Red Lake Remote Video Salmon Escapement Monitoring Project, 2024

by

Edward O. Otis

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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	$(F, t, \chi^2, \text{etc.})$
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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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

From 28 May through 2 November 2024, Alaska Department of Fish and Game staff operated an autonomous video counting tower (AVCT) below the outlet of Red Lake within the Southern District of the Lower Cook Inlet Management Area (LCIMA). The AVCT was programmed to record time-lapse video during all daytime and select nighttime hours to document the run-timing and magnitude of Pacific salmon (*Oncorhynchus* spp.) escapements into Red Lake. This project first operated during the 2022 field season and is a component of the Alaska Energy Authority's preliminary assessment of fishery resources in the Martin River drainage, which is under consideration for future hydroelectric power development. Sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), and Dolly Varden (*Salvelinus malma*) were observed on video migrating upstream to Red Lake in 2024. Additionally, juvenile salmonids were recorded emigrating from the system, although they were too small to count or identify to species. The video camera operated without error throughout the 2024 season, recording 3,812 h of video. However, a major flood event on August 7 destroyed the underwater lighting system and created significant turbidity for 5 days. Fortunately, this disturbance occurred after the sockeye salmon run, and the light was restored before the coho salmon run began. The peak daily count of sockeye salmon (253) occurred on 12 June, and the total escapement was 1,197 sockeye salmon, 548 (45.8%) of which migrated upstream at night. The peak count for coho salmon (31) occurred on 6 October, with a total observed escapement of 182 fish, 139 (76.4%) of which migrated upstream at night. No pink salmon were observed in 2024, but the AVCT documented 88 Dolly Varden and 14 species of wildlife including brown (*Ursus arctos)* and black bears (*U. americanus*).

Keywords   Lower Cook Inlet, Kachemak Bay, Red Lake, Martin River, Pacific salmon, sockeye salmon, coho salmon, Dolly Varden, video, escapement monitoring, autonomous video counting tower, AVCT

INTRODUCTION

This project was developed in 2022 and continued in 2023 and 2024 as a component of the Alaska Energy Authority's (AEA) preliminary assessment of fishery resources in the Martin River drainage, which is under consideration for future hydroelectric power development. AEA funded the Alaska Department of Fish and Game (ADF&G) to document the run timing and magnitude of Pacific salmon (*Oncorhyncus* spp.) escapements into Red Lake, which resides in the Southern District of ADF&G's Lower Cook Inlet Management Area (LCIMA; Figure 1).

The use of aerial surveys to monitor salmon escapement on small clear streams in Alaska began in the 1930s (Eicher 1953) and continues today (Otis and Hollowell 2023). This technique is favored for remote and marginally productive stocks which otherwise may go unassessed due to the high cost of intensive monitoring methods (e.g., weir, sonar) relative to the stream's modest escapement. However, aerial surveys have several drawbacks. Observer experience, water clarity, stream morphology and habitat type, timing and periodicity of survey flights, and stream residency are just a few factors shown to influence the accuracy and precision of aerial survey estimates of salmon escapement (Bevan 1961; Neilson and Geen 1981; Cousens et al. 1982; Shardlow et al. 1987; Perrin and Irvine 1990; Hill 1997; Bue et al. 1998; and Jones et al. 2007). Researchers have developed sophisticated statistical approaches for dealing with some of these problems (Hilborn et al. 1999; Adkison and Su 2001; Su et al. 2001), but aerial survey remains an imprecise escapement monitoring tool. At best, an aerial survey provides consistent indices of inriver escapement among years. It does not provide accurate, reliable estimates of spawner-abundance, particularly when inriver exploitation or predation of salmon is high (Peirce et al. 2011; Peirce et al. 2013) and observer efficiency and stream residency are not precisely known (Perrin and Irvine 1990; Bue et al. 1998; Jones et al. 1998).

Accurate, reliable estimates of spawner abundance are required to assess stock–recruit relationships (Walters and Ludwig 1981), monitor long-term trends in the status of salmon resources (Baker et al. 1996), set appropriate spawning escapement goals for individual streams

(Otis et al. 2023), and manage commercial fisheries in season (Hollowell et al. 2023). Because aerial surveys cannot always provide this level of information and more accurate methods are prohibitively expensive for streams with marginal escapements, a niche exists that remote video technology has helped fill. Uncrewed (autonomous) underwater video systems are not practical for most Alaska streams because the camera and weir would be vulnerable to high water events, inquisitive bears, and other mammals. Researchers in Alaska have been experimenting with human operated (Hetrick et al. 2004) and uncrewed video counting towers (Otis and Dickson 2002; O'Neal 2007; Otis 2012; Otis 2023). Towers are more practical for uncrewed, remote operation because there is nothing in the creek to obstruct fish passage or become vulnerable to bears or high-water events. Unlike traditional counting towers, where human observers sample the escapement by counting fish during predefined periods every hour, video counting towers can be programmed to record fish passage continuously. Uncrewed or autonomous video counting towers (AVCT) are well suited for many small clear streams that are otherwise monitored by aerial survey. When deployed at appropriate locations, AVCTs have demonstrated the ability to collect near census quality escapement estimates (Otis et al. 2010) that far surpass the accuracy of aerial survey indices.

Red Lake is difficult to survey using fixed-wing aircraft due to local topography and its small size and dark, vegetated bottom. However, the outlet of Red Lake is well suited to monitoring salmon escapement with an AVCT. The outlet stream, before it joins the Martin River, is narrow, generally very clear, has shallow laminar flow, and has adequate solar exposure. All these traits are needed for AVCTs to produce high quality video images of migrating salmon. Because salmon escapement was expected to be modest, and access to Red Lake is difficult and expensive (i.e., helicopter), an AVCT was determined to be the most effective and economical method for assessing this stock. Currently, in addition to Red Lake, ADF&G uses AVCTs to monitor escapements for 2 wild salmon stocks in the LCIMA: Mikfik Lake sockeye salmon (*O. nerka*) and Chenik Lake sockeye salmon (Otis 2023). The AVCT at Red Lake was modeled after the design and functionality of those systems.

OBJECTIVES

1. Operate an AVCT at Red Lake to census the daily escapement of adult Pacific salmon during all daylight and nighttime hours, from 28 May through 2 November.

2. Identify and document other fish and wildlife species (e.g., juvenile salmonids, bears) captured on video transiting the camera site.

METHODS

STUDY SITE

Red Lake is located approximately 8.8 river km (5.5 mi) upstream of the mouth of the Martin River near the head of Kachemak Bay, in the Southern District of the LCIMA (Figure 1). The Red Lake AVCT was located approximately 100 m below Red Lake along the outlet stream that flows into the Martin River (Figure 2; approximately 59.6966 N, 151.0031 W). This location was selected because it met key criteria for successful AVCT operations (e.g., shallow/clear water, laminar flow, narrow stream width, and adequate southern exposure for generating enough solar power to exceed system requirements).

