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Columbia River Project Water Use Plan

Columbia River White Sturgeon Management Plan

CLBMON-23A Egg Mat Monitoring Program

Implementation Year 16

Prepared by:
Okanagan Nation Alliance
#101-3535 Old Okanagan Highway
Westbank, BC
V4T 3L7

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Middle Columbia River White Sturgeon Spawn Monitoring (CLBMON-23A): 2022 Data Report (Year 16) – Final Report

Authors:

Evan Smith, RPBio, BSc.
Carson Kettlewell, DipTech
Shelley Hackett, BSc.

Okanagan Nation Alliance
Castlegar, BC

Prepared for:

James Crossman, PhD., BC Hydro
Castlegar, BC

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Executive Summary

The population of White Sturgeon in the Canadian portion of the Columbia River are listed as Endangered under the federal Species at Risk Act. A small portion of this population exists in Arrow Lakes Reservoir (ALR) and the Middle Columbia River (MCR), situated between Revelstoke Dam and Hugh L. Keenleyside Dam. The only known spawning location for this segment of the population is located approximately 6 km downstream of Revelstoke Dam adjacent to the Revelstoke Golf Course. Spawning has been documented at this location intermittently but recruitment to the juvenile stage from these spawning events has not been detected.

The MCR White Sturgeon Spawn Monitoring Program (CLBMON-23A) has been conducted annually since 2008, with monitoring occurring previously between 1999 and 2007 as part of other programs. The main objectives of CLBMON-23A are to document the timing, duration and frequency of spawning, and to identify important early life stage habitat conditions. In addition, CLBMON-23A supports a conservation aquaculture program by transferring live eggs and larvae captured during monitoring to the Kootenay Sturgeon Hatchery for rearing and subsequent release back into the MCR. Additional objectives were added to the program in 2019 to address key uncertainties identified by the Mid-Columbia River White Sturgeon Technical Forum and included:

- Describe the timing and spatial extent of larval dispersal
- Assess the risk of eggs or larvae becoming stranded due to hydroelectric operations

In 2022, egg collection mats and drift nets were used to sample for eggs and larvae in the primary spawning area during the typical spawning season (late July to mid September), as defined by previous years of the monitoring program. In total, 20 eggs (including two mortalities) were collected using D-ring drift nets. All live eggs were transferred to the conservation aquaculture program. Based on the developmental stages at the time of capture and water temperatures, the eggs and the larvae were estimated to be from two spawning events; Aug 14-16 and Aug 19-20 2022. As sampling effort was prioritized for maximizing egg collection when spawning was detected, less effort was expended to describe larval dispersal later in the season.

The Arrow Lakes Reservoir elevation was below 437 MASL for the latter half of the project (from Aug 13 onward), indicating the survey area was not backwatered by the reservoir during the period when adults were spawning. However, high flows from Revelstoke Dam prevented de-watering of substrate in the spawning area; therefore, standing risk was low.

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The following employees of the **BC Hydro** contributed to this project in 2022-23:

James Crossman, PhD	Contract Manager
Teri Neighbour,	Contract Oversight
Devon Smith,	Field Support

The following employees of the **Okanagan Nation Alliance** contributed to this project in 2022-23:

Evan Smith, RPBio, BSc.	Project Manager; Report Author; Field Lead
Michael Zimmer, MSc, RPBIo	Project Oversight
Ross Zeleznik, BiT, BSc.	Field Crew
Carson Kettlewell, DipTech	Report Author, Data Entry, Field Crew
Paul Snow, Technician	Field Crew
Shelley Hackett, DipTech	Report Author, Data entry, Field Crew

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1.0 Introduction

The population of White Sturgeon (*Acipenser transmontanus*) in the Canadian section of the Columbia River was listed as Endangered under the federal Species at Risk Act in 2006. A segment of this population exists between Hugh L. Keenleyside Dam (HLK) near Castlegar BC and Revelstoke Dam (REV) near Revelstoke BC. This portion of the Columbia River includes Arrow Lakes Reservoir (ALR) and an approximately 48 km section of the Middle Columbia River (MCR) between ALR and REV. In 2006, the ALR adult White Sturgeon population was estimated at approximately 52 adults (37 – 92 individuals at 95% confidence level; Golder 2006), all of which are assumed to have been present prior to the building of HLK Dam in 1968. In 2021, the estimated population of adult White Sturgeon may be around 26 individuals, calculated with a 97% annual adult survival rate (DFO 2014). The only known spawning area for this population is located adjacent to the Revelstoke Golf Course, approximately 2 km downstream of REV. Spawning has been documented intermittently at this location using egg collection mats and drift nets between 1999 and 2021 (Golder and ONA 2020). However, wild juvenile White Sturgeon surviving from these spawning events have never been captured, which suggests failure to recruit to the juvenile life stage for this population (Hildebrand and Parsley 2013).

Initiated in 2007, BC Hydro's CLBMON-23 Mid-Columbia River White Sturgeon Egg Mat Monitoring and Feasibility Study was developed to monitor the annual spawning of White Sturgeon at the only known spawning site between REV and HLK. CLBMON-23A includes two components: (1) the MCR White Sturgeon Spawn Monitoring Program (CLBMON-23A), which uses egg collection mats and drift nets and (2) the MCR White Sturgeon Underwater Videography Feasibility Study (CLBMON-23B), which evaluated the feasibility of monitoring sturgeon using sonar (Johnson *et al.* 2010; Crossman et al. 2011). Sixteen years of monitoring have been completed in the CLBMON-23A program to date (2007 to 2022). This report describes the methods and results of egg mat and drift net monitoring for CLBMON-23A in 2022 (Year 16).

CLBMON-23A meets the requirement of the Columbia River Project Water License Order to document spawn timing, duration, and frequency, and to identify important early life stage habitat conditions (BC Hydro 2019). In addition, CLBMON-23A supports a conservation aquaculture program through the on-site incubation of eggs and transfer of larvae to the Kootenay Sturgeon Hatchery for rearing and subsequent release back into the MCR.

Specific management questions associated with CLBMON-23A as per the Terms of Reference (BC Hydro 2007) are as follows:

1. Where are the primary White Sturgeon incubation sites below Revelstoke Dam?
2. How do dam and reservoir operations affect egg and larvae survival in this area? Specifically, do significant numbers of eggs become dewatered as a result of operations?
3. Can underwater videography or other remote sensing methods be used to effectively monitor staging and spawning of White Sturgeon?
4. What is the most effective method for monitoring spawning of White Sturgeon?
5. Can modifications be made to operation of Revelstoke Dam and Arrow Lakes Reservoir to protect or enhance White Sturgeon incubation habitat?

Management Question 3 has been addressed by a different monitoring program (CLBMON-23B; Johnson et al. 2010). Management Questions 1, 2, 4, and 5 are relevant to the CLBMON-23A monitoring program.

A review of CLBMON-23A in 2018 identified the following key uncertainties (BC Hydro 2019):

1. The number of adults contributing to spawning events
2. Survival of early life stages
3. The risk of eggs or larvae becoming stranded due to operations

Following the review, an additional objective of the monitoring program was to provide information to address the key uncertainties listed above, where possible. Genetic analyses to address uncertainty #1 are captured under CLBMON-24 (Mid Columbia River White Sturgeon Genetic Assessment) and eggs and larvae that were dead after capture were preserved and provided to BC Hydro. Survival of early life stages (uncertainty #2) cannot be directly measured or estimated using the data provided by this monitoring program, but given that no natural recruitment has identified in this sub-population survival is expected to be low. Stranding risk (uncertainty #3) has been assessed by examining river discharge data and ALR surface elevation data for large flow reductions during periods when there were known to be White Sturgeon eggs or larvae present in the spawning and incubation area.

In addition to the main objective of annual spawn monitoring and addressing these uncertainties, two additional objectives were identified at the Mid-Columbia River White Sturgeon Technical Forum in December 2018 (BC Hydro 2018):

- Increasing the number of progeny (eggs or larvae) collected and transferred to the conservation aquaculture program to capture the genetic diversity of the wild adults in the MCR
- Describe the timing and spatial extent of larval dispersal through additional sampling

This report summarizes the results from the 2022 study year and compares them to previous years of this program. Recommendations for future sampling years are also provided. Detailed background information, interpretation of previous years' results, and discussion of the status of management questions are available in historic annual reports of this program[1].

