Fishery Data Series No. 24-10

Red Lake Remote Video Salmon Escapement Monitoring Project, 2023

by

Timothy J. Blackmon

and

Edward O. Otis

April 2024

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

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, 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 REPORT NO. 24-10

RED LAKE REMOTE VIDEO SALMON ESCAPEMENT MONITORING PROJECT, 2023

by
Timothy J. Blackmon and Edward O. Otis
Alaska Department of Fish and Game, Division of Commercial Fisheries, Homer

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

April 2024

This project (SP-429) was funded through a reciprocal services agreement (RSA) between the Alaska Energy Authority (AEA) and the Alaska Department of Fish and Game (ADF&G).

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

Timothy J. Blackmon and Edward O. Otis
Alaska Department of Fish and Game, Division of Commercial Fisheries,
3298 Douglas Place, Homer, AK, USA

This document should be cited as follows:
Blackmon, T. J., and E. O. Otis. 2024. Red Lake remote video salmon escapement monitoring project, 2023. Alaska Department of Fish and Game, Fishery Data Series No. 24-10, Anchorage.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

From 22 May through 1 November 2023, 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 daylight and select nocturnal 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 2023. Additionally, juvenile salmonids were recorded emigrating from the system, although they were too small to count or identify to species. Despite 2 interruptions during the sockeye salmon run, the AVCT recorded video for 2,960 hours out of 4,041 deployment hours (73.2%) and documented 66 sockeye salmon, with the peak count occurring on 29 June. The peak count for coho salmon occurred on 16 October with a total observed escapement of 205 fish, 200 (97.5%) of which migrated upstream at night. We estimated an additional 89 coho salmon may have escaped past the AVCT at night while the auxiliary lights were off. The AVCT also documented 58 Dolly Varden and 16 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 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 Alaskan 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, 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 select nighttime hours, from 22 May through 1 November.

2. Identify and document other fish and wildlife species (e.g., juvenile salmonids, bears, etc.) 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)*
- (1) 12 V battery *(Absorbed Glass Mat [AGM], Group 31)*
- (1) 12 V timer switch *(Model JVR 12V)*
- (1) 12 V photocell
- 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 mega-pixel (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 two 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 stream bed 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). Illumination was provided by a single 5 W LED bulb, initially triggered by a 12 V photocell to remain on from dusk to dawn. The system was powered by one 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 of 22 May, hard drives were exchanged on 22 June, 20 July, 24 August, 18 September, and 20 October, with final retrieval on 1 November.

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 (2022), and Appendices A–F in Otis (2023).

VIDEO RECORDING

While the camera was capable of recording at resolutions up to 1440P (2560x1440), to balance hard drive capacity with image quality, we ultimately used 480P (640x480), recording 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. Time-lapse recording rate was set at 3 frames per second (fps) 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 typically accommodated about 50 days of recorded video when programmed to record 3 fps at 640x480 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 select nighttime hours. Initially, the UWL was triggered by a photocell switch to turn on and off at dusk and dawn, respectively. However, after battery capacity became a concern, the photocell was replaced by a DC timer switch to activate the light during select hours of the night.

VIDEO REVIEW

Video was reviewed during and after the season to enumerate daytime and nocturnal fish passage (Figure 6). Review of video 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 sightings of bears, moose, or other wildlife captured on video) were recorded in uniform *MS Excel* spreadsheets. Daily fish counts were stratified by species into 6-hour time blocks (e.g., 00:01–06:00, 06:01–12:00, 12:01–18:00, and 18:01–24:00). Staff also recorded periods of video loss or other technical difficulties. See Appendix E in Otis (2023) for further details and an example of this spreadsheet.

METHODS FOR EXPANDING COUNTS OF NOCTURNAL MIGRATION

Due to power constraints, our UWL was not operated continuously during all hours of darkness. Instead, we programmed the light to operate for 4–12 h each night to sample nocturnal migration. Postseason review revealed that the vast majority 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. For instance, if there were 14 h of darkness and the light was on for 7 h, then the count from the illuminated period was doubled to estimate total nocturnal migration that night. 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=151.0031&label=Red+Lake%2C+Kachemak+Bay+Alaska&tz=9.00&tz_sign=-1&submit=Get+Data).

RESULTS

ADULT SALMONID ENUMERATION

Sockeye salmon, coho salmon, and Dolly Varden (*Salvelinus malma*) were observed migrating to Red Lake during 2023 operations. The AVCT documented a total of 66 sockeye salmon with the peak count (19 fish) occurring on 29 June (Table 1, Figure 7). The peak count for coho salmon occurred on 16 October (33 fish), with a total observed escapement of 205 fish (Table 1, Figure 8). Use of underwater lighting revealed that 16.7% (11) of the sockeye run and 97.5% (200) of the coho run occurred during hours of darkness. The AVCT documented 58 Dolly Varden char in 2023, with the peak count (11 fish) occurring on 16 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 2023, but schools of juvenile salmonids were observed on video emigrating from Red Lake multiple times throughout the season. Due to their small size, it was not possible to count or identify them to species.

AVCT PERFORMANCE

The AVCT was programmed to operate 24 h per day (00:00–24:00) from 13:03 on 22 May until 10:41 on 1 November 2023 (4,041 h). However, there were 2 separate recording interruptions (9–22 June and 27 July–4 August) that led to 1,082 h of lost video. The first interruption occurred during the early portion of the sockeye salmon run and the second occurred between the sockeye and coho salmon runs (Figures 7 and 8). We also experienced an issue with the solar charging system controlling the UWL, which led to incomplete nocturnal fish counts. Statistics related to the UWL (e.g., proportion of dark hours illuminated by auxiliary lighting, nocturnal fish counts) are summarized in Table 2.

OTHER WILDLIFE DOCUMENTED

- American dipper *Cinclus mexicanus*
- Bald eagle *Haliaeetus leucocephalus*
- Beaver *Castor canadensis*
- Black bear *Ursus americanus*
- Brown bear *Ursus arctos*
- Common merganser *Mergus merganser*
- Coyote *Canis latrans*
- River otter *Lontra canadensis*
- Harlequin duck *Histrionicus histrionicus*
- Belted kingfisher *Megaceryle alcyon*
- Mountain goat *Oreamnos americanus*
- American Mink *Neovison vison*
- Red squirrel *Tamiasciurus hudsonicus*
- Red fox *Vulpes vulpes*
- Spotted sandpiper *Actitis macularius*
- Unidentified hawk *Accipiter* sp.