VIDEO COMPONENTS

The Red Lake AVCT consisted of a camera, external hard drive, batteries, solar panels, and an auxiliary lighting system. The video and lighting systems were independent of one another:

Video system:

- (1) video surveillance camera *(GeoVision Model GV-BX3400)*
- (1) 2 TB hard drive *(Oyen Novus 7200RPM)*
- (4) 85 W solar panels *(Model BP585U)*
- (2) 15 A solar power regulators *(Model AST-15A)*
- (2) 12 V batteries *(Absorbed Glass Mat [AGM], Group 31)*
- (1) 12 V timer switch *(Model JVR 12V)*
- (1) 12 Circuit fuse block *(Blue Sea Systems)*
- Other assorted wires and electrical components

Lighting system:

- (2) 85 W solar panels *(Model BP585U)*
- (1) 15 A solar power regulator *(Model AST-15A)*
- (2) 12 V battery *(Absorbed Glass Mat [AGM], Group 31)*
- (1) 12 V timer switch *(Model JVR 12V)*
- Other assorted wires and electrical components

Components for the video system were mounted to a 3-meter (10 ft) section of antenna tower. Approximately 30–60 cm (1–2 ft) of the bottom of the tower were buried in the ground to create a solid base. The top of the tower was stabilized by 3 radially spaced guy lines extending downward to *Duckbill* earth anchors (*Model-88*). A 122 cm (4 ft) length of 6.4 cm diameter (2.5 in) aluminum pipe was secured to the top of the tower for additional height and to provide a place to attach an adjustable video camera housing (Figure 3).

The camera (*GeoVision* Model *GV-BX3400*) was a 3 megapixel (MP) progressive scan CMOS IP box camera outfitted with a varifocal (*GeoVision* 3–10.5 mm), auto-iris lens. The camera was powered by a dedicated 12 V direct current (VDC) cable, but it also had power over ethernet (PoE) capability. Setup and review of the camera required a laptop computer running *GeoVision* software (Model *GV-IPCAM H.264*) that was connected to the camera via an ethernet cable. In the field, during setup and periodic maintenance visits, we confirmed the camera was functioning properly using the laptop or a portable monitor connected via coaxial cable.

The camera was enclosed in a custom-fabricated, aluminum, weatherproof camera housing attached to the top of the tower where it was adjusted so the view encompassed the entire wetted width of the creek. The other sensitive electronic components were protected inside a commercially available weatherproof aluminum strongbox (Model *UWS-ATV: 81.3 cm L x 30.5 cm W x 30.5 cm H*) set atop a platform secured to the tower approximately 1 m above ground (Figure 3). A 2.5 cm diameter (1 in) flexible conduit protected all cables needed for communication between the camera and strongbox components. Communication cables included: ethernet, 12/2 power, USB, and coaxial. Video from the camera was recorded to a 2 TB external hard drive via a 4.6 m (15 ft) length of USB cable (USB-C to 2.0 mini-B).

Electronic components in the video system were powered by 2 Group 31, 12 VDC, 110-ampere hour (Ah) absorbed glass mat (AGM) batteries. They were connected in parallel to provide a single 220 Ah capacity battery bank outputting 12 VDC. Four 85 W solar panels (Model *BP585U*), set up as 2 isolated pairs, were used to recharge the battery bank. Wire leads from each pair of solar panels were run through a 15 A fuse block and a 15 A solar power regulator (Model *AST 15*) before going to the battery bank (Figure 4). All sensitive electronic components (e.g., camera, hard drive, monitor) were protected by appropriately sized fuses inside a fuse block, like those used for small boat accessories.

To enhance the visibility of fish passing the AVCT, a high-contrast substrate panel was fabricated out of a 4.6 mm (3/16 in) mesh beach seine. It was dyed light green because fish can sometimes be reluctant to swim across a bright white panel (E. Otis, ADF&G Division of Commercial Fisheries Biologist, personal observation). The panel was placed across the bottom of the stream, perpendicular to water flow (Figure 3B). The upstream edge of the panel was secured to an anchor chain fastened to the stream bottom using a *Duckbill* earth anchor (Model *DB-68*). The downstream edge of the panel was left unencumbered as it was held tight to the streambed by the current.

Auxiliary lighting was added to the Red Lake AVCT in 2023 (Figure 5) after it was learned that a high proportion of the coho salmon (*O. kisutch*) passage at nearby Battle Creek occurred during hours of darkness in 2022 (H. Dickson, ADF&G, Division of Sport Fish Biologist, Homer, personal communication, October 2022). At Red Lake in 2023, >97% of coho salmon migrated upstream at night (Blackmon and Otis 2024), so auxiliary lighting was again deployed in 2024. Illumination was provided by a single 5 W LED bulb powered via a 12 VDC timer *(Model JVR 12V)* that was programmed to turn on for 8 h (midnight–0800) each night. The system was powered by 2 Group 31, 12 VDC AGM battery and maintained by two 85 W solar panels (Model *BP585U*) and a 15 A solar power regulator (Model *AST-15A*). The light fixture was an underwater pond light (Best Pro Lighting Model *LED-BPL500-FG*) ensconced in an aluminum protective housing with the cable routed though flexible conduit to the aluminum job box containing the electrical components. Large rocks were placed on top of the light and conduit to deter inquisitive wildlife (Figure 5).

VIDEO INSTALLATION, OPERATION, AND REMOVAL

Given the expense of accessing the site by helicopter, we coordinated with other researchers to share flights to service our respective field equipment. After an initial deployment on 28 May, hard drives were exchanged on 20 June, 2 July, 23 July, 9 August, 29 August, and 24 September, with final retrieval on 8 November. Significantly reduced hours of daylight in the fall led to insufficient solar power generation, eventually depleting the batteries and causing the camera to cease operation at 6:53 AM on November 3 after the coho run was over, but while some fish were still actively spawning.

For more details on the installation, operation, and maintenance of the AVCT, including programming the camera and reviewing video using *GeoVision* software, see Otis and Blackmon (2023), and Appendices A–F in Otis (2023).

VIDEO RECORDING

While the camera was capable of recording at resolutions up to 1440 P (2560 x 1440), to balance hard drive capacity with image quality, we ultimately used 1.3 MP (1280 x 960, 4:3), in the MJPEG

codec, which compresses video within frames. We have found that other video codecs that compress video across frames, such as H.264, can result in rapid image degradation when recording through a medium of moving water, especially when surface turbulence is present. The AVCT was programmed to record 24 h per day. A time-lapse recording rate of 3 frames per second (fps) was selected to optimize hard drive space without compromising the reviewer's ability to track individual fish transiting the video site. Although disk space required for a day's video varies with the complexity of the images (e.g., varying light conditions, surface turbulence, cloud shadows), the 2 TB hard drives we used can accommodate approximately 50 days of recorded video when programmed to record 3 fps at 1280 x 960 resolution in the MJPEG format. Hard drives larger than 2 TB are not compatible with *GeoVision* cameras due to BIOS limitations. Auxiliary underwater lighting (UWL) was used to illuminate the water channel during nighttime hours. The UWL was triggered by a DC timer switch to power the light from midnight to 0800 h.