2.0 Methods

In response to the objectives identified at the Mid-Columbia River White Sturgeon Technical Forum (BC Hydro 2018), the study design of CLBMON-23A was modified in 2020 to include more adaptive management to prioritize the collection of progeny for conservation aquaculture. Sample sites and effort were be adjusted during the sampling season based on the timing and location of captured eggs or larvae. This differed from previous years, where the index sample sites and schedule were set. Due to the prioritization of White Sturgeon progeny collection, the larval dispersal component of this program became a secondary objective.

[1] Reports from previous years of the monitoring program are available online at: https://www.bchydro.com/toolbar/about/sustainability/conservation/water_use_planning/southern_interior/columbia_river/columbia-sturgeon.html

2.1 Study Area

The study area for CLBMON-23A extends from the upstream end of the primary spawning area (river kilometer [RKm] 230.3, as measured upstream from HLK) downstream to the Trans-Canada Highway Bridge (RKm 227). In 2022, the program was focused in the area that all White Sturgeon eggs and larvae have been captured in previous years of this program (RKm 229.9 and 226.3; Wood 2019; Golder and ONA 2020; ONA 2021; ONA 2022). In an attempt to maximize captures in 2022, sampling was concentrated during the primary spawning and incubation period. Sampling downstream of RKm 226.3 for fall larval dispersal was not conducted in 2022 as effort was prioritized to collect eggs when spawning was detected.

2.2 Sampling Equipment

Egg collection mats ('egg mats') and drift nets were used to capture White Sturgeon eggs and larvae. This was consistent with all previous years of the monitoring program (Wood 2019; Golder and ONA 2020; ONA 2021; ONA 2022). Egg mats consisted of a 0.77 x 0.92 m steel frame filled with latex-coated animal hair filter material. When deployed in the river, egg mats rest on the substrate and eggs or larvae may adhere to or become lodged in the filter material. Egg mats were deployed either as 'shore-sets' or 'mid-sets'. Shore-sets were anchored with line to a natural feature above the high water mark (e.g., boulder or tree), allowing sets to be retrieved from shore. Line spanned from the anchor point to the egg mat and was connected via a rope or cable bridle (i.e., approximated 0.5 m rope or cable attached in a V-formation to one end of the end mat). Egg mats had a float line (10 – 20 m) with a LD2 buoy attached as a secondary retrieval method in case the primary anchor line was compromised.

To sample locations further from shore, egg mats were deployed as mid-sets that were held in place by a portable anchor system (two 30 kg claw anchors connected by steel chain). Mid-sets had a float line and LD2 buoy connected to the upstream anchor, and a second float line and LD2 buoy connected to the egg mat. The egg mat was connected to the downstream anchor by approximately 10 m of line.

Drift nets consisted of a D-shaped metal frame (0.8 m wide at the base and 0.6 m high) to which a drift net was attached (3.6 m long, 0.16 cm knotless mesh, tapered to an 11.4 cm diameter collection cup). The D-ring frame was weighted at the front corners or base of the frame and a flow meter was affixed to the D-ring frame (over the opening) to measure the volume of water sampled over time. All drift nets were deployed using the mid-set anchor system described above.

Egg mats and drift nets were deployed and retrieved from a jet-drive river boat by a three-person crew. Shore-sets were retrieved from shore and mid-sets were retrieved by the downstream float line attached to the egg mat or drift net. Egg mats and drift nets were pulled from the bow winch or side-mounted winch on a davit, depending on the site. Generally, the side winch was used when possible to allow for better crew ergonomics. Use of the bow winch was limited to sites situated in very high water velocities or if a greater force was required to retrieve (i.e. equipment or anchors were stuck).

2.3 Spawn Monitoring

Spawn monitoring took place from July to August – with egg mats deployed on Jul 25 2022 and retrieved on Aug 23 2022. Drift nets were deployed daily for each sampling session. Timing of sampling and the amount of effort expended was prioritized to cover the historical peak of the spawning period when most eggs and larvae had been captured in past years of monitoring. Following a review of CLBMON-23A in 2018, the study plan became "adaptive" with the objective of maximizing effort around the period when spawning was detected. This was due to the significant reduction in embryo or larval captures in the weeks following spawning events in previous years. Additional sampling effort at sites where eggs or larvae were captured was conducted and additional sites were installed adjacent to, or downstream, of the capture location when possible. If significant numbers of eggs or larvae were captured, the session would be extended up to three days to continue sampling with drift nets; which often catch more eggs/larvae than egg mats and maximize catch during periods when spawning was occurring. During each sampling session, egg mats were brought on board (with the exception of the first sampling session), checked for eggs / embryos, and redeployed. When possible, egg mats were replaced with drift nets that were fished for a short duration (1 – 3 hours) while the crew was on site sampling or overnight between the two days of weekly sampling (16 – 23 hours). Drift nets created more drag in the water current than egg mats and therefore lower water velocities were required to deploy drift nets safely and reduce net damage or loss. Therefore, drift nets were only deployed at locations and during discharge conditions where it was feasible and safe to do so. After retrieving the drift nets, they were replaced with egg mats that were left to sample until the following week.

Sample sites were located between RKm 227.0 and 229.0 between mid-channel and downstream river left (Figure 1). Seven sites were sampled in 2022 (RKm 227.8M, 227.9L, 228.1M, 228.5M, 228.6M, 228.8L, 228.9M). Exact locations may have been modified slightly in the field depending on river conditions. Sampling did not occur on river right or upstream of Rkm 229.0 since eggs and larvae were not captured at these locations between 2012 and 2019 (Wood 2019). This study design was intended to provide comparable monitoring to previous years, while not expending effort in areas unlikely to catch eggs and larvae. For complete site location data see Appendix A – 2022 Data.

Due to high water velocities and fluctuating flows from REV, some of the mid-set anchor systems were dislodged and moved downstream while crews were not on site. If displaced anchor systems were still located within the spawning area and situated where the equipment could effectively sample, the anchor systems were left at the new location. Anchor systems that were displaced to locations where catching eggs or larvae was unlikely were re-set at their original locations.

