Nechako River Substrate Monitoring Program
2022 Design and Installation Report

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EXECUTIVE SUMMARY

The Nechako River White Sturgeon (*Acipenser transmontanus*) population has been undergoing near complete recruitment failure since around 1967. This project was commissioned by the Ministry of Environment and Climate Change Strategy to evaluate the rate of sedimentation and “cleaning” (i.e., winnowing) of natural substrates within the critical spawning reach at Vanderhoof, BC. This work is intended to inform future habitat restoration measures, including both direct (e.g., gravel addition) and indirect (e.g., flow manipulation) approaches towards restoring natural recruitment.

This study used three temperature sensor arrays to remotely monitor sediment infiltration based on the hot wire principle (Zimmermann and Lapointe, 2005). A fixed underwater camera was also installed near the sensor arrays to allow for continuous, real-time observations of local substrate conditions and sediment transport. While both the sensor arrays and underwater camera were designed as passive monitoring systems (i.e., capable of monitoring over relatively long periods of time), the scope for this study was to monitor changes in substrate composition over an “initial period”, defined as the period immediately prior to and during the 2022 spawning season (early-April to early-June). Additional analysis to evaluate longer-term trends in sedimentation is not within the current scope but will be considered as part of future work.

The main findings from the temperature sensor arrays during the initial monitoring period (early-April to early-June of 2022) are summarized below:

- The Offshore Sensor Array (Grid 1378) took the least amount of time to begin infilling, as an increase in the measured heat signal was detected only two days after deployment. Interestingly, the magnitude of the heat pulses measured by all five sensors of the Offshore Sensor Array (Grid 1378) decreased abruptly between 20:30 on May 15th and 00:30 on May 16th, 2022. This does not appear to be due to heater malfunction or human disturbance, but rather may reflect some interstitial cleaning. That said, the heat signals began to progressively increase shortly after this event, suggesting persistent and continued sedimentation at this location.
- The Inshore Sensor Array (Grid 1377) took the longest amount of time to begin infilling, as an increase in the measured heat signal was detected approximately 27 days after deployment. However, all five sensors on the Inshore Sensor Array (Grid 1377) began measuring an increased heat signal only three days later, suggesting that the entire frame began to infill relatively quickly once sedimentation began. This is consistent with a sheet or dune of sand bedload moving over the area.
- The magnitude of the heat pulses measured by the Offshore Sensor Array (Grid 1378) (Sensors 1 through 4) were generally comparable to those measured by the Inshore Sensor Array (Grid 1377), while the magnitude of the heat signals measured by the Middle Sensor Array (Grid 1379) were generally lower. While preliminary, these results suggest that the amount of sedimentation may have been lower at the Middle Sensor Array (Grid 1379) during the initial monitoring period (i.e., the 2022 spawning period).

A review of the underwater imagery collected during the initial monitoring period showed the following:

- Medium to coarse gravels appeared to be intermittently mobilized, suggesting that near-threshold/partial mobility conditions are common (at least for flows below 300 m^3/s). While the framework gravels were rarely displaced for long downstream distances, the clasts often showed *in-situ* “vibration”, which may have important implications regarding the release of infilled fines.

- Small gravels and granules appeared to be frequently mobilized, with nearly continuous, partial mobility of the grains.
- No sheets of sand bedload were observed to be moving over the substrate during the 2022 spawning period (within the camera’s field-of-view).
- Periodic cycles of local aggradation and degradation occurred with associated increases/decreases in fine gravels and granules. While local deposits of fine gravels may not contain a large amount of surficial sand, these grains were highly mobile, which may limit the quality of incubation habitat (too unstable to retain larvae).
- Increased scour and winnowing of the gravel bed adjacent to camera mount resulted in local bed lowering and continuous sloughing/raveling of medium to coarse gravels towards the camera mount. The winnowed gravel appeared to create a surficial layer of clean gravel with no infilled fines to a depth of several gravels thick. This observation may provide insight into the potential application of restoration measures (e.g., induced winnowing).

Based on these findings, NHC recommends that the following tasks be considered as part of future research and restoration activities intended to advance the recovery effort:

- Continue monitoring local substrate conditions in 2022/2023 using the fixed underwater camera; however, the camera will need to be cleaned and/or repositioned (fall of 2022).
- Given that visual observations of the bed were only limited by high turbidity over a brief period, the use of several fixed underwater cameras may be considered as a monitoring tool for the 2023 spawning period.
- Continue monitoring sedimentation using the temperature sensor arrays (2022/2023), especially given that relatively high flows are forecasted for 2022. Leaving the arrays in place throughout this period would provide an indication as to whether an increase in discharge may result in increased winnowing of infilled gravels.
- Temperature sensor arrays may also be used in future studies to monitor infilling rates at various locations within the spawning reach, as well as to monitor the quality of previously restored habitats (i.e., post-cleaning).
- Additional data analyses should be completed in 2022/2023 to gain further insight into the process of substrate infilling both during the initial monitoring period and moving forward. For example, additional data processing may be used to remove the background trend in water temperature and evaluate how the magnitude of the heat signal and the duration required for heating/cooling changed over time at each sensor. When related to time of year and flow conditions, this may provide information on how these environmental variables influence the rate and timing of sediment transport.
- Additional analyses may also be completed to generate order-of-magnitude volumetric estimates of sediment transport. For example, the porosity of the clean gravel mixture placed in the sensor arrays may be used to estimate the volume of sediment required to produce the observed heat signal. While approximate, these estimates may be useful when considering potential future restoration strategies (e.g., sediment capture basin).

- Collect underwater images of the grids to see the condition of the interstitial substrate and relate that to the maximum temperature recorded by each grid.

TABLE OF CONTENTS

LIST OF TABLES IN TEXT

LIST OF FIGURES IN TEXT

LIST OF PHOTOS IN TEXT

1 INTRODUCTION

The Nechako River White Sturgeon (*Acipenser transmontanus*) population has undergone near complete recruitment failure since around 1967 (McAdam et al., 2005). The Nechako White Sturgeon Recovery Initiative (NWSRI) was established in response to the reproductive decline to support the recovery of this population. The Vanderhoof reach of the Nechako River (Figure 1.1) represents a critical spawning reach for white sturgeon and has been the focus of numerous research and restoration projects over the past two decades (see NHC, 2022).

This project was commissioned by the Ministry of Environment and Climate Change Strategy (hereafter referred to as “the Ministry”) under the NWSRI. The aim of the project was to evaluate the rate of sedimentation and “cleaning” (i.e., winnowing) of natural substrates over time, and across a range of flow conditions. This work is intended to inform future habitat restoration measures, including both direct (e.g., gravel addition) and indirect (e.g., flow manipulation) approaches towards restoring natural recruitment.

DATA SOURCES: ORTHOPHOTO COLLECTED FOR MFLNRORD ON OCT. 3, 2017 AT A DISCHARGE OF 50 M3/S AT VANDERHOOF

Figure 1.1 Overview map of the critical White Sturgeon spawning reach on the Nechako River depicting key location references.

1.1 Scope

The scope for this project included the design, fabrication, and deployment of three temperature sensor arrays capable of monitoring substrate infilling continuously and remotely. The arrays were deployed within a 100 m radius from the Water Survey of Canada (WSC) Hut (Figure 1.1), where 120 Volt AC power, an existing metal enclosure and a cell modem were previously installed. The objective was to position the arrays laterally across the channel (e.g., 40 m, 60 m, and 80 m from the north bank) to monitor cross-channel differences in sediment transport, infilling, and (possibly) winnowing.

