Shore-Spawning Kokanee Habitat Restoration & Research Project (Year 2)

2021-2022

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Prepared for: Fish & Wildlife Compensation Program

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Executive Summary

In 2021-22 the Friends of Kootenay Lake conducted post-restoration monitoring, assessments, and habitat research at McDonald's Landing Regional Park in partnership with the BC Provincial Government, the Okanagan Nation Alliance, University of BC Okanagan, FortisBC, and BC Hydro as part of a multi-year initiative to address the concern of shore-spawning kokanee salmon (SSKS) (*Oncorhynchus nerka*) redds and fry dewatering with the annual spring drawdown of Kootenay Lake.

In September 2020, 80 cubic metres of gravel was sifted, sorted, and deposited along the foreshore of McDonald's Landing Regional Park at a known SSKS spawning location in a 50x2 metre strip below the low water mark (LWM). In addition to providing improved spawning habitat, this was done in an attempt to encourage SSKS to spawn below the LWM where redds will not dewater.

Year two of the Shore-Spawning Kokanee Habitat Restoration & Research Project involved monitoring spawning kokanee numbers and redd development; examining spatial and temporal variability of near-shore groundwater seepage; assessing gravel morphology and conducting gravel maintenance; comparing egg-to-fry survival in the restored substrate below the low water mark to the historical substrate above the low water mark; collecting water temperature data; conducting multi-spectral imaging of the spawning habitat; assessing dewatered SSKS redds, and conducting community education and outreach about shore-spawning kokanee salmon in Kootenay Lake.

2021 was considered a "peak" spawning year for shore-spawning kokanee with the highest density of 1 fish per 1.4 m^2 recorded at the McDonald's Landing restoration site. SSKS utilized the installed spawning gravel across the entire restoration site, even at the deepest gravel locations, though they did not appear to show utmost preference for the restored gravel. On average, 27.5% of spawners were counted above the LWM.

Egg-to-fry survival rates of installed triploid kokanee eggs were 23% on average, with 24% survival in the control and 22% survival in the restored areas. This indicated that there is a negligible difference in the survival of eggs-to-fry above versus below the LWM prior to lake drawdown. These results show that kokanee offspring would not be detrimentally impacted if deposited below the LWM. Eggs deposited below the LWM would also not dewater in the spring, resulting in a much greater overall survival rate compared to eggs deposited above the LWM. Therefore, there is some level of confidence that kokanee eggs and fry would benefit from interventions to keep spawners lower in elevation.

Majority of redds were formed along the LWM in areas of high groundwater upwelling, indicating that groundwater is a better predictor of redd development than substrate. Majority of dewatered redds identified did however consist of some or most of the installed gravels, showing that spawning kokanee were using the new gravel for redd-building. The development and survival of stranded fry appeared to be greater within redds that were created using the installed gravels compared to the finer historical substrate. The larger substrate allows for more interstitial water flow and room for fry growth. Lake levels dropped until Apr 19, 2022 to 1739.2 ft. Redds that had been dewatered for one-month were discovered to contain mostly live kokanee on April 12, 2022, indicating that if there is groundwater flow, kokanee fry can survive long periods in stranded redds. The final dewatered red survey conducted on May 4, 2021 revealed some skinny, but live fry still clinging to life within dewatered redds.

Groundwater presence can be seen in the thermal images taken of both the McDonald's Landing and Bonaventure Lagoon spawning sites, both on land and in the water, though, more precise calibration would improve the usability of thermal imagery. The visual presence of groundwater in the thermal images almost perfectly correlated with the locations of identified dewatered SSKS redds at both spawning sites. This showed that thermal imagery can be used to identify groundwater presence and the probable locations of dewatered SSKS redds.

Ten education hours related to kokanee salmon and FoKLSS's Shore-Spawning Kokanee Habitat Restoration & Research project were provided to more than 100 students from daycare to college in the Kootenay Lake area. Twelve stakeholders participated in our groundwater research presentation on January 27, 2022. An educational video about shore-spawning kokanee salmon in Kootenay Lake was released in April 2022 to use as an education tool. Fourteen homes were visited to educate neighbouring residents about Friends of Kootenay Lake's project and to collect data on community knowledge and values. Nine people participated in the survey, which concluded that majority of adjacent landowners are aware of the spawning habitat in Bonaventure Lagoon, are concerned about the habitat quality, and would like to see work happen at the site to improve the habitat.

Recommendations outlined at the end of this report are intended to guide continued monitoring, assessments, and research in year three of this project.

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Introduction

Friends of Kootenay Lake Stewardship Society's Shore-Spawning Kokanee Habitat Restoration & Research Project is a multi-year initiative to address the concern of shore-spawning kokanee salmon (SSKS) (*Oncorhynchus nerka*) redds and fry dewatering with the annual spring drawdown of Kootenay Lake.

Kokanee populations in Kootenay Lake have suffered extreme declines, with a more than 99% population decline of main-lake kokanee observed between 2012 and 2017 from 1.25 million to 12 thousand, respectively (Province of BC, 2021). Kokanee returns since 2015 are only about three percent of the long-term historic average and egg deposition is decreasing over time (McPhearson, 2018).

Shore-spawning kokanee, a genetically distinct population of kokanee salmon in Kootenay Lake that spawn along shorelines in areas of upwelling groundwater, are at greater odds as they are met with additional severe habitat constraints. The annual dam-controlled drawdown of Kootenay Lake in preparation for spring freshet causes the dewatering of SSKS redds and fry that were deposited the previous fall when water levels were higher. An analysis of Kootenay Lake's hydrograph showed an average 12% SSKS redd dewatering in pre-dam conditions between 1928 and 1932, and an average of 70% dewatering in post-dam conditions between 2000 and 2010 (Poisson and Redfish 2012).

SSKS redd dewatering is being mitigated one in every three years by drawing down Kootenay Lake to 1742 feet between mid-September and mid-October during the spawning period – this has occurred in 2012, 2015, 2018 and 2021. While there is evidence that these actions help mitigate redd dewatering, it is not enough to support egg-to-fry survival for all redds, or every year. Therein lied the opportunity to pilot a restoration and research project to 1) better understand SSKS and their habitats and 2) test whether habitat restoration can be an effective mechanism for mitigating SSKS redd dewatering.

In September 2020, 80 cubic metres of gravel was sifted, sorted, and deposited along the foreshore of McDonald's Landing Regional Park at a known SSKS spawning location in a 50x2 metre strip below the low water mark (LWM). This was done in attempt to encourage SSKS to spawn below the LWM at an elevation that will not dewater. The restoration project involved gravel maintenance and ongoing monitoring, assessment, and research into SSKS spawning numbers, redd development, groundwater discharge and egg-to-fry survival in the restored versus natural substrate, and in deeper versus shallower areas.

Year two of the project (2021-22) involved post-restoration effectiveness monitoring and assessments, as well as habitat research. Valuable data were gathered that will help formulate recommendations and methods for addressing the dewatering of SSKS redds and fry throughout the west arm of Kootenay Lake. The project activities were made possible with considerable support and guidance from provincial government scientists, First Nations partners, hydroelectric industry representatives, and numerous volunteers.

Goals and Objectives

The goals and objectives of the Shore-Spawning Kokanee Habitat Restoration & Research Project (year 2) were as follows:

Goal 1: Examine spatial and temporal variability of near-shore groundwater seepage

Objective 1.a.: Quantify groundwater discharge through the installation and use of seepage metres.
Objective 1.b.: Collect data on groundwater temperature through the installation and use of vertical sediment temperature profiling rods.
Objective 1.c.: Collect data on lake level/ elevation through the installation of a water level logger.
Objective 1.d.: Monitor the water table elevation through the installation and use of a piezometer and water level logger.
Objective 1.e.: Determine the composition and source of nearshore interstitial water using isotope analysis and natural tracers.
Objective 1.f.: Determine interplay between groundwater upwellings and lake stage through data analysis.

Goal 2: Assess morphological changes to gravel deposits over time and if necessary, conduct maintenance to further improve spawning habitat for SSKS

Objective 2.a.: Assess gravel morphology and pileup during regular site visits through visual survey.
Objective 2.b.: Smooth and level gravel piles and rake and shovel gravel deeper into the water column to reduce pileup on the shoreline and enhance usability and quality for spawning (with necessary permitting).

Goal 3: Monitor the restored habitat for evidence of SSKS usage of gravel and spawning activity

Objective 3.a.: Monitor spawning activity weekly from mid-September to mid-October, enumerating spawning kokanee and visible redds.
Objective 3.b.: Collaborate with the Ministry of FLNRORD regarding their weekly SSKS surveys and share data.

Goal 4: Assess egg to fry survival in the restored and control areas where spawning is observed, and measure temperature fluctuations

Objective 4.a.: (November) Install five capsules each containing 200 kokanee eggs and temperature data loggers above the low water mark (in the natural substrate) and five below the LWM (in the restored substrate).
Objective 4.b.: (January) Exhume the egg capsules and enumerate eggs, alevin and fry contained within each. Compare survival rates between restored and control areas.

Goal 5: Increase community engagement and education surrounding SSKS

Objective 5.a: Engage First Nations in educational programming and provide professional development opportunities for Indigenous graduates and environmental professionals

The project is aligned with the following FWCP Priority Action items:

COLRLL.ECO.HB.19.01 Conservation, enhancement or restoration of Kokanee Habitat - P3.

Kokanee shore-spawning habitat was enhanced in attempt to reduce the extent of redds that are dewatered with the drawdown of Kootenay Lake each spring. The enhancements also improved the ability of kokanee to build redds, as the installed gravel allows for better percolation of upwelling groundwater, as well as more space (between substrate) for kokanee fry to develop.

COLRLL.ECO.ME.21.01 Effectiveness monitoring of past Kokanee projects-P3

Year two of the project involved monitoring and evaluating the effectiveness of a previous FWCP Kokanee habitat-based project. The project involved extensive collaboration with partners and stakeholders. Effectiveness monitoring will help determine the efficacy of habitat restoration and/or deeper spawning as a mechanism of reducing redd dewatering of shore-spawning kokanee salmon. This will help to inform options for reducing redd dewatering at other shore-spawning sites in the west arm of Kootenay Lake.

COLRLL.ECO.RI.18.01 Develop habitat-based planning for Kokanee-P3

Post-restoration monitoring and habitat research is being done with anticipation of future projects that address shore-spawning kokanee redd dewatering in Kootenay Lake's west arm. Egg-to-fry survival assessments, groundwater monitoring, kokanee monitoring, redd development monitoring, and dewatered redd surveys produce valuable information and data that can help answer questions such as:

- Do spawning kokanee appear to prefer restored habitat/installed substrate for redd building?
    - Are kokanee utilizing the substrate at its deepest levels?
- How do survival rates of kokanee eggs-to-fry compare in deeper areas vs shallower areas and in sand vs gravel?
    - If we prevent kokanee from spawning in shallower areas, would offspring be negatively impacted?
- What is the rate of groundwater upwelling (discharge) that kokanee are selecting for redd development at this particular site and how does this change over the incubation period?
- What composition of groundwater to lake water do spawning kokanee (seem to) prefer for redd development?
- How does lake stage (level) impact groundwater upwelling?
- Can thermal imagery be used to identify areas of groundwater upwelling?
    - Can thermal imagery be used to estimate groundwater upwelling volume/ discharge?
- Can LiDAR imagery be used to identify the locations of redds (watered and/or dewatered?)
- What is the approximate survival rate of dewatered kokanee redds?
    - What distance from the LWM do redds need to be within to have a chance at surviving until water levels rise?

Study Area

The study area lies along the foreshore of Kootenay Lake next to McDonald's Landing Regional Park, about 11 kilometers northeast of Nelson, BC. The study site is delineated into control and enhanced habitat, pictured below (figure 1).

