Final Report

Shore-Spawning Kokanee Habitat Restoration & Research Project Year 3 (2022–2023)

COL-F23-F-3696

Prepared for: Fish & Wildlife Compensation Program

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31-05-2023

Executive Summary

In 2022-23, 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 and the University of BC Okanagan 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 2020 (year one of the project), 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 an attempt to encourage SSKS to spawn below the LWM where redds will not dewater.

In the two years since the gravel installation (2021 and 2022), the Friends of Kootenay Lake and partners monitored spawning kokanee numbers and redd development; examined spatial and temporal variability of near-shore groundwater seepage; assessed gravel morphology and conducted maintenance as needed; compared egg-to-fry survival in the restored substrate below the low water mark to the historical substrate above the low water mark; collected water temperature data; conducted multi-spectral imaging of the spawning habitat; assessed dewatered SSKS redds; and conducted community education and outreach about SSKS in Kootenay Lake.

Results from the third and final year of the project (2022-2023) confirmed and expanded those from previous years. In fall 2022, spawning SSKS were observed in the natural and installed spawning gravel in roughly equal proportions. However, there were more redds above the LWM (77%, n = 50) than below the LWM (23%, n = 15).

In winter 2023, egg-to-fry survival rates of installed triploid kokanee eggs were comparable in the natural gravel above the LWM (33% ± 12.3) and the restored gravel below the LWM (22% ± 7.9). These results suggest that kokanee offspring would not be negatively 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, kokanee eggs and fry would likely benefit from interventions to keep spawners lower in elevation.

In fall 2022, the majority of redds were formed above the LWM in areas of significant groundwater upwelling, indicating that groundwater is a better predictor of redd development than substrate. Redds contained mostly live kokanee on March 30, 2023, indicating that if there is groundwater flow, kokanee fry can survive multiple weeks above the LWM during the low water period. Aerial photos were found to be useful for identifying areas of worked gravel (and potentially spawning fish, in ideal conditions that allow crisp, non-shadowy images). However, to obtain accurate redd and spawning fish counts, boat surveys would still be required.

Groundwater presence can be seen in the thermal images taken of both the McDonald's Landing and Bonaventure Lagoon spawning sites on April 6, 2023. Groundwater presence correlated with redd location, confirming that thermal imagery can be used to identify groundwater presence and the probable locations of dewatered SSKS redds. The collected LiDAR imagery, showing the elevational profiles of the two sites, can aid in identifying other probable spawning areas on the West Arm of Kootenay Lake. However, it was too coarse to allow the visual identification of redds from the imagery.

Nearly 60 residents participated directly in outreach activities in year three. Activities included a groundwater study presentation on August 22, 2022, an online project feedback survey released in June, 2022, and a kokanee monitoring workshop delivered on October 15, 2022. Participant feedback was positive and additional engagement with some of the same individuals has occurred. Future engagement is expected as well, as we enter the 2023/4 spawning season. Survey feedback shows that residents support the project and learned more about SSKS through the project. Numerous educational videos, social media posts, funder acknowledgements, and event promotions related to SSKS were released across our various online platforms. The social media posts alone reached 4,630 people between February 2022 and April 2023. We also posted a permanent informational sign about SSKS at the McDonald's Landing site on January 20, 2023, which was reviewed by fisheries personnel and produced by professional designers and printers.

Recommendations outlined at the end of this report are intended to guide continued SSKS monitoring, assessments, and research on the West Arm of Kootenay Lake. FoKLSS is already applying the findings from the McDonald's Landing project to the SSKS spawning site at Bonaventure Lagoon. We are currently assessing the feasibility of restoring the lagoon to limit the dewatering of redds by lowering the nearshore elevation and installing gravel. Depending on the findings of the 2023 feasibility assessment, we may conduct a full-scale enhancement of Bonaventure Lagoon in future years.

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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). Main-lake kokanee returns since 2015 are only about three percent of the long-term historic average and egg deposition is decreasing over time (McPhearson, 2018). West Arm kokanee have also declined, beginning in the 1970s (Redfish Consulting 2002 as cited in Schleppe and McPherson 2022).

Shore-spawning kokanee, a genetically distinct population of kokanee salmon in Kootenay Lake that spawn along shorelines in areas of upwelling groundwater, face 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 (mitigated 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 approach to 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 an 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.

Years two and three of the project (2021-2023) involved post-restoration effectiveness monitoring and assessments, as well as habitat research. Valuable data were gathered that helped 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 contracted specialists, academic partners, hydroelectric industry representatives, provincial government scientists, and numerous volunteers.

Year Three (2022–2023) Goals and Objectives

1. Continue assessing groundwater infiltration at the McDonald's Landing spawning site and determine rate of groundwater influence using seepage meters, temperature sensors, and isotope analysis.
Approach: Provincial Hydrologist and UBC Okanagan (UBCO) Hydrogeologists installed seepage meters and temperature sensors to measure groundwater presence and quantity and develop a temperature profile. Monthly samples were collected and sent to UBCO Laboratory to undergo isotope analysis and determine the water source.

2. Monitor the restored habitat for evidence of SSKS spawning activity.
Approach: Conducted weekly visual surveys by boat during spawning season, mid-September to late October. Recorded SSKS presence and redd development for both the control and restored site.

3. Assess egg-to-fry survival in the restored versus control site where spawning is observed, and measure temperature fluctuations.
Approach: Divers installed perforated egg tubes containing kokanee eggs within the substrate in the fall, and we assessed the number of egg-to-fry developments in late winter. We obtained kokanee eggs from Regional Fisheries staff to ensure viability, and we installed temperature data loggers with these egg tubes to assess Accumulated Thermal Units (ATUs).

4. Acquire thermal, LiDAR and high-resolution RGB imagery of the site to visualize groundwater influence and habitat usage by spawners.
Approach: We contracted GIS specialists with the Okanagan Nation Alliance (ONA) who imaged the site with drones during the spawning season in fall 2022 and during low water in spring 2023.

5. Increase community engagement and education surrounding SSK.
Approach: We implemented outreach programs on SSKS to provide opportunities for individuals to learn more about this keystone species. We communicated (via social and traditional media) information on this species and the work FoKLSS is doing to enhance SSKS habitat. We installed signage at the site with information relating to SSKS and the restoration work completed.

These goals align with the following FWCP Priority Action items:

<u>COLRLL.ECO.ME.21.01 Effectiveness monitoring of past Kokanee projects-P3 (PRIMARY ACTION)</u>

This project monitored and evaluated the effectiveness of a FWCP funded kokanee habitat-based project. We assessed the success of this restoration action by conducting a multi-parameter monitoring protocol on SSKS spawning behavior and habitat features. Data collected as a result of this project was shared with the Province's Fish and Wildlife branch, and the progress and final reports will be made publicly available. In addition to data collection, monitoring allowed us to check for any needed maintenance to the site, as advised by fish biologists and environmental consultants. This project assessment enhanced FoKLSS' 2-year data set available on SSKS spawning habitat restoration and will be used to inform future restoration action at similar sites.

COLRLL.ECO.RI.18.01 Develop habitat-based planning for Kokanee-P3 (SECONDARY ACTION)

This project contributes to the existing data set on spawning habitat values and provides valuable metrics on the potential for substrate installation to promote spawning at lower elevations. The final report of this pilot project will be made available to agencies who are pursuing this compensatory strategy at other spawning sites on the lake. Previous research done on SSKS had found that SSKS are attracted to areas with groundwater infiltration, which provide the temperature requirements for egg development (Arndt, 2009). Methods to measure groundwater seepage at depths where spawning occurs were carried out in-kind by advisors. This study helped develop an understanding of groundwater influence at depth at McDonald's Landing and provides replicable methods for other sites.

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/restored habitat, pictured below (Figure 1).

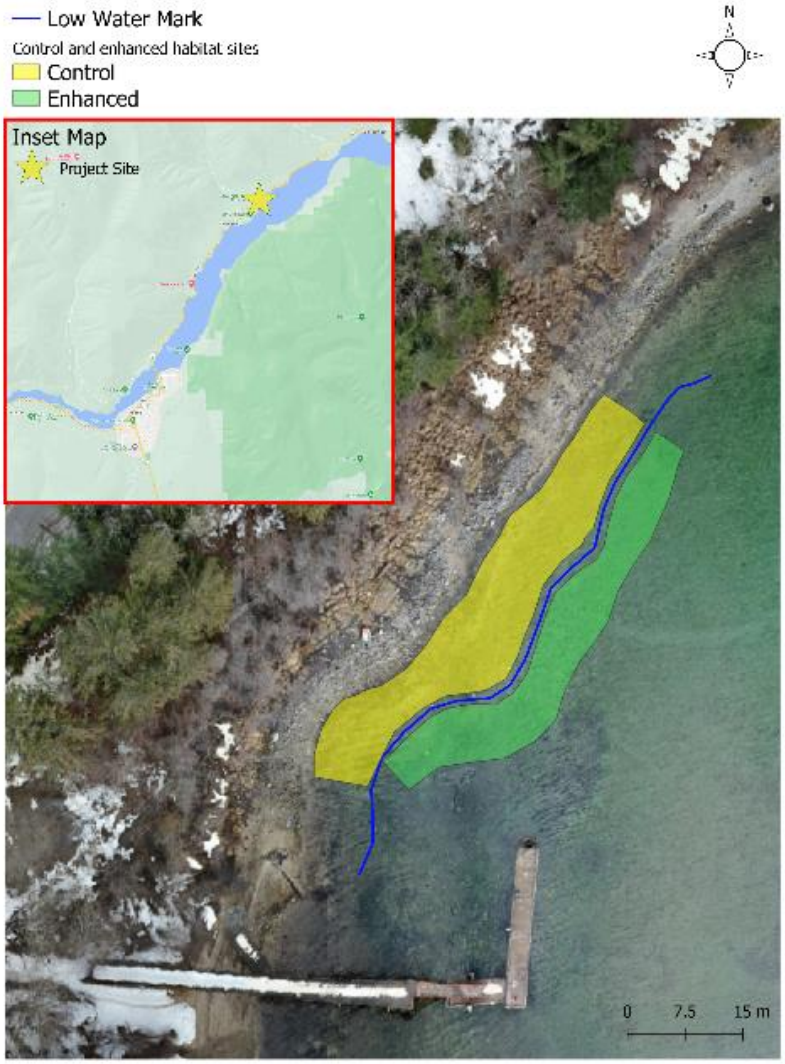

Figure 1: Study Site

Methods

Spawning Kokanee Monitoring

Spawning kokanee numbers were enumerated weekly between September 28 and October 19, 2022 by FoKLSS staff. Five monitoring days were completed by FoKLSS in total in 2022. FoKLSS monitoring expeditions were conducted by boat at coasting speeds across the restoration site. The site was traversed one to six times for each survey. One monitor counted all kokanee observed, and one monitor counted all kokanee observed above the LWM. Both redds and dead kokanee were enumerated using fish counters.

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

Egg Capsule Installation

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 October 28, 2022 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 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. Capsules were placed into buckets of fresh lake water and

carried to the shoreline. Egg capsules 1-5 were installed directly adjacent to naturally created redds in ~100-150 cm of water in areas of known groundwater upwelling. Egg capsules 6-10 were installed within the restored substrate by scuba divers, directly adjacent to naturally created redds, in 165-180 cm of water. Egg capsules were buried horizontally ~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. Photos were taken of the contents of each egg capsule for a more precise count of eggs later in the office. Temperature data loggers collected a temperature reading once every four hours from October 28, 2022 to January 20, 2023.

Figure 3: Oct 28, 2022, Kokanee egg capsule install. Counting and weighing kokanee eggs. Photo credit: Moriah Tanguay

Figure 4: Oct 28, 2022, Kokanee egg capsule install. Divers installing egg capsules. Photo credit: Moriah Tanguay

Egg Capsule Removal

Egg capsules were removed from the substrate on January 28, 2022 with support from volunteers and scuba divers; accumulated thermal units (ATUs) were approximately 864.4 on this date. Egg capsule contents were emptied and assessed by provincial 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 5: Jan 20, 2022. Egg capsule retrieval. Removing capsule from substrate. Photo credit: Kayla Tillapaugh

Figure 6: Jan 20, 2023. Egg capsule retrieval. Inspecting capsule contents and counting dead eggs. Photo credit: Kayla Tillapaugh

Egg-to-Fry Survival Assessment

The number of eggs installed and remaining were carefully counted from photographs taken during installation (Oct 28, 2022) and removal (Jan 20, 2023). The difference between the number of eggs installed and remaining was taken as the number of surviving/escaping fry. Data were analyzed to compare survival rates (%) between the control and restored areas. The temperature data from the ten loggers was compiled and summarized as the minimum, maximum, average, and median.