The second component of the study was to install a fixed underwater camera near the sensor arrays to visually monitor substrate mobility and bedload transport. The underwater camera was supplied by the Ministry, while NHC was tasked with designing a mount for it, ruggedizing cables, and scripting the image acquisition program. To retain value from previous work, an underwater camera mount built in 2019 (NHC, 2020) was reused for this project, although the housing was modified to reduce the potential for debris accumulation and fouling of the lens.

The sensor arrays were designed as a passive monitoring system capable of monitoring changes in substrate composition over relatively long periods of time (e.g., 6-12 months). The scope for this study was to monitor changes in substrate composition over an “initial period”, defined as the period immediately prior to and during the 2022 spawning season (early-April to early-June). Additional analysis to evaluate longer-term trends in sedimentation is not within the current scope but will be considered as part of future work.

1.2 Project Timeline

The initial timeline for this project was to deploy the arrays and underwater camera in October of 2021. However, unexpectedly high flows reaching 300 m^3/s at Vanderhoof[1] prevented the work from taking place due to logistical constraints and safety concerns. The fieldwork was therefore postponed to mid-November to target the period of low flow immediately before freeze-up. Unfortunately, this timing corresponded with the 2021 floods in southern BC, which resulted in the closure of all major transportation routes through the province. The fieldwork was ultimately rescheduled for mid-April of 2022, with the goal of monitoring habitat conditions during the 2022 spawning period (early-April to early-June).

2 INSTRUMENTATION

The following subsections of this report describe the design and development of the temperature sensor arrays (Section 2.1) and fixed underwater camera (Section 2.2).

2.1 Temperature Sensor Arrays

The temperature sensor arrays were designed to remotely monitor changes in sediment composition by measuring changes in heat transfer and retention within a given substrate. The following subsections describe the theoretical basis underlying the methodology (Section 2.1.1) as well as the actual design specifications used in this study (Section 2.1.2).

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[1] WSC gauge 08JC001 Nechako River at Vanderhoof.

2.1.1 Theoretical Basis

The design for the sensor arrays was based on an innovative method for monitoring infiltration originally presented by Zimmermann and Lapointe (2005). This technique uses the hot wire principle to monitor changes in substrate composition, where the amount of heat removed by a fluid can be related to the fluid's velocity. Sedimentation within interstitial voids would thus be expected to reduce the intergravel flow velocity, resulting in both an increase in the magnitude and (under ideal conditions) the duration of the heat pulse transferred downstream. Conversely, winnowing or removal of infilled fines would allow the intergravel flow to move more freely, thereby decreasing the magnitude and duration of the heat pulse. These principals can be used to monitor infilling because measured heat signal is related to the degree of sediment infilling, as heat is more readily transferred away from the temperature sensors if water flow is present (i.e., substrate is not infilled), while a greater amount of heat is retained if infilled.

2.1.2 Design Specifications

Each sensor array was mounted to a 1 m x 1 m x 0.1 m steel frame covered by ½" steel mesh (Photo 2.1). Each array contained one 45 Watt "U-shaped" heating element positioned at the upstream end of the frame, along with an array of five Campbell Scientific (CS225) temperature sensors positioned beneath and downstream of the heating element (Photo 2.2). The sensor arrays and data acquisition system were designed to be powered from a 24 Volt battery bank to allow for the system to be deployed remotely in future projects (i.e., independent of the WSC Hut). Finally, prior to deployment, each frame was filled with a mixture of clean gravels to a thickness of 7-10 cm (Photo 2.3); the grainsize distribution of the gravel mixture, as determined through photo-sieving analysis, is shown in Figure 2.1.

All temperature sensors and heating elements were wired to a Campbell Scientific CR800 Measurement and Control Datalogger located within a metal enclosure next to the WSC Hut (Figure 1.1). The datalogger was connected to a cellular modem, allowing for remote and real-time configuration of the instruments and data monitoring. Initially, the datalogger was configured to power each heating element for 30 minutes every hour; however, rapid infilling at one site (see Section 4) resulted in excessive heat retention using this heating frequency/interval (i.e., sensors were progressively getting warming and not returning to baseline/ambient temperature between heating intervals). To correct this, the script was modified five days after deployment to power the heating elements for 30 minutes once every four hours (starting 2022-04-18 at 08:00:00).

Photo 2.1 **Configuration of each sensor array prior to deployment.**

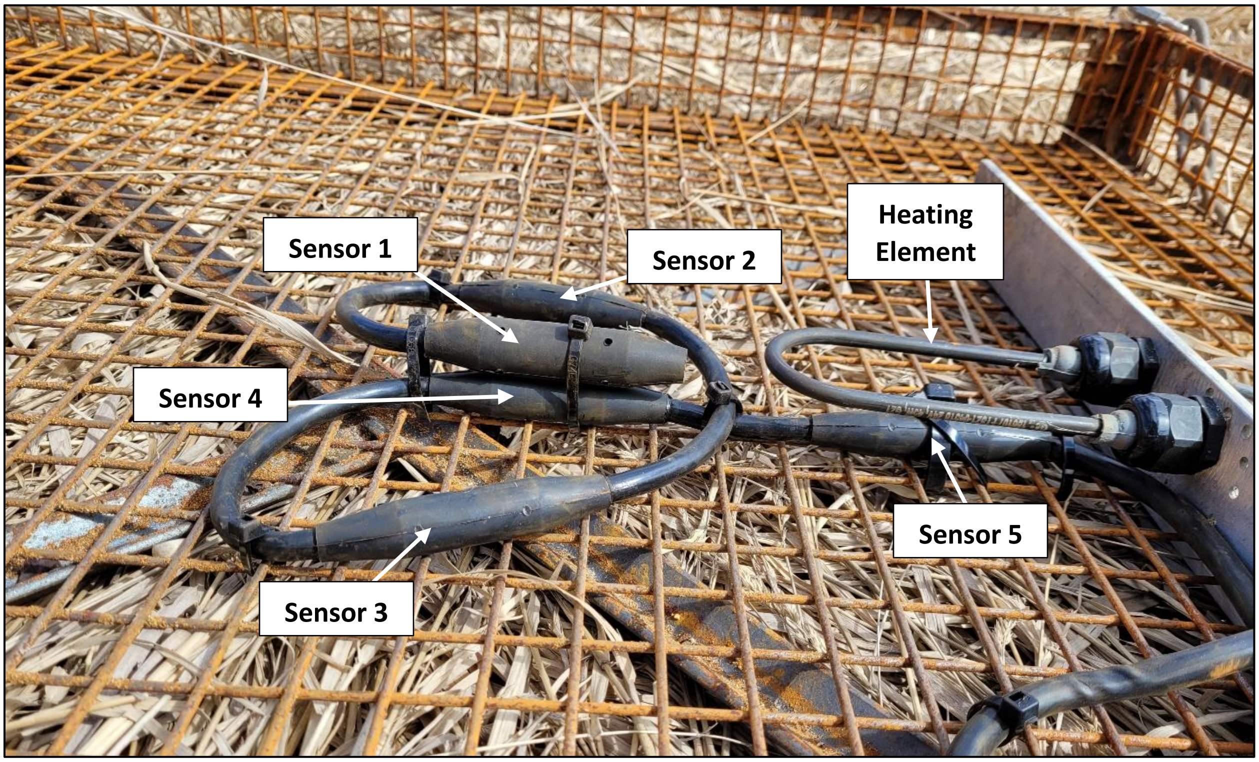


Photo 2.2 **Configuration of the heating element in relation to the five temperature nodes.**

Photo 2.3 Sensor array covered with clean gravel prior to deployment.

