Fishery Data Series No. 16-20

Kanalku Lake Subsistence Sockeye Project: 2015 Annual Report

by

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and

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May 2016

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

FISHERY DATA SERIES NO. 16-20

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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 2015, we counted 1,180 sockeye salmon through a video camera weir near the lake outlet. The standard picket weir was removed mid-season due to intense predation on sockeye salmon by resident river otters (*Lontra canadensis*), and consequently, we were unable to calculate a mark–recapture estimate of escapement. We also operated a video camera weir in lower Kanalku Creek, downstream of Kanalku Falls, to estimate the total escapement into the Kanalku system and estimate the in-river mortality associated with the partial barrier falls. The estimated total escapement was 1,911 sockeye salmon; thus only 62% of the sockeye salmon that entered Kanalku Creek in 2015 successfully ascended the falls and were counted at the lake camera weir. The sockeye salmon escapement was composed primarily of age-1.2 fish (84%), similar to previous years.

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 provide 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 noncommercial 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 (Bednarski 2014). 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).

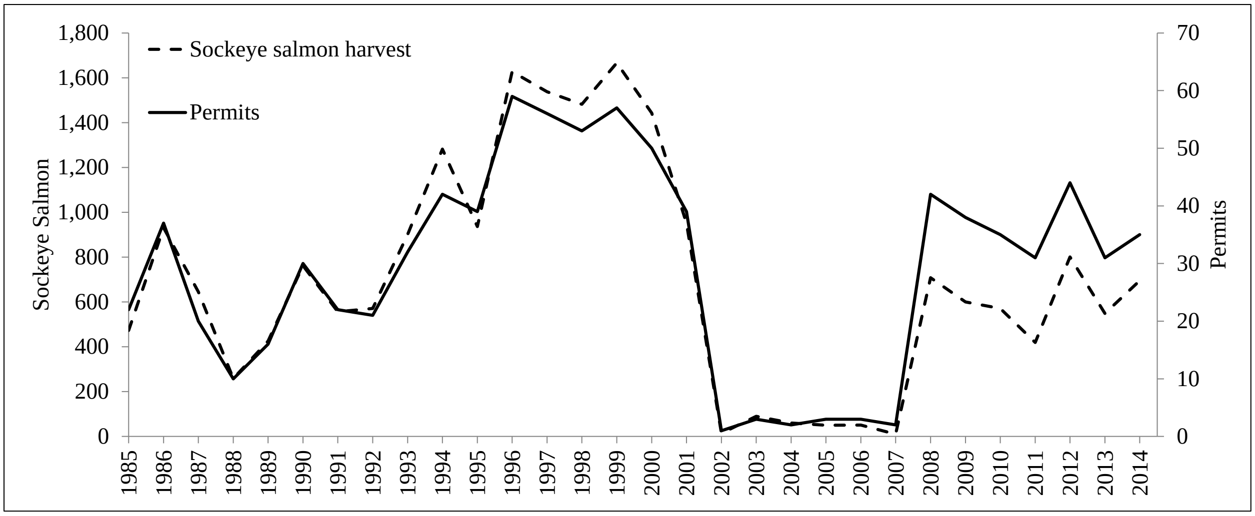

Figure 1.–Reported subsistence sockeye salmon harvest and permits issued, 1985 to 2014.

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 A; Vinzant et al. 2009).

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, the department 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, because 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, 24% in 2013, and 35% in 2014 (Vinzant et al. 2013; Vinzant and Heinl 2014 and 2015). 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).

Commercial harvest of Kanalku-bound sockeye salmon occurs in mixed stock purse seine fisheries targeting pink salmon (*O. gorbuscha*) in Chatham and Icy straits, although it has been assumed that the contribution of small Chatham sockeye salmon stocks, such as Kanalku, is very low (Geiger et al. 2007). The timing of commercial purse seine fishery openings and their distance from Kanalku Lake are managed to minimize incidental harvest of Kanalku fish, and subsistence permit harvest data indicates the majority of the subsistence harvest of sockeye salmon in Kanalku Bay (80%) is completed prior to the average first date of the commercial purse seine opening in statistical area 112-16, where the majority (65%) of sockeye salmon are harvested in the fishery (Bednarski et al. 2014). A 3-year genetic mixed stock analysis study was conducted from 2012 to 2014 to better understand the contribution, run timing, and distribution of northern Chatham Strait sockeye salmon harvested in these fisheries (Gilk-Baumer et al. 2015). In 2012 and 2014, years of poor pink salmon runs and limited purse seine fishing, small Chatham Strait sockeye salmon populations were combined into one reporting group for the mixed stock analysis. The “Chatham Small” reporting group contributed an estimated 200 fish per year to the commercial fisheries sampled, of which Kanalku fish would have contributed a small portion. In 2013, very large pink salmon runs and more extensive purse seine fishing allowed for greater sampling opportunity and fine-scale analysis of the harvest, and Kanalku fish were estimated to account for 0.5% (less than 300 fish) of the sockeye salmon harvested in the fisheries that were sampled (Gilk-Baumer et al. 2015).

In 2015, we conducted the 15th 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. This information, 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. More effective management will better ensure the sustainability of the harvest and continued rebuilding of this important subsistence resource. Information collected on the in-river mortality rate associated with fish passage over Kanalku Falls will help to assess the success of the recent barrier modification work and determine if further modification will be required to improve fish passage.

