Fishery Data Series No. 15-45

Kanalku Lake Subsistence Sockeye Salmon Project: 2014 Annual Report

by

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and

Steven C. Heinl

December 2015

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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ABSTRACT

The sockeye salmon (*Oncorhynchus nerka*) run at Kanalku Lake, Southeast Alaska, is the preferred traditional subsistence sockeye salmon stock for the nearby community of Angoon. A stock assessment program was initiated at Kanalku Lake in 2001 in response to community concerns over declining run size and possible overexploitation by local fishermen. Annual escapements were estimated through mark–recapture studies from 2001 to 2006 and through a standard picket weir operated at the outlet of the lake since 2007. In 2014, we counted 1,398 sockeye salmon at the picket weir near the lake outlet, and counted 1,321 sockeye salmon through a video camera weir just upstream of the picket weir. The difference in the two counts was likely due to predation by river otters (*Lontra canadensis*) between the weirs, and we consider the camera weir count to be the best estimate of the spawning escapement. We also operated a pair of video camera weirs in lower Kanalku Creek to estimate total sockeye salmon escapement into the Kanalku system and estimate the in-river mortality associated with Kanalku Falls, a partial barrier to sockeye salmon migration. The estimated total escapement was 2,160 fish; thus only 65% of the sockeye salmon that entered Kanalku Creek in 2014 successfully ascended the falls and were counted at the picket weir at Kanalku Lake. As in previous years, the escapement was composed primarily of age-1.2 sockeye salmon (78%).

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

INTRODUCTION

Kanalku Lake, located on the western side of Admiralty Island, supports a small run of sockeye salmon (*Oncorhynchus nerka*) that provides the primary sockeye salmon subsistence resource for the nearby community of Angoon (Bednarski et al. 2014). The use of Kanalku Bay as a traditional subsistence fishery has been documented in several historical and archaeological records, and artifacts from a traditional salmon weir at the head of Kanalku Bay provides 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). Other sockeye salmon runs in the vicinity, including Sitkoh and Basket bays, also provide subsistence opportunity for Angoon residents, but require travel across the open waters of Chatham Strait; thus, Kanalku Bay remains the preferred harvest area due to its close proximity to the village and ease of access through sheltered waterways (Geiger et al. 2007).

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 Alaska 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 placed under a permit system (Turek et al. 2006). Participation in commercial fisheries by Angoon residents has declined steadily since the 1980s; in 1980, 90 residents fished 134 commercial fisheries permits; however, by 2010, only six residents fished six commercial permits (data from the Commercial Fisheries Entry Commission http://www.cfec.state.ak.us/fishery_statistics/earnings.htm). This decline in participation in commercial fisheries has led to a loss in mobility, which has concentrated the community's subsistence activities closer to home (Bednarski et al. 2014). Residents of Angoon can obtain subsistence fishing permits for Kanalku and other nearby areas, but most people prefer to fish in Kanalku Bay (Conitz and Burril 2008). From 1985 to 2001, Kanalku Bay accounted for an average 85% of the reported sockeye salmon subsistence harvest by Angoon residents, and the reported annual harvest and participation at Kanalku increased substantially from a 1985–1992 average of 580 fish and 24 permits to a 1993–2001 average of 1,300 fish and 58 permits (Figure 1; Bednarski et al. 2014).

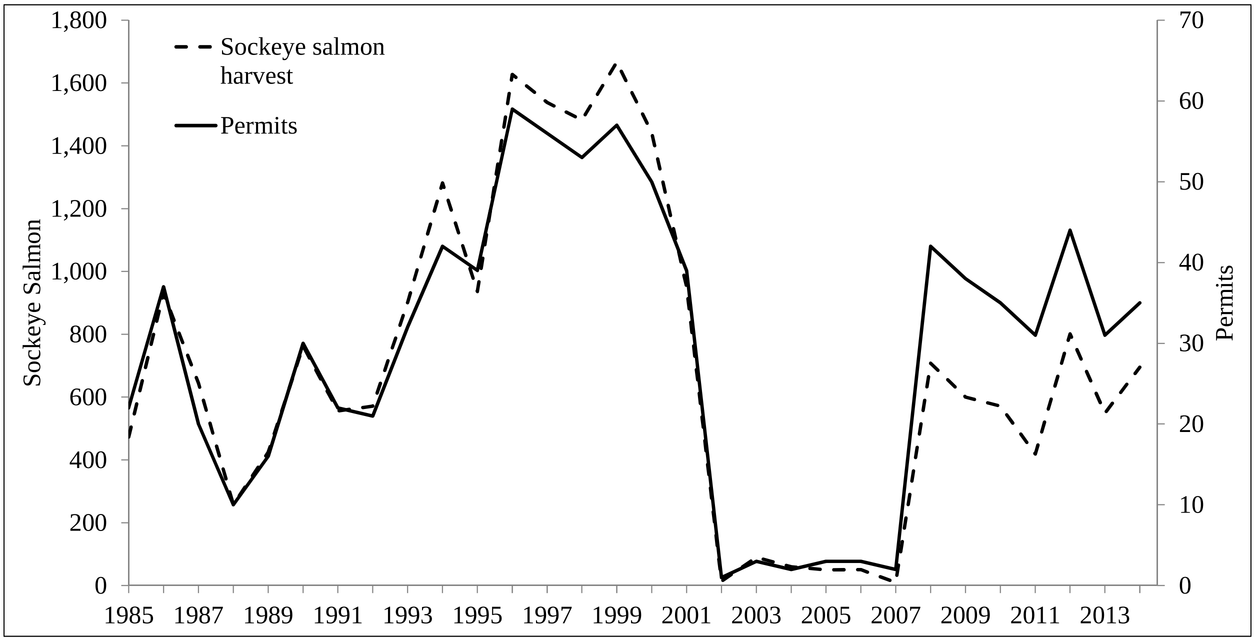

Figure 1.–Reported subsistence sockeye salmon harvest and permits issued, 1985 to 2014. (2014 data are preliminary.)

In 2001, the Alaska Department of Fish and Game (ADF&G), the Angoon Community Association (ACA), and the USDA Forest Service (USFS), initiated a stock assessment program at Kanalku Lake in response to concern by some Angoon residents regarding increased harvest, possible decline in run size, and lack of information about spawning escapements (Conitz and Cartwright 2005). Funding for this project has been provided by grants from the Federal Office of Subsistence Management. From 2001 to 2006, mark–recapture studies were conducted at Kanalku Lake to estimate the spawning population of sockeye salmon (Conitz and Burrill 2008). In 2007, ADF&G and the ACA improved the stock assessment project by operating a salmon counting weir directly below the outlet of Kanalku Lake and conducting mark–recapture studies to verify weir counts (Appendix B).

In 2001, the reported subsistence harvest of 951 sockeye salmon far exceeded a mark–recapture estimate of only 250 spawners at Kanalku Lake (Conitz and Cartwright 2005). In an effort to rebuild the run, ADF&G and the community of Angoon instituted a voluntary subsistence harvest closure at Kanalku from 2002 to 2005. In addition, ADF&G liberalized annual harvest limits at nearby, traditionally used systems to provide opportunity for Angoon residents to fulfill subsistence needs (Conitz and Burril 2008; Bednarski et al. 2014). During that time, the reported Kanalku subsistence harvest averaged 50 fish and spawning escapements averaged 1,060 fish. In 2006, ADF&G and the community agreed to end the voluntary closure at Kanalku; however, the annual limit at Kanalku was reduced from 25 to 15 fish per household to allow for a conservative harvest and to continue rebuilding the run (Bednarski et al. 2014). Since 2008, the reported Kanalku subsistence harvest has averaged 610 fish and spawning escapements improved to an average 1,690 fish.