Groundwater Monitoring

The groundwater monitoring study was led by Master of Science Candidate Cameron Spooner (UBCO), Research Hydrologist Dr. Natasha Neumann (Province of BC), 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. Four weeklong measurements were taken over the egg development period in 2021-2022 and eight in 2022-2023.

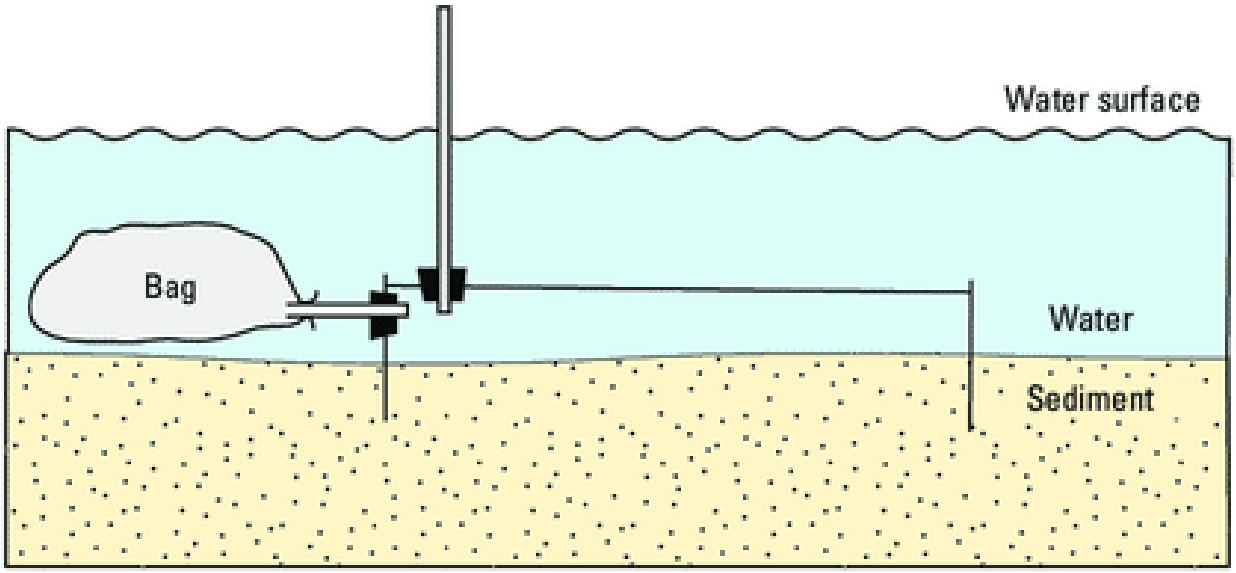

Figure 7: Diagram of seepage metre. Diagram credit: Cameron Spooner.

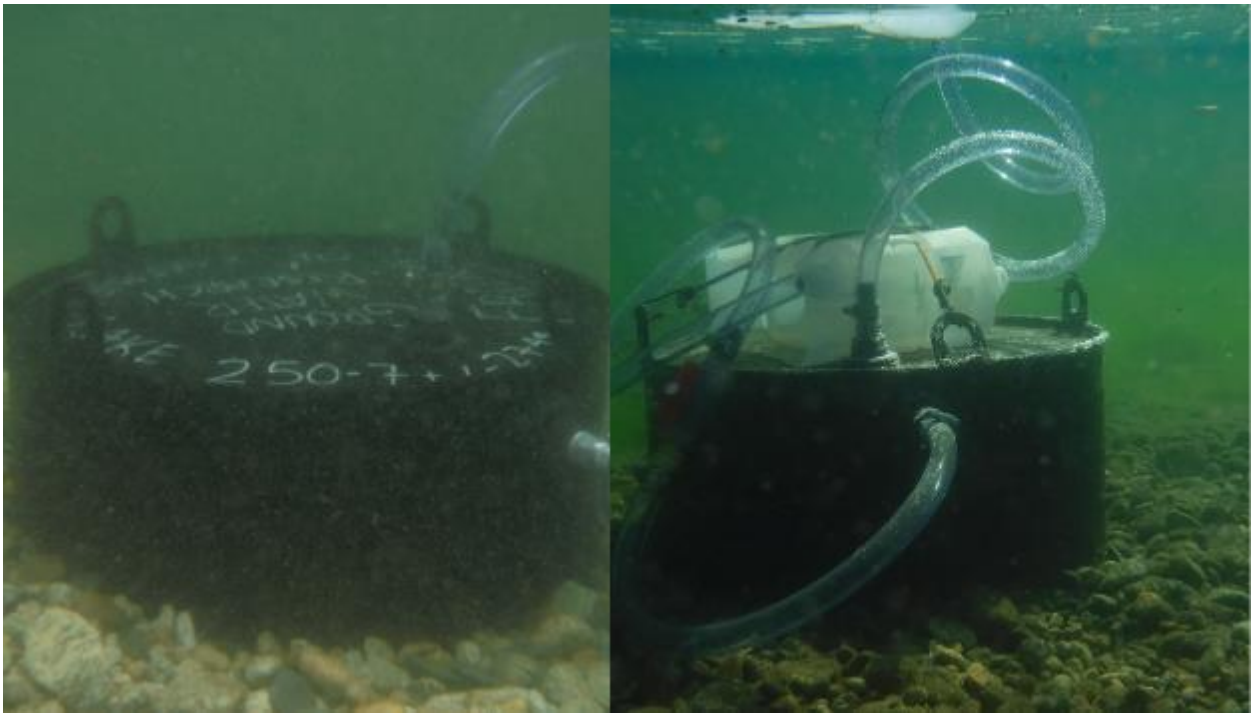

Figure 8: Underwater photos of seepage metres installed at McDonald's Landing restoration site. Photo credit: Bruce Morrison

Four vertical sediment temperature profiles were installed using steel pipes and a set of 4 thermistors or Tidbit loggers. The goal was to measure sediment temperature and use it to model vertical groundwater flow. The pipes were driven into the substrate and the temperature probes were placed inside - one 30 cm below the lakebed, one 20cm below the lakebed, one 10cm below the lakebed, and one at the lakebed (0cm). Surface water and groundwater temperature signals were acquired from the water level loggers in the lake and lakebed (60cm below the lakebed). Temperatures were recorded every 30 minutes from November – April of 2021 – 2023. Vertical groundwater flow was then modelled using 1DTempPro, a USGS graphical user interface (GUI) for the VS2DH model.

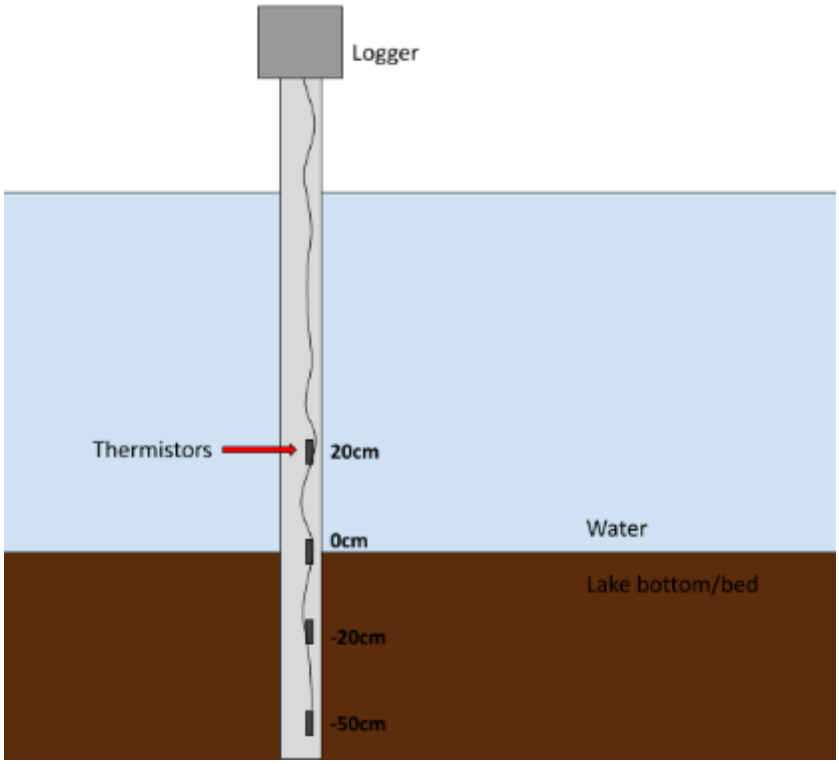

Figure 9: Diagram of vertical sediment temperature profiling probe. Diagram credit: Cameron Spooner.

Figure 10: Photo of vertical sediment temperature profiling probes installed at McDonald's Landing restoration site. Photo credit: Cameron Spooner.

Water sampling was completed to measure natural tracers in the lakebed porewater, shallow groundwater, deep groundwater, lake water, Duhamel creek and precipitation. Isotope analysis is ongoing to determine possible sources of lakebed porewater and establish a ratio of groundwater to lake water in the nearshore gravel. This data can also be used to look at any changes in this ration and when they occur. Other Natural tracers such as radon-222 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 the lakebed porewater and salmon redds.

Two piezometers were installed, one to measure the height of the nearshore water table and another to measure the groundwater head at 0.6m depth below the lakebed. One stilling well with a water level logger was installed in the lake to measure lake stage. These loggers collected water level and temperature data on a 30-minute interval. This can be used to infer the magnitude of groundwater flow into the lake and monitor any changes to groundwater flow potential. The lakebed piezometer was also used to perform slug tests to analyze the hydraulic conductivity of the lakebed sediments.

Figure 11: 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 contracted the Okanagan Nation Alliance to conduct multispectral imaging of shore-spawning habitat at McDonald's Landing and Bonaventure Lagoon using a specialized drone. The imagery was collected during spawning (October 15, 2022) and during low water (April 6, 2023). 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.

Figure 12: Oct 15, 2022. Santiago Botero (Above Sensing) preparing drone for flight at McDonald's Landing. Photo credit: Kayla Tillapaugh

Dewatered Redd Survey

On March 30, 2023, FoKLSS assisted BC fisheries technicians with a dewatered redd survey at McDonald's Landing and Bonaventure Lagoon. 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. Identified redds were geolocated and water temperature was taken. Other data including egg and fry condition and temperature were collected for each identified redd.

Figure 13: March 30, 2023. Dewatered redd survey crew locating dewatered redds. Photo credit: Joelle Burnie

Figure 14: March 30, 2023. Dewatered redds containing live fry (left) and dead fry (right). Photo credits: Kayla Tillapaugh

Outreach & Education

In June 2022, FoKLSS released an online survey to gather community feedback about the project. The survey was advertised on posters at McDonald's Landing to target site users and residents of the general area (6-mile). Survey questions included:

1. Are you in support of the project?
2. Please elaborate on your answer to question 1
3. Do you feel that you have had adequate opportunity to provide feedback on the project or get involved?
4. If no, what opportunities for feedback or involvement would you like to see?
5. Has FoKLSS or this project helped to increase your knowledge about shore-spawning kokanee salmon in Kootenay Lake?

On August 22, 2022, a presentation was offered to stakeholders/interest groups about the project, with a strong focus on the groundwater research component. Moriah Tanguay, FoKLSS Stewardship Coordinator hosted the event and discussed the Shore-Spawning Kokanee Habitat Restoration & Research Project and Cameron Spooner, UBCO Master's Student, presented the research methodology and preliminary findings for the groundwater study.

On October 15, 2022, FoKLSS staff hosted a shore-spawning kokanee monitoring workshop at McDonald's Landing and Bonaventure Lagoon. Instruction was provided by knowledgeable staff and local experts, and short boat rides in the shallows were provided by a local resident. Clickers and polarized sunglasses were provided to all participants, and each participant had the chance to practice counting kokanee redds from the shoreline and the boat. FoKLSS followed up with all participants to encourage them to keep an eye out for redds on Kootenay Lake and submit their observations to us. Follow-up emails included written monitoring instructions and datasheets for participants to record their future SSKS observations.

On January 20, 2023, FoKLSS posted a permanent SSKS informational sign at the McDonald's Landing research site. The sign was professionally drafted and printed, and the content was written with input from provincial fisheries personnel.

Educational and informative content was routinely published online on the Friends of Kootenay Lake website and on our two social media channels. Content always included a highlight or recap of all project-related events and major activities. Content also included educational resources such as articles, news stories, reports, 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.

Results & Outcomes

Spawning Season Observations

Our highest spawner count for the entire McDonald's Landing site was 39 fish, observed on October 12, 2022. Spawners were observed in roughly equal proportions in the control and restored sites. However, redds are better indicators of fine-scale habitat use than spawners, as kokanee are highly mobile and wary of the motorized monitoring boat. Early redd observations were all in the control site (Sept 28 - Oct 15). But by the final count (Oct 19), we observed a total of 65 redds in the entire McDonald's Landing site, 23% (n = 15) of which were in the restored area. The redd areas observed on October 19, were identified as circular depressions of cleaned gravel. These areas, where the majority of redds were observed, are approximated in Figure 15 below.