DISCUSSION

AVCT PERFORMANCE

Although there were no apparent malfunctions with the AVCT hardware, errors made in programing the video settings and wiring the UWL electronics unfortunately resulted in 2 episodes of lost video footage and some lost nocturnal counts in 2023. During deployment on 22 May, the video resolution settings were increased to improve image quality. However, the higher resolution settings expanded file storage sizes more than anticipated, shortening the time span the 2 TB hard drive could operate before reaching capacity. As a result, the hard drive was filled on 8 June, after 18 days, leaving the remaining 14 days of the initial deployment unrecorded. This problem was identified and resolved during the 22 June site visit and the system performed flawlessly through the 2nd month of operation. Unfortunately, when the hard drive was swapped again on 20 July, the frame rate was accidentally set to 30 fps instead of the intended 3 fps. This resulted in the hard drive filling 10X faster than expected, in just 7 days, leading to 29 days of lost video (27 July–24 August). The frame rate issue was discovered and corrected on the next site visit on 24 August, and no further video recording issues were experienced for the rest of the season. Also, during the 24 August site visit, it was discovered that the solar panels for the UWL system were wired incorrectly, resulting in a completely discharged battery. The dead battery was swapped out for a fresh battery and the wiring issue was corrected on 24 August. No UWL or AVCT failures occurred after this point and the only subsequent downtime was related to brief shutdowns to swap hard drives. However, there was insufficient power to operate the UWL through all hours of darkness, which affected nocturnal fish counts, as discussed in the next section.

ADULT SALMON ENUMERATION

Review of available video files revealed that 66 sockeye salmon, 205 coho salmon, and 58 Dolly Varden migrated upstream past the AVCT site at the outlet of Red Lake in 2023. Unfortunately, there were 2 separate interruptions to the video system and 1 interruption to the underwater lighting system in 2023, each of which may have affected our estimates of total escapement, particularly for sockeye salmon. The first video interruption occurred from 9–22 June (Figure 7B), a period that coincided with the peak of the sockeye salmon run in 2022 (Figure 7A). Fortunately, the second interruption (27 July–24 August) occurred during the lull between the sockeye and coho salmon runs when no salmon were observed in 2022. Comparing daily video counts of sockeye salmon passage from 2022 and 2023 (Figure 7), it appears run timing may have been a week later in 2023. The peak sockeye salmon count in 2022 and 2023 occurred on 21 and 29 June, respectively. If the 2023 run timing was indeed a week later and the peak was captured on video, then our 2023 estimate for sockeye salmon may accurately represent total escapement, despite 14 days of lost video. However, if run timing was similar in both years, then we did not record the peak of the run in 2023 and our total run estimate of 66 sockeye salmon is probably very low. Unfortunately, it is difficult to say which scenario is most likely.

Another factor affecting the accuracy of our total escapement estimates was the new UWL system deployed in 2023. This addition clearly improved the accuracy of our total escapement estimate for coho salmon, 97.5% of which were recorded migrating past the AVCT at night. However, due to power issues, the UWL was not operational during all hours of darkness in 2023. The UWL worked for 5 days after video was restored on 24 June, recording 6 sockeye salmon migrating at night. However, the battery/charging issue with the UWL was not resolved until 24 August, so any nocturnal migration that occurred between 30 June and 24 August was not documented. While the UWL was operational throughout the coho salmon run, it was not programmed to stay on throughout the night due to power concerns. We illuminated progressively increasing portions of the night as the hours of darkness and our confidence in the UWL charging system increased throughout the fall. Statistics related to the UWL are summarized in Table 2. Assuming fish passage rates were similar between the illuminated and non-illuminated hours of darkness, it is likely that an additional 89 coho salmon migrated past the AVCT while the UWL was off (Table 2). If so, that would raise the total escapement of coho salmon to 294 fish in 2023. It should be noted that the very high proportion of coho salmon we observed migrating at night in 2023 suggests that the 2022 estimate (48 coho), made without auxiliary lighting, was likely very conservative. The 2023 Dolly Varden count (58) may also be conservative due to the diminutive size and coloration of the fish, which makes them difficult to distinguish when viewed from above.

AVCTs have many advantages over periodic aerial and ground survey counts, some of which are discussed in Otis (2012). The potential limitations of AVCTs include the operational integrity of the system and the inability to monitor all 24 hours in a day without adding auxiliary lighting. Hence, in 2022, there was the potential to underestimate the size of the total run when only counting during daylight hours. On the Anchor River, diurnal timing of local Chinook (*O. tshawytscha*) and coho salmon runs has been monitored for many years. During some years, 30% of the escapement has occurred after 19:00 (Kerkvliet and Booz 2010). Perhaps more notably, approximately 75% of the coho salmon that migrated through a video weir operated by ADF&G on nearby Battle Creek in 2022, did so during hours of darkness (H. Dickson, ADF&G, Division of Sport Fish Biologist, Homer, October 2022, personal communication). Although there is limited coho salmon spawning habitat available above the Red Lake AVCT, it was assumed that the coho salmon documented in 2022 during daylight hours only represented a fraction of the total run. In 2023, the Red Lake system was designed to accommodate the additional power generation needed for auxiliary lighting. 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.

JUVENILE SALMON

Schools of juvenile salmonids were observed on video emigrating from Red Lake in 2023. 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 and 2023, it would appear Red Lake may also provide 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.

ACKNOWLEDGEMENTS

AEA provided funding for this project through a Reciprocal Services Agreement with ADF&G. The authors would like to acknowledge the collaborators and employees that helped to make this project possible. Scheduling and helicopter logistics were often facilitated by Bryan Carey at AEA and Euan-Angus MacLeod at Dickinson Oswald Walch Lee (DOWL). Maritime helicopters made safely accessing this remote site relatively easy and efficient. ADF&G technicians were extremely productive and thorough in reviewing over 2959.5 h of video recorded during this season.

REFERENCES CITED

Adkison, M. D., and Z. Su 2001. A comparison of salmon escapement estimates using a hierarchical Bayesian approach versus separate maximum likelihood estimation of each year's return. Canadian Journal of Fisheries and Aquatic Science 58:1663–1671.