In addition to concerns regarding increased subsistence harvest and small escapements, there is also concern regarding the impact that a partial barrier falls on Kanalku Creek has on the total size of the sockeye salmon spawning population. After swimming upstream from saltwater, sockeye salmon sit in pools below the falls for variable lengths of time, depending on water flow, where they are subjected to high rates of predation and additional physical stress as they repeatedly attempt to scale the falls and migrate upstream. In 1970, the USFS and ADF&G blasted four shallow step pools on the left side apron of Kanalku Falls to improve fish passage (Geiger et al. 2007; USDAFS 2011). The effect on fish passage is not known, however, since no pre- or post-modification studies were conducted, and many fish still do not successfully ascend the falls. Incomplete studies conducted in 2008 and 2009 suggested that a large portion of the sockeye salmon escapement did not migrate past the falls in those years, but those studies did not provide precise estimates of the total sockeye salmon escapement into the Kanalku system (Vinzant and Bednarski 2010).

In 2012, ADF&G initiated a study to quantify the in-river mortality incurred by sockeye salmon at Kanalku Falls. This project has been funded through grants from the Alaska Sustainable Salmon Fund. A pair of camera weirs, equipped with motion-detection digital video recorders (DVR) and underwater cameras, were used to count the total sockeye salmon escapement into lower Kanalku Creek below Kanalku Falls. The in-river mortality, determined by direct comparison of the total escapement below the falls to the spawning escapement at Kanalku Lake, was estimated to be 51% in 2012 and 24% in 2013 (Vinzant et al. 2013; Vinzant and Heinl 2014). In August 2013, the USFS and ADF&G conducted Phase I of a project to further modify the Kanalku Falls and improve sockeye salmon passage. A large shelf of bedrock was blasted out of the plunge-pool at the base of Kanalku Falls to widen and deepen the pool and provide sockeye salmon a better jump at the falls (Greg Albrecht, Habitat Biologist, ADF&G, Douglas; memorandum 24 September 2013).

In 2014, we conducted the 14th year of stock assessment work at Kanalku to estimate the total sockeye salmon escapement into the Kanalku system, the spawning escapement at Kanalku Lake, and the in-river mortality associated with Kanalku Falls—a significant source of mortality on the run and a key aspect of their life history that has only recently been quantified. The information gathered, along with biological data on age and size at return, will directly benefit management of the Kanalku subsistence fishery through more complete accounting of sockeye salmon production by brood year and improved expectations of annual run size. Information collected on the in-river mortality rate associated with fish passage over Kanalku Falls will help to assess the recent barrier modification work and determine if further modifications are needed to improve the spawning escapement of sockeye salmon at Kanalku Lake.

OBJECTIVES

1. Count all salmon species entering lower Kanalku Creek, below Kanalku Falls, through a series of two double-camera weirs for the duration of the sockeye salmon run to estimate total escapement into the Kanalku system.
2. Count all salmon species passed through a picket weir into Kanalku Lake for the duration of the sockeye salmon run to estimate spawning escapement.
3. Validate the picket weir escapement count with a mark–recapture estimate of the sockeye salmon spawning population with an estimated coefficient of variation no greater than 15% of the point estimate.
4. Estimate the sockeye salmon mortality rate at Kanalku Falls.

5. Estimate the age, length, and sex composition of the Kanalku Lake sockeye salmon spawning escapement such that the estimated proportion of each age class is within 5% of the true value with at least 95% probability.

METHODS

STUDY SITE

Kanalku Lake (lat. 57° 29.22'N, long. 134° 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 (Nowacki et al. 2001). 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 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.

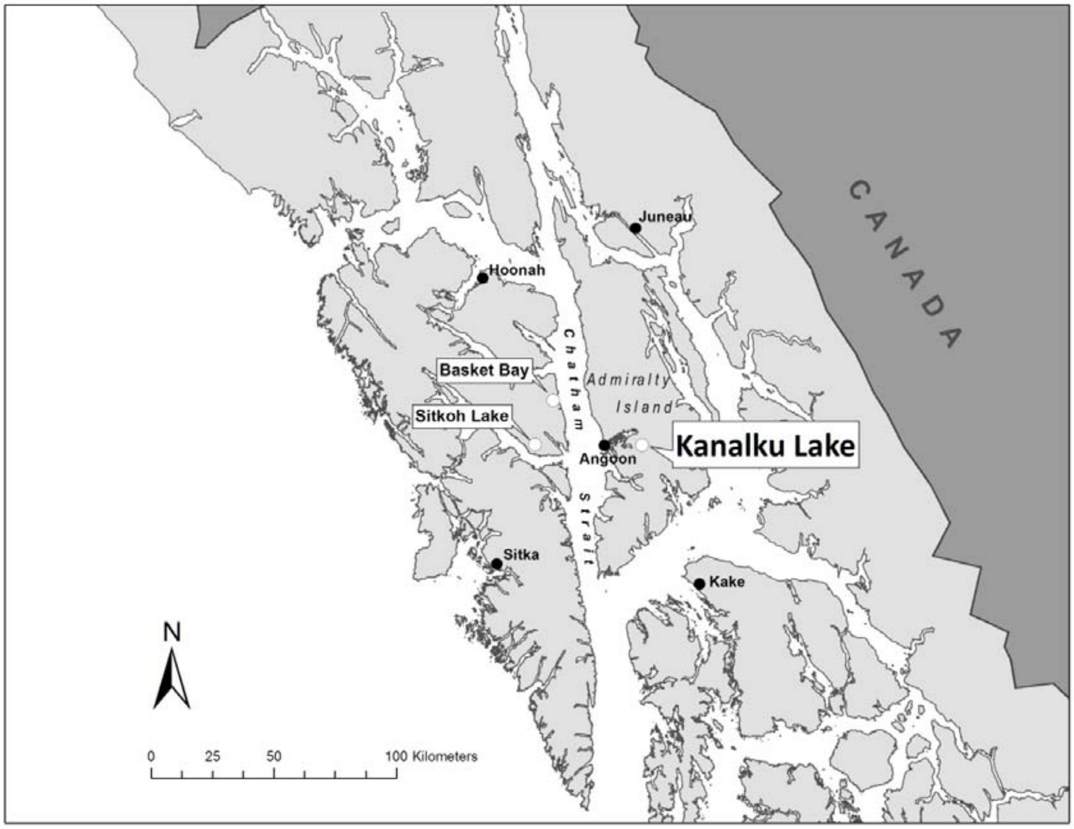

Figure 2.–Map of Southeast Alaska showing location of Kanalku Lake, the village of Angoon, and other locations mentioned in the text.