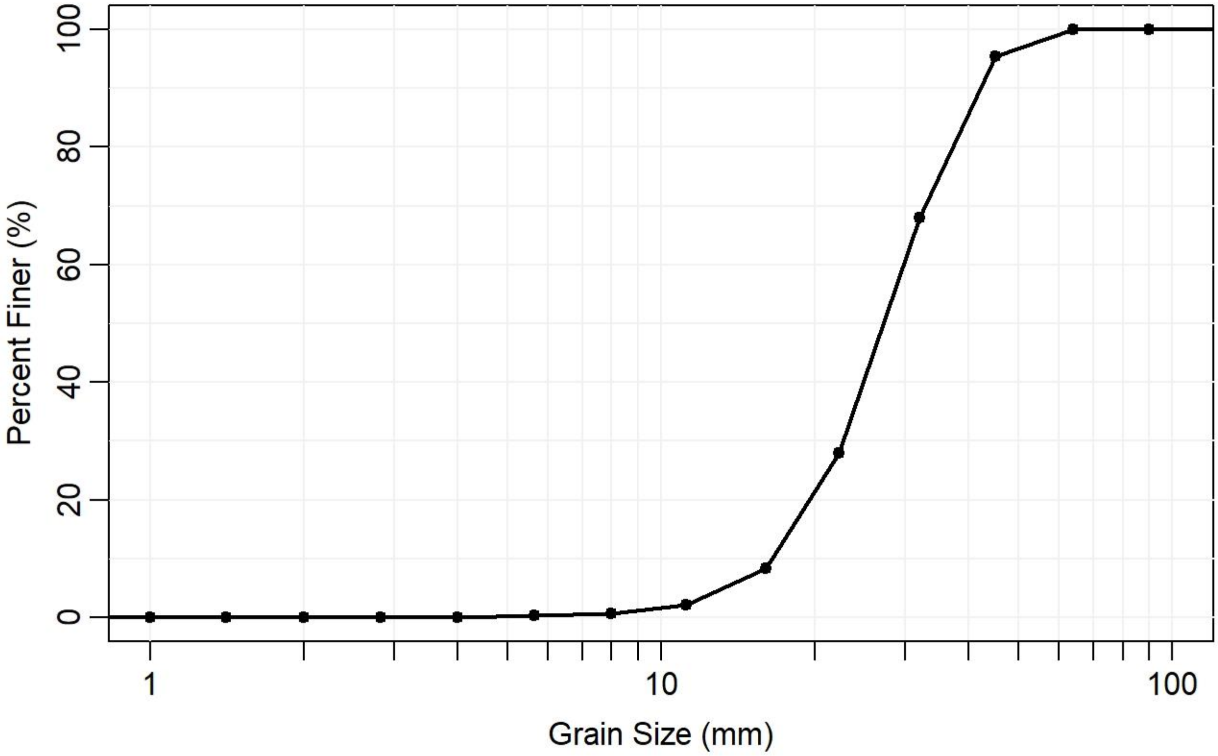


Figure 2.1 Grainsize distribution of the placed gravel determined through photo-sieving analysis.

2.2 Fixed Underwater Camera

As previously mentioned, an underwater camera was provided by the Ministry for use in this project. NHC was tasked with designing a mount for it, ruggedizing cables, developing the image acquisition system, and deploying the camera to visually monitor the riverbed during the 2022 spawning period (and potentially longer). A housing for the camera was made to reduce the potential for debris accumulation and fouling of the lens by fitting two plastic buckets around the lens (Photo 2.4). The underwater camera was connected to a field computer on-site, allowing for remote configuration of the camera and real-time viewing of the underwater imagery.

Photo 2.4 Plastic housing for the underwater camera installed to minimize risk of fouling due to debris accumulation.

3 DEPLOYMENT

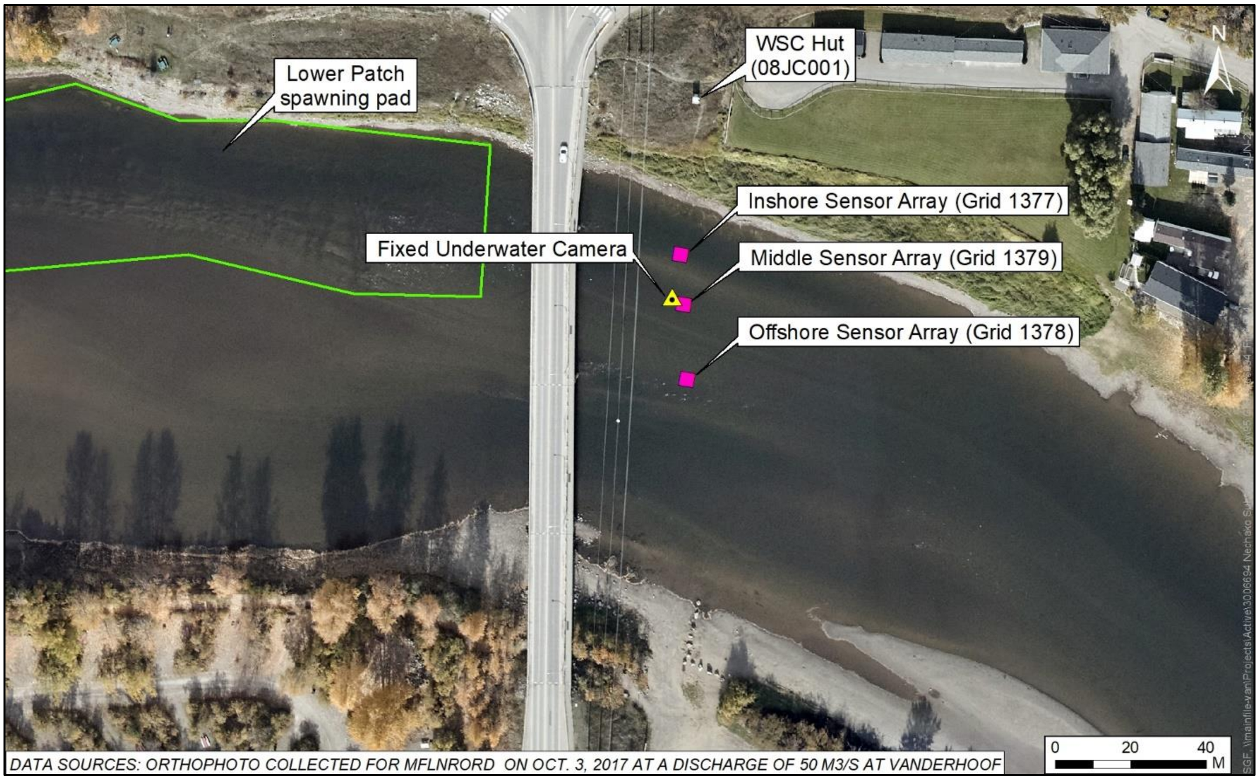
The temperature sensor arrays and fixed underwater camera were deployed on April 12th and 13th, 2022. The discharge at Vanderhoof was approximately 75 m^3/s at the time of deployment. The following subsections describe the site selection (Section 3.1) and methods (Section 3.2) used to deploy the instrumentation.

3.1 Site Selection

To select suitable monitoring locations, a mobile underwater camera was used to pre-screen the existing substrate within a 100 m radius of the WSC Hut (instruments were limited by 100 m cable length). The selected sites had a range of substrate types, as well as varying degrees of exposure to bedload transport. As shown on Figure 3.1, the three monitoring sites were positioned across a transect located approximately 30 m downstream of the Burrard Ave. Bridge. Across this transect, the temperature sensor arrays were deployed 40 m (“Inshore Sensor Array (Grid 1377)”), 55 m (“Middle Sensor Array (Grid 1379)”), and 75 m (“Offshore Sensor Array (Grid 1378)”) offshore from the WSC Hut.

