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Kanalku Lake Subsistence Sockeye Salmon Project: 2010 Annual Report

by

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and

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September 2011

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

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ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.adfg.alaska.gov/sf/publications/ This publication has undergone editorial and peer review.

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ABSTRACT

The sockeye salmon (*Oncorhynchus nerka*) run at Kanalku Lake, Southeast Alaska, has provided the preferred traditional subsistence sockeye salmon stock for the people of Angoon for generations. A stock assessment program at Kanalku Lake began in 2001 in response to community concerns over declining run size and possible overexploitation by local fishermen. Mark-recapture studies were conducted between 2001 and 2006 to estimate the spawning escapement. To add confidence to the escapement estimates, an adult counting weir was added to the project in 2007 and weir operation was continued through 2010. The 2010 season weir-to-spawning-grounds mark-recapture estimate was 2,970 (95% CI 2,660–3,380). A substantial increase in escapement was observed in both the 2009 and 2010 seasons; escapements in both years were more than twice the average escapement of 1,000 sockeye salmon estimated from 2001–2008. In both 2009 and 2010, we believe the increased escapement into Kanalku Lake can be attributed in part to higher rate of success of fish ascending the partial barrier falls on Kanalku Creek as a result of the low water conditions that were prevalent throughout the sockeye salmon migration period. As is in most years, age diversity was low, and the escapement was dominated by age-1.2 (86.9%) fish, followed by age-1.3 (12.3%), and ages 2.2 and age-2.3 (<1.0%). Subsistence fishing effort and harvest of sockeye salmon at Kanalku Bay appeared similar to the 2008 and 2009 harvests.

Key words: sockeye salmon, *Oncorhynchus nerka*, subsistence, Kanalku Lake, escapement, weir, mark-recapture, age composition, Southeast Alaska.

INTRODUCTION

The coastal village of Angoon, Alaska, located on the western side of Admiralty Island, has a long history of utilizing sockeye salmon (*Oncorhynchus nerka*) from the Kanalku Lake drainage. The use of Kanalku Bay as a traditional subsistence fishery site has been documented in several historical and archaeological records, and artifacts from a traditional salmon weir have been found at the head of Kanalku Bay providing physical evidence of the exploitation of salmon resources for at least the last 1,000 years (de Laguna 1960; Moss 1989; Thornton et al. 1990; Goldschmidt and Haas 1998). Although other sockeye salmon runs in the vicinity are available for Angoon subsistence fishermen, including Sitkoh and Basket bays (Geiger et al. 2007), Kanalku Bay remains the preferred harvest area due to its close proximity to the village and ease of access through sheltered waterways.

The introduction of the commercial fishing industry in Southeast Alaska greatly influenced the lives of Native families since the early 20th century. New federal fishing laws and Native participation in the commercial fishing industry led to changes in traditional fishing practices among the Natives of Angoon and other Southeast villages (Thornton et al. 1990; Betts and Wolfe 1992; Turek et al. 2006). After the adoption of Alaska statehood, a non-commercial subsistence fishery was defined and put under a permit system (Turek et al. 2006). Residents of Angoon can obtain subsistence fishing permits for Kanalku, Sitkoh, and Basket Bays, along with other nearby areas, but most people prefer to fish in Kanalku Bay (Conitz and Burril 2008). Participation in commercial fisheries by Angoon residents has declined since the 1980s, from 119 permits for salmon, halibut, and other species in 1990, to 28 permits in 2000 (Geiger et al. 2007). This decline in participation in commercial fisheries has led to an increased dependence on obtaining fish in subsistence fisheries rather than retaining commercially captured fish (Geiger et al. 2007).

In the late 1990s, annual reported subsistence harvests at Kanalku Bay increased substantially at the same time abundance of Kanalku Lake sockeye salmon appeared to decline. Although reported subsistence harvest tends to under-represent the true community harvest (Conitz and Cartwright 2003, Lewis and Cartwright 2004, Lorrigan et al. 2004, Walker 2009), the reported harvests are useful for looking at trends in subsistence catch (Geiger et al. 2007). The reported subsistence harvest at Kanalku Bay increased from an average of 580 sockeye salmon in the late 1980s to an average of 1,550 in the late 1990s (Figure 1). Some Angoon residents reported a decline in the overall abundance of Kanalku sockeye salmon in the 1990s and suggested that community members "slow down" in harvesting that stock (Conitz and Cartwright 2005, Conitz and Burril 2008).

The Alaska Department of Fish and Game (ADF&G) initiated a stock assessment program in 2001 in response to the concern about declining run size and the lack of information about spawning escapements (Conitz and Cartwright 2005). From 2001 to 2006, mark-recapture estimates were conducted on the spawning grounds of Kanalku Lake to estimate the spawning population of sockeye salmon. In 2001, the reported subsistence harvest of sockeye salmon at Kanalku Bay far exceeded an alarmingly low mark-recapture estimate of less than 300 sockeye salmon spawners at Kanalku Lake (Conitz and Cartwright 2005). The Angoon community and ADF&G fisheries managers agreed by consensus that the community would voluntarily curtail fishing in Kanalku Bay during at least the first half of the run (defined as through 14 July) for the 2002 season (Conitz and Burril 2008). Harvest limits at other nearby subsistence sockeye salmon fisheries were also increased to encourage fishing effort elsewhere to allow the Kanalku stock to rebuild. During the voluntary closure from 2002 to 2006, the reported harvest of sockeye salmon in Kanalku Bay was minimal. The escapement in 2003 was estimated to be less than 300 sockeye salmon but escapement estimates in 2002 and from 2004 to 2006 averaged about 1,300 fish (Conitz and Cartwright 2005).

The voluntary closure at Kanalku Bay was respected, for the most part, and the regular permitted subsistence fishery was resumed in 2006 with a later fishing season and smaller harvest limit of 15 sockeye salmon per household (Conitz and Burril 2008). The later season timing in 2006 made subsistence harvest difficult and subsequently it was shifted back to an earlier season in 2007 to provide more opportunity for subsistence fishermen. The harvest limit per household remained unchanged. The subsistence fishing effort and harvest increased substantially, with reported harvests of about 700 sockeye salmon in 2008 and 600 in 2009 (Figure 1).