VIDEO REVIEW

Video footage was reviewed during and after the season to enumerate daytime and nocturnal fish passage (Figure 6). All recorded video was reviewed, with no subsampling. Image resolution was sufficient to speciate adult salmonids, but not juveniles. The run timing for sockeye and coho salmon did not overlap, which also helped ensure the 2 most abundant species would not be misidentified. Dolly Varden were easily distinguished by their smaller size and behavior. Video review was easiest when run through the same *GeoVision* camera that was used to record the images, but that was not possible when the camera was still in the field recording fish passage. To overcome this, we installed software (*Ext2Fsd* and *RemoteViewlog*) on select office computers that allowed us to review video files directly from the *Linux* formatted field hard drives. *Ext2Fsd* is a free file system driver, written in *C* for *Microsoft* OS systems, which facilitates read/write access to *Linux* formatted drives and files (e.g., ext2, ext3, ext4). *RemoteViewlog* is *GeoVision*'s video review software, which provides the reviewer with control over a variety of playback features (e.g., screen size, playback speed, brightness, contrast). For more details on the use of *GeoVision* software for video review, see Appendix F in Otis (2023).

Fish counts and other noteworthy observations (e.g., weather, dawn/dusk, video quality, and wildlife sightings) were recorded in uniform *MS Excel* spreadsheets. Daily fish counts were stratified by species into 6-hour time blocks (e.g., 0001–0600, 0601–1200, 1201–1800, and 1801–2400). Staff also recorded periods of video loss or other technical difficulties (e.g., loss of the UWL). See Appendix E in Otis (2023) for further details and an example of this spreadsheet.

METHODS FOR EXPANDING COUNTS OF NOCTURNAL MIGRATION

Due to solar power generation constraints caused by daylight diminishing in the fall, our UWL was not operated continuously during all hours of darkness during the coho salmon run. Instead, we programmed the light to operate for 8 h each night (midnight to 0800 h) to sample nocturnal migration. Postseason review revealed that the vast majority (76.4%) of coho salmon migrated at night. To estimate how many coho salmon migrated past the AVCT while the light was off, we expanded our nocturnal counts based on the percentage of hours of darkness that were illuminated for counting each night:

$$P = h_L/h_d \qquad , \qquad (1)$$

where

P	=	Percentage of nighttime h illuminated by the UWL,
h_L	=	hours the UWL was operated each night, and
h_d	=	hours of darkness each night.

The proportion of night sampled by the UWL (P) was then used to expand the night count to estimate unobserved nocturnal migration:

$$N_x = N + (N*(1-P)),\qquad(2)$$

where

N_x	=	expanded night count estimate, and
N	=	observed night count while UWL was operating.

For instance, if there was 16 h of darkness (h_d) and the light was on for 8 h (h_L), the night count from the illuminated period (N) was doubled to estimate total nocturnal migration that night (N_x). To determine the proportion of dark hours that were sampled with light each night, we consulted a U.S. Navy website that provides h:min of darkness by date for any given latitude and longitude (https://aa.usno.navy.mil/calculated/durdaydark?year=2023&task=1&lat=59.6966&lon=151.003 1&label=Red+Lake%2C+Kachemak+Bay+Alaska&tz=9.00&tz_sign=-1&submit=Get+Data).

RESULTS

AVCT PERFORMANCE

The AVCT operated 24 h per day (0000–2400) from 1053 on 28 May until 0626 on 3 November 2024 (3,812 h). There were no recording interruptions that led to lost video in 2024. However, there were 3 events (7 August, 6 September, 12 October) that precluded some daytime, nighttime, or both counts due to high turbidity, loss of the UWL, or both (Tables 1 and 2, Figure 7). Limited solar power availability in the fall also precluded full illumination of all nighttime hours, which led to incomplete nocturnal fish counts. Statistics related to the UWL (e.g., proportion of dark hours illuminated by auxiliary lighting) and nocturnal fish counts are summarized in Table 2.

ADULT SALMONID ENUMERATION

Sockeye salmon, coho salmon, and Dolly Varden were observed migrating to Red Lake during 2024 operations. The AVCT documented a total of 1,197 sockeye salmon with the peak count (253 fish) occurring on 12 June (Table 1, Figure 7A). The peak count for coho salmon occurred on 6 October (31 fish), with a total escapement of 182 fish (Table 1, Figure 7B). Use of underwater lighting revealed that 45.8% (548) of the sockeye run, and 76.4% (139) of the coho run occurred during hours of darkness. The AVCT documented 88 Dolly Varden char in 2024, with the peak count (10 fish) occurring on 3 October (Table 1).

JUVENILE SALMON

During a brief opportunistic sampling event on 8 June 2022, several juvenile salmon observed along the shoreline of Red Lake were caught using a makeshift beach seine. Specimens were collected and transported to our lab in Homer where they were all positively identified as coho salmon. No specimens were collected in 2024, but 24 schools of juvenile salmonids were observed

on video emigrating downstream from Red Lake, primarily in June. Due to their small size, it was not possible to count or identify them to species.

OTHER WILDLIFE DOCUMENTED

- American dipper   *Cinclus mexicanus*
- American Mink   *Neogale vison*
- Bald eagle   *Haliaeetus leucocephalus*
- Beaver   *Castor canadensis*
- Belted kingfisher   *Megaceryle alcyon*
- Black bear   *Ursus americanus*
- Black-billed Magpie   *Pica hudsonia*
- Brown bear   *Ursus arctos*
- Common merganser   *Mergus merganser*
- Great blue heron   *Ardea herodias*
- Red squirrel   *Tamiasciurus hudsonicus*
- River otter   *Lontra canadensis*
- Spotted sandpiper   *Actitis macularius*
- Unidentified hawk   *Accipiter* sp.

DISCUSSION

AVCT PERFORMANCE

There were no malfunctions with the AVCT hardware in 2024, and the camera never lost power or failed to record video during all the hours it was scheduled to operate. The only video that was not reviewable in 2024 derived from 2 flood-related periods of high turbidity (7–11 August and 12 October), nocturnal periods when the UWL was destroyed by a flood (7–28 August) or covered by silt (6–23 September), 2 short (~1.5 h) intervals in October when the camera lens was covered by snow, and brief downtime while hard drives were being swapped (<5 min each). Also, due to solar power generation constraints with diminished daylight in the fall, the UWL was only programmed to operate for 8 h (midnight–0800) during August through October. This resulted in 1.5–7.0 h per day of unmonitored nocturnal migration (Table 2), which may have affected coho salmon counts.

ADULT SALMON ENUMERATION

Review of video files revealed that 1,197 sockeye salmon, 182 coho salmon, and 88 Dolly Varden migrated upstream past the AVCT site at the outlet of Red Lake in 2024 (Table 1). Sockeye salmon run timing peaked in mid-June (Figure 7), similar to 2022 (Blackmon and Otis 2023) and about a week earlier than the 2023 run (Blackmon and Otis 2024). Coho salmon run timing peaked in the first week of October (Figure 7), similar to both the 2022 (Blackmon and Otis 2023) and 2023 runs (Blackmon and Otis 2024). The duration of the run for both species during all 3 years was relatively short, with most fish passing the video site in 7–10 days (Figure 7; Blackmon and Otis 2023, 2024). When considering the run timing for Red Lake sockeye and coho salmon and evaluating potential impacts that may derive from future hydroelectric development activities in the drainage, it should be noted that there is an unknown migratory lag time between the date salmon enter the Martin River from Kachemak Bay and the date they are observed at the Red Lake AVCT. Anecdotally, it

appeared the migratory lag time for coho may be slightly longer than sockeye salmon based on the former generally being more "blushed" in color when passing the video site.