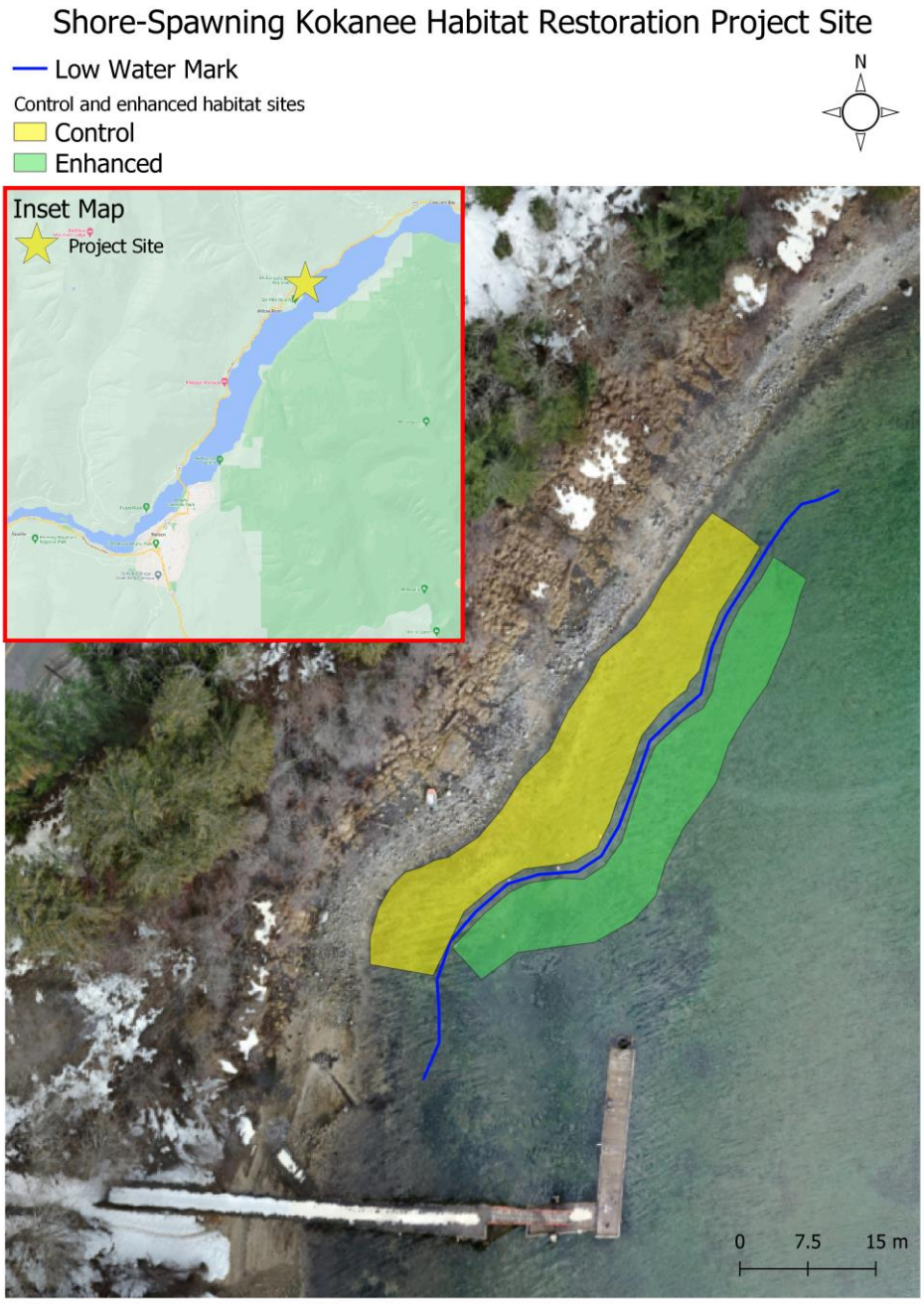

Figure 1: Study Site

Methods

Spawning kokanee monitoring

Spawning kokanee numbers were enumerated weekly between September 22 and October 12, 2021 by FoKLSS staff, and weekly between September 23 and October 14, 2021 by Ministry of FLNRORD fisheries personnel. Four monitoring days were completed by FoKLSS in total in 2021. FoKLSS monitoring expeditions were conducted by Jon-style flat-deck boat at coasting speeds across the restoration site. The site was traversed six times for each survey. One monitor counted all kokanee observed, and one monitor counted all kokanee observed above the LWM. Dead kokanee were enumerated, redds were enumerated and marked, and spawning behavior was noted. Spawning behaviour such as guarding, tail digging or visible pairings were recorded. Fish-counters were used to tally counted kokanee and redds and a specific counting method was used to ensure accuracy. A linear object such as a pen or finger was held steady in the middle of the observer's vision. Each kokanee that crossed the line as the observer passed by, or as the kokanee swam by, was counted. Double counting was mitigated by subtracting for each fish that crossed back over the line.

Figure 2: Oct 4, 2021. Spawning kokanee at McDonald's Landing Regional Park (cleaned areas visible)

Gravel Maintenance

Gravel maintenance was performed twice weekly by hand from April 19th to 28th to smooth deposits and push gravel deeper into the water column. Large gravel heaps were raked and shoveled flat and gravel pileup on the shoreline was reduced. The foreshore elevation was lowered by about 4 inches, reducing the extent of exposed gravels, and improving the quality of the spawning habitat.

Egg Capsule Installations

A fish transfer permit and a Section 11 Water Sustainability Act (changes in and about a stream) notification were obtained.

Ten perforated capsules containing kokanee eggs and water temperature data loggers were installed on November 1, 2021 at varying elevations in the control and restored substrate. One-hundred eggs were counted and weighed. Each labelled capsule was loaded with ~200 triploid (infertile) kokanee eggs derived from the BC Freshwater Fisheries Society in Cranbrook, a HOBO Tidbit temperature data logger, and a rock (for extra weight). A length of coloured flagging tape was tied through the tube for easy identification. Each of ten capsules were placed into buckets of fresh lake water and carried to the shoreline. Egg capsules 1-5 were installed within the natural substrate above the LWM in ≈50cm of water in areas of known groundwater upwelling. Egg capsules 6-10 were installed by scuba divers within the restored substrate in ~125-150cm of water. Egg capsules were buried ~10cm below the substrate surface. Data collected included capsule ID, lake level, date, water depth at insertion, time of insertion, weight of eggs, GPS data point ID and additional notes. Temperature data loggers collected a temperature reading once ever four hours from November 1, 2021 to January 28, 2022.

Figure 3: Nov 1, 2021, Kokanee egg capsule install. Weighing kokanee eggs. Photo credit: Joanne Siderius

Figure 4: Nov 1, 2021, Kokanee egg capsule install. Divers installing egg capsules. Photo credit: Joanne Siderius

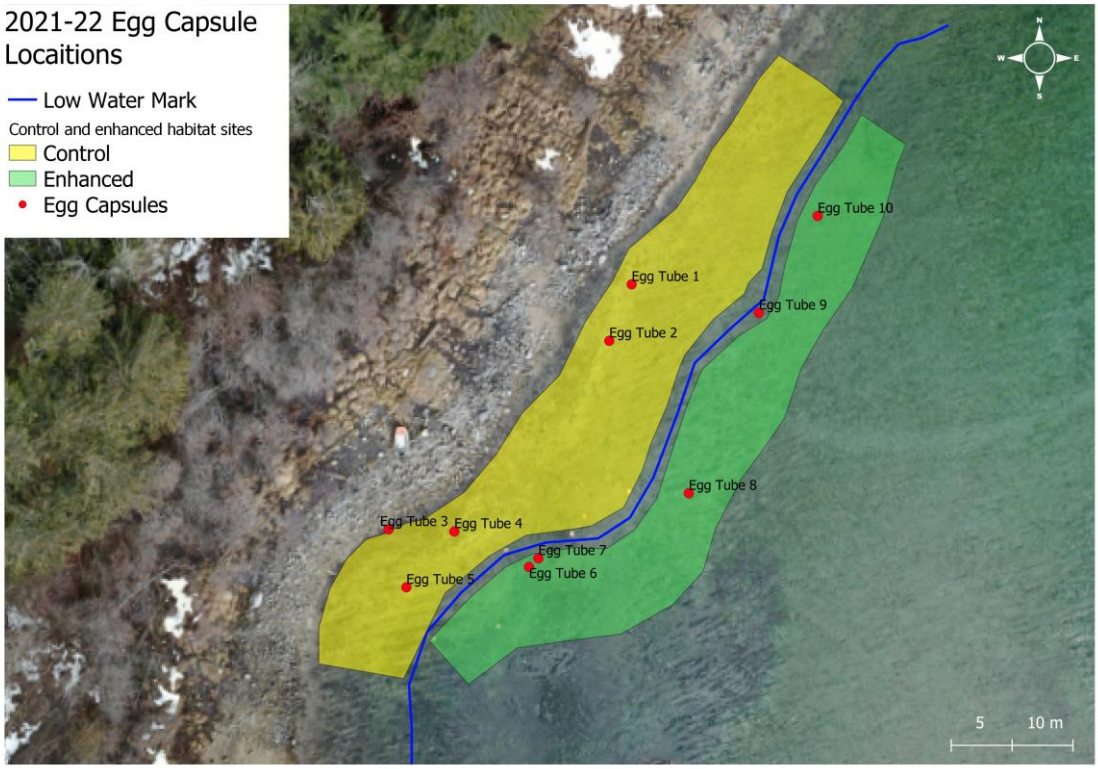

Figure 5: Nov 1, 2021. Egg capsule locations at McDonald's Landing.

Egg Capsule Removals

Egg capsules were removed from the substrate on January 28, 2022 with support from volunteers and scuba divers; accumulated thermal units (ATUs) were 894 on this date. Egg capsule contents were emptied and assessed by Ministry of FLNORD fish biologists. Data collected included egg tube ID, lake level, water depth at removal, time of removal, GPS data point ID, water temperature, substrate, presence of invertebrates inside and outside the capsule, egg, fry and alevin count, presence of fungus on eggs and additional notes. Photos were taken of the contents of each egg capsule for a more precise count later in the office, and data loggers were offloaded.

Figure 6: Jan 28, 2022. Egg capsule retrieval. Removing capsule and inspecting for invertebrates. Photo credit: Joanne Siderius

Figure 7: Jan 28, 2022. Egg capsule retrieval. Inspecting capsule contents and counting dead eggs. Photo credit: Joanne Siderius

Egg-to-Fry Survival Assessment

Eggs were carefully counted from photographs using the program Paint 3D. Each egg that was counted was marked with a blue dot and tallied on a sheet of paper (Figure 6). Eggs were only counted 5-10 at a time to maintain accuracy with tallying. The number of eggs remaining in each tube upon removal were compared to the number of eggs inserted. Pieces of broken eggs were counted using best judgment – for example, if there were 4 pieces of egg that each looked to be the size of ¼ of an egg, only one piece would be counted as one. The difference in eggs were considered survived and escaped. Data were analyzed to compare survival rates between the control and restored sites.

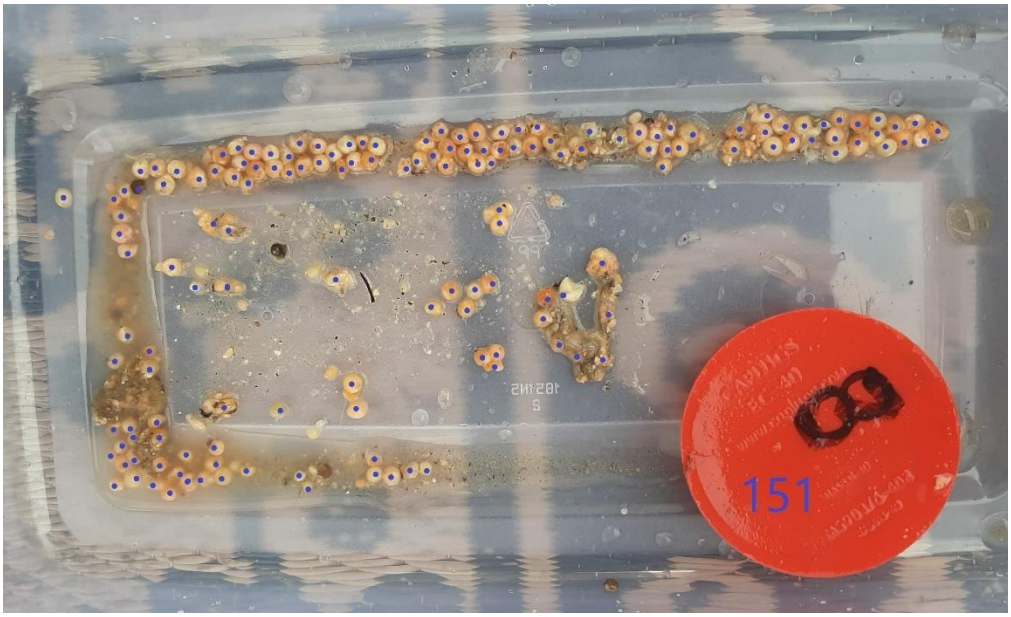

Figure 8: Example of photo that shows counted eggs. Each blue dot equals 1 egg counted.

Logger data was downloaded in .csv, HOBO and .pdf format. Csv data were copied into one Excel document. Temperature data were amalgamated into one spreadsheet. Data were removed for Nov 2, 2021 and Jan 28, 2022 for temperature discrepancies from insertion and removal. Maximum, minimum, average, median and standard deviation were calculated. PDF files were combined into one document.

Groundwater Monitoring

The groundwater monitoring study was led by Master of Science Candidate Cameron Spooner (UBCO), Research Hydrologist Dr. Natasha Neumann (Ministry of FLNRORD), and Dr. Ed. Hornibrook (UBCO), with support from FoKLSS. In September of 2021, six seepage meters were installed along the foreshore of McDonald's Landing Regional Park to measure discharge of upwelling groundwater. Seepage meters are sealed metal drums with an open bottom and two attached tubes – one to capture water, and one to vent gas. The drums are driven into the sediment and capture groundwater flow by pushing water into the catchment bag at the end of the tube. Groundwater flow or flux is calculated by measuring the mass of captured water over a known amount of time. Seepage meters are one way to directly measure groundwater flow.