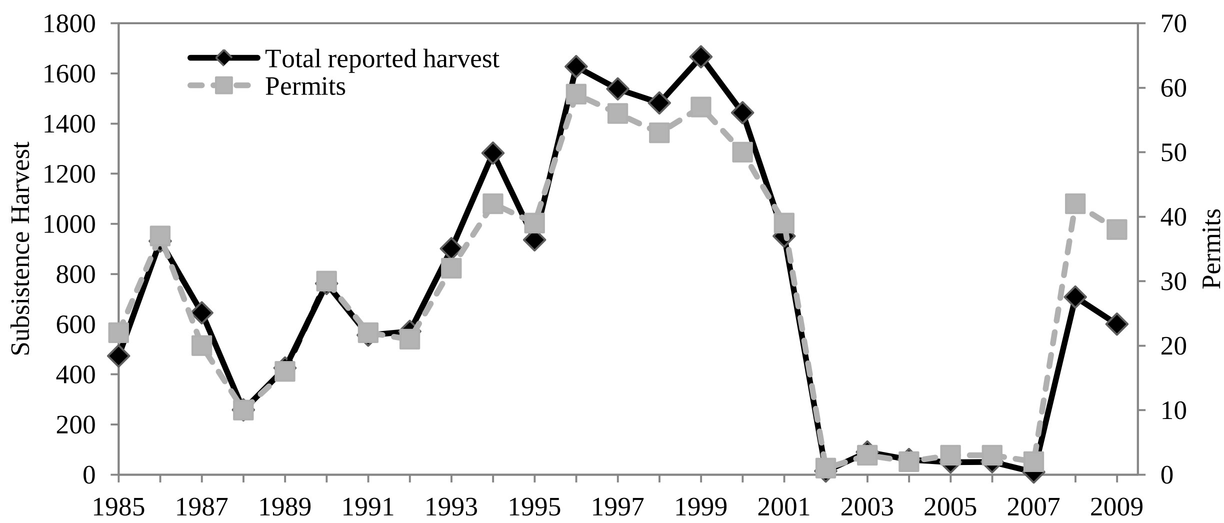

Figure 1.–Reported subsistence sockeye salmon harvest and permits issued, 1985 to 2009.

Beginning in 2007, ADF&G, in cooperation with the Angoon Community Association, expanded the stock assessment project by installing a sockeye salmon weir directly below the outlet of Kanalku Lake to observe run timing, count the sockeye salmon escapement, and conduct a weir-to-spawning grounds mark-recapture estimate of escapement. Escapements were less than 1,000 fish in both 2007 and 2008, but improved to more than 2,600 sockeye salmon in 2009 (Vinzant et al. 2009; Vinzant et al. 2010; Vinzant and Bednarski 2010).

Kanalku Falls, a partial barrier to sockeye salmon migration in Kanalku Creek, is known to have a major influence on the size of the sockeye salmon escapement at Kanalku Lake. In most years, substantial numbers of sockeye salmon sit in the pools below the falls where they are susceptible to predation, and repeatedly batter themselves on the rocks as they attempt to jump the falls and migrate upstream. In 1970, the U.S. Forest Service blasted resting pools and a small channel in the falls bedrock to assist migrating salmon (Geiger et al. 2007) but many fish still do not successfully ascend the falls. Our work at the weir, combined with efforts by the U.S. Forest Service, suggests that a larger portion of the sockeye salmon run is able to ascend the falls during periods of low water flow (Vinzant et al. 2010; Vinzant and Bednarski 2010). In 2008, a year of high precipitation, we estimated that fewer than half of the sockeye salmon that entered Kanalku Creek successfully ascended Kanalku Falls, whereas in 2009, a year of low precipitation, about 75% of the sockeye salmon were able to pass the falls (Vinzant et al. 2010).

Sockeye salmon escapement at Kanalku Lake may also be affected by interception in nearby commercial fisheries conducted in Chatham Strait where sockeye salmon are harvested incidentally in purse seine fisheries targeting pink salmon (*O. gorbuscha*). Although we have no estimates of the harvest of Kanalku sockeye salmon, management of the Chatham Strait fisheries is based on the assumption that this interception is insignificant because of the early run timing of Kanalku sockeye salmon compared to the timing of fishery openings, the distance of Kanalku Bay from these fisheries, and the nature of the mixed stock area where fishing occurs (Geiger et al. 2007). Based on subsistence harvest data collected since 1985, 87% of the total season's subsistence harvest is completed by the time the first purse seine fishery opens in Upper Chatham, and 97% by the end of July (Geiger et al. 2007). In addition, the Chatham Strait shoreline along an area of approximately nine nautical miles from Parker Point to Point Samuel, west and north of Kootznahoo Inlet and the community of Angoon and Kanalku Inlet, has been closed to the purse seine fishery.

The primary focus of the sockeye salmon assessment project has been to produce reliable annual estimates of the spawning escapement at Kanalku Lake. In 2010, we continued weir operations on the outlet stream of Kanalku Lake to count fish entering the lake, observe run-timing, collect biological data, and to estimate the total escapement of sockeye salmon with a weir-to-spawning grounds mark-recapture estimate.

OBJECTIVES

1. Count all salmon species passed through the weir to Kanalku Lake for the duration of the sockeye salmon run.
2. Estimate the escapement of sockeye salmon into Kanalku Lake with mark-recapture studies so the estimated coefficient of variation is less than 15%.
3. Estimate the age, length, and sex composition of the Kanalku Lake sockeye salmon escapement.