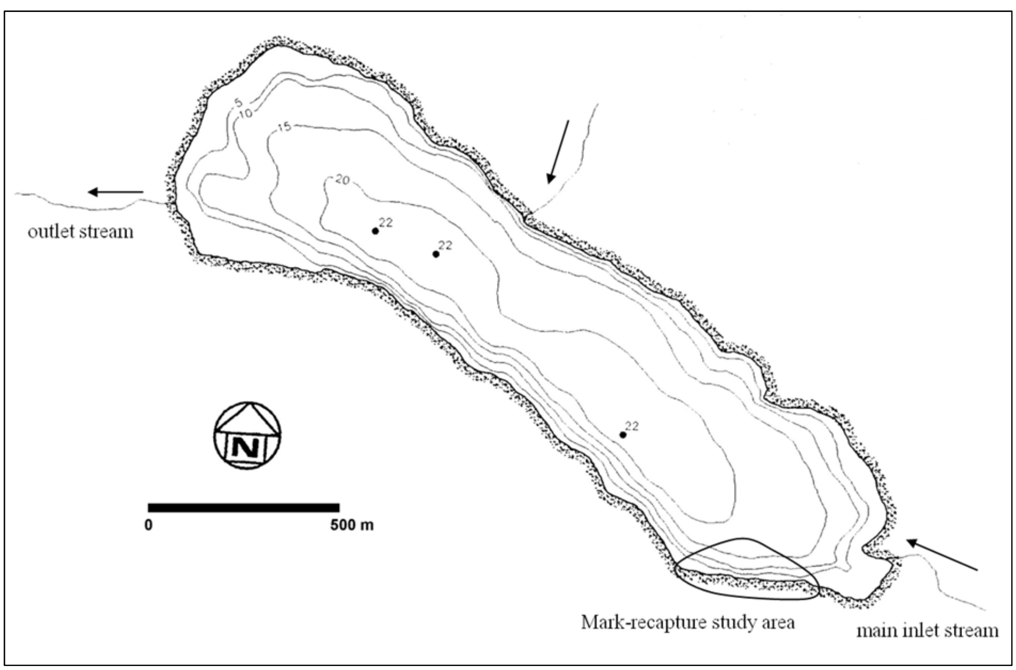

Figure 3.–Bathymetric map of Kanalku Lake showing 5-m depth contours and the mark–recapture study area. Arrows indicate direction of stream flow.

SOCKEYE SALMON TOTAL ESCAPEMENT ESTIMATE

The total sockeye salmon escapement to the Kanalku system was counted through a series of two video camera weirs located approximately 0.5 km upstream from the mouth of Kanalku Creek and approximately 300 m downstream of Kanalku Falls. Two video cameras were mounted to a video chute at each weir, and fish were recorded 24 hours per day as they swam through the video chutes (Figure 4). The double-redundancy of the two-weir, four-camera system allowed us to validate fish counts and eliminated the need for a back-up mark–recapture estimate (Van Alen and Mahara 2011).

Lower Creek Camera Weirs

The camera weirs were operated from 15 June to 29 August. The weirs were constructed by anchoring an aluminum video chute to the stream bed. A series of weir panels were attached to each side of the video chute, anchored into the stream bed, and aligned in a "V" shape to help guide fish quickly through the video chute (Figure 5). The weir panels were fitted with 1.5-m tall, 1.3-cm diameter EMT conduit pickets, with "pink salmon" spacing of 4.45 cm on center. Vinyl-coated welded wire fencing (2.5 cm^2 mesh) was attached to the weir panel ends and extended to the stream banks as wings. The fencing material was supported by a series of 2-m fence posts driven into the stream bottom and spaced approximately 2.4 m apart. Two rows of 1.3 cm EMT conduit were used as horizontal stringers and attached to the vertical posts. The bottom of the fencing material was also folded to form an apron on the upstream side of the weir, approximately 45 cm wide, and was secured to the stream bottom with a double row of sandbags. The fencing material was secured to the EMT stringers and posts with cable ties. The crew cleaned the weirs daily, checked for holes or scouring, and ensured the structure was fish-tight.

Camera Counts

Two underwater color video cameras containing Sony 8.47 mm HAD CCD 3.6 mm sensors were installed on each video chute to record passing fish. Video cables transferred data from the cameras to mini-DVRs (Digital Video Recorders). The video was motion-detected, 30-frames-per-second, and video files were stored on SD memory cards. The video chutes were lighted at night by two 25.4 cm, 14-bulb bright white LED light strips attached to the top of the chutes. Photoelectric sensors were used to turn the lights on only from dusk to dawn to conserve battery power. The paired video systems at each video chute were powered by two 140-watt solar panels that trickle charged a 100 ah AGM (absorption glass matt) 12V DC battery through a metered 30A charge controller. The solar panels were positioned to face both the morning and afternoon sun. The mini-DVRs and a 17.78 cm color TFT monitor were housed in a Pelican case (Figure 6). DC-DC step-down voltage converters were used to regulate power to the mini-DVRs (5V DC).

Figure 4.–Sockeye salmon swimming through a lower creek camera weir. (©2013 ADF&G/photo by Raymond F. Vinzant.)

At each camera station, a pair of SD cards (for left and right cameras) were changed out daily. The crew used a laptop computer to review video data back at camp. Video footage was reviewed daily by the crew, and separate counts were kept for all salmon species captured by the cameras at each of the camera weirs. Counts by hour for each camera and any other observations were recorded onto spreadsheets. Video files were backed up daily on a laptop computer and an external hard drive. At the end of the season, video files were reviewed again to corroborate inseason counts.

Figure 5.–Camera weirs installed in lower Kanalku Creek, below Kanalku Falls, 2012. (©2012 ADF&G/photo by Raymond F. Vinzant.)

Figure 6.–Camera weir video recording components housed in a waterproof Pelican case. (©2012 ADF&G/photo by Raymond F. Vinzant.)

SOCKEYE SALMON SPAWNING ESCAPEMENT ESTIMATE

We used a standard picket weir to estimate the spawning escapement of sockeye salmon into Kanalku Lake. We also used a camera weir upstream of the standard picket weir to count fish into the lake, validate the picket weir count, and serve as a recapture location for a back-up mark–recapture estimate. Successful application of a camera weir at Kanalku Lake would result in a reduction in both the handling of live fish on the spawning grounds and the overall cost of the project by eliminating mark–recapture work conducted on the spawning grounds in September.

Picket Weir count

The picket weir was operated from 25 June to 3 September, and 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 4.45 cm on center of the pickets. This spacing allowed for 52 pickets per channel with a maximum space of approximately 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. The field crew 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. White sandbags were placed on the bottom of the stream bed at the 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 (cm), air and water temperature (°C), and weather were recorded at the weir. Water level was measured daily at approximately the same location (within 1 m^2) as the 2007 to 2013 field seasons.

Lake Camera Weir

Fish were counted with a video camera weir placed directly upstream of the standard picket weir, at the outflow of Kanalku Lake (Figure 7). The lake camera weir was constructed with 1/3-length EMT weir pickets (100 cm) placed in 52 hole stringers, 4.45 cm on center. The stringers were supported by iron pipes driven into the stream bed, sandbags, and ropes tied off to nearby trees. Fish passed through an aluminum chute containing two underwater cameras connected to a DVR recording system. (See Camera Counts section above for details on video operation and camera counts.)

Figure 7.–Lake camera weir, directly below the outlet of Kanalku Lake, 2014. The standard picket weir is seen downstream of fallen tree. (©2014 ADF&G/photo by Raymond F. Vinzant.)