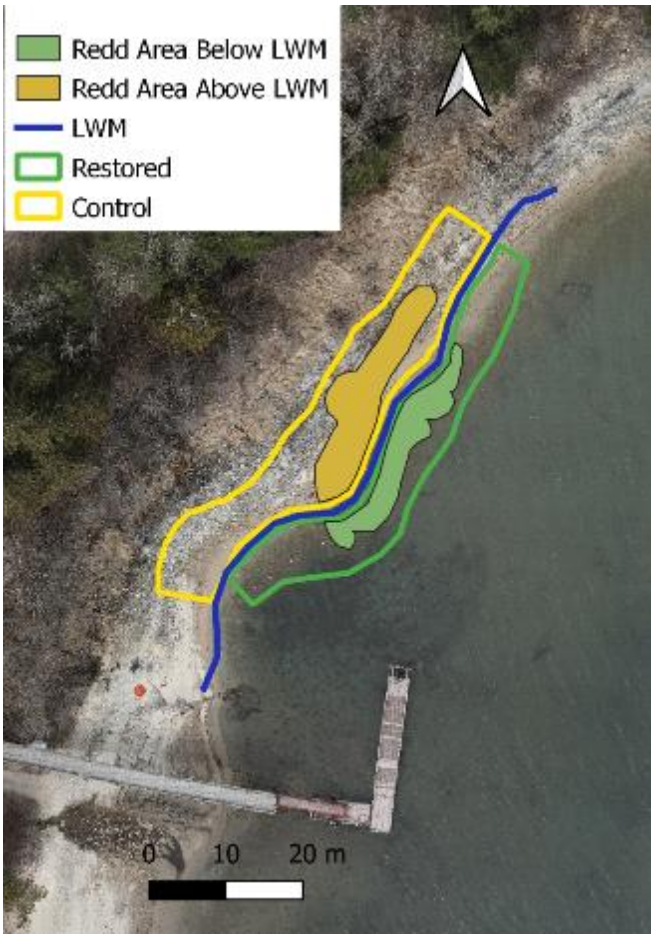

Figure 15: Estimated redd areas in the control and restored areas of McDonald's Landing, as observed on October 19, 2023

Egg-to-Fry Survival Rates

Egg-to-fry survival rates were similar in the control and restored areas (Figure 16). Eggs in the control area (egg capsules 1-5) averaged 33% ± 12.3 survival (range of 21–46%); those in the restored area (egg capsules 6-10) averaged 22% ± 7.9 (range of 14–30%). The average water temperature associated with the egg capsules was 6.47 °C, the median was 6.41 °C, and the range was 2.77–12.07 °C. The kokanee eggs were reported at 310.4 Accumulated Thermal Units (ATUs) on October 28, 2022 when they were

installed. With an average water temperature of 6.4 °C throughout the incubation period, the eggs were estimated at 864.4 ATUs upon extraction (January 20, 2023). Fry emergence can be expected any time after 850 ATUs.

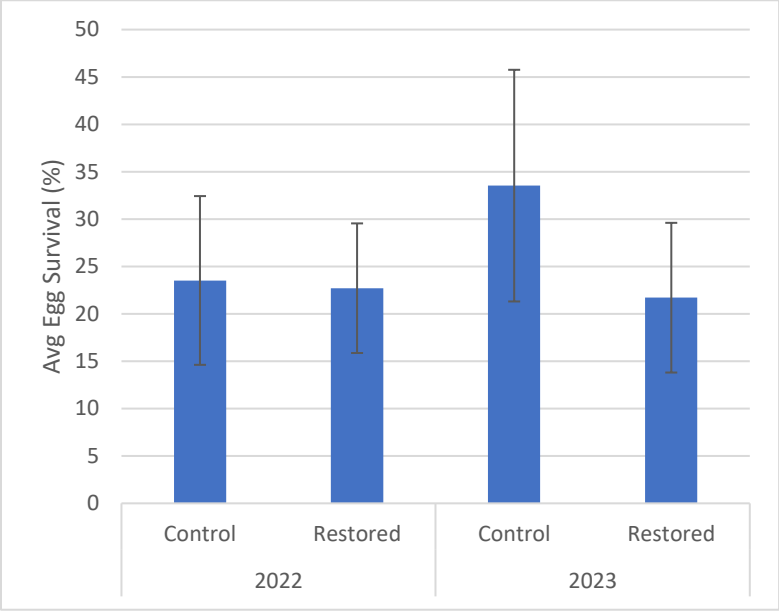

Figure 16: Comparison of average egg-to-fry survival rates (%) in the control and restored areas of McDonald's Landing, winter 2022 and 2023.

Groundwater Observations

Early sediment temperature modelling shows a clear increase in vertical groundwater flow as the lake level drops in the spring (Figure 17). Preliminary radon and water isotope samples also indicate that the lakebed porewater is strongly connected to the local groundwater at McDonald's Landing (Figure 18). This data is still under review and the results are expected to be published in late 2023 to early 2024.

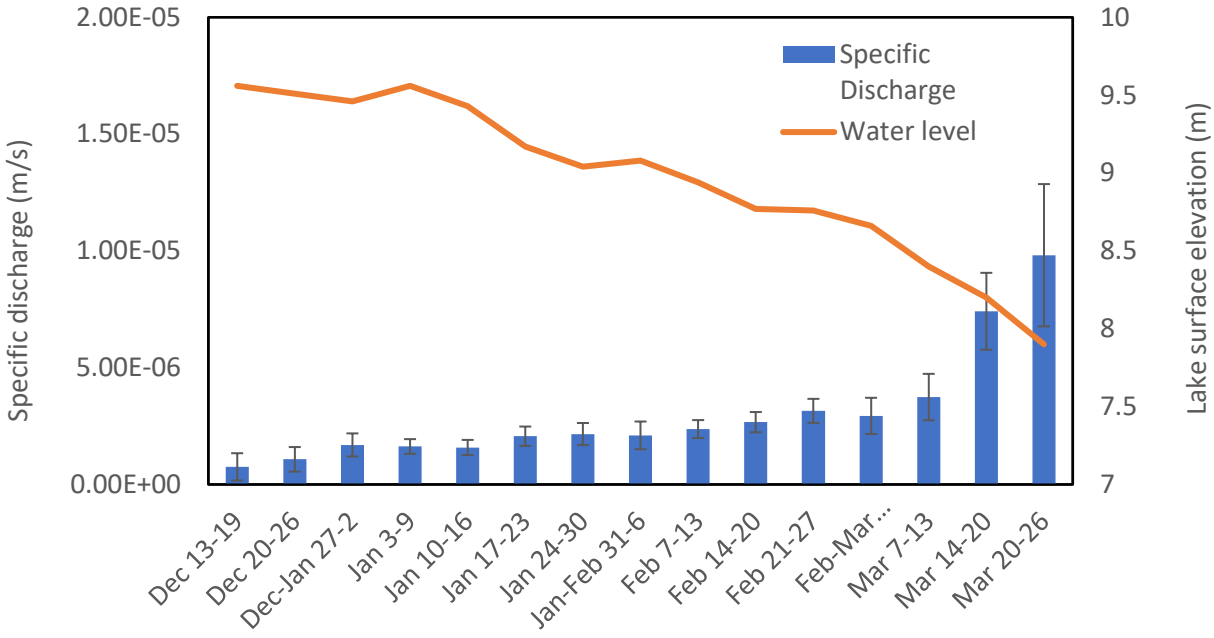

Figure 17: Modelled specific discharge and changes in lake level from December 2021 to March 2022. C Spooner, presented at the CGU 2023 Annual Meeting.

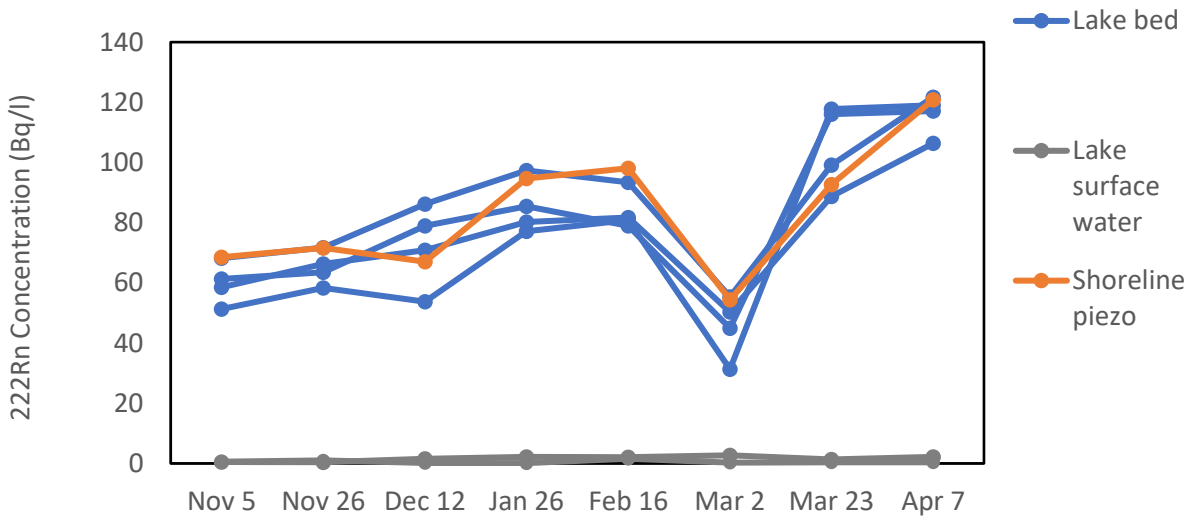

Figure 18: 222RN concentration at 0.2m in the lakebed, local groundwater and the lake from November 2022 to April 2023 – C Spooner, presented at the CGU 2023 Annual Meeting

Drone Images

Aerial images, including regular, thermal and LiDAR photographs, were successfully collected during spawning season (October 15, 2022) and during low water (April 6, 2023) at McDonald's Landing and Bonaventure (Figure 19–Figure 28).

McDonald's Landing

Figure 19: Aerial photo of McDonald's Landing Regional Park, April 6, 2023

Figure 20: Aerial photo of McDonald's Landing Regional Park, October 15, 2022. Black arrows indicate some of the redd areas visible in the photo (patches of cleaned, lighter coloured substrate).

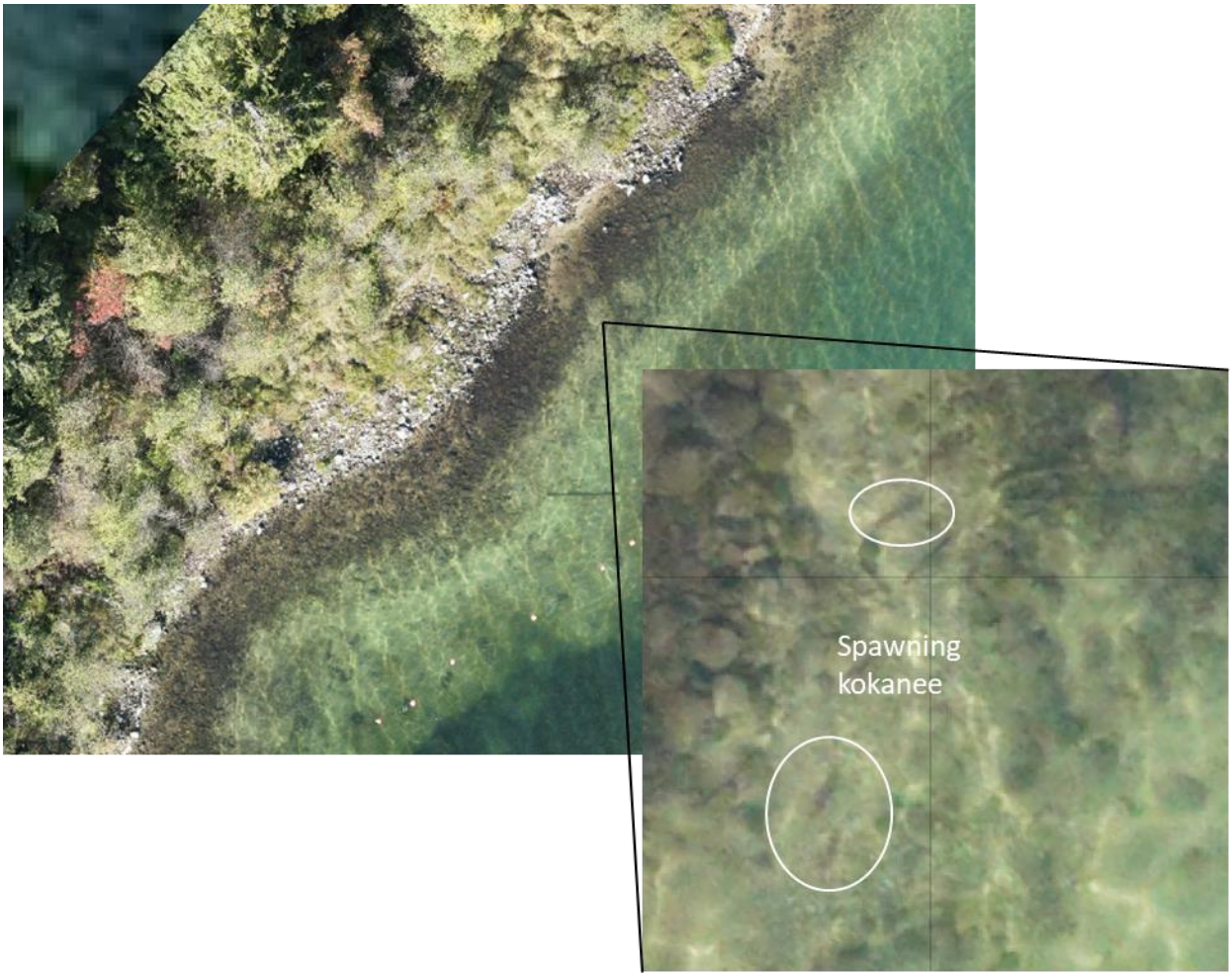

Figure 21: Aerial photo of McDonald's Landing Regional Park, October 15, 2022, with inset map showing kokanee spawning in cleaned redd area