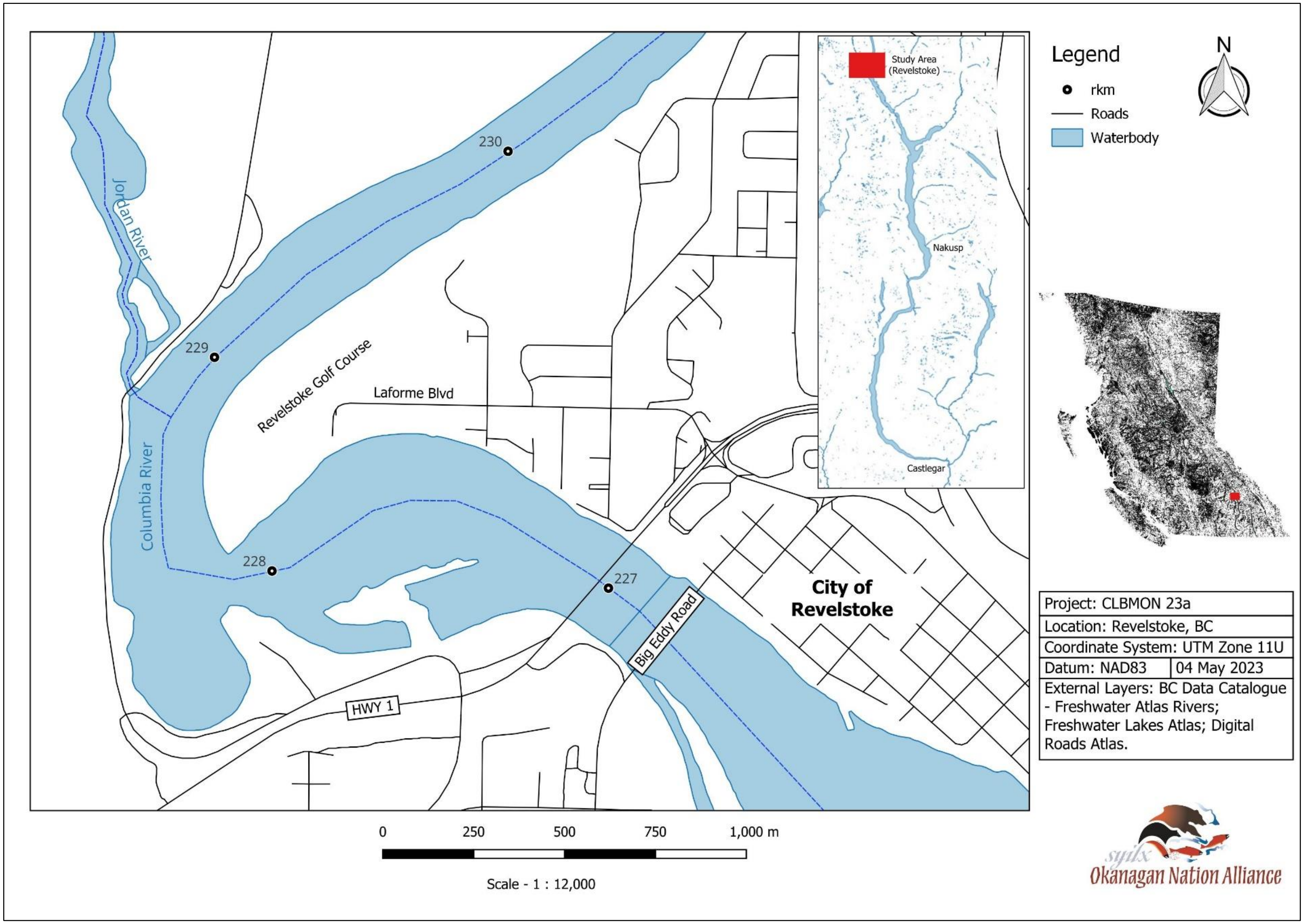

Figure 1. CLBMON-23A study location defined by river kilometers (rkm) in relation to the City of Revelstoke.

2.4 Study Period

Activities and the timing of sampling in 2022 were consistent with previous years. The majority of sampling occurred during the suspected spawning window and early life history phases of White Sturgeon (Table 1). Larval dispersal monitoring was not conducted in 2022.

Table 1. Summary of CLBMON-23A sampling activities in the Mid-Columbia River (MCR) during 2022 relative to the suspected timing of sturgeon spawning and early life developmental stages.

CLBMON-23A Sampling			White Sturgeon Early Life History (suspected)[1]			
Session	Activity	Date	Spawning	Yolk Sac / Hiding Phase	Larval Dispersal	Date Range
1	Deploy egg mats; drift net sampling	Jul 25 - 26				Jul 24 - Aug 1
2	Egg mat and drift net sampling	Aug 02 - 03				
3	Egg mat and drift net sampling	Aug 08 - 09				
4	Egg mat and drift net sampling	Aug 15 - 18				Aug 7 - 22
5	Egg mat retrieval; drift net sampling	Aug 23 - 25				
	No sampling conducted					Aug 28 - Sep 13
	No sampling conducted					Sep 18 - Oct 2
	No sampling conducted					Oct 09 - Nov 13

[1]These are approximate timings based on typical MCR water temperature of approximately 9–11°C and the developmental rates reported in the literature (Beer 1981; Wang *et al.* 1985; Wang *et al.* 1987; Parsley *et al.* 2011). These authors reported 13 days to hatch and 30 days to completion of yolk absorption at 11°C. With the slightly cooler temperatures in the MCR, this table assumes 14–20 days post fertilization for hatch and 30-40 days post fertilization for completion of yolk sac absorption.

2.5 Egg and Larval Samples

All White Sturgeon eggs collected were developmentally staged in the field. Eggs were removed from egg mats or drift nets and transferred using forceps or spoons to small containers filled with river water. Eggs were examined using a hand lens and developmental stages were assigned using the stages (1 to 36) identified by Dettlaff *et al.* (1993) and further described by Jay *et al*. (2016). All live eggs were held in insulated coolers filled with river water and transferred to the Kootenay Sturgeon Hatchery. Any eggs that were dead at capture were preserved in 90% ethanol and provided to BC Hydro for future genetic analysis.

2.6 Data Collection

Hourly discharge from REV and reservoir water surface elevation in ALR at Nakusp BC (08NE104) were obtained from BC Hydro's Columbia Basin Hydrological Database. One temperature logger (HOBO TidbiT v2) was deployed to sample water temperature every hour and were secured to a sampling set anchor at RKm 227.8M and 228.6M.

Data recorded at each sample site during egg mat and drift net sampling included the following:

- Site name
- GPS location
- Deploy and retrieval date and time
- Deploy and retrieval water temperature (°C)
- Deploy water depth (m)
- Number of eggs and larvae collected (live) and number preserved (dead)
- Developmental stage of eggs and larvae
- Other species observed
- Comments (e.g., station drift, quantity of debris)

Data were recorded in the field on standardized datasheets, digitized as a back-up, and later entered into Microsoft Excel for analyses.

2.7 Stranding Risk

A simple method was used to estimate the approximate amount of area dewatered at the cobble / gravel bar on river left (as viewed facing downstream) between the Jordan River and Big Eddy, which is a suspected incubation area (Hildebrand *et al.* 2014). Georeferenced spatial data were recorded along the water line and up to the permanently vegetated high water mark near the incubation area using a hand-held GPS (Garmin 62st; ± 3 m accuracy). Tracks were recorded at three different discharge / ALR elevation levels and GIS software was used to calculate the area of the bar exposed. While transects were recorded, a visual search was conducted looking for dewatered eggs or larvae.

2.8 Data Analyses

Spawn timing (spawning dates) were estimated from the date of egg collection using the egg developmental stage, the mean daily water temperature, and temperature-dependent rates of development reported in the literature (Beer 1981; Wang *et al.* 1985; Parsley *et al.* 2004; Parsley *et al.* 2011). The number of discrete spawning events was then estimated based on the spawning dates and their spatial distribution.

Sampling effort (hours) was calculated from deploy and retrieval dates and times. Catch-per-unit-effort (CPUE) was calculated by dividing the total number of eggs/larvae by the total sampling effort for both egg mats and drift nets. QGIS software (version 3.28.3) was used to map the location of sample sites and egg and larvae capture locations.

3.0 Results

3.1 Discharge, Reservoir Elevation, and Water Temperature

During sampling in 2022, discharge in the MCR exhibited large daily fluctuations that are typical for the hydropeaking operations at REV (Figure 2). Daily peak discharge during the sampling period ranged from 1,314 – 2,183 m^3/s and minimum discharge ranged from 274 – 1,462 m^3/s.