Baker, T. T., A. C. Wertheimer, R. D. Burkett, R. Dunlop, D. M. Eggers, E. I. Fritts, A. J. Gharret, R. A. Holmes, and R. L. Wilmot. 1996. Status of pacific salmon and steelhead escapements in Southeastern Alaska. Fisheries 21(10):6–18.

Bevan, D. E. 1961. Variability in aerial counts of spawning salmon. Journal of the Fisheries Research Board of Canada 18:337–348.

Bue, B. G., S. M. Fried, S. Sharr, D. G. Sharp, J. A. Wilcock, and H. J. Geiger. 1998. Estimating salmon escapement using area-under-the-curve, aerial observer efficiency, and stream-life estimates: the Prince William Sound pink salmon example. North Pacific Anadromous Fish Commission Bulletin 1:240–250.

Cousens, N. B., G. A. Thomas, S. G. Swann, and M. C. Healy. 1982. A review of salmon escapement estimation techniques. Department of Fisheries and Oceans Fisheries Research Branch. Canadian Technical Report of Fisheries and Aquatic Sciences 1108, Nanaimo, British Columbia.

Eicher, G. J. 1953. Aerial methods of assessing red salmon populations in western Alaska. Journal of Wildlife Management 17:521–527.

Hetrick, N. J., K. M. Simms, M. P. Plumb, and J. P. Larson. 2004. Feasibility of using video technology to estimate salmon escapement in the Ongivinuk River, a clear-water tributary of the Togiak River. U. S. Fish and Wildlife Service, King Salmon Fish and Wildlife Field Office, Alaska Fisheries Technical Report Number 72, King Salmon, Alaska.

Hilborn, R., B. G. Bue, and S. Sharr. 1999. Estimating spawning escapement from periodic counts: a comparison of methods. Canadian Journal of Fisheries and Aquatic Sciences 56:888–896.

Hill, R. A. 1997. Optimizing aerial count frequency for the area-under-the-curve method of estimating escapement. North American Journal of Fisheries Management 17:461–466.

Hollowell, G., E. O. Otis, and E. Ford. 2023. 2022 Lower Cook Inlet area salmon annual management report. Alaska Department of Fish and Game, Fishery Management Report No. 23-04, Anchorage.

Jones III, E. L., T. J. Quinn, and B. W. Van Alen. 1998. Observer accuracy and precision in aerial and foot survey counts of pink salmon in a Southeastern Alaska stream. North American Journal of Fisheries Management 18:832–846.

Jones III, E. L., S. Heinl, and K. Pahlke. 2007. Aerial counts. Pages 399–410 [*In*] D. H. Johnson, B. M. Shrier, J. S. O'Neil, J. A. Knutzen, X. Augerot, T. A. O'Neil, and T. N. Pearsons, editors. Salmonid field protocols handbook: Techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, MD.

Kaeriyama, M., and H. Ueda. 1998. Life history strategy and migration pattern of juvenile sockeye (*Oncorhynchus nerka*) and chum salmon (*O. keta*) in Japan: a review. North Pacific Anadromous Fish Commission Bulletin No. 1:163–171.

REFERENCES CITED (Continued)

Kerkvliet, C. M., and M. D. Booz. 2010. Anchor River Chinook and Coho Salmon Escapement, 2009. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Serie No. 12-07.

Neilson, J. D., and G. H. Geen. 1981. Enumeration of spawning salmon from spawner residence time and aerial counts. Transactions of the American Fisheries Society 110(4):554–556.

O'Neal, J. S. 2007. Video methodology. Pages 443–457 [*In*] D. H. Johnson, B. M. Shrier, J. S. O'Neil, J. A. Knutzen, X. Augerot, T. A. O'Neil, and T. N. Pearsons, editors. Salmonid field protocols handbook: Techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, MD.

Otis, E. O., and T. J. Blackmon. 2022. Red Lake remote video salmon escapement monitoring operational plan, 2022. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Operational Plan No. ROP.CF.2A.2022.03, Anchorage.

Otis, E. O., and M. Dickson. 2002. Improved salmon escapement enumeration using remote video and time-lapse recording technology. Exxon Valdez Oil Spill Restoration Project Final Report (Restoration Project 00366), Alaska Department of Fish and Game, Division of Commercial Fisheries, Homer, AK.

Otis, E. O., N. J. Szarzi, L. F. Fair, and J. W. Erickson. 2010. A review of escapement goals for salmon stocks in Lower Cook Inlet, Alaska, 2010. Alaska Department of Fish and Game, Fishery Manuscript No. 10-07, Anchorage.

Otis, E. O. 2012. Fish TV: Using video to remotely monitor salmon escapement. Newsletter of the Alaska Chapter of the American Fisheries Society, Oncorhynchus 32(1):1–5.

Otis, E. O. 2023. Lower Cook Inlet remote video salmon escapement monitoring operational plan, 2023. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Operational Plan No. ROP.CF.2A.2023.01, Anchorage.

Otis, E. O., and G. J. Hollowell. 2023. Lower Cook Inlet Aerial and Ground Survey Salmon Escapement Monitoring Operational Plan, 2022–2024. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Operational Plan No. ROP.CF.2A.2022.01, Anchorage.

Otis, E. O., J. W. Erickson, M. D. Booz, and T. McKinley. 2023. A review of escapement goals for salmon stocks in Lower Cook Inlet, Alaska, 2023. Alaska Department of Fish and Game, Fishery Manuscript Series No. 23-02, Anchorage.

Peirce, J. M., E. O. Otis, M. S. Wipfli, E. H. Follmann. 2011. Radio telemetry to estimate stream life of adult chum salmon in McNeil River, Alaska. North American Journal of Fisheries Management 31:315–322.

Peirce, J. M., E. O. Otis, M. S. Wipfli, and E. H. Follmann. 2013. Interactions between brown bears and chum salmon at McNeil River, Alaska. Ursus 24(1):42–53.

Perrin, C. J., and J. R. Irvine 1990. A review of survey life estimates as they apply to the area-under-the-curve method for estimating the spawning escapement of pacific salmon. Department of Fisheries and Oceans Fisheries Research Branch. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1733, Nanaimo, British Columbia.

Shardlow, T., R. Hilborn, and D. Lightly. 1987. Components analysis of instream escapement methods for pacific salmon (*Oncorhynchus* spp.). Canadian Journal of Fisheries and Aquatic Sciences 44:1031–1037.