Although there were no interruptions to the video system in 2024, there were 2 events that resulted in disruptions to the underwater lighting system. The first UWL interruption occurred from 7–28 August and the second from 6–23 September (Figure 7). Fortunately, both interruptions occurred during the lull between the sockeye and coho salmon runs when very few salmon were observed during daylight hours, suggesting minimal impact (Table 2, Figure 7).

Despite the UWL not operating continuously all season, its use clearly improved the accuracy of our total escapement estimates for sockeye and coho salmon, 45.8% and 76.4% of which, respectively, were recorded migrating past the AVCT at night (Table 1). However, due to solar power generation constraints in the fall, the UWL was not operational during all nighttime hours in 2024. The UWL illuminated all hours of darkness throughout the sockeye salmon run, facilitating a complete census for that species. Although the UWL was operational throughout virtually all of the coho salmon run, it was not programmed to stay on throughout the night due to power concerns. We illuminated 8 h of darkness (midnight–0800) each night during the coho salmon run. However, after the 7 August flood event, the new light had to be relocated upstream of the substrate panel, resulting in illumination spanning ~40–50% of the stream rather than its full width. It is unknown how this affected the accuracy of night counts for coho salmon because the unlit portion of the stream could mask both up and downstream passage, each of which occurred, particularly after coho salmon began spawning around 7 October. Statistics related to the UWL are summarized in Table 2. Assuming fish passage rates were similar between the illuminated and nonilluminated hours of darkness, we estimated an additional 39 coho salmon migrated past the AVCT while the UWL was off (Table 2), raising the total nocturnal escapement of coho salmon from 100 (observed) to 139 fish (observed plus estimated; Table 2). Summing the daytime (43) and nocturnal counts (139) produced a total escapement of 182 coho salmon in 2024.

It should be noted that the very high proportions of coho salmon we observed migrating at night in 2023 (97.5%) and 2024 (76.4%) suggest that the 2022 estimate (48 coho), made without auxiliary lighting, was probably very conservative. The 2024 Dolly Varden count (88) may also be conservative due to the diminutive size and cryptic coloration of this species, which makes them difficult to distinguish when viewed from above, particularly after the high-contrast substrate panel was washed downstream by high water on 4 October.

Juvenile Salmon

Schools of juvenile salmonids were observed on video emigrating from Red Lake in 2024. However, they could not be speciated or counted due to their small size. Sampling juvenile salmonids was not the objective of this study, but coho salmon fry were observed and sampled opportunistically in 2022. However, that was a cursory effort, and the juvenile coho salmon caught were not considered to be representative of all species present. For example, given the number of adult sockeye salmon counted past the AVCT in 2022, 2023, and 2024, it appears Red Lake also provides appropriate rearing habitat for juvenile sockeye salmon. Future survey efforts could determine if juvenile sockeye salmon rear in Red Lake for 1 or 2 years, or if they leave the system soon after emerging from the gravel, as they sometimes do in systems lacking sufficient lake resources (Kaeriyama and Ueda 1998). A more thorough and systematic survey involving sampling of different habitats throughout the lake using a variety of capture methods should be used if this becomes a future study objective.

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TABLES AND FIGURES

Table 1.–Daily fish passage at Red Lake autonomous video counting tower (AVCT) by species in 2024.

Date	Sockeye salmon			Coho salmon			Dolly Varden	
	Day	Night	Total	Day	Night[a]	Total	Daily	Total
28-May	0	0	0	0	0	0	0	0
29-May	0	0	0	0	0	0	0	0
30-May	17	0	17	0	0	0	0	0
31-May	1	1	19	0	0	0	1	1
1-Jun	0	0	19	0	0	0	0	1
2-Jun	0	0	19	0	0	0	0	1
3-Jun	0	0	19	0	0	0	0	1
4-Jun	1	0	20	0	0	0	0	1
5-Jun	0	0	20	0	0	0	0	1
6-Jun	0	0	20	0	0	0	0	1
7-Jun	0	0	20	0	0	0	0	1
8-Jun	8	0	28	0	0	0	0	1
9-Jun	3	0	31	0	0	0	0	1
10-Jun	0	0	31	0	0	0	0	1
11-Jun	22	39	92	0	0	0	0	1
12-Jun	201	52	345	0	0	0	0	1
13-Jun	130	0	475	0	0	0	0	1
14-Jun	40	65	580	0	0	0	0	1
15-Jun	23	94	697	0	0	0	0	1
16-Jun	16	46	759	0	0	0	0	1
17-Jun	25	0	784	0	0	0	0	1
18-Jun	20	28	832	0	0	0	2	3
19-Jun	12	38	882	0	0	0	5	8
20-Jun	17	21	920	0	0	0	6	14
21-Jun	14	22	956	0	0	0	4	18
22-Jun	18	9	983	0	0	0	2	20
23-Jun	19	16	1,018	0	0	0	1	21
24-Jun	10	11	1,039	0	0	0	2	23
25-Jun	8	32	1,079	0	0	0	1	24
26-Jun	3	13	1,095	0	0	0	0	24
27-Jun	14	4	1,113	0	0	0	1	25
28-Jun	3	3	1,119	0	0	0	1	26
29-Jun	3	6	1,128	0	0	0	0	26
30-Jun	16	1	1,145	0	0	0	0	26
1-Jul	0	5	1,150	0	0	0	0	26
2-Jul	2	5	1,157	0	0	0	1	27
3-Jul	0	8	1,165	0	0	0	1	28
4-Jul	0	1	1,166	0	0	0	0	28
5-Jul	0	11	1,177	0	0	0	0	28
6-Jul	0	3	1,180	0	0	0	0	28
7-Jul	0	0	1,180	0	0	0	1	29
8-Jul	3	0	1,183	0	0	0	2	31
9-Jul	0	0	1,183	0	0	0	0	31
10-Jul	0	3	1,186	0	0	0	0	31
11-Jul	0	1	1,187	0	0	0	1	32
12-Jul	0	1	1,188	0	0	0	3	35
13-Jul	0	0	1,188	0	0	0	2	37

-continued-

Table 1.–Page 2 of 4.