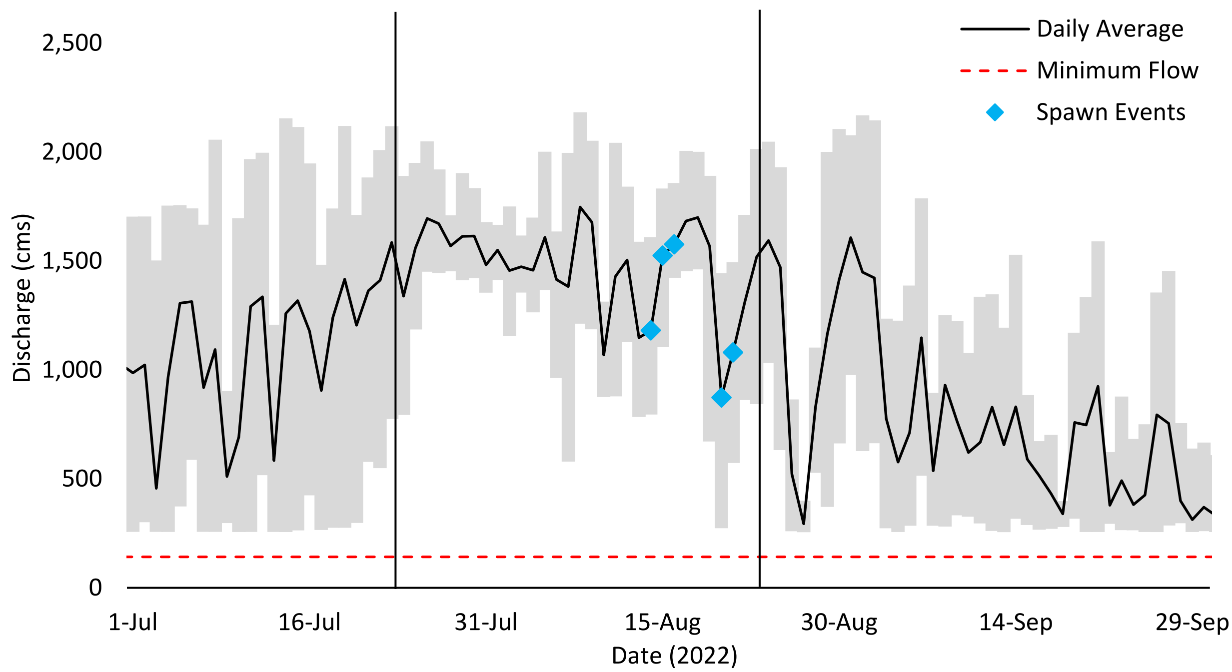

Figure 2. Average-daily discharge (black; cms) in the Mid-Columbia River downstream of Revelstoke Dam in 2022 compared to the minimum flow requirement (142 cms) with daily minimum and maximum flows shaded in grey. CLBMON-23A sturgeon monitoring occurred between vertical black lines and dates of White Sturgeon spawning events are identified by in blue diamonds.

In 2022, ALR water surface elevation was 438.3 MASL at the start of the sample period on Jul 25 2022 and gradually declined to 435.5 MASL by the end of the sample period on Aug 25 2022 (Figure 3). The ALR water surface elevation was above 437 MASL, the level above which the spawning area is backwatered, until Aug 14 which accounted for 6 sampling days (Jul 25-26, Aug 2-3, Aug 9-10). For the remainder of the 2022 sampling period, the water surface elevation remained below 437 MASL.

Water temperature collected at 228.1M between Jul 19 and Sep 25 2023 ranged from 8.3°C (Jul 21) to 13.6 (Aug 24) and averaged 10.5°C ± 0.05°C (with 95% confidence; n = 1,633; Figure 4).

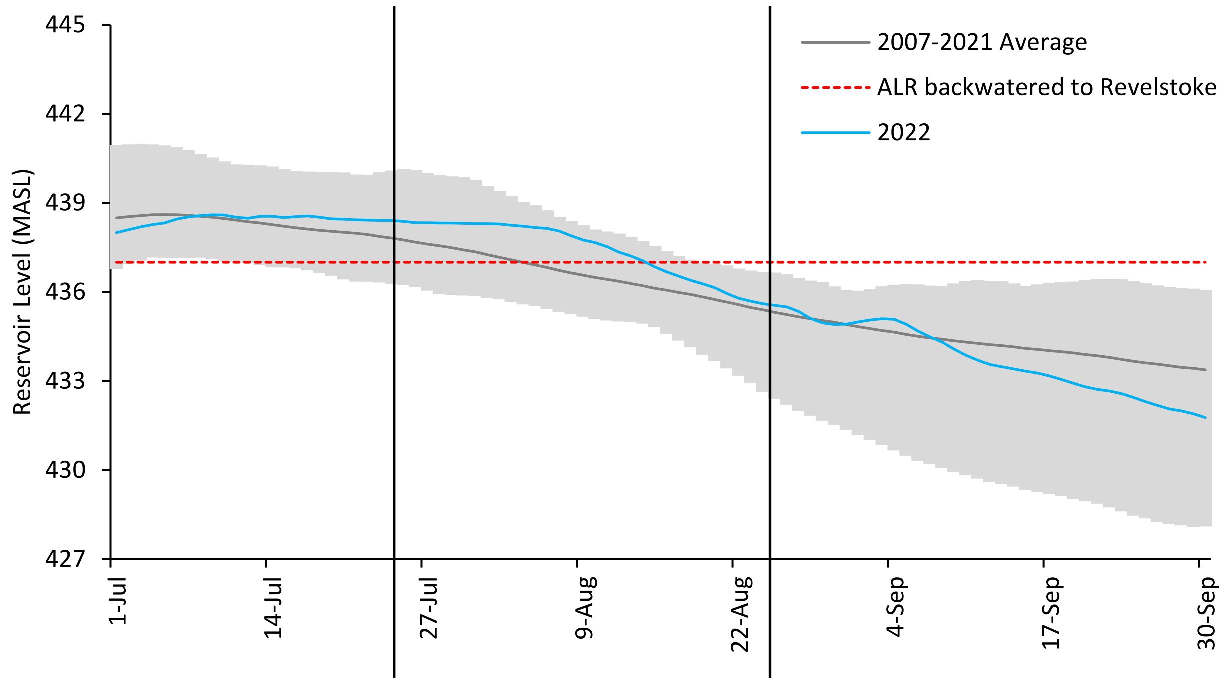

Figure 3. Average daily Arrow Lakes Reservoir (ALR) water surface elevation at Naksup BC from July to September compared to the level at which the reservoir is through to backwater the spawning and incubation area of White Sturgeon near Revelstoke (437 MASL; Hildebrand *et al.* 2014). The greyed area shows the variation in reservoir elevation from 2007 – 2021 (minimum and maximum average daily values). CLBMON-23A sturgeon monitoring occurred between vertical black lines.

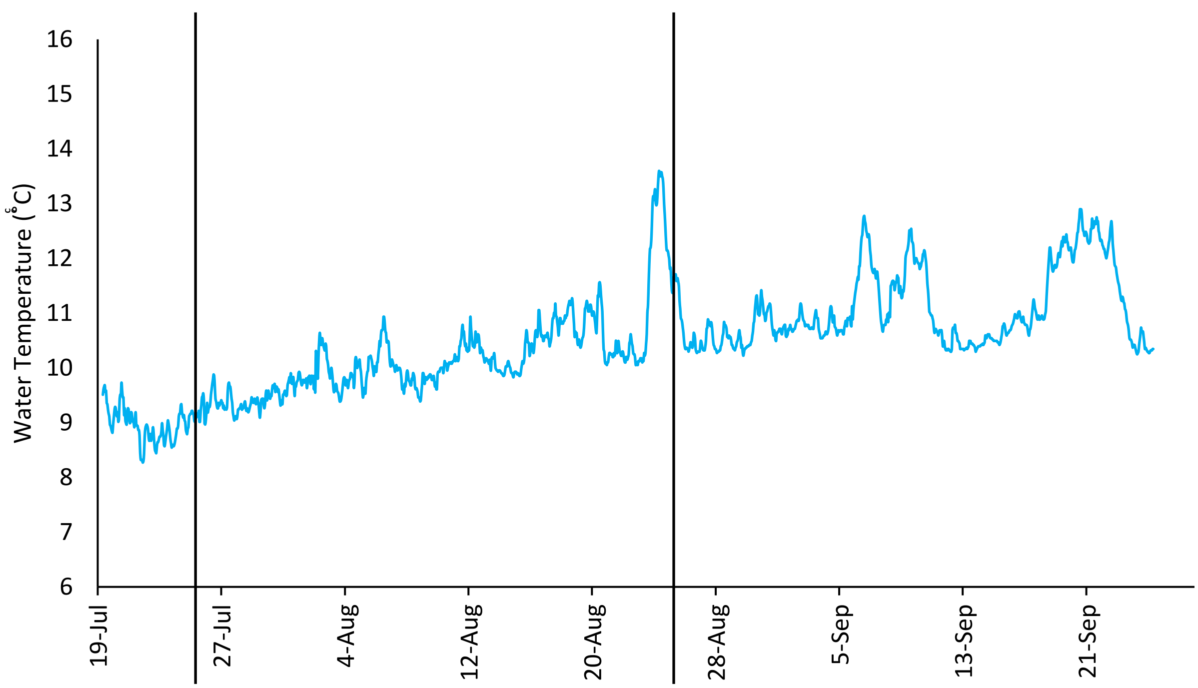

Figure 4. Water temperature (hourly) in the Mid-Columbia River measured at White Sturgeon spawning areas during CLBMON-23A in 2022. CLBMON-23A sturgeon monitoring occurred between vertical black lines.

