



DWB Consulting Services Ltd.

Use of Wildlife Cameras to Monitor Kokanee Spawning in Williston Reservoir

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Prepared for: The Fish and Wildlife Compensation Program (Peace Region)

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Executive Summary

From August to October 2022, six remote wildlife cameras were installed at three kokanee spawning sites on Williston Reservoir: Germansen River, Mason River, and Russel Creek. The purpose of this project was to determine the start, end and peak of spawning activity at three representative spawning sites on the reservoir and address uncertainty regarding kokanee spawner run timing on the reservoir. This work was also intended as a pilot project to explore the use of remote camera technology for observing and monitoring kokanee spawning on the reservoir.

Two cameras were installed at each of the three spawning sites, with camera sites selected to maximize visibility of the streambed and allow reliable observations of spawning fish. Spawning kokanee were observed on four of the six cameras deployed, with spawners observed at both cameras on Germansen and Russel, but none observed on either camera on Manson. The spawning period was shorter in duration on Germansen (37 days) compared to Russel (54 days), with the first spawners observed at Germansen on August 31 and the last spawners observed on October 6. The spawning period was longer in duration on Russel (54 days) with the first spawners observed as early as August 23 and the final spawners observed on cameras as late as October 16. However, spawning on Russel was known to be ongoing as late as October 19 as spawners were observed by field crews when retrieving cameras. The spawning peak was earlier on Germansen, with the highest capture rates on images occurring during the fourth week of the study (September 9-15), while the spawning peak on Russel occurred during the fifth week of the study (September 16-22).

Confidence in spawner counts from camera images was high, with 89% of images having percent visibility estimates of the streambed $\geq 60\%$. The biggest factors influencing visibility of spawners in camera images were light reflection and turbulence on the water surface. Overall, remote wildlife cameras were successful in documenting spawning kokanee in spawning streams on Williston Reservoir, and therefore represent an excellent potential method for passively collecting fine-scale temporal data on kokanee spawning activity on Williston Reservoir or other similar systems. Future projects that use wildlife cameras to monitor spawners should use a camera model that provides timelapse images as JPEG files to allow more efficient processing of camera images. Future projects should also allow sufficient time to perform site reconnaissance (to select suitable camera sites) and to review images once cameras are retrieved. The use of a polarized lenses on cameras may also help reduce surface glare and improve visibility of spawning fishing within the water column.

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1.0 INTRODUCTION

1.1 GOALS AND OBJECTIVES

This report describes the work completed in 2022 by DWB Consulting Services Ltd. (DWB) for the Fish and Wildlife Compensation Program (FWCP). FWCP is a partnership between BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations, and Public Stakeholders to conserve and enhance fish and wildlife in watersheds impacted by BC Hydro dams.

Remote cameras were used to document kokanee spawner activity at three spawning sites on Williston Reservoir from mid-August to mid-October. The primary goal of this work was to address uncertainties related to spawner run timing and duration in the reservoir. Previous aerial enumeration surveys have relied on data gathered in 2002 from repeated (weekly) aerial surveys conducted from late-August to late-October, which identified the third week of September as the peak run timing for introduced Columbia-origin kokanee (Langston 2012). However, recent evidence from Mission Creek, Trepanier Creek and other kokanee spawning streams on the Okanagan River system suggest that peak run timing for Columbia-origin kokanee stocks can vary by up to three weeks (approximately 20 days) from year to year (Randy Zemplak and Kristen King, *personal communication*). The primary objective of this work was to use remote cameras to identify the start, end, and peak run timing for three representative spawning sites to improve confidence that spawner counts from past aerial surveys have been comparable among years.

A broader goal of this project was to explore the utility of remote camera technology for observing and studying kokanee spawning activity. Remote wildlife cameras are widely used to study various facets of wildlife populations. However, the current use of wildlife cameras is mostly limited to terrestrial wildlife and there are few publications available that use conventional wildlife cameras to monitor fish populations (however, see Deacy et al. 2016).

This work is an extension of a larger FWCP project “*Studying Kokanee in our Peace Region*”. The project was designed to meet the following FWCP priority actions in the [FWCP Peace Region Rivers, Lakes, and Reservoirs Action Plan \(Action 5\)](#) to “assess the distribution and abundance of kokanee spawners in tributaries of the Williston Reservoir using aerial surveys,” with the intended outcome to, “[increase] knowledge on the status of Kokanee in the watershed to support identification of actions to help address concerns about introduced kokanee and impacts to other fish species or populations.” The ultimate goal of the project is to better understand the abundance and distribution of kokanee spawning populations across the Williston watershed to inform future management decisions and studies. Aerial enumeration surveys were most recently performed between 2018 and 2021 (see Section 1.2 for summary). Although aerial surveys were initially planned for 2022, they did not occur due to logistical and budget constraints.

1.2 PROJECT BACKGROUND

Kokanee Biology and Life History

Kokanee are the non-anadromous ecotype of sockeye salmon (*Oncorhynchus nerka*) and are widely distributed across watersheds of the Pacific region (Taylor et al. 2000). Unlike their anadromous counterpart, kokanee spawn and rear exclusively in freshwater habitats (streams, rivers and lakes). Sockeye, like most Pacific salmon species, mature in saltwater before migrating to freshwater streams to

spawn (Nelson 1968). Morphologically, kokanee mature at a much smaller body size than sockeye salmon, reflecting their exclusive use of freshwater habitats (Wood and Foote 1996; McGurk 2000). Like most Pacific salmon species, kokanee and sockeye are both semelparous, meaning they spawn only once before they die. Both ecotypes are planktivorous, relying on zooplankton and other invertebrates for food. Kokanee are known to exhibit considerable variation in life history traits, particularly with respect to the types of spawning habitat used, and can utilize a variety of lentic (standing water) and lotic (flowing water) habitats for spawning (Taylor et al. 2000; Whitlock et al. 2018). As pelagic planktivores, kokanee are well-suited to reservoir environments, where periodic water level changes result in frequent disturbance to littoral (near-shore) habitats, and have shown to have been successful in other BC reservoirs (Blackman and Jesson 1990).

History of Kokanee in Williston Reservoir

Prior to construction of the W.A.C. Bennett Dam and formation of the Williston Reservoir, several lakes were known to contain native kokanee populations. These lakes included Thutade Lake, located within the Finlay River headwaters, and Arctic and Tacheeda Lakes, both tributaries of the Parsnip River (Figure 1). Aerial spawner surveys were first conducted in 1989 to locate and enumerate native kokanee in the Finlay River (McLean and Blackman 1991). Surveys were expanded in the Finlay River and included 18 other tributaries in 1990, four of which were re-surveyed in 1994 (Langston and Zemplak 1998). The results of these early surveys (5,000 or fewer kokanee observed) indicated that relatively low numbers of native kokanee inhabited the reservoir (Langston 2012). Between 1990 and 1998, kokanee were stocked in several streams of the Williston Reservoir to create a sport fishery, and to provide an additional food source for resident piscivorous fish species. A total of five tributary systems were used for introduction: Carbon Creek, Davis River, Dunlevy Creek, Manson River, and Nation River (Langston 2012). Individuals used for introduction were sourced from Meadow Creek and Hill Creek in the Columbia River basin and were, therefore, genetically distinct from the native populations. Although stocked kokanee populations potentially benefit sport fisheries and local First Nations, there has been concerns that population expansion of stocked kokanee from the Columbia River watershed may pose a risk to local fish species, such as Arctic Grayling (*Thymallus arcticus*), as well as native kokanee populations in the Williston Reservoir (Langston 2012).

Summary of Previous Kokanee Surveys (2002-2021)

Kokanee spawner surveys were previously conducted between 2002 and 2006 (Langston 2012), in 2010 (Langston et al. *unpublished data*), and from 2018 to 2021 (McDermot-Fouts and Robinson 2019, Robinson 2020, 2021, 2022). A smaller subset of streams was also surveyed from 2007 to 2009 (Langston et al., *unpublished data*). During the 2002 to 2006 surveys, Langston (2012) found that the peak spawning period for Williston kokanee was mid-September. Surveys conducted in 2018 found that total spawner abundance in the reservoir had decreased between 2010 and 2018, with a total of 184,024 spawners enumerated in 2018, compared to 598,096 in 2010 (McDermot-Fouts and Robinson 2019). Similarly, in 2019, a 4.5-fold decrease in spawner abundance was observed relative to 2018 with only 40,670 spawners enumerated. Survey data from 2002 to 2006 indicated that kokanee spawner abundance was initially highest in the Omineca (60-89% of spawners) and Finlay sub-watersheds (2-36%), depending on the study year. In comparison, spawner abundance in the Peace and Parsnip sub-watersheds was considerably lower in the same five-year span, containing <1% and <8% of spawners, respectively (Langston 2012).

However,

in 2010, a reservoir-wide shift in kokanee distribution became apparent among the 4 sub-watersheds, with the highest proportion of spawners observed in the Finlay Reach. In 2018, the Finlay Reach accounted for 53% of the total kokanee spawners enumerated, followed closely by the Omineca Reach at 45%. The Peace and Parsnip Reaches made up a comparatively lower proportion of the total kokanee spawners in 2018 at 2% and <1%, respectively (McDermot-Fouts and Robinson 2019). The distribution among the four sub-watersheds in 2019 was heavily weighted toward the Finlay, which accounted for 83% of the total spawners enumerated. The Omineca accounted for the second highest proportion of spawners in 2019 at 13%, followed by the Peace and Parsnip Reaches at 3% and 1%, respectively.

Spawner surveys from 2002 to 2006, and in 2010, documented kokanee in most of the tributaries within the four main sub-watersheds of the Williston Reservoir: the Finlay, Omineca, Peace and Parsnip River Reaches (Figure 1). From 2018 to 2021, a smaller sub-sample of these tributaries were surveyed for kokanee spawners (28 or 29 streams and rivers, depending on survey year).

1.3 STUDY AREA AND TARGET STREAMS

The Williston Reservoir (56° N latitude, 124° W longitude) is located approximately 140 km north of Prince George, British Columbia (Figure 1) and represents the largest lentic freshwater system in BC. The reservoir was created in 1968 after construction was completed on the W.A.C. Bennett Dam, located on the upper Peace River near Hudson's Hope, B.C. The Peace River flows east to Lake Athabasca within the Mackenzie River drainage system, which flows north and discharges into the Arctic Ocean (Langston 2012). The reservoir has a mean depth of 44 m and a maximum depth of 166 m (BC Research 1977).