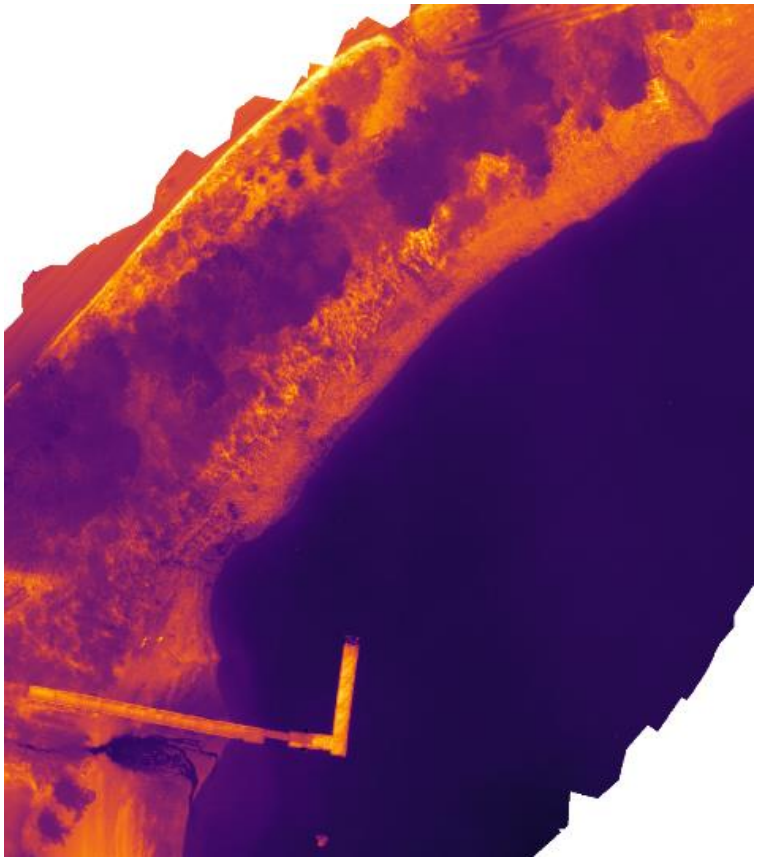

Figure 22: Thermal imagery of McDonald's Landing Regional Park, April 6, 2023. Colder temperatures (e.g., groundwater, stream water, and lake water) shown in dark purple; warmer temperatures in orange

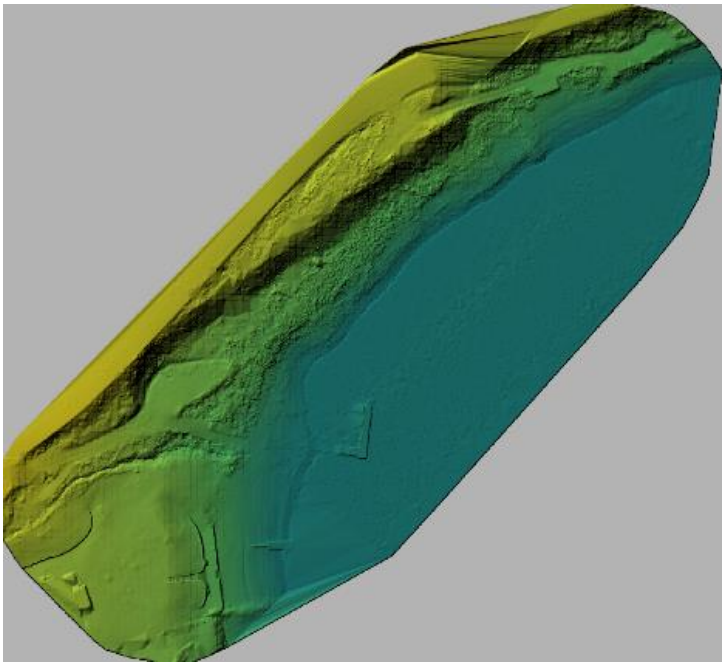

Figure 23: LiDAR imagery of McDonald's Landing Regional Park, April 6, 2023. Lower elevations (e.g., lake level) shown in turquoise; higher elevations in green/yellow

Bonaventure Lagoon

Figure 24: Aerial photo Bonaventure Lagoon, April 6, 2023

Figure 25: Aerial photo of Bonaventure Lagoon, Oct 15, 2023, with primary redd area visible (indicated by areas of cleaned, lighter-coloured substrate)

Figure 26: Aerial photo of Bonaventure Lagoon, October 15, 2022, with inset map showing kokanee spawning in cleaned redd area

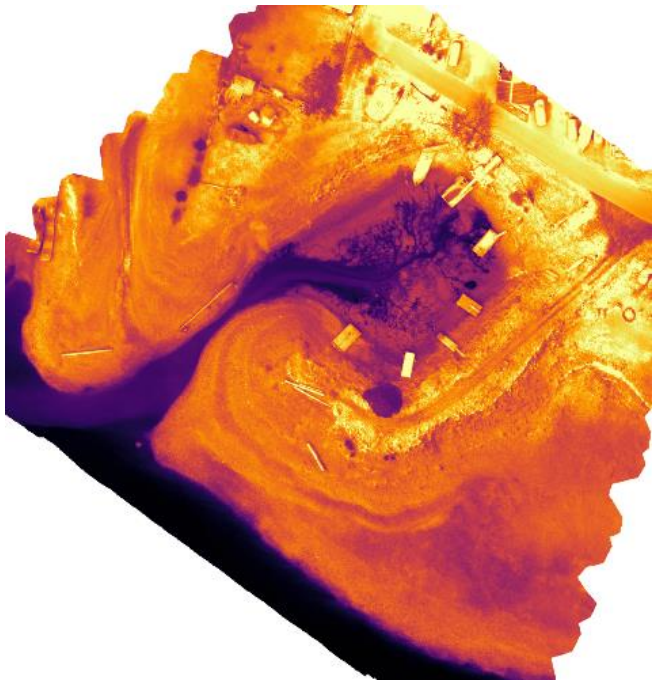

Figure 27: Thermal imagery of Bonaventure Lagoon, April 6, 2023. Colder temperatures (e.g., groundwater, stream water, and lake water) shown in dark purple; warmer temperatures in orange.

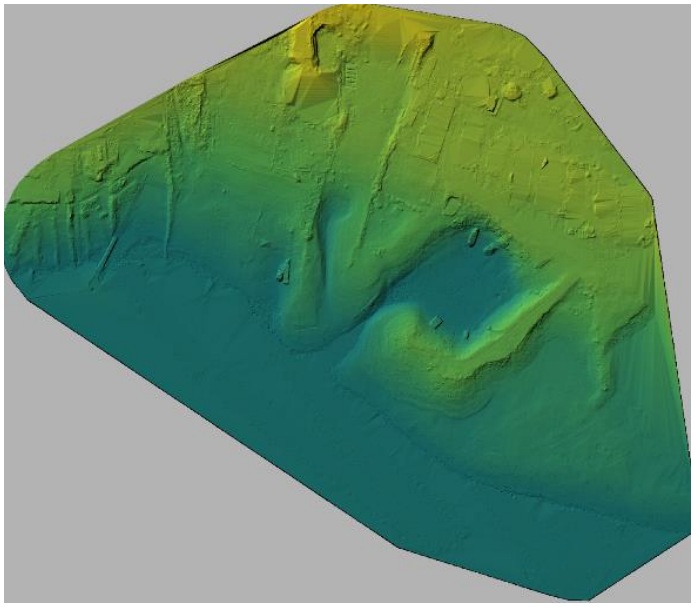

Figure 28: LiDAR imagery of Bonaventure Lagoon, April 6, 2023. Lower elevations (e.g., lake level) shown in turquoise; higher elevations in green/yellow.

Dewatered Redd Observations

During an informal dewatered redd survey at McDonald's Landing on March 30, 2023, we located six redd locations above the low water mark, some containing multiple redds. All redd locations contained live fry; only the two most southern redd locations contained a combination of live fry and dead eggs/fry (Figure 29). We also located a dewatered redd area at Bonaventure Lagoon (Figure 31). Environmental consultants recently performed detailed dewatered redd surveys at both sites on behalf of BC Hydro, FortisBC and Columbia Power Corporation. Results are available from them on request. Redds at both McDonald's Landing and Bonaventure were associated with locations of upwelling groundwater (dark purple streams in thermal imagery; Figure 30, Figure 31).

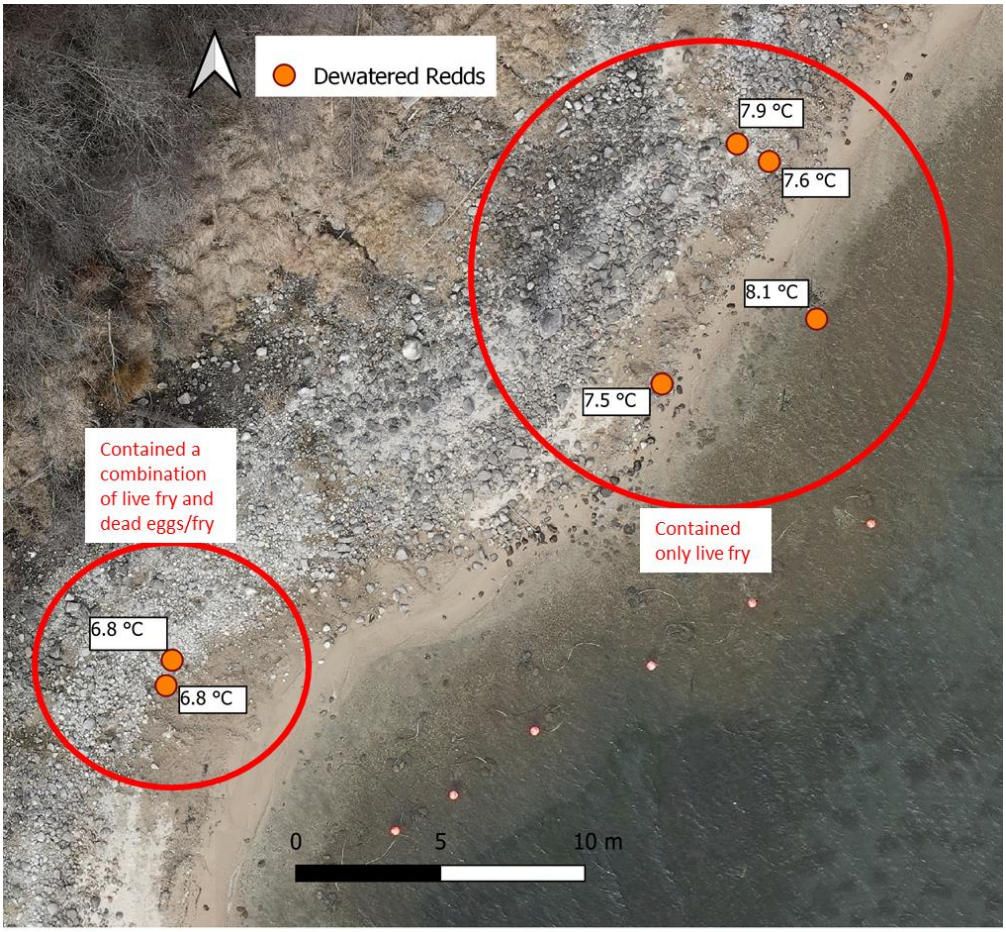

Figure 29: Contents and temperatures of dewatered redds at McDonald's Landing, as observed on March 30, 2023