The substrate around the Inshore Sensor Array (Grid 1377) generally consisted of medium to large gravel with trace small cobbles and minor sand between the larger clasts (Photo 3.1). Numerous mussels were also observed to be embedded within the substrate in this area. The substrate around the Middle Sensor Array (Grid 1379) generally consisted of small to medium gravel with some larger gravels, with a greater amount of granules and sand between the clasts (Photo 3.2). And finally, the substrate around the Offshore Sensor Array (Grid 1378) was generally composed of medium to large gravels with trace small cobbles, and had the greatest amount of surficial sand compared to the other two sites (Photo 3.3). While the offshore site was not directly exposed to sand bedload at the time of deployment, lanes of high sediment transport were observed approximately 5 m inshore from this sensor array despite the relatively low flows (75 m^3/s) (Photo 3.4).

The fixed underwater camera was deployed approximately 2 m inshore and 3 m upstream of the Middle Sensor Array (Grid 1379). The camera was installed facing the sensor array, allowing for the corner of the sensor array to be seen in the field-of-view during low to moderate turbidity.



DATA SOURCES: ORTHOPHOTO COLLECTED FOR MFLNRORD ON OCT. 3, 2017 AT A DISCHARGE OF 50 M3/S AT VANDERHOOF

Figure 3.1 Locations of the temperature sensor arrays and fixed underwater camera deployed on April 12-13, 2022.

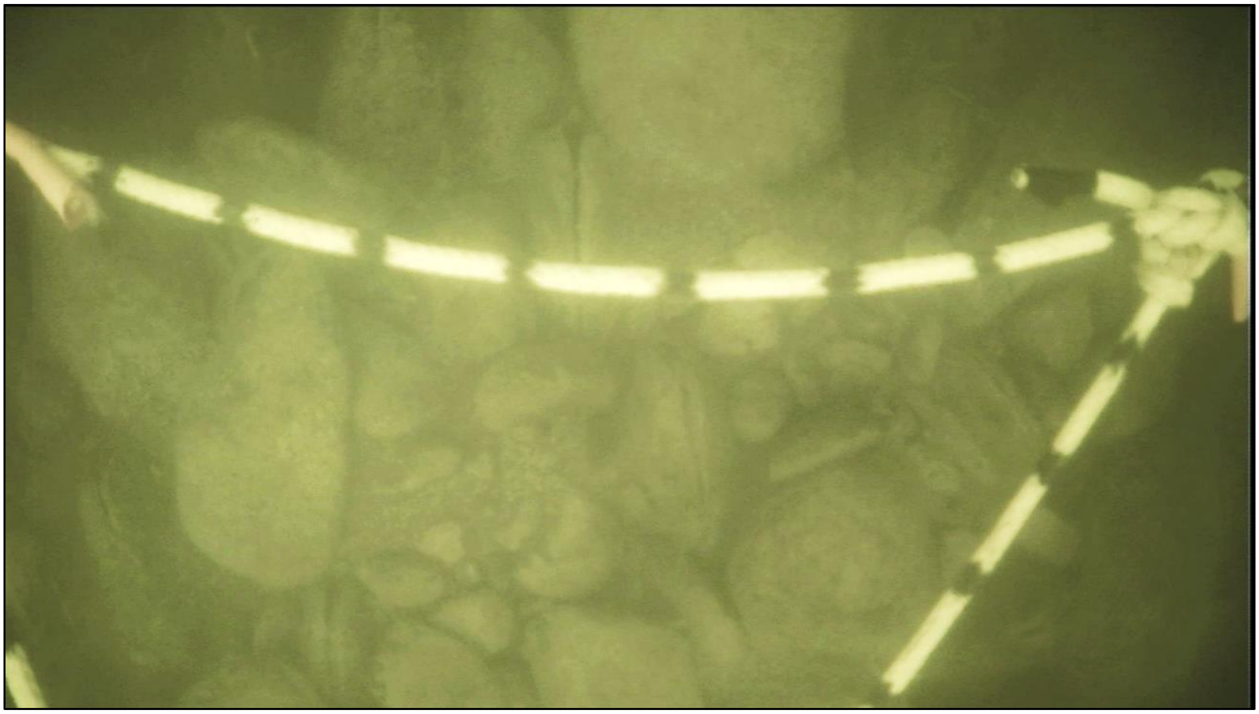


Photo 3.1 **Typical substrate observed around the Inshore Sensor Array (Grid 1377) immediately prior to deployment on April 12, 2022. Black lines on rope are 2.5 cm apart.**

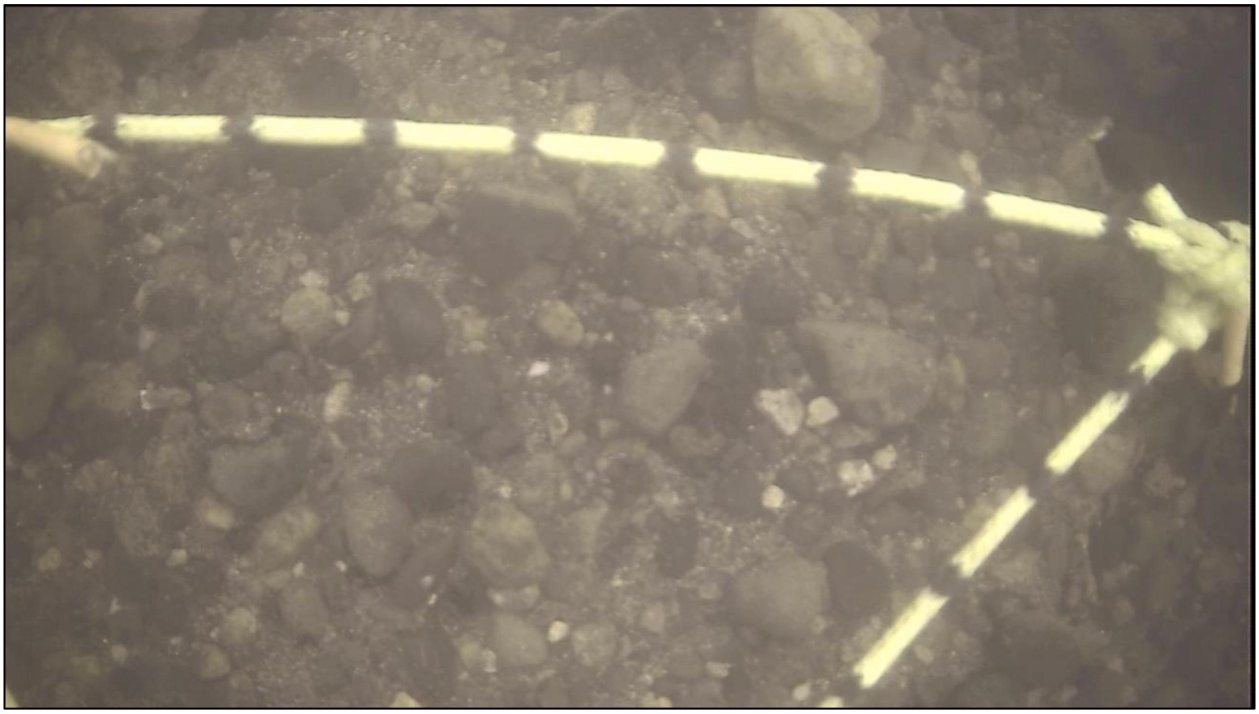


Photo 3.2 **Typical substrate observed around the Middle Sensor Array (Grid 1379) immediately prior to deployment on April 12, 2022.**