3.2 Sampling Effort and Catch

From Jul 25 – Aug 25 2022, five to seven sites were sampled each session for a total of 25 egg mat sets (Table 2). White Sturgeon progeny (eggs and larvae) were not captured on egg mats in 2022.

Table 2. Egg mat sampling effort in the Mid-Columbia River during CLBMON-23A in 2022.

Dates	Effort (mat-hours)	# Sites Actual
Jul 25 – Aug 01	902.75	5
Aug 02 – 07	904.97	7
Aug 08 – 14	928.95	6
Aug 15 – 23	1,006.68	7

From Jul 25 – Aug 25 2022, five sites were sampled with 58 drift net sets (31 day sets and 27 night sets), which resulted in the capture of 20 White Sturgeon eggs (18 alive and two mortalities; Figure 5 and Table 3). Drift net CPUE was 0.04 White Sturgeon/hour with a total effort of 464 hours. Day sets were deployed for 1 – 6 hours (nets retrieved before 4-hours of soak time were typically slipping in high-velocity flows). Night sets were deployed for 15 – 19 hours. Six nets were damaged during the 2022 season (four night sets and two days sets) resulting in 73 hours of lost effort.

Table 3. Expected (total soak time) and actual (total soak time minus damaged sets) drift net sampling effort for day and night sets including catch of White Sturgeon eggs and associated Catch-Per-Unit-Effort (CPUE; using Actual Effort) in the Mid-Columbia River during CLBMON-23A in 2022.

Dates	Day / Night	Expected Effort (net-hours)	Actual Effort (net-hours)	# of Sets	# Eggs Live (Dead)	# Larvae Live (Dead)	CPUE (#/h)
Jul 25 - 26	Day	8	8	3	0	0	0
	Night	48	48	3	0	0	0
Aug 02 - 03	Day	6	6	3	0	0	0
	Night	64	64	4	0	0	0
Aug 08 - 09	Day	3	3	1	0	0	0
	Night	48	17	3	0	0	0
Aug 15 - 18	Day	42	33	14	5 (2)	0	0.21
	Night	192	192	11	7 (0)	0	0.04
Aug 23 – 25	Day	28	28	10	2 (0)	0	0.07
	Night	98	65	6	4 (0)	0	0.06

The majority of eggs were captured at stations 228.5M (40% of catch) and 228.1M (35% of catch), with 80% of eggs captured in rKm 228 (Figure 6; Table 4).

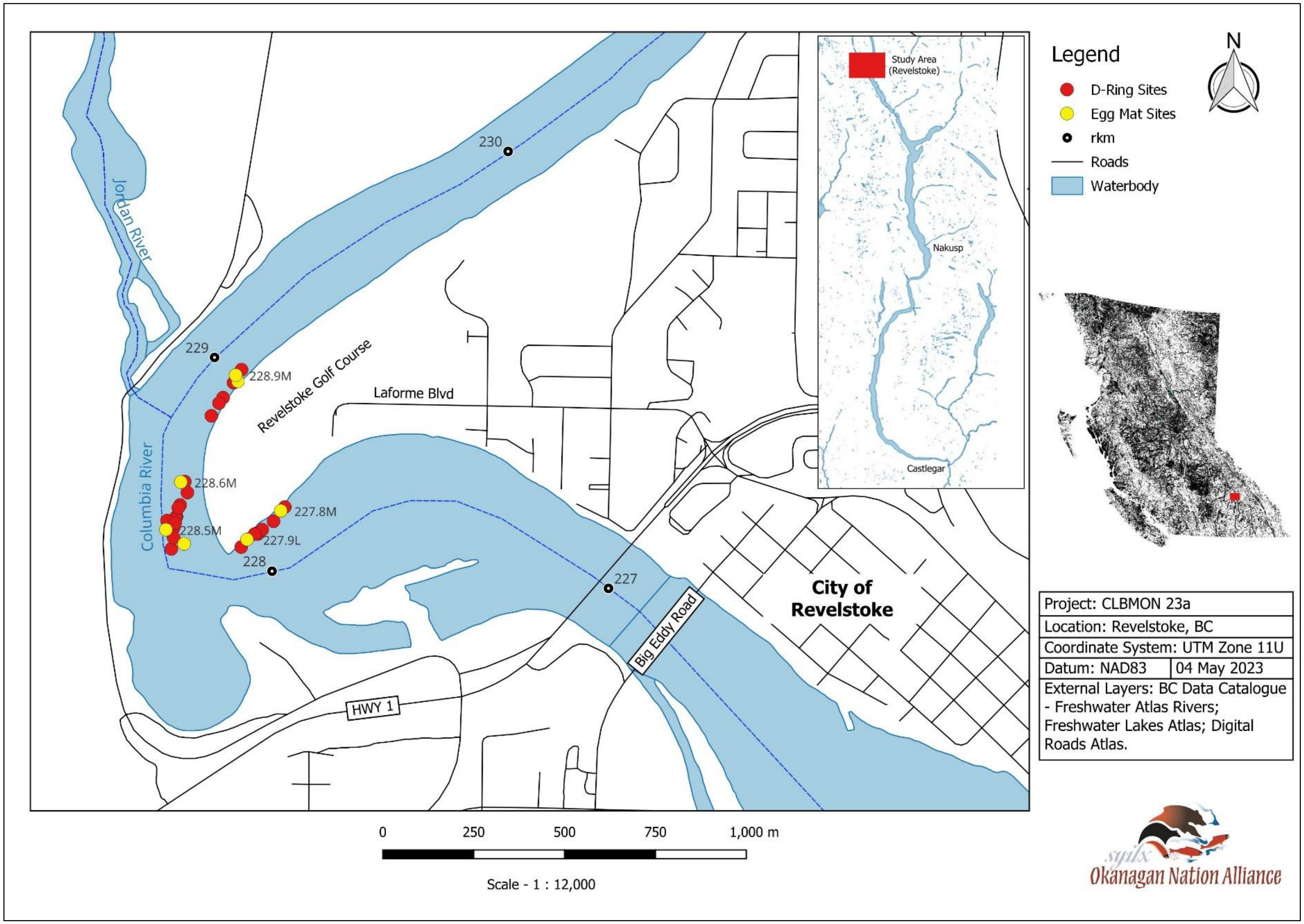

Figure 5. Location of D-ring drift net and egg mat sampling in the Mid-Columbia River during CLBMON-23A in 2022 (some sites overlap).