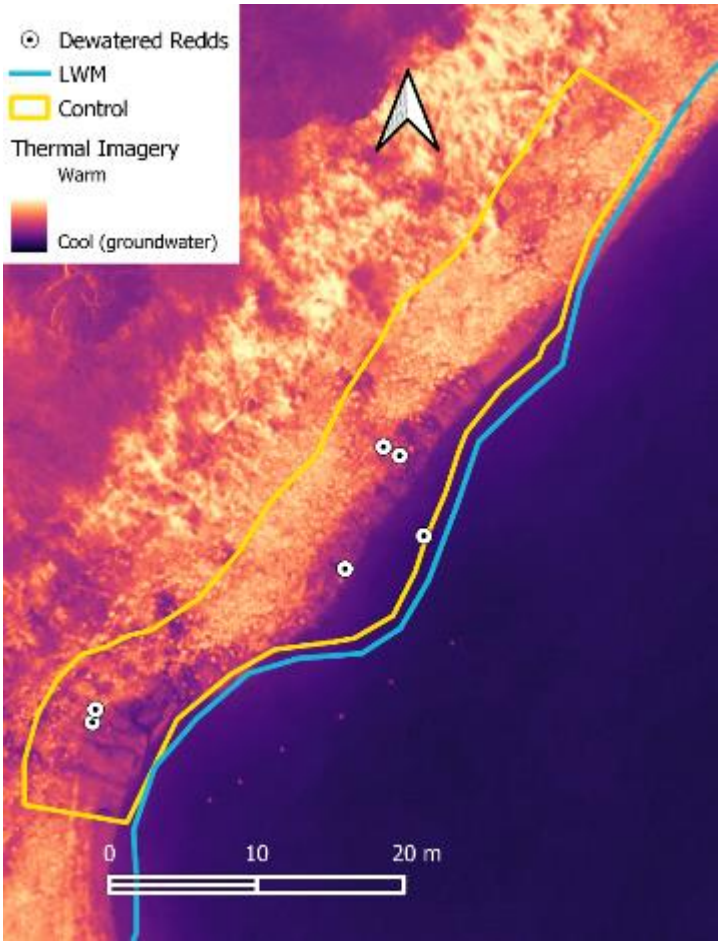

Figure 30: Association between redds (white dots) and upwelling groundwater (dark purple band and streams along the shoreline) at McDonald's Landing, spring 2023

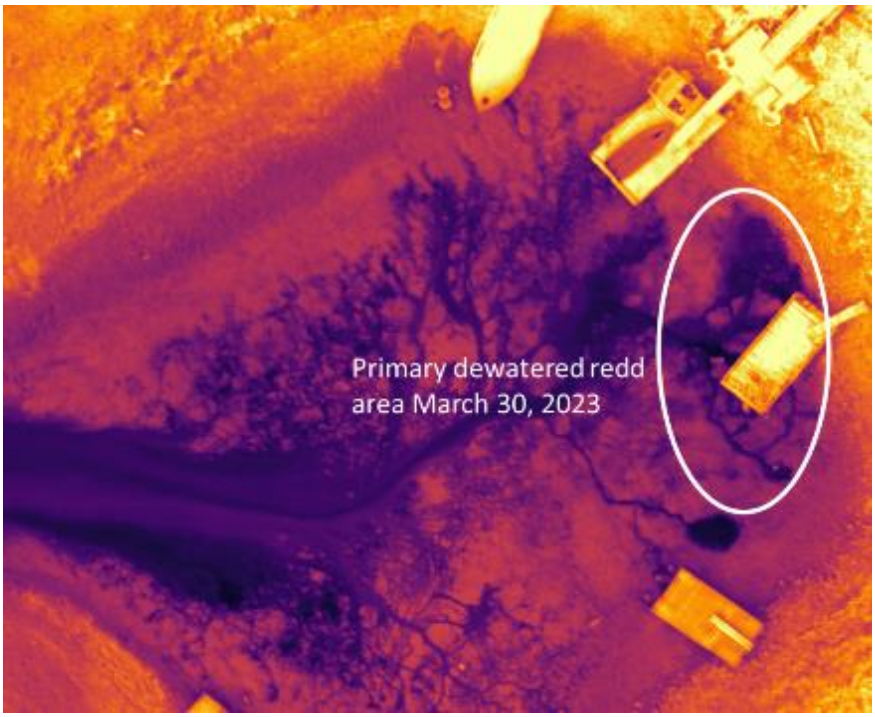

Figure 31: Association between redd area (white circle) and upwelling groundwater (dark purple streams) at Bonaventure Lagoon, spring 2023

Outreach & Education

Twenty-eight residents of the 6-mile area participated in our online project feedback survey, which went live June 2022. 78.57% of respondents (n = 22) supported the project, 65.38% (n = 17) felt there was adequate opportunity to provide feedback or get involved, and 51.85% (n = 14) said FoKLSS/the project helped increase their knowledge about shore-spawning kokanee salmon in Kootenay Lake.

Eighteen people attended the August 22, 2022 groundwater study presentation. Many participants expressed contentment with the presentation and said they valued the information shared. Connections were made between participants and good questions were asked.

Eleven people attended the kokanee monitoring workshop on October 15, 2022, including a range of people from local educators to college students to curious community members. The workshop was clearly engaging, as almost all participants stayed for the entire 2-hour duration, happily relocating from the first site (McDonald's Landing) to the second site (Bonaventure Lagoon). Some participants went on to volunteer on our other programs that fall, and multiple participants signed up to submit 2023 kokanee observations to FoKLSS.

Figure 32: October 15, 2022. Kokanee monitoring workshop participants learn about monitoring at Bonaventure Lagoon (potential future restoration area). Photo credit: Moriah Tanguay

The informational SSKS sign (Figure 33) was installed on January 20, 2023. The sign provides background on SSKS on Kootenay Lake, describes the research and restoration project, and discourages trampling/interference at the sensitive site.

Figure 33: SSKS informational sign installed January 20, 2023 at McDonald's Landing research site. Photo credit: Kayla Tillapaugh. Original file provided in Appendix (Figure A.1)

Link to shore-spawning kokanee educational video:

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

Links to 2022-2023 social media posts (below posts were also shared on Facebook):

Shore-spawning Kokanee Project Reel (February 1, 2022):
https://www.instagram.com/p/CZdJLtqPiOe/?fbclid=IwAR2aNPP0Ouys-MB7DcvUR-FsDU7ZsLjpOyYeP6PzPPVsUncm29vcsjrNHjs

The A Team of our Shore-Spawning Kokanee Restoration Project (February 18, 2022):
https://www.instagram.com/p/CaINTJuBpvY/?img_index=1

Research and Restore Event (August 15, 2022):
https://www.instagram.com/p/ChTYYd9Bw92/?img_index=1

Kokanee Salmon Workshop (September 21, 2022):
https://www.instagram.com/p/CiypzSUNzQd/?img_index=1

Kokanee Egg Capsule Retrieval (January 23, 2023):
https://www.instagram.com/p/CnyDO_ivcRM/?img_index=1

FWCP Funder Friday Feature (February 17, 2023):
https://www.instagram.com/p/CoybGtdBqVP/?img_index=1

Dewatered Redd Survey Reel (April 4, 2023): https://www.instagram.com/p/Cqoa5glpT4Z/?img_index=1

Links to 2022-23 blog posts about the project:

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/

Shore-Spawning Kokanee Habitat Restoration & Research Feedback Survey:
https://www.friendsofkootenaylake.ca/news/shore-spawning-kokanee-habitat-restoration-research-feedback-survey/

Social media posts on Facebook and Instagram relating to our Shore-Spawning Kokanee Habitat Restoration & Research Project reached **4,630** people between February 2022 and April 2023.

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

Our Shore-Spawning Kokanee Habitat Restoration & Research project at MacDonald's Landing Regional Park piloted restoring spawning habitat by depositing gravel below the low water mark to entice spawning kokanee to lay eggs where redds will not dewater. We found that (i) spawners congregated and created redds above and below the LWM, (ii) redd densities were highest closer to shore where there is more groundwater upwelling, and (iii) triploid eggs survived at similar rates in the natural and installed gravel.

Spawning kokanee numbers did not indicate a preference for either the natural or the installed gravel in the fall of 2022. 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). Spawners were however observed using the restored habitat for redd making across the entire restoration site, 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 pre- and post-restoration spawning behavior at this elevation.

Egg-to-fry survival rates of the triploid kokanee eggs were similar in the restored and control habitat, suggesting 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, kokanee eggs and fry would likely 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 to the necessary level of homeostasis required for egg-to-fry development.

Early data suggests that the lakebed pore water at McDonald's landing is strongly connected to the local groundwater and that vertical groundwater flow decreases as the lake level rises. The results of the groundwater study and connections to habitat restoration are still be analyzed and are expected to be published in Cameron Spooner's thesis in the fall of 2023.

In the areas in which one can visually identify groundwater presence both at Bonaventure Lagoon and McDonald's Landing, redds were identified. The dark, shadowed depressional areas at McDonald's Landing had the highest abundance of redds. At Bonaventure Lagoon, all the dark blue pools 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. LiDAR imagery was not fine-scale enough to allow the identification of redds on the landscape (small depressions in the substrate). However, the LiDAR data is still important for identifying the elevational gradients present at shore-spawning kokanee sites, and could potentially be used in combination with thermal imagery to pin-point other likely shore-spawning sites on the lake.

The majority of redds were formed above the LWM in areas of significant groundwater upwelling, indicating that groundwater is a better predictor of redd development than substrate. Redds contained

mostly live kokanee on March 30, 2023, indicating that if there is groundwater flow, kokanee fry located above the LWM can survive the low water period. Aerial photos were found to be useful for identifying areas of worked gravel, and potentially spawning fish in ideal conditions that allow crisp images of the lakebed. However, to obtain accurate redd and spawning fish counts, boat surveys would still be required.

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

Recommendations

Based on our findings, we suggest future projects explore the feasibility of combining the installation of gravel and the lowering of the nearshore elevation. This would create ideal spawning substrate at ideal elevations where there is significant groundwater upwelling. FoKLSS is currently assessing the feasibility of implementing such a restoration project at Bonaventure Lagoon. An alternative option would be to install gravel below the LWM and block spawners from spawning in natural habitat above the LWM (e.g., using exclusion fencing). We also recommend the continued use of drone imagery and groundwater measurements to understand SSKS habitat and potentially identify other spawning sites on the West Arm and elsewhere. Additionally, we suggest continued engagement with residents, waterfront property owners, and relevant agencies to build knowledge, interest, and political will surrounding shore-spawning kokanee conservation in the West Arm of Kootenay Lake.

Acknowledgments

Funding for the 2022-23 Shore-Spawning Kokanee Habitat Restoration & Research Project was provided by the Fish and Wildlife Compensation Program, FortisBC, and Columbia Basin Trust Resident Directed Grants.