Three stream systems were targeted for camera-based spawner monitoring: Germansen River, Manson River and Russel Creek. These sites were selected because they were known kokanee spawning areas and because they represented a latitudinal gradient for kokanee spawning across the reservoir. Both Germansen and Manson were located within the Omineca sub-watershed, while Russel Creek was located in the Finlay at the north end of the reservoir (Figure 1). No streams were monitored within the Parsnip or Peace sub-watersheds. Selecting spawner monitoring sites along a north-south gradient allowed for an examination of variation in spawner run timing among different sub-watersheds of the reservoir.

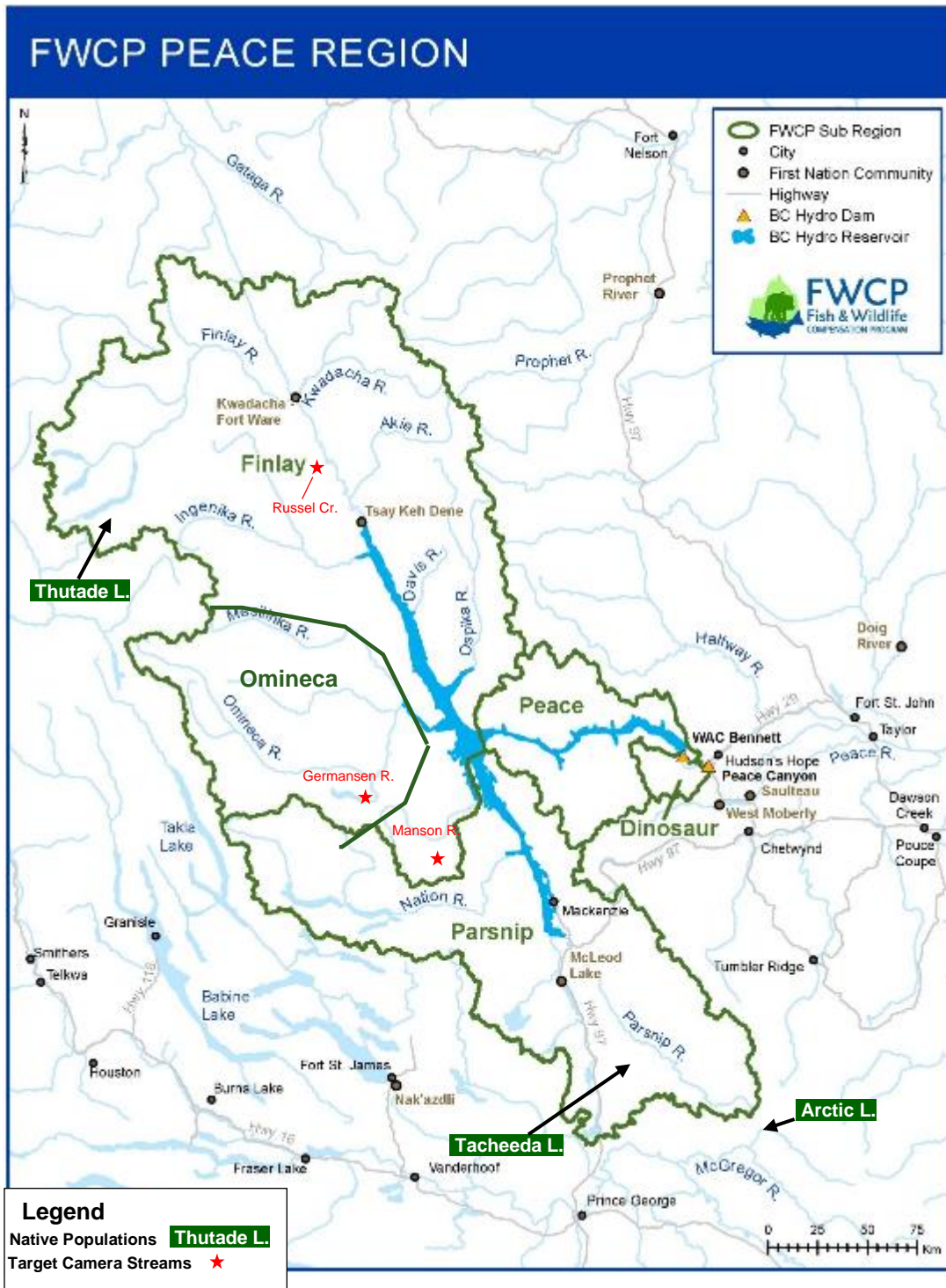


Figure 1. Williston Reservoir watershed showing the four main sub-watersheds relevant to past kokanee enumeration surveys in bold (Parsnip, Peace, Omineca, and Finlay). The Omineca sub-watershed is not an FWCP Sub-Region but has always been treated as a distinct reach for the purpose of kokanee enumerations. Lakes known to have had native kokanee populations prior to the introduction of Columbia-origin kokanee in the 1990's are highlighted in green. Red stars show locations of streams targeted during camera-based spawner monitoring.

2.0 METHODS

2.1 CAMERA DEPLOYMENT

A total of six remote cameras were deployed as part of this study, with two cameras installed at each of the three spawning sites (Figure 1). Newly purchased Browning® Strike Force HD Pro (Model BTC-5HDPX) cameras were used (Figure 2), with each containing a 128 GB SD memory card (SanDisk Extreme Pro®) to store images collected during the deployment period. Cameras were set to the Timelapse+ setting, which allows the user to specify a regular time interval at which the camera takes photos. The Timelapse+ function also allows a camera to be activated by motion-trigger in the event that wildlife activates it outside of the predefined timelapse photo interval. Cameras were programmed to take a single photo every 10 minutes between 6:00 am and 9:00 pm each day. Detailed camera settings are provided in Table A1 (Appendix A).

Cameras were attached to mature trees a minimum of 4.0 m above the water surface. In some cases, the bank was elevated above the streambed. In these cases, the bank height was also measured and accounted for when determining the total height of each camera from the water surface. For added security, each camera was placed within a Browning® Pro X/XD Security Case and secured to the tree with a Python Cable Lock. A Universal Security Case Swivel Bracket was fastened to the rear end of the security case which allowed the camera to be angled up to 45 degrees in any direction. Camera equipment and an example set-up is shown in Figure 2.

A telescopic ladder was used to access attachment sites in mature trees. Each camera unit was secured to a mature tree using two lag bolts (one on the top and bottom of the swivel bracket). Nearby branches and other vegetation were cleared from each camera's field of view to reduce potential false triggers of the camera. A false trigger refers to when a camera is activated by non-wildlife activity, such as moving vegetation or other debris. Cameras were installed in mid-August and were collected in late-October (Table 1), resulting in a deployment period of approximately nine weeks where cameras were actively collecting data. Detailed camera deployment data, including camera settings, are available in Tables A1 and A2, Appendix A. Each camera was checked approximately two weeks after the initial deployment to ensure each was still in position and functioning as intended. During camera checks, cameras were briefly removed from the security case and turned off so that the photos from the memory card could be reviewed on a laptop.

Table 1. Coordinates and deployment dates for 6 cameras used for kokanee spawner monitoring.

Stream	Location ID	Location/UTM	Distance from Stream Mouth	Deployment Date	2-Week Check Date	Collection Date
Germansen	GERM 1	10U 394270, 6183343	1 km	16 Aug 2022	30 Aug 2022	17 Oct 2022
Germansen	GERM 2	10U 394355, 6182543	2 km	16 Aug 2022	30 Aug 2022	17 Oct 2022
Manson	MAN 1	10U 445667, 6172200	11 km	16 Aug 2022	29 Aug 2022	17 Oct 2022
Manson	MAN 2	10U 445722, 6172230	11 km	16 Aug 2022	29 Aug 2022	17 Oct 2022
Russel	RUS 1	10U 356063, 6342866	3 km	18 Aug 2022	1 Sept 2022	19 Oct 2022
Russel	RUS 2	10U 356154, 6342943	2.5 km	18 Aug 2022	1 Sept 2022	19 Oct 2022



Figure 2. Camera equipment and set-ups used for kokanee spawner monitoring, including Browning Strike Force camera (A-B), Security case and Universal Swivel Bracket for mounting cameras (C-E), and camera unit secured to mature tree at spawning site (F).

2.2 CAMERA SITE SELECTION

Camera deployment sites were selected to maximize the visibility of the streambed and spawning fish. The goal was to target sections of the stream relatively close to the stream mouth (within 1-3 km) to increase the likelihood of capturing spawning fish on cameras early in their upstream migration. Kokanee spawner distribution data from past aerial surveys were also consulted to ensure areas targeted on the stream had previous spawner observations.

Camera deployment sites were accessed on foot. Access to the downstream end of Germansen was achieved by hiking several kilometers east of the old post office at Germansen Landing. Similarly, access to the mouth of Russel Creek was achieved by driving an old, partially grown-in timber harvest road east of the Russel-Finlay Forest Service Road (FSR) and hiking approximately 300 m north to the downstream end of Russel Creek. The furthest downstream section of Manson River was not easily accessed by foot and so two camera deployment sites were selected approximately 400 m downstream of the bridge crossing on the Finlay-Manson FSR (see Camera Deployment Maps, Appendix B). These sites were both 11 km from the river mouth. Despite the longer distance between the camera deployment sites and the stream mouth on the Manson River, the sites did correspond to one of the few locations on the river

where spawners had previously been observed during aerial surveys. Spawners were only observed on the lower end of the Manson River (below the Manson Lakes) in 2018 and 2020, and were only observed between kilometer 11 and kilometer 15 (Robinson 2022).

The crew attempted to select locations that would target migrating spawners, but priority was given to sites that provided maximum visibility for viewing fish on images. Criteria considered for the selection of high-visibility camera sites included the following:

1. Areas that allowed either a north or south-facing camera direction to minimize direct glare from the sun.
2. Minimal vegetation along stream banks, but with at least one mature tree present to mount the camera. This represented a trade-off between trying to minimize shadows on the water surface, while still having at least one mature tree to mount the camera on.
3. Relatively shallow (< 1m) run habitats with little to no surface water turbulence (i.e., in riffles).
4. No instream obstacles (e.g., large woody debris, boulders) that fish could hide beneath.

