Fishery Data Series No. 17-25

Kanalku Lake Subsistence Sockeye Salmon Project: 2016 Annual Report

by

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and

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December 2017

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

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Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm
Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd
Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s
Physics and chemistry	
all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

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

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 spawning escapements were estimated through mark–recapture studies from 2001 to 2006, through a standard picket weir from 2007 to 2014, and through a camera weir since 2015. In 2016 we counted a total of 2,236 sockeye salmon through a double-fence camera weir at the outflow of Kanalku Lake. We also operated a camera weir downstream of Kanalku Falls in lower Kanalku Creek to estimate the total escapement into the Kanalku system, and to estimate the inriver mortality associated with the partial barrier falls. We estimated the total escapement to Kanalku Creek was 3,093 sockeye salmon; thus, the inriver mortality was estimated to be 28% in 2016. Although scale samples collected in 2016 were highly resorbed and could not be accurately aged, length data suggested approximately 92% of the spawning population was age-1.2 fish.

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 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 6 residents fished 6 commercial permits (Bednarski et al. 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).

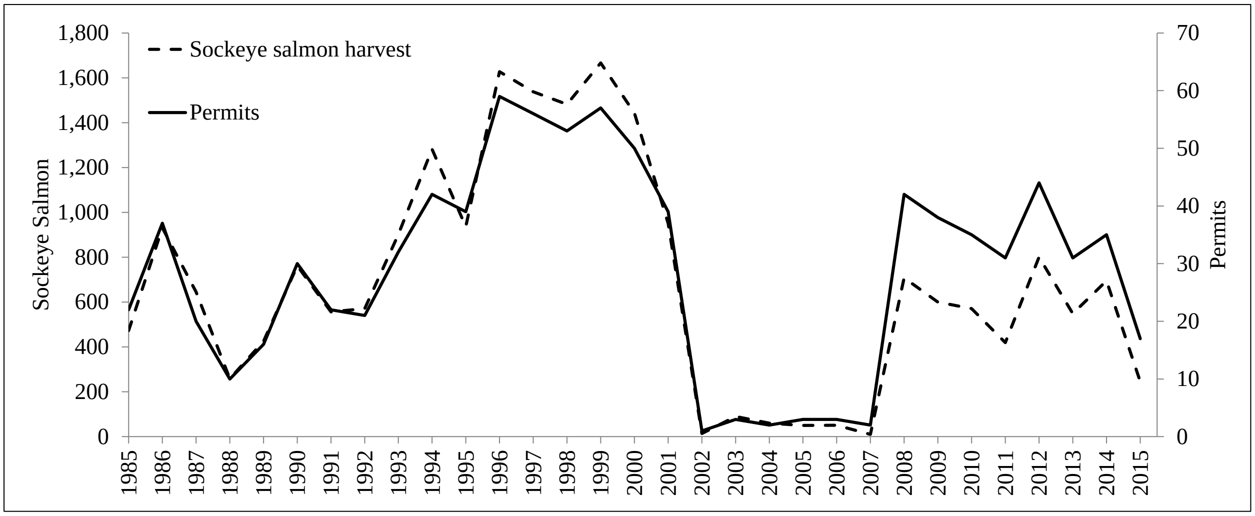

Figure 1.–Reported subsistence sockeye salmon harvest and permits issued, 1985 to 2015.

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 some Angoon residents' concerns 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 other traditionally used systems nearby to provide opportunity for Angoon residents to fulfill subsistence needs (Conitz and Burril 2008; Bednarski et al. 2014). During the voluntary closure years (2002–2005), the reported Kanalku subsistence harvest averaged 50 fish (Figure 1) 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 570 fish and spawning escapements improved to an average 1,580 fish.

In addition to concerns regarding increased subsistence harvest and small escapements, there are concerns regarding the negative impact the 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 4 shallow step pools on the left side apron of Kanalku Falls to improve fish passage (Geiger et al. 2007). The effect on fish passage is not known, however, because no pre- or postmodification 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 inriver mortality of sockeye salmon incurred at Kanalku Falls. This project has been funded through grants from the Alaska Sustainable Salmon Fund. 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 inriver 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, 35% in 2014, and 38% in 2015 (Figure 2) (Vinzant et al. 2013; Vinzant and Heinl 2014–2016). 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).

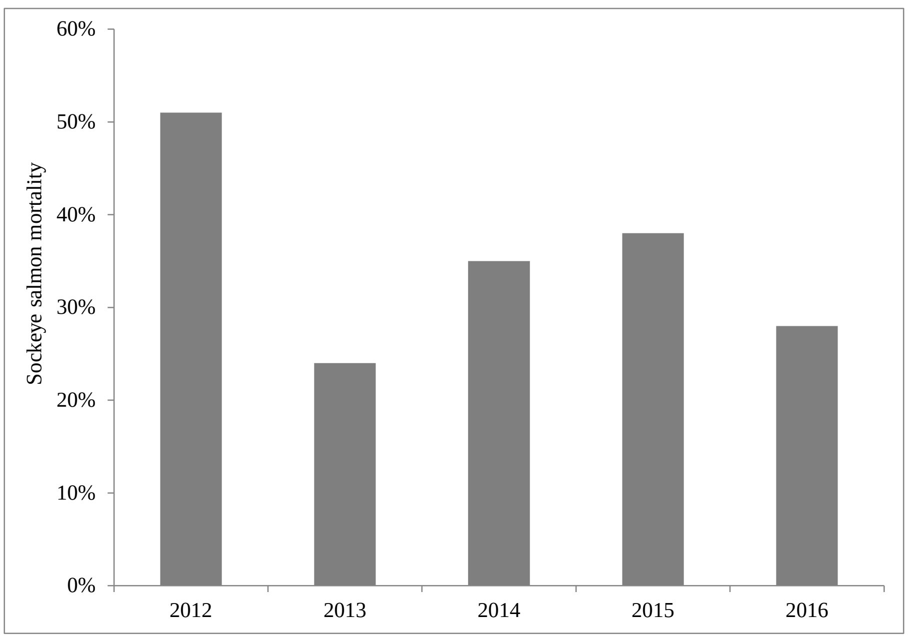

Figure 2.–Estimated inriver mortality of sockeye salmon associated with passage over Kanalku Falls, 2012 to 2015. The falls were modified to improve fish passage following the 2013 season.