OBJECTIVES

1. Count all salmon species entering lower Kanalku Creek, below Kanalku Falls, through a camera weir 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 90% 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.

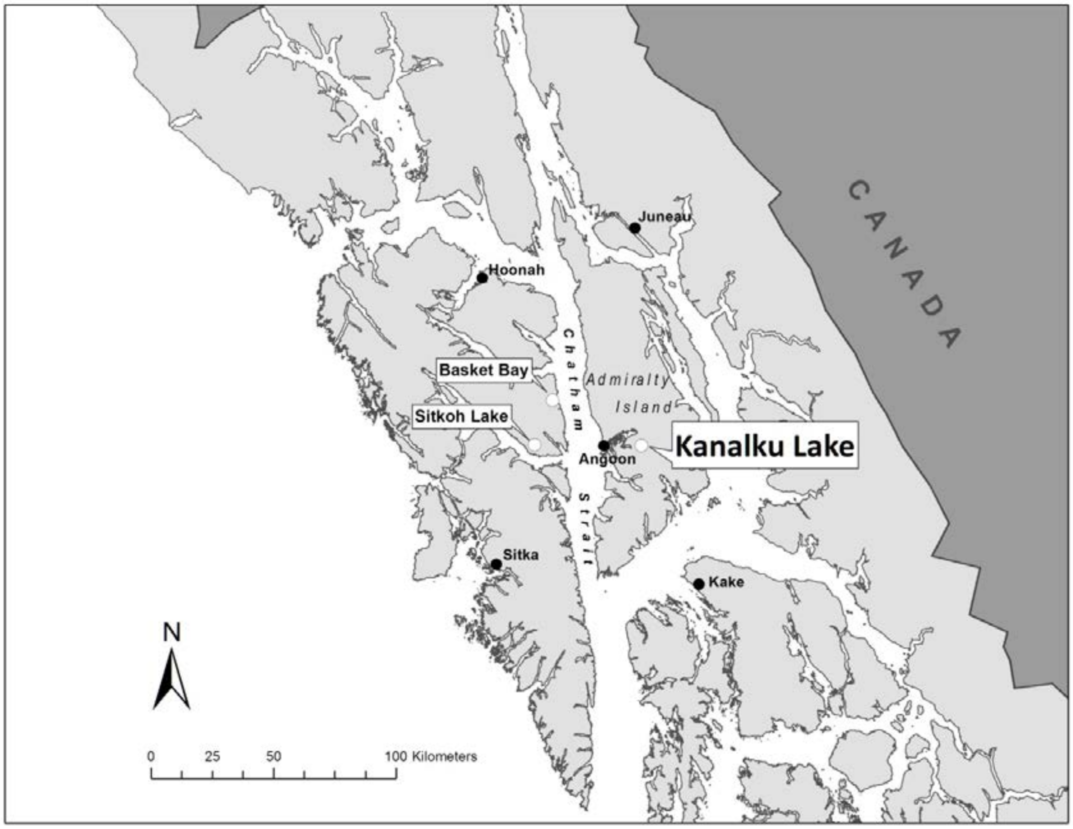

Figure 2.–Map of Southeast Alaska showing location of Kanalku Lake, the village of Angoon, and other locations mentioned in the text.

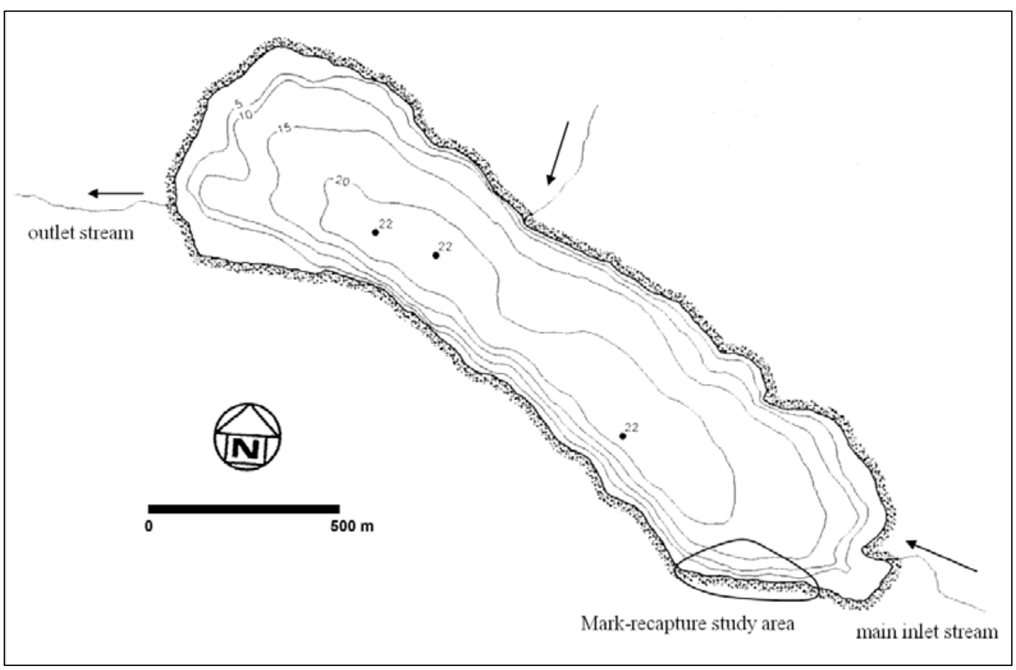

Figure 3.–Bathymetric map of Kanalku Lake showing 5 m depth contours and the mark–recapture study area. Arrows indicate direction of stream flow.