Where possible, the crew also attempted to select camera sites where kokanee spawners would be traveling upstream, rather than staying to spawn. An underlying assumption in the processing of spawner data from images was that each image would represent independent spawner observations (new fish). The assumption was considered more likely if camera sites targeted non-spawning habitat where fish would be travelling through the camera's field of view, rather than remaining in place for long periods.

The two camera deployment sites on Germansen and Russel were approximately 1 km from each other (Table 1), whereas the two sites on Manson were approximately 60 m from each another. All six cameras were installed on the right bank of the stream. All except one camera captured the entire width of the stream channel. One camera on the Manson River (MAN 1) only captured half the width of the channel, while the second (MAN 2) captured the entire width. Since the Manson River was about twice as wide (about 30 m) as Germansen or Russel (13-15 m), capturing the full channel width required placing the camera higher above the streambed. This resulted in potential reduction in viewing potential as fish viewed on images (if present) would appear smaller and potentially more difficult to observe. Therefore, the second camera targeted only half the channel width in the event that fish on the first camera appeared too small to detect.

At each camera site, the crew collected stream width, average channel depth, and a description of the habitat within each stream section targeted. For channel depth, three depth measurements were taken in the targeted field of view: one in the middle of the channel and one 5 m from both the left and right banks. Mean stream depth was then calculated from these three measurements. Camera deployment locations are provided in Table 1 and an example of each camera's field of view is shown in Figure 3. Detailed camera deployment data, including description of habitats present, are provided in Table A2 (Appendix A) and maps showing camera deployment locations are provided in Appendix B.



Figure 3. Views of six cameras deployed for kokanee monitoring on three spawning sites: Germansen (A-B), Manson (C-D), and Russel (E-F). All cameras except one on Manson (MAN 1) captured the entire width of the channel. MAN 1 only captured the half the channel width on the Manson River which was about twice as wide (34 m) as cameras sites on Germansen or Russel.

2.2 IMAGE PROCESSING

All camera images were reviewed by a single observer with previous experience performing aerial enumeration surveys. During image review, the reviewer estimated the number of kokanee spawners present in each image using the criteria used in previous aerial enumeration surveys (Langston 2012). Kokanee were grouped into schools of 5, 10, 50 or 100 individuals. The reviewer also estimated the percent of streambed visible in each photo to the nearest 5%. This provided an estimate of confidence when estimating spawner counts (see Section 2.3). The reviewer noted any instances where reflection, shadows,

rain, wind, or other features obscured visibility of the streambed in images. The reviewer also documented any other wildlife observed in images (e.g., bears, eagles, waterfowl).

2.3 DATA ANALYSIS

Images were filtered to contain only images taken between August 19 and October 17. This gave a consistent deployment period and sampling effort of 59 days across all camera sites. Image data were further filtered to only include images taken between 08:00 and 17:00, since light conditions were too poor to view the streambed and spawning fish outside of this period. Data were also filtered to include only images where visibility estimates were $\geq 60\%$, which was considered an acceptable level of confidence that the majority of fish present within each camera's field of view would be observable. The total number of images for each camera after filtering are provided in Tables C1 and C2 (Appendix C).

The start and end of spawning was defined as the first and last dates where spawners were observed on cameras, respectively. The spawning period duration was then calculated as the number of days between the spawning start and end dates. Peak run timing refers to the part of the spawning period where the highest number of spawners were assumed to be spawning in a river or stream. To determine the peak run period, the image dataset was subdivided into nine 1-week periods (Week 1 to Week 9, Table 2) within which the total number of spawners observed across all images was summed. Since the total number of images (and therefore, potential spawner observations), varied between camera sites (see Section 3.1), count estimates were standardized for each week by dividing each weekly spawner count by the total number of images used per week. This gave a Catch Per Unit Effort (CPUE) estimate of the number of kokanee spawners per image for each week cameras were deployed. All 1-week periods were seven days, with the exception of the final week (week 9) which was only three days. A confidence interval of 15% was assigned to each CPUE estimate, as this was the percent error used for the "high confidence" category when estimating spawner group sizes during aerial count surveys (Langston 2012). The process was also performed for daily CPUE estimates to provide finer-scale temporal data on spawner capture rates. However, the primary results are summarized by week and the daily CPUE estimates are provided as supplementary data in Appendix C.

Table 2. Allocation of nine weekly periods and associated dates used to subset spawner counts from cameras.

Week Number	Date Range
Week 1	August 19 –25
Week 2	August 26 – September 1
Week 3	September 2 – 8
Week 4	September 9 – 15
Week 5	September 16 – 22
Week 6	September 23 – 29
Week 7	September 30 – October 6
Week 8	October 7 - 14
Week 9	October 15 - 17

2.4 SPAWNER COLLECTION

Spawner collections were performed opportunistically during early September when camera checks were performed, and during mid-October when cameras were collected. Spawners were collected from only two of the three spawning sites: Germansen and Russel. No spawning fish were observed at Manson River during any camera visits in September or October. Spawners were collected using a combination of dipnetting and backpack electrofishing. Where possible, dipnetting was performed without backpack electrofishing to minimize stress to fish and to limit potential impacts on spawning habitats and eggs.

Where dipnetting was performed without electrofishing, the crew identified narrow side channels or braids of the stream where spawners were holding in deeper pools on the downstream end (Figure 4). The upstream ends of such sites were characterized by shallow riffle habitat (10-15 cm deep). A blocknet was installed at the downstream end of the channel to prevent fish from escaping downstream and one person coaxed fish (usually 1-3 fish at a time) to the upstream riffle area where they were dipnetted out of the water by a second crew member. Where electrofishing was used, one crew member used the electrofisher to stun fish while a second crew stationed downstream captured fish with a dipnet.



Figure 4. Fish collection at Russel Creek on September 1, 2022 showing (A) installation of blocknet at downstream end of side channel, (B) kokanee spawners holding at downstream end of channel and (C) fish capture by dipnet on a shallow riffle at the upstream end of the channel.

Captured fish were humanely dispatched using a single blow to the head. Care was taken to use an appropriate level of force when dispatching female fish to avoid expulsion of eggs, which could affect later fecundity estimates. Fish were then weighed using a scale accurate to 0.01 grams and fork lengths were measured using a tape measure accurate to one millimetre. Fish were individually bagged and labeled with a unique identifier that corresponded to date and site of capture. Collected kokanee were then

frozen

and delivered to the University of Northern British Columbia (UNBC) in Prince George for further analysis (not addressed in this report). Scientific Fish Collection Permits were obtained through the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development in the Omineca Region (permit No. PG22-732443) before kokanee were collected and all appropriate animal care protocols were followed. Spawner collection data was submitted to the Ministry's Fish Data Submission Website as per permit conditions (<https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=60174>). Fork lengths, weights, and sex for all individual spawners from 2022 collections are provided in Table D1 (Appendix D).

3.0 RESULTS

3.1 IMAGE SUMMARY AND REMOTE CAMERA PERFORMANCE

In total, 30,904 images were captured across all six cameras, with the total number of images per camera ranging from 3806-6945 (mean = 5150 ± 957). When images were filtered by percent visibility, a total of 27,629 images remained, with the proportion of photos retained for each camera ranging from 72-93 % (Table C1 – Appendix C). GERM 1 was the camera with the fewest photos retained (72%), owing to the most variable visibility conditions and the highest number of photos with less than 60% visibility. The other five cameras all had consistently better visibility conditions, and all had at least 85% of images retained after filtering. The number of images classified by percent visibility estimates is provided in Table C2 (Appendix C).

Spawning kokanee were observed in four of six cameras. Both cameras on Germansen and Russel consistently captured images of spawners, whereas no spawner observations were made on either camera on the Manson River. Spawner group size estimates in individual images ranged from 0 to 100. All six cameras remained operational throughout the 9-week deployment period, with battery life and memory card capacity sufficient to accommodate data collection. However, the timelapse data collection interval was not consistent for all cameras and days, which resulted in a variable number of images captured for each camera (Table C3 – Appendix C). During image review, the time interval between successive images occasionally deviated from the 10-minutes programmed for each camera. The inconsistent time interval was suspected to be the result of the nature of the timelapse setting in the Browning Strike Force camera model used. The only timelapse function available for this model is called "Timelapse +", which also allows the cameras to be motion-triggered. Blowing vegetation and other debris warmed by the sun may have variably triggered cameras at different times, resulting in the variable number of images observed for each camera.

3.2 SPAWNER RUN TIMING

Spawning began at Germansen on August 31 and ended on October 6, giving a spawning duration of 37 days (Table 3). In contrast, Russel Creek had a longer spawning period of about 50 days, with spawners first observed on August 23 and last observed on October 16. Spawners were observed on cameras approximately one week earlier and one week later at Russel compared to Germansen. The two cameras on Russel Creek - RUS 1 and RUS 2 - differed slightly in their respective spawning end dates of October 13 and October 16. Though camera data indicated October 16 was the final day spawners were observed at Russel, spawners were observed on October 19 when cameras were retrieved from Russel. Therefore, spawning was potentially occurring as late as October 19 on Russel. In contrast, no kokanee spawners

were observed on Germansen between kilometers 1-2 on October 17 when cameras were retrieved.

Table 3. Spawning start and end dates, spawning duration, and peak spawning period for six remote cameras monitoring spawning activity at three spawning sites on Williston Reservoir (Germansen, Manson and Russel).

Stream	Deployment ID	Spawning Start Date	Spawning End Date	Spawning Duration (days)	Peak Spawning Period
Germansen	GERM 1	31 Aug 2022	6 Oct 2022	37	Sept 9 - 15
Germansen	GERM 2	31 Aug 2022	6 Oct 2022	37	Sept 9 - 15
Manson	MAN 1	No Fish Observed	No Fish Observed	---	---
Manson	MAN 2	No Fish Observed	No Fish Observed	---	---
Russel	RUS 1	23 Aug 2022	13 Oct 2022*	51	Sept 16 - 22
Russel	RUS 2	23 Aug 2022	16 Oct 2022*	54	Sept 16 - 22

* Spawning end dates as indicated by final spawner observations on cameras. Kokanee spawners were observed as late as October 19 on Russel when cameras were retrieved.

The peak spawning period for Germansen occurred from September 9 – 15 (Week 4), with this period corresponding to the highest spawner capture rates for both cameras (Figure 4). The camera located further downstream at 1 km from the river mouth (GERM 1) had a higher spawner capture rate of 21.88 ± 3.28 spawners/image, compared to the camera located at 2 km upstream (GERM 2) with 8.11 ± 1.22 spawners/image. Both cameras, however, indicated that peak spawning occurred during the fourth week of the study.