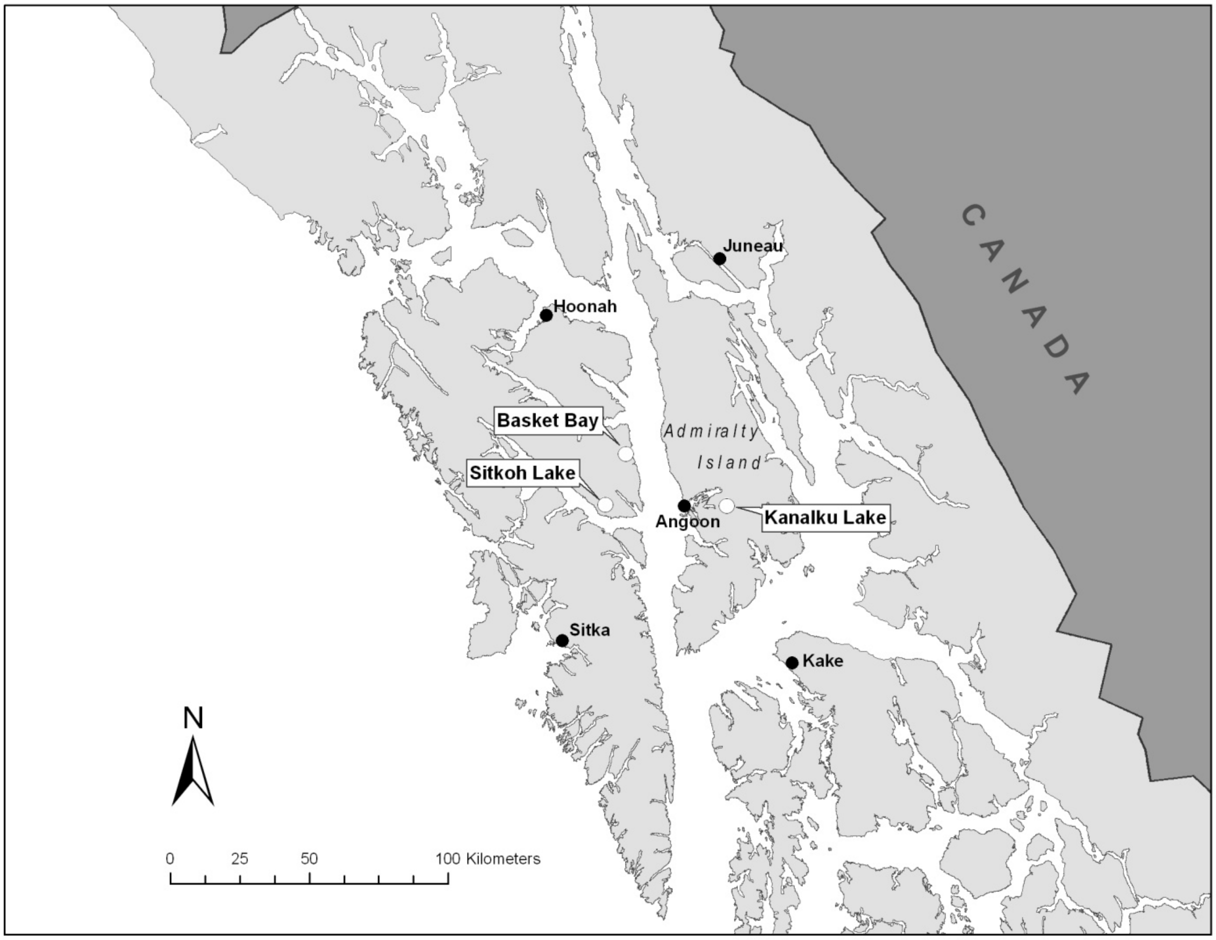

Figure 2.–Map of Southeast Alaska showing location of Kanalku Lake and the village of Angoon.

METHODS

STUDY SITE

Kanalku Lake (lat 57^{o} 29.22'N, long 134^{o} 21.02'W) is located about 20 km southeast of Angoon (Figure 2) and lies in a steep mountainous valley within the Hood-Gambier Bay carbonates ecological subsection (Nowacki et al. 2001). The U-shaped valley and rounded mountainsides are characterized by underlying carbonate bedrock and built up soil layers supporting a highly productive spruce forest, especially over major colluvial and alluvial fans. The watershed area is approximately 32 km^2, with one major inlet stream (ADF&G stream no. 112-67-060) draining into the east end of the lake. The lake elevation is approximately 28 m. The lake surface area is approximately 113 hectares, with mean depth of 15 m, and maximum depth of 22 m (Figure 3). The outlet stream, Kanalku Creek (ADF&G stream no. 112-67-058), is 1.7 km long and drains into the east end of Kanalku Bay. In addition to sockeye salmon spawning in the lake, large numbers of pink salmon (*O. gorbuscha*) spawn in the lower part of the outlet creek and intertidal area. A few coho (*O. kisutch*) and chum (*O. keta*) salmon spawn in the Kanalku system, and resident populations of cutthroat trout (*O. clarkii*), Dolly Varden char (*Salvelinus malma*), and sculpin (*Cottus sp.*) are found in Kanalku Lake. Kanalku Falls, a waterfall approximately 8–10 m high and about 0.8 km upstream from the tidewater, forms a partial barrier to migrating sockeye salmon.

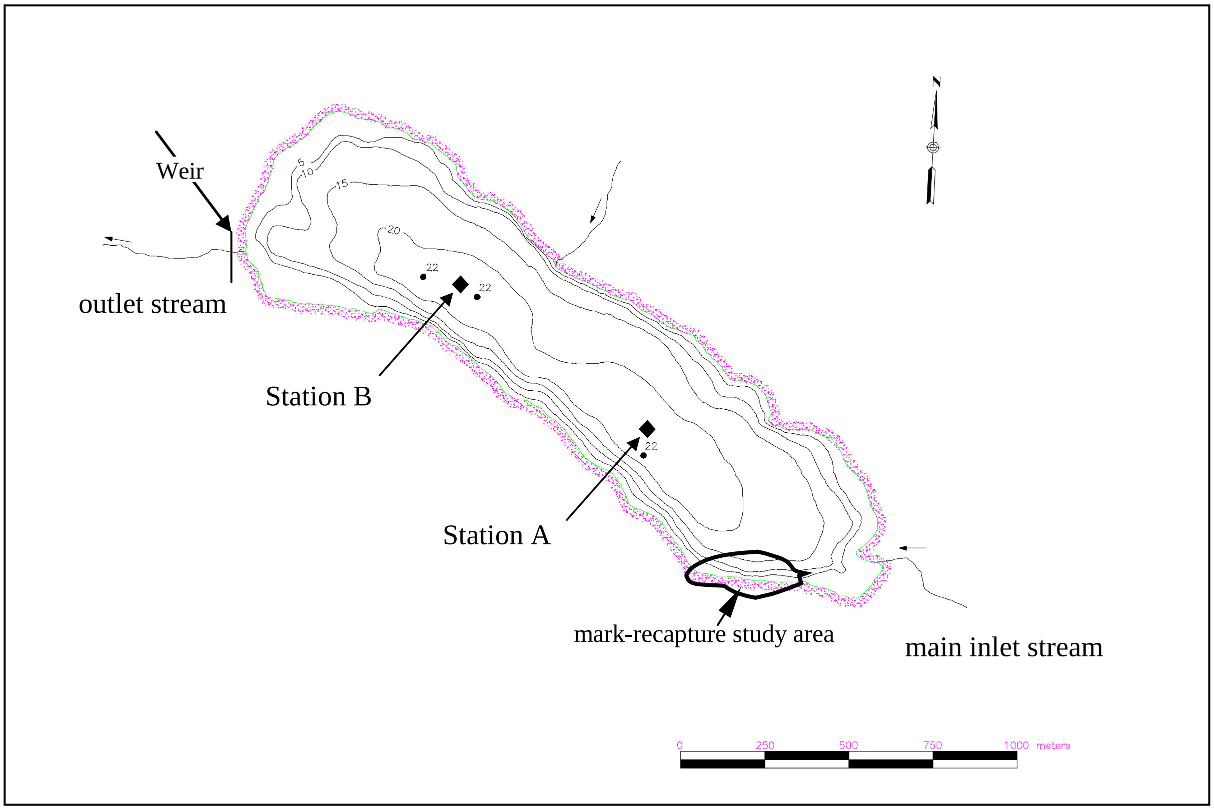

Figure 3.–Bathymetric map of Kanalku Lake, showing 5 m depth contours, the mark-recapture study area, and limnology sampling stations A and B. Arrows indicate direction of stream flow.