SOCKEYE SALMON TOTAL ESCAPEMENT ESTIMATE

The total sockeye salmon escapement to the Kanalku system was counted through a video camera weir located approximately 0.5 km upstream from the mouth of Kanalku Creek and approximately 300 m downstream of Kanalku Falls (Figure 4). Two video cameras were mounted to a video chute at the weir, and fish were recorded 24 hours per day as they swam by the underwater cameras (Figure 5).

Lower Creek Camera Weir

The weir was constructed by anchoring an aluminum video chute to the streambed. Four 2.4 m weir panels were attached to each side of the video chute and anchored into the streambed in a "V" alignment (pointing upstream) to help guide fish quickly through the chute. Weir panels and stringers were fitted with 0.75 m-tall, 1.3 cm-diameter EMT conduit pickets with "pink salmon" spacing at 4.4 cm on center. Sandbags were placed on the downstream side of the fencing to help reduce scouring of the streambed. The weir was cleaned and inspected daily for holes or scouring to ensure the structure remained fish-tight. Stream height was measured daily at a fixed location at the weir site so that measurements are comparable across all years of the project.

Camera Counts

Two underwater color video cameras containing Sony 8.47 mm HAD CCD 3.6 mm sensors were installed on the 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. A photoelectric sensor was used to turn the lights on only from dusk to dawn to conserve battery power. The paired video system was powered by four 130-watt solar panels that trickle charged a pair of 100 ah AGM (absorption glass matt) 12V DC batteries through metered 30A charge controllers. 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). For each camera in the video chute (left and right cameras), two SD cards were swapped back and forth daily. The crew used a laptop computer to review and back up video data at camp. Counts of sockeye salmon by hour for each camera and any other observations were recorded on daily data sheets and in electronic files. At the end of the season, all video files were reviewed to corroborate inseason counts.

Figure 4.–Camera weir installed in lower Kanalku Creek, below Kanalku Falls, 2015. (©2015 ADF&G/Photo by Raymond F. Vinzant.)

Figure 5.–Sockeye salmon swimming through a lower creek camera weir. (©2013 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. Fish were also sampled at the weir for scales, and marked as part of a 2-event mark–recapture study (Seber 1982) to verify the weir count. We installed a camera weir upstream of the standard picket weir to serve as the recapture location for the mark–recapture study and to provide a second count of fish into the lake. In the past 2 seasons, we observed frequent predation on sockeye salmon by river otters (*Lontra canadensis*) between the two weirs at the outlet of the lake (Vinzant and Heinl 2014 and 2015). Therefore, we determined to closely monitor otter activity during the 2015 season. If predation continued to be a problem, we would remove the picket weir and use only the camera weir count to estimate the spawning escapement of sockeye salmon (Vinzant and Heinl 2015)—which is exactly what happened (see Results section).

Picket Weir Count

The picket 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 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 2014 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 visible downstream of fallen tree. (©2014 ADF&G/Photo by Raymond F. Vinzant.)

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 sockeye salmon escapement was determined from a minimum of 265 scale samples. A sample of 230 fish will ensure estimated proportions of each age class will be within 5% of the true value with at least 90% probability (Cochran 1977; Angers 1989; Thompson 1987), based on 2 age classes (age-1.2 and -1.3 fish account for an average 96% of the escapement) and a population of 1,500 fish (2007–2014 average spawning escapement). We increased the sampling objective to 265 fish to account for an average 15% of scale samples that cannot be aged due to regeneration or other causes.

Scale samples were collected from live fish sampled at the picket weir (prior to 28 July) and on the spawning grounds in Kanalku Lake (beginning in late August). 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, in which freshwater and saltwater years are separated by a period (e.g., 1.3 denotes a 5-year-old fish with 1 freshwater and 3 ocean years; Koo 1962).

RESULTS

Sockeye Salmon Total Escapement Estimate

The camera weir on lower Kanalku Creek, downstream of Kanalku Falls, was operated between 16 June and 31 August. Sockeye salmon were first recorded on 1 July (Figure 8). A total of 1,911 adult sockeye salmon were counted through the camera weir. Sockeye salmon migration was greatest mid-July through mid-August. The largest daily count occurred on 20 July, when 111 adult sockeye salmon were recoded (Figure 8). Sockeye salmon primarily traveled through the weir in the darkness, between 23:00 and 04:00, as observed in previous seasons. No jack salmon were observed in the video files.

The camera weir was operated without problems for the duration of the sockeye salmon migration. No serious high water events occurred, and no holes or gaps were found on the weir face that would have allowed fish to pass undetected. During installation, efforts were made to deepen the streambed by approximately 30 cm under and around the video chute. The slightly deeper and slower water seemed effective in encouraging sockeye salmon to swim more slowly through the chute, which greatly reduced the number of video files of partial fish compared to previous seasons. Sockeye salmon were easily identified by the field crew while viewing the video files, and a postseason review of all video resulted in a difference of only one sockeye salmon.

Other species of fish recorded at the camera weir included numerous pink salmon, abundant Dolly Varden and cutthroat trout, and several chum 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. Smaller cutthroat trout and Dolly Varden are able to freely pass through the weir fence and pickets and bypass the video cameras entirely.