In contrast, the peak spawning period for Russel Creek occurred about 1 week later than Germansen, between September 16 –22 (Week 5). In this case, the camera located further downstream at 2 km from the stream mouth (RUS 1) had a lower spawner capture rate of 11.18 ± 1.68 spawners/image compared to the second camera located further upstream at km 2.5 (RUS 2) with a capture rate of 20.97 ± 3.14 . Again, both cameras indicated the third week of September as the peak spawning period for Russel. Additional supporting data, including weekly image spawner counts, weekly image counts, CPUE calculations, and confidence intervals can be found in Table C3 (Appendix C). Similarly, daily spawner counts and daily CPUE values are shown in Figures C4 and C5, respectively (Appendix C).

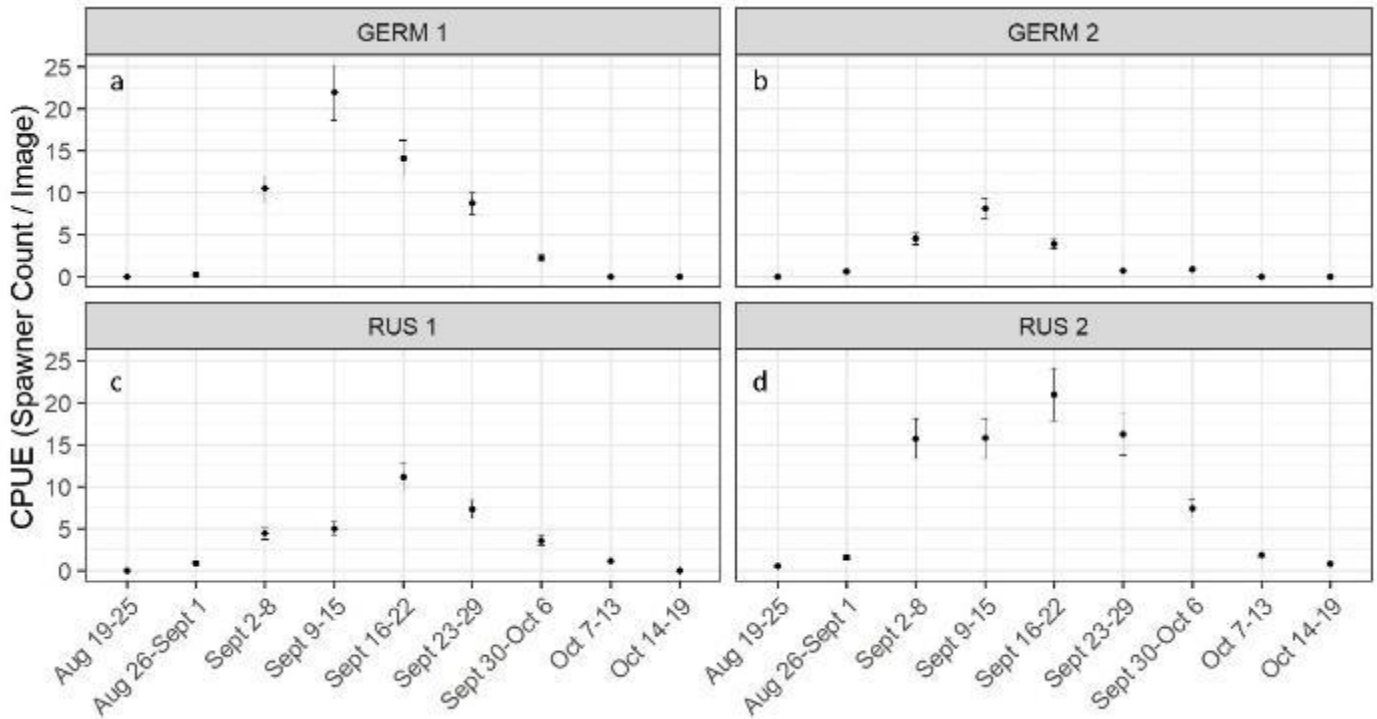


Figure 5. Comparison of weekly CPUE (Catch Per Unit Effort) between two cameras at Germansen River (a-b) and Russel Creek (c-d). CPUE was calculated as the total number of fish enumerated during a week, divided by the total number of images used in the enumeration for that week. Confidence intervals represent $\pm 15\%$ of the CPUE estimate.

3.3 FISH COLLECTIONS

A total of 50 spawners were successfully collected from both Germansen and Russel. At Germansen, there were 22 female and 28 male spawners retained, while at Russel there were 26 female and 24 male spawners retained (Table D1, Appendix D). All fish collected from Germansen were captured during a single capture session on September 4, while the spawners collected on Russel were captured over two days (September 1 and October 19). A total of 33 spawners were collected from Russel on September 1, eight of which were carcasses. Due to time limitations, the 50-fish target for Russel was not obtained on September 1. The remaining 17 fish of the sample were captured on October 19 when the cameras were retrieved. Data collected from individual spawners are provided in Appendix D.

4.0 DISCUSSION

4.2 SPAWNER RUN TIMING

Images from remote wildlife cameras were successfully used to estimate the start, end, and peak spawning periods during the 2022 kokanee spawning run at two sites on Williston Reservoir (Germansen River and Russel Creek). Both the spawning duration and peak spawning period varied between

Germansen and Russel, with the spawning period of Russel lasting approximately two weeks longer, and peaking one week later, than Germansen. Though this represents only one year of data, and only two sites, these findings provide some evidence that variation exists in run timing among different spawning streams on the reservoir. This, in turn, has important implications for timing of enumeration surveys, should they occur again the future.

Kokanee spawning populations on the reservoir have historically been monitored using aerial enumeration surveys. In the most recent monitoring period from 2018 to 2021, spawner counts were estimated for 28 - 29 spawning sites (depending on the year) using a single enumeration flight for each spawning site per year (Robinson 2022). The spawning sites surveyed were located across all four major sub-watersheds of the reservoir (Parsnip, Omineca, Peace and Finlay). Survey flights were intentionally timed to occur during the third week of September, as past evidence suggested that this period represented the peak spawning period for kokanee in the reservoir (Langston 2012). This peak spawning period was based on aerial surveys performed in 2002 when 85 streams were surveyed three to four times between the last week of August and end of October to identify the period of highest spawner counts.

Ideally, to obtain a consistent and comprehensive enumeration estimate of spawners across a set of spawning sites, surveys should be timed during the peak spawning period to allow enumeration estimates to occur when the highest number of fish are present in the stream. A critical assumption of past spawner enumeration surveys was that spawner run timing was synchronous across all streams surveyed. However, this assumption may not necessarily be valid for all spawning sites across the reservoir. Our results also demonstrated that spawning may be starting earlier in some Williston streams than previously thought. Repeated aerial surveys performed in 2002 found that spawners had not entered spawning tributaries during the last week of August (Langston 2002). However, results from spawning cameras in 2022 indicated that spawners were present as early as August 31 on Germansen, and August 23 on Russel.

Salmonid species are known to exhibit considerable variability in their life history patterns, including the timing of migration and spawning events (Quinn et al. 2002). Spawner run timing, including maximum or peak spawning periods, can vary annually within and among stocks of the same species (Óskarsson and Taggart 2009; Quinn et al. 2002). Though this variation in annual run timing has typically been associated with anadromous salmonid species, similar variation has also been noted for non-anadromous kokanee in other systems in British Columbia, including spawner runs affected by dams constructed for hydroelectric operations. For example, kokanee spawning populations have been monitored annually on the Lower Duncan River as part of the Water Use Plan for The Duncan Dam (Plate et al. 2018). The Duncan Dam, created in the mid 1960s, along with the Mica and Hugh Keenleyside Dams, was created under the Columbia River Treaty, and resulted in the creation of the Duncan Reservoir, a 45-km long waterbody created to provide water storage for downstream hydroelectric power generation and flood control (BC Hydro 2007). The dam also provides fish flow regulation for the Lower Duncan River between the dam and the river mouth at the north end of Kootenay Lake. During a 10-year monitoring period, kokanee spawning surveys on the Lower Duncan River have found that peak run timing varied annually by as much as 20 days, with peak spawning occurring anywhere between September 24 and October 10 between 2008-2017 (Plate et al. 2018).

4.1 CAMERA EFFECTIVENESS

Cameras were successful in capturing images of spawning kokanee in two of three of the target spawning streams on Williston Reservoir. The crew attempted to select camera deployment sites where spawning fish would be expected to be migrating upstream, but also sites that offered the best conditions for viewing fish (i.e., high visibility sites). To target sites likely to have migrating fish (rather than those staying to spawn), the crew looked for areas with minimal spawning habitat (gravels), instead selecting cobble-dominated sections whenever possible. Though the crew was generally able to achieve this goal at camera sites, maximizing streambed visibility usually took priority over the type of habitat present. As a result, one camera on Germansen (GERM 2) and both cameras on Russel had a small proportion of spawning gravels present in the channel section targeted by cameras. However, it was known from past aerial surveys and ground reconnaissance during camera deployment, that suitable spawning sites existed upstream of these camera sites. Therefore, we are confident that the majority of spawners observed on cameras were migrating, rather than spawning.

4.1.2 Conditions Affecting Visibility

Despite efforts to select sites with the best visibility, streambed visibility conditions varied throughout the day, even on days where the weather was clear and sunny. The most common factors affecting visibility were light reflection off the water surface, surface water turbulence, and shadows. The most common factor affecting streambed visibility was shadows and lighting conditions. Typically, visibility was best during the early morning hours (approximately 8:00 – 11:00, and/or in the late-afternoon (approximately 15:00-16:30), depending on the camera's orientation. These time periods corresponded to when the sun was lower in the horizon – east in the morning and west in the afternoon – and, therefore, provided the greatest illumination of the streambed. This pattern was most notable for cameras that had either north or south-facing orientations. When the sun was higher in the sky during mid-afternoon, it resulted in a higher proportion of shadows from trees along stream banks, which in turn created a “dappling effect” on the streambed where there was a mixture of light and shadowed sections in the camera's field of view. The middle of the afternoon also tended to be when surface reflections were most prevalent (Figure 6). A polarized lens or polarized film placed over the camera lens may aid in reducing glare from the sun in future projects.