Commercial harvest of Kanalku-bound sockeye salmon occurs in mixed stock purse seine fisheries that target pink salmon (*O. gorbuscha*) in Chatham and Icy straits, although the contribution is assumed to be very low (Geiger et al. 2007). The timing of commercial purse seine fishery openings and their distance from Kanalku Bay are managed to minimize incidental harvest of Kanalku fish. Subsistence harvest data indicate most (80%) of the Kanalku Bay subsistence harvest occurs prior to the average first date of the commercial purse seine opening in statistical area 112-16, where the majority (65%) of sockeye salmon harvest in this fishery takes place (Bednarski et al. 2014). ADF&G conducted a study from 2012 to 2014 to better understand the contribution, run timing, and distribution of Northern Chatham Strait sockeye salmon stocks harvested in these fisheries using genetic mixed stock analysis. In 2012 and 2014, small Chatham Strait sockeye salmon stocks were combined into 1 reporting group and were estimated to have contributed fewer than 300 fish to the commercial fisheries that were sampled—of which Kanalku stock would have contributed a small portion. In 2013, a year with some of the most extensive purse seine fishing on record, Kanalku fish accounted for an estimated 0.5% of the sockeye salmon harvested (fewer than 300 fish) in the fisheries sampled (Gilk-Baumer et al. 2015). Approximately 9 nautical miles along the eastern shore of Chatham Strait between Parker Point and Point Samuel has been closed to the purse seine fishery since 1999 to conserve Kanalku sockeye salmon. This area, which encompasses the community of Angoon, Kootznahoo Inlet, and the entrance to Kanalku Bay, was added to the list of closed waters in state regulation (5AAC 33.350(m)(10)) at the Alaska Board of Fisheries meeting in 2015. Additional time and area closures were also put into regulation along the Admiralty shore north of Parker Point (5AAC 33.366 (c)(1 and 2)) to conserve Kanalku sockeye salmon.

In 2016, we conducted the 16th 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 inriver 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 help ensure harvest sustainability and continued rebuilding of this important subsistence resource. Information collected on the inriver mortality rate associated with fish passage over Kanalku Falls will help to assess the success of recent barrier modification work and determine if further alteration will be required to improve fish passage.

OBJECTIVES

1. Count all salmon species that enter 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 camera weir into Kanalku Lake, upstream of Kanalku Falls, for the duration of the sockeye salmon run to estimate spawning escapement.
3. Estimate the sockeye salmon mortality rate at Kanalku Falls.
4. 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 3) 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 1 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 4). 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.

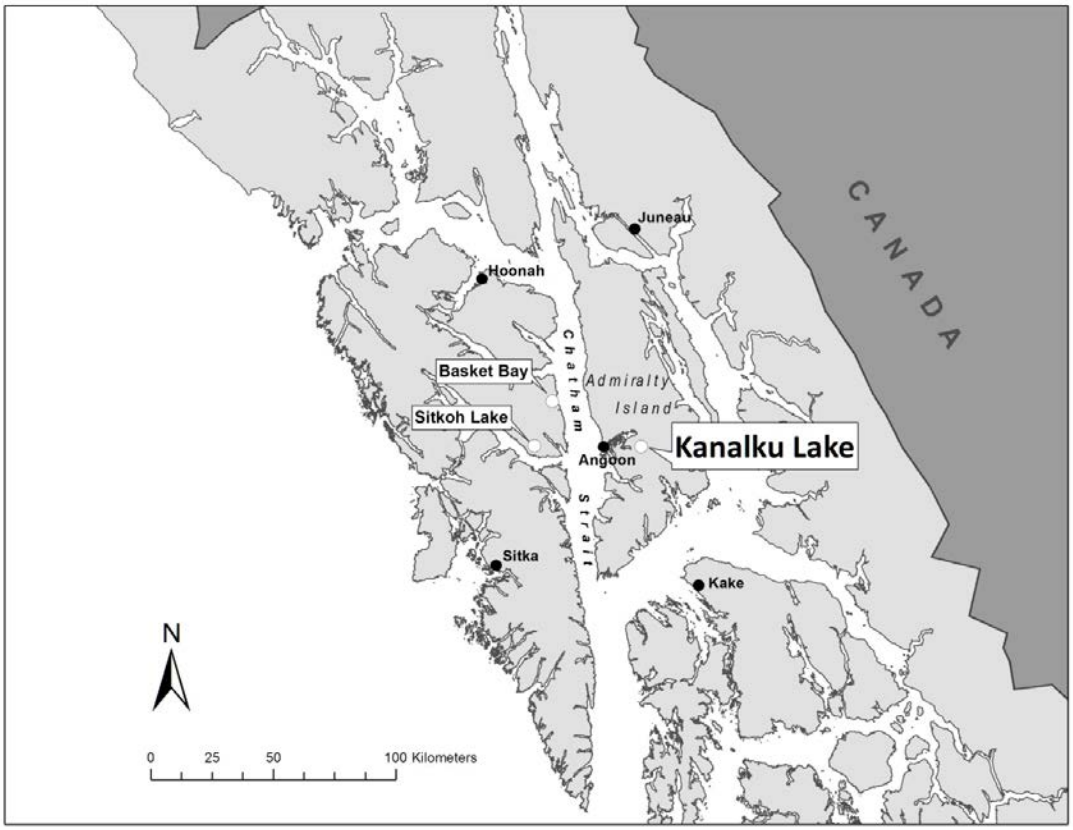

Figure 3.–Map of Southeast Alaska showing location of Kanalku Lake, the village of Angoon, and other locations mentioned in the text.