Su, Z., M. D. Adkison, and B. W. Van Alen. 2001. A hierarchical Bayesian model for estimating historical salmon escapement and escapement timing. Canadian Journal of Fisheries and Aquatic Science 58:1648–1662.

Walters, C. J., and D. Ludwig. 1981. Effects of measurement errors on the assessment of stock-recruitment relationships. Canadian Journal of Fisheries and Aquatic Sciences 38:704–710.

TABLES AND FIGURES

Table 1.–Daily fish passage at Red Lake AVCT by species in 2023. En dashes (–) represent video loss.

	Sockeye salmon		Dolly Varden		Coho salmon	
Date	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative
22 May	0	0	0	0	0	0
23 May	0	0	0	0	0	0
24 May	0	0	0	0	0	0
25 May	0	0	0	0	0	0
26 May	0	0	0	0	0	0
27 May	0	0	0	0	0	0
28 May	0	0	0	0	0	0
29 May	0	0	0	0	0	0
30 May	0	0	0	0	0	0
31 May	0	0	0	0	0	0
1 Jun	0	0	0	0	0	0
2 Jun	0	0	0	0	0	0
3 Jun	0	0	0	0	0	0
4 Jun	0	0	0	0	0	0
5 Jun	0	0	0	0	0	0
6 Jun	0	0	0	0	0	0
7 Jun	1	1	0	0	0	0
8 Jun	0	1	0	0	0	0
9 Jun	–	1	–	0	–	0
10 Jun	–	1	–	0	–	0
11 Jun	–	1	–	0	–	0
12 Jun	–	1	–	0	–	0
13 Jun	–	1	–	0	–	0
14 Jun	–	1	–	0	–	0
15 Jun	–	1	–	0	–	0
16 Jun	–	1	–	0	–	0
17 Jun	–	1	–	0	–	0
18 Jun	–	1	–	0	–	0
19 Jun	–	1	–	0	–	0
20 Jun	–	1	–	0	–	0
21 Jun	–	1	–	0	–	0
22 Jun	–	1	–	0	–	0
23 Jun	0	1	0	0	0	0
24 Jun	0	1	0	0	0	0
25 Jun	2	3	0	0	0	0
26 Jun	0	3	0	0	0	0
27 Jun	0	3	0	0	0	0
28 Jun	3	6	0	0	0	0
29 Jun	19	25	0	0	0	0
30 Jun	10	35	0	0	0	0
1 Jul	11	46	0	0	0	0
2 Jul	3	49	0	0	0	0
3 Jul	0	49	0	0	0	0
4 Jul	0	49	0	0	0	0
5 Jul	0	49	0	0	0	0
6 Jul	0	49	0	0	0	0

-continued-

Table 1.–Page 2 of 4.

Date	Sockeye salmon Daily	Sockeye salmon Cumulative	Dolly Varden Daily	Dolly Varden Cumulative	Coho salmon Daily	Coho salmon Cumulative
7 Jul	0	49	0	0	0	0
8 Jul	5	54	0	0	0	0
9 Jul	2	56	0	0	0	0
10 Jul	1	57	0	0	0	0
11 Jul	0	57	0	0	0	0
12 Jul	1	58	0	0	0	0
13 Jul	2	60	0	0	0	0
14 Jul	0	60	0	0	0	0
15 Jul	2	62	0	0	0	0
16 Jul	0	62	0	0	0	0
17 Jul	0	62	0	0	0	0
18 Jul	0	62	0	0	0	0
19 Jul	0	62	0	0	0	0
20 Jul	0	62	0	0	0	0
21 Jul	1	63	0	0	0	0
22 Jul	1	64	0	0	0	0
23 Jul	0	64	0	0	0	0
24 Jul	0	64	0	0	0	0
25 Jul	0	64	0	0	0	0
26 Jul	0	64	0	0	0	0
27 Jul	–	64	–	0	–	0
28 Jul	–	64	–	0	–	0
29 Jul	–	64	–	0	–	0
30 Jul	–	64	–	0	–	0
31 Jul	–	64	–	0	–	0
1 Aug	–	64	–	0	–	0
2 Aug	–	64	–	0	–	0
3 Aug	–	64	–	0	–	0
4 Aug	–	64	–	0	–	0
5 Aug	–	64	–	0	–	0
6 Aug	–	64	–	0	–	0
7 Aug	–	64	–	0	–	0
8 Aug	–	64	–	0	–	0
9 Aug	–	64	–	0	–	0
10 Aug	–	64	–	0	–	0
11 Aug	–	64	–	0	–	0
12 Aug	–	64	–	0	–	0
13 Aug	–	64	–	0	–	0
14 Aug	–	64	–	0	–	0
15 Aug	–	64	–	0	–	0
16 Aug	–	64	–	0	–	0
17 Aug	–	64	–	0	–	0
18 Aug	–	64	–	0	–	0
19 Aug	–	64	–	0	–	0
20 Aug	–	64	–	0	–	0
21 Aug	–	64	–	0	–	0

-continued-

Table 1.–Page 3 of 4.

Date	Sockeye salmon		Dolly Varden		Coho salmon	
	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative
22 Aug	–	64	–	0	–	0
23 Aug	–	64	–	0	–	0
24 Aug	0	64	0	0	0	0
25 Aug	0	64	0	0	0	0
26 Aug	0	64	0	0	0	0
27 Aug	0	64	0	0	0	0
28 Aug	0	64	0	0	0	0
29 Aug	0	64	0	0	0	0
30 Aug	0	64	0	0	0	0
31 Aug	0	64	0	0	0	0
1 Sep	0	64	0	0	0	0
2 Sep	0	64	0	0	0	0
3 Sep	0	64	0	0	0	0
4 Sep	0	64	0	0	0	0
5 Sep	0	64	0	0	0	0
6 Sep	0	64	0	0	0	0
7 Sep	0	64	1	1	0	0
8 Sep	0	64	0	1	0	0
9 Sep	0	64	1	2	0	0
10 Sep	0	64	0	2	0	0
11 Sep	0	64	2	4	0	0
12 Sep	0	64	3	7	0	0
13 Sep	0	64	1	8	0	0
14 Sep	0	64	1	9	0	0
15 Sep	1	65	0	9	0	0
16 Sep	0	65	0	9	0	0
17 Sep	0	65	0	9	0	0
18 Sep	1	66	0	9	0	0
19 Sep	0	66	1	10	0	0
20 Sep	0	66	1	11	2	2
21 Sep	0	66	3	14	0	2
22 Sep	0	66	6	20	5	7
23 Sep	0	66	4	24	2	9
24 Sep	0	66	5	29	4	13
25 Sep	0	66	7	36	7	20
26 Sep	0	66	1	37	0	20
27 Sep	0	66	1	38	1	21
28 Sep	0	66	-1	37	0	21
29 Sep	0	66	-1	36	0	21
30 Sep	0	66	0	36	0	21
1 Oct	0	66	1	37	22	43
2 Oct	0	66	2	39	4	47
3 Oct	0	66	0	39	1	48
4 Oct	0	66	0	39	4	52
5 Oct	0	66	4	43	17	69
6 Oct	0	66	0	43	15	84

-continued-

Table 1.–Page 4 of 4.