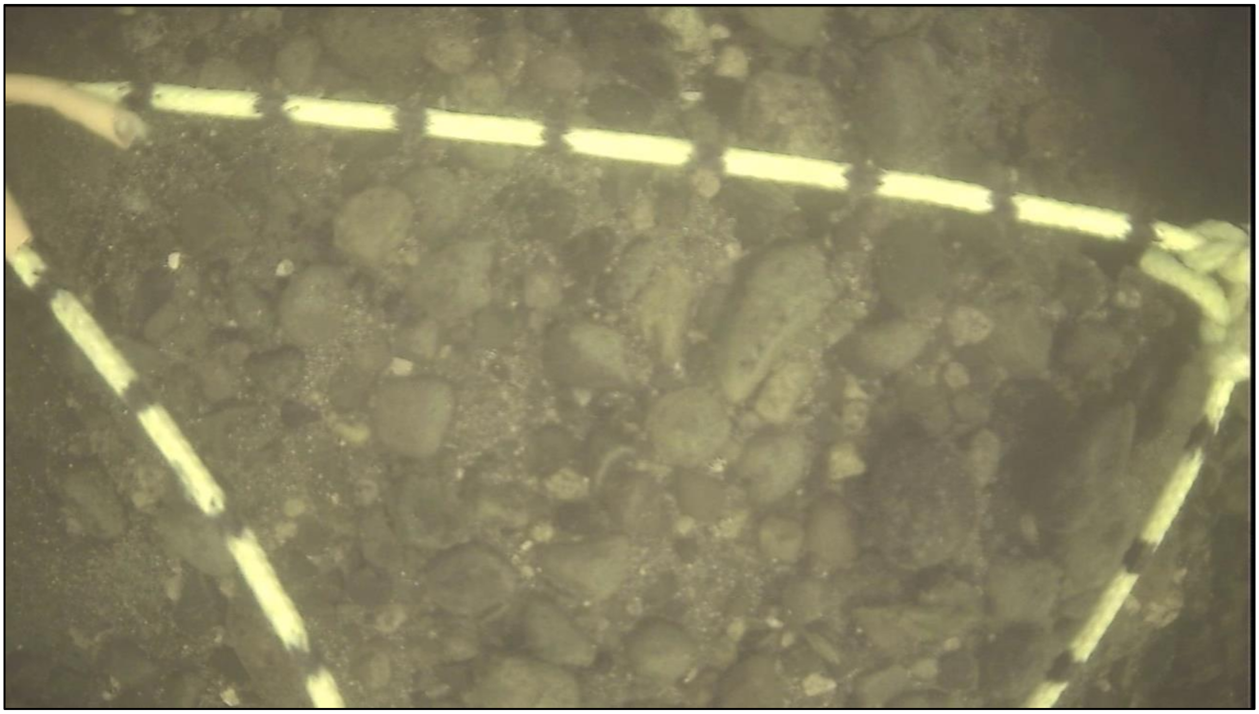


Photo 3.3 Typical substrate observed around the Offshore Sensor Array (Grid 1378) immediately prior to deployment on April 12, 2022.

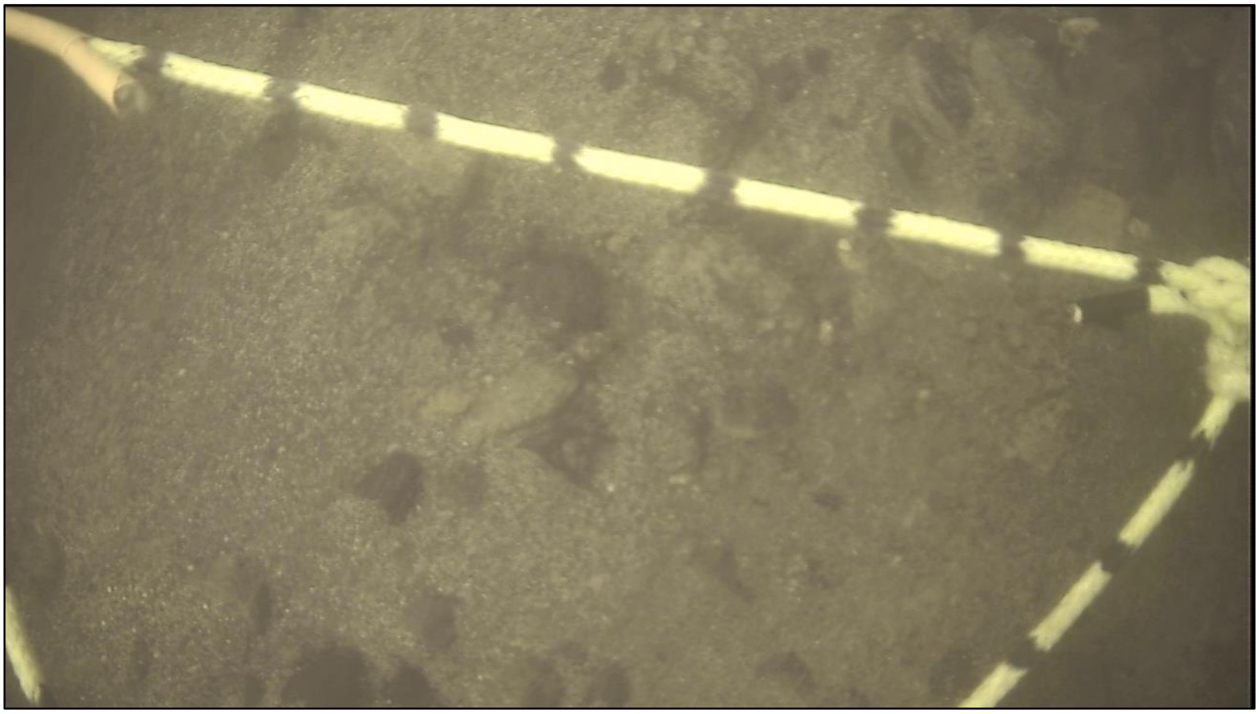


Photo 3.4 Lane of high sand transport observed approximately 5 m inshore from the Offshore Sensor Array (Grid 1378) on April 12, 2022 (75 m^3/s).

3.2 Deployment Method

The estimated weight of each temperature sensor array was approximately 130 kg (285 lbs) once loaded with clean gravel. To manage this weight safely using a small jetboat, a pontoon system was designed to position and deploy the sensor arrays (Photo 3.5). The sensor arrays were assembled and loaded with clean gravel from the north bank of the river near the WSC Hut, after which the pontoon system was tethered to the boat and ferried offshore to a pre-set anchoring system. Once anchored in place, the sensor arrays were slowly lowered to the bed using a pulley system attached to the pontoon. This method was used to deploy the Inshore Sensor Array (Grid 1377) first on April 12th, 2022, followed by the Middle Sensor Array (Grid 1379) and Offshore Sensor Array (Grid 1378) on April 13th, 2022.

Photo 3.5 Pontoon system used to lower the sensor arrays onto the riverbed.

4 MONITORING RESULTS DURING THE 2022 SPAWNING PERIOD

The following subsections describe initial observations and monitoring results obtained during the 2022 spawning period from both the temperature sensors and fixed underwater camera.

4.1 Temperature Sensor Arrays

All three temperature sensor arrays began monitoring changes in substrate condition immediately following deployment. The three sensor arrays showed that sedimentation occurred at different rates across the monitoring locations, but that ultimately, all sites became infilled with fine sediment over the course of the monitoring period. The different trends in sedimentation generally align with the substrate conditions observed in the vicinity of the three monitoring locations (Section 3.1) and are described in detail below.