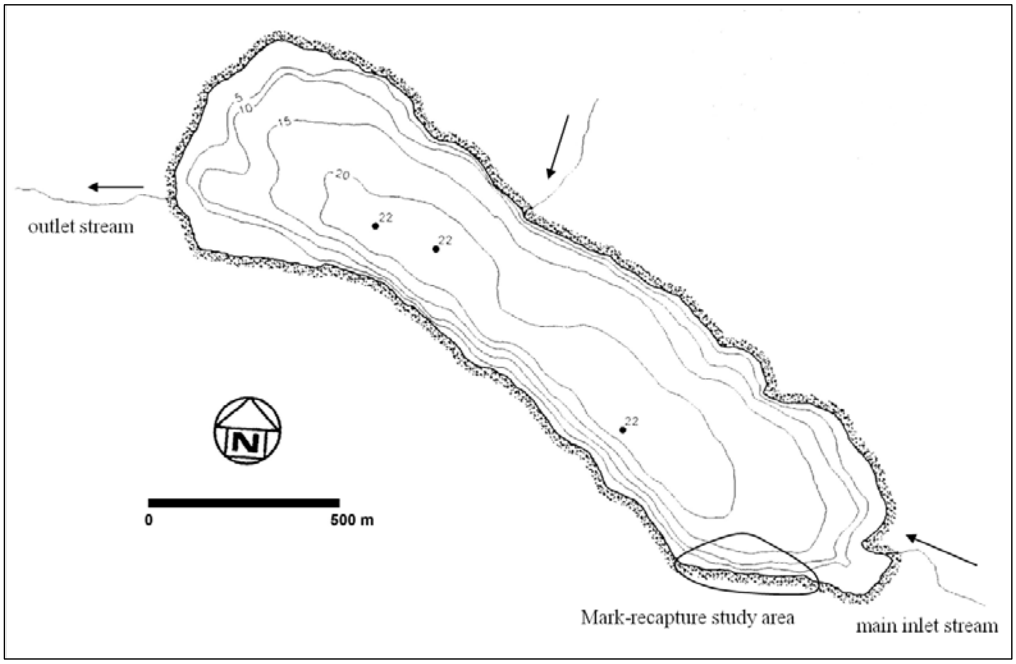

Figure 4.–Bathymetric map of Kanalku Lake showing 5-m depth contours and the mark–recapture study area. Arrows indicate direction of stream flow.

SOCKEYE SALMON TOTAL ESCAPEMENT ESTIMATE

The total sockeye salmon escapement into 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. 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 (Figures 5–7).

Lower Creek Camera Weir

The weir was constructed by anchoring an aluminum video chute to the stream bed. Four 2.4 m weir panels were attached to each side of the video chute and anchored into the stream bed 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 upstream 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 was fish-tight.

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 two 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 8). 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) 2 SD cards were swapped back and forth daily. The crew used a laptop computer to review and backup 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. New DVR firmware allowed "pre-alarm" motion detection recording in which the device records video prior to a motion event.

Figure 5.–Sockeye salmon swimming through a lower creek camera weir. (©2013 ADF&G/photo by Raymond F. Vinzant.)

Figure 6.–Camera weir installed in lower Kanalku Creek, below Kanalku Falls, 2016. (©2016 ADF&G/photo by Raymond F. Vinzant.)

Figure 7.–Camera weir installed in lower Kanalku Creek, below Kanalku Falls, 2016. (©2016 ADF&G/photo by Steven C. Heinl.)

Figure 8.–Camera weir video recording components housed in a waterproof Pelican case. (©2012 ADF&G/photo by Raymond F. Vinzant.)

SOCKEYE SALMON SPAWNING ESCAPEMENT ESTIMATE

In previous seasons we used a standard picket weir to count the spawning population of sockeye salmon into Kanalku Lake. In 2013, 2014, and 2015 we also incorporated a camera weir upstream of the standard picket weir to provide a second count to validate the picket weir count. In all 3 years, however, we observed frequent predation on sockeye salmon by river otters (*Lontra canadensis*) between the 2 weirs (Vinzant and Heinl 2014–2016). As a result, we removed the standard picket weir mid-season in 2015 and used only the camera weir to estimate the spawning escapement of sockeye salmon (Vinzant and Heinl 2016). In 2016 we simplified the operation by installing a camera chute between a double-fence picket weir. This configuration allowed us to record fish as they swam freely through the weir 24 hours per day, and it eliminated the need for a mark–recapture estimate to validate the weir count.

Lake Camera Weir count

The camera weir was located in Kanalku Creek, across the outlet stream at the west side of the lake. The primary fence was constructed from the standard picket weir used in previous seasons and consisted of aluminum bipod supports anchored to the stream sediment. The supports were connected by rows of aluminum stringers and panels that extended across the entire stream bed. Pickets (300 cm long) were inserted through regularly-spaced holes in the stringers and panels and extended to the stream bottom. Picket spacing was 4.4 cm on center of the pickets, allowing for 52 pickets per channel and a maximum space of approximately 3.81 cm between pickets, or "pink salmon" spacing.

To ensure the primary weir was fish tight and no sockeye salmon could pass through it undetected, we installed a secondary picket fence directly upstream of the primary weir structure. The secondary fence consisted of 52-hole "pink salmon" spaced stringers and panels that were anchored to the stream bed with steel pipe and braced to the primary weir face. The pickets were approximately 100 cm long and extended to the stream bottom. A small fish trap, approximately 125 by 245 cm, was connected to the upstream side of the secondary weir fence. A 2-camera video chute was used to count fish traveling through the weir structure. The chute was approximately 125 cm long and spanned both the primary and secondary weir fences allowing fish to swim through both fences unimpeded. A "V" shaped entrance guided fish into the chute where they swam through the entire double-fence weir structure (Figures 9–11).

Any sockeye salmon that were able to slip through holes or gaps in the primary weir fence were trapped between the 2 fences, and/or captured in the fish trap. The presence of a sockeye salmon between the weir fences or in the fish trap would indicate a breach in the primary weir fence. The field crew would immediately assess the weir structure to locate and fix the breach. Sandbags were placed along both weir fences to help stabilize the substrate and secure the pickets in place, and a catwalk was constructed and attached to the primary weir face. The weir was inspected daily for breaches or malfunctions. 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.

Figure 9.–Double-fence camera weir, Kanalku Lake, 2016. (©2016 ADF&G/photo by Raymond F. Vinzant.)

Figure 10.–Double-fence camera weir, Kanalku Lake, 2016. (©2016 ADF&G/photo by Steven C. Heinl.)

Figure 11.–Lake camera weir chute (blue) and “V” entrance, 2016. (©2016 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 spawning escapement (the number of fish counted into the lake) from the total sockeye salmon escapement (the number of fish counted into the Kanalku Creek system below Kanalku Falls).

ADULT POPULATION AGE AND SIZE COMPOSITION

The age composition of the 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.

Beginning in late August, scale samples were collected from live fish captured with a beach seine on the spawning grounds in Kanalku Lake. 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 mid eye to fork of tail (MEF) to the nearest millimeter. Sex was determined by length and shape of the kype. 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 5-year-old fish with 1 freshwater and 3 ocean years; Koo 1962).

RESULTS

SOCKEYE SALMON TOTAL ESCAPEMENT ESTIMATE

The lower Kanalku Creek camera weir was installed downstream of Kanalku Falls and was fish-tight from 18 June to 31 August. The first sockeye salmon was recorded by the DVR system on 30 June. A total of 3,093 adult sockeye salmon were counted through the lower creek camera weir. The largest daily count occurred on 7 August, when 304 adult sockeye salmon were recorded (Figure 12; Appendix B). Sockeye salmon primarily traveled through the weir in the darkness, between 23:00 and 04:00, as was observed in previous seasons. No jack sockeye salmon were observed in the video files.