Friends of Kootenay Lake gratefully acknowledges and thanks all the BC Ministry of Water, Land, and Resource Stewardship fish and wildlife staff and community members and volunteers who helped to make this project a success. Friends of Kootenay Lake would also like to thank the following organizations and individuals who gave their assistance, expertise, and/or in-kind support to the project:

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Saxon Bowick

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Above Sensing

BC Freshwater Fisheries Society

BC Hydro

BC Ministry Water, Land and Resource Stewardship

FortisBC

Kootenay Lake Sailing Association

Okanagan Nation Alliance

Regional District of Central Kootenay, Parks

University of BC Okanagan

Wood PLC

West Kootenay Boating Association

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3. Schleppe, J., and S. McPherson. 2022. Kootenay Lake Foreshore Integrated Management Planning. Prepared for Living Lakes Canada. Prepared by: Ecoscape Environmental Consultants Ltd., and Lotic Environmental Ltd. Available at: https://data.cbwaterhub.ca/dataset/a2d42d87-c804-4bc5-9679-204fd998280f/resource/b7772bcf-b050-413c-9970-c71d269983a0/download/kootenay-lake-fimp-2021_final_march-31-2022-1.pdf
4. 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

Figure A.1: SSKS informational sign posted on January 20, 2023 at the McDonald's Landing project site

Raw Data

Spawning

Table A.1: Sep 28–Oct 19 kokanee shore-spawning data from McDonald's Landing project site

Date	Start time (24 hour 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	Notes
2022-09-28	8:30:00	Sunny, warm, no wind, calm water	531.42	4	3	2	3	1	0	NA	4 redd areas suspected (all above LWM), 2 that might already contain eggs
2022-10-04	8:30:00	Sunny, clear, calm	531.43	6	29	13	23	8	0	19	Only counted redds once. All redds were observed above LWM
2022-10-12	9:00:00	Sunny with choppy water (very poor visibility)	531.45	6	39	18	24	7	2	35	Signs of new redd area (cleaned area)
2022-10-15	13:00:00	Sunny, calm	531.45	1	35	NA	8	NA	NA	NA	Count conducted later than usual, and following boat-based kokanee counting workshop. Fish potentially moving around more than usual
2022-10-19	8:30:00	Calm	531.45	3	23	12	9	NA	4	65	50 redds above LWM, 15 below LWM

Egg Capsules

Table A.2: Oct 28, 2022. Egg capsule installation data from McDonald's Landing project site

Date	2022-10-28	**Lake Level**	531.45 m	
Egg tube ID	**Water Depth (cm)**	**Time of insertion**	**Number of eggs**	**GPS data points**
1	120	11:55	112	1
2	150	12:00	205	2
3	146	12:04	204	3
4	145	12:09	190	4
5	97	12:14	210	5
6	172	12:21	187	6
7	168	12:23	200	7
8	180	12:26	198	8
9	165	12:28	213	9
10	170	12:32	337	10

Table A.3: Jan 20, 2023. Egg capsule removal data from McDonald's Landing project site

Date	2023-01-20	**Lake Level**	531.17 m (Nelson)					
Egg Tube ID	**Area**	**Water Depth (cm)**	**Time of Removal**	**Logger ID**	**Alevin Count**	**Fry Count**	**Fungus (y/n)**	**Notes**
1	Control	91	10:46	1	2	0	N	No inverts, less rotten than 2. Roughly 50 eggs
2	Control	122	10:46	2	0	0	Y	Snail on outside.192 eggs (incl 2 squished into mesh). Sandier, more clogged than 1
3	Control	122	10:59	3	1	0	N	Very Sandy. Few inverts. 83 eggs
4	Control	91	10:56	4	1	0	Y	1 live alevin. 159 eggs
5	Control	76	10:54	5	0	0	Y	1 live alevin. Clean. 141 eggs (quite an accurate count)
6	Restored	152	10:53	6	0	0	Y	153 eggs. Lots of snails
7	Restored	152	10:52	7	0	0	Y	Very clean. 149 eggs. Very few inverts
8	Restored	122	10:52	8	0	0	N	Clean. 169 eggs
9	Restored	122	10:50	9	0	0	N	Taupe worm on outside. Very clean. Worm inside. 85 eggs
10	Restored	122	10:49	10	0	0	N	Clean. 283 eggs

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

Egg Tube ID	Number of Eggs Installed	Number of eggs Remaining	Percent Mortality	Percent Escapement
1	112	44	39	61
2	205	196	96	4
3	204	79	39	61
4	190	174	92	8
5	210	141	67	33
6	187	161	86	14
7	200	161	81	20
8	198	171	86	14
9	213	101	47	53
10	337	307	91	9

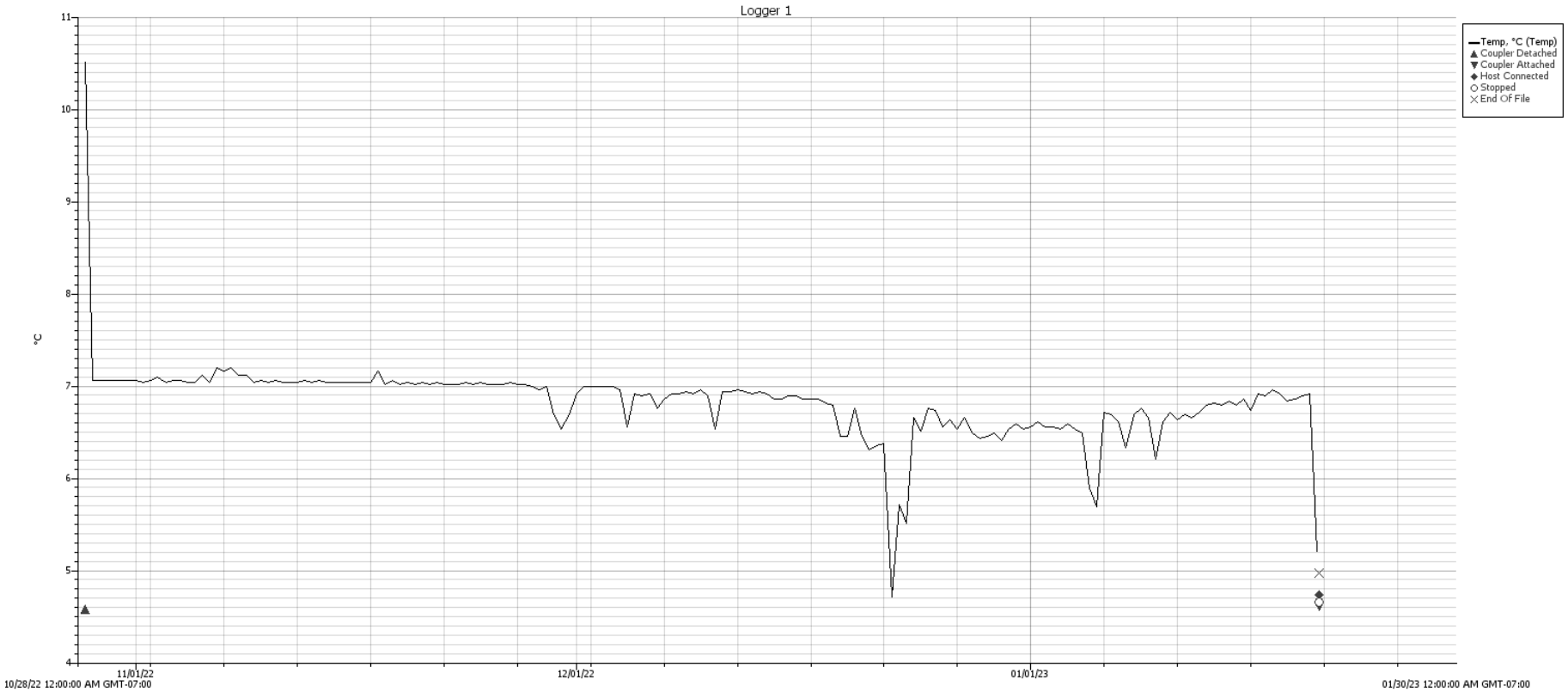

Figure A.2: Temperature data from Egg Capsule 1 covering Oct 28, 2022 to Jan 20, 2023

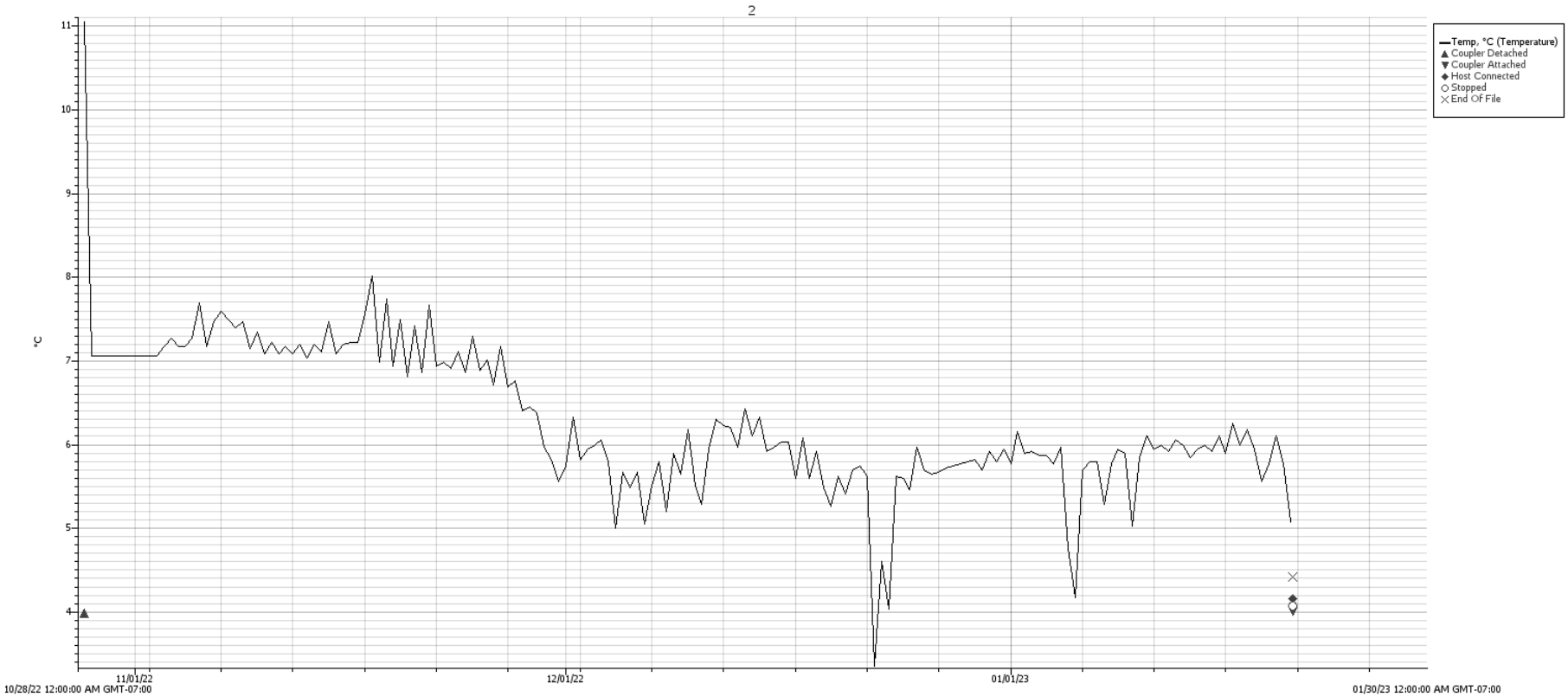

Figure A.3: Temperature data from Egg Capsule 2 covering Oct 28, 2022 to Jan 20, 2023

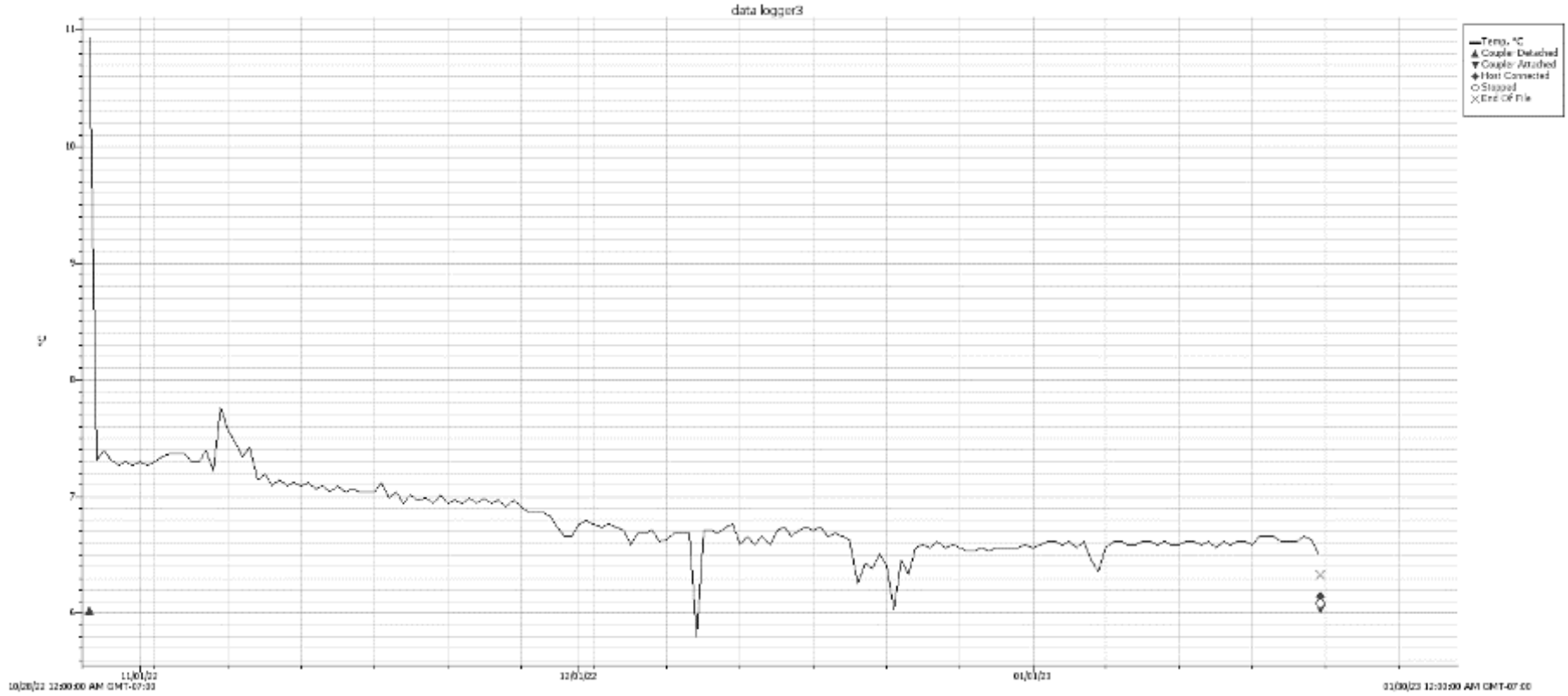

Figure A.4: Temperature data from Egg Capsule 3 covering Oct 28, 2022 to Jan 20, 2023