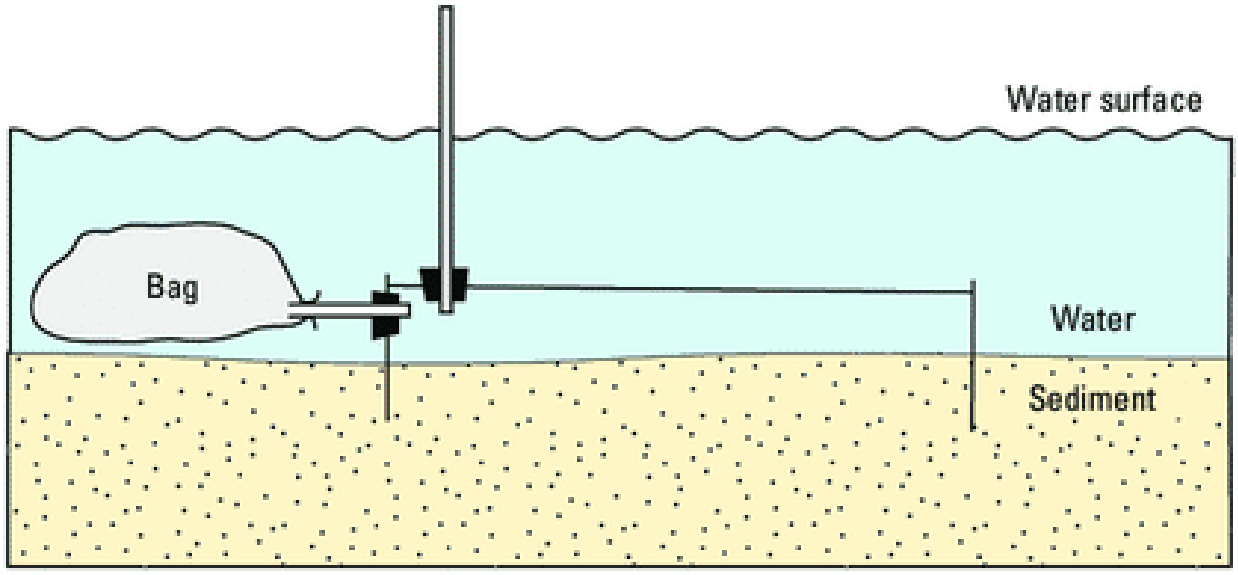

Figure 9: Diagram of seepage metre. Diagram credit: Cameron Spooner.

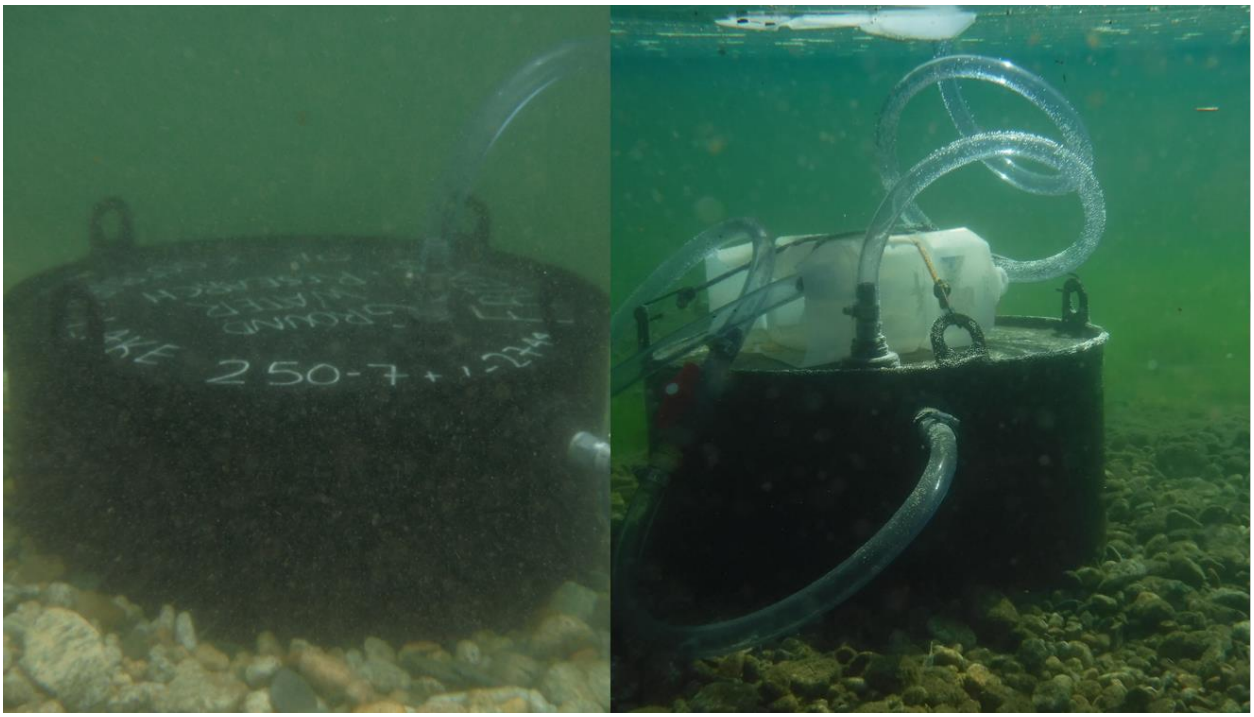

Figure 10: Underwater photos of seepage metres installed at McDonald's Landing restoration site. Photo credit: Bruce Morrison

Four vertical sediment temperature profiles were installed using steel pipes and a set of 4 thermoresistors. The goal was to measure sediment temperature and look for signals of groundwater upwelling. The pipes were driven into the substrate containing a temperature logger on top and four probes along the length of the pipe - one 50cm below the lakebed, one 20cm below the lakebed, one at the lakebed, and one 20cm above the lakebed in the water column. The temperature profile shows the difference in temperature between groundwater and lake water, and whether groundwater is pushing upward and influencing sediment temperatures.

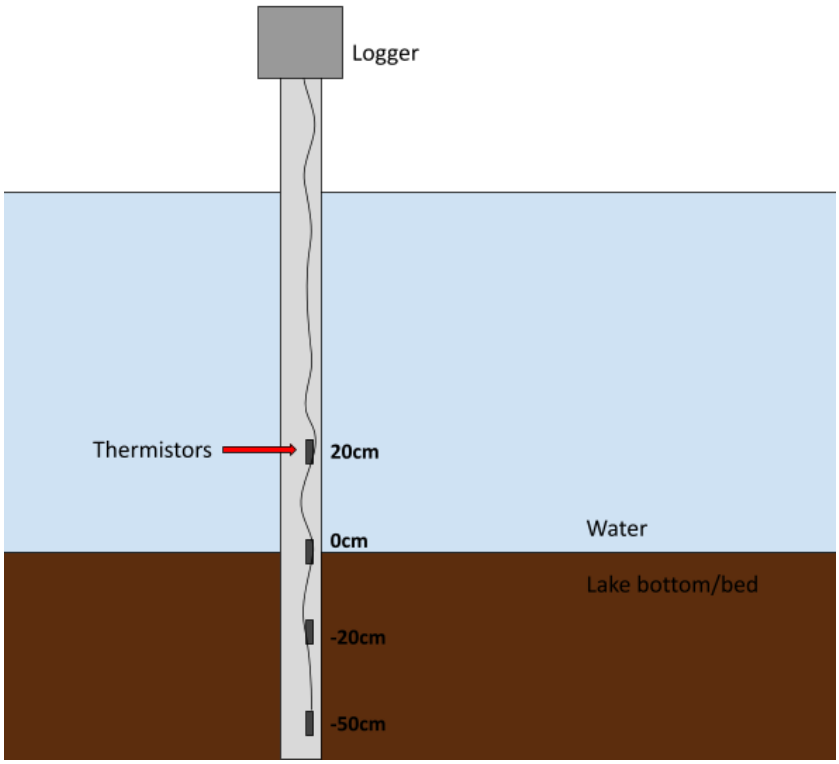

Figure 11: Diagram of vertical sediment temperature profiling probe. Diagram credit: Cameron Spooner.

Figure 12: Photo of vertical sediment temperature profiling probes installed at McDonald's Landing restoration site. Photo credit: Cameron Spooner.

Water sampling has been completed to measure natural tracers in the nearshore water. Isotope analysis is ongoing to determine the ratio of groundwater to lake water in nearshore gravel by comparing hydrogen and oxygen isotope ratios. Natural tracers such as radon and dissolved cations are being measured in lake water, groundwater, and nearby surface water to determine possible sources of groundwater and the composition of water in nearshore gravels and salmon redds.

A piezometer was installed to measure the height of the nearshore water table, and a water level logger was installed in the lake to measure lake stage. These loggers collected continuous data on lake stage and water table level which can influence the magnitude of groundwater flow into the lake.

Figure 13: Photo of water level logger measuring lake stage at restoration site. Photo credit: Cameron Spooner.

All of this data is being used in conjunction to look at possible relationships between lake stage and groundwater seepage as well as track variability in seepage over time and across the study site/spawning gravels.

Drone imaging

Friends of Kootenay Lake partnered with the Okanagan Nation Alliance to conduct multispectral imaging of shore-spawning habitat at McDonald's Landing and at the Bonaventure Lagoon using a specialized drone. Both spawning sites were imaged on February 15, 2022 and March 23, 2022 to capture high water versus low water states. Three types of images were produced: high-resolution RGB, thermal, and LiDAR. Each drone survey required two flights, one with the thermal/RGB sensor, and one with the LiDAR sensor. Each survey consisted of about 30 minutes of total flight time. A Global Navigation Satellite System (GNSS) was installed at the exact elevation of the lake surface to calibrate elevation readings.

Figure 14: Feb 15, 2022. Skyeler Folks (ONA) attaching sensor to drone. Photo credit: Kayla Tillapaugh.

Dewatered Redd Surveys

In 2022, Wood PLC, an environmental consulting firm was hired by BC Hydro to conduct a detailed survey of dewatered shore-spawning kokanee redds in the west arm of Kootenay Lake. The FoKLSS Program Manager was invited to attend two of the field days to help locate and assess dewatered redds at the McDonald's Landing, Bonaventure, 6-mile and Harrop/Procter spawning sites. Each spawning site was surveyed weekly from the first week of March to mid-April.

The ground-crew moved along the shoreline to visually identify potential redd locations and then dig them up using a shovel or hand-held trowel. Holes were dug approximately 30-60 cm apart across the

length of the spawning site/ shoreline. Identified redds were geolocated and water temperature was taken. Other data including estimated age, condition, distance from lake, percent mortality etc. were collected for each identified redd. The total number of dewatered redds was estimated based on the number of redds discovered and ground covered. The same process was followed each week as water levels dropped. Sections of redds were flagged and left untouched in March so that they could be assessed with the rising of the water in April. From there, researchers could estimate the probability of redd survival given a specific distance and elevation from the lake.

Figure 15: March 14, 2022. Dewatered redd survey crew locating dewatered redds. Photo credit: Kayla Tillapaugh

Figure 16: March 14, 2022. Dewatered redd, live fry. Photo credit: Kayla Tillapaugh

Figure 17: March 24, 2022. Dewatered redd, dead fry. Photo credit: Kayla Tillapaugh.

Outreach and Education

On January 27, 2022, a presentation was offered to stakeholders/ interest groups about the project, with a strong focus on the groundwater research component. Kayla Tillapaugh, FoKLSS Program Manager hosted the event and discussed the Shore-Spawning Kokanee Habitat Restoration & Research Project and Cameron Spooner, UBCO Masters Student presented the research methodology for the groundwater study.

On February 9, 2022, two FoKLSS staff members visited 14 homes in the Bonaventure Trailer Park to discuss the project and inform residents of the drone surveys that were planned for February 15 and March 23, 2022. Each resident was provided a slip containing information about the project, our plans to conduct drone surveys, contact information and website address. We took this opportunity to survey residents (with consent) about the lagoon and the spawning habitat. The questions we asked included:

1. Are you aware of the spawning site?
2. Are you aware that the redds dewater each spring?
3. Do you have any concerns about the spawning habitat?
4. Would you be supportive of any future potential efforts to restore the habitat?
5. What would you like to see happen?
6. Other observations, concerns, ideas, comments, etc.?

On July 8, 2021, FoKLSS staff joined Cornerstone Daycare at Lakeside Park for an educational afternoon. On October 8, 2021, a FoKLSS team member joined a class with École des Sentiers-Alpins for a presentation and discussion session. On March 22, 2022, an education day was held with two classes from Forest Path. On March 25, 2022, students in the Integrated Environmental Planning (IEP) program at Selkirk College and two instructors met FoKLSS staff at McDonald's Landing to learn about shore-spawning-kokanee salmon, Friends of Kootenay Lake's project, and to see the dewatered redds first-hand. On April 5, 2022, an education day was held with two classes from Nelson Christian Community School. All K-12 students got to learn about Kootenay Lake, kokanee, fish habitat requirements and more by participating in numerous engaging and educational activities and games.

Friends of Kootenay Lake staff created a short, simple educational video about shore-spawning kokanee salmon to share online and during educational presentations. Footage for the video was primarily recorded during the 2022 late-March dewatered redd surveys but feature photos and images taken throughout the duration of the project.

Educational and informative content is routinely published online on the Friends of Kootenay Lake website and on our two social media channels. Content always includes a highlight or recap of all project-related events and major activities. Content also includes educational resources such as articles, news stories, reports or other publishing, fun facts and more. Additionally, all monitoring data is uploaded to the open-sourced Columbia Basin Water Hub, and all project results are published on our website. One additional item of note is that volunteers are invited to join staff during kokanee monitoring, as an additional first-hand opportunity to see and learn about Kootenay Lake kokanee.