	Sockeye salmon		Dolly Varden		Coho salmon	
Date	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative
7 Oct	0	66	0	43	13	97
8 Oct	0	66	1	44	12	109
9 Oct	0	66	0	44	5	114
10 Oct	0	66	1	45	16	130
11 Oct	0	66	0	45	11	141
12 Oct	0	66	0	45	7	148
13 Oct	0	66	0	45	6	154
14 Oct	0	66	1	46	6	160
15 Oct	0	66	0	46	1	161
16 Oct	0	66	11	57	33	194
17 Oct	0	66	0	57	0	194
18 Oct	0	66	0	57	0	194
19 Oct	0	66	1	58	0	194
20 Oct	0	66	0	58	0	194
21 Oct	0	66	0	58	0	194
22 Oct	0	66	0	58	0	194
23 Oct	0	66	0	58	0	194
24 Oct	0	66	0	58	-1	193
25 Oct	0	66	0	58	2	195
26 Oct	0	66	0	58	3	198
27 Oct	0	66	0	58	1	199
28 Oct	0	66	0	58	0	199
29 Oct	0	66	0	58	4	203
30 Oct	0	66	0	58	2	205
31 Oct	0	66	0	58	0	205
1 Nov	0	66	0	58	0	205

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 AVCT at Red Lake from 24 August–31 October 2023.

	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	7:13					9:53	4:00	40.5%	0	0	12:34	7:00	55.7%	22	32
2	7:18					10:00	4:00	40.0%	0	0	12:39	7:00	55.3%	4	6
3	7:23					10:05	4:00	39.7%	0	0	12:44	7:00	55.0%	1	1
4	7:28					10:10	4:00	39.3%	0	0	12:50	7:00	54.5%	4	6
5	7:33					10:15	4:00	39.0%	0	0	12:55	7:00	54.2%	21	31
6	7:37					10:21	4:00	38.6%	0	0	13:00	7:00	53.8%	14	20
7	7:42					10:26	4:00	38.3%	0	0	13:06	7:00	53.4%	13	19
8	7:47					10:31	4:00	38.0%	0	0	13:11	7:00	53.1%	12	18
9	7:52					10:37	4:00	37.7%	0	0	13:16	7:00	52.8%	4	6
10	7:57					10:42	4:00	37.4%	0	0	13:22	7:00	52.4%	14	21
11	8:02					10:47	4:00	37.1%	0	0	13:27	7:00	52.0%	9	13
12	8:07	No auxiliary lights August 1–23				10:53	4:00	36.8%	0	0	13:32	7:00	51.7%	6	9
13	8:12					10:58	4:00	36.5%	0	0	13:38	7:00	51.3%	6	9
14	8:17					11:03	4:00	36.2%	0	0	13:43	7:00	51.0%	6	9
15	8:23					11:09	4:00	35.9%	0	0	13:48	7:00	50.7%	1	1
16	8:28					11:14	4:00	35.6%	0	0	13:54	7:00	50.4%	32	48
17	8:33					11:19	4:00	35.3%	0	0	13:59	7:00	50.1%	0	0
18	8:38					11:25	4:00	35.0%	0	0	14:04	7:00	49.8%	0	0
19	8:43					11:30	7:00	60.9%	0	0	14:09	7:00	49.5%	0	0
20	8:48					11:35	7:00	60.4%	1	1	14:15	12:00	84.2%	0	0
21	8:54					11:41	7:00	59.9%	0	0	14:20	12:00	83.7%	0	0
22	8:59					11:46	7:00	59.5%	5	7	14:25	12:00	83.2%	0	0
23	9:04					11:51	7:00	59.1%	2	3	14:30	12:00	82.8%	3	4
24	9:09	4:00	43.7%	0	0	11:57	7:00	58.6%	4	6	14:36	12:00	82.2%	-1	-1
25	9:15	4:00	43.2%	0	0	12:02	7:00	58.2%	7	10	14:41	12:00	81.7%	1	1
26	9:20	4:00	42.9%	0	0	12:07	7:00	57.8%	0	0	14:46	12:00	81.3%	2	2

-continued-

Table 2.–Page 2 of 2.

	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
27	9:25	4:00	42.5%	0	0	12:13	7:00	57.3%	1	1	14:51	12:00	80.8%	0	0
28	9:30	4:00	42.1%	0	0	12:18	7:00	56.9%	0	0	14:56	12:00	80.4%	0	0
29	9:36	4:00	41.7%	0	0	12:23	7:00	56.5%	0	0	15:02	12:00	79.8%	3	4
30	9:41	4:00	41.3%	0	0	12:28	7:00	56.1%	0	0	15:07	12:00	79.4%	2	2
31	9:46	4:00	41.0%	0	0						15:12	12:00	78.9%	0	0
Estimate of undocumented migration:					0					8					81

Source: For hours of darkness by date at Red Lake: https://aa.usno.navy.mil/calculated/durdaydark?year=2023&task=1&lat=59.6966&lon=151.0031&label=Red+Lake%2C+Kachemak+Bay+Alaska&tz=9.00&tz_sign=-1&submit=Get+Data