MARK–RECAPTURE POPULATION ESTIMATE

The spawning population of sockeye salmon was estimated with a two-event mark–recapture study for a closed population (Seber 1982). The mark–recapture study allowed us to determine if sockeye salmon passed through the primary picket weir undetected and served as a back-up estimate in the case that either the picket weir or lake camera weir was breached or damaged. In Event 1, fish were marked at the picket weir with an adipose fin clip. To minimize handling, we marked fish that were also sampled for age, sex, and length (see below). Sockeye salmon that appeared unhealthy were enumerated and released without marks. In Event 2, fish counted at the lake camera weir were examined for presence/absence of an adipose fin and mark status was recorded. Fish that could not confidently be examined for presence of an adipose fin were not included in the mark–recapture study.

If the lake camera weir estimate was compromised, Event 2 mark–recapture sampling would be conducted on the spawning grounds on at least four sampling trips between late August and late September. Fish would be captured and sampled with a beach seine at 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; Conitz and Burril 2008). An opercular punch would be applied to all sockeye salmon in these samples to prevent double sampling on that day or on subsequent sampling days. Carcasses would also be sampled and marked with an opercular punch during the recovery events.

We estimated the sockeye salmon spawning escapement using Chapman's Modified Petersen estimator (Seber 1982):

$$\hat{N} = \frac{(m+1)(c+1)}{(r+1)} - 1, \quad (1)$$

where $\hat{N}$ is the estimated population size, m is the estimated number of fish marked during Event 1, c is the number of fish captured and sampled for marks during Event 2, and r is the number of fish recaptured during Event 2 that were marked in Event 1.

We used a parametric bootstrap procedure to estimate the standard error and construct the 95% confidence intervals for the escapement estimate. We assumed that the number of marked fish recaptured (r) in Event 2 followed a hypergeometric probability distribution. We then used the number of fish marked (m) in Event 1, the number of fish caught (c) in Event 2, and the Petersen estimate of escapement ($\hat{N}$) to generate 5,000 simulated recapture numbers (r), based on the hypergeometric probability density function, $f(r| m, c, \hat{N})$. From the bootstrap values of r, we derived 5,000 Petersen escapement estimates, and then calculated the standard error of these estimates and used the 0.025 and 0.975 quantiles to construct the 95% confidence intervals. We deemed the picket weir count of sockeye salmon to be "verified" if the count fell within the 95% confidence intervals of the mark–recapture estimate.

ESTIMATE OF MORTALITY RATE AT KANALKU FALLS

The mortality rate at the Kanalku Falls (i.e., the number of fish that did not successfully ascend the falls) was estimated by simply subtracting the best estimate of spawning escapement from the estimated total sockeye salmon escapement into the Kanalku Creek system.

ADULT POPULATION AGE AND SIZE COMPOSITION

The age composition of the sockeye salmon escapement was determined from a minimum of 425 scale samples collected from live fish at the picket weir. Based on the work by Thompson (1992), and assuming a run of around 1,000 sockeye salmon, a sample of 338 fish was determined to be adequate to ensure estimated proportions of each age class would be within 5% of the true value with at least 95% probability. We increased our sampling goal to 425 fish to ensure we met the target sample size even if 25% of the scale samples were unreadable. We began the season with a weekly sampling goal of 30% of the cumulative weekly escapement. Weekly sampling goals were adjusted by the project leader depending on inseason run strength.

If a fish appeared overly stressed, 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 mideye to tail fork, to the nearest millimeter. 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 B).

RESULTS

SOCKEYE SALMON TOTAL ESCAPEMENT ESTIMATE

Lower Creek Camera Weir Count

The dual camera weirs on lower Kanalku Creek, below Kanalku Falls, were operated between 15 June and 29 August. The first sockeye salmon of the season was recorded on 16 June (Figure 8). A total of 2,123 adult sockeye salmon were counted through the downstream camera weir and 2,160 adult sockeye salmon were counted through the upstream camera weir (or 2% more than the lower weir). Sockeye salmon migration into lower Kanalku Creek was greatest between 5 July and 10 August. The largest daily count occurred at the downstream camera weir on 26 July, when 130 adult sockeye salmon were recorded (Figure 8). As observed in previous seasons, sockeye salmon primarily traveled in the darkness between 23:00 and 04:00. No jack sockeye salmon were observed.

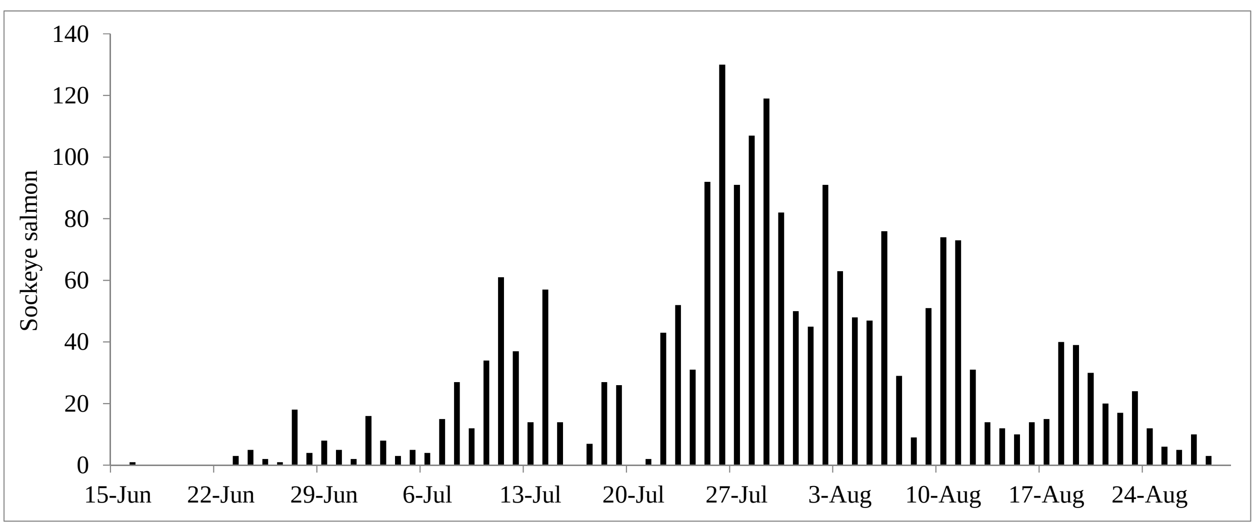

Figure 8.–Daily sockeye salmon counts at the lower Kanalku Creek camera weir, 2014.

Both camera weirs were operated without major incident throughout the season. Neither camera weir was breached by high water events, nor were any holes or gaps found in the weirs that would have allowed fish to pass undetected. The difference in counts between the upper and lower camera weirs was likely due to fish passing through the video chute too quickly to be captured by the motion sensing capabilities of the DVRs. Review of the video data files revealed many video clips containing only a partial shot of a fish tail from which the species could not be positively identified. The downstream camera weir, which had the lower sockeye salmon count, was in relatively shallow water, which may have encouraged fish to swim more quickly through the camera chute. We chose the larger upstream camera weir count of 2,160 sockeye salmon (Appendix C) as the best estimate of the total sockeye salmon escapement for the 2014 season.