Results & Outcomes

Kokanee Spawning monitoring

2021 was considered a "peak" spawning year for shore-spawning kokanee due to water levels having been kept low in the fall of 2018. The most fish counted within the restoration site in 2021 was 146 on October 8, 2021 (146 fish in a 200m^2 area equals 1 fish per 1.4m^2 area), with 47 fish, or, 32% of fish spotted lingering above the LWM. On average, 27.5% of spawners were counted above the LWM. Ministry of FLNRORD fisheries personal counted 107 redds at McDonald's Landing on October 14, 2021. Spawning behaviors including pairing and circling were observed by FoKLSS staff and volunteers on the gravel at its deepest locations. Table 1 below summarizes FoKLSS's kokanee monitoring data from 2021.

Table 1: Sep 22 – Oct 12 kokanee shore-pawning data at McDonald's Landing restoration site.

Date	Start time (24-hr clock)	Weather and water conditions	Lake level (m)	Number of rounds	Max fish count total	Avg fish count total	Max fish count above LWM	Avg fish count above LWM	Dead fish count	Max redds count	Avg redds count	notes
22-Sep-21	7:15	Cloudy, spotty sun, mix of broken and unbroken surface	530.99	6	14	4	4	1	0	40	29	
29-Sep-21	8:18	Broken surface, 8 degrees	530.96	6	110	88	15	9	1	48	42	
08-Oct-21	8:13	Calm and cold	530.96	6	146	103	47	40	4	80	56	Lots of fish, most on the low water line.
12-Oct-21	7:30	Calm and cold	530.93	6	133	115	45	38	7	48	36	mapping conducted on this date. Appear to be making redds near seepage metres.

Gravel Maintenance

Gravel maintenance was successful in smoothing out clumps and pushing gravel deeper into the water column. The foreshore elevation was lowered by about 4-inches across the restoration site. This reduced the amount of exposed gravel at low water, which ultimately reduced the elevation at which redds dewater along the LWM. The gravel appearance remained flat and smooth by the fall of 2021 when spawners returned to the site. Evidence of redd-making was apparent, showing the gravel was suitable for building redds. In spring of 2022, there were no gravel

clumps or pileup on the shoreline, showing that gravel maintenance in 2021 had long-lasting results. Figures 16 through 18 below show the results of the maintenance performed.

Figure 18: April 20. 2021 foreshore gravel morphology at McDonald's Landing restoration site (after one previous day of shovelling). Photo credit: Kayla Tillapaugh.

Figure 19: April 26, 2021. Gravel morphology at McDonald's Landing restoration site (after 2 previous days of shoveling). Photo credit: Kayla Tillapaugh.

Figure 20: Apr 28, 2021. Gravel morphology at McDonald's Landing restoration site (after 4 days of shoveling). Photo credit: Kayla Tillapaugh.

Egg-capsule installations

Table 2 below shows the data collected for the egg capsule installation on November 1, 2021. The weight of 100 eggs was equal to 8.28g, therefore the weight of 1 egg was estimated to be equal to about 0.0828g.

Table 2: Nov 1, 2021. Egg capsule installations, field data.

Egg tube ID	Lake Level (ft)	Date	Water Depth (cm)	Time of insertion	Egg Weight (g)	Number of eggs	Notes
1	1742.7	2021-11-01	54	12:27:00	16.67	201	
2	1742.7	2021-11-01	52	12:24:00	15.57	201	
3	1742.7	2021-11-01	43	12:00:00	16.66	201	
4	1742.7	2021-11-01	51	12:10:00	15.63	189	
5	1742.7	2021-11-01	53	12:15:00	15.05	182	
6	1742.7	2021-11-01	152	12:36:00	15.88	192	
7	1742.7	2021-11-01	152	12:38:00	16.59	200	Tube had to be duct taped - wrong size lid
8	1742.7	2021-11-01	152	12:39:00	15.98	193	
9	1742.7	2021-11-01	123	12:41:00	15.9	192	
10	1742.7	2021-11-01	123	12:43:00	18.44	223	

Egg capsule removals

Table 3 below shows the data collected for the egg capsule removals on January 28, 2022. Please note that eggs were counted on-site, but then re-counted more accurately later in the office. The number of eggs recorded in the “notes” section of the table below are not the final numbers that were used to analyze the results. Overall, the exhumed eggs showed greater survival rates compered to the previous year of the study, and the eggs that had died were further developed than the previous study year. The eggs were much smellier and mushier the previous year, whereas in the current study year they were more intact and less decayed.

Table 3: Jan 28, 2022. Egg capsule removals, field data.

ID	Lake Lvl (ft)	Date	Water temp (°C)	Water Depth (cm)	Time of removal	Logger #	Substrate	Invertebrates outside the tube (Y/N)	Invertebrates inside the tube (Y/N)	Alevin count	Fry count	Fungus on eggs?	Notes
1	1743.4	28-Jan-22	4.9	42	01:03	1	Sand	N	Y	0	0	Y	Darker eggs; look like they made it further along in development. But still dead. 146 eggs
2	1743.4	28-Jan-22	4.9	37	01:01	3	Sand	Y	Y	0	0	N	Pre alevin, darker eggs, but all dead, 183 eggs
3	1743.4	28-Jan-22	4.9	32.5	12:57	2	Sand, silt	Y	Y	0	0	N	More decomposed than capsule 2, eggs are falling apart, 131 eggs (rough estimate because lots of mushy eggs)
4	1743.4	28-Jan-22	4.9	37.5	12:59	4	Sand	Y	Y	0	0	N	All dead, 132 eggs
5	1743.4	28-Jan-22	4.9	32	12:56	5	Sand	Y	N	0	0	N	All dead, 172 eggs
6	1743.4	28-Jan-22	4.9	152	12:54	6	Sand	N	N	0	0	N	94 eggs (cross reference to see if any eggs have hatched)
7	1743.4	28-Jan-22	4.9	137	12:52	7	Sand	N	Y	0	0	Y	All eggs in tact, less decomposed than 8, 120 eggs
8	1743.4	28-Jan-22	4.9	137	12:42	8	Sand	Y	Y	0	0	Y	More decomposed than others, slim, 140 eggs
9	1743.4	28-Jan-22	4.9	122	12:47	9	Sand	N	Y	0	0	Y	Fungus on outside of tube, 146 eggs
10	1743.4	28-Jan-22	4.9	122	12:48	10	Sand	N	Y	0	0	N	Similar to #2 capsule, died more recently, all eggs dead

Egg-to-Fry survival assessment

Table 4 below provides a breakdown of the number of eggs installed versus removed, and the percent mortality and percent escaped for each egg capsule. Percent escaped assumes missing eggs were surviving fry.

Table 4: Egg-to-fry survival for each egg capsule installed at the McDonald's Landing restoration site

Tube ID	**# eggs INSERTION** (counted by weight)	**# eggs REMOVAL** (counted by photos)	**Percent mortality**	**Percent escaped**
1	201	140	69.53	30.46
2	201	171	84.93	15.06
3	201	94	46.71	53.28
4	188	153	81.05	18.94
5	181	182	100.13	-0.13
6	191	115	59.96	40.03
7	200	130	64.88	35.11
8	193	151	78.24	21.76
9	192	165	85.92	14.07
10	222	217	97.43	2.56

The average survival rate of all eggs installed was 23% (Table 5). Egg capsules installed in the control area (#1-5) on average showed a survival rate of 24% and egg capsules installed in the restored area (#6-10) on average showed a survival rate of 22% (Table 5). The standard deviation of percent escaped was 17%.

Table 5: Egg-to-fry survival for egg capsules installed in the restored versus control habitat

	Number INSERTED	**Number REMOVED / DIED**	**Number ESCAPED**	**Percent DIED**	**Percent ESCAPED**
Total number	1974	1518	456	76.89	23.11
1 to 5 (control)	974	740	234	75.94	24.06
6 to 10 (restored)	1000	778	222	77.81	22.19

Water Temperature

Table 6 below shows the maximum, minimum, average and median temperature values recorded by temperature data loggers between November 1, 2021, and January 28, 2022. See Appendix A for the temperature charts produced by each logger.

Table 6: Water temperature summary for egg capsules installed at McDonald's Landing restoration site

Statistic	Temperature (degrees C)	Note
MAX	10.418	Nov 3, 2:00 p.m. logger # 4
MIN	3.459	Dec 28, 7:00 a.m. Logger # 2
AVG	6.437925	
MEDIAN	6	

Accumulated Thermal Units

The kokanee eggs were reported at 330.8 Accumulated Thermal Units (ATUs) on November 1, 2021 when they were inserted. With an average water temperature of 6.4 degrees Celsius throughout the incubation period, the eggs were estimated at 894 ATUs upon extraction. Fry emergence can be expected any time after 850 ATUs.

Groundwater Monitoring

The groundwater monitoring component of the project is being led independent of FoKLSS's project and therefore results are unavailable at this time. Data and results will be available upon Cameron Spooner's thesis completion in the summer of 2023.

Drone imaging

Figures 20 through 26 below show the RGB and thermal drone image outputs from Feb 15 and Mar 24.[1]

Figure 21: Feb 15, 2022. RGB drone imagery of McDonald's Landing

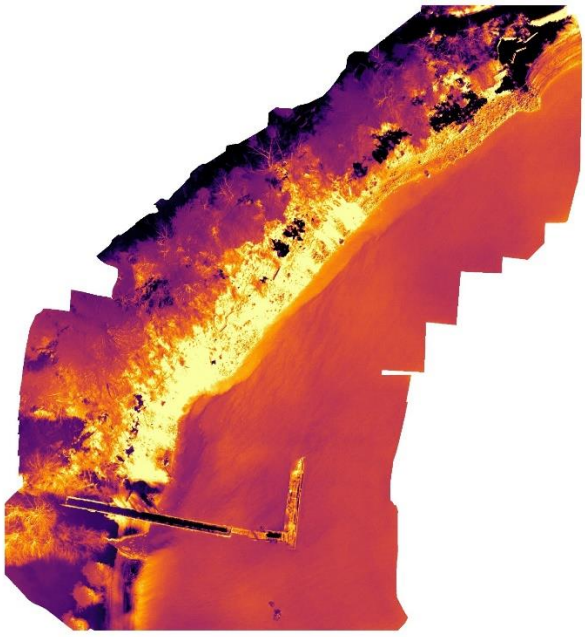

Figure 22: Feb 15, 2022. Thermal drone imagery of McDonald's Landing

Figure 23: Mar 23, 2022. RGB drone imagery of McDonald's Landing

Figure 24: Mar 23, 2022. Thermal drone imagery of McDonald's Landing

[1] LiDAR data was delivered only days before the due date of this report and therefore will appear in next year's report.

Figure 25: Feb 15, 2022. RGB Drone Imagery of Bonaventure Lagoon.

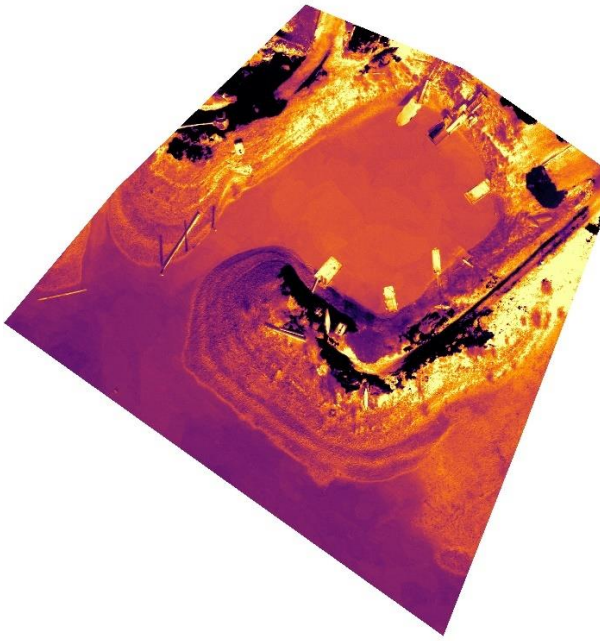

Figure 26: Feb 15, 2022. Thermal imagery of Bonaventure Lagoon.

Figure 27: Mar 23, 2022. RGB Drone Imagery of Bonaventure Lagoon.

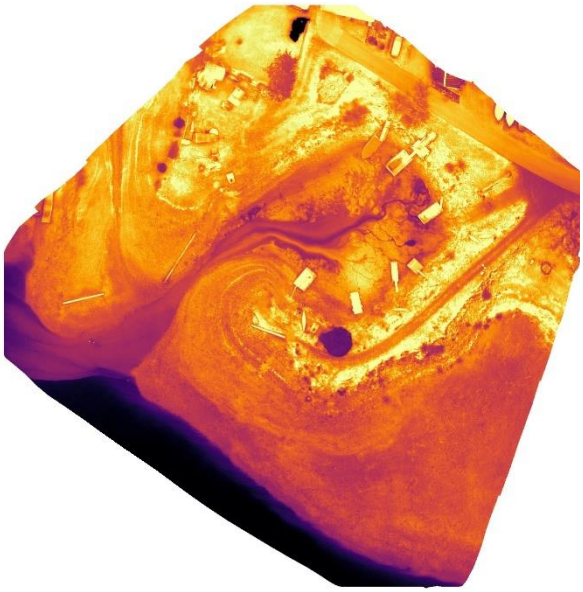

Figure 28: Mar 23, 2022. Thermal Drone Imagery of Bonaventure Lagoon.