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

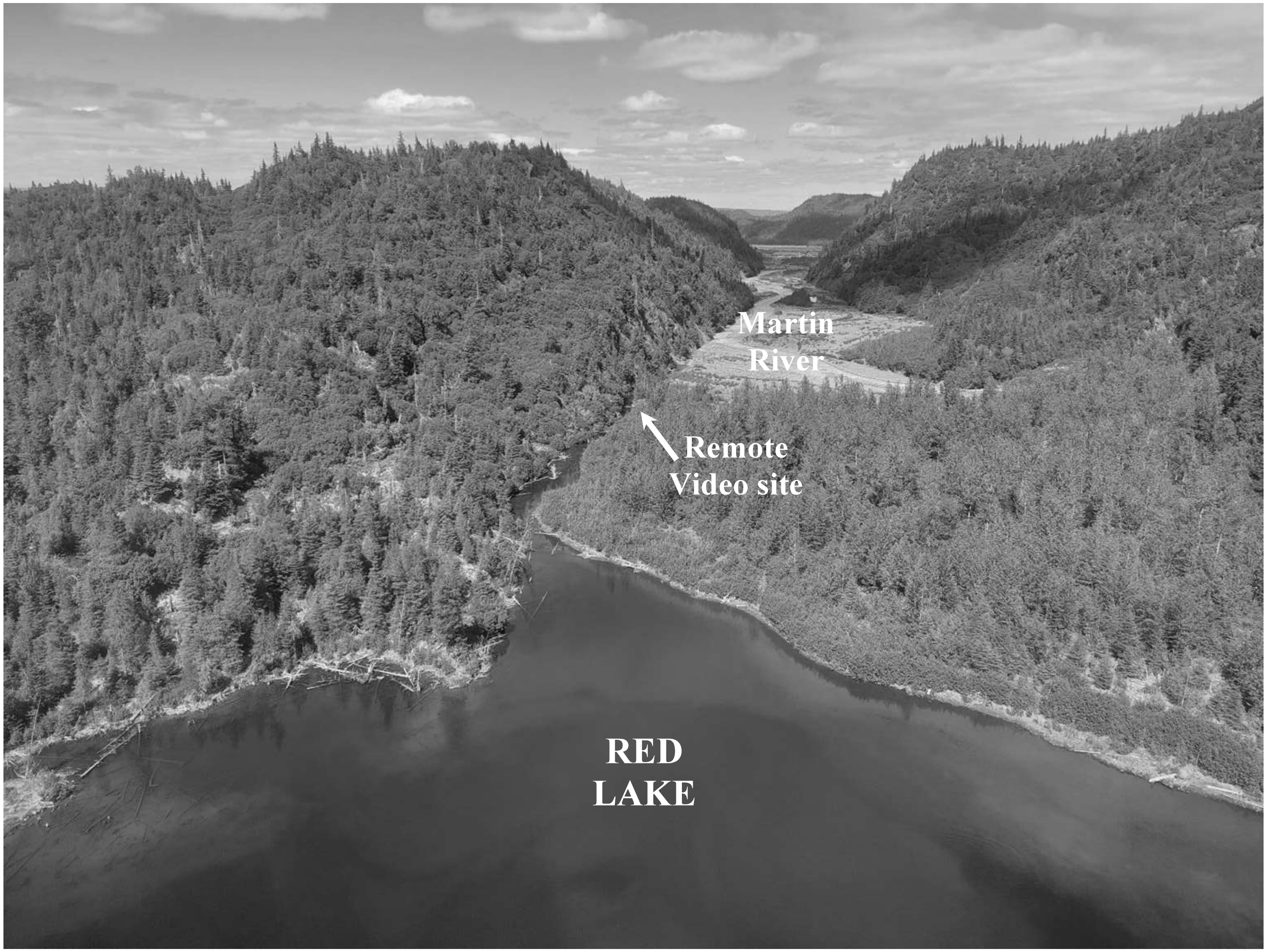

Figure 2.–Photograph illustrating the location of the Red Lake remote video salmon escapement project.

A. B.

Figure 3.–Photographs of 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.