Since sites were selected with little to no natural water turbulence, surface water disturbance was usually only associated with periods of wind or rain events. The only exception to this was the cameras on Russel, both of which had some natural surface disturbance. The degree of turbulence at these sites, however, was not enough to drastically impair streambed visibility (Figure 7). Further aiding spawner count from images was the contrast in color between spawning fish and the streambed. Kokanee spawners are a good species for camera-based monitoring in part because the Columbia-origin stock that currently make up the majority of the kokanee in the reservoir turn bright red when they spawn. This feature helps spawners stand out from the stream substrate, especially when the stream is well-illuminated by sunlight.



Figure 6. Examples of impaired visibility conditions caused by (A) surface water turbulence and (B) increased mid-afternoon reflection off the water surface.



Figure 7. Spawning kokanee in bright-red spawning colors contrasting with bottom substrate on Russel Creek, despite presence of some surface water turbulence.

4.1.2 Camera Model Selection

For this study, we used Browning Strike Force XD model which had only one timelapse setting called “Timelapse+”. This setting allowed the user to specify a set time interval at which to take photos, but the camera was still able to capture motion triggered photos as well. When retrieving memory cards, it was discovered that timelapse and motion-trigger images were stored in separate files on the SD card. Further, although motion-trigger photos were stored as JPEGs, the timelapse photos were stored as a TLS file, which were essentially video files that each contained 10-minute interval represented by frames in the video. Although these videos could be viewed with Windows Media Player, or other related applications, they could not be used with many software programs that are available for efficient processing of wildlife camera images (e.g., *Timelapse*, Greenberg 2019). Therefore, future studies should consider selecting camera models that produce JPEG image files as part of the timelapse function.

4.1.3 Lack of Spawner Observations in Manson River

Unlike Germansen and Russel, no spawning kokanee were observed on cameras placed on the Manson River. This may be due in part to placement of cameras further upstream relative to the river mouth. Due to logistical constraints, both cameras were placed at approximately 11 km upstream of the river mouth. This area was selected as it was most easily accessed downstream of the bridge on the Finlay FSR (see camera deployment maps, Appendix B). Time and budget constraints within the projects schedule did not allow a larger reconnaissance along the length of the river to locate additional camera sites. The Manson River is a comparatively smaller spawning run than Germansen or Russel, with only 270 and 60 spawners

enumerated in 2018 and 2020, respectively. Although camera sites located close to the river mouth may have increased chances of capturing fish entering the river to spawn, past kokanee observations were actually made further upstream between km 11 and km 15 from the mouth (Robinson 2002).

Another factor that may have influenced our ability to detect spawning kokanee at Manson, is the 10-minute interval used for the camera timelapse settings. Although 10 minutes appears to have been an appropriate timelapse interval for Germansen and Russel, both of which have relatively large spawning populations, this interval may have missed spawners passing though given the lower number spawner counts experienced on Manson the past few years. A short time interval may therefore be more appropriate for streams expected to have fewer spawning fish migrating to increase the likelihood of spawner detection.

The lower Manon River is also a larger system than either Germansen or Russel, having a nearly double the channel width than the other two streams at camera deployment sites. The size of the river, combined with the fact that Manson has historically had a much smaller spawner run than other sites, suggest it may not be suitable for camera-based spawner monitoring.

5.0 FUTURE CONSIDERATIONS

Based on the results of this pilot project, the following considerations have been provided for future projects that use remote cameras to monitor spawning kokanee or other fish:

1. This program could potentially be expanded to monitor kokanee spawning across a wider range of streams on Williston Reservoir or other similar systems. An expanded camera-based spawner monitoring program could be used to collect fine-scale temporal data of spawner run timing. Additional modifications could be also made to the methodology that may allow additional spawner metrics to be estimated, such as spawner abundance or behavior.
2. Future projects should ensure sufficient field time is budgeted for site reconnaissance and selection of suitable camera sites. Though preliminary desktop-based reconnaissance can assist in locating potential camera sites along spawning streams, sites require ground-truthing to ensure they meet the appropriate criteria (good visibility, desired habitat features present etc.). For larger streams with difficult access, an inflatable zodiac or similar watercraft, outfitted with an outboard motor, may aid in accessing potential camera deployment sites located too far to hike.
3. The size of the spawning tributary (depth, channel width) as well as the historic spawner run size, should be considered when selecting potential spawner monitoring sites. The absence of spawners captured on cameras at the Manson River suggest the system may have been too large, and the spawning run too small, to act as a suitable site for monitoring spawning kokanee.
4. In future projects, camera placement along the streambank of target sites should be standardized to ensure comparability of resulting data. Camera placement parameters such as height, distance to streambed, orientation, and target habitat should all be standardized as best possible. Project managers and biologists should consider both the target habitat within the camera's field of view,

as well upstream and downstream of the camera site, in order to capture target kokanee spawning behavior (e.g., migrating, spawning, holding). A protocol or Standard Operating Procedure (SOP) should be developed that standardizes camera placement for monitoring spawning kokanee.

5. In areas with a scarcity of mature trees, custom wooden mounts or t-posts may be used to mount cameras in areas expected to have good visibility for viewing spawning fish.
6. Though a 10-minute timelapse interval may be sufficient for spawning sites where a relatively high number of fish are spawning, sites with smaller spawning populations may require a shorter time interval to increase likelihood that spawning fish will be detected on cameras.
7. In future spawner monitoring, a camera model should be selected that provides timelapse images as JPEG files. This will result in more efficient image review by allowing the use of existing image processing software programs (e.g., Timelapse®) to automatically read and enter date and time data from JPEGs, thereby eliminating the need to enter these data manually.
8. A polarized lens or polarized film placed over the camera lens may aid in reducing glare from the sun. This feature should be tested in future applications. Color detection software may also assist in rapid or automated enumeration of spawners in photos. Since Columbia-origin kokanee spawners are red, they typically contrast well with the surrounding streambed. This feature may lend itself well to color-detection or machine learning programs to assist with spawner count estimation from images.
9. Appropriate time should be budgeted for image review when cameras are used estimate spawner counts. For this project, a single reviewer required 18 days to review 30,904 images, giving an image processing rate of about 1,700 images/day. The rate of image review did, however, increase as the reviewer became more experienced with the review process. With more cameras and/or a shorter photo timelapse interval, time should be appropriately budgeted for reviewing the number of photos expected from a project of a certain scale.
10. Future projects may consider the use of video footage in place of still images to monitor spawning kokanee. Most conventional wildlife cameras have settings that allow the collection videos. Motion of fish in resulting video clips may assist in detecting and enumerating spawning fish, and may provide additional behavioral data not present in still images.

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Appendix A

Camera Deployment Data

Table A1. Remote camera settings used for cameras deployed at three spawning sites on Williston Reservoir

Camera Settings	
Model	Browning Strike Force Pro XD
Mode	Timelapse+
Capture Delay	1 min
PicSize	Medium [8MP]
Cap Start	6:00 AM
Cap End	9:00 PM
Smart IR	On
Night Exp	Long Range
TL Frequency	10 Min
TL Period	All Day
Temp Unit	C
Info Strip	On
SD Management	Off
Motion Detect	Long

Table A2. Camera deployment data for 6 remote cameras deployed at Germansen, Manson and Russel Creek on Williston Reservoir in fall 2022.

Stream	Germansen		Manson		Russel	
Camera ID	GERM 1	GERM 2	MAN 1	MAN 2	RUS 1	RUS 2
Deployment Date	16 Aug 2022	16 Aug 2022	16 Aug 2022	16 Aug 2022	18 Aug 2022	18 Aug 2022
Removal Date	17 Oct 2022	17 Oct 2022	17 Oct 2022	17 Oct 2022	19 Oct 2022	19 Oct 2022
UTM	10U 394270, 6183343	10U 394270, 6183343	10U 394270, 6183343	10U 394270, 6183343	10U 394270, 6183343	10U 394270, 6183343
Distance from Stream Mouth	Km 1	Km 2	Km 11	Km 11	Km 3	Km 2.5
Stream Width (m)	13.0	15.2	31.0	34.0	12.5	14.5
Avg. Stream Depth (m)	0.42	0.55	0.49	0.38	0.46	0.47
Height off Ground (m)	4.0	1.8	1.85	8.0	3.1	3.9
Distance to Streambed (m)	4.95	9	5.25	8.0	5.0	5.0
Compass Bearing	42°	13°	136°	196°	260°	49°
Habitat Description	Shallow run habitat; no riffles or turbulence. Cobble-dominated substrate.	Shallow riffle/run habitat, no water turbulence. Mostly cobble-dominated substrate, but some patches of spawning gravels present in middle and near left and right banks. Prominent patch of spawning gravels located at top right of frame along right bank. Kokanee spawners consistently observed here.	Riffle/run habitat, mostly cobble-dominated. Total height was lower than MAN 2 camera so camera framed only about 1/2 of stream width.	Shallow riffle run habitat. Camera placed higher since bank was elevated, so as result we captured entire stream width. Predominantly cobble dominated substrate.	Shallow riffle run habitat. Trees close to bank and stream channel created shading at certain times of day. Mostly cobble dominated substrate, but some smaller gravel patches present.	Shallow riffle-run habitat. Trees close to bank and stream channel created shading at certain times of day. Mostly cobble-dominated substrate, but some smaller gravel patches present.