The temperature scale is not included in the thermal images at this time because they require calibration and therefore show incorrect temperature values. Figure 29 below shows the colour values of the thermal images from low to high temperature.

Figure 29: Thermal scale, left to right, lower to higher temperature.

At Bonaventure Lagoon on March 23, groundwater is very clearly seen as dark-blue streams and pools contrasted against the orange-yellow mud. On shore at McDonald's Landing, the groundwater is seen as a darker purple shadowing against the orange/yellow rocks. In the water it is seen as a lighter purple plume over a dark blue-black water. The cold, black-blue surface water of the small stream just west of the dock can also be seen creating a back-eddy and flowing toward the spawning site. Figure 30 below shows four confirmed dewatered redds overlaying thermal imagery. The areas between Redd1 and Redd2, and between Redd3 and Redd4 were identified as the areas with the highest redd density. It is easy to see the correlation between the shadowed blue-purple tones within the areas identified as having high redd density, especially between Redd1 and Redd2.

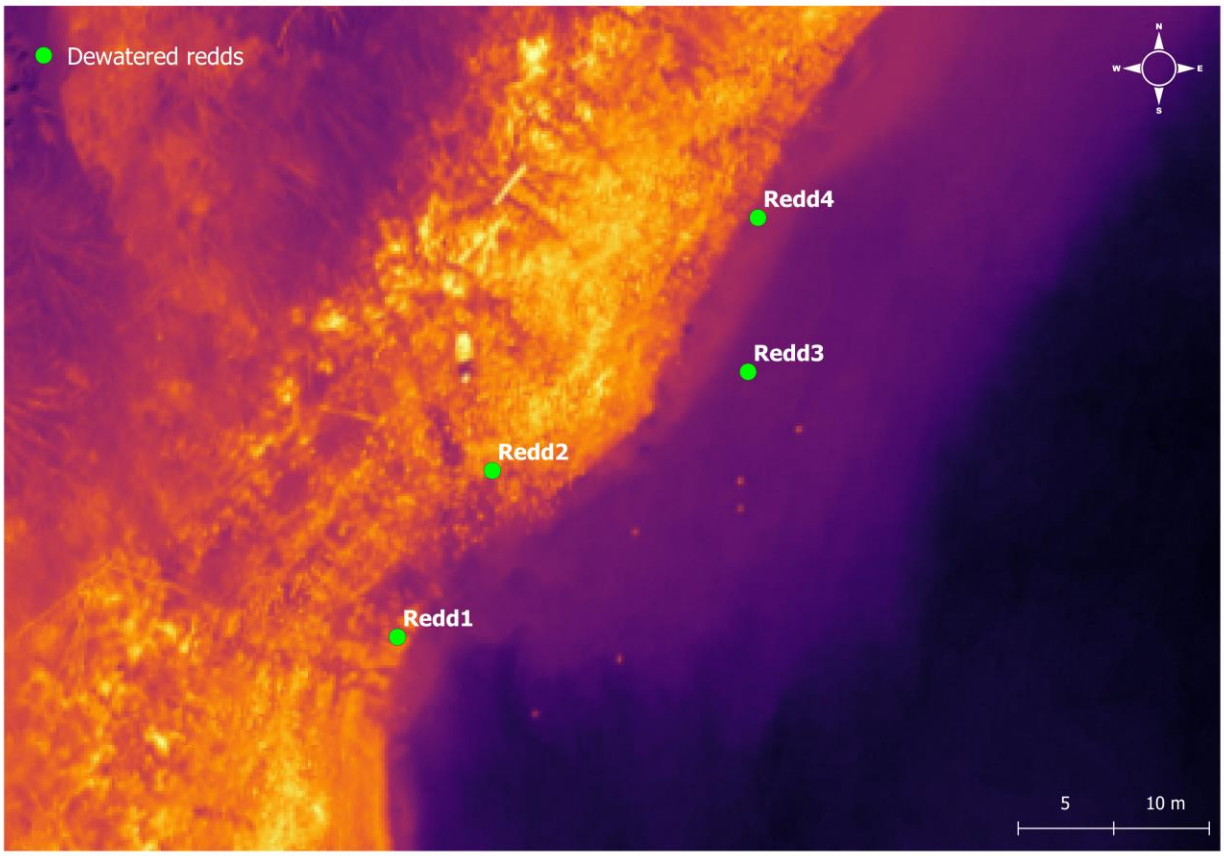

Figure 30: Mar 23, 2022 (thermal). Mar 24, 2022 (redd locations). Four confirmed dewatered redds overlaid with thermal imagery at McDonald's Landing.

Dewatered Redd Surveys

Dewatered redd data were collected and analyzed by Wood PLC, the environmental consulting firm contracted to conduct the dewatered shore-spawning kokanee redd surveys in 2022. Data and results will be available upon request from BC Hydro, FortisBC and Columbia Power Corporation in the summer of 2022.

Observational results from the dewatered redd surveys included redd locations corresponding greatly with groundwater upwelling and substrate type. Redds were almost always found in areas where the groundwater level was within ~5 centimetres of the ground surface in gravelly deposits. All redds that had groundwater contained live fry. Very few redds contained any dead eggs, indicating high survival rates. Redd locations were sometimes easy to identify due to dead or live kokanee fry laying on top of the ground surface. Kokanee fry that were found in the restored substrate (larger gravels) appeared larger and more energetic than fry found in fine gravels or sand. It appeared that the larger gravels created more space between substrate both for water to move through, and for kokanee fry to grow and develop. Lake levels continued to drop until April 19, 2022. Interestingly, live kokanee fry were found high up on the shoreline in stranded redds on April 12, 2022. These redds had been dewatered for one-month by this point. It appeared majority of kokanee fry were still alive in the redds located, indicating that if there is groundwater moving through them, kokanee fry can survive long periods in a dewatered redd. The final dewatered redd survey on May 4, 2022 revealed that some redds still contained live fry, though they were skinny, showing signs of starvation.

Outreach and Education

Twelve people attended the January 27th groundwater study presentation. Many participants expressed contentment with the presentation and that they valued the information shared. Connections were made between participants and good questions were asked.

Nine residents of Bonaventure Trailer Park participated in our survey on February 9th. See Appendix A for a scan of the raw survey data. Of all people surveyed, 78% knew about the shore-spawning habitat and were aware that the redds dewater each spring. Eighty-nine percent of people surveyed expressed that yes, they would like to see action taken to improve the SSKS habitat. The other 1 person was not opposed, but just did not have an opinion.

Ten education hours related to kokanee salmon and FoKLSS's Shore-Spawning Kokanee Habitat Restoration & Research project were provided to more than 100 students from daycare to college in the Kootenay Lake area. Some students went on to volunteer with FoKLSS during beach cleanup events, and continued to be active volunteers past the period this report is dated.

Figure 31: March 25, 2022. Selkirk College IEP students observe dewatered kokanee redds at the McDonald's Landing restoration area. Photo credit: Kayla Tillapaugh.

Link to shore-spawning kokanee educational video:

https://www.youtube.com/watch?v=_MH4vh20A0g&t=2s

Links to 2021-22 blog posts about the project:

FoKLSS Youth Education Program Recaps (Jul 28, 2021):
https://www.friendsofkootenaylake.ca/news/foklss-youth-education-program-recaps/

One Fish, Two Fish, Red Fish, Kokanee (Nov 10, 2021):
https://www.friendsofkootenaylake.ca/news/one-fish-two-fish-red-fish-kokanee/

The A Team of our Shore-Spawning Kokanee Restoration Project (Feb 16, 2022):
https://www.friendsofkootenaylake.ca/news/the-a-team-of-our-shore-spawning-kokanee-restoration-project/

Taking Learning to the Lake (April 13, 2022):
https://www.friendsofkootenaylake.ca/news/taking-learning-to-the-lake/

Social media posts on Facebook and Twitter relating to our Shore-Spawning Kokanee Habitat Restoration & Research Project and kokanee education reached **10,374** people between April 2021 and April 2022.

Link to open-sourced project data:

Columbia Basin Water Hub, Shore Spawning Kokanee: Post Habitat Restoration Monitoring:
https://data.cbwaterhub.ca/dataset/shore-spawning-kokaneee-post-habitat-restoration-monitoring

Discussion

Spawning kokanee did not visually appear to prefer the restored habitat for redd building in the fall of 2021. Majority of redds observed followed closely along the LWM in the areas where there was an obvious large amount of groundwater upwelling (indicated by overland flow) and where the installed substrate mixed with the original fine gravels and sand. Spawners were however observed utilizing the restored habitat for redd making across the entire restoration site, even at the deepest locations of the gravel, which indicated that the installed substrate is workable and useable for redd building, and that some kokanee choose to spawn in it below the LWM. There is inadequate historical data to compare spawning behavior at this elevation pre versus post gravel installation.

Egg-to-fry survival rates of the triploid kokanee eggs installed in the restored versus control habitat were similar (22% restored, 24% control).[2] This indicated that there is a negligible difference in the survival of eggs-to-fry above versus below the LWM prior to lake drawdown. These results show that kokanee offspring would not be detrimentally impacted if deposited below the LWM. Eggs deposited below the LWM would also not dewater in March, resulting in a much greater overall survival rate compared to eggs deposited above the LWM. Therefore, there is some level of confidence that kokanee eggs and fry would benefit from either keeping water levels low during spawning season, by reducing the elevation of the spawning habitat, or by creating a spawning barrier, excluding spawning above the LWM.

Water temperatures collected by temperature data loggers inside each egg capsule were indicative of groundwater presence. Temperatures remained steady despite many extreme cold weather events. It is likely that the upwelling groundwater maintained a consistent interstitial water temperature and contributed some extent to the necessary level of homeostasis required for egg-to-fry development.

It appeared that the gravels installed at McDonald's landing both provided better habitat for developing fry and helped increase the survivability of dewatered fry. Majority of the redds that were excavated contained some of the installed gravel, showing that kokanee preferred to use this new substrate. Redds that were created using more of the installed gravel contained fry that appeared larger, more resilient to transport and more energetic. The larger gaps between substrate seemed to allow for more water flow and room for fry to grow and could also allow for interstitial movement of fry with the groundwater, increasing the possibility of fry escaping to open water.

Differences in water temperature can be visually differentiated in the thermal images of the spawning habitat both at McDonald's Landing and Bonaventure Lagoon. At McDonald's Landing, both in the February 15 and March 23 thermal images, groundwater can be seen both on the shore and in the water. Only through the thermal imagery were we able to see the interplay between groundwater and stream water at influencing water temperature for incubating eggs.

The areas in which one can visually identify groundwater presence both at the Bonaventure Lagoon and McDonald's Landing, redds were identified. The dark, shadowed depressional areas at McDonald's

[2] It is important to note that the survival rates (23% average) of kokanee eggs installed do not reflect survival rates of naturally deposited shore-spawning kokanee eggs. Triploid kokanee eggs are expected to have lower survival rates due to a higher oxygen demand, and it is possible that shore-spawning kokanee are better adapted to developing in shoreline habitats. This was partially ground-truthed when very few dead eggs were discovered in natural redds. Conversely, the triploid eggs were deposited later, reaching 380 ATUs in a hatchery, which could increase survival rates of triploid eggs compared to natural. Lastly, the fact that the triploid eggs developed within a container could impact survival rates, though it is unknown whether it would increase or decrease survival.

Landing had highest abundance of redds. At Bonaventure Lagoon, all the dark blue pools, save the largest one near the boat launch, contained redds. These results show that thermal imagery can help to identify the probable locations of shore-spawning kokanee redds based on the presence of groundwater, which is indicated by a noticeable difference in colour in the thermal imagery.

Live kokanee fry were found within dewatered redds on May 4, 2022. Very few live fry were found, and the ones discovered were skinny and showed signs of starvation. However, these interesting results show that kokanee fry can survive long periods in dewatered redds so long as there is a consistent flow of groundwater.

Outreach and education continue to be some of the most important tools for creating awareness, increasing capacity, instigating action, and finding answers. Survey results from Feb 9, 2022 outreach show that residents are knowledgeable and passionate about their community connections to natural spaces and eager to see positive changes happen.

Recommendations

The following recommendations have been outlined to guide continued monitoring and research in year three of this project:

1. Assess the level of sedimentation on the gravel after year three.
    a. Determine whether the installed gravel at McDonald's Landing will maintain habitat values over time or if continued maintenance will be required.
    b. If continued maintenance may be required, determine what methods of gravel maintenance should be considered. E.g., scarification, raking, installation of additional gravel, etc.
2. Continue to monitor spawning kokanee and redd development at McDonald's Landing to track changes in habitat usage over time.
    a. Identify the highest and lowest elevation redds each year.
3. Install one or two egg capsules of the same batch of triploid kokanee eggs in a nearby spawning channel to compare survival rates between eggs installed in the stream versus the shoreline.
4. Conduct dewatered redd surveys weekly as lake levels rise to determine whether stranded fry are able to survive in the gravels until lake levels rise.
    a. Measure the elevation and distance to the water's edge for each redd identified to determine the maximum distance from the LWM stranded fry stand a chance at surviving.