Other species of fish recorded at the camera weirs included numerous pink salmon, abundant Dolly Varden and cutthroat trout, several chum salmon, and one coho salmon. We did not enumerate fish species other than sockeye salmon, because we considered those counts to be incomplete. Pink and chum salmon primarily spawn downstream of the weir site and coho salmon migration occurs primarily after the project ends for the season. Smaller cutthroat trout and Dolly Varden are able to freely pass through the weir fence and pickets and bypass the video cameras entirely.

SOCKEYE SALMON SPAWNING ESCAPEMENT ESTIMATE

Picket Weir Count

A total of 1,398 adult sockeye salmon were counted through the picket weir between 25 June and 3 September 2014 (Figure 9; Appendix D). The first day sockeye salmon were counted at the picket weir was 28 June; nine days after fish were first observed at the camera weirs below Kanalku Falls (Figures 9 and 10). No other salmon species or jack sockeye salmon were counted at the picket weir. No high water events occurred and no holes were found in the weir that would have allowed fish to pass uncounted. Daily sockeye salmon counts were greatest between 24 July and 18 August and the peak daily escapement occurred on 3 August when 156 sockeye salmon were passed through the picket weir.

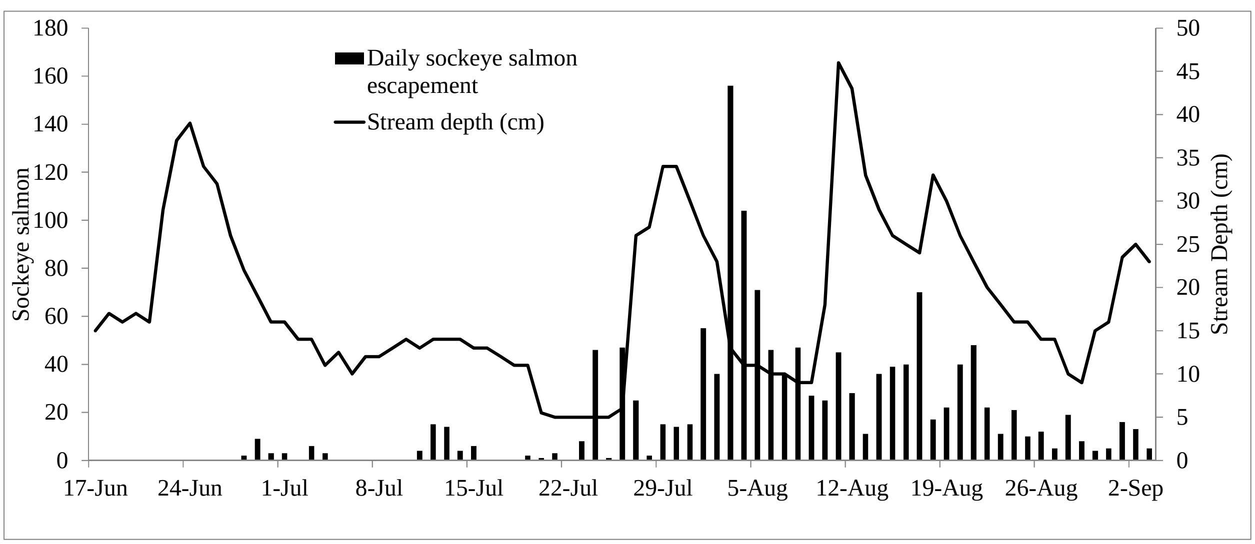

Figure 9.–Daily sockeye salmon escapement and stream depth (cm) at the Kanalku Lake picket weir, 2014.

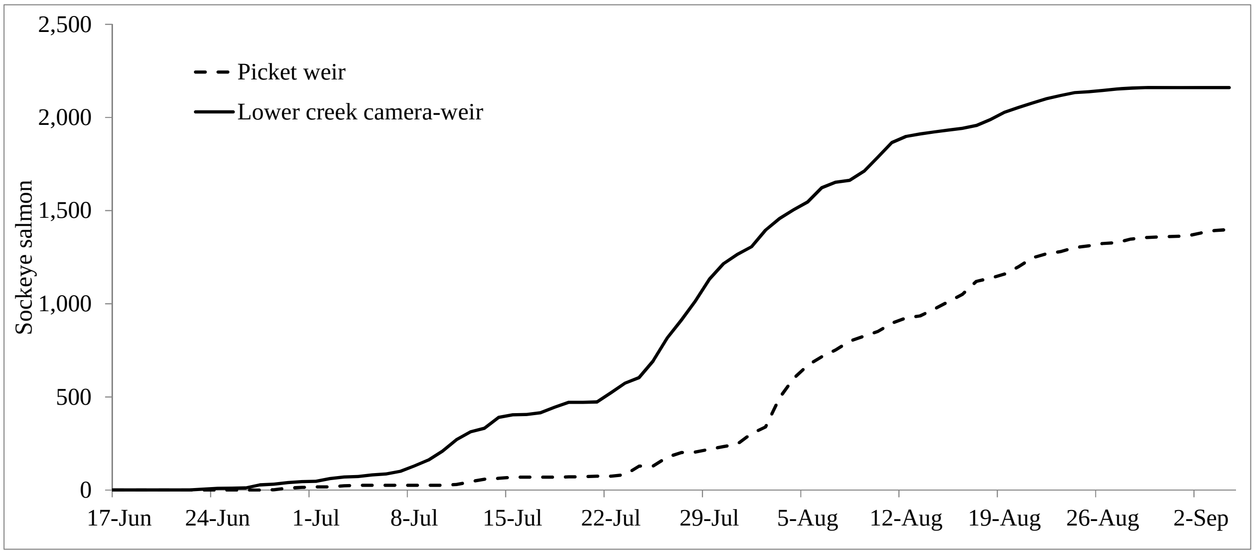

Figure 10.–Comparison of timing and cumulative escapement of sockeye salmon between the camera weirs on lower Kanalku Creek and the picket weir near Kanalku Lake, 2014.

Mark–Recapture Population Estimate

A total of 445 adult sockeye salmon were marked with adipose fin clips at the picket weir between 28 June and 2 August 2014 (Table 1). The lake camera weir was installed above the standard picket weir in the outlet of the lake on 28 June 2014. Video quality was good, and the crew was able to easily determine if sockeye salmon were marked with an adipose fin clip on nearly all fish recorded. A total of 1,321 adult sockeye salmon were counted through the lake camera weir, which was 77 fish (6%) less than the picket weir count of 1,398 fish. Predation on sockeye salmon by river otters (*Lontra canadensis*) was observed in the video data, and otters were seen on video carrying 44 sockeye salmon through the lake camera weir. More sockeye salmon were undoubtedly preyed upon by otters than was observed in the video data. (Appendix E).

A total of 1,295 (98%) of the 1,321 sockeye salmon that passed through the lake camera weir were inspected for adipose fin clips, of which 426 fish were marked (Table 1). We calculated a very precise Petersen estimate of approximately 1,360 sockeye salmon with a 95% confidence interval of approximately 1,330 to 1,375 fish. The coefficient of variation (CV) of 0.8% met our objective of an estimate with a CV of less than 15%.