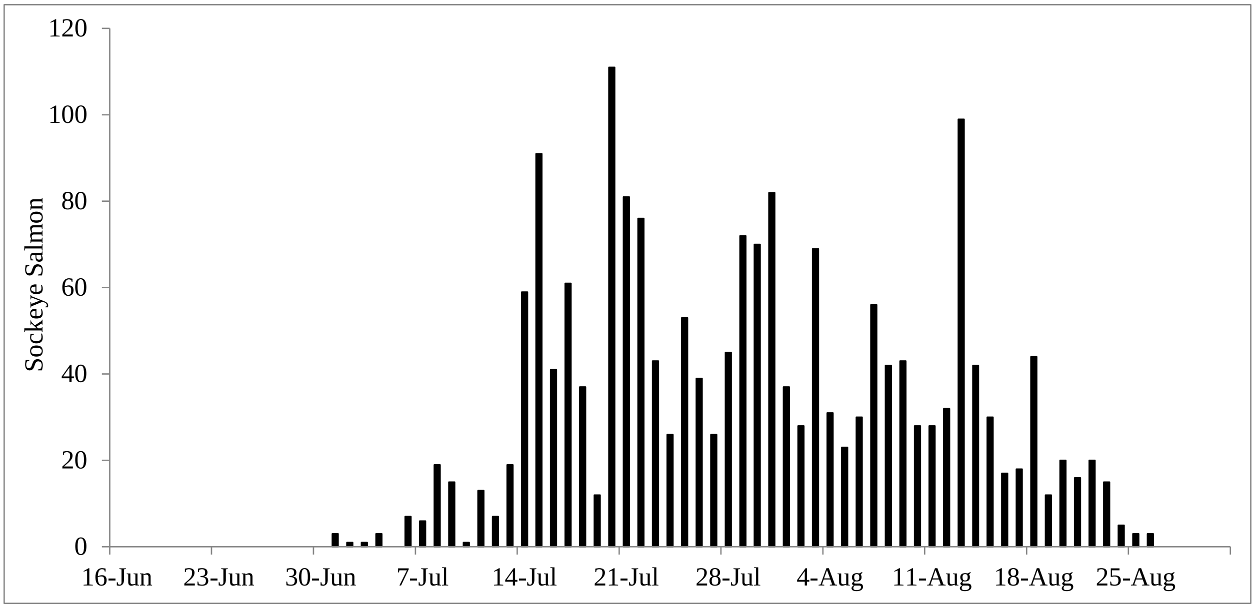

Figure 8.–Daily sockeye salmon counts at the lower Kanalku Creek camera weir, 2015.

SOCKEYE SALMON SPAWNING ESCAPEMENT ESTIMATE

Picket Weir Count

The picket weir was installed on 19 June and operated until 28 July. The first sockeye salmon was counted on 16 July, 15 days after sockeye salmon were first recorded at the camera weir downstream of Kanalku Falls. A total of 216 sockeye salmon were counted through 28 July; however, the field crew also observed 25 river otter mortalities (i.e., 12% of the sockeye salmon counted at the picket weir) in the video files recorded at the lake camera weir, directly upstream of the picket weir. More sockeye salmon were undoubtedly preyed upon by otters than was recorded in the video files. As a result of this predation, we abandoned both the picket weir (which was removed on 28 July) and the backup mark–recapture study.

Lake Camera Weir Count

The lake camera weir was installed on 20 June and operated through 8 September (Figure 9, Appendix D). A total of 1,180 adult sockeye salmon were counted through the camera weir (Figure 9). No other salmon species or jacks were observed in the video files. The largest daily count of sockeye salmon occurred on 29 July, the day following the removal of the picket weir, when 188 adult sockeye salmon swam through the weir. No holes, gaps, or breaks in the weir were found throughout the season. A high water event occurred from 30 August to 1 September, and muddy debris blocked nearly all visibility in the camera chute for approximately 14 hours. It is likely that few, if any, sockeye salmon passed the camera weir during this event, because it was at the very end of the sockeye salmon migration into the lake (Figure 9). The lake camera weir worked well throughout the season, and good images of fish traveling through the video chute allowed for an accurate count by the field crew.