References

1. Province of British Columbia. 2021. Kootenay Lake Kokanee Recovery Update (January 2021). Ministry of Forests, Lands, Natural Resource Operations and Rural Development. Nelson, B.C. Available at: https://www.env.gov.bc.ca/kootenay/fsh/main/mainfish.htm
2. McPherson, S. 2018. Kootenay Lake Fisheries Workshop Summary, May 15/16, 2018. Prepared by Lotic Environmental Ltd. for the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Nelson. Available at: https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/fish-fish-habitat/fishery-resources/kootenay_lake_fisheries_workshop_summary_may_2018_final.pdf
3. Poisson and Redfish, 2012. Assessment of Lake Levels and Their Variation on The Recruitment of Shore Spawning Kokanee Fry Within the West Arm of Kootenay Lake. Prepared for the Columbia Operations Fisheries Advisory Committee. Nelson, BC.

Appendix A

Water Temperature Data Logger Charts

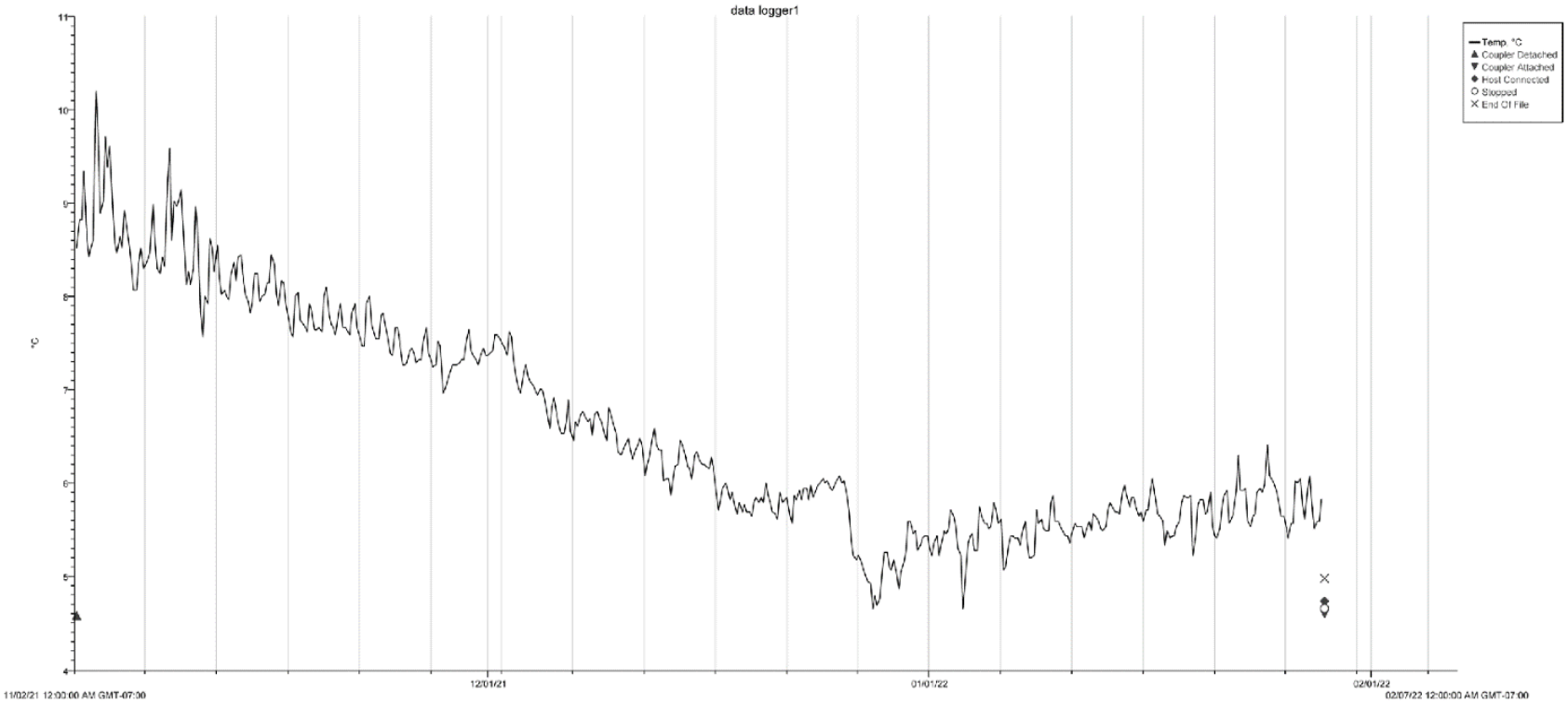

Figure 32: Temperature data from Egg Capsule 1 covering Nov 1, 2021 to Jan 28, 2022

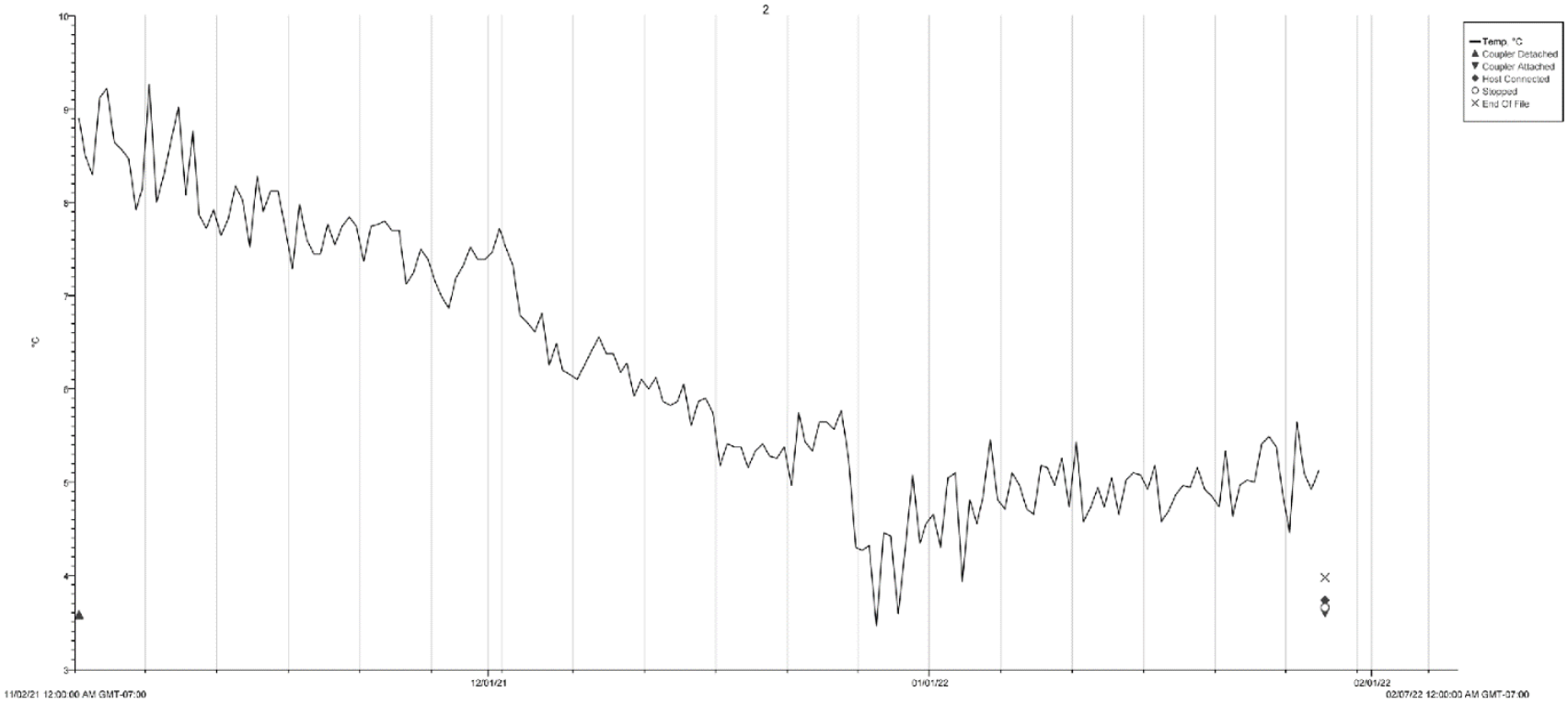

Figure 33:Temperature data from Egg Capsule 3 covering Nov 1, 2021 to Jan 28, 2022

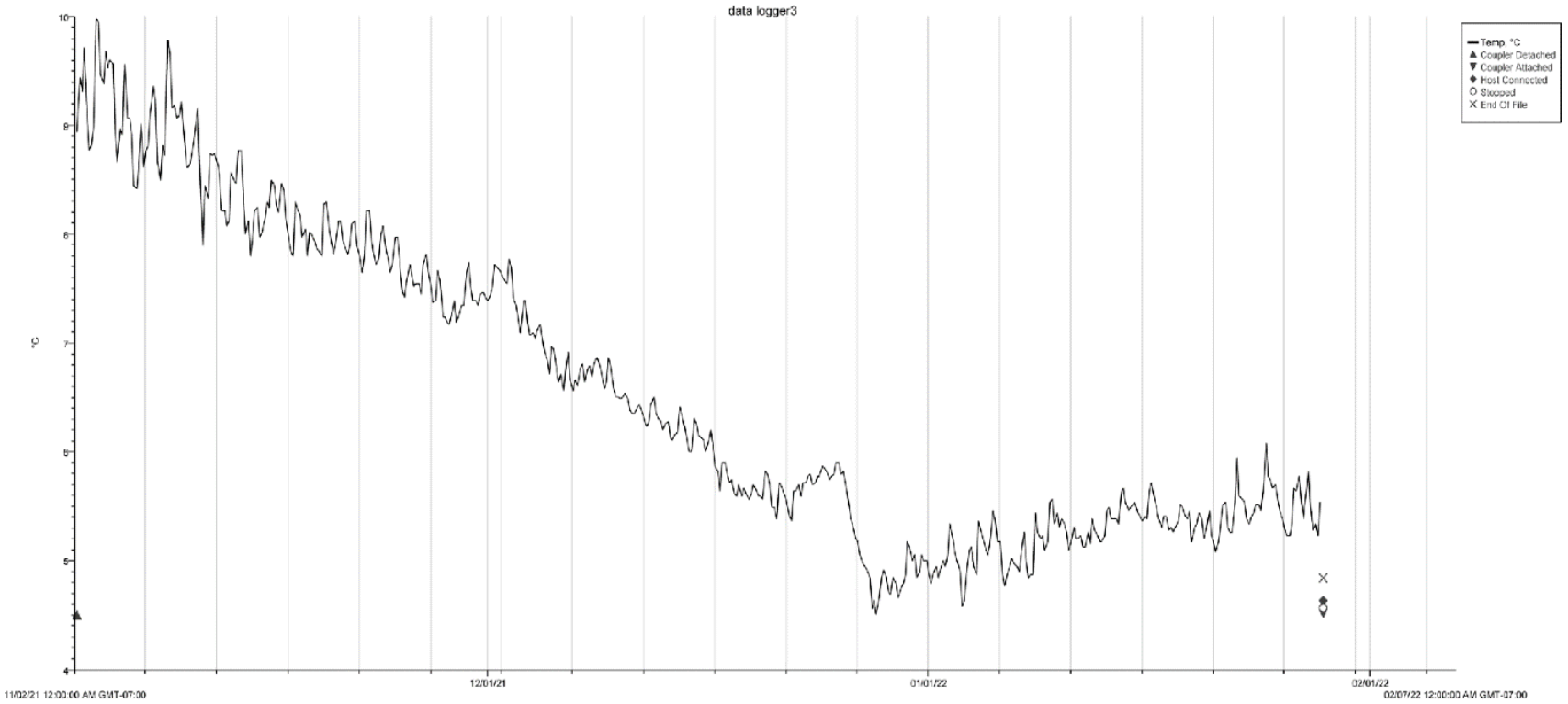

Figure 34: Temperature data from Egg Capsule 2 covering Nov 1, 2021 to Jan 28, 2022