SOCKEYE SALMON ESCAPEMENT ESTIMATE

Weir Count

The Kanalku weir was located in Kanalku Creek, across the outlet stream at the west side of the lake. The weir consisted of aluminum bipod supports anchored in the stream sediment. The supports were connected by rows of stringers that extended across the entire stream bed, with pickets inserted through regularly-spaced holes in the stringers and extended to the stream bottom. Picket spacing was 1-3/4 inches (4.45 cm) on center of the pickets. This spacing, called "pink salmon spacing," allows for 52 pickets per channel with a maximum space of approximately 1-1/2 inches (3.81 cm) between pickets. Sandbags were placed across the stream along both sides of the weir to help stabilize the substrate and secure the pickets in place. A weir trap, sampling station, and catwalk were constructed and attached to the weir. Technicians inspected the weir daily for malfunction and breaches.

To minimize handling, fish were counted through the weir by pulling one or two pickets at the upstream side of the weir trap. We placed white sandbags on the bottom of the stream bed at this exit point to aid in fish identification. In addition to counting all fish by species, all sockeye salmon were visually categorized as jacks (fish less than 400 mm in length) or full-size adults. Daily observations of the water level, air and water temperature, and weather were recorded at the weir. The weir was in operation from 25 June to 3 September. Water level was measured daily at approximately the same location (within 1 m^2) as the 2007 to 2009 field seasons.

Weir to Spawning Grounds Mark-Recapture Estimate

The total population of sockeye salmon was estimated with a stratified mark-recapture study. The mark-recapture study allowed us to determine if sockeye salmon passed through the weir undetected, and served as a back-up estimate in the case that the weir was breached or damaged. Fish were marked at the weir with a combination of an adipose fin clip and either an axillary process clip or dorsal fin clip. Marking at the weir was stratified through time on the following schedule: left axillary process clip from 2 July to 23 July, right axillary process clip from 24 July to 8 August, and dorsal fin clip from 9 August to 3 September. The adipose fin clip facilitated easy identification of marked fish and served as the primary mark. Any fish marked and released with only an adipose fin clip was noted. To minimize handling, fish sampled for age, sex, and length were also marked. The target marking rate was 35% of the weekly sockeye salmon escapement. Sockeye salmon that appeared unhealthy were enumerated and released without marks.

Fish were sampled for mark recovery with a beach seine in the only major spawning area found in Kanalku Lake, which is located along the eastern shoreline adjacent to the mouth of the inlet stream (Figure 3). No other spawning areas have been observed in Kanalku Lake (Conitz and Burril 2008). Sampling occurred on 31 August, 8 September, 14 September, and 20 September 2010. An opercular punch was applied to all sockeye salmon in these samples to prevent double sampling on that day or on subsequent sampling events.

We used Stratified Population Analysis System[1] (SPAS) software (Arnason et al. 1996; http://www.cs.umanitoba.ca/~popan/) to analyze the mark-recapture data. SPAS was designed for analysis of two-sample mark-recapture data where the first (marking) and second (mark-recovery) samples are collected over a number of strata. This software was used to calculate the maximum likelihood Darroch and pooled-Petersen (Chapman's modified) estimates and their standard errors. We evaluated the validity of full pooling of marking and mark-recovery data (pooled-Petersen estimate) by using the first two chi-square tests provided in the output. These tests provided a reasonable indication of serious violation of the basic mark-recapture assumptions by evaluating 1) complete mixing of marked fish between release and recovery strata, and 2) equal proportions of fish recovered from each marking stratum. A test statistic with P-value ≤ 0.05 was considered "significant," but serious bias was indicated in the pooled-Petersen estimate only if both test statistics were significant. If neither test statistic, or only one of them, was significant, we accepted the pooled-Petersen estimate. Otherwise, we evaluated the stratified Darroch estimate and attempted to find a reasonable partial pooling scheme in order to reduce the number of parameters that needed to be estimated. We used two additional goodness-of-fit tests for the Darroch estimate provided in the SPAS software, along with the guidelines and suggestions in Arnason et al. (1996) and Schwarz and Taylor (1998), in evaluating the estimate and partial pooling schemes. We deemed the weir count of sockeye salmon to be "verified" if the count fell within the 95% confidence interval of the mark-recapture estimate.

If we used a pooled-Petersen estimate, a parametric bootstrap procedure was used to estimate the standard error and construct the 95% confidence interval for the escapement estimate. We assumed that the number of marked fish recaptured in the second sample, m_2, follows a hypergeometric probability distribution. Then we used the number of fish marked in the first

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

sample, n_1, the number of fish caught in the second sample, n_2, and the Petersen estimate of escapement, $\hat{N}$, to generate 5,000 simulated recapture numbers based on the hypergeometric probability density function, $f(m_2| n_1, n_2, \hat{N})$. From the bootstrap values of m_2, we derived 5,000 Petersen escapement estimates, then calculated the standard error of these estimates and used the 0.025 and 0.975 quantiles to form the 95% confidence interval.

ADULT POPULATION AGE AND SIZE COMPOSITION

The age composition of sockeye salmon at Kanalku Lake was to be determined from a minimum sample of 500 fish collected from live fish at the weir, depending on the run strength. Based on the work by Thompson (1992), and assuming a run of around 1,000 sockeye salmon, a sample of 390 fish was determined to be the size needed to ensure the estimated proportions of each age class would be within 5% of the true value 95% of the time. We increased our sampling goal to 500 fish for the season to ensure we meet the sampling target size even if 15% of the scale samples were unreadable. We began the season with a weekly sampling goal of 30% of the cumulative weekly escapement. Depending on the run strength, weekly sampling goals were adjusted by the project leader. We attempted to sample all sockeye salmon to be marked for the mark-recapture study to minimize fish handling. If a fish appeared overly stressed after marking, or if the handling time exceeded 30 seconds out of the water, the fish was released without additional sampling. The length of each fish was measured from mid eye to tail fork, to the nearest millimeter (mm). Sex was determined by length and shape of the kype or jaw. Three scales were taken from the preferred area of each fish (INPFC 1963), mounted on a gum-card, and prepared for analysis as described by Clutter and Whitesel (1956).