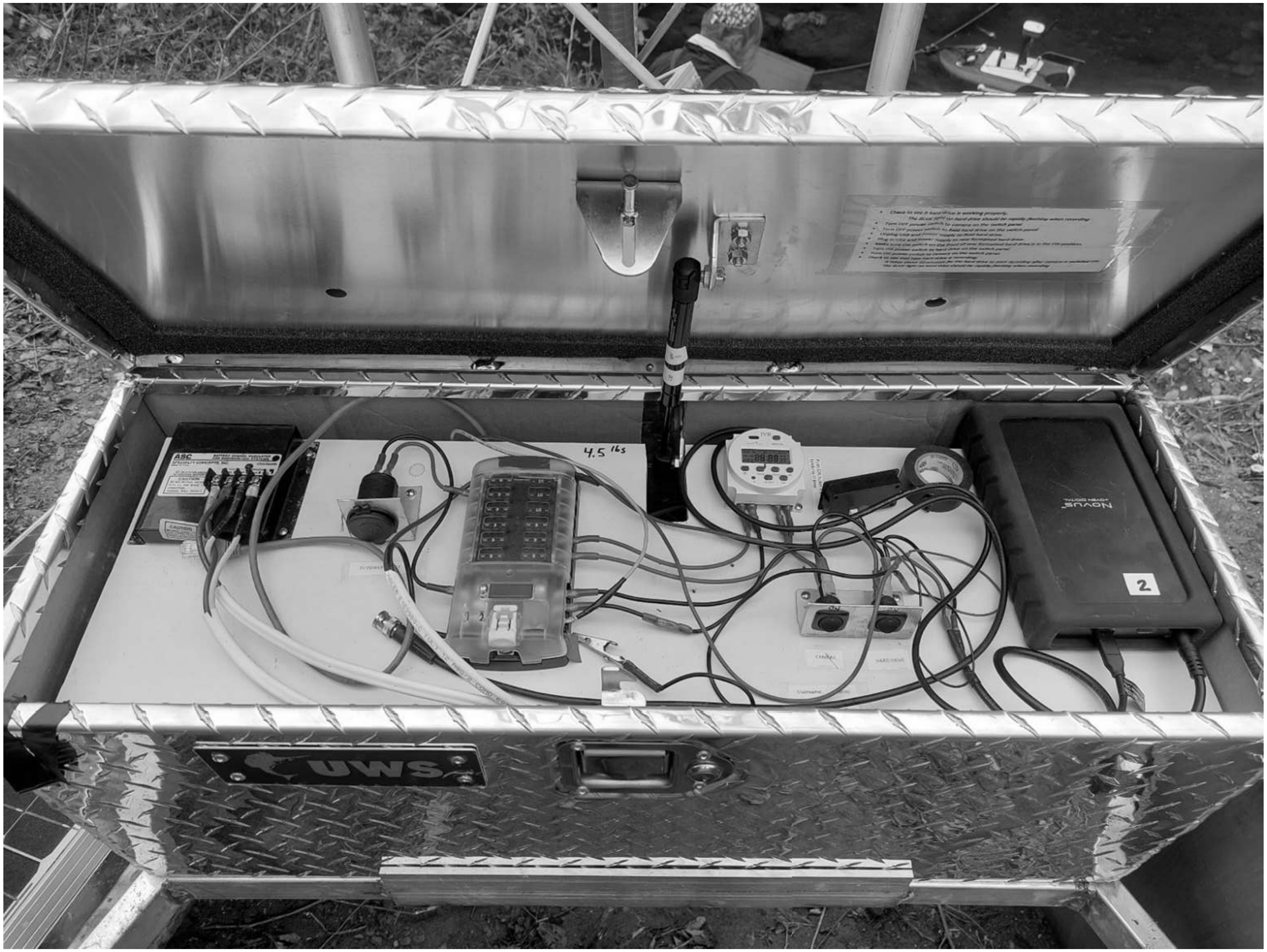

Figure 4.–Photograph illustrating the inside of the aluminum strongbox housing various electronic components and two Group 31 12V batteries (underneath the dash panel) that were connected in parallel to make a single 220-amp hour battery bank outputting 12VDC.

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 LED light and power cables are covered by rocks for protection.)

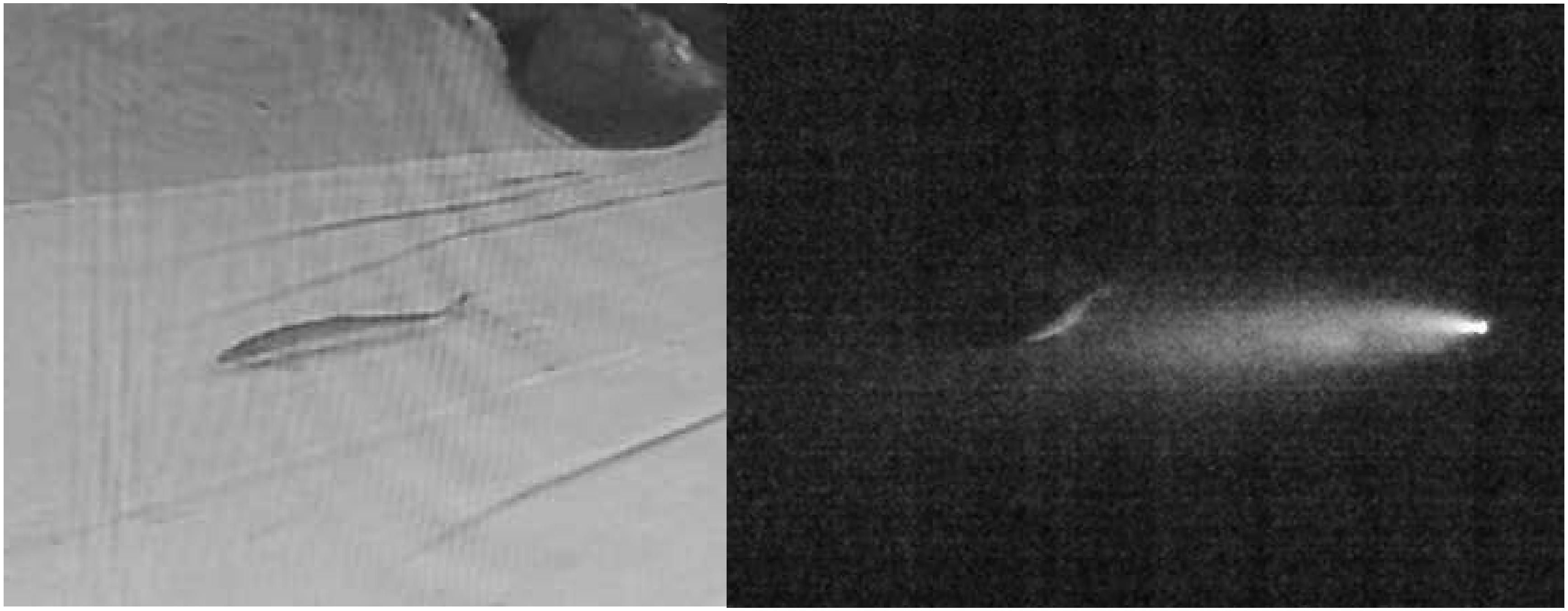

Figure 6.–Screen grab images of adult sockeye salmon migrating upstream, as documented by the AVCT system at Red Lake during hours of daylight (left) and darkness (right).