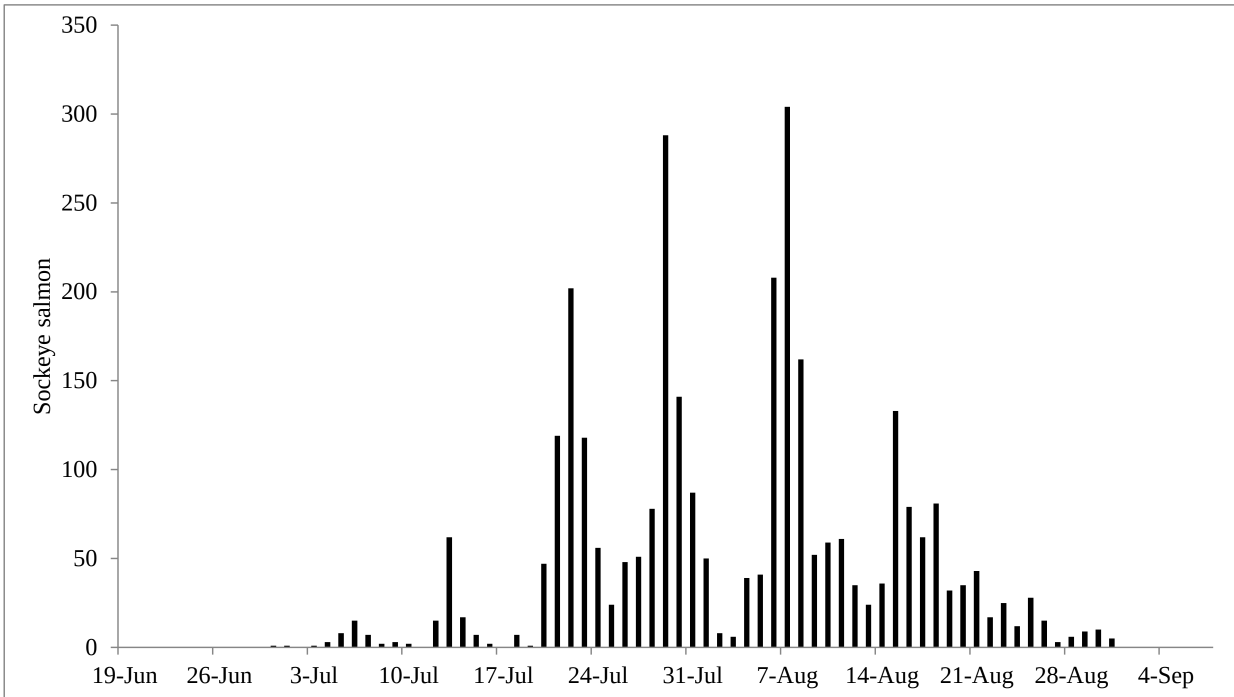

Figure 12.–Daily sockeye salmon counts at the lower Kanalku Creek camera weir, 2016.

The camera weir was operated without problem 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 through undetected. During installation, efforts were made to deepen the streambed under and around the video chute by approximately 30 cm. The slightly deeper channel and reduced current 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 reviewing the video files, and a post-season review of all video resulted in a difference of only 1 fish.

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 bypass the video cameras entirely.

SOCKEYE SALMON SPAWNING ESCAPEMENT ESTIMATE

Lake Camera Weir Count

The lake camera weir was installed and fish-tight on 20 June and operated until 7 September. The first sockeye salmon was seen on 5 July, 5 days after the first sockeye salmon was observed at the lower creek weir downstream of Kanalku Falls. A total of 2,236 adult sockeye salmon were counted through the lake camera weir (Figure 13). No other salmon species or jack sockeye salmon were observed on the video files. The largest daily count occurred on 31 July, when 225 adult sockeye salmon were counted through the weir (Figure 13; Appendix C). On 2 occasions single small sockeye salmon were found to have breached the primary weir fence and were caught in the fish trap. The first breach occurred on 29 July. The weir crew determined the problem was at the corner of the "V" entrance to the video chute where a small gap was found. The hole was sealed with 1-inch by 1-inch wire mesh and sandbags. The second breach was found on 10 August. The crew discovered a sandbag had fallen out of place near the "V" entrance to the video chute and another small gap was found. The offending sandbag was replaced and reinforced with additional bags. No other leaks in the primary weir fence were encountered.

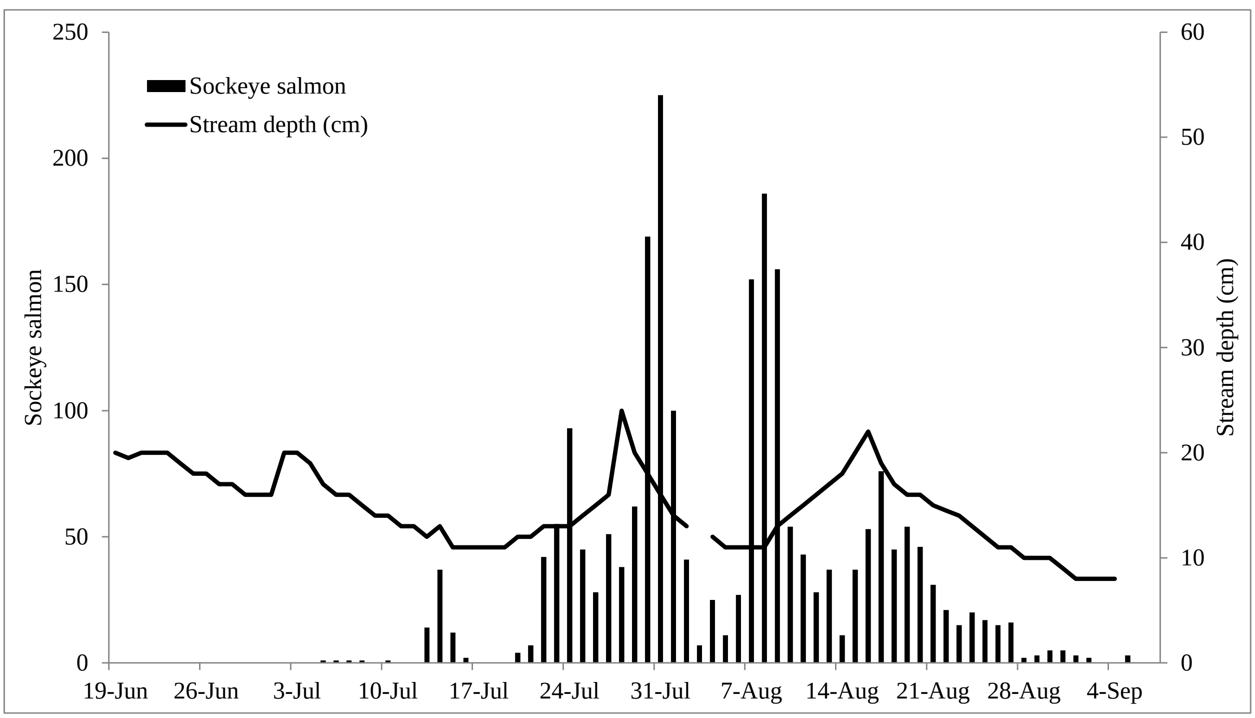

Figure 13.–Daily sockeye salmon counts and stream depth (cm) at the lake camera weir, Kanalku Lake, 2016.