Scale samples were analyzed at the ADF&G salmon aging laboratory in Douglas, Alaska. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period (e.g., 1.3 denotes a five-year-old fish with one freshwater and three ocean years; Koo 1962). We estimated multiple age-class proportions and means, together with estimates for their standard errors, as described by Thompson (1992) and Cochran (1977). The weekly age-sex distribution, the seasonal age-sex distribution weighted by week, and the mean length by age and sex weighted by week were calculated using equations from Cochran (1977; Appendix A).

RESULTS

SOCKEYE SALMON ESCAPEMENT ESTIMATE

Weir Count

The field crew at Kanalku Lake passed a total of 2,555 adult sockeye salmon through the weir between 25 June and 3 September 2010 (Figure 4; Appendix B). No jacks were observed. Stream depth remained very low throughout the field season at the weir, and no high water events occurred. Daily escapements of sockeye salmon were strongest during the last two weeks of July, with a peak daily escapement of 195 fish recorded on 24 July. Daily escapements of sockeye salmon steadily declined throughout August.

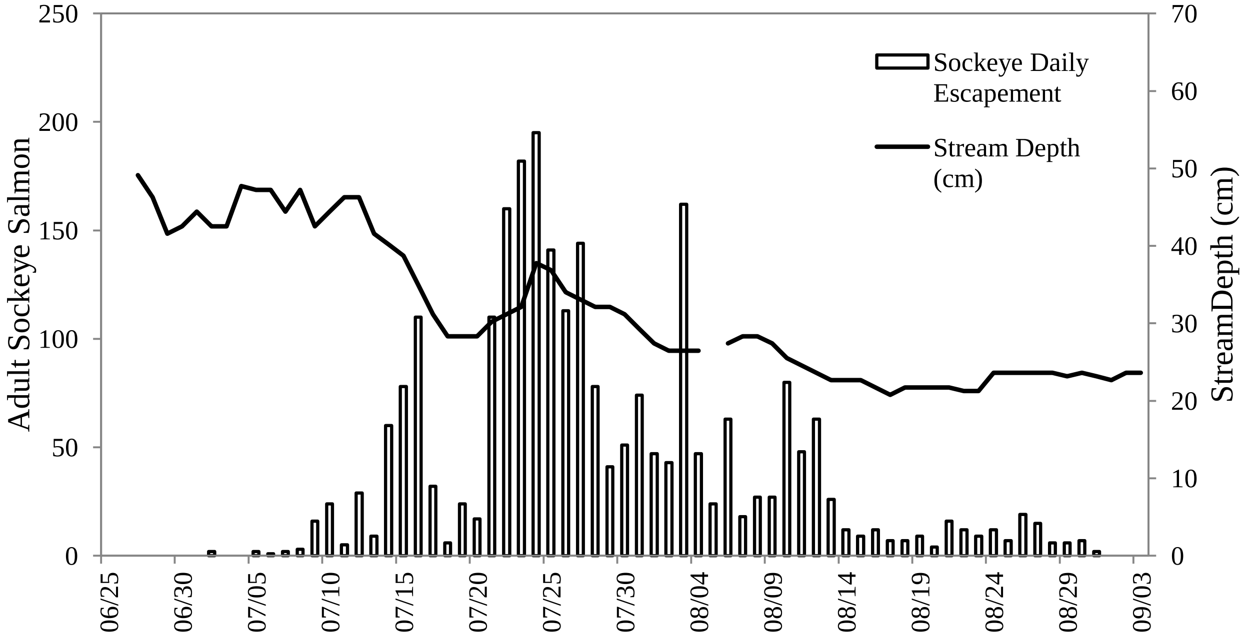

Figure 4.–Daily sockeye salmon escapement and stream depth at the Kanalku Lake weir, 2010.

Weir to Spawning Grounds Mark Recapture

The sampling crew at the Kanalku Lake weir captured and marked a total of 889 adult sockeye salmon: 271 with left axillary process clips 2 July–23 July, 471 with right axillary process clips 24 July–8 August, and 147 with dorsal fin clips from 9 August–3 September. Recapture efforts were conducted on the spawning grounds in Kanalku Lake on 31 August, 8 September, 14 September, and 20 September. During the recapture events, a total of 519 adult sockeye salmon were captured with a beach seine, of which 155 were weir-marked recaptures (Table 1). The result of the chi-square test of complete mixing of marked fish between the marking and recovery events was significant (χ^2 = 17.3, df = 2, P < 0.05). However, the result of the test for equal proportions of marked fish on the spawning grounds was not significant (χ^2= 1.93, df = 3, P = 0.59). A non-significant result for one of these diagnostic tests indicated the pooled estimator was appropriate for estimating abundance in this study. Therefore, we pooled the data and calculated a Petersen estimate of 2,970 (SE = 182) adult sockeye salmon, with a 95% confidence interval of approximately 2,660 to 3,380 fish. The coefficient of variation of 6.1% met our objective of an estimate with a coefficient of variation of less than 15%. Since the weir count of 2,555 sockeye salmon fell below the lower bound of the confidence interval of the mark-recapture estimate, and the Petersen estimate met our criteria for acceptance, we used the Petersen estimate as our best estimate of escapement in 2010.

Table 1.–Number of sockeye salmon marked at the weir, number sampled for marks, and number recaptured at the Kanalku Lake spawning area in 2010 by marking stratum.

Marking stratum end date	Number marked at weir	Count at weir	Marks recovered by sampling date				Total marks recovered	Proportion of marks recovered
			31-Aug	8-Sep	14-Sep	20-Sep		
23-Jul	271	872	13	25	17	7	62	0.23
8-Aug	471	1,268	24	25	22	12	83	0.18
3-Sep	147	415	9	0	1	0	10	0.07
Totals	889	2,555	46	50	40	19		
Number sampled			159	178	132	50	519	
Proportion marked in samples			0.29	0.28	0.30	0.38		

ADULT POPULATION AGE AND SIZE COMPOSITION

The Kanalku Lake crew sampled 501 adult sockeye salmon for age, sex, and length composition in 2010, of which 458 were successfully aged. The sockeye salmon sampled were found to be predominately age-1.2 fish (86.9%). Only a small proportion of the fish sampled were found to have spent more than one year in their freshwater environment (Table 2). Age-1.2 and age-2.2 fish had mean lengths of 494 mm and 492 mm respectively (Table 3). Age-1.3 fish had a mean length of 543 mm. Only one age-2.3 sockeye salmon was sampled, with a length of 540 mm.