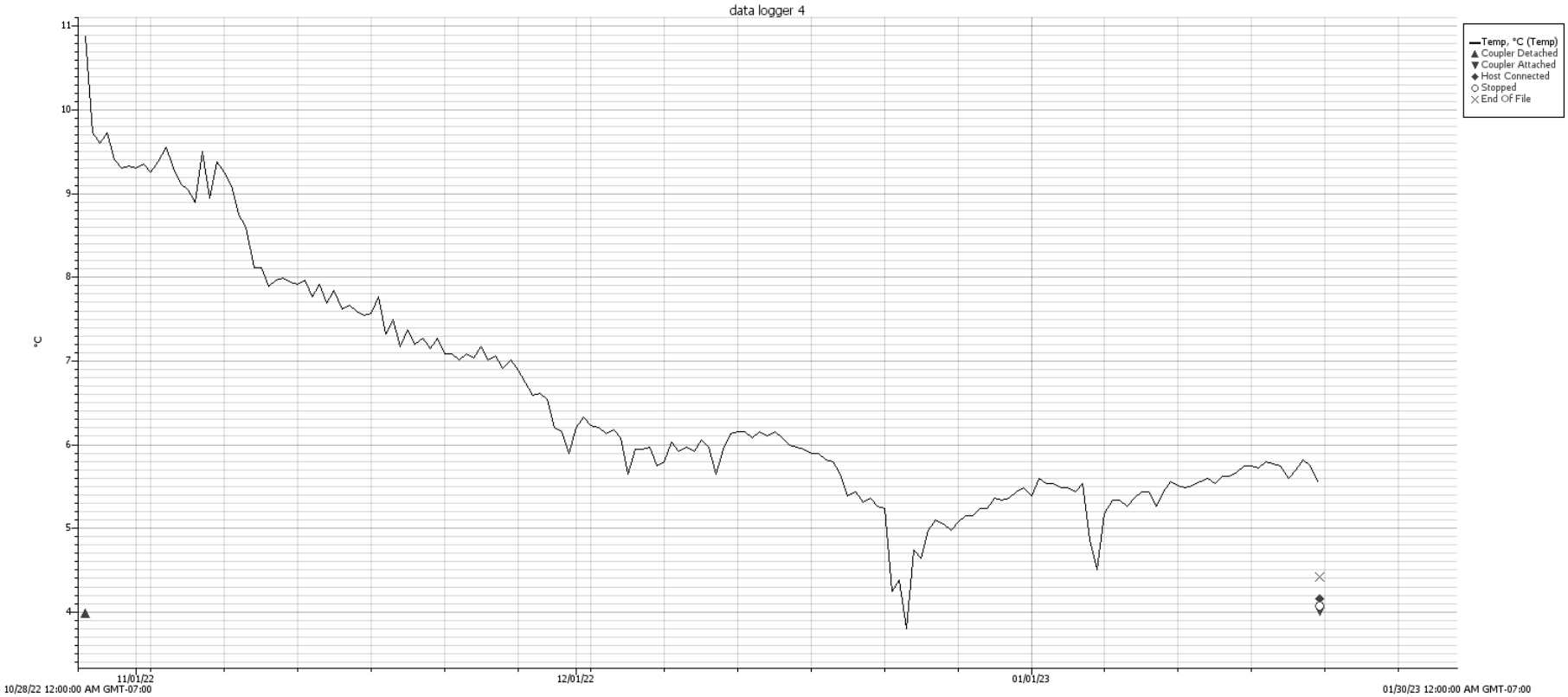

Figure A.5: Temperature data from Egg Capsule 4 covering Oct 28, 2022 to Jan 20, 2023

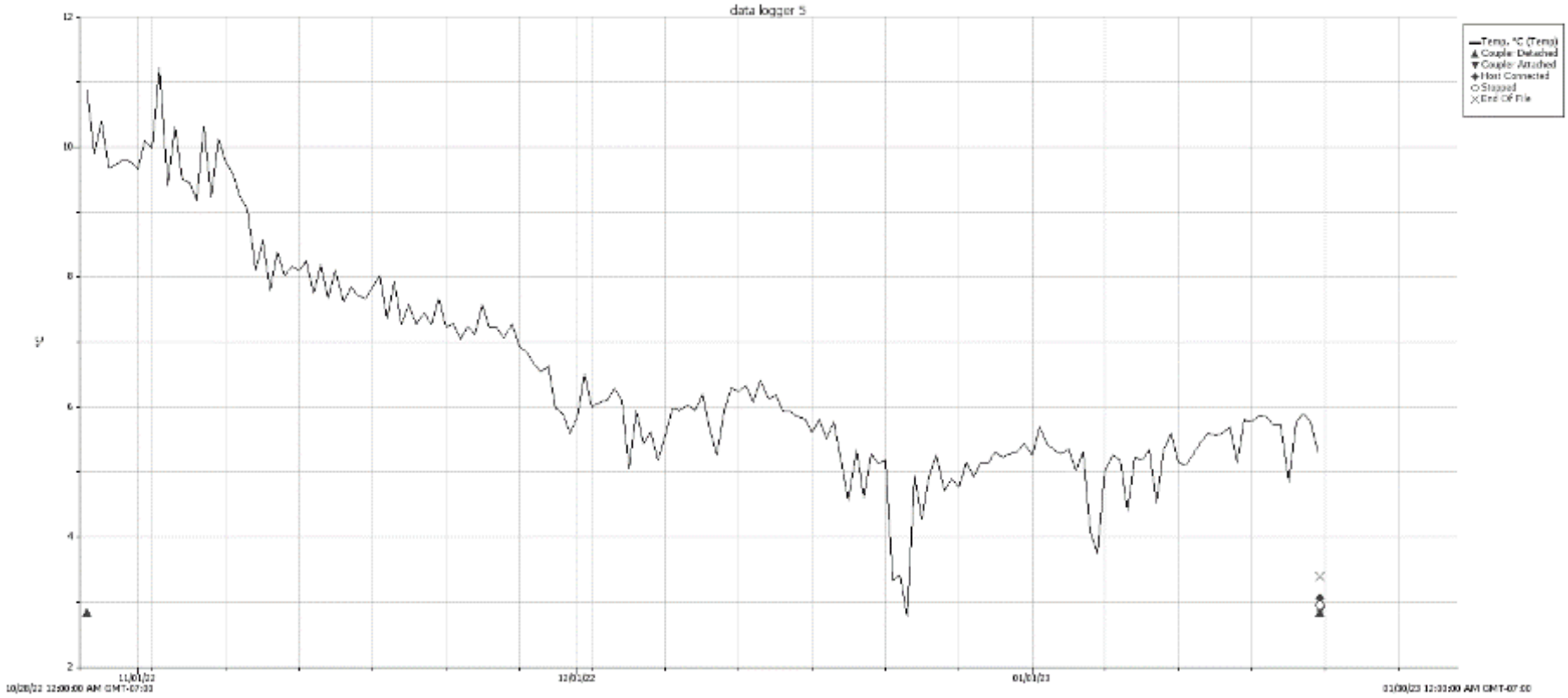

Figure A.6: Temperature data from Egg Capsule 5 covering Oct 28, 2022 to Jan 20, 2023

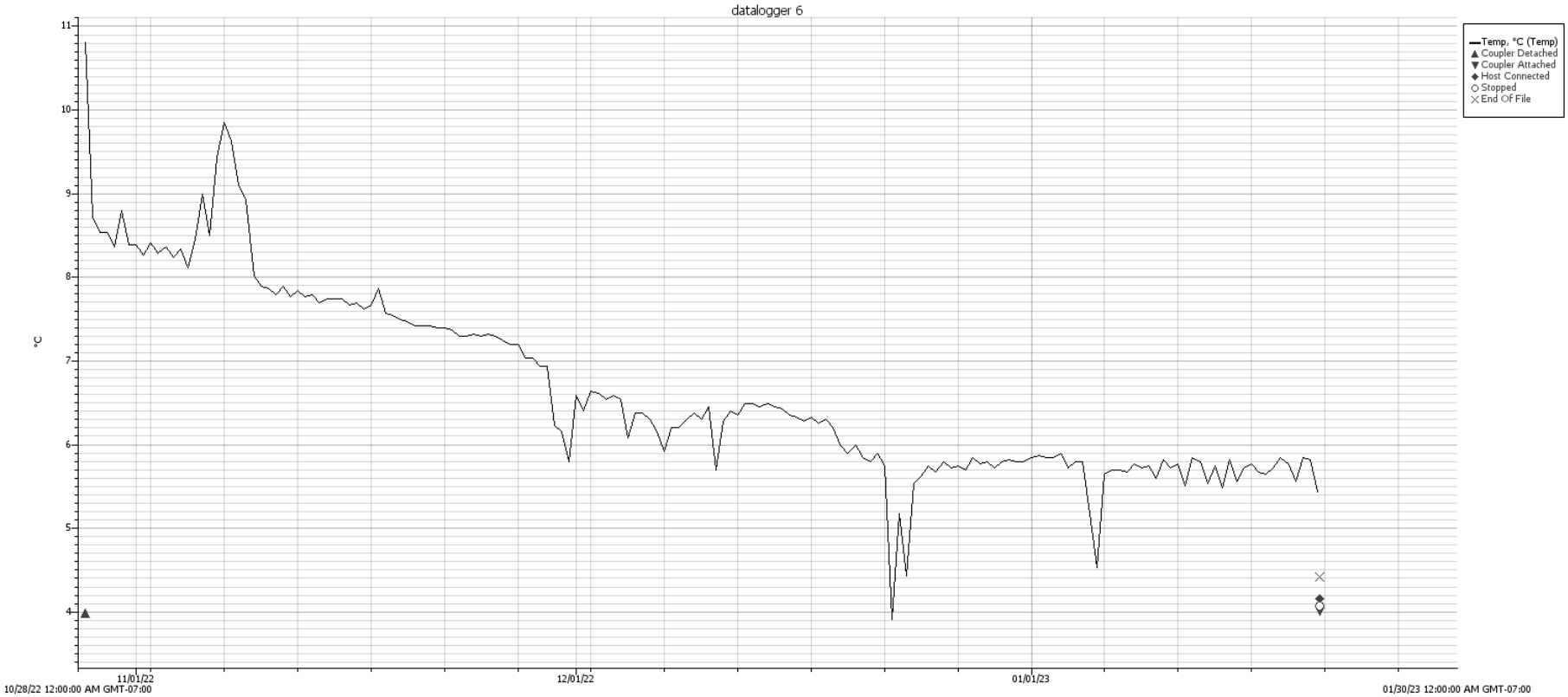

Figure A.7: Temperature data from Egg Capsule 6 covering Oct 28, 2022 to Jan 20, 2023