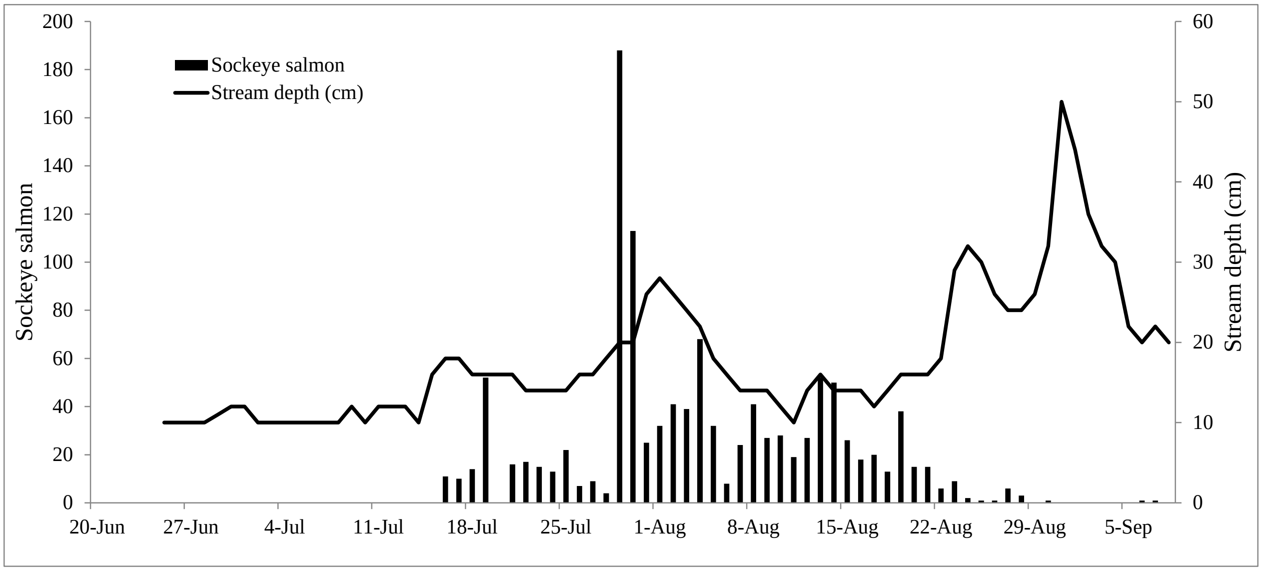

Figure 9.–Daily sockeye salmon escapement and stream depth (cm) at the lake camera weir, Kanalku Lake 2015.

ADULT POPULATION AGE AND SIZE COMPOSITION

A total of 245 sockeye salmon were sampled for age, sex, and length composition in 2015. Of those fish, 45 were sampled at the picket weir prior to its removal on 28 July. The remaining samples were collected on the spawning grounds in Kanalku Lake, where fish were captured with a beach seine between 28 August and 6 September. A total of 207 scale samples were successfully aged. The spawning escapement was composed primarily of age-1.2 fish (84%; brood year 2011), followed by age-1.3 fish (10%; brood year 2010), age-2.2 fish (5%; brood year 2010), a single age-2.3 fish (<1%; brood year 2009), and a single age-1.1 jack (<1%; brood year 2012) (Table 1). Age-1.2 fish had a mean length of 485 mm for males and 481 mm for females. Age-1.3 fish had a mean length of 541 mm for males and 545 mm for females (Table 2). The higher proportion of male sockeye salmon sampled (71%) was probably due to the gear type used to capture fish on the spawning grounds of Kanalku Lake, because males' larger teeth were more likely to become ensnared in the beach seine.

Table 1.–Estimated age composition of the 2015 sockeye salmon spawning escapement at Kanalku Lake.

Brood year/ age	2012 1.1	2011 1.2	2010 1.3	2010 2.2	2009 2.3	Total aged
Male						
Sample size	1	121	19	6	0	147
Percent	0.5%	58%	9%	3%	0%	71%
SE	0.5%	3.4%	2.0%	1.2%	0.0%	3.2%
Female						
Sample size	0	53	2	4	1	60
Percent		26%	1%	2%	0%	29%
SE		3.0%	0.7%	1.0%	0.5%	3.2%
All Fish						
Sample size	1	174	21	10	1	207
Percent	0.5%	84%	10%	5%	0.5%	100%
SE	0.5%	2.6%	2.1%	1.5%	0.5%	

Table 2.–Estimated length composition of the 2015 sockeye salmon spawning escapement at Kanalku Lake.

Brood year/ age	2012 1.1	2011 1.2	2010 1.3	2010 2.2	2009 2.3
Male					
Sample size	1	121	19	6	0
Mean length	380	485	541	503	
SE	27.3	2.5	6.3	11.2	
Female					
Sample size	0	53	2	4	1
mean length	—	481	545	488	540
SE	—	3.8	19.3	13.7	27.3
All Fish					
Sample size	1	174	21	10	1
Mean length	380	484	541	497	540
SE	27.3	2.1	6.0	8.6	27.3

DISCUSSION

Our lower creek camera weir count in 2015 of 1,911 adult sockeye salmon represented the fourth consecutive estimate of the total number of sockeye salmon that entered the Kanalku system, and the second since the barrier-modification work was conducted at the base of Kanalku Falls in 2013 (Vinzant and Heinl 2014). We also counted 1,180 sockeye salmon at the outlet of Kanalku Lake, which was slightly below the 2001−2014 average spawning escapement of 1,265 sockeye salmon (Figure 10). We estimate that 64% of the sockeye salmon that entered Kanalku Creek reached the spawning grounds in Kanalku Lake in 2015—an in-river mortality rate of 38% of all fish entering the system, similar to the estimated mortality rate of 35% in 2014 (Vinzant and Heinl 2015). In the 2 years prior to the barrier-modification work, in-river mortality was estimated to be 51% (2012) and 24% (2013) (Vinzant et al. 2013; Vinzant and Heinl 2014).