Table 1.–Number of sockeye salmon marked at the picket weir, number sampled and recaptured on video at the lake camera weir and the Petersen estimate of abundance, 2014.

Count at picket weir	1,398
Marked at picket weir	445
Proportion marked at picket weir	0.32
Sampled during recapture events	1,295
Marked recaptures	426
Proportion marked in sample	0.33
Petersen estimate of abundance	1,360
95% CI of estimate	1,330–1,375
SE of estimate (CV)	11 (0.8%)

ADULT POPULATION AGE AND SIZE COMPOSITION

A total of 453 adult sockeye salmon were sampled for age, sex, and length composition in 2014, of which 394 fish were successfully aged. As observed in previous years, the spawning escapement was composed primarily of age-1.2 fish (78%; brood year 2010), followed by age-1.3 fish (18%; brood year 2009), age-2.2 fish (4%; brood year 2009), and a few age-3.2 fish (<1%; brood year 2008) (Tables 2 and 3). Age-1.2 sockeye salmon had a mean length of 508 mm for males and 493 mm for females, and age-1.3 fish had a mean length of 579 mm for males and 541 mm for females (Table 4).

Table 2.–Age composition of the 2014 sockeye salmon escapement at Kanalku Lake based on scale samples, weighted by statistical week.

Brood year	2010	2009	2009	2008	
Age	1.2	1.3	2.2	3.2	Total
Sample size	304	74	15	1	394
Escapement by age class	1,087	253	55	3	1,398
SE of escapement	28	22	10	---	
Percent	78%	18%	4%	0%	
SE of %	2%	2%	1%	0%	

Table 3.–Estimated age composition of the Kanalku Lake sockeye salmon escapement, 2001–2014.

Year	Age class 1.1	1.2	1.3	2.1	2.2	2.3	3.2
2001	–	0.55	0.43	–	0.02	–	–
2002	–	0.80	0.16	–	0.03	–	–
2003	–	0.87	0.11	–	0.01	–	–
2004	–	0.76	0.23	–	0.01	–	–
2005	–	0.85	0.11	0.01	0.03	–	–
2006	–	0.97	0.03	–	–	–	–
2007	–	0.37	0.54	–	0.08	0.01	–
2008	–	0.96	0.02	–	0.03	–	–
2009	–	0.57	0.37	–	0.06	–	–
2010	–	0.87	0.12	–	0.01	–	–
2011	–	0.52	0.43	–	0.04	–	–
2012	–	0.89	0.06	–	0.05	–	0.01
2013	–	0.80	0.15	–	0.03	–	0.01
2014	–	0.78	0.18	–	0.04	–	0.01
Mean	0.00	0.75	0.21	0.00	0.03	0.00	0.00

Table 4.–Estimated length composition of the 2014 sockeye salmon escapement at Kanalku Lake, weighted by statistical week.

Brood year	2010	2009	2009	2008	
Age	1.2	1.3	2.2	3.2	Total
Male					
Sample size	130	43	6	1	180
Mean length (mm)	508	579	514	570	
SE	1.9	2.9	8.3	---	
Female					
Sample size	174	31	9	0	214
Mean length (mm)	493	541	501	---	
SE	1.5	3.1	6.4	---	
All fish					
Sample size	304	74	15	1	394
Mean length (mm)	501	560	508	570	
SE	1.7	3.0	7.4	---	

DISCUSSION

In 2014, our lower creek camera weir count of 2,160 sockeye salmon represented the third consecutive season we have estimated the total escapement of sockeye salmon into the Kanalku system, below Kanalku Falls. The picket weir count of 1,398 sockeye salmon represented the best estimate of the number of fish that successfully ascended the falls. Thus, we estimate that 65% of the in-river run successfully ascended the falls in 2014; an in-river mortality rate of 35%. This was also the first year that escapement was measured since barrier-modification work was conducted at Kanalku Falls in August 2013. In the two years prior, in-river mortality was estimated to be 51% (2012) and 24% (2013) (Vinzant et al 2013; Vinzant and Heinl 2014).

Previous work at Kanalku suggested that lower water flows favor sockeye salmon passage over the falls (Vinzant and Bednarski 2010; Vinzant et al. 2010).The estimated in-river mortality was higher in 2012 (51%; Vinzant et al. 2013) when stream depth was above average (2007–2014) throughout the season, in contrast to the lower estimated in-river mortality found in 2013 (24%; Vinzant and Heinl 2014) when stream depth was below average. Although stream depth was below average over most of the 2014 season (Figure 11), sharp increases in stream depth around 29 July and 11 August appeared to delay movement of fish over the falls (Figures 8 and 9), which may have accounted for the higher in-river mortality (35%) compared to 2013. Additional years of information should provide a better understanding of how water depth affects fish movement over the falls and if Phase I of the barrier modification project improved fish passage. If needed, Phase II may be implemented, which would add an 18–24 inch concrete sill to raise the water level of the plunge pool at the base of the falls.

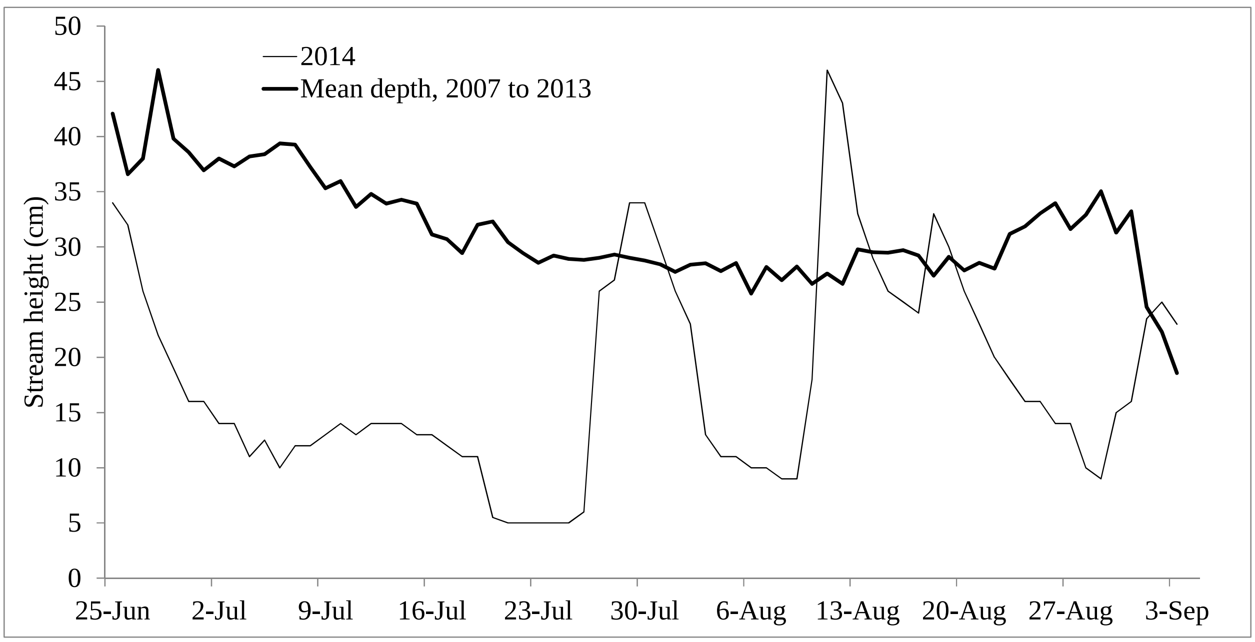

Figure 11.–Stream depth (cm) at the Kanalku Lake picket weir in 2014, compared to mean stream depth, 2007–2013.