Date	Sockeye salmon			Coho salmon			Dolly Varden	
	Day	Night	Total	Day	Night[a]	Total	Daily	Total
14-Jul	0	0	1,188	0	0	0	0	37
15-Jul	0	0	1,188	0	0	0	2	39
16-Jul	0	0	1,188	0	0	0	3	42
17-Jul	0	1	1,189	0	0	0	4	46
18-Jul	0	0	1,189	0	0	0	3	49
19-Jul	0	0	1,189	0	0	0	0	49
20-Jul	0	0	1,189	0	0	0	2	51
21-Jul	0	0	1,189	0	0	0	1	52
22-Jul	0	0	1,189	0	0	0	2	54
23-Jul	0	0	1,189	0	0	0	2	56
24-Jul	0	3	1,192	0	0	0	0	56
25-Jul	0	0	1,192	0	0	0	0	56
26-Jul	0	0	1,192	0	0	0	0	56
27-Jul	0	0	1,192	0	0	0	0	56
28-Jul	0	1	1,193	0	0	0	0	56
29-Jul	0	1	1,194	0	0	0	0	56
30-Jul	0	0	1,194	0	0	0	0	56
31-Jul	0	0	1,194	0	0	0	0	56
1-Aug	0	0	1,194	0	0	0	0	56
2-Aug	0	0	1,194	0	0	0	0	56
3-Aug	0	0	1,194	0	0	0	0	56
4-Aug	0	0	1,194	0	0	0	0	56
5-Aug	0	1	1,195	0	0	0	0	56
6-Aug	0	2	1,197	0	0	0	0	56
7-Aug*	–	–	1,197	–	–	0	–	56
8-Aug*	–	–	1,197	–	–	0	–	56
9-Aug*	–	–	1,197	–	–	0	–	56
10-Aug*	–	–	1,197	–	–	0	–	56
11-Aug*	–	–	1,197	–	–	0	–	56
12-Aug*	0	0	1,197	0	0	0	0	56
13-Aug*	0	0	1,197	0	0	0	0	56
14-Aug*	0	0	1,197	0	0	0	0	56
15-Aug*	0	0	1,197	0	0	0	0	56
16-Aug*	0	0	1,197	0	0	0	0	56
17-Aug*	0	0	1,197	0	0	0	0	56
18-Aug*	0	0	1,197	0	0	0	0	56
19-Aug*	0	0	1,197	0	0	0	0	56
20-Aug*	0	0	1,197	0	0	0	0	56
21-Aug*	0	0	1,197	0	0	0	0	56
22-Aug*	0	0	1,197	0	0	0	0	56
23-Aug*	0	0	1,197	0	0	0	0	56
24-Aug*	0	0	1,197	0	0	0	0	56
25-Aug*	0	0	1,197	0	0	0	0	56
26-Aug*	0	0	1,197	0	0	0	0	56
27-Aug*	0	0	1,197	0	0	0	0	56
28-Aug*	0	0	1,197	0	0	0	0	56
29-Aug	0	0	1,197	0	0	0	0	56

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13

Table 1.–Page 3 of 4.

Date	Sockeye salmon			Coho salmon			Dolly Varden	
	Day	Night	Total	Day	Night[a]	Total	Daily	Total
30-Aug	0	0	1,197	1	0	1	1	57
31-Aug	0	0	1,197	0	0	1	0	57
1-Sep	0	0	1,197	0	0	1	0	57
2-Sep	0	0	1,197	0	0	1	0	57
3-Sep	0	0	1,197	2	0	3	0	57
4-Sep	0	0	1,197	0	0	3	0	57
5-Sep	0	0	1,197	0	0	3	0	57
6-Sep*	0	0	1,197	0	0	3	0	57
7-Sep*	0	0	1,197	0	0	3	0	57
8-Sep*	0	0	1,197	0	0	3	0	57
9-Sep*	0	0	1,197	4	0	7	0	57
10-Sep*	0	0	1,197	2	0	9	0	57
11-Sep*	0	0	1,197	0	0	9	0	57
12-Sep*	0	0	1,197	0	0	9	0	57
13-Sep*	0	0	1,197	0	0	9	0	57
14-Sep*	0	0	1,197	0	0	9	0	57
15-Sep*	0	0	1,197	0	0	9	0	57
16-Sep*	0	0	1,197	0	0	9	0	57
17-Sep*	0	0	1,197	0	0	9	0	57
18-Sep*	0	0	1,197	0	0	9	0	57
19-Sep*	0	0	1,197	0	0	9	0	57
20-Sep*	0	0	1,197	0	0	9	0	57
21-Sep*	0	0	1,197	0	0	9	0	57
22-Sep*	0	0	1,197	0	0	9	0	57
23-Sep*	0	0	1,197	1	0	10	0	57
24-Sep	0	0	1,197	0	0	10	0	57
25-Sep	0	0	1,197	0	0	10	0	57
26-Sep	0	0	1,197	0	0	10	0	57
27-Sep	0	0	1,197	0	0	10	4	61
28-Sep	0	0	1,197	0	0	10	3	64
29-Sep	0	0	1,197	1	0	11	0	64
30-Sep	0	0	1,197	0	0	11	0	64
1-Oct	0	0	1,197	1	0	12	2	66
2-Oct	0	0	1,197	0	5	17	3	69
3-Oct	0	0	1,197	0	3	20	10	79
4-Oct	0	0	1,197	0	30	50	-9	70
5-Oct	0	0	1,197	3	7	60	1	71
6-Oct	0	0	1,197	7	24	91	0	71
7-Oct	0	0	1,197	4	26	121	5	76
8-Oct	0	0	1,197	0	22	144	0	76
9-Oct	0	0	1,197	5	20	168	0	76
10-Oct	0	0	1,197	0	0	168	0	76
11-Oct	0	0	1,197	3	0	171	0	76
12-Oct	–	–	1,197	–	–	171	–	76
13-Oct	0	0	1,197	1	1	174	2	78
14-Oct	0	0	1,197	2	0	176	0	78
15-Oct	0	0	1,197	3	0	179	4	82

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14

Table 1.–Page 4 of 4.

Date	Sockeye salmon			Coho salmon			Dolly Varden	
	Day	Night	Total	Day	Night[a]	Total	Daily	Total
16-Oct	0	0	1,197	1	0	180	0	82
17-Oct	0	0	1,197	1	0	181	1	83
18-Oct	0	0	1,197	0	0	181	1	84
19-Oct	0	0	1,197	0	0	181	1	85
20-Oct	0	0	1,197	1	0	182	0	85
21-Oct	0	0	1,197	0	0	182	3	88
22-Oct	0	0	1,197	0	0	182	0	88
23-Oct	0	0	1,197	0	0	182	0	88
24-Oct	0	0	1,197	0	0	182	0	88
25-Oct	0	0	1,197	0	0	182	0	88
26-Oct	0	0	1,197	0	0	182	0	88
27-Oct	0	0	1,197	0	0	182	0	88
28-Oct	0	0	1,197	0	0	182	0	88
29-Oct	0	0	1,197	0	0	182	0	88
30-Oct	0	0	1,197	0	0	182	0	88
31-Oct	0	0	1,197	0	0	182	0	88
1-Nov	0	0	1,197	0	0	182	0	88
2-Nov	0	0	1,197	0	0	182	0	88
3-Nov	0	0	1,197	0	0	182	0	88
Sum	649	548	1,197	43	139	182	88	88
Percent (%)	54.2	45.8		23.6	76.4			

Note: En dashes (–) represent days too turbid to count, and asterisks (*) represent nights the underwater lighting (UWL) was not functioning.

[a] Coho salmon "Night" count includes an estimate of fish (taken from Table 2) that passed while the UWL was not functioning.

Table 2.–Duration of darkness (h:min), hours of auxiliary lighting, effective sampling rate (% of night illuminated), actual nocturnal count, and expanded nocturnal count of coho salmon migrating past the autonomous video counting tower (AVCT) at Red Lake from 1 August–31 October 2024.