4.1.1 Inshore Sensor Array (Grid 1377)

An increased response to heating was initially measured by Sensor 5 on May 9th, 2022, approximately 27 days after the sensor array was deployed. The increased heat response can be seen on Figure 4.1 as a sharp rise in temperature detected each time the heater is activated. Sensor 3 began to show an increased heat response shortly after on May 10th, followed by Sensor 4 on May 11th, and finally Sensors 1 and 2 on May 12th, 2022. After May 12th, all five sensors on Grid 1377 showed an increased heat response (Figure 4.2), with the greatest magnitude of heating observed for Sensor 5, Sensor 1, Sensor 3, Sensor 4, and Sensor 2, respectively (see Photo 2.2 for sensor arrangement). The increased heat response for all sensors persisted until the end of the initial monitoring period (June 1, 2022).

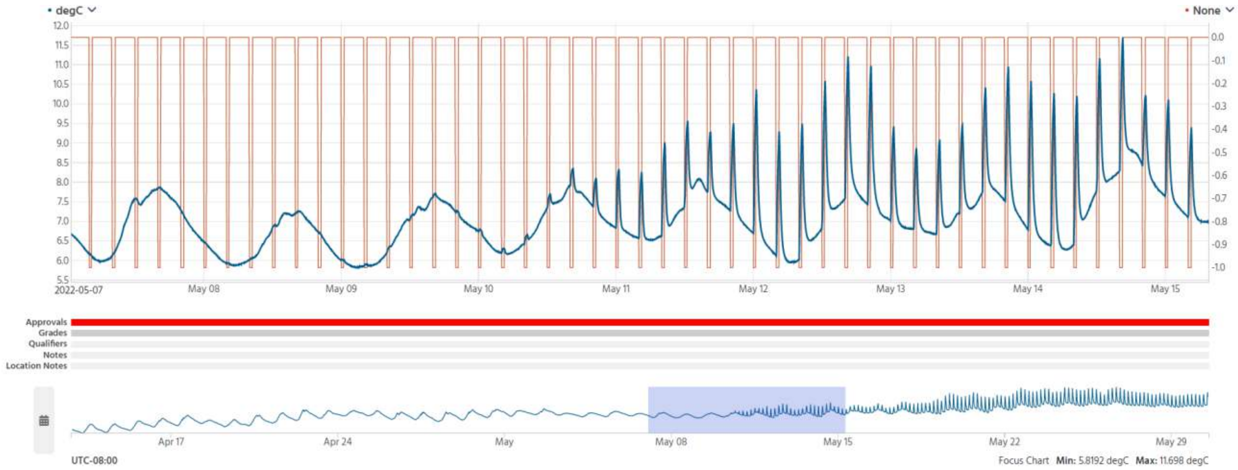


Figure 4.1 Sensor 5 on Grid 1377 showing increased response to heating starting on 2022-05-09; Sensor 5 shown in blue, Heater shown in orange (0 = OFF, -1 = ON). The lower panel of the figure highlights when the portion of the data shown in the upper panel occurred within the monitoring period (April 12 to June 1, 2022).

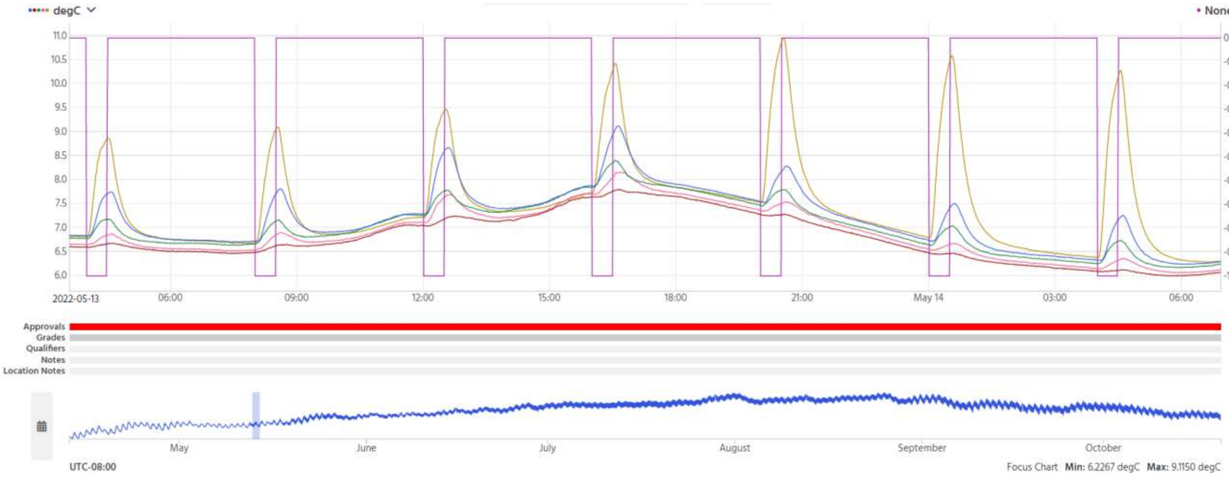


Figure 4.2 All five sensors on Grid 1377 showing a response to heating after 2022-05-12; Sensor 1 shown in blue, Sensor 2 shown in dark red, Sensor 3 shown in green, Sensor 4 shown in pink, Sensor 5 shown in dark yellow, and Heater shown in purple (0 = OFF, -1 = ON).

4.1.2 Middle Sensor Array (Grid 1379)

A low heat response was initially measured by Sensor 5 on April 18th, 2022, approximately 5 days after the sensor array was deployed. The heat response for Sensor 5 gradually increased over time, and by April 22nd, a distinct heat pulse was being measured by this sensor every time the heater was activated. Sensor 4 subsequently began to show a subdued response to the heating starting May 1st, 2022, while sensors 1, 2 and 3 began to show an initial response to the heating on May 4th.

The magnitude of the heat pulse measured by Sensor 5 was much greater than those measured by all other sensors on this grid (Figure 4.3; Figure 4.4), as well as all sensors on the Inshore Sensor Array (Grid 1377), reaching an increase in temperature of +10-12°C; by comparison, the maximum increase in temperature measured by Sensor 5 on the Inshore Sensor Array (Grid 1377) was typically around +5°C. Interestingly, the magnitudes of the heat pulses measured by the remaining four sensors on the Middle Sensor Array (Grid 1379) were all lower than those measured by the same sensors on the Inshore Sensor Array (Grid 1377), suggesting a greater amount of infilling may have occurred at the Inshore Sensor Array (Grid 1377), despite the greater amount of time required for initial infilling to occur.

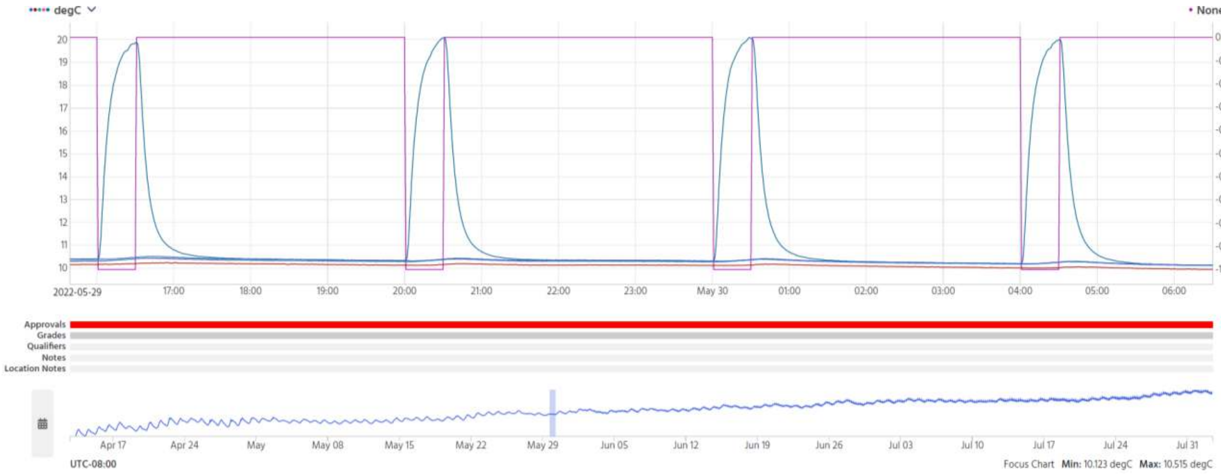


Figure 4.3 **All five sensors on Grid 1379 showing a response to heating by the end of the monitoring period (data period shown is from 2022-05-29 to 2022-05-30). The magnitude of the heat pulse measured by Sensor 5 (shown in blue) was much greater than that measured by all other sensors on this grid, making it difficult to see the heat pulse measured by the other sensors; see Figure 4.4 below for the heat response measured by Sensors 1 to 4 only.**