Table 2.–Estimated age composition of the 2010 sockeye salmon escapement at Kanalku Lake based on scale samples, weighted by statistical week.

Brood Year	**2006**	**2005**	**2005**	**2004**	
Age	**1.2**	**1.3**	**2.2**	**2.3**	**Total**
Male					
Sample Size	182	42	1	1	226
Proportion	81.1%	18.2%	0.3%	0.4%	
SE of proportion	1.9	0.5	0	0	
Escapement by age class	981	221	4	5	
SE	23	5	0	0	
Female					
Sample Size	214	15	2	0	231
Proportion	92.8%	6.3%	0.9%	0	
SE of proportion	1.4	0.1	0	0	
Escapement by age class	1,098	75	11	0	
SE	17	1	0	0	
All Fish					
Sample Size	397	57	3	1	458
Proportion	86.9%	12.3%	0.6%	0.2%	
SE of proportion	1.3	0.2	0	0	
Escapement by age class	2,079	295	14	5	
SE	30	4	0	0	

Table 3.–Length composition of the 2010 sockeye salmon escapement at Kanalku Lake, weighted by statistical week.

Brood Year	**2006**	**2005**	**2005**	**2004**	
Age	**1.2**	**1.3**	**2.2**	**2.3**	**Total**
Male					
Sample size	182	42	1	1	226
Mean length (mm)	498	544	540	540	
SE	1.4	2.1	0	0	
Female					
Sample size	214	15	2	0	231
Mean length (mm)	491	540	475		
SE	1.1	3.2	16.1		
All Fish					
Sample size	397	57	3	1	458
Mean length (mm)	494	543	492	540	
SE	0.9	1.8	19.8	0	

DISCUSSION

The Petersen mark-recapture estimate of 2,970 sockeye salmon was chosen as the best estimate of escapement in 2010 since the weir count was below the lower end of the 95% confidence interval for the mark-recapture study. The discrepancy between the mark-recapture estimate and the weir count of 2,555 sockeye salmon could have resulted from bias in either the weir count or the mark-recapture study. Loss of marked fish due to mortality or change in behavior prior to reaching the spawning grounds would result in a mark-recapture estimate that was biased high (Seber 1982, Schwarz and Taylor 1998). Such losses of marked fish could have been caused by handling effects at the weir, predation on marked fish, or stress and injuries incurred as the fish attempted to scale the partial barrier falls. Salmon weirs must be rigorously maintained, however, and, although the crew checked for holes and gaps in the weir daily, it is also possible that a number of sockeye salmon were able to pass through the weir undetected, resulting in the lower weir count.

The 2010 sockeye salmon escapement of 2,970 at Kanalku Lake was similar to the 2009 escapement of 2,664 and larger than escapements in the previous eight years, 2001–2008 (Figure 5). From 2001 to 2010, sockeye salmon escapement estimates at Kanalku Lake averaged about 1,300 sockeye salmon. We believe the strong escapement observed in 2010 was due in part to low water conditions present throughout the sockeye salmon migration which increased fish passage over Kanalku Falls.

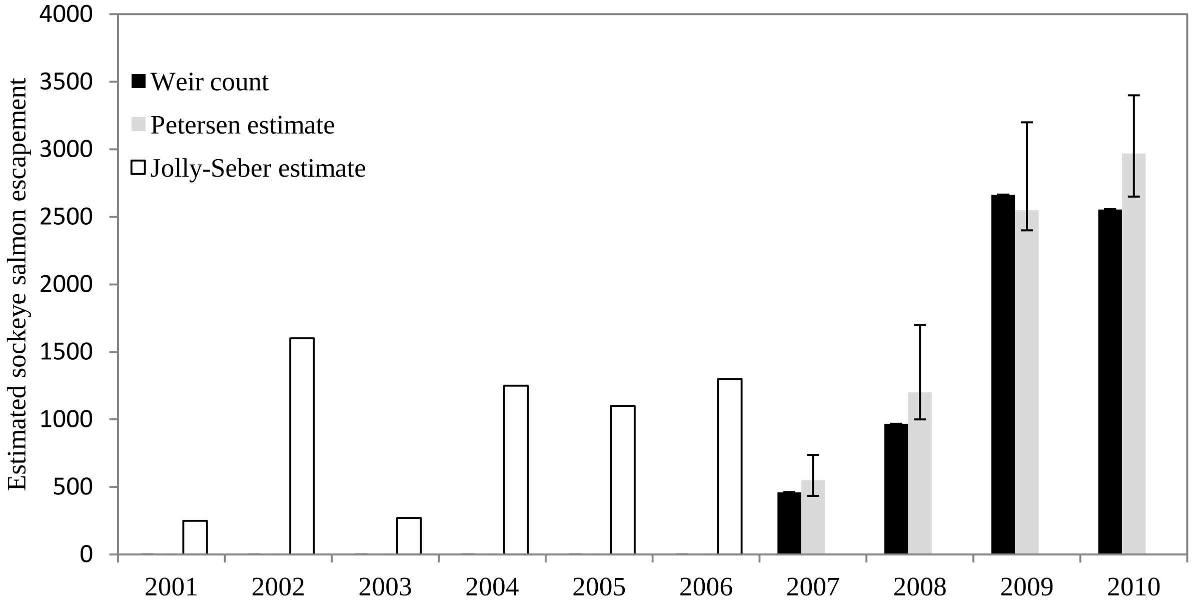

Figure 5.–Estimated adult sockeye salmon escapements from 2001 to 2010. Error bars represent the 95% confidence intervals of the Petersen mark-recapture estimates.