ADULT POPULATION AGE AND SIZE COMPOSITION

A total of 237 sockeye salmon were sampled for age, sex, and length composition in 2016. All fish were captured with a beach seine on the spawning ground of Kanalku Lake during 5 sampling events between 24 August and 6 September. A large proportion of the scale samples collected in 2016 were highly resorbed and reliable ocean ages could not be determined at the ADF&G aging laboratory.

In order to estimate the age composition of the 2016 escapement, we first assumed the escapement was composed entirely of age-1.2 and age-1.3 fish since those 2 age classes accounted for an average 96% of total escapements from 2001 to 2015 (Appendix D). We then compared the length frequencies of those 2 age classes by sex to historical age, length, and sex information (Appendix E). The greatest degree of overlap in the lengths of age-1.2 and age-1.3 fish occurred in the range of 520–560 mm (MEF) for males and 530–560 mm for females. In 2016, 113 of 130 males sampled were smaller than 520 mm, and 105 of 107 females sampled were smaller than 530 mm (Appendix E). Therefore, we estimated that age-1.2 fish composed 92% (2,057 fish) of the spawning escapement in 2016. The remaining 8% of the spawning escapement (179 fish) was probably split between age-1.2 and age-1.3 fish. The overall small size of fish sampled in 2016 (none greater than 550 mm MEF) suggests that age-1.3 fish comprised only a very small proportion of the spawning population.

DISCUSSION

This was the fifth consecutive year we have used a video camera weir below Kanalku Falls to count the total number of sockeye salmon that entered the Kanalku Lake system. The total escapement of 3,093 sockeye salmon in 2016 was approximately 1,000 fish above the 2012–2015 average of 2,076 fish (Figure 14) and the largest total escapement recorded since we began monitoring the total escapement downstream of Kanalku Falls. Upstream, at the outflow of Kanalku Lake, the spawning escapement of 2,236 adult sockeye salmon was also approximately 1,000 fish above the 2001–2015 average (1,260 fish; Figure 15). This was the third season since barrier-modification work was done at the base of the falls in 2013 (Vinzant and Heinl 2014). The estimated inriver mortality rate (28%) in 2016 was 10% less than the average mortality rate estimated between 2012 and 2015 (Figure 14; Vinzant and Heinl 2016). Both the highest (51% in 2012) and lowest (24% in 2013) estimates of inriver mortality occurred prior to the barrier-modification work done in August 2013 (Vinzant et al. 2013; Vinzant and Heinl 2014).

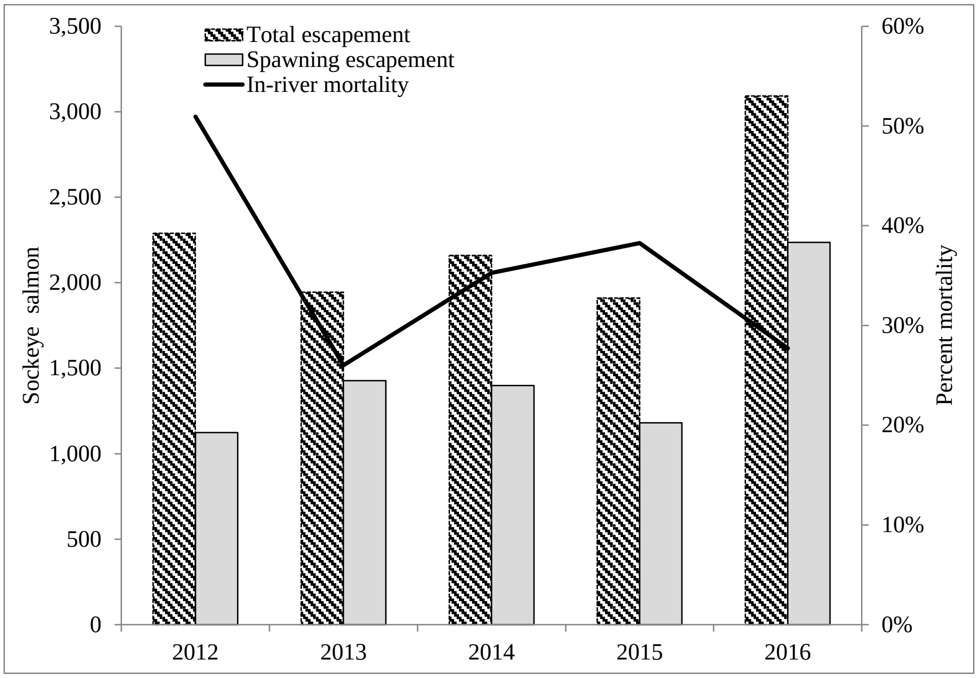

Figure 14.–Total escapement downstream of Kanalku Falls, spawning escapement at Kanalku Lake, and inriver mortality, 2012 to 2016. The falls were modified to improve fish passage following the 2013 season.