In 2014, we produced three estimates of the spawning escapement above the falls, all of which were very similar: the picket weir count of 1,398 fish, the mark–recapture estimate of 1,360 fish, and the lake camera weir count of 1,321 fish. The lake camera weir worked very well as a mark–recapture platform, and nearly all sockeye salmon "captured" by video were "sampled" for adipose fin clips. As a result, our mark–recapture estimate was extraordinarily precise (95% CI 1,330–1,375; CV < 1%). The 77 fish difference between the picket weir count and the camera weir count was likely due to otter predation, much of which (44 fish) was documented at the camera weir. Therefore, we chose the lake camera weir count of 1,321 sockeye salmon as the best estimate of the 2014 spawning escapement into Kanalku Lake—an escapement very close to the 2001–2013 average of 1,260 fish (Figure 12).

Video cameras and DVR recorders were successfully used to enumerate sockeye salmon again in 2014. Late in the season, we experienced some problems with low battery power due to prolonged periods of low cloud cover. Incorporating a larger battery bank or more solar panels would likely eliminate any power issues in the future. The motion-detection DVR and camera systems worked well to capture fish throughout all hours, day and night, and video quality was generally good. Video images were grainy in low-light hours when the lights were not on; however, species identification was not a problem. Sockeye salmon did not appear reluctant to travel through the video chutes and generally moved right through both lower creek camera weirs with little lag time. Adipose fin clips (marks) were easily observed on the majority of sockeye salmon captured on video at the lake camera weir, which proved an excellent mark–recapture platform.

In future years, we recommend operating only one camera weir below Kanalku Falls instead of two. In all three seasons of operation, the difference in counts between the two lower creek camera weirs was 3% or less (Vinzant et al. 2013; Vinzant and Heinl 2014). We have experienced few problems with the video systems or the weirs, which are relatively small and easy to maintain, and we are confident that a reliable count can be obtained with one weir in the lower creek. Operating one weir would greatly reduce the amount of time required to review video data and the amount of equipment needed to run the project. It would also eliminate potential predation between the camera weirs. Otter activity at the outlet of Kanalku Lake will be closely monitored next season and, if predation on sockeye salmon appears to be a problem, we will remove the picket weir and operate only the camera weir, which will allow sockeye salmon to swim unimpeded into the lake.

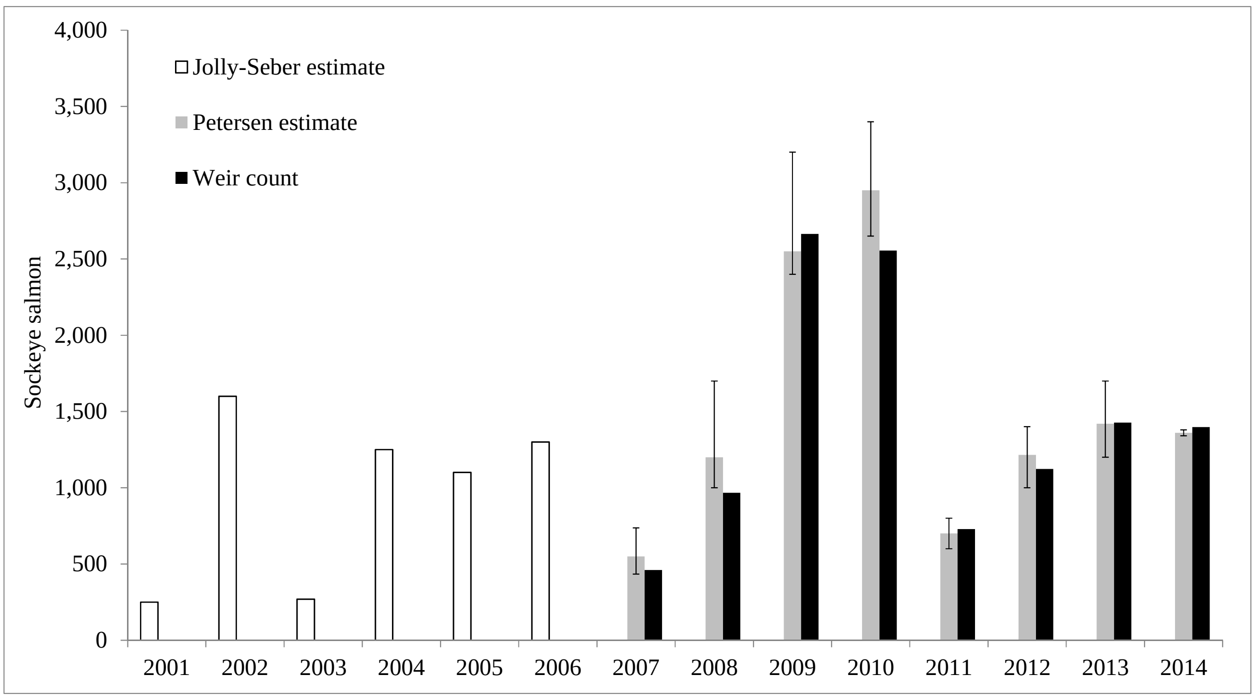

Figure 12.–Estimated sockeye salmon spawning escapements at Kanalku Lake from 2001 to 2014. Error bars represent the 95% confidence intervals of the Petersen mark–recapture estimates.

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APPENDICES

Appendix A.–Estimated annual spawning escapement and subsistence harvest of Kanalku Lake sockeye salmon, 2001–2014. Escapement estimates were based on weir counts and mark–recapture estimates.

			Mark–recapture estimate					
Year	Picket weir count	Camera Weir count	Petersen estimate[a]	Jolly-Seber estimate	95% CI	Expanded Jolly-Seber[b]	Final Escapement estimate	Subsistence harvest[c]
2001	–	–	–	250	130–380	250	250	951
2002	–	–	–	1,300	1,200–1,400	1,600	1,600	14
2003	–	–	–	280	250–300	280	280	90
2004	–	–	–	820	750–900	1,250	1,250	60
2005	–	–	–	950	900–1,000	1,100	1,100	50
2006	–	–	–	1,100	1,000–1,200	1,300	1,300	51
2007	461	–	576	–	430–740	–	461	10
2008	967	–	1,200	–	1,000–1,500	–	1,200	708
2009	2,664	–	2,750	–	2,500–3,200	–	2,664	600
2010	2,555	–	2,970	–	2,660–3,380	–	2,970	571
2011	728	–	690	–	600–800	–	728	419
2012	1,123	–	1,215	–	1,000–1,400	–	1,123	801
2013	1,427	–	1,440	–	1,220–1,690	–	1,427	549
2014	1,398	1,321	1,360	–	1,330–1,375	–	1,321	735

[a] Chapman's modified Petersen estimate.

[b] Jolly-Seber estimates from 2001 to 2006 were expanded based on the ratio of the number sockeye salmon observed in the mark recapture study area to the number observed in the entire lake (see Conitz and Burril 2008).

