195	0	822	1,877	0	1,180	25,749
1999	1,678	6,024	1,930	6,067	29,328	0	485	2,456	0	1,807	49,775
2000	396	300	0	4,895	9,565	0	2,244	4,142	0	883	22,425
2001	1,720	3	0	13,483	37,117	171	62	2,575	0	1,948	57,079

-continued-

Appendix B.–Page 2 of 2.

	District 112							Tenakee Inlet	Fresh-water Bay	District 113	All Sub-Districts
YEAR	**11**	**12**	**13**	**14**	**16**	**17**	**18**	**41,42,45**	**50**	**51**	
2002	354	384	0	3,517	15,040	650	153	1,120	0	1,123	22,341
2003	1,345	1	0	7,659	45,172	5,697	1,879	238	0	1,681	63,672
Decade Averages											
1980–89	774	2,231	73	252	16,428	301	334	1,821	0	1,044	23,259
1990–99	1,645	3,167	193	2,157	23,617	630	1,750	3,287	316	2,425	39,188
2000–03	954	172	0	7,389	26,724	1,630	1,085	2,019	0	1,409	41,379
All Years	1,167	2,278	111	2,235	21,139	660	1,049	2,465	132	1,680	32,916

Appendix C.–Sockeye escapement estimates in Sitkoh, Kook, and Kanalku Lakes, 1994–2003.

			Estimated Sockeye Escapement		
Lake	**Year**	**Type of Estimate**	**Study Area**	**Whole Lake**	**Citation**
Sitkoh	1996	weir with mark-recap	na	16,300	Cook 1998
	1997	mark-recap	4,500	6,000	Cook 1999
	1998	mark-recap (incomplete)	na	6,600	Crabtree 2000
	1999	mark-recap	8,300	10,500	Crabtree 2001
	2000	mark-recap	12,400	17,000	Crabtree 2001
	2001	mark-recap	8,800 (7,900–11,000)[a]	14,100	Conitz and Cartwright 2002a[b]
	2002	mark-recap	7,300 (6,500–8,200)[a]	11,900	Conitz and Cartwright 2003a
	2003	mark-recap	5,100 (4,700–5,700)[a]	8,700	unpublished
Kook	1994	weir count	na	1,800	Conitz and Cartwright 2002b
	1995	weir count	na	5,800	Conitz and Cartwright 2002b
	2001	mark-recap (lake)	230 (180– 390)[1]	380	Conitz and Cartwright 2002b[b]
	2002	mark-recap (lake)	590 (490– 800)[1]	3,600	Conitz and Cartwright 2003a
	2003	mark-recap (inlet stream)	180 (160– 210)[1]	na	unpublished
Kanalku	2001	mark-recap	220 (130– 380)[1]	240	Conitz and Cartwright 2002a[b]
	2002	mark-recap	1,300 (1,200– 1,400)[1]	1,600	Conitz and Cartwright 2003a
	2003	mark-recap	270 (250– 300)[1]	280	unpublished

Sources: Cook 1998; Crabtree 2000, 2001; Conitz and Cartwright 2002a,b, 2003a.

[a] *95% confidence interval.

[b] Estimates shown here have been updated according to most recent data analysis methods (this report), and may be slightly different from those shown in the source cited.

Appendix D.–Sockeye fry densities and average weights of age-0 fry in selected Southeast Alaska lakes with important subsistence runs, 2002. Total population estimates of small pelagic fish were based on hydroacoustic surveys of each lake, and sockeye populations were estimated from the proportions of sockeye fry in tow net samples. Fry density estimates are the total sockeye population divided by the estimated surface area for each lake. Average weights of age-0 fry will vary with sample date; in general, the later in the season the lake was sampled the larger the fry.

Lake	Date sampled	Fry·100 m^{-2}	Av. wt. age-0 fry (g)
Hetta	Jul 18	44	0.3
Kutlaku	Aug 9	41	1.1
Gut Bay	Aug 23	25	0.5
Klag	Aug 25	23	1.1
Luck	Jul 22	23	0.4
Hoktaheen	Oct 13	18	1.4
Sitkoh	Aug 13	11	1.1
Klawock I	Jul 17	4	0.6
Kanalku	Aug 10	3	1.0
Klawock II	Oct 2	3	1.8
Falls	Aug 24	2	0.7
Kook	Aug 11	2	0.8
Salmon Bay	Sep 22	2	1.0

Appendix E.–Seasonal mean biomass of all zooplankton and of *Daphnia* sp. and mean length of *Daphnia* sp. (weighted by abundance) in selected sockeye-producting lakes in Southeast Alaska.