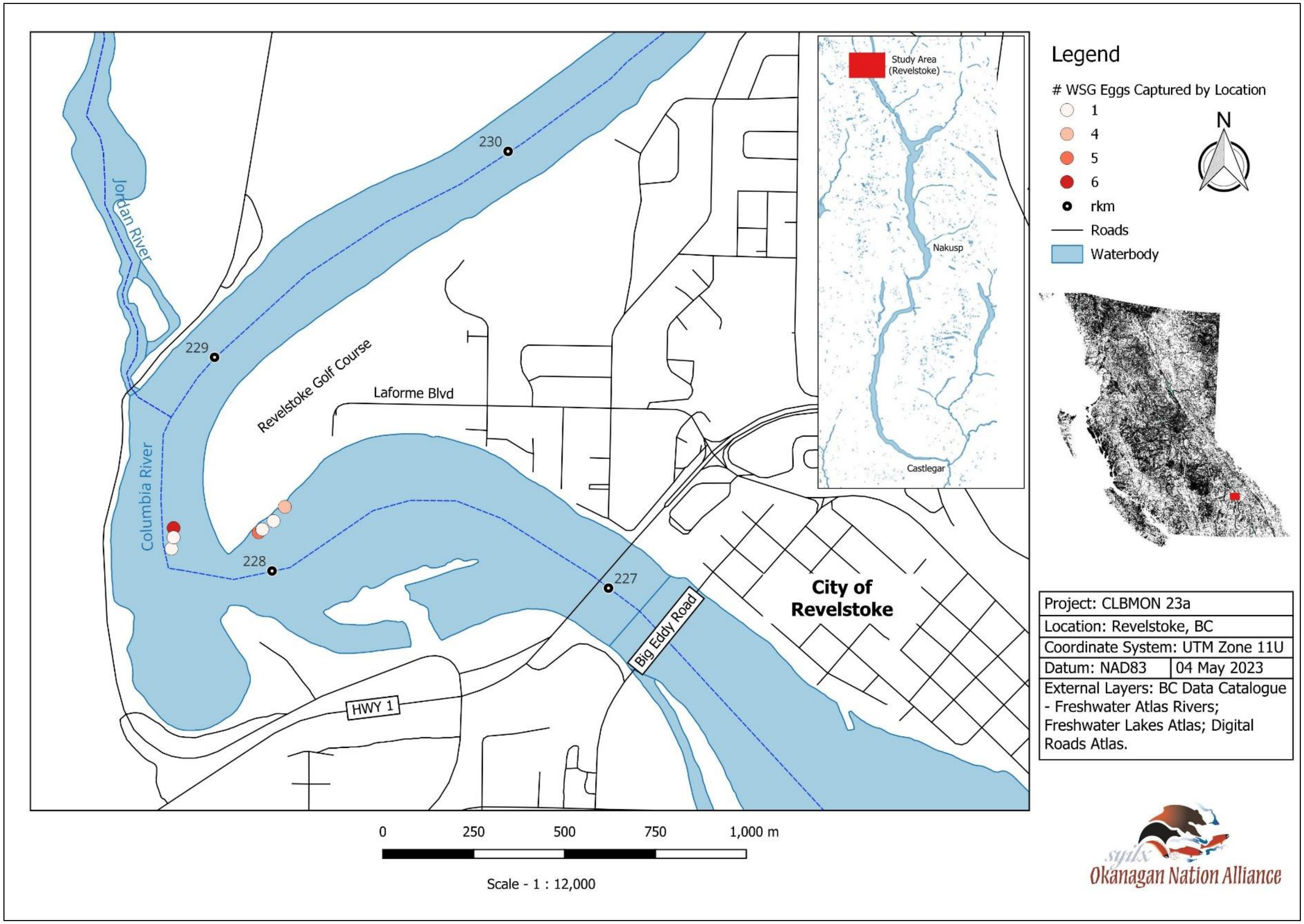

Figure 6. Capture locations of White Sturgeon eggs via drift net sampling in the Mid-Columbia River during CLBMON-23A in 2022.

Table 4. Temporal (columns) and geographical (rows) data of all sampling effort (greyed boxes) including the number of White Sturgeon egg captures (green boxes). Data collected in the Mid-Columbia River for CLBMON-23A in 2022.

Station	July					August								Total
	25	26	30	31	02	03	15	16	17	18	23	24	25	
227.8M												4		4
227.9L														
228.1M							1			5	1			7
228.5M									7	1				8
228.6M												1		1
228.8L														
228.9M														

3.3 Developmental Staging and Estimated Spawn Timing

Based on capture dates, water temperature, and egg development stages, two spawning events were detected in 2022 (Table 5). Spawning is suspected to have occurred between Aug 14 – 16 and August 19-20.

Table 5. Estimated White Sturgeon spawn dates based on developmental stages (Parsely *et al.* 2011; Dettlaff *et al.* 1993) of eggs captured in the Mid-Columbia River during CLBMON-23A in 2022. Hours post fertilization calculated using daily average water temperature (from the day before capture) and developmental stage (Parsley *et al.* 2011).

Capture Date	Type	# Captured	Dettlaff / Parsley Stage	Hours Post Fertilization	Estimated Spawn Date
Aug 15	Eggs	1	3 / 12	0 – 3	Aug 15
Aug 17	Eggs	5	12 - 16 / 18 – 21	28 – 58	Aug 14 – 16
Aug 18	Eggs	6	15 / 21	58	Aug 15
Aug 23	Eggs	1	24 / 24	107	Aug 19
Aug 24	Eggs	5	24 - 26 / 24 – 25	85 – 118	Aug 19 – 20

3.4 Stranding Risk

Due to ALR backwatering and high discharge from Revelstoke Dam, substrate dewatering was not observed in 2022. Therefore, stranding surveys did not occur.

There is some uncertainty in developmental rates of White Sturgeon in the cool water temperatures of the MCR (Parsley *et al.* 2011). Beer (1981) found that egg hatch occurred 11 days after fertilization at 10 °C, which is similar to typical water temperatures in the MCR during the spawning period. However, a study mimicking the temperature regime of the MCR found that hatch occurred 13 – 16 days post-fertilization at water temperatures of approximately 10 – 11 °C (Parsley *et al.* 2011). During the yolk-sac larva phase, development took 14 days post-hatch to reach the exogenous feeding and larval dispersal phase at 12.5 °C (Jay *et al.* 2020). As water temperature in some years in the MCR may be cooler (9 – 11 °C) than these laboratory studies, it was assumed that it would take 13 to 20 days post-fertilization for hatch, and 30 to 40 days post-fertilization for complete absorption of the yolk sac, swim-up, and begin dispersing based on field studies conducted in the area (Crossman and Hildebrand, 2014). Therefore, for the stranding assessment, it is assumed that there were early life stages (eggs or yolk-sac larvae) present in the spawning and incubation area from the first detected spawning event until 40 days after the last detected spawning event in each year.

4.0 Discussion

White Sturgeon spawning was documented in the MCR in 2022, estimated to have taken place between Aug 14 and Aug 20 2022. In previous years of the program, spawning dates have ranged between Jul 21 and Sep 05 and up to six spawning events have been detected within a year. Spawning has now been detected in 16 of the 21 years that monitoring has been conducted in the MCR, and annually since 2015. This suggests a large enough adult population for annual spawning. Assuming the adult population sex ratio in the MCR is similar to the population downstream of HLK Dam (1:1; Hildebrand and Parsley 2013), there may be more than the estimated 26 adults remaining in the MCR; based on the intermittent spawning (2 – 4 years, increasing with age) of female White Sturgeon and annual spawning capability of male White Sturgeon. On-going genetics analyses using collected sturgeon eggs and larvae will provide an estimate of the number of adult sturgeon that have contributed to collected progeny.

A total of 20 White Sturgeon progeny were captured in 2022; all on D-ring drift nets (typically overnight sets). One egg was visibly deceased and preserved in ethyl alcohol for DNA analysis while the other 19 were transferred to the Freshwater Fisheries Society for transportation to the Kootenay Trout Hatchery near Wardner, BC. The sampling session Aug 15 – 16 was extended to Aug 18 to maximize effort during the spawning window; this resulted in 13 eggs captured on Aug 17 and 18. A sampling session was also extended for the Aug 23 – 24 session to include Aug 25; as a result six eggs were captured on Aug 25. Prior to 2020, crews had followed a set schedule and sampled set locations. Maintaining an adaptive schedule is recommended to increase capture success in future years of the program.

4.1 Management Questions

The Management Questions outlined in the Terms of Reference for CLBMON-23A have been addressed in previous years of this program (Wood *et al.* 2019); however, results from 2022 can be used to update Management Questions 2 and 4:

Management Question 2:

How do dam and reservoir operations affect egg and larval survival in this area? Specifically, do significant numbers of eggs become dewatered as a result of operations?