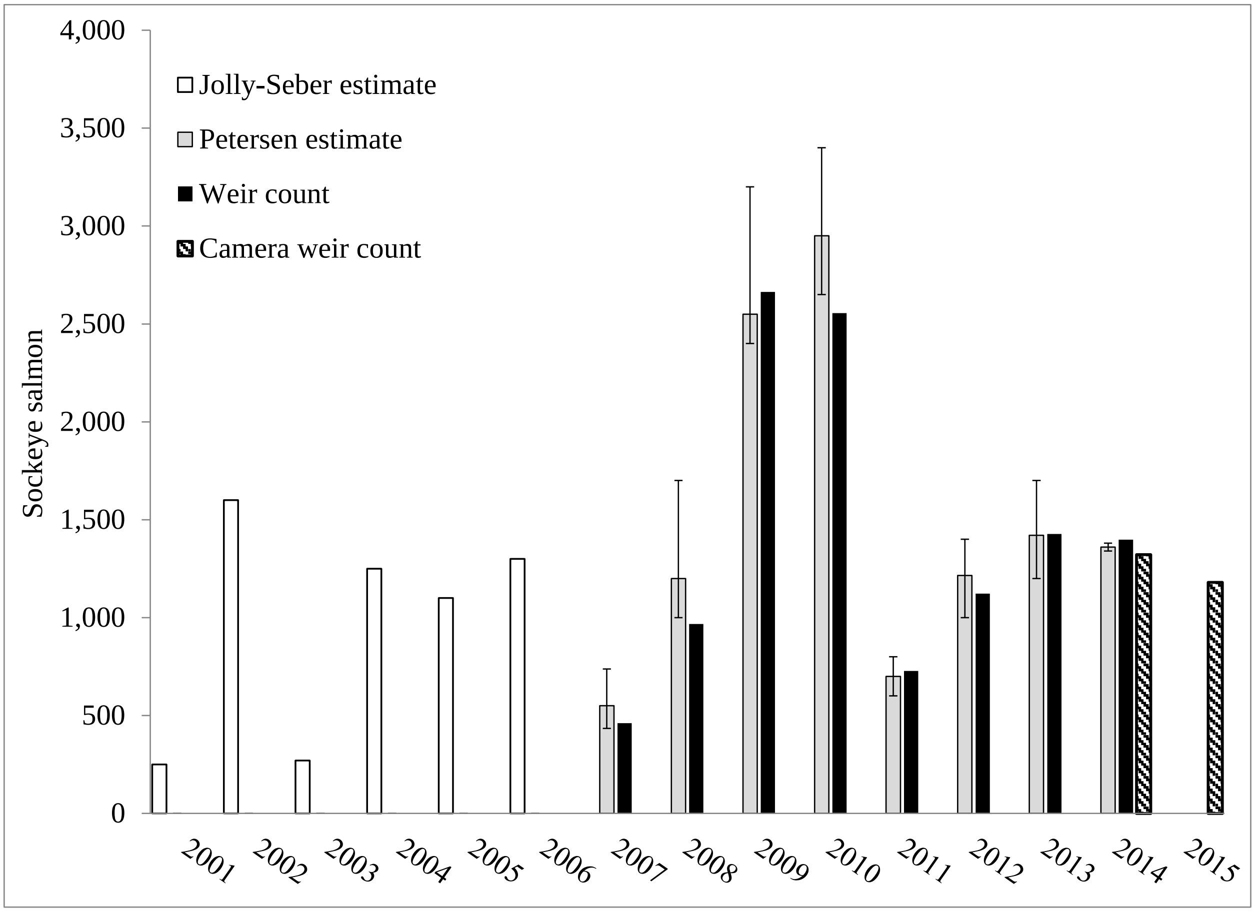

Figure 10.–Estimated sockeye salmon spawning escapements at Kanalku Lake from 2001 to 2015. Error bars represent the 95% confidence intervals of the Petersen mark–recapture estimates.

Prior studies suggested that water flow probably has significant impact on sockeye salmon passage over Kanalku Falls (Vinzant and Bednarski 2010; Vinzant et al 2010). In the 4 seasons we have estimated the in-river mortality of sockeye salmon associated with the falls, the highest estimated mortality was found in 2012 (51%) when stream depth was higher than average throughout most of the sockeye salmon migration (Figure 10; Vinzant et al. 2013). Lower mortality rates were estimated in the following years (24% in 2013, 35% in 2014, 38% in 2015), all of which had lower than average stream depth throughout much of the sockeye salmon migration (Vinzant and Heinl 2014 and 2015). The 2013 escapement, which occurred prior to the barrier-modification work, experienced the lowest in-river mortality rate (24%) estimated to date. Although it appears the barrier-modification has not dramatically improved sockeye salmon passage during lower flow seasons, it remains to be seen if fish passage will improve during years of higher water flow, similar to the 2012 season (Figure 11). Additional years of information should provide a better understanding of how stream depth affects sockeye salmon passage over the falls and whether Phase I of the barrier-modification improved fish passage. If needed, Phase II may be implemented, which would add an 18–24 inch concrete sill to raise the plunge pool at the base of the falls.