	August					September					October				
Day	Dark	Aux. light	Sample rate (%)	Night count	Exp. count	Dark	Aux. light	Sample rate (%)	Night count	Exp. count	Dark	Aux. light	Sample rate (%)	Night count	Exp. count
1	7:19	8:00	100.0	0	0	9:57	8:00	80.4	0	0	12:37	8:00	63.4	0	0
2	7:23	8:00	100.0	0	0	10:03	8:00	79.6	0	0	12:42	8:00	63.0	4	5
3	7:28	8:00	100.0	0	0	10:08	8:00	78.9	0	0	12:48	8:00	62.5	2	3
4	7:33	8:00	100.0	0	0	10:13	8:00	78.3	0	0	12:53	8:00	62.1	22	30
5	7:38	8:00	100.0	0	0	10:19	8:00	77.5	0	0	12:58	8:00	61.7	5	7
6	7:43	8:00	100.0	0	0	10:24	8:00	76.9	0	0	13:04	8:00	61.2	17	24
7	7:48	—	—	—	—	10:29	8:00	76.3	0	0	13:09	8:00	60.8	19	26
8	7:53	—	—	—	—	10:35	—	—	—	—	13:14	8:00	60.5	16	22
9	7:58	—	—	—	—	10:40	—	—	—	—	13:20	8:00	60.0	14	20
10	8:03	—	—	—	—	10:45	—	—	—	—	13:25	8:00	59.6	0	0
11	8:08	—	—	—	—	10:51	—	—	—	—	13:30	8:00	59.3	0	0
12	8:13	—	—	—	—	10:56	—	—	—	—	13:36	8:00	58.8	0	0
13	8:18	—	—	—	—	11:01	—	—	—	—	13:41	8:00	58.5	1	1
14	8:23	—	—	—	—	11:07	No UWL 8–23 Sep	—	—	—	13:43	8:00	58.3	0	0
15	8:28	—	—	—	—	11:12	—	—	—	—	13:51	8:00	57.8	0	0
16	8:34	No UWL 7–28 Aug	—	—	—	11:17	—	—	—	—	13:57	8:00	57.3	0	0
17	8:39	—	—	—	—	11:19	—	—	—	—	13:59	8:00	57.2	0	0
18	8:44	—	—	—	—	11:28	—	—	—	—	14:07	8:00	56.7	0	0
19	8:49	—	—	—	—	11:33	—	—	—	—	14:12	8:00	56.3	0	0
20	8:54	—	—	—	—	11:38	—	—	—	—	14:18	8:00	55.9	0	0
21	9:00	—	—	—	—	11:44	—	—	—	—	14:23	8:00	55.6	0	0
22	9:05	—	—	—	—	11:49	—	—	—	—	14:28	8:00	55.3	0	0
23	9:10	—	—	—	—	11:54	8:00	67.2	0	0	14:33	8:00	55.0	0	0
24	9:15	—	—	—	—	12:00	8:00	66.7	0	0	14:39	8:00	54.6	0	0
25	9:21	—	—	—	—	12:05	8:00	66.2	0	0	14:44	8:00	54.3	0	0
26	9:26	—	—	—	—	12:10	8:00	65.8	0	0	14:49	8:00	54.0	0	0

-continued-

Table 2.–Page 2 of 2.

Day	August					September					October				
	Dark	Aux. light	Sample rate (%)	Night count	Exp. count	Dark	Aux. light	Sample rate (%)	Night count	Exp. count	Dark	Aux. light	Sample rate (%)	Night count	Exp. count
27	9:31	–	–	–	–	12:16	8:00	65.2	0	0	14:54	8:00	53.7	0	0
28	9:36	–	–	–	–	12:21	8:00	64.8	0	0	14:59	8:00	53.4	0	0
29	9:42	8:00	82.5	0	0	12:26	8:00	64.3	0	0	15:05	8:00	53.0	0	0
30	9:47	8:00	81.8	0	0	12:32	8:00	63.8	0	0	15:10	8:00	52.7	0	0
31	9:52	8:00	81.1	0	0	–	–	–	–	–	15:15	8:00	52.5	0	0
Nocturnal migration:				0	0				0	0	Migration:			100	139

Note: En dashes (–) denote the dates night counts were were not available (7–28 August and 8–23 September) due to technical difficulties with the underwater light (UWL).

a For hours of darkness by date at Red Lake: https://aa.usno.navy.mil/calculated/durdaydark?year=2024&task=1&lat=59.6966&lon=-151.0031&label=Red+Lake=Red+Lake%2C+Kachemak+Bay+Alaska&trz=9.00&tz=9.00&tz_sign=-1&submit=Get+Data
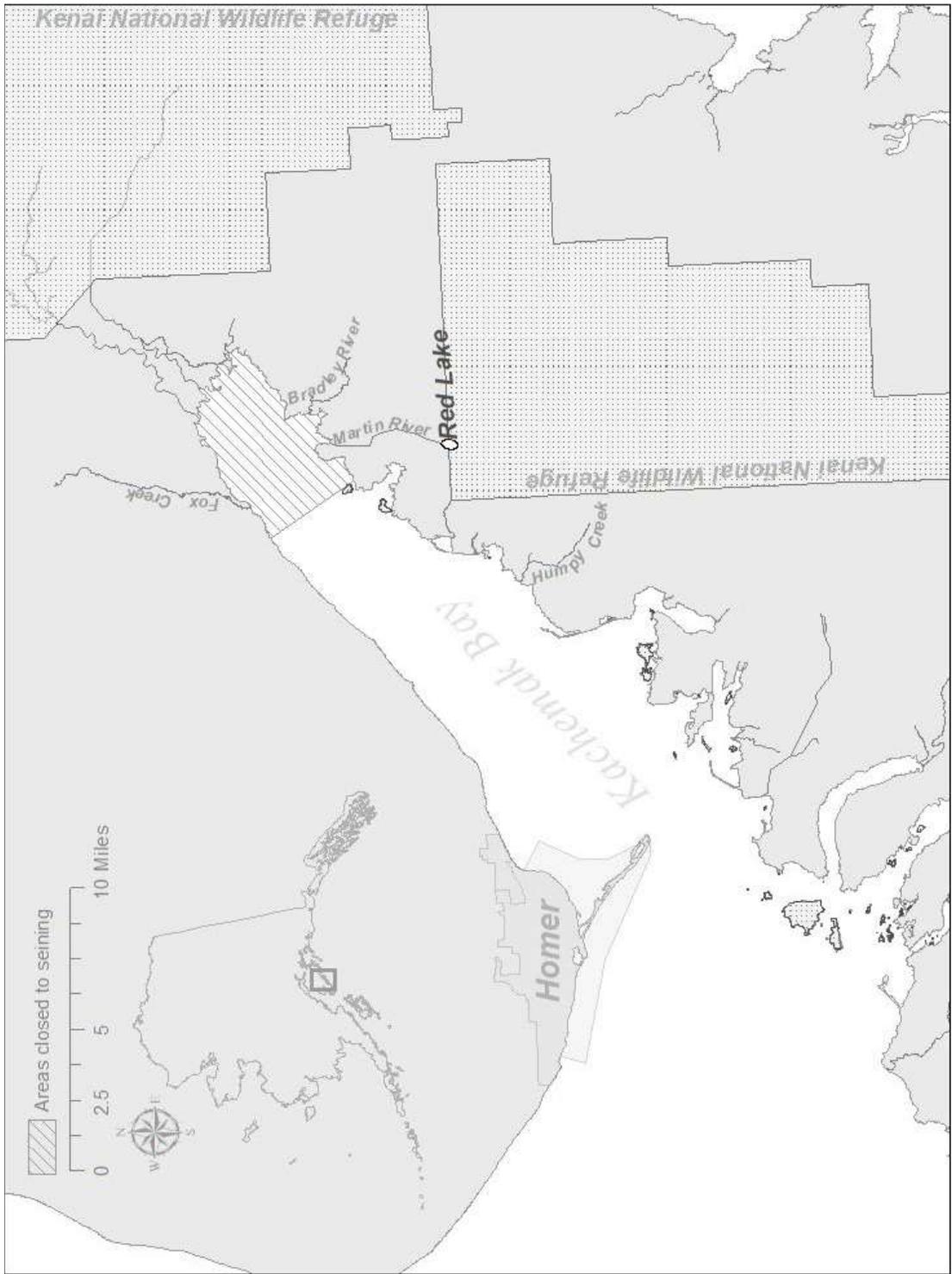
17