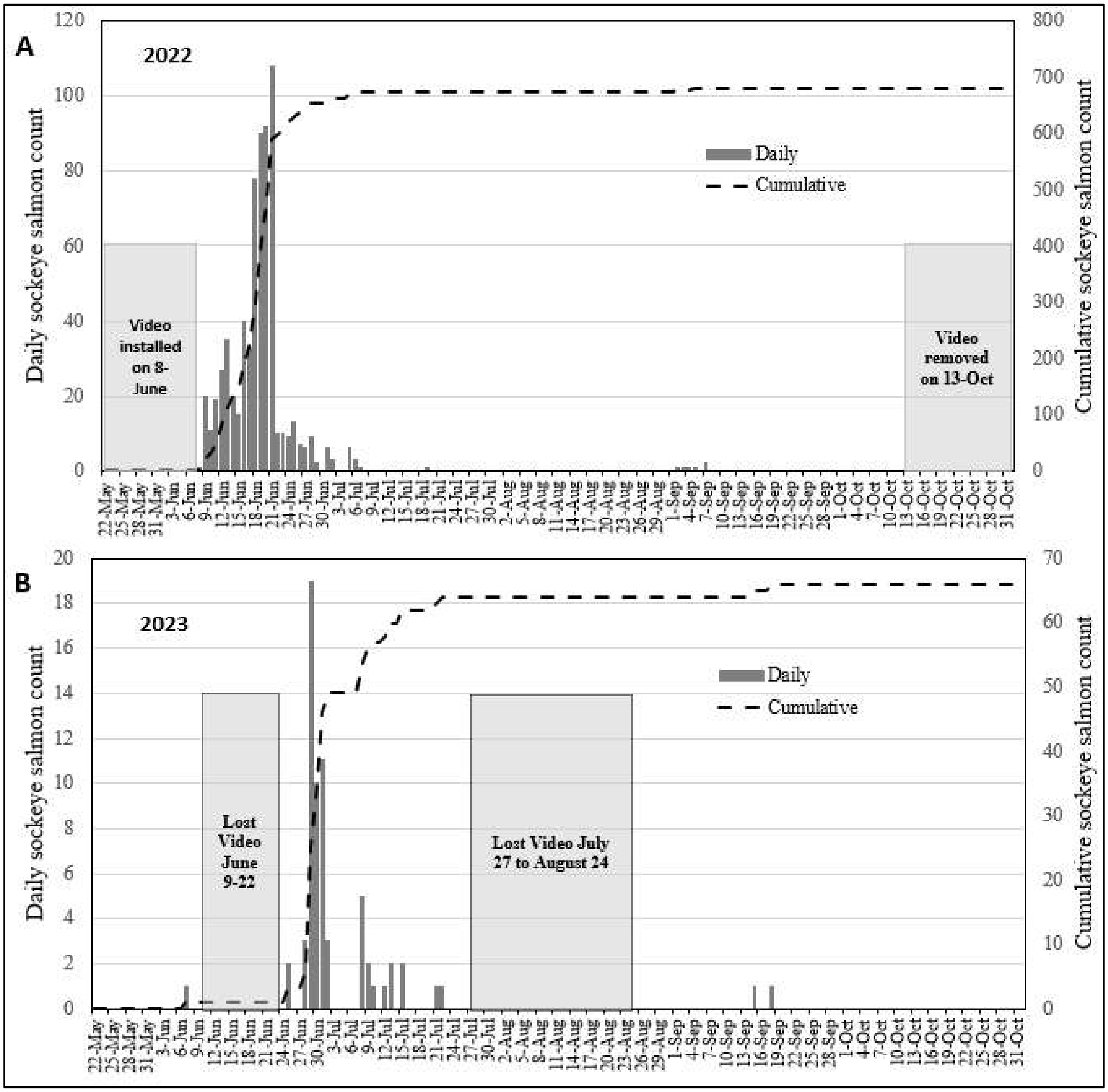

Figure 7.–Chart of daily and cumulative sockeye salmon escapement to Red Lake in 2022 (A) and 2023 (B). Note that auxiliary lights were used to facilitate partial nocturnal counts in 2023.

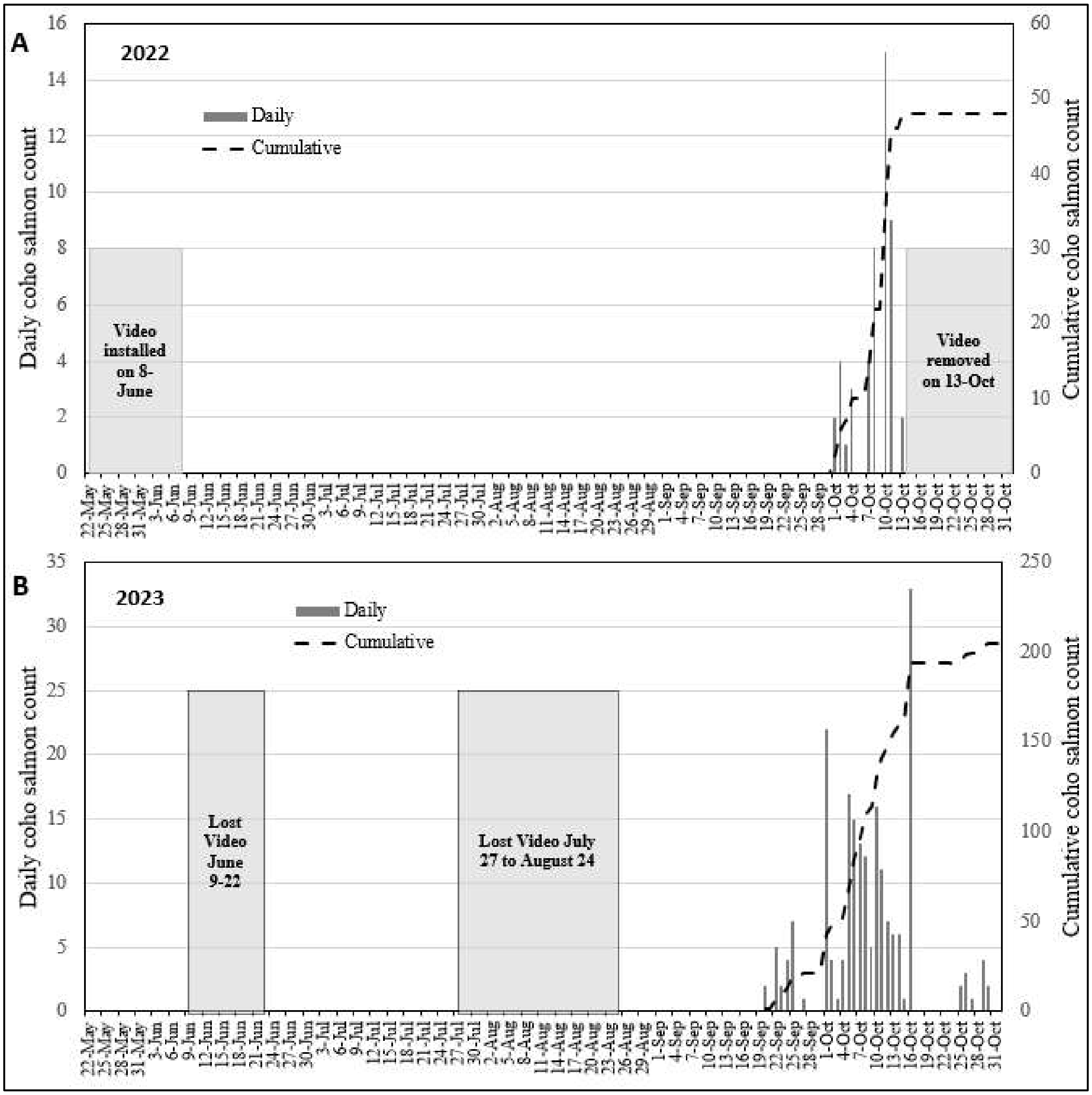

Figure 8.–Chart of daily and cumulative coho salmon escapement to Red Lake in 2022 (A) and 2023 (B). Note that auxiliary lights were used to facilitate partial nocturnal counts in 2023.