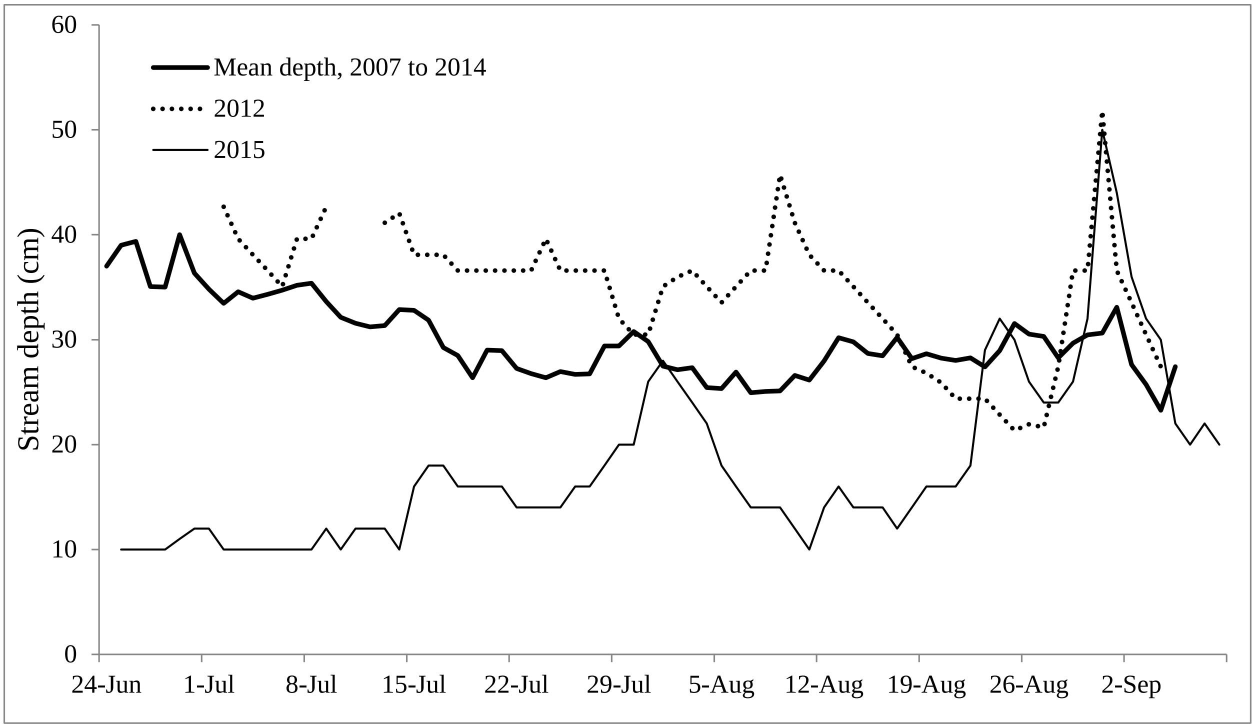

Figure 11.–Stream depth (cm) at the Kanalku Lake picket weir in 2015, compared to the mean stream depth (2007−2014) and stream depth in 2012.

We made 2 changes to our project in 2015 based on recommendations from the previous season (Vinzant and Heinl 2015). First, we operated a single camera weir downstream of Kanalku Falls, rather than the double-weir system used from 2012 to 2014. In the previous 3 seasons of operation, the difference in counts between the 2 lower creek camera weirs was very low (3% or less), and we are confident in the accuracy of the count obtained using one weir (Vinzant et al. 2013; Vinzant and Heinl 2014 and 2015). Use of a single camera weir below Kanalku Falls had many advantages. The time required to review video files was greatly reduced (review of the files can be made tedious by the large numbers of pink salmon, Dolly Varden, and cutthroat trout below Kanalku Falls, many of which like to seek refuge in the camera chute during periods of low water). Predation on sockeye salmon was probably reduced, because fish could move more freely through the creek and we observed very few otter predation events in the video files. Finally, we were able to combine weir materials to build a stronger and superior weir structure, and combine the solar panels and batteries into a single system, which improved power supply for the DVRs, cameras, and lights. Overall, both camera weirs (below the falls and at the lake outlet) worked very well throughout the season without any major problems.

The second change we made to the project in 2015 was to abandon the traditional picket weir and fish trap at the outlet of Kanalku Lake, and rely instead on the lake camera weir to estimate the spawning escapement. Consequently, we were unable to produce a mark-recapture estimate of the spawning escapement in 2015 and did not meet Objective 3 of our study. As was observed in 2013 and 2014, river otter predation on sockeye salmon occurred nightly between the weir structures, much of which was directly observed in the lake camera weir video files (Vinzant and Heinl 2014 and 2015). Otter activity was greatly reduced after the picket weir was removed, and no additional otter predation was recorded. In addition, a large proportion of the spawning escapement passed through the lake camera weir in the nights following removal of the picket weir, which suggested the picket weir may have been impeding the natural movement to the spawning grounds (Figure 9). In 2014, we produced 3 estimates of the spawning escapement with the picket weir, the lake camera weir, and a very precise mark–recapture estimate, all of which were very similar (Vinzant and Heinl 2015). Therefore, we are confident that the camera weir count of 1,180 sockeye salmon is an accurate and reliable estimate of the spawning escapement in 2015 based on our previous experience with the camera weirs both below the falls and at the lake.

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APPENDICES

Appendix A.–Estimated annual spawning escapement and subsistence harvest of Kanalku Lake sockeye salmon, 2001–2015. Escapement estimates were based on weir counts and mark-recapture estimates.

			Mark–recapture estimate					
Year	Weir count	Camera-weir count	Petersen estimate[a]	Jolly-Seber estimate[b]	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	695
2015	–	1,180	–	–	–	–	1,180	NA

[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 2015 were not available at the time of publication.

Appendix B.–Number of sockeye salmon counted in lower Kanalku Creek camera weir in 2015. Other fish species were not enumerated.