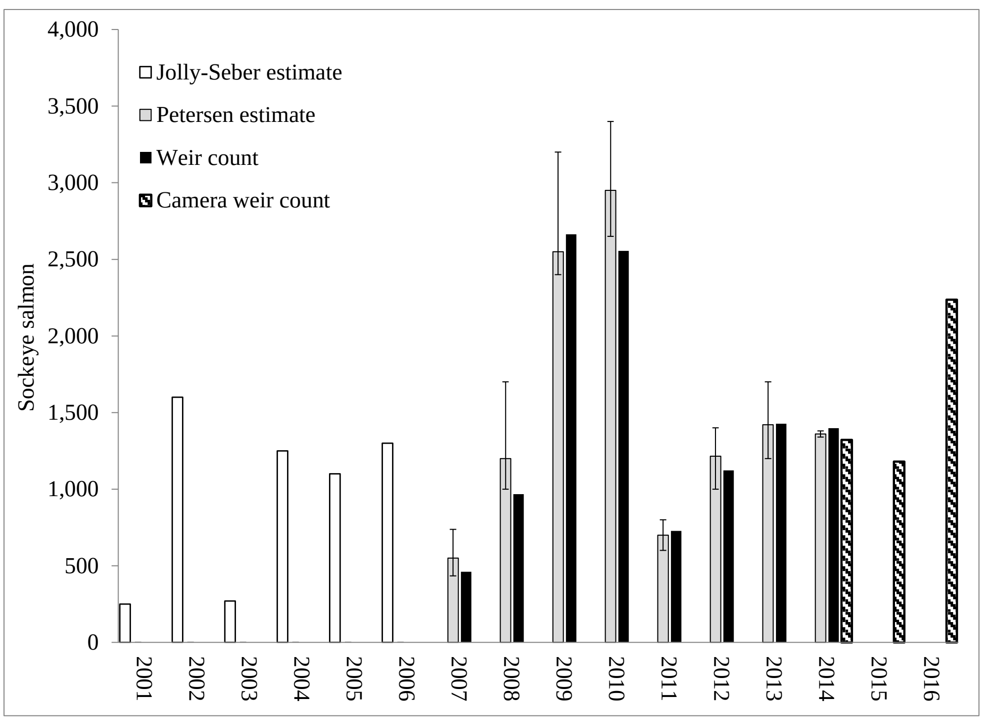

Figure 15.–Estimated sockeye salmon spawning escapements at Kanalku Lake from 2001 to 2016. Error bars represent the 95% confidence intervals of the Petersen mark–recapture estimates.

Prior studies suggested that water flow likely has significant impact on sockeye salmon passage over Kanalku Falls (Vinzant and Bednarski 2010). The inriver mortality was highest in 2012 (51%), when stream depth was higher than average throughout most of the sockeye salmon migration (Figure 16; Vinzant et al. 2013). Lower mortality rates were recorded in 2013–2015, when recorded stream depths were lower than average (Figure 14; Vinzant and Heinl 2014–2016). The inriver mortality rate in 2016 (28%) was very similar to the inriver mortality in 2013 (24%; Figure 14), the year prior to the barrier modification. Stream depths were lower than average in both years. Although the barrier modification does not appear to have 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 that observed in 2012 (Figure 16). Additional years of information should provide a better understanding of how stream depth affects sockeye salmon passage over the falls and whether or not Phase I of the barrier modification improved fish passage. If required, Phase II of the barrier modification may be implemented, which would raise the plunge pool at the base of the falls by 45–60 cm.

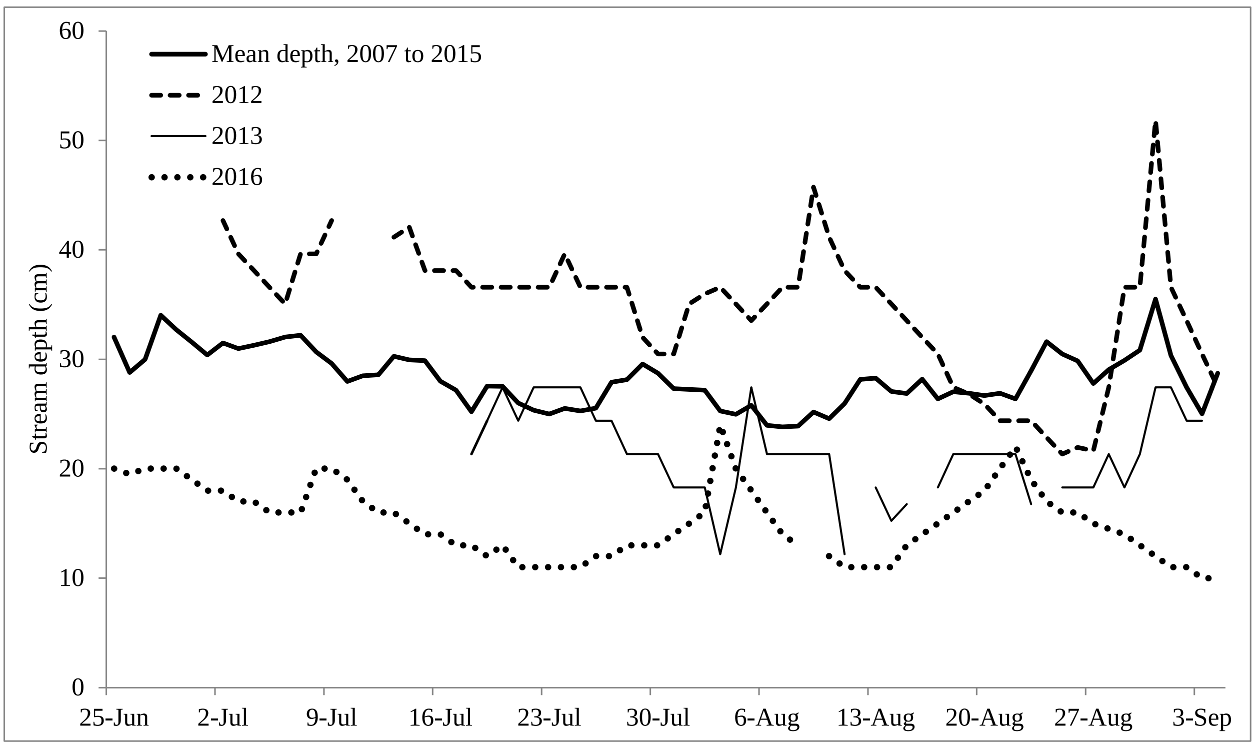

Figure 16.–Stream depth (cm) at the Kanalku Lake camera weir in 2016, compared to 2012 and 2013 and to the mean stream depth from 2007 to 2014.

The new weir design we implemented for the lake camera weir worked very well in 2016. The double-fence allowed us to use a single camera chute, greatly reduced the probability of fish passing the weir uncounted, reduced predation by river otters, and allowed fish to pass unimpeded through the weir 24 hours per day. Additionally, the “tattle-tale” design immediately informed the crew when fish had sneaked through holes in the primary fence so that problems could be addressed and repaired promptly. Furthermore, operating a single weir structure at the lake greatly reduced the time required to review video files each day and simplified the electrical components needed to obtain a reliable count of the sockeye salmon spawning escapement.