	2001				**2002**				**2003**		
	Seasonal mean biomass (mg ·m^2)				**Seasonal mean biomass (mg ·m^2)**				**Seasonal mean biomass (mg ·m^2)**		
Lake	**All zooplankton**	***Daphnia* sp.**	**Mean length *Daphnia* (mm)**	**Lake**	**All zooplankton**	***Daphnia* sp.**	**Mean length *Daphnia* (mm)**	**Lake**	**All Zooplankton**	***Daphnia* sp.**	**Mean length *Daphnia* (mm)**
Sitkoh	651	93	0.73	Hoktaheen	651	20	0.91	Kutlaku	618	84	0.51
Kanalku	371	119	0.95	Sitkoh	579	201	0.79	Tumakof	500	0	0.66
Salmon Bay	364	85	0.94	Tumakof	496	2	0.65	Klawock	431	37	0.97
Hoktaheen	328	32	0.87	Klawock	499	16	0.90	Kanalku	371	78	0.75
Kook	299	37	0.87	Kanalku	420	137	0.75	Salmon Bay	351	32	0.93
Luck	234	17	0.86	Kook	315	52	0.80	Klag	316	7	0.68
Klawock	217	12	0.94	Luck	316	18	0.77	Luck	201	6	0.73
Klag	181	4	0.65	Klag	222	5	0.97	Thoms	163	7	0.55
Kutlaku	177	32	0.63	Salmon Bay	205	19	0.75	Eek	147	0	na
Falls	104	0	0.66	Kutlaku	131	35	0.51	Hetta	45	2	0.68
Thoms	144	9	0.60	Thoms	119	7	0.57	Falls	29	1	0.66
Hetta	34	0	0.63	Hetta	49	7	0.67	Sitkoh	na	na	na
Gut Bay	33	1	0.60	Falls	29	1	0.69	Kook	na	na	na
				Gut Bay	24	1	0.61	Gut	na	na	na
Average	245	34	0.76	Average	311	40	0.75	Average	288	23	0.71
Median	217	17	0.73	Median	269	17	0.75	Median	316	7	0.68

Appendix F.–Summary of age and length distributions of sockeye salmon escapement in Kanalku Lake, 2001–2003. Lengths are mideye-to-fork of tail.

Age distributions

		Percent of sample by age class		
Year	**Sample Size**	**1.2**	**1.3**	**2.2**
2001	89	53.9	43.8	2.2
2002	426	80.3	16.4	3.3
2003	156	87.2	11.5	1.3

Length distributions

		Average length by age class (mm)			
Year	**Sample Size**	**1.2**	**1.3**	**2.2**	**All age classes**
2001	89	474	538	478	506
2002	426	477	530	481	485
2003	156	482	554	498	489

Appendix G.–Summary of age and length distributions of sockeye salmon escapement in Sitkoh Lake, 1982–2003. Lengths are mideye-to-fork of tail.

Age distributions

		Percent of sample (mm) by age-class								
Year	**Sample Size**	**0.2**	**0.3**	**1.1**	**1.2**	**1.3**	**1.4**	**2.1**	**2.2**	**2.3**
1982	764				24.3	71.7	0.1		1.3	2.5
1983	329			0.6	62.6	34.7			0.9	1.2
1984	417			0.2	7.9	90.6			0.5	0.7
1987	495			1.2	36.0	58.0	0.2	0.4	3.2	1.0
1996	480			2.9	17.7	75.6	0.6	0.2	0.8	2.1
1997	355		0.3	0.6	34.6	55.5		0.3	6.8	2.0
1998	410			5.1	41.0	50.7		1.0	1.2	1.0
1999	169			1.2	49.1	49.1			0.0	0.6
2000	269	0.4		1.1	17.5	78.1			1.9	1.1
2001	467			1.5	5.4	92.5			0.0	0.6
2002	543			1.1	35.9	61.0			1.3	0.7
2003	466			2.4	79.2	18.2			0.2	

<u>Length distributions</u>

		Average length (mm) by age-class									
Year	**Sample size**	**0.2**	**0.3**	**1.1**	**1.2**	**1.3**	**1.4**	**2.1**	**2.2**	**2.3**	**All**
1982	764				496	556	600		502	559	541
1983	329			345	475	533			498	540	496
1984	417				490	543			490	515	539
1987	495			357	482	548	550	373	475	552	519
1996	480			345	506	561	597	360	515	562	546
1997	355		535	365	504	554		380	496	557	530
1998	410			353	490	544		338	496	548	510
1999	169			346	485	541				543	512
2000	269	454		345	507	562			507	563	550
2001	467			351	485	555				568	548
2002	543			344	487	548			502	556	522
2003	466			351	489	543			530		495
all years		454	535	350	489	551	588	355	495	555	527

Appendix H.–Summary of age and length distributions of sockeye salmon escapement in Kook Lake, 1983–2002. Lengths are mideye-to-fork of tail.

Age distributions

		Percent of sample by age class									
	Sample size	**0.2**	**0.3**	**1.1**	**1.2**	**1.3**	**1.4**	**2.1**	**2.2**	**2.3**	**3.2**
1983	442	0	0	0	5	94.8	0	0	0	0.2	0
1984	470	0	0	0	4.3	95.7	0	0	0	0	0
1985	54	0	0	0	50	29.6	13	0	0	7.4	0
1987	372	0	0	0	0	99.2	0.3	0	0	0.5	0
1994	849	0	0.1	0.2	71.8	21.7	0	0.1	4.9	0.8	0.2
1995	1357	0.1	0	0	39	53.3	0	0	3.3	4.3	0
2001	37	0	0	2.7	54.1	37.8	0.0	0	5.4	0	0
2002	400	0.3	0.0	0.0	80.3	18.8	0.0	0.0	0.3	0.5	0

Length distributions

		Average length (mm) by age class										
	Sample size	**0.2**	**0.3**	**1.1**	**1.2**	**1.3**	**1.4**	**2.1**	**2.2**	**2.3**	**3.2**	**All**
1983	442				473	559				570		555
1984	470				498	560						557
1985	54				466	540	570			531		506
1987	372					576	605			570		576
1994	849		545	372	467	535		340	484	532	480	483
1995	1357	515			488	535			498	538		516
2001	37			358	504	551			503			519
2002	400	480			473	523			485	525		483