Date	Sockeye salmon	Date	Sockeye salmon	Date	Sockeye salmon
16-Jun	0	19-Jul	12	21-Aug	16
17-Jun	0	20-Jul	111	22-Aug	20
18-Jun	0	21-Jul	81	23-Aug	15
19-Jun	0	22-Jul	76	24-Aug	5
20-Jun	0	23-Jul	43	25-Aug	3
21-Jun	0	24-Jul	26	26-Aug	3
22-Jun	0	25-Jul	53	27-Aug	0
23-Jun	0	26-Jul	39	28-Aug	0
24-Jun	0	27-Jul	26	29-Aug	0
25-Jun	0	28-Jul	45	30-Aug	0
26-Jun	0	29-Jul	72	31-Aug	0
27-Jun	0	30-Jul	70	Total	1,911
28-Jun	0	31-Jul	82		
29-Jun	0	1-Aug	37		
30-Jun	0	2-Aug	28		
1-Jul	3	3-Aug	69		
2-Jul	1	4-Aug	31		
3-Jul	1	5-Aug	23		
4-Jul	3	6-Aug	30		
5-Jul	0	7-Aug	56		
6-Jul	7	8-Aug	42		
7-Jul	6	9-Aug	43		
8-Jul	19	10-Aug	28		
9-Jul	15	11-Aug	28		
10-Jul	1	12-Aug	32		
11-Jul	13	13-Aug	99		
12-Jul	7	14-Aug	42		
13-Jul	19	15-Aug	30		
14-Jul	59	16-Aug	17		
15-Jul	91	17-Aug	18		
16-Jul	41	18-Aug	44		
17-Jul	61	19-Aug	12		
18-Jul	37	20-Aug	20		

Appendix C.–Daily and cumulative counts of sockeye salmon, water depth, and air and water temperature at the Kanalku Lake camera weir in 2015. No other salmon species were observed.

	Sockeye salmon		Water	Water	Air
Date	Daily	Cumulative	Depth (cm)	Temperature (°C)	Temperature (°C)
20-Jun	0	0	–	–	–
21-Jun	0	0	–	–	–
22-Jun	0	0	–	19	17
23-Jun	0	0	–	20	17
24-Jun	0	0	–	20	17
25-Jun	0	0	10	19	17
26-Jun	0	0	10	19	15
27-Jun	0	0	10	19	16
28-Jun	0	0	10	19	15
29-Jun	0	0	11	19	16
30-Jun	0	0	12	19	16
1-Jul	0	0	12	19	16
2-Jul	0	0	10	18	15
3-Jul	0	0	10	19	16
4-Jul	0	0	10	18	15
5-Jul	0	0	10	19	18
6-Jul	0	0	10	19	19
7-Jul	0	0	10	20	19
8-Jul	0	0	10	21	18
9-Jul	0	0	12	20	17
10-Jul	0	0	10	21	16
11-Jul	0	0	12	21	16
12-Jul	0	0	12	21	16
13-Jul	0	0	12	20	15
14-Jul	0	0	10	20	17
15-Jul	0	0	16	20	17
16-Jul	11	11	18	20	17
17-Jul	10	21	18	19	17
18-Jul	14	35	16	19	16
19-Jul	52	87	16	19	17
20-Jul	0	87	16	10	16
21-Jul	16	103	16	20	18
22-Jul	17	120	14	19	16
23-Jul	15	135	14	19	14
24-Jul	13	148	14	20	15
25-Jul	22	170	14	19	15

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Date	Sockeye salmon Daily	Sockeye salmon Cumulative	Water Depth (cm)	Water Temperature (°C)	Air Temperature (°C)
26-Jul	7	177	16	19	16
27-Jul	9	186	16	19	14
28-Jul	4	190	18	19	15
29-Jul	188	378	20	19	15
30-Jul	113	491	20	18	14
31-Jul	25	516	26	18	14
1-Aug	32	548	28	18	16
2-Aug	41	589	26	19	16
3-Aug	39	628	24	18	15
4-Aug	68	696	22	19	18
5-Aug	32	728	18	18	17
6-Aug	8	736	16	18	16
7-Aug	24	760	14	18	16
8-Aug	41	801	14	18	18
9-Aug	27	828	14	18	18
10-Aug	28	856	12	18	17
11-Aug	19	875	10	17	16
12-Aug	27	902	14	17	16
13-Aug	52	954	16	17	16
14-Aug	50	1004	14	18	16
15-Aug	26	1030	14	19	17
16-Aug	18	1048	14	18	17
17-Aug	20	1068	12	18	16
18-Aug	13	1081	14	19	17
19-Aug	38	1119	16	19	16
20-Aug	15	1134	16	19	15
21-Aug	15	1149	16	18	16
22-Aug	6	1155	18	19	15
23-Aug	9	1164	29	19	15
24-Aug	2	1166	32	17	14
25-Aug	1	1167	30	18	15
26-Aug	1	1168	26	18	14
27-Aug	6	1174	24	17	14
28-Aug	3	1177	24	17	13
29-Aug	0	1177	26	17	13
30-Aug	1	1178	32	16	12

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Date	Sockeye salmon Daily	Sockeye salmon Cumulative	Water Depth (cm)	Water Temperature (°C)	Air Temperature (°C)
31-Aug	0	1178	50	16	10
1-Sep	0	1178	44	15	10
2-Sep	0	1178	36	15	8
3-Sep	0	1178	32	15	9
4-Sep	0	1178	30	16	11
5-Sep	0	1178	22	15	11
6-Sep	1	1179	20	15	11
7-Sep	1	1180	22	15	12
8-Sep	0	1180	20	15	11