Prior to the installation of the weir at Kanalku Lake in 2007, little was known about the effect of stream level and water flow on fish passage over the falls. Initially, it was assumed that higher water conditions would favor sockeye salmon passage over the falls. However, our observations suggest that lower water flow at the falls may better aid sockeye salmon migration over the falls (Vinzant et al. 2010; Vinzant and Bednarski 2010). The mean stream depth during the peak period of sockeye salmon migration (15 July–10 August) was approximately 47 cm in 2007, 38 cm in 2008, 24 cm in 2009, and 32 cm in 2010 (Figure 6). Our stream gauge was located within the same 1 m^2 area each year and measurements provided rough (but not exact) annual comparison of stream height. During both the 2009 and 2010 field seasons when we observed larger sockeye escapements, the stream depth at Kanalku Creek was very low throughout the season (Figure 4; Vinzant and Bednarski 2010; Appendix B). Observations by the field crew at Kanalku Falls suggested that far fewer sockeye salmon were held up below the falls in both 2009 and 2010, and fish were regularly observed making successful jumps past the large plunge pool at the base of the falls. Additionally, sockeye salmon captured at the weir appeared in better health, with fewer injuries than observed during the 2007 and 2008 field seasons. In 2008 and 2009, the U.S. Forest Service used a dual-net weir system to estimate the number of sockeye salmon that entered lower Kanalku Creek below the falls. Their results, when compared to our weir data, suggested that less than 50% of the sockeye salmon that entered the creek in 2008—a high water season—successfully ascended the falls. Conversely, in 2009—a low water season—about 75% of the sockeye salmon that entered the Kanalku system were able to pass the falls (Vinzant and Bednarski 2010). Although the USFS did not continue their studies on lower Kanalku Creek in 2010, the larger escapement observed at Kanalku Lake, paired with low water conditions throughout the sockeye salmon migration period, strengthened our hypothesis that migration over Kanalku Falls is highly dependent on stream flow levels. Passage of sockeye salmon could possibly be improved by modifying or bypassing the partial barrier falls, although a well-designed study is needed to better evaluate the impact of any such modifications.

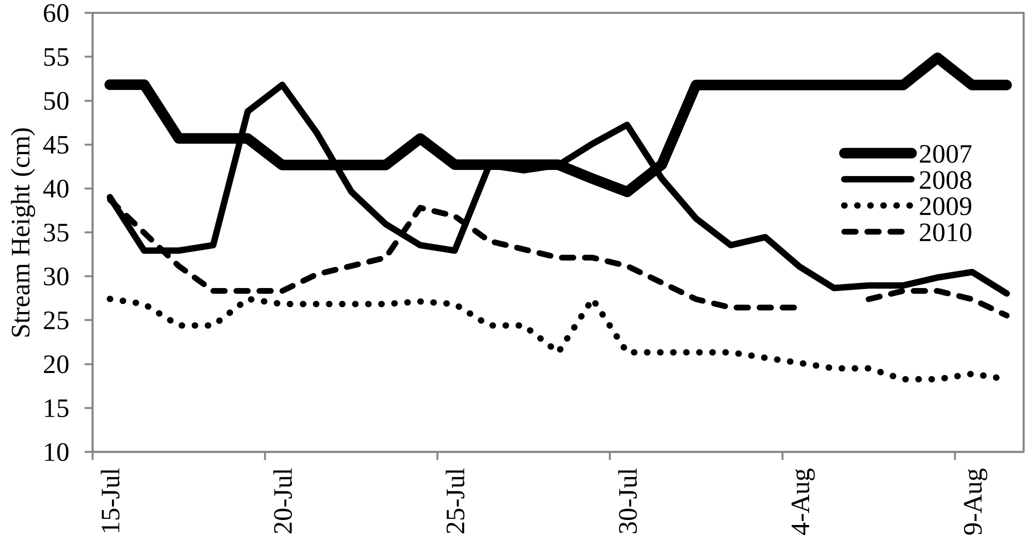

Figure 6.–Approximate daily stream depth at Kanalku Lake weir during the peak of sockeye salmon migration (15 July–10 August), 2007–2010.

The age composition of sockeye salmon sampled at the Kanalku Lake weir in 2010 was found to be predominately age-1.2 fish (86.9%). The remainder of the sockeye salmon sampled were nearly all age-1.3 fish (12.3%). As observed in previous seasons, very few other age classes were observed in 2010 (Table 4). Sockeye salmon sampled in 2010 were predominately from the 2006 and 2005 brood years, with one fish sampled from the 2004 brood year (Table 1). Age diversity has been low during our stock assessment studies at Kanalku Lake, with age-1.2 fish representing an average 75% of the escapement from 2001 to 2010 (Table 4).

Table 4.–Proportions of aged sockeye salmon sampled at Kanalku Lake from 2001 to 2010.

Year	**1.1**	**1.2**	**1.3**	**2.1**	**2.2**	**2.3**	**Age 1.-**	**Age 2.-**
2001	0.00	0.54	0.44	0.00	0.02	0.00	0.98	0.02
2002	0.00	0.80	0.16	0.00	0.03	0.00	0.97	0.03
2003	0.00	0.87	0.12	0.00	0.01	0.00	0.99	0.01
2004	0.00	0.76	0.23	0.00	0.01	0.00	0.99	0.01
2005	0.00	0.85	0.11	0.01	0.03	0.00	0.96	0.04
2006	0.00	0.97	0.03	0.00	0.00	0.00	1.00	0.00
2007	0.00	0.37	0.54	0.00	0.08	0.01	0.91	0.09
2008	0.00	0.96	0.02	0.00	0.03	0.00	0.97	0.03
2009	0.00	0.57	0.37	0.00	0.06	0.00	0.94	0.06
2010	0.00	0.87	0.12	0.00	0.01	0.00	0.99	0.01
Mean	0.00	0.75	0.21	0.00	0.03	0.00	0.97	0.03
SE	0.01	0.15	0.14	0.02	0.05	0.02	0.06	0.06

Harvest reporting is not yet complete for the 2010 season, but observations made on the fishing grounds suggested that the subsistence harvest of sockeye salmon at Kanalku Bay and Kanalku Creek was similar to that of the 2008 and 2009 seasons (Figure 1). In recent years it has been encouraging that local fishermen have been able to harvest sockeye salmon for their subsistence needs while allowing for improved escapement into Kanalku Lake. The Kanalku Lake sockeye salmon stock remains an important management priority for Angoon-area subsistence fisheries. Continuing the stock assessment activities, including annual observations of the spawning escapement, along with insights into the effects of stream flow and the associated mortality incurred at Kanalku Falls, will better help fisheries managers provide a sustainable balance between the escapement of spawning sockeye salmon and the traditional subsistence harvest by local residents.

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APPENDICES

The weekly age-sex distribution, the seasonal age-sex distribution weighted by week, and the mean length by age and sex weighted by week, for smolt and adults, were calculated using equations from Cochran (1977; pages 52, 107–108, and 142–144).

Let

h	=	index of the stratum (week),
j	=	index of the age class,
p_{hj}	=	proportion of the sample taken during stratum *h* that is age *j*,
n_h	=	number of fish sampled in week *h*, and
n_{hj}	=	number observed in class *j*, week *h*.