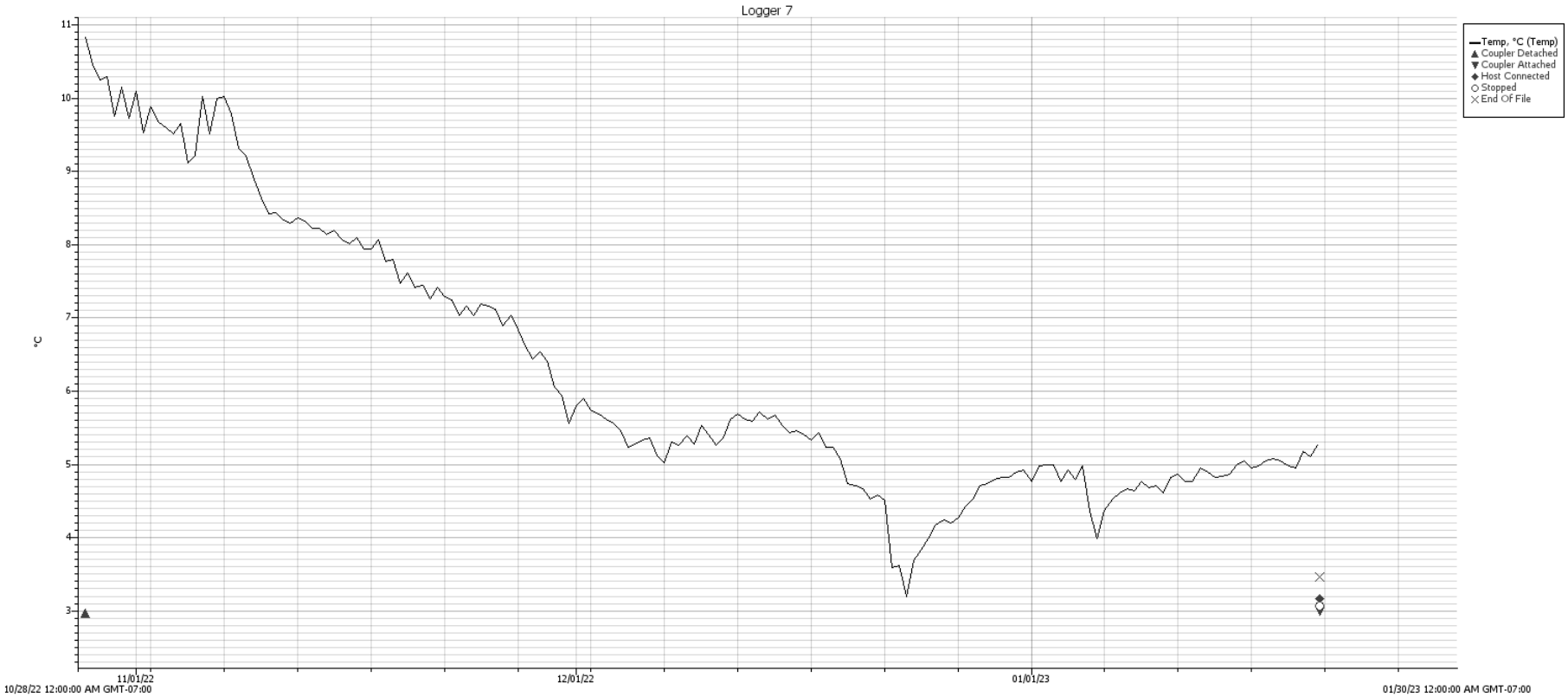

Figure A.8: Temperature data from Egg Capsule 7 covering Oct 28, 2022 to Jan 20, 2023

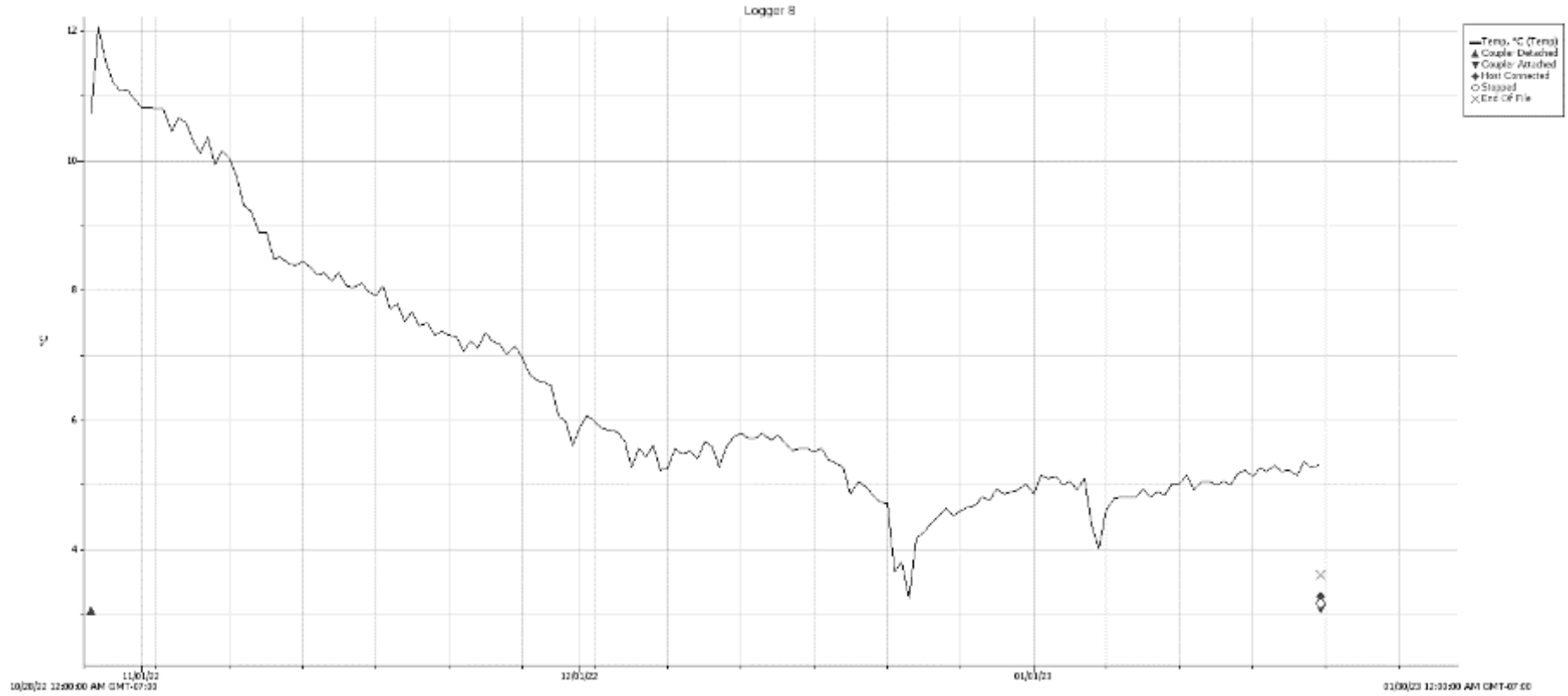

Figure A.9: Temperature data from Egg Capsule 8 covering Oct 28, 2022 to Jan 20, 2023

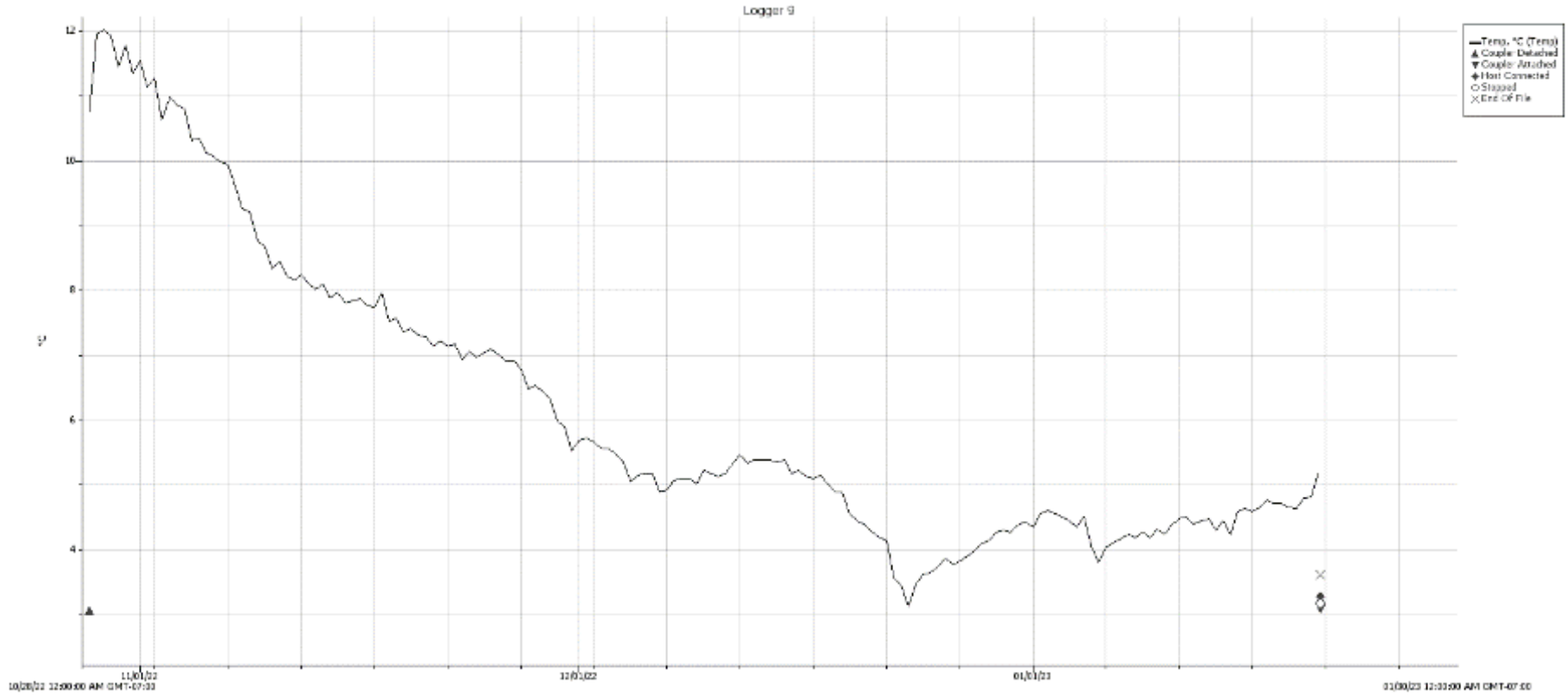

Figure A.10: Temperature data from Egg Capsule 9 covering Oct 28, 2022 to Jan 20, 2023

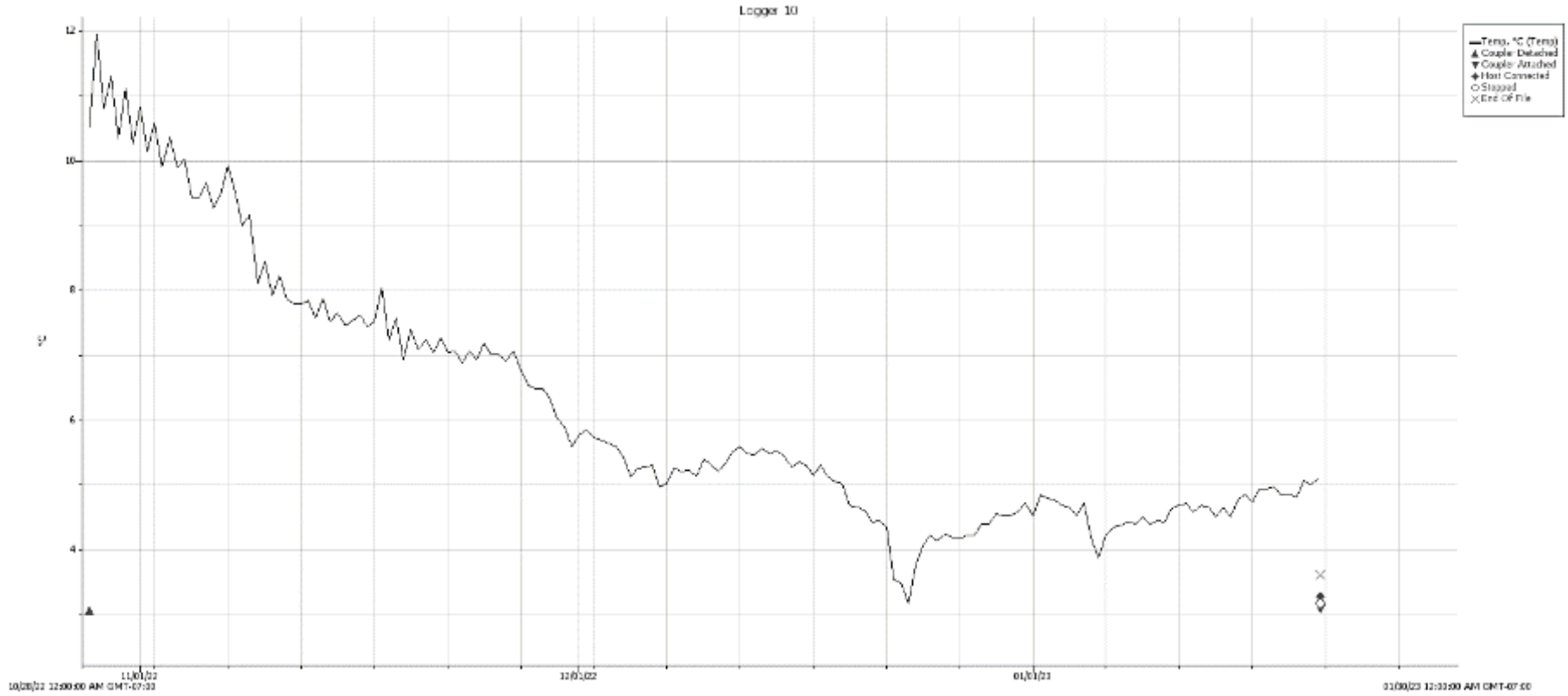

Figure A.11: Temperature data from Egg Capsule 10 covering Oct 28, 2022 to Jan 20, 2023

Table A.5: Water temperature summary for egg capsules installed at McDonald's Landing project site

Statistic	Temperature (°C)
MIN	2.77
MAX	12.07
MEAN	6.48
MEDIAN	6.41