Appendix B

Camera Deployment Maps

FWCP Kokanee Spawner Monitoring 2022 Germansen River

- ★ Camera Site
- Km Marker
- Spawner Collection Site



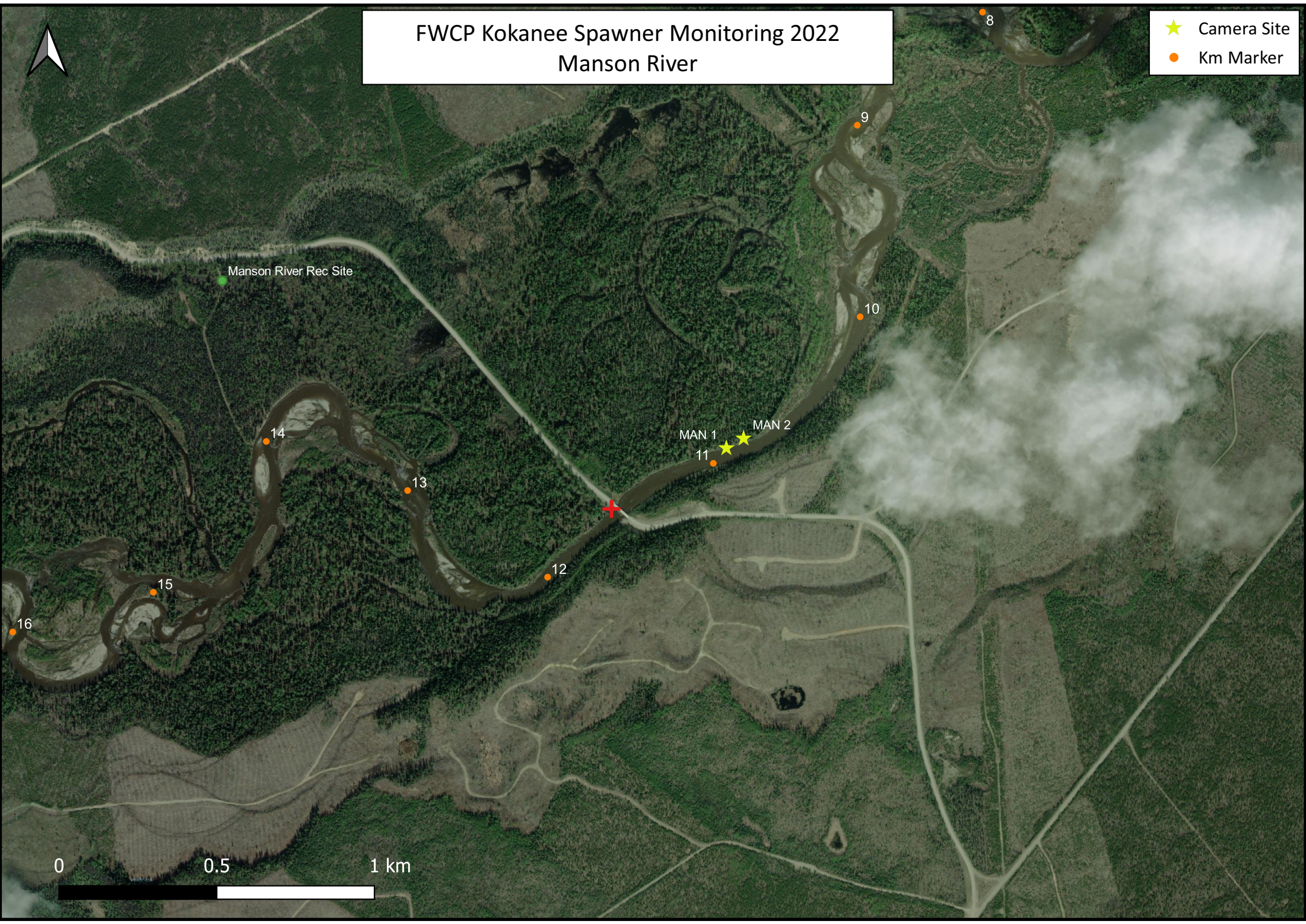
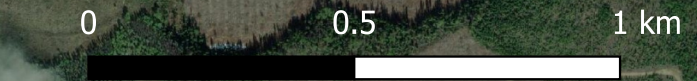
FWCP Kokanee Spawner Monitoring 2022 Manson River

- ★ Camera Site
- Km Marker

Manson River Rec Site

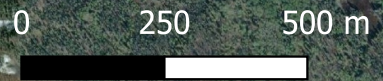
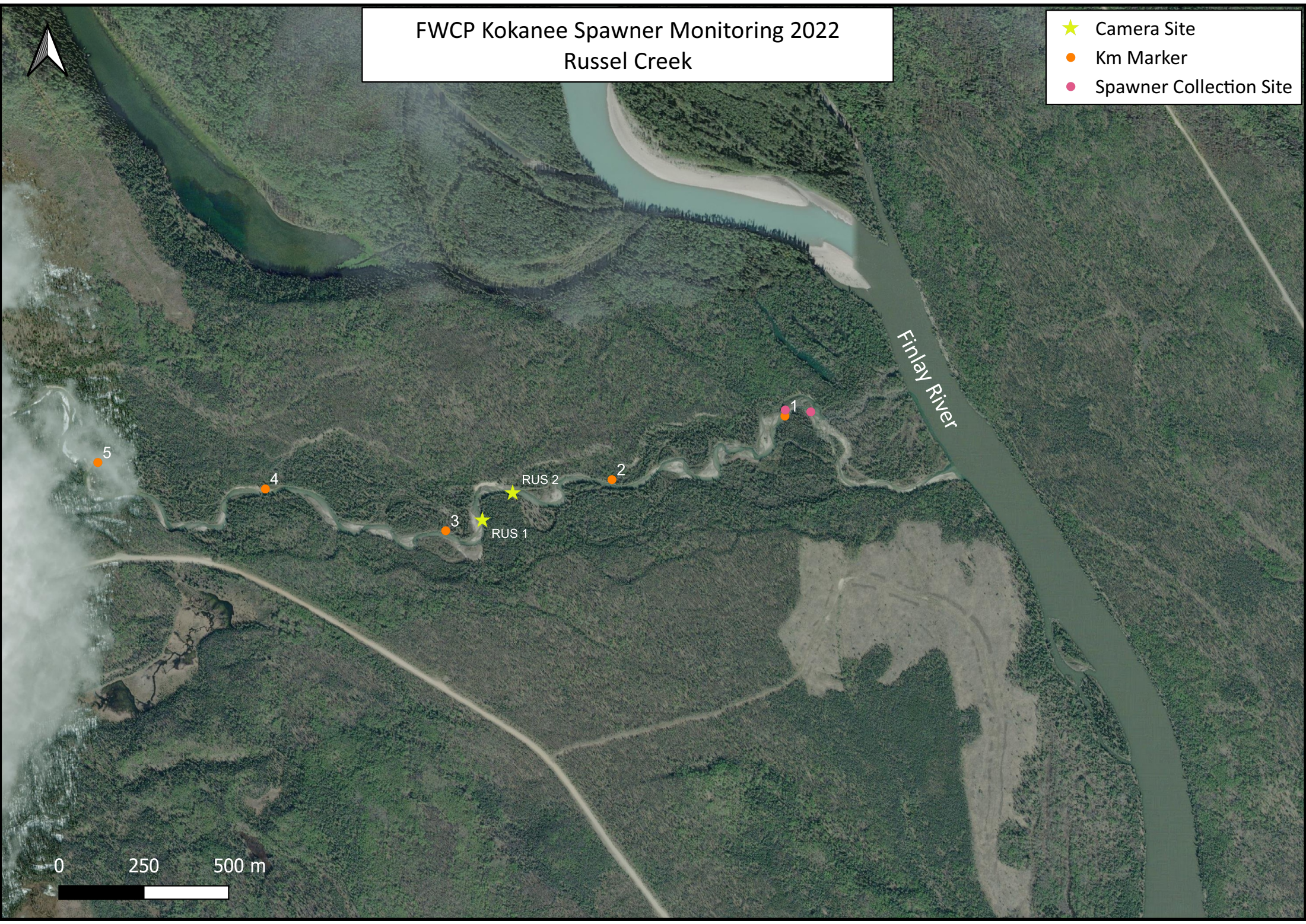
MAN 1
11

MAN 2



FWCP Kokanee Spawner Monitoring 2022
Russel Creek

- ★ Camera Site
- Km Marker
- Spawner Collection Site



Appendix C

Supplementary Camera Data

Table C1. Total photos taken by each of six remote cameras deployed at three spawning sites (Germansen, Manson and Russel). Also shown are the number and proportion of photos retained for spawner count analysis after image sets were filtered to retain photos with percent visibility estimates $\geq 60\%$.

	GERM 1	GERM 2	MAN 1	MAN 2	RUS 1	RUS 2	Total
All Photos	3806	4850	6945	4894	4814	5595	30904
Filtered By Visibility ($\geq 60\%$)	2747	4552	6519	4140	4454	5217	27629
Proportion Photos Retained	0.72	0.94	0.94	0.84	0.92	0.93	0.89

Table C2. Total number of images* taken by each camera and present visibility estimate.

Percent Visibility	Total Number of Images						Total
	GERM 1	GERM 2	MAN 1	MAN 2	RUS 1	RUS 2	
0	146	1	6	439	67	51	710
10	20	1				1	22
20	80	26			5		111
25	1						1
30	85	28			1		114
40	192	91	28		7		318
45	5						5
50	207	103	84	73	12	9	488
60	408	316	126	24	109	180	1163
65	39				15		54
70	268	564	159	7	91	270	1359
75	99	299	8		307	86	799
80	761	1029	2627	2614	459	906	8396
85	227	198	1041	11	495	586	2558
90	425	1127	2009	1236	1043	2573	8413
95	351	195	417	17	983	748	2711
100	492	872	440	473	1220	185	3682
Total	3806	4850	6945	4894	4814	5595	30904
Total Filtered by Visibility ($\geq 60\%$)	2747	4552	6519	4140	4454	5217	27629
% Images Retained	72.1%	93.9%	93.9%	84.6%	92.5%	93.2%	89.4%