Then the age distribution was estimated for each week of the escapement in the usual manner:

$$\hat{p}_{hj} = n_{hj} / n_h \ . \tag{1}$$

If N_h equals the number of fish in the escapement in week *h*, standard errors of the weekly age class proportions are calculated in the usual manner (Cochran 1977, page 52, equation 3.12):

$$SE(\hat{p}_{hj}) = \sqrt{\left[\frac{(\hat{p}_{hj})(1-\hat{p}_{hj})}{n_h - 1}\right][1 - n_h/N_h]} . \tag{2}$$

The age distributions for the total escapement were estimated as a weighted sum (by stratum size) of the weekly proportions. That is,

$$\hat{p}_j = \sum_h p_{hj}(N_h/N), \tag{3}$$

such that N equals the total escapement. The standard error of a seasonal proportion is the square root of the weighted sum of the weekly variances (Cochran 1977, pages 107–108):

$$SE(\hat{p}_j) = \sqrt{\sum_j^h [SE(\hat{p}_{hj})]^2 (N_h/N)^2} \ . \tag{4}$$

The mean length, by sex and age class (weighted by week of escapement), and the variance of the weighted mean length, were calculated using the following equations from Cochran (1977, pages 142–144) for estimating means over subpopulations. That is, let *i* equal the index of the individual fish in the age-sex class *j*, and y_{hij} equal the length of the *i*th fish in class *j*, week *h*, so that,

$$\hat{\bar{Y}}_j = \frac{\sum_h (N_h/n_h) \sum_i y_{hij}}{\sum_h (N_h/n_h) n_{hj}} \text{, and} \tag{5}$$

$$\hat{V}\left(\hat{\bar{Y}}_j\right) = \frac{1}{\hat{N}_j^2} \sum_h \frac{N_h^2(1-n_h/N_h)}{n_h(n_h-1)} \left[\sum_i (y_{hij} - \bar{y}_{hj})^2 + n_{hj}\left(1 - \frac{n_{hj}}{n_h}\right)\left(\bar{y}_{hj} - \hat{\bar{Y}}_j\right)^2\right].$$

Appendix B.–Daily and cumulative counts of sockeye salmon, water depth, and temperature at Kanalku Lake in 2010. No other salmon species were observed.

Date	Sockeye salmon Daily	Sockeye salmon Cumulative	Water depth (m)	Water temperature (°C)	Air temperature (°C)
25-Jun	0	0	0.6	13.0	12.0
26-Jun	0	0	-	13.0	13.0
27-Jun	0	0	0.49	13.0	12.0
28-Jun	0	0	0.46	13.0	13.0
29-Jun	0	0	0.42	13.0	13.0
30-Jun	0	0	0.43	12.0	12.0
1-Jul	0	0	0.44	13.0	9.5
2-Jul	2	2	0.43	13.0	12.0
3-Jul	0	2	0.43	13.0	13.0
4-Jul	0	2	0.48	13.0	12.5
5-Jul	2	4	0.47	13.0	11.5
6-Jul	1	5	0.47	13.0	12.0
7-Jul	2	7	0.44	13.0	15.0
8-Jul	3	10	0.47	14.0	17.0
9-Jul	16	26	0.43	15.0	17.0
10-Jul	24	50	0.44	15.0	15.5
11-Jul	5	55	0.46	15.0	14.0
12-Jul	29	84	0.46	13.5	11.5
13-Jul	9	93	0.42	14.0	17.0
14-Jul	60	153	0.40	13.5	14.0
15-Jul	78	231	0.39	13.5	16.0
16-Jul	110	341	0.35	13.0	13.0
17-Jul	32	373	0.31	14.0	13.0
18-Jul	6	379	0.28	14.0	13.0
19-Jul	24	403	0.28	14.0	13.0
20-Jul	17	420	0.28	15.0	15.0
21-Jul	110	530	0.30	15.0	14.0
22-Jul	160	690	0.31	15.0	14.0
23-Jul	182	872	0.32	14.0	13.0
24-Jul	195	1,067	0.38	15.0	12.0
25-Jul	141	1,208	0.37	14.0	14.0
26-Jul	113	1,321	0.34	14.0	15.0
27-Jul	144	1,465	0.33	15.0	15.0
28-Jul	78	1,543	0.32	15.0	15.0
29-Jul	41	1,584	0.32	15.0	16.0
30-Jul	51	1,635	0.31	15.0	16.0
31-Jul	74	1,709	0.29	18.0	20.0
1-Aug	47	1,756	0.27	18.0	18.0
2-Aug	43	1,799	0.26	17.0	17.0

-continued-

Date	Sockeye salmon Daily	Sockeye salmon Cumulative	Water depth (m)	Water temperature (°C)	Air temperature (°C)
3-Aug	162	1,961	0.26	17.0	15.0
4-Aug	47	2,008	0.26	17.0	18.0
5-Aug	24	2,032	-	-	-
6-Aug	63	2,095	0.27	13.0	12.0
7-Aug	18	2,113	0.28	13.0	14.0
8-Aug	27	2,140	0.28	13.0	13.0
9-Aug	27	2,167	0.27	13.0	13.0
10-Aug	80	2,247	0.26	13.0	13.5
11-Aug	48	2,295	0.25	14.0	17.0
12-Aug	63	2,358	0.24	18.0	17.0
13-Aug	26	2,384	0.23	17.5	18.0
14-Aug	12	2,396	0.23	18.0	19.0
15-Aug	9	2,405	0.23	17.5	18.0
16-Aug	12	2,417	0.22	19.0	19.0
17-Aug	7	2,424	0.21	19.0	18.5
18-Aug	7	2,431	0.22	18.0	13.0
19-Aug	9	2,440	0.22	18.0	13.0
20-Aug	4	2,444	0.22	17.0	14.0
21-Aug	16	2,460	0.22	16.5	15.0
22-Aug	12	2,472	0.21	16.5	14.0
23-Aug	9	2,481	0.21	16.5	12.0
24-Aug	12	2,493	0.24	16.5	14.0
25-Aug	7	2,500	0.24	16.5	13.5
26-Aug	19	2,519	0.24	16.0	14.0
27-Aug	15	2,534	0.24	18.0	14.0
28-Aug	6	2,540	0.24	16.0	14.5
29-Aug	6	2,546	0.23	16.0	13.0
30-Aug	7	2,553	0.24	15.5	12.0
31-Aug	2	2,555	0.23	16.0	13.0
1-Sep	0	2,555	0.23	15.0	12.0
2-Sep	0	2,555	0.24	15.0	12.5
3-Sep	0	2,555	0.24	15.0	13.0
Season total		2,555			