[c] Subsistence harvest was reported from returned ADF&G subsistence salmon fishing permits. A voluntary subsistence closure was in place from 2002 to 2005. Subsistence harvest data for 2014 are preliminary.

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).

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):

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

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 ith 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 C.–Number of sockeye salmon counted in the upper camera weir in lower Kanalku Creek, in 2014. Other fish species were not enumerated.

Date	Sockeye salmon	Date	Sockeye salmon	Date	Sockeye salmon
15-Jun	0	18-Jul	33	21-Aug	24
16-Jun	1	19-Jul	26	22-Aug	24
17-Jun	0	20-Jul	0	23-Aug	17
18-Jun	0	21-Jul	2	24-Aug	16
19-Jun	0	22-Jul	50	25-Aug	5
20-Jun	0	23-Jul	51	26-Aug	7
21-Jun	0	24-Jul	30	27-Aug	7
22-Jun	0	25-Jul	90	28-Aug	5
23-Jun	4	26-Jul	123	29-Aug	3
24-Jun	5	27-Jul	95	Total	2,160
25-Jun	1	28-Jul	101		
26-Jun	1	29-Jul	122		
27-Jun	16	30-Jul	84		
28-Jun	4	31-Jul	50		
29-Jun	8	1-Aug	41		
30-Jun	5	2-Aug	89		
1-Jul	2	3-Aug	63		
2-Jul	14	4-Aug	47		
3-Jul	9	5-Aug	42		
4-Jul	3	6-Aug	76		
5-Jul	9	7-Aug	29		
6-Jul	4	8-Aug	11		
7-Jul	15	9-Aug	48		
8-Jul	30	10-Aug	84		
9-Jul	23	11-Aug	84		
10-Jul	26	12-Aug	33		
11-Jul	60	13-Aug	14		
12-Jul	41	14-Aug	10		
13-Jul	19	15-Aug	10		
14-Jul	55	16-Aug	9		
15-Jul	13	18-Aug	16		
16-Jul	2	19-Aug	31		
17-Jul	10	20-Aug	26		

Appendix D.–Daily and cumulative counts of sockeye salmon, water depth, and air and water temperature at the Kanalku Lake picket weir in 2014. No other salmon species were observed.

	Sockeye salmon				
Date	Daily	Cumulative	Water depth (cm)	Water temperature (°C)	Air temperature (°C)
25–Jun	0	0	34	15	13
26–Jun	0	0	32	14	14
27–Jun	0	0	26	15	14
28–Jun	2	2	22	14	12
29–Jun	9	11	19	13	13
30–Jun	3	14	16	13	12
1–Jul	3	17	16	13	12
2–Jul	0	17	14	18	17
3–Jul	6	23	14	18	19
4–Jul	3	26	11	19	18
5–Jul	0	26	13	18	17
6–Jul	0	26	10	18	18
7–Jul	0	26	12	19	19
8–Jul	0	26	12	19	15
9–Jul	0	26	13	18	17
10–Jul	0	26	14	19	20
11–Jul	4	30	13	18	15
12–Jul	15	45	14	17	15
13–Jul	14	59	14	18	18
14–Jul	4	63	14	18	18
15–Jul	6	69	13	18	15
16–Jul	0	69	13	18	20
17–Jul	0	69	12	N/A	N/A
18–Jul	0	69	11	19	16
19–Jul	2	71	11	19	17
20–Jul	1	72	6	19	15
21–Jul	3	75	5	18	14
22–Jul	0	75	5	19	17
23–Jul	8	83	5	19	15
24–Jul	46	129	5	19	14
25–Jul	1	130	5	18	14
26–Jul	47	177	6	18	15
27–Jul	25	202	26	18	16
28–Jul	2	204	27	18	15
29–Jul	15	219	34	18	13
30–Jul	14	233	34	18	14

-continued-

Appendix D.–Page 2 of 2.

Date	Sockeye salmon		Water depth (cm)	Water temperature (°C)	Air temperature (°C)
	Daily	Cumulative			
31–Jul	15	248	30	17	14
1–Aug	55	303	26	18	14
2–Aug	36	339	23	19	14
3-Aug	156	495	14	19	18
4-Aug	104	599	11	20	20
5-Aug	71	670	11	19	20
6-Aug	46	716	10	19	15
7-Aug	36	752	10	19	14
8-Aug	47	799	9	17	17
9-Aug	27	826	9	18	15
10-Aug	25	851	18	17	16
11-Aug	45	896	46	18	16
12-Aug	28	924	43	19	15
13-Aug	11	935	33	18	15
14-Aug	36	971	29	18	15
15-Aug	39	1010	26	18	15
16-Aug	40	1050	25	17	15
17-Aug	70	1120	24	17	14
18-Aug	17	1137	33	17	14
19-Aug	22	1159	30	17	14
20-Aug	40	1199	26	17	13
21-Aug	48	1247	23	17	15
22-Aug	22	1269	20	18	14
23-Aug	11	1280	18	18	15
24-Aug	21	1301	16	18	15
25-Aug	10	1311	16	18	15
26-Aug	12	1323	14	16	13
27-Aug	5	1328	14	17	13
28-Aug	19	1347	10	16	12
29-Aug	8	1355	9	17	12
30-Aug	4	1359	15	17	13
31-Aug	5	1364	16	16	12
1-Sep	16	1380	24	16	13
2-Sep	13	1393	25	16	11
3-Sep	5	1398	23	13	13

Appendix E.–Daily and cumulative counts of sockeye salmon at the Kanalku Lake camera weir in 2014. No other salmon species were observed.

	Sockeye salmon	
Date	Daily	Cumulative
30-Jun	3	3
1-Jul	3	6
2-Jul	2	8
3-Jul	9	17
4-Jul	3	20
5-Jul	0	20
6-Jul	0	20
7-Jul	1	21
8-Jul	0	21
9-Jul	0	21
10-Jul	0	21
11-Jul	4	25
12-Jul	16	41
13-Jul	13	54
14-Jul	4	58
15-Jul	6	64
16-Jul	0	64
17-Jul	0	64
18-Jul	0	64
19-Jul	1	65
20-Jul	1	66
21-Jul	1	67
22-Jul	0	67
23-Jul	9	76
24-Jul	36	112
25-Jul	1	113
26-Jul	41	154
27-Jul	24	178
28-Jul	2	180
29-Jul	14	194
30-Jul	11	205
31-Jul	13	218
1-Aug	55	273
2-Aug	28	301

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	Sockeye salmon	
Date	Daily	Cumulative
3-Aug	127	428
4-Aug	126	554
5-Aug	64	618
6-Aug	46	664
7-Aug	48	712
8-Aug	48	760
9-Aug	23	783
10-Aug	29	812
11-Aug	41	853
12-Aug	24	877
13-Aug	20	897
14-Aug	33	930
15-Aug	40	970
16-Aug	15	985
17-Aug	64	1049
18-Aug	22	1071
19-Aug	15	1086
20-Aug	34	1120
21-Aug	52	1172
22-Aug	22	1194
23-Aug	23	1217
24-Aug	14	1231
25-Aug	12	1243
26-Aug	17	1260
27-Aug	3	1263
28-Aug	16	1279
29-Aug	12	1291
30-Aug	3	1294
31-Aug	5	1299
1-Sep	16	1315
2-Sep	6	1321
3-Sep	0	1321