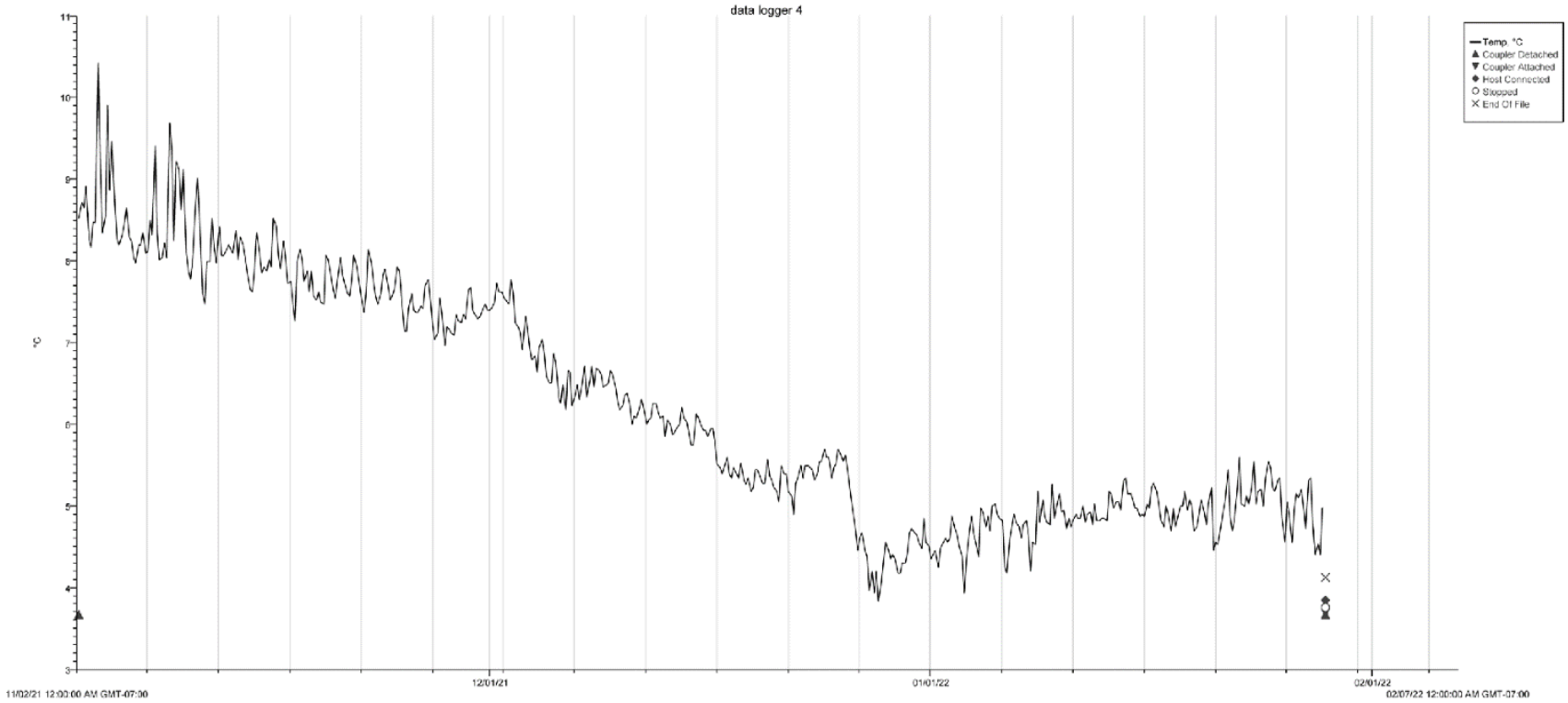

Figure 35: Temperature data from Egg Capsule 4 covering Nov 1, 2021 to Jan 28, 2022

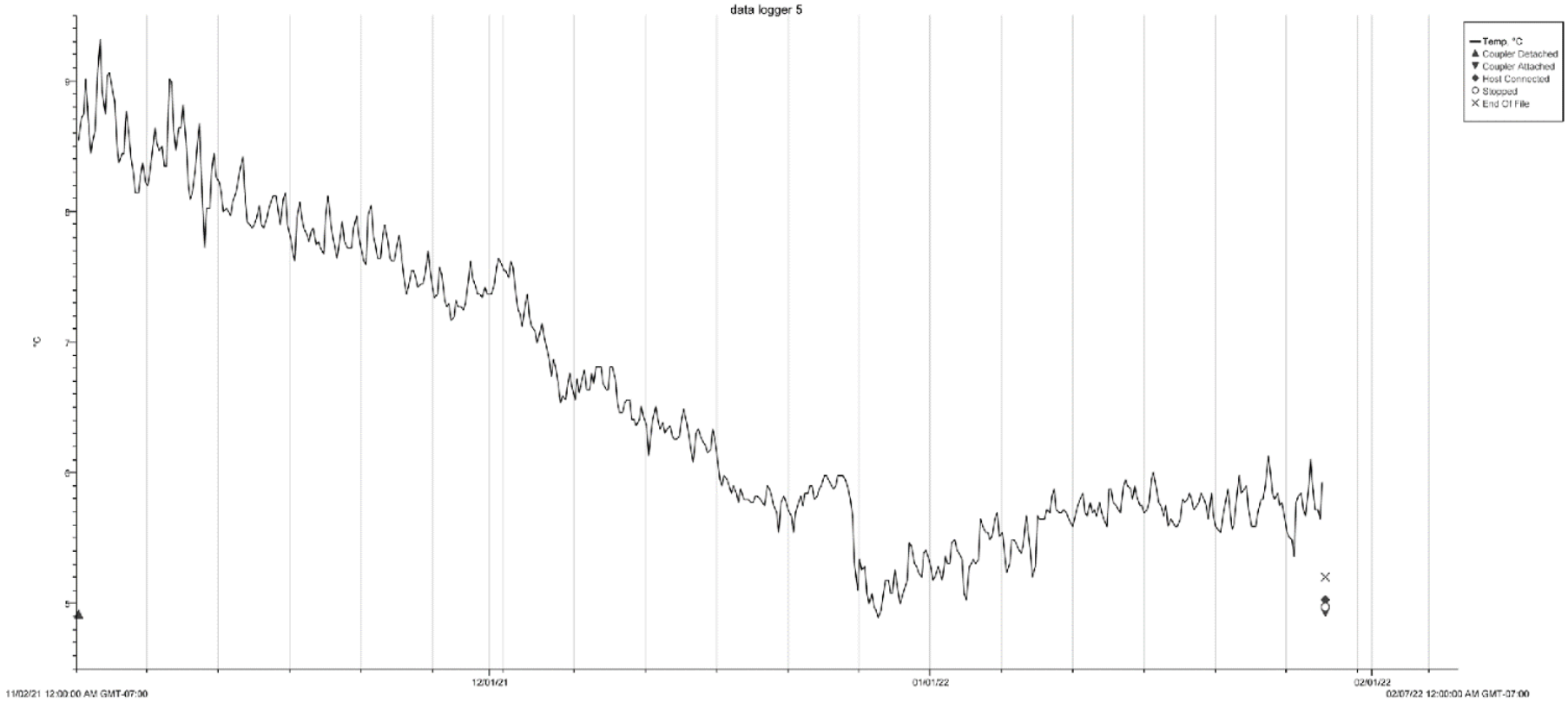

Figure 36: Temperature data from Egg Capsule 5 covering Nov 1, 2021 to Jan 28, 2022

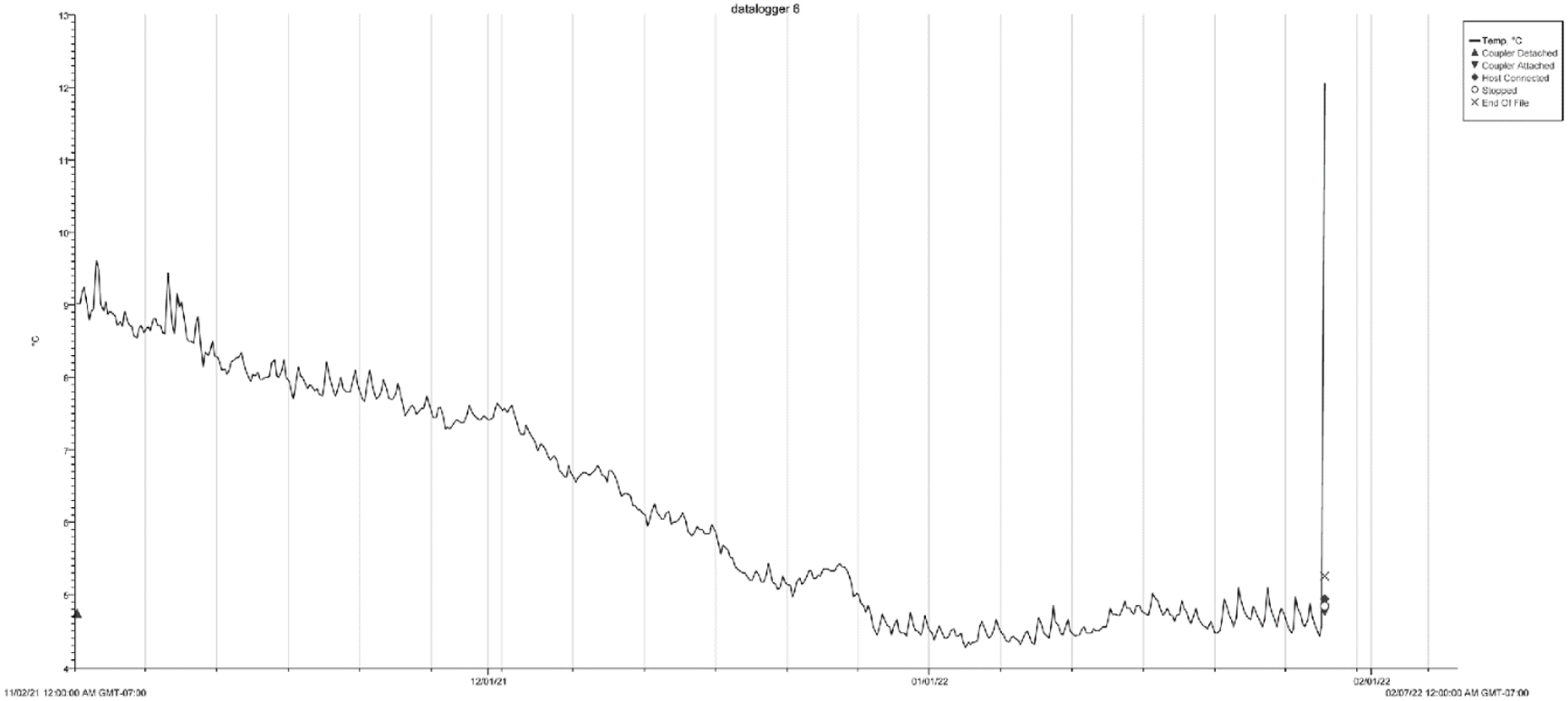

Figure 37: Temperature data from Egg Capsule 6 covering Nov 1, 2021 to Jan 28, 2022

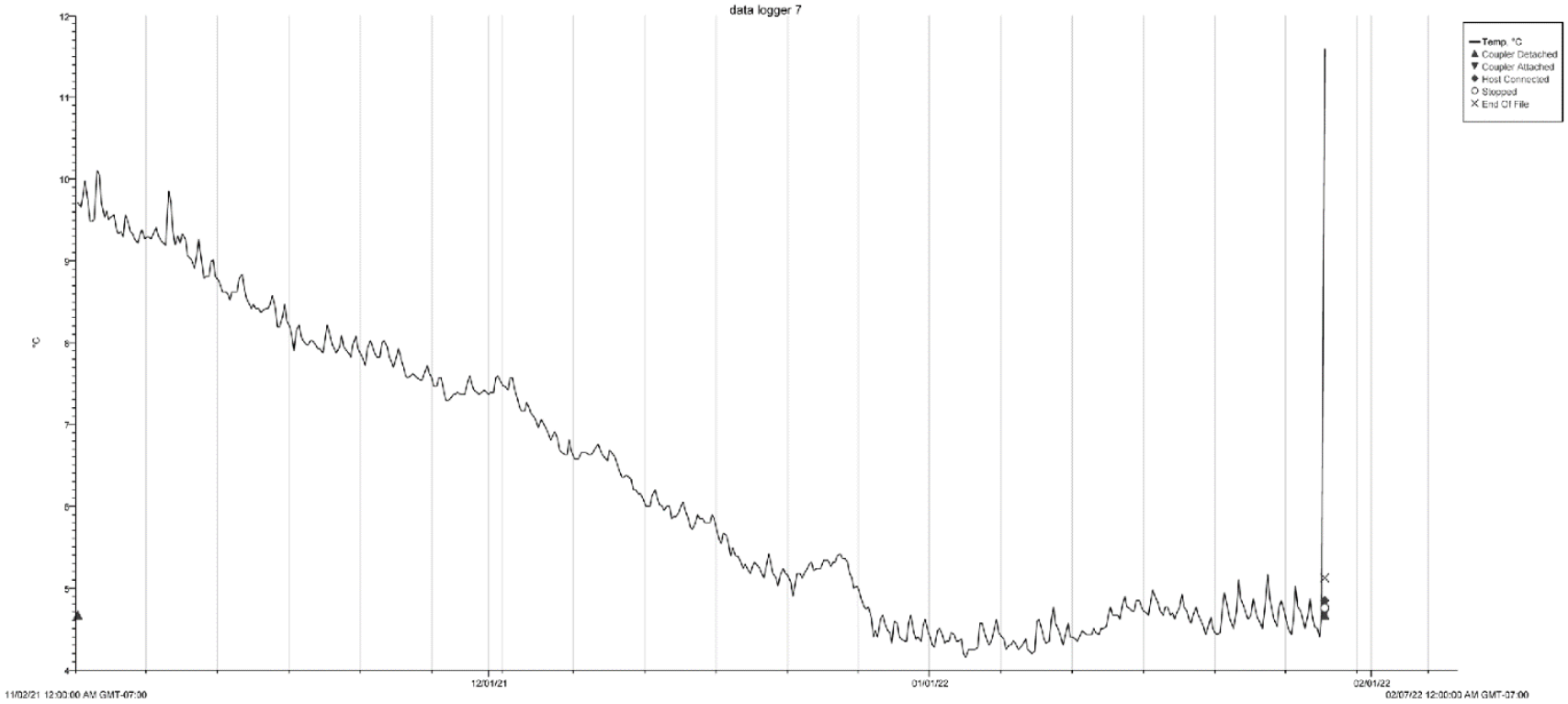

Figure 38:Temperature data from Egg Capsule 7 covering Nov 1, 2021 to Jan 28, 2022