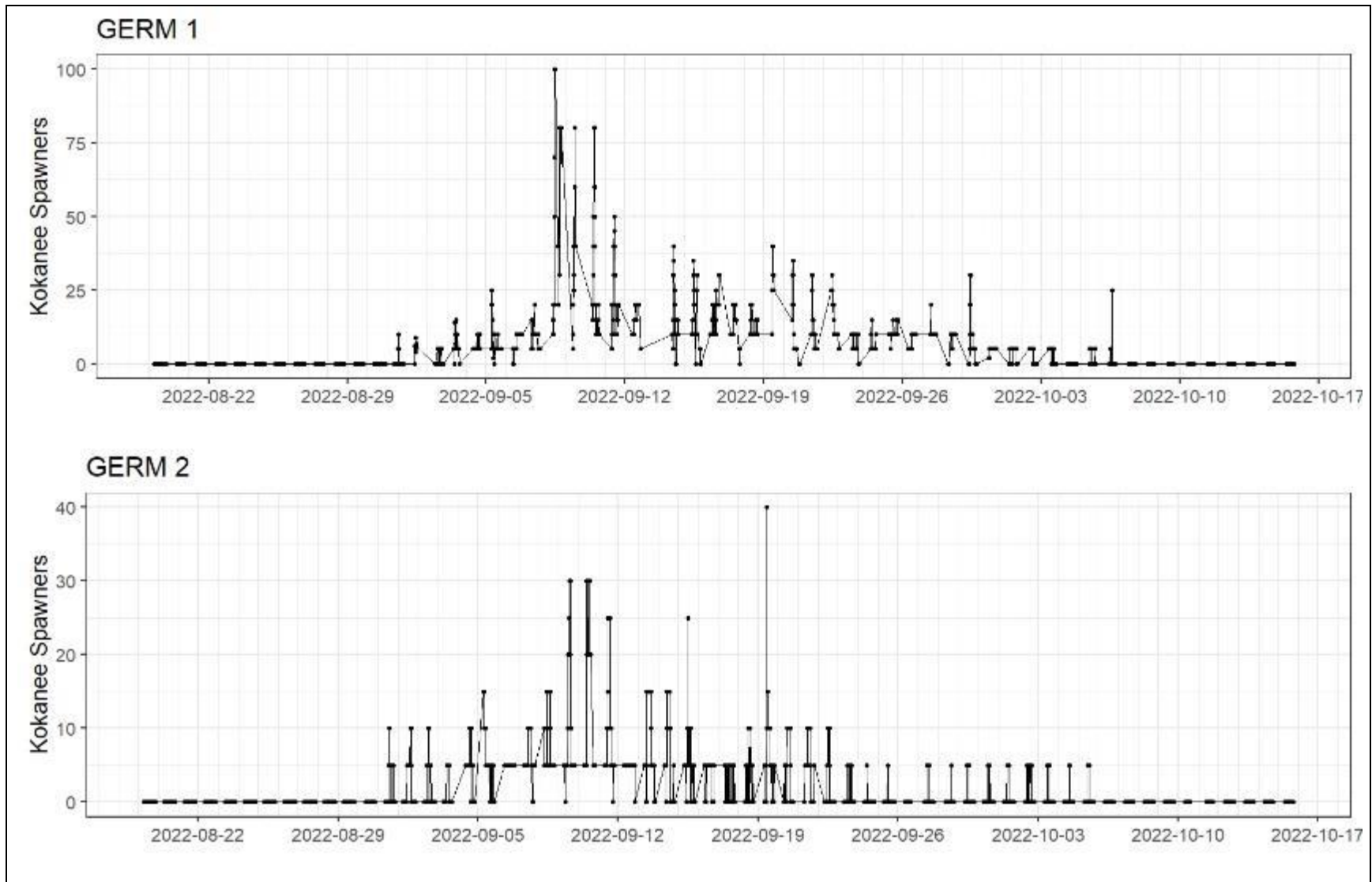
* Data only includes images retained for count analysis where percent visibility estimates were $\geq 60\%$.

Table C3. Total number of kokanee spawners counted and images per week, as well as (Catch Per Unit Effort) after filtering data to include only images with percent visibility estimates $\geq 60\%$.

Camera	Week	Dates	Total Spawners	Total Images	Weekly CPUE* (spawners/image)	Confidence Interval ($\pm 15\%$ of CPUE)
GERM 1	1	Aug 19 - 25	0	462	0	0
	2	Aug 26 - Sept 1	90	375	0.24	0.036
	3	Sept 2 - 8	2218	212	10.46	1.57
	4	Sept 9 - 15	4420	202	21.88	3.28
	5	Sept 16 - 22	3570	253	14.11	2.12
	6	Sept 23 - 29	2635	303	8.7	1.30
	7	Sept 30 - Oct 6	1000	449	2.23	0.33
	8	Oct 7 - Oct 13	0	380	0	0
	9	Oct 14 - 17	0	112	0	0
GERM 2	1	Aug 19 - 25	0	611	0	0
	2	Aug 26 - Sept 1	365	617	0.59	0.088
	3	Sept 2 - 8	2230	496	4.49	0.67
	4	Sept 9 - 15	4430	546	8.11	1.22
	5	Sept 16 - 22	1905	490	3.88	0.58
	6	Sept 23 - 29	325	477	0.68	0.10
	7	Sept 30 - Oct 6	425	506	0.84	0.13
	8	Oct 7 - Oct 13	0	390	0	0
	9	Oct 14 - 17	0	119	0	0
RUS 1	1	Aug 19 - 25	15	641	0.023	0.0034
	2	Aug 26 - Sept 1	535	587	0.91	0.14
	3	Sept 2 - 8	2510	566	4.43	0.66
	4	Sept 9 - 15	2770	555	4.99	0.75
	5	Sept 16 - 22	5790	518	11.18	1.68
	6	Sept 23 - 29	3860	529	7.3	1.09
	7	Sept 30 - Oct 6	1710	476	3.59	0.54
	8	Oct 7 - Oct 13	500	454	1.10	0.16
	9	Oct 14 - 17	0	128	0	0
RUS 2	1	Aug 19 - 25	395	774	0.51	0.076
	2	Aug 26 - Sept 1	1250	782	1.60	0.24
	3	Sept 2 - 8	9835	626	15.71	2.36
	4	Sept 9 - 15	10130	642	15.78	2.37
	5	Sept 16 - 22	11910	568	20.97	3.14
	6	Sept 23 - 29	10380	641	16.19	2.43
	7	Sept 30 - Oct 6	4020	546	7.36	1.10
	8	Oct 7 - Oct 13	920	501	1.84	0.28
	9	Oct 14 - 17	110	137	0.80	0.12

* CPUE calculated as the total number of kokanee spawners enumerated each week, divided by the total number of images retained for that week.

Figure C4. Kokanee spawner count observations across four remote cameras placed at Germansen River and Russel Creek (two cameras at each site) between August 19 and October 17. Count records are only shown for images taken between 08:00 and 17:00 and those where confidence in spawner counts was considered high (percent visibility $\geq 60\%$). No kokanee spawners were observed on cameras placed at Manson River.



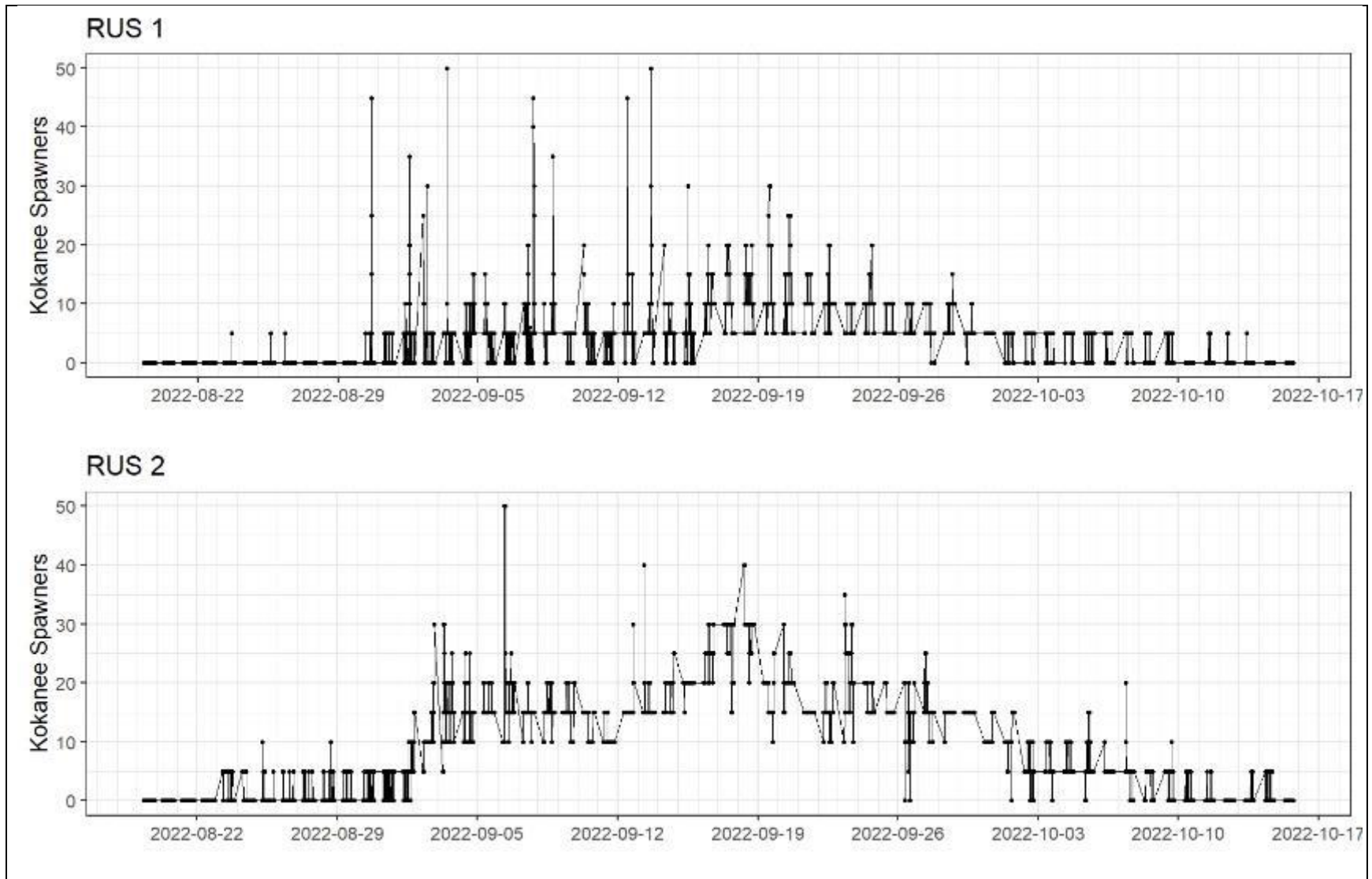
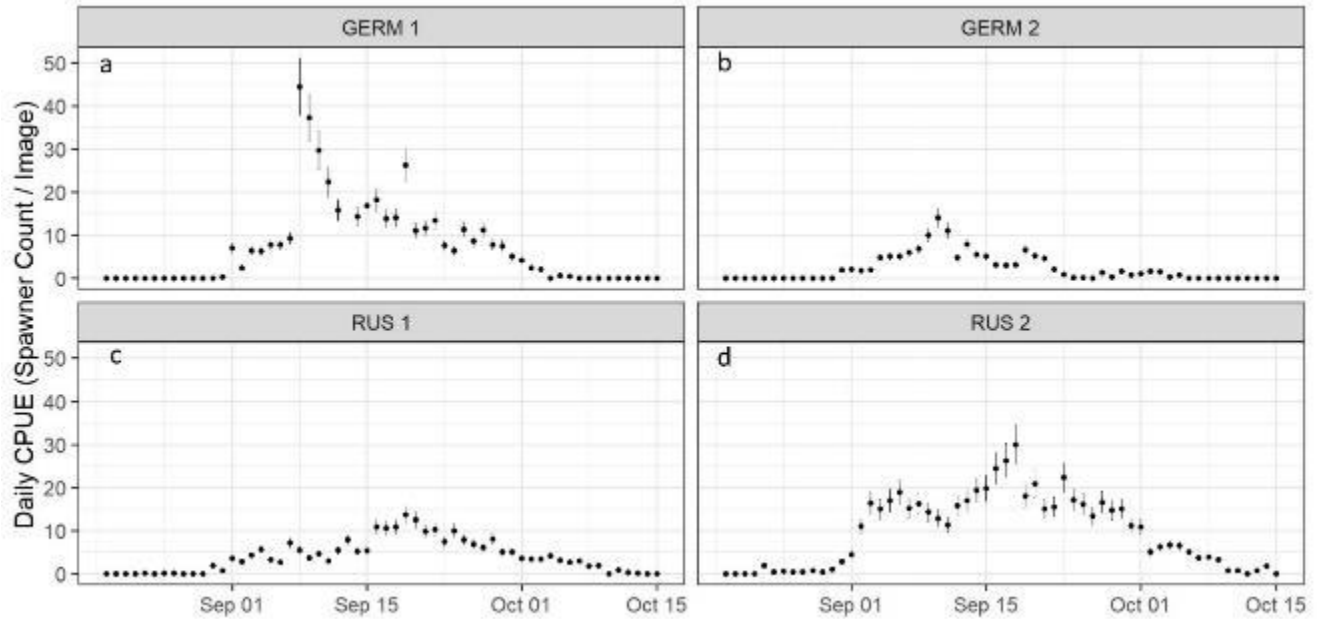