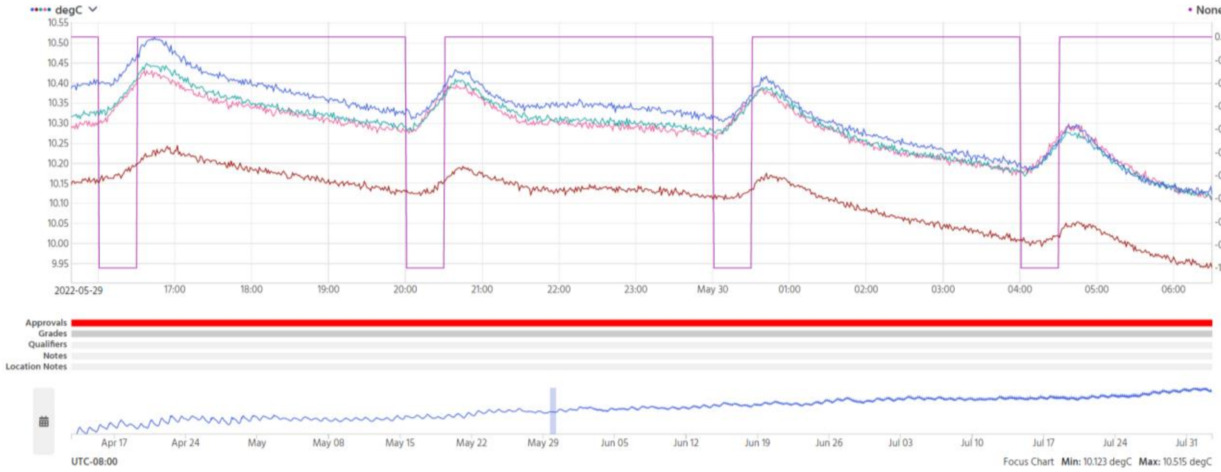


Figure 4.4 **Sensors 1 to 4 on Grid 1379 all showing a response to heating by the end of the monitoring period (data period shown is from 2022-05-29 to 2022-05-30); Sensor 1 shown in blue, Sensor 2 shown in red, Sensor 3 shown in green, Sensor 4 shown in pink, and Heater shown in purple (0 = OFF, -1 = ON).**

4.1.3 Offshore Sensor Array (Grid 1378)

An increased heat response was initially measured by Sensor 5 on April 15th, only two days after deployment. Sensors 1, 3 and 4 began to measure an increased heat pulse shortly after on April 16th, while Sensor 2 began to measure a subdued heat pulse beginning around April 17th.

The magnitude of the heat pulse measured by Sensor 5 was the highest of all sensors deployed, reaching +18-20°C shortly after deployment. Interestingly, the magnitude of the heat pulses measured by all five sensors on the Offshore Sensor Array (Grid 1378) decreased abruptly between 20:30 on May 15th and

00:30 on May 16th, 2022 (Figure 4.5). This does not appear to be due to malfunction of the heater, as the magnitude of the measured heat pulses increases progressively once again starting May 17th. NHC contacted NWSRI Hatchery Staff as well as Carrier Sekani Tribal Council (CSTC) fisheries to inquire as to whether this grid may have been disturbed accidentally (e.g., anchor, egg mat, etc.); both groups confirmed that they were not working in the area at this time. Furthermore, experimental trials in the NHC physical laboratory completed as part of design development showed that physical disturbance of the grid typically resulted in greater settling of fines, and thus greater heating. Given that the opposite trend was observed (i.e., cooling not heating), it is possible that sediment was winnowed from the grid, resulting in greater interstitial flow (and hence less heating). That said, the measured heat signals from all five sensors progressively increased following the event, suggesting persistent and ongoing sedimentation, but did not reach pre-May 15th levels by the end of the monitoring period (Figure 4.6).

The magnitude of the heat pulses measured by Sensors 1 through 4 were generally similar to those measured by the Inshore Sensor Array (Grid 1377), while the Middle Sensor Array (Grid 1379) measured the lowest heat pulses over the monitoring period. While preliminary, these results suggest that the volume of infilled sediment may have been lower at the Middle site over the course of the 2022 spawning period. It may be possible to collect underwater images as part of future work to validate these interpretations.

Figure 4.5 Abrupt decrease in the heat pulse measured by all five sensors on the Offshore Sensor Array (Grid 1378) between 20:30 on May 15th and 00:30 on May 16th, 2022; Sensor 1 shown in purple, Sensor 2 shown in red, Sensor 3 shown in blue, Sensor 4 shown in pink, Sensor 5 shown in green, and Heater shown in yellow (0 = OFF, -1 = ON).

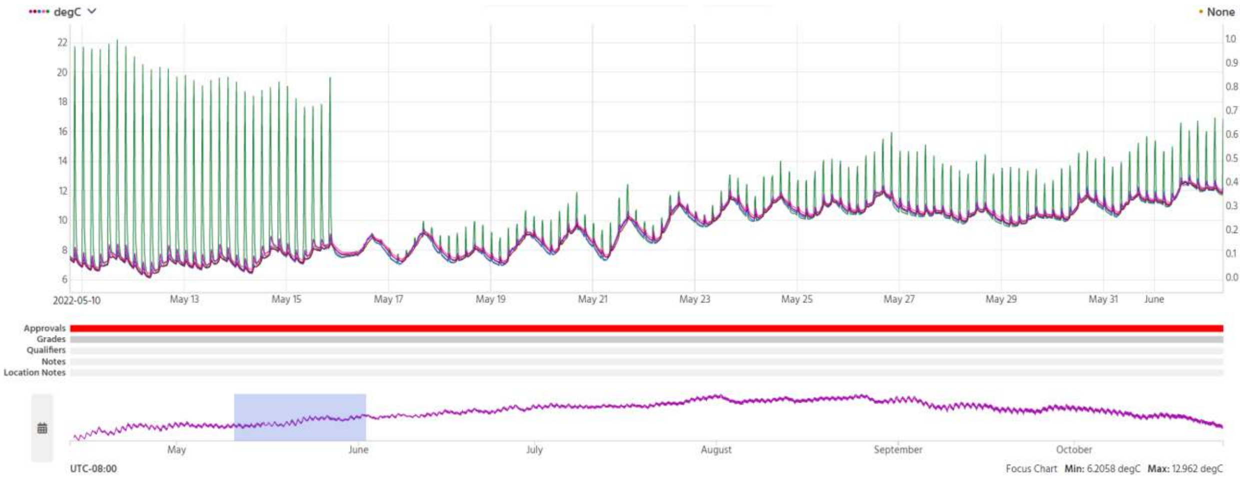


Figure 4.6 Progressive increase in heat measured by all five sensors on the Offshore Sensor Array (Grid 1378) after the abrupt decrease on May 15-16, 2022; Sensor 1 shown in purple, Sensor 2 shown in red, Sensor 3 shown in blue, Sensor 4 shown in pink, and Sensor 5 shown in green.