New DVRs with updated firmware available in 2016 allowed “pre-alarm” motion detection recording in which the DVR initiates recording immediately prior to a motion event. In previous seasons, without “pre-alarm,” many video files contained only partial images of the posterior ends of fish. This season, we were able to capture a full image of nearly every sockeye salmon that swam through the camera weirs with the firmware upgrade and the “pre-alarm” feature set to record just 1 second before a motion event. The new DVRs, however, were significantly more sensitive to underwater debris than older versions, especially at night when the LED lights were on. Through some trial-and-error we were able to block algae and debris from entering the chute and triggering the DVRs of the lake camera weir by anchoring a small piece of vexar fencing to the streambed approximately 1 m upstream of the video chute opening. This greatly reduced the number of video files that did not contain images of fish passing through the weir.

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APPENDICES

Appendix A.–Estimated annual spawning escapement and subsistence harvest of Kanalku Lake sockeye salmon, 2001–2016. 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	–	1,360	695
2015	–	1,180	–	–	–	–	1,180	245
2016	–	2,236	–	–	–	–	2,236	N/A

[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 2016 were not available at the time of publication.

Appendix B.–Number of sockeye salmon counted in lower Kanalku Creek camera weir in 2016. Other fish species were not enumerated.

	Sockeye salmon			Sockeye salmon			Sockeye salmon	
Date	Daily	Cumulative	Date	Daily	Cumulative	Date	Daily	Cumulative
19-Jun	0	0	20-Jul	47	201	20-Aug	35	2,920
20-Jun	0	0	21-Jul	119	320	21-Aug	43	2,963
21-Jun	0	0	22-Jul	202	522	22-Aug	17	2,980
22-Jun	0	0	23-Jul	118	640	23-Aug	25	3,005
23-Jun	0	0	24-Jul	56	696	24-Aug	12	3,017
24-Jun	0	0	25-Jul	24	720	25-Aug	28	3,045
25-Jun	0	0	26-Jul	48	768	26-Aug	15	3,060
26-Jun	0	0	27-Jul	51	819	27-Aug	3	3,063
27-Jun	0	0	28-Jul	78	897	28-Aug	6	3,069
28-Jun	0	0	29-Jul	288	1,185	29-Aug	9	3,078
29-Jun	0	0	30-Jul	141	1,326	30-Aug	10	3,088
30-Jun	1	1	31-Jul	87	1,413	31-Aug	5	3,093
1-Jul	1	2	1-Aug	50	1,463	1-Sep	0	3,093
2-Jul	0	2	2-Aug	8	1,471	Total	3,093	3,093
3-Jul	1	3	3-Aug	6	1,477			
4-Jul	3	6	4-Aug	39	1,516			
5-Jul	8	14	5-Aug	41	1,557			
6-Jul	15	29	6-Aug	208	1,765			
7-Jul	7	36	7-Aug	304	2,069			
8-Jul	2	38	8-Aug	162	2,231			
9-Jul	3	41	9-Aug	52	2,283			
10-Jul	2	43	10-Aug	59	2,342			
11-Jul	0	43	11-Aug	61	2,403			
12-Jul	15	58	12-Aug	35	2,438			
13-Jul	62	120	13-Aug	24	2,462			
14-Jul	17	137	14-Aug	36	2,498			
15-Jul	7	144	15-Aug	133	2,631			
16-Jul	2	146	16-Aug	79	2,710			
17-Jul	0	146	17-Aug	62	2,772			
18-Jul	7	153	18-Aug	81	2,853			
19-Jul	1	154	19-Aug	32	2,885			

Appendix C.–Daily and cumulative counts of sockeye salmon, water depth, and air and water temperature at the Kanalku Lake camera weir in 2016. No other salmon species were observed.

Date	Sockeye salmon		Water depth (cm)	Water temperature (°C)	Air temperature (°C)
	Daily	Cumulative			
19-Jun	0	0	20.0	–	–
20-Jun	0	0	19.5	18.0	13.0
21-Jun	0	0	20.0	19.0	13.0
22-Jun	0	0	20.0	18.0	14.0
23-Jun	0	0	20.0	18.0	14.0
24-Jun	0	0	19.0	19.0	15.0
25-Jun	0	0	18.0	18.0	16.0
26-Jun	0	0	18.0	18.0	15.0
27-Jun	0	0	17.0	19.0	14.0
28-Jun	0	0	17.0	18.0	16.0
29-Jun	0	0	16.0	18.0	15.0
30-Jun	0	0	16.0	18.0	16.0
1-Jul	0	0	16.0	18.0	16.0
2-Jul	0	0	20.0	18.0	14.0
3-Jul	0	0	20.0	17.0	14.0
4-Jul	0	0	19.0	18.0	13.0
5-Jul	1	1	17.0	18.0	15.0
6-Jul	1	2	16.0	17.5	14.0
7-Jul	1	3	16.0	19.0	15.0
8-Jul	1	4	15.0	20.0	16.0
9-Jul	0	4	14.0	19.0	17.0
10-Jul	1	5	14.0	20.0	15.0
11-Jul	0	5	13.0	20.0	18.0
12-Jul	0	5	13.0	20.0	17.0
13-Jul	14	19	12.0	21.0	18.0
14-Jul	37	56	13.0	20.5	17.0
15-Jul	12	68	11.0	20.5	18.0
16-Jul	2	70	11.0	20.0	17.5
17-Jul	0	70	11.0	20.0	17.5
18-Jul	0	70	11.0	20.0	19.0
19-Jul	0	70	11.0	20.0	18.0
20-Jul	4	74	12.0	19.5	17.0
21-Jul	7	81	12.0	20.5	18.0
22-Jul	42	123	13.0	20.0	17.5
23-Jul	55	178	13.0	19.5	16.0
24-Jul	93	271	13.0	19.0	17.0