> Survival of eggs or larvae can't be estimated given data collected. The stranding risk analyses is updated to 2020. Reservoir levels increase following sampling in 2021, and high flows from REV

with backwatering of the ALR occurred in 2022, so stranding risk was assumed to be low. The Standing Risk analyses for 2021 – 2023 will be updated in the Year 17 (2023) Technical Report. In 2020, only 15% of the spawning period was considered "high risk" in this year due to backwatering of ALR. This assessment is based on several untested assumptions and the rankings should be considered as the potential for stranding due to discharge variability, and only in a relative sense within and between years. High flows from Revelstoke Dam and backwatering of the Arrow Lakes Reservoir in 2022 kept the gravel bar submerged during all sampling sessions.

Management Question 4:

What is the most effective method for monitoring spawning of White Sturgeon?

The most effective methods for monitoring *White Sturgeon* in the MCR is drift nets and egg mats (Wood et al., Golder and ONA 2020). Throughout this program, a total of 109 progeny have been captured using egg mats (0.01 CPUE) and 1,171 using drift nets (0.25 CPUE). In 2022, the increase in drift net effort, especially those sampled overnight, resulted in all eggs captured for the year. Going forward, overnight drift net sets should be prioritized to maximize captures in the MCR with egg mats deployed between sessions for early detection of spawning events.

This data report is intended to detail the methods and results of monitoring in 2022. For further discussion of the status of management questions and comparisons between previous study years, readers are referred to the interpretive reports from previous years of this monitoring program (Wood 2019; Golder and ONA 2020).

4.2 Summary of Effort, Catch, and Survival (2007 – 2022)

Egg mat effort was relatively consistent between 2007 and 2018, with the exception of 2012. In 2019 an adaptive study design was adopted, and as a result egg mat effort was focused on sites with previous White Sturgeon captures. Therefore, the amount of egg mat sample sites was reduced in 2019 – 2022 compared to 2007 – 2018 (Table 6; Figure 7). In contrast, D-ring drift net effort has increased in 2020 – 2022 compared to 2007 – 2019. This is due to overnight sampling effort and the frequent re-deployment of sets that slip or drift due to high flows (rather than removing those sets).

Table 6. Summary of annual expected effort, White Sturgeon (WSG) egg and larvae captures, and associated Catch-Per-Unit-Effort (CPUE) in the Mid-Columbia River during CLBMON-23A from 2007 to 2022.

Year	Egg Mats				Drift Nets				Total
	Egg Mats Deployed	Effort (hours)	# WSG	CPUE (# / 24 h)	Drift Nets Deployed	Effort (hours)	# WSG	CPUE (# / h)	
2022	25	3,743	0	0.00	58	537.4	20	0.04	20
2021	27	6,378	1	< 0.01	53	578.6	701	1.21	702
2020	30	4,215	1	0.05	67	825.5	230	0.30	231
2019	82	11,569	2	< 0.01	52	148.5	10	0.07	12
2018	140	23,068	6	0.01	71	387.2	93	0.24	99
2017	143	23,263	7	0.01	66	379.5	2	0.01	9
2016	140	22,771	1	< 0.01	55	341.6	0	0.00	1
2015	132	21,560	0	0.00	60	311.0	0	0.00	0
2014	123	20,850	19	0.02	64	375.9	38	0.10	57
2013	135	20,019	2	< 0.01	67	424.3	0	0.00	2
2012	61	8,773	0	0.00	28	106.8	8	0.07	8
2011	128	22,169	30	0.03	23	61.2	18	0.30	48
2010	96	20,514	0	0.00	15	67.4	0	0.00	0
2009	115	18,860	36	0.05	22	65.3	47	0.70	83
2008	164	27,009	4	< 0.01	6	12.6	4	0.30	8
2007	136	25,818	0	0.00	8	24.7	0	0.00	0
WSG Total			**109**				**1,171**		**1,280**

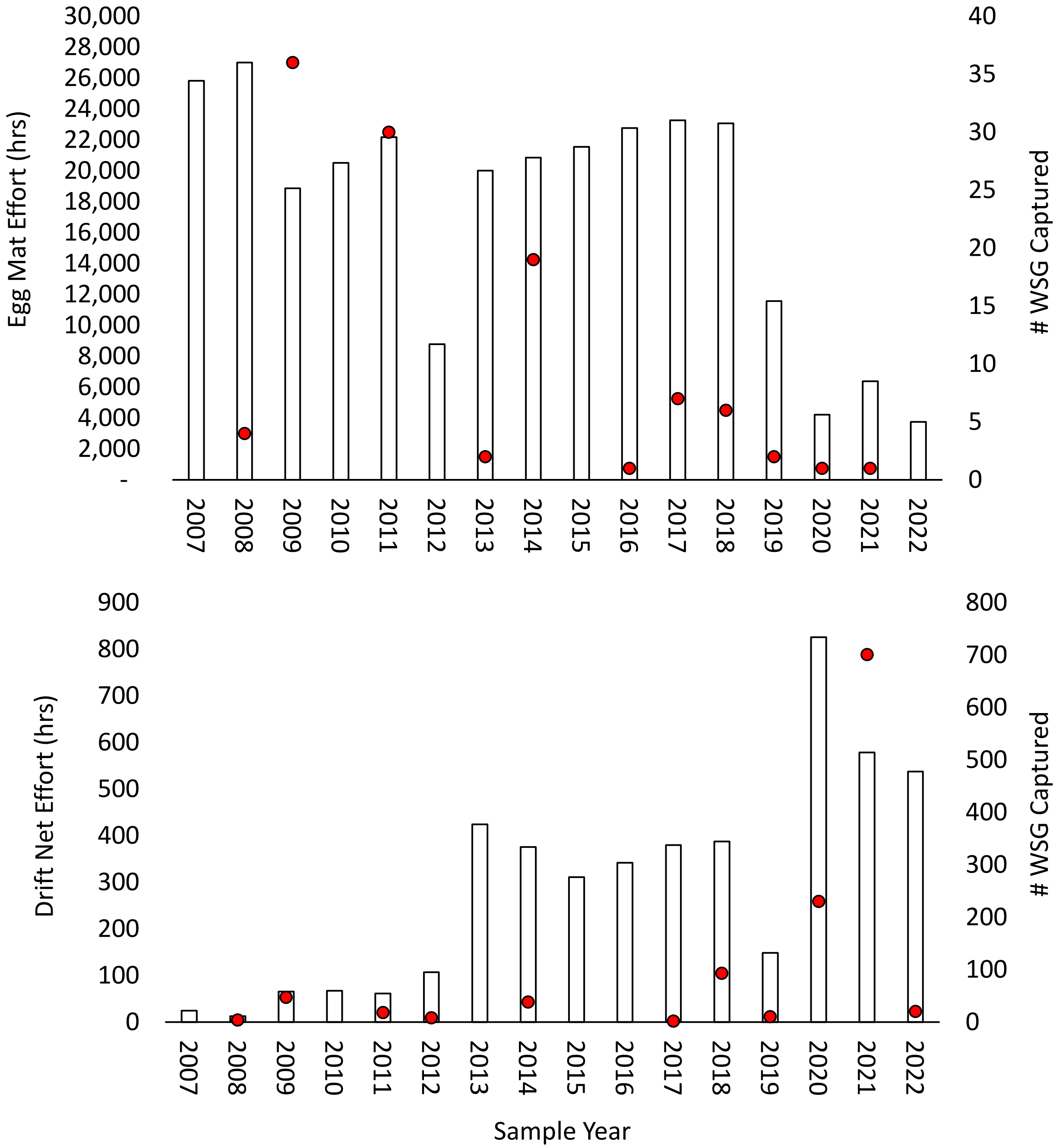

Figure 7. (Top) Egg Mat effort (hrs) and the number of White Sturgeon captured by year; (bottom) Drift net (D-ring) effort (hrs) and the number of White Sturgeon captured by year.

White Sturgeon capture success appeared to be highest between Jul 22 and Aug 25, typically at rkm 227.8 and 228.6 (Table 7). Effort in 2019 – 2022 has been focused on rkm 227.8 and 229.0, which may skew results.

Table 7. White Sturgeon captures (egg and larvae) by week from July 22 to September 15 (2007 – 2022) and rkm for all capture methods.