Figure 1.–Map of the Southern District of Lower Cook Inlet showing location of Martin River and Red Lake.

Figure 2.–Photograph illustrating the location of the Red Lake remote video salmon escapement project.

19

B.

A.

Figure 3.–Photographs of the autonomous video counting tower (AVCT) system at Red Lake showing (A) the tower, camera, and aluminum strongbox; and (B) the solar panels and high contrast substrate panel across the stream bottom to enhance the contrast of fish swimming past the camera.
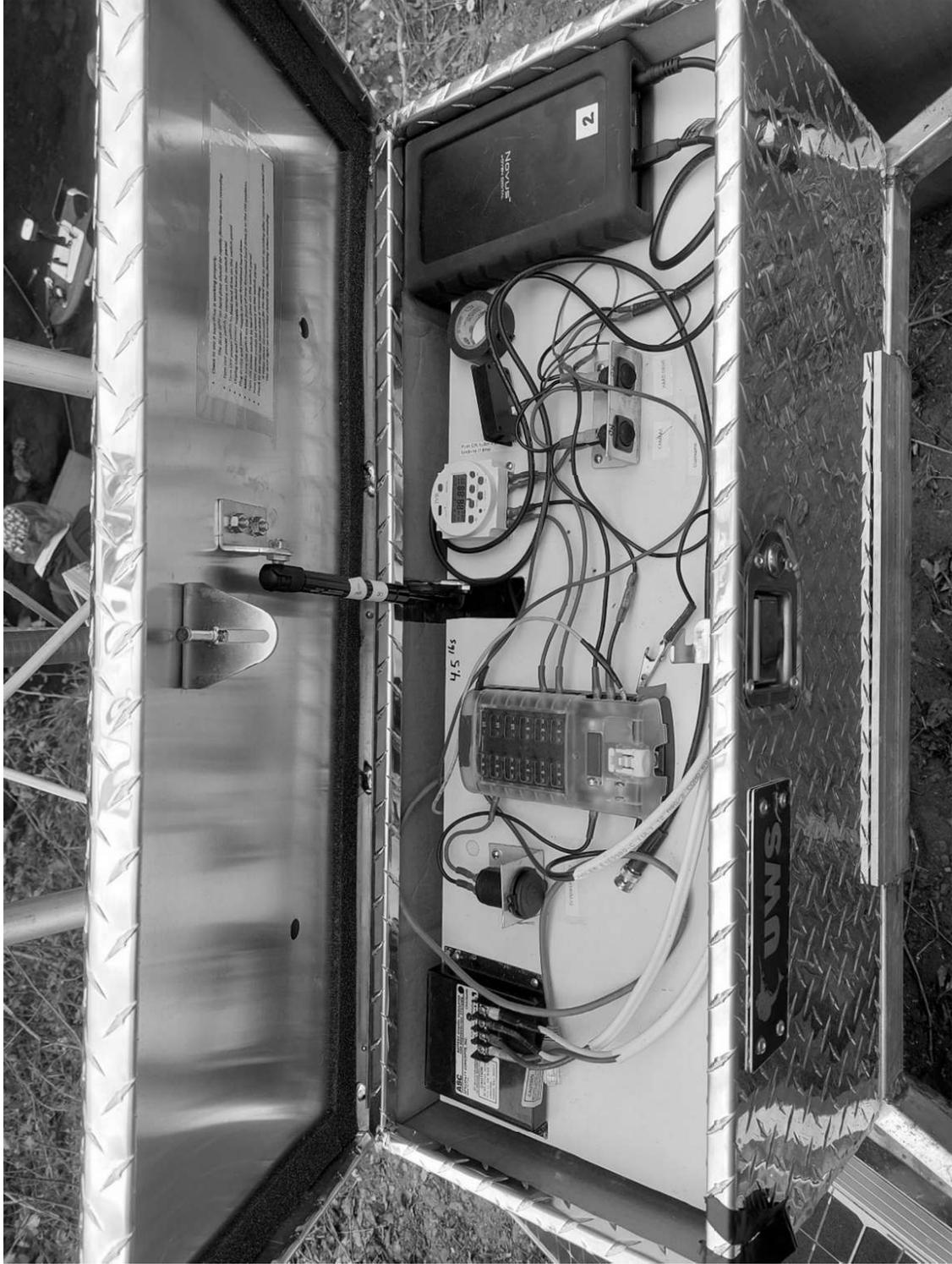
Figure 4.–Photograph illustrating the inside of the aluminum strongbox housing various electronic components and 2 Group 31 12 V batteries (underneath the dash panel) that were connected in parallel to make a single 220-ampere hour battery bank outputting 12 VDC.
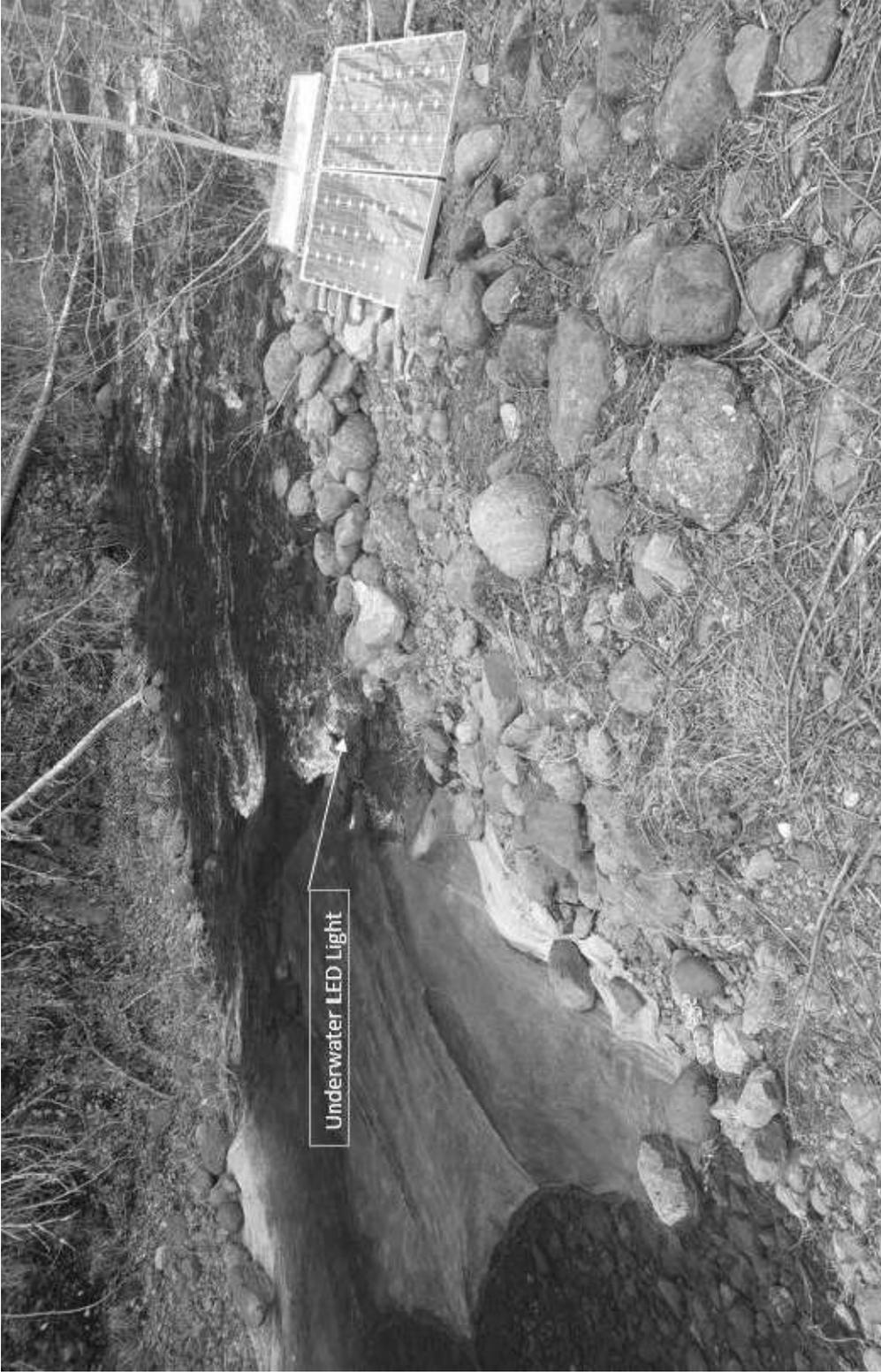
Figure 5.–Photograph illustrating the auxiliary lighting system, including the solar panels, a strongbox containing the battery, solar charging regulator, and other sensitive electronic components.