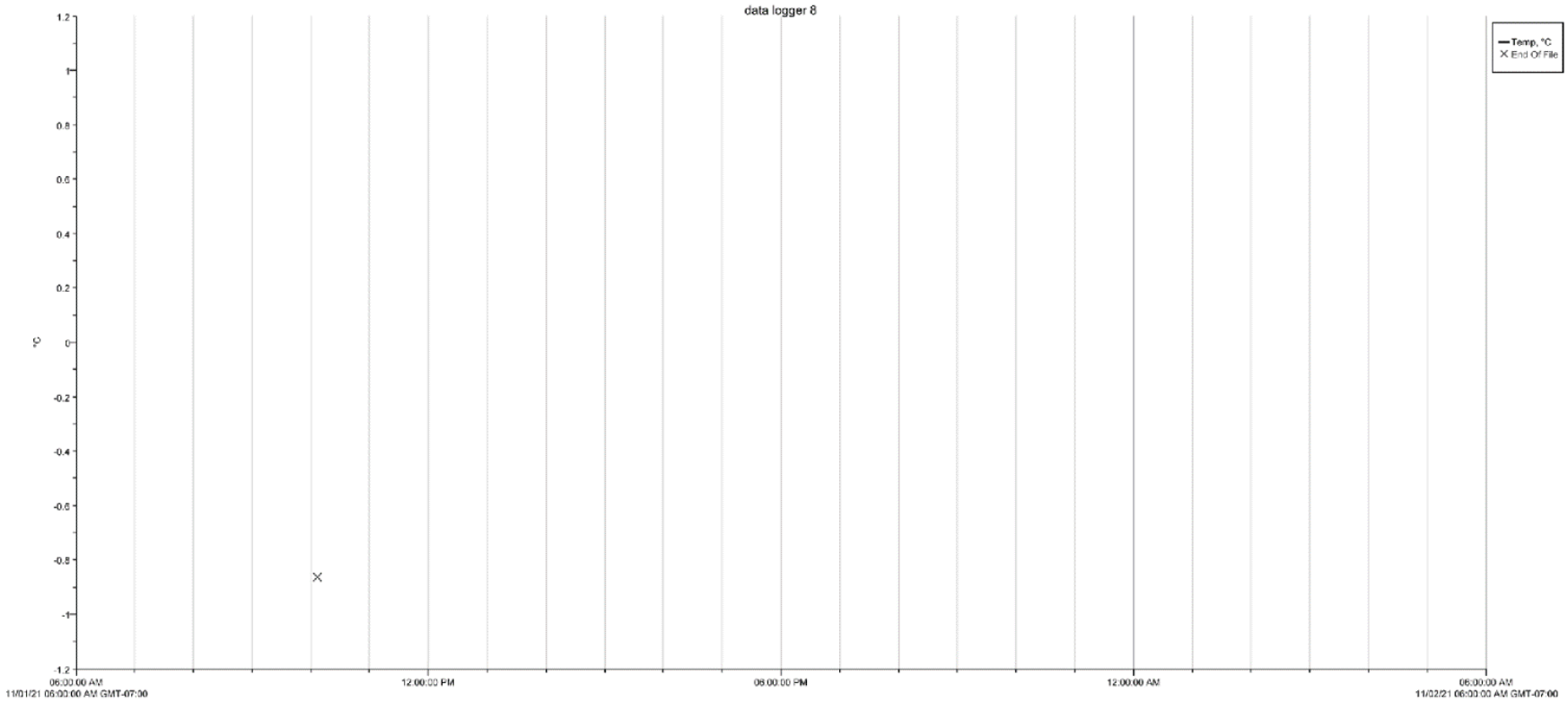

Figure 39: Temperature data from Egg Capsule 8 covering Nov 1, 2021 to Jan 28, 2022 (logger short-circuited)

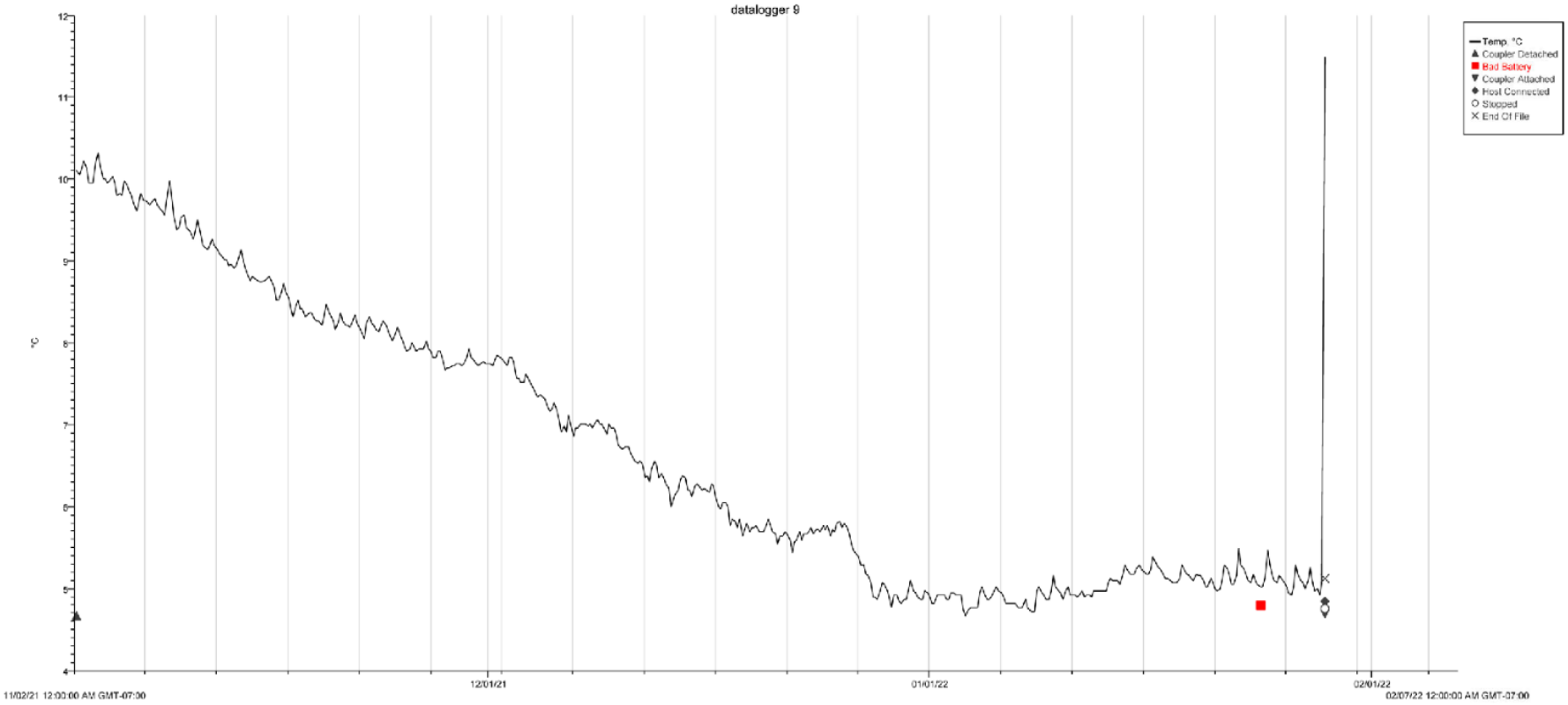

Figure 40: Temperature data from Egg Capsule 9 covering Nov 1, 2021 to Jan 28, 2022

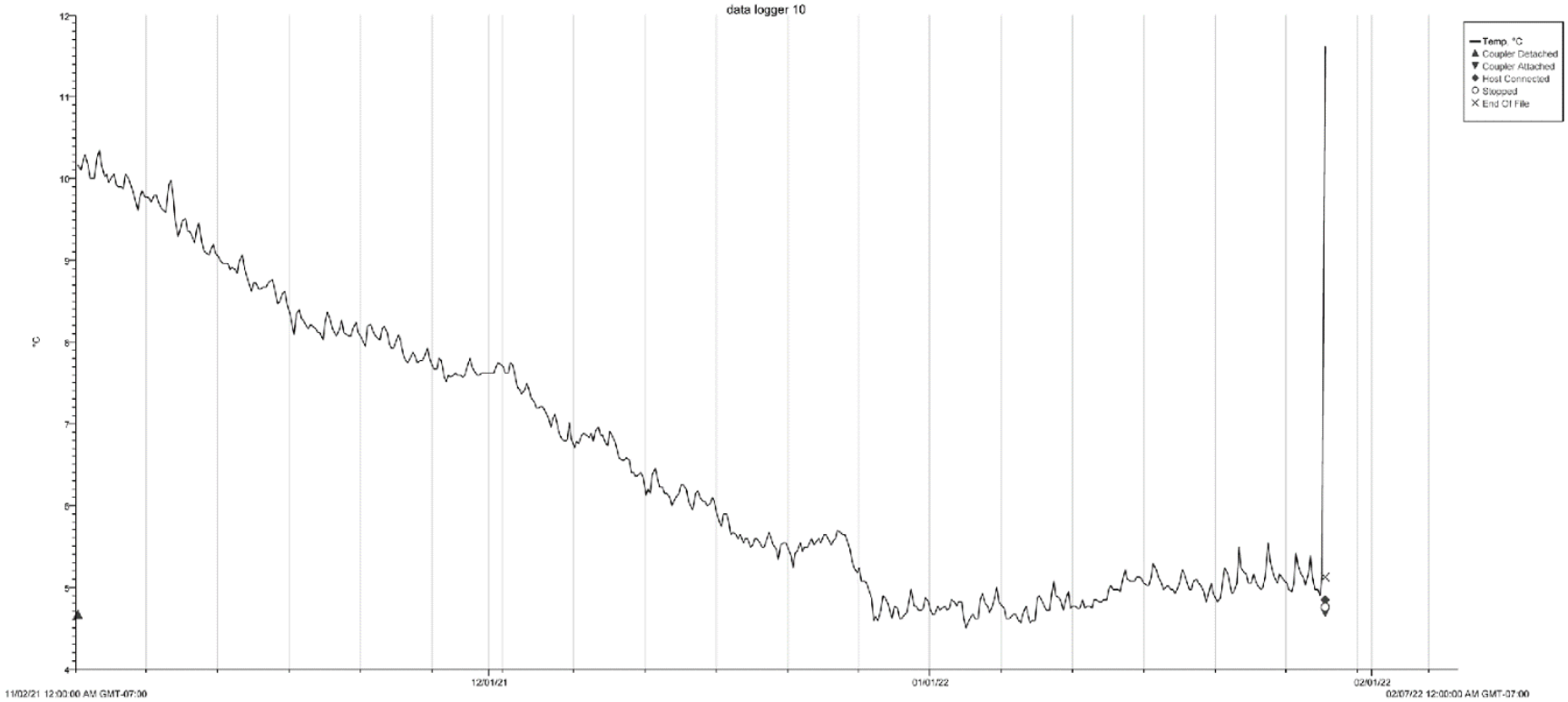

Figure 41: Temperature data from Egg Capsule 10 covering Nov 1, 2021 to Jan 28, 2022

Bonaventure Trailer Park Survey Results

Houses visited
~~||||~~ ~~||||~~ ||||

Are you aware of the spawning site?

Yes	No
~~||||~~ ||	||

Comments:

Are you aware that the redds dewater each spring?

Yes	No
~~||||~~ ||	||

Comments:

Do you have any concerns about the spawning habitat?

Comments:

- informed on it
- could put boats away early • fact it's so shallow
- water level
- not really - understand couldn't going down
- dewatering
- low water, narrow pass
- Big concern about dewatering + channel
  - kids play in channel. Rocks fall in. Extremely shallow now compared to 14 yrs ago
- Duhamel - flood - boulders - not pulling out ice - creek beds need to be worked.
- no
- deepened - mud - help Kokanee

Would you be supportive of any future potential efforts to restore the habitat?

Comments:

- yes
- yes
- yes, dredging
- yes
- yes
- think so
- yes
- yes
- yes

What would you like to see happen?

Comments:

- don't care much
- dredging, invasive spp removal, stop mowing to shoreline. stop using pesticides.
- Habitat restoration + dredging
- support for dredging
- dredging
- don't know
- dredging, widening channel. signage deterring installing gravels
- yes, dredging, widening
- dredging, deepening

Other observations, concerns, ideas, comments etc.:

- neighbours want entrance of lagoon dredged.
- get grant, dredge, get study going.
- All for what we've doing.
- no
- no
- concerned about flooding from creeks.
- Mark + Angelica - sent notice to all residents.
- Phoned FoKLSS about Beaver Dam
- can send out email to all residents
- Keep it local