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Date	Sockeye salmon Daily	Sockeye salmon Cumulative	Water depth (cm)	Water temperature (°C)	Air temperature (°C)
25-Jul	45	316	14.0	18.5	17.0
26-Jul	28	344	15.0	18.5	16.0
27-Jul	51	395	16.0	18.0	16.0
28-Jul	38	433	24.0	18.5	16.0
29-Jul	62	495	20.0	18.0	16.0
30-Jul	169	664	18.0	18.0	16.5
31-Jul	225	889	16.0	18.0	16.0
1-Aug	100	989	14.0	18.0	16.0
2-Aug	41	1,030	13.0	18.5	15.5
3-Aug	7	1,037	–	–	–
4-Aug	25	1,062	12.0	19.5	17.0
5-Aug	11	1,073	11.0	19.5	18.0
6-Aug	27	1,100	11.0	19.0	16.5
7-Aug	152	1,252	11.0	20.0	18.0
8-Aug	186	1,438	11.0	19.5	16.5
9-Aug	156	1,594	13.0	19.5	17.0
10-Aug	54	1,648	14.0	19.0	17.0
11-Aug	43	1,691	15.0	20.0	17.5
12-Aug	28	1,719	16.0	19.5	16.0
13-Aug	37	1,756	17.0	19.0	16.0
14-Aug	11	1,767	18.0	19.0	18.0
15-Aug	37	1,804	20.0	18.5	16.5
16-Aug	53	1,857	22.0	19.0	16.0
17-Aug	76	1,933	19.0	18.0	16.5
18-Aug	45	1,978	17.0	19.0	17.0
19-Aug	54	2,032	16.0	19.0	16.0
20-Aug	46	2,078	16.0	19.5	16.5
21-Aug	31	2,109	15.0	19.0	17.0
22-Aug	21	2,130	14.5	18.5	16.0
23-Aug	15	2,145	14.0	18.5	16.5
24-Aug	20	2,165	13.0	19.0	16.0
25-Aug	17	2,182	12.0	19.0	16.0
26-Aug	15	2,197	11.0	19.0	16.5
27-Aug	16	2,213	11.0	19.0	16.0
28-Aug	2	2,215	10.0	19.5	16.5
29-Aug	3	2,218	10.0	19.0	16.0

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Date	Sockeye salmon		Water depth (cm)	Water temperature (°C)	Air temperature (°C)
	Daily	Cumulative			
30-Aug	5	2,223	10.0	19.0	15.5
31-Aug	5	2,228	9.0	19.0	15.0
1-Sep	3	2,231	8.0	19.0	14.0
2-Sep	2	2,233	8.0	19.0	14.5
3-Sep	0	2,233	8.0	19.5	16.0
4-Sep	0	2,233	8.0	19.5	15.0
5-Sep	3	2,236	–	–	–
6-Sep	0	2,236	–	–	–
7-Sep	0	2,236	–	–	–

Appendix D.–Age composition of sockeye salmon spawning escapements at Kanalku Lake, 2001–2015. Age composition from 2007 to 2014 was based on weighted weekly escapement counts at the Kanalku Lake weir; age composition in other years was based on unweighted samples collected on the spawning grounds.

	Age class						
Year	1.1	1.2	1.3	2.1	2.2	2.3	3.2
2001	0.000	0.551	0.427	0.000	0.022	0.000	0.000
2002	0.000	0.803	0.164	0.000	0.033	0.000	0.000
2003	0.000	0.873	0.115	0.000	0.013	0.000	0.000
2004	0.000	0.760	0.228	0.000	0.012	0.000	0.000
2005	0.003	0.847	0.111	0.008	0.029	0.003	0.000
2006	0.000	0.968	0.032	0.000	0.000	0.000	0.000
2007	0.000	0.330	0.594	0.000	0.063	0.013	0.000
2008	0.000	0.956	0.015	0.000	0.026	0.003	0.000
2009	0.000	0.660	0.278	0.000	0.062	0.000	0.000
2010	0.000	0.870	0.123	0.000	0.006	0.002	0.000
2011	0.000	0.494	0.460	0.000	0.041	0.005	0.000
2012	0.000	0.885	0.066	0.000	0.044	0.000	0.005
2013	0.000	0.798	0.145	0.000	0.031	0.002	0.024
2014	0.000	0.770	0.202	0.000	0.027	0.000	0.001
2015	0.005	0.841	0.101	0.000	0.048	0.005	0.000
Mean	0.000	0.760	0.204	0.001	0.031	0.002	0.002

Appendix E.–Kanalku Lake sockeye salmon age-length frequencies by sex, 2001–2015, and comparison to 2016 sockeye salmon lengths. Shaded areas indicate >5% overlap in lengths between age-1.2 and age-1.3 fish.

MEF length	Males 2001–2015						Females 2001–2015						2016 length frequency		
(mm)	1.2	1.3	2.2	2.3	3.2	*n*	1.2	1.3	2.2	2.3	3.2	*n*	Males	Females	*N*
410	1.00	---	---	---	---	1	1.00	---	---	---	---	3	---	---	---
420	1.00	---	---	---	---	1	0.86	---	0.14	---	---	7	---	---	---
430	1.00	---	---	---	---	8	0.60	---	0.40	---	---	5	1	---	1
440	1.00	---	---	---	---	24	0.93	---	0.07	---	---	29	3	---	3
450	0.98	0.02	---	---	---	51	0.96	---	0.04	---	---	81	8	3	11
460	0.98	---	0.02	---	---	92	0.95	---	0.05	---	---	152	8	8	16
470	0.98	---	0.02	---	---	184	0.97	---	0.03	---	---	272	16	14	30
480	0.98	---	0.02	---	---	241	0.96	0.00	0.03	---	---	325	24	28	52
490	0.98	0.00	0.01	---	---	295	0.97	0.01	0.02	---	---	370	33	24	57
500	0.94	0.02	0.04	---	---	258	0.95	0.01	0.04	---	0.00	323	13	19	32
510	0.92	0.04	0.03	---	0.00	239	0.93	0.03	0.03	---	0.00	273	7	6	13
520	0.84	0.14	0.03	---	0.00	237	0.86	0.04	0.09	---	0.01	162	5	3	8
530	0.59	0.32	0.07	0.02	0.01	199	0.65	0.28	0.06	---	0.01	120	7	1	8
540	0.43	0.54	0.02	0.01	0.01	175	0.53	0.39	0.04	0.03	0.01	72	3	---	3
550	0.27	0.68	0.06	---	---	145	0.37	0.53	0.11	---	---	38	2	1	3
560	0.07	0.92	---	0.01	---	133	0.20	0.76	0.04	---	---	25	---	---	---
570	0.02	0.97	---	0.01	0.01	126	---	1.00	---	---	---	15	---	---	---
580	---	1.00	---	---	---	78	0.13	0.88	---	---	---	8	---	---	---
590	0.02	0.98	---	---	---	42	---	1.00	---	---	---	1	---	---	---
600	---	0.94	0.06	---	---	16	---	1.00	---	---	---	2	---	---	---
610	---	1.00	---	---	---	10	---	---	---	---	---	0	---	---	---
620+	---	1.00	---	---	---	7	---	---	---	---	---	0	---	---	---
Total						2,562						2,283	130	107	237