Note: The underwater lighting system pictured was destroyed by a flood on 7 August and was subsequently replaced.

Figure 6.–Screen grab images of adult sockeye salmon migrating upstream, as documented by the autonomous video counting tower (AVCT) system at Red Lake during hours of daylight (left) and darkness (right).
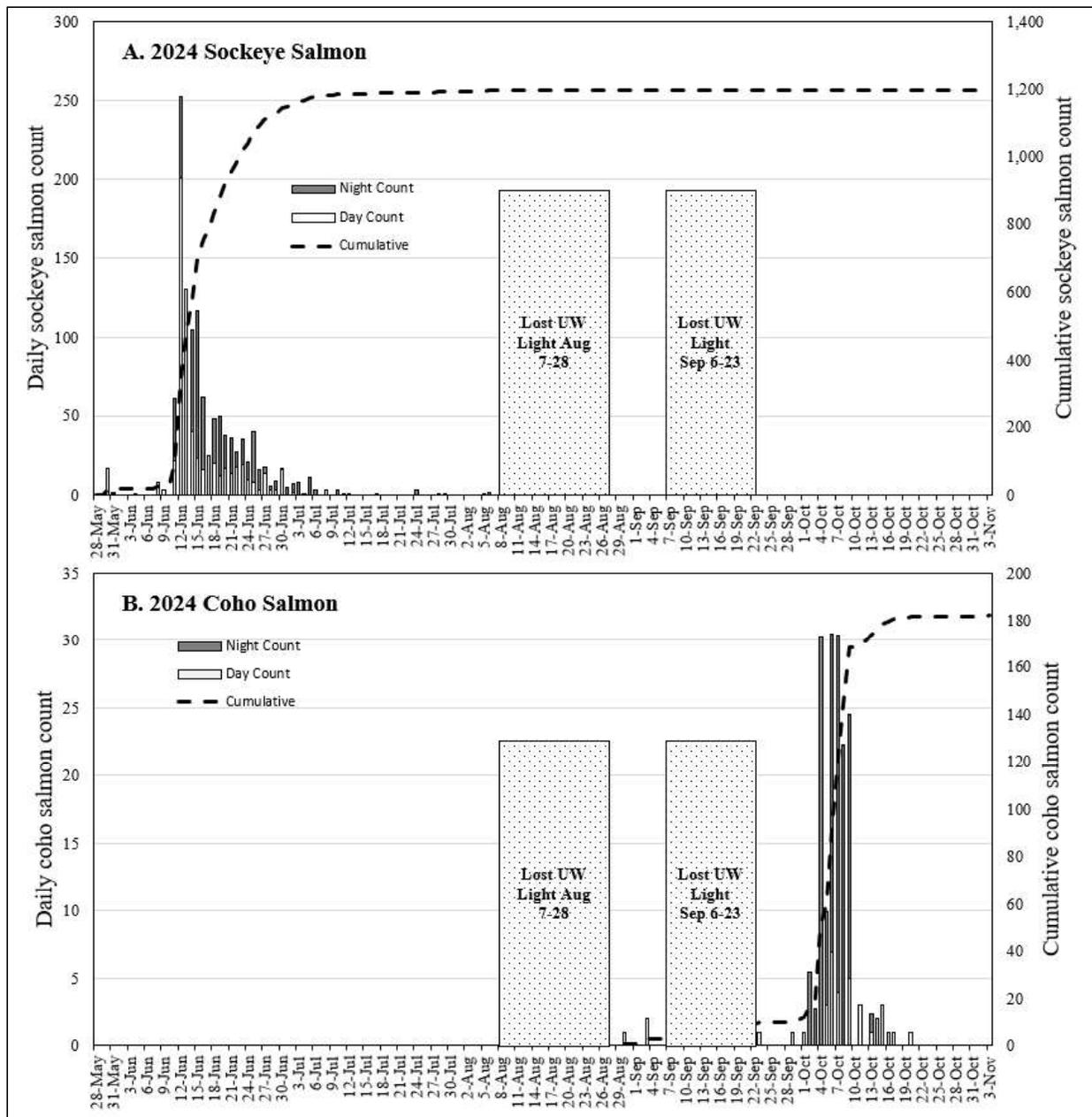
Figure 7.–Chart of daily and cumulative sockeye (A) and coho (B) salmon escapement to Red Lake in 2024.

Note: Auxiliary lights were used to facilitate nocturnal counts in 2024.