4.2 Fixed Underwater Camera

The following table summarizes observations from the underwater imagery recorded during the initial monitoring period (early-April to early-June of 2022):

Table 4.1 Summary of observations from the fixed underwater camera (April 13-June 1, 2022).

Time Period	Discharge[2]	Observations
April 13, 2021	75 m^3/s	• Camera deployed; bed primarily composed of medium to coarse gravels with small gravels interspersed between the larger clasts. Trace small cobbles and no visible accumulations of sand.
April 13-23, 2021	75 m^3/s	• Continuous, partial mobility of small gravels. • Infrequent/intermittent partial mobility of medium to coarse gravels. • Clasts “vibrating”, but framework gravels relatively stable. • No sand bedload observed. • Low turbidity.
April 23-30, 2021	75-100 m^3/s	• Turbidity increases rapidly (April 22-23, 2022) limiting depth of view. • Minor scour and winnowing adjacent to camera due to altered local hydraulics. • No sand bedload observed.

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[2] WSC gauge 08JC001 Nechako River at Vanderhoof.

Time Period	Discharge[2]	Observations
April 30-May 12, 2021	100-180 m^3/s	• Increased scour and winnowing adjacent to camera resulting in local bed lowering and continuous sloughing/raveling of medium to coarse gravels towards the camera mount. • Winnowed gravel appears to have created a surficial layer of clean gravels with no infilled fines to a depth of several gravels thick. • Further increase in turbidity prevents visual observation of substrate (May 7-12, 2022).
May 12-18, 2022	180-200 m^3/s	• Woody debris becomes lodged on upstream side of camera mount (May 12, 2022). • Woody debris causing scour of bed material, resulting in a downstream deposit of fine to medium gravels; gravel particles highly mobile and being frequently reworked. • Turbidity decreasing throughout this period.
May 18-22, 2022	200-225 m^3/s	• Period of winnowing and raveling in lee of woody debris resulting in relatively thick (5-10 cm) local deposit of large gravel with highly mobile small to medium gravel deposit immediately downstream.
May 22-25, 2022	225-235 m^3/s	• Increased accumulation of small to medium gravels raised the local bed elevation (+2-5 cm) downstream of the woody debris; by May 25, small to medium gravel had covered the previously exposed larger gravels downstream of the woody debris. • Increased abundance of smaller gravels appears to increase the mobility of larger gravels located immediately adjacent to the woody debris.
May 25-28, 2022	235-260 m^3/s	• Woody debris and camera slightly shift position on May 26, 2022 (i.e., field-of-view altered). • Increased accumulation of finer gravels and granules downstream of debris (apparent fining of the local surficial deposit). • Mussel embedding into the substrate on May 28, 2022.
May 28-June 1, 2022	260-300 m^3/s	• Continued high mobility of small to large gravels downstream of the woody debris. • A noticeable amount of winnowing occurs immediately adjacent to the woody debris between May 31 and June 1, 2022, lowering the gravel bed by 5-10 cm and producing a deposit of large gravel that is free of fine sediment (sand and granules). The bed lowers sufficiently to expose the embedded mussel (to the point where it falls over).

Overall, the fixed underwater camera provided more information than was initially anticipated, as the continuous imagery was very useful for better understanding near-bed conditions and substrate mobility. In particular, the camera has shown that modest flows (< 300 m^3/s) can result in partial mobility and semi-continuous “vibration” of the gravel and cobble clasts, and that the movement (including removal) of coarse sand and fine gravel from interstitial voids can occur at the site under certain conditions. Furthermore, the underwater imagery showed that relatively small disturbances created by wood accumulation (as well as by the camera mount itself) can directly impact the substrate conditions and may create the potential for some interstitial habitat.

The observations of grain mobility described above indicate some mobility of gravel even prior to the accumulation of woody debris on May 12th, 2022. Despite observed partial mobility and “vibration” of clasts on the natural riverbed, no evidence of winnowing was detected by the temperature sensor arrays. As such, these two methodologies used to monitor changes in substrate composition may yield slightly different results, where the temperature sensor arrays may retain a greater amount of fine sediment due to the immobility of the framework gravels contained within the grid itself (i.e., gravels can not readily be transported out of the steel frame). That said, no appreciable winnowing of the natural riverbed was observed using the underwater camera apart from where local hydraulics were altered by the camera mount and accumulation of woody debris.

5 FUTURE MONITORING AND DATA ANALYSIS

Based on the findings presented in this report, NHC recommends that the following tasks be considered as part of future research and restoration activities intended to advance the recovery effort:

- Continue monitoring local substrate conditions in 2022/2023 using the fixed underwater camera; however, the camera will need to be cleaned and/or repositioned (fall of 2022).
- Given that visual observations of the bed were only limited by high turbidity over a brief period, the use of several fixed underwater cameras may be considered as a monitoring tool for the 2023 spawning period. Under low turbidity conditions, the field-of-view is approximately 2-2.5 m deep (i.e., viewing outwards from the front of the lens) by 1.2-1.5 m wide (i.e., viewing perpendicular to the lens direction). Several cameras could therefore be deployed to monitor substrate conditions at key locations within the critical spawning reach.
- Continue monitoring sedimentation using the temperature sensor arrays (2022/2023), especially given that relatively high flows are forecasted for 2022. Leaving the arrays in place throughout this period would provide an indication as to whether an increase in discharge may result in increased winnowing of infilled gravels. Continued monitoring throughout the winter period may also be highly valuable given that little to no information is currently available on how ice cover can affect local hydraulic, substrate and sediment transport conditions.
- Temperature sensor arrays may also be used in future studies to monitor infilling rates at various locations within the spawning reach, as well as to monitor the quality of previously restored habitats (i.e., post-cleaning). These additional monitoring stations could be powered by battery banks and solar arrays.
- Additional data analyses should be completed in 2022/2023 to gain further insight into the process of substrate infilling both during the initial monitoring period and moving forward. For example, additional data processing may be used to remove the background trend in water temperature and evaluate how the magnitude of the heat signal and the duration required for

heating/cooling changed over time at each sensor. When related to time of year and flow conditions, this may provide information on how these environmental variables influence the rate and timing of sediment transport.

- Additional analyses may also be completed to generate order-of-magnitude volumetric estimates of sediment transport. For example, the porosity of the clean gravel mixture placed in the sensor arrays may be used to estimate the volume of sediment required to produce the observed heat signal. While approximate, these estimates may be useful when considering potential future restoration strategies (e.g., sediment capture basin).
- Collect underwater images of the grids to see the condition of the interstitial substrate and relate that to the maximum temperature recorded by each grid.

6 CONCLUSION

The purpose of this project was to evaluate the rate of sedimentation and potential winnowing of natural substrates within the critical white sturgeon spawning reach of the Nechako River at Vanderhoof. The temperature sensor arrays developed and deployed as part of this project were successful in monitoring *in-situ* changes in substrate composition at three sites during the 2022 spawning period remotely and in real-time. The fixed underwater camera installed as part of this project also provided valuable observations regarding sediment mobility and potential application of restoration measures (e.g., induced winnowing). Given the promising results to date, it is recommended that these methods be considered for future applications related to biological and geomorphological monitoring within the spawning reach.

7 REFERENCES

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