Figure C5. Daily CPUE (Catch per Unit Effort) estimates for four remote cameras placed at Germansen River (a-b) and Russel Creek (c-d) between August 19 and October 17. Two cameras were placed at each site. CPUE (Catch per Unit Effort) was calculated as the total number of fish enumerated across all images a day, divided by the total number of images retained. Confidence intervals represent the $\pm 15\%$ of CPUE estimate corresponding to the “high” confidence rating used in past aerial enumeration surveys (Langston 2012). Only images with percent visibility estimates of $\geq 60\%$ were retained for analysis.



Appendix D

Fish Capture Data

Table D1. Fish capture data from kokanee spawners collected at Germansen River and Russel Creek. Spawners were collected at Germansen on single date (September 4), but were collected over two dates at Russel (September 1 and October 19).

Stream	Date	Fish ID	Fork Length (cm)	Weight (g)	Sex	Notes
Russel Creek	09/01/2022	R1	24.7	179.83	M	
Russel Creek	09/01/2022	R2	22.5	134.1	M	
Russel Creek	09/01/2022	R3	21.5	123.3	M	
Russel Creek	09/01/2022	R4	23.4	148.28	F	
Russel Creek	09/01/2022	R5	21	130.52	M	
Russel Creek	09/01/2022	R6	24.6	179.08	M	
Russel Creek	09/01/2022	R7	21.5	132.89	M	
Russel Creek	09/01/2022	R8	24	182.36	M	
Russel Creek	09/01/2022	R9	22.8	137.25	F	
Russel Creek	09/01/2022	R10	23.5	158.51	M	
Russel Creek	09/01/2022	R11	22.5	119.67	M	
Russel Creek	09/01/2022	R12	23.3	142.62	M	
Russel Creek	09/01/2022	R13	23.1	134.71	M	
Russel Creek	09/01/2022	R14	24.1	151.91	F	
Russel Creek	09/01/2022	R15	22	134.53	M	
Russel Creek	09/01/2022	R16	23.4	123.66	F	
Russel Creek	09/01/2022	R17	23.3	131.43	F	
Russel Creek	09/01/2022	R18	23	136.66	F	
Russel Creek	09/01/2022	R19	23	127.76	M	
Russel Creek	09/01/2022	R20	23.7	122.59	F	
Russel Creek	09/01/2022	R21	23.8	145.73	M	
Russel Creek	09/01/2022	R22	23	114.31	M	
Russel Creek	09/01/2022	R23	23.2	105.8	F	
Russel Creek	09/01/2022	R24	21.3	100.57	M	
Russel Creek	09/01/2022	R25	23.1	139.35	M	
Russel Creek	09/01/2022	R26	22.9	130.72	F	Carcass
Russel Creek	09/01/2022	R27	23.3	119.75	F	Carcass
Russel Creek	09/01/2022	R28	23.2	136.29	F	Carcass
Russel Creek	09/01/2022	R29	23	124.2	F	Carcass
Russel Creek	09/01/2022	R30	24.4	159.25	F	Carcass
Russel Creek	09/01/2022	R31	23.4	113.55	F	Carcass
Russel Creek	09/01/2022	R32	22.8	112.85	F	Carcass
Russel Creek	09/01/2022	R33	24	152.53	F	Carcass
Russel Creek	10/19/2022	R34	21	105.4	M	
Russel Creek	10/19/2022	R35	23.5	132.59	M	
Russel Creek	10/19/2022	R36	23	130.97	M	
Russel Creek	10/19/2022	R37	21.4	80.09	F	
Russel Creek	10/19/2022	R38	20.5	73.3	F	
Russel Creek	10/19/2022	R39	23.3	105.56	F	
Russel Creek	10/19/2022	R40	22	93.38	F	
Russel Creek	10/19/2022	R41	21	91.6	F	
Russel Creek	10/19/2022	R42	23	128.98	M	
Russel Creek	10/19/2022	R43	22.5	100.33	F	
Russel Creek	10/19/2022	R44	22	92.11	F	
Russel Creek	10/19/2022	R45	21.9	93.61	F	

Stream	Date	Fish ID	Fork Length (cm)	Weight (g)	Sex	Notes
Russel Creek	10/19/2022	R46	21.5	87.87	F	
Russel Creek	10/19/2022	R47	23.3	125.55	M	
Russel Creek	10/19/2022	R48	23.2	132.75	M	
Russel Creek	10/19/2022	R49	22	106.91	M	
Russel Creek	10/19/2022	R50	22.5	101.69	F	
Germansen River	09/04/2022	G1	23	125.53	F	
Germansen River	09/04/2022	G2	23.5	111.7	F	
Germansen River	09/04/2022	G3	22.4	125.05	M	
Germansen River	09/04/2022	G4	25.5	179.04	M	
Germansen River	09/04/2022	G5	24.5	177.79	M	
Germansen River	09/04/2022	G6	24.6	164.15	M	
Germansen River	09/04/2022	G7	23	135.5	M	
Germansen River	09/04/2022	G8	23	144.2	M	
Germansen River	09/04/2022	G9	23.7	172.36	M	
Germansen River	09/04/2022	G10	23	130.16	F	
Germansen River	09/04/2022	G11	23.6	150.57	M	
Germansen River	09/04/2022	G12	22.7	149.6	M	
Germansen River	09/04/2022	G13	21.9	129.23	M	
Germansen River	09/04/2022	G14	22.4	135.02	M	
Germansen River	09/04/2022	G15	23.4	142.9	F	
Germansen River	09/04/2022	G16	23	124.08	F	
Germansen River	09/04/2022	G17	23.5	136.22	F	
Germansen River	09/04/2022	G18	23.5	152.8	M	
Germansen River	09/04/2022	G19	23.5	145.46	M	
Germansen River	09/04/2022	G20	23.5	163.65	M	
Germansen River	09/04/2022	G21	23.8	119.09	F	
Germansen River	09/04/2022	G22	23.5	139.9	M	
Germansen River	09/04/2022	G23	22	105.9	F	
Germansen River	09/04/2022	G24	23.5	159.35	M	
Germansen River	09/04/2022	G25	24.4	159.35	M	
Germansen River	09/04/2022	G26	22.9	133.67	F	
Germansen River	09/04/2022	G27	22.9	144.17	M	
Germansen River	09/04/2022	G28	23.9	181.54	M	
Germansen River	09/04/2022	G29	21.5	139.28	M	
Germansen River	09/04/2022	G30	21.5	101.57	F	
Germansen River	09/04/2022	G31	23.6	135	F	
Germansen River	09/04/2022	G32	24.8	173.21	M	
Germansen River	09/04/2022	G33	22.8	161.53	M	
Germansen River	09/04/2022	G34	23.6	166.8	M	
Germansen River	09/04/2022	G35	22.8	122.54	F	
Germansen River	09/04/2022	G36	23.3	157.17	M	
Germansen River	09/04/2022	G37	23	112.54	F	
Germansen River	09/04/2022	G38	23.6	142.21	F	
Germansen River	09/04/2022	G39	19.4	97	F	
Germansen River	09/04/2022	G40	23.6	163.38	M	
Germansen River	09/04/2022	G41	23	115.66	F	
Germansen River	09/04/2022	G42	23.5	154.87	M	
Germansen River	09/04/2022	G43	22.8	152.15	F	
Germansen River	09/04/2022	G44	22	108.69	F	

Stream	Date	Fish ID	Fork Length (cm)	Weight (g)	Sex	Notes
Germansen River	09/04/2022	G45	23.4	161.48	M	
Germansen River	09/04/2022	G46	22.4	149.86	F	
Germansen River	09/04/2022	G47	23	130.43	F	
Germansen River	09/04/2022	G48	23.7	137.68	F	
Germansen River	09/04/2022	G49	22.3	150.6	M	
Germansen River	09/04/2022	G50	22.7	122.76	F	

Appendix E

Photos



Photo 1. Group of kokanee spawners (circled) on GERM 1 camera located 1 km from mouth at Germansen River



Photo 2. Dispersed kokanee spawners (circled) on GERM 1 camera located 1 km from mouth at Germansen River.



Photo 3. Bald eagle observed on GERM 1 camera located 1 km from mouth at Germansen River.



Photo 4. Sow grizzly and cub observed on GERM 1 camera located 1 km from mouth at Germansen River.



Photo 5. Beaver observed swimming downstream on RUS 2 camera located 2.5 km from mouth on Russel Creek.