Site (rkm)	Date (2007 - 2022)								Total (Location)
	July 22 - 28	July 29 - Aug 4	Aug 5 - Aug 11	Aug 12 - Aug 18	Aug 19 - Aug 25	Aug 26 - Sep 1	Sep 2 - Sep 8	Sep 9 - Sep 15	
226.8				3					**3**
230.6					1				**1**
230.3					1		1		**2**
230.0				7	14	3			**24**
229.9				4	3				**7**
229.8			1		1	1	1		**4**
229.7				1					**1**
229.5			3	1					**4**
229.4		2	2	2	8	17			**31**
229.3			14	1	1		2		**18**
229.2			2						**2**
229.1		2	6			1			**9**
229.0			3		2				**5**
228.9		11	12		4				**27**
228.8		5	4	4	2	5	10		**30**
228.7			3	1	1				**5**
228.6	45	29	52		27				**153**
228.5	101	31	63	8	534*	5		1	**743**
228.2				1	3				**4**
228.1	11	39	82	14	3				**149**
227.9		1	10	4	1	2		11	**29**
227.8	3	7	13	3	4				**30**
227.4							1		**1**
Total (Date)	**160**	**127**	**270**	**54**	**610**	**34**	**15**	**12**	

* 529 of 534 White Sturgeon captured at this location in this week were from 2021.

Survival rate (to release from the hatchery) of collected White Sturgeon progeny has ranged from 11% to 21% (2018 – 2022), while survival of progeny collected in 2021 and 2022 are currently at 11% and 37% respectively (as of Mar 09 2023; pers. comm., Mike Keehn [Freshwater Fisheries Society of British Columbia], 2023; Table 8).

Table 8. The number of eggs and larvae received by the Freshwater Fisheries Society by year and the number of White Sturgeon that survived to release the respective release year; where red indicates survival to Mar 9 2023 (pers. comm., Mike Keehn [Freshwater Fisheries Society of British Columbia], 2023).

Year	# Eggs Received	# Larvae Received	# Survive to Release	Release Year
2018	89	0	16	2018*
2019	7	2	1	2021
2020	195	2	42	2022
2021	685	0	78	2023
2022	19	0	7	2024

* pre two-year hold back.

Factors contributing to post-collection mortality are suspected to include:

- Harm from displacement from high velocity flows
- Harm from substrate and/or debris while in collection cups
- Harm from equipment drift (anchor tines disrupting substrate in high velocity flows)
- Harm from didymo (suffocation)
- Stress from immediate transport from collection site to hatchery

5.0 Recommendations

The following are recommended to improve egg/larval collection:

1. Continue the adaptive management approach regarding sampling effort to maximize progeny collection.
2. Deploy additional effort or gear at sites that collect progeny (example: if 228.1M has progeny, deploy two D-ring drift nets at 228.1M for the next set).

The following are recommended to reduce mortality:

1. Increased communication between collection crews and hatchery regarding handling
2. Consider testing the use of collection socks rather than collection cups
3. Relocate the BC Hydro streamside hatchery facility to Revelstoke to reduce stress on collected progeny
4. Reduce handling of early stage eggs (when possible)

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Appendix A – 2022 Data

Table 9. Egg mat collection data including location (WP = waypoint), set and pull date and time, site temperature (°C) and depth (m), number of White Sturgeon (WSG) eggs and larvae, and effort (soak time in hours).

Session	Station	WP	UTM Zone 11U		Set		Pull		Temperature (°C)		Depth (m)	No. WSG Eggs	No. WSG Larvae	Soak Time (hrs)	Stage of WSG
			Easting	Northing	Date in	Time in	Date out	Time out	Set	Pull					
1	228.8L	202	413381	5651770	25-Jul-22	16:11	2-Aug-22	15:29	9.1	10.1	4.0	0	0	191.30	-
1	227.9L	203	413406	5651335	25-Jul-22	16:19	2-Aug-22	16:29	9.1	10.3	3.7	0	0	192.17	-
1	228.5M	206	413233	5651323	26-Jul-22	8:25	2-Aug-22	14:32	9.4	10.2	2.8	0	0	174.12	-
1	228.1M	201	413436	5651350	26-Jul-22	9:09	2-Aug-22	15:01	9.4	10.3	4.0	0	0	173.87	-
1	228.6M	204	-	-	26-Jul-22	10:57	2-Aug-22	13:31	9.4	10.3	2.4	0	0	170.57	-
2	228.8L	202	-	-	2-Aug-22	15:52	8-Aug-22	14:25	10.2	9.8	3.9	0	0	142.55	-
2	227.9L	203	-	-	2-Aug-22	16:54	8-Aug-22	15:28	10.3	9.7	4.1	0	0	142.57	-
2	228.9M	211	413375	5651787	3-Aug-22	7:48	8-Aug-22	14:01	9.5	9.8	4.5	0	0	126.22	-
2	228.1M	201	-	-	3-Aug-22	9:17	8-Aug-22	14:53	9.3	9.5	4.1	0	0	125.60	-
2	228.5M	212	413183	5651362	3-Aug-22	10:35	8-Aug-22	13:14	9.5	9.8	3.6	0	0	122.65	-
2	228.6M	213	413224	5651493	3-Aug-22	11:01	8-Aug-22	12:25	9.7	9.7	3.5	0	0	121.40	-
2	227.8M	214	413499	5651414	3-Aug-22	11:09	8-Aug-22	15:08	9.5	9.6	4.1	0	0	123.98	-
3	228.8L	202	-	-	8-Aug-22	14:47	15-Aug-22	14:17	9.5	10.1	4.3	0	0	167.50	-
3	227.9L	203	-	-	8-Aug-22	15:50	15-Aug-22	14:34	9.8	10.1	3.9	0	0	166.73	-
3	228.6M	216	413242	5651464	9-Aug-22	7:53	15-Aug-22	12:53	9.7	10.0	1.5	0	0	149.00	-
3	228.5M	215	413222	5651430	9-Aug-22	8:27	15-Aug-22	13:22	9.7	10.0	2.1	0	0	148.92	-
3	227.8M	214	-	-	9-Aug-22	9:23	15-Aug-22	14:00	9.7	10.1	3.5	0	0	148.62	-
3	228.1M	201	-	-	9-Aug-22	9:29	15-Aug-22	13:40	9.7	10.0	4.0	0	0	148.18	-
4	228.8L	202	-	-	15-Aug-22	14:29	23-Aug-22	14:22	10.1	10.9	4.0	0	0	191.88	-
4	227.9L	203	-	-	15-Aug-22	15:05	23-Aug-22	14:30	10.3	11.0	2.7	0	0	191.42	-
4	227.8M	214	-	-	18-Aug-22	7:45	23-Aug-22	14:07	10.8	10.9	3.6	0	0	126.37	-
4	228.1M	260	413438	5651354	18-Aug-22	7:50	23-Aug-22	13:29	10.9	10.8	3.5	0	0	125.65	-
4	228.5M	264	413204	5651340	18-Aug-22	9:23	23-Aug-22	13:18	10.8	10.7	2.9	0	0	123.92	-
4	228.6M	257	413202	5451390	18-Aug-22	9:48	23-Aug-22	13:03	10.9	10.5	2.0	0	0	123.25	-
4	228.9M	262	413329	5651710	18-Aug-22	9:44	23-Aug-22	13:56	10.8	11.0	3.5	0	0	124.20	-

Table 10. D-Ring drift net collection data including location (WP = waypoint), set and pull date and time, site temperature (°C) and depth (m), number of White Sturgeon (WSG) eggs and larvae, and effort (soak time in hours).

Session	Station	WP	UTM Zone 11 U		Set			Pull			Temperature (°C)		Depth	No. WSG Eggs	No. WSG Larvae	Soak Time (hrs)	Stage of WSG
			Easting	Northing	Date in	Time in	Flow Meter Reading	Date out	Time out	Flow Meter Reading	Set	Pull					
1	228.6M	199	413235	5651494	25-Jul-22	14:04	400397	25-Jul-22	16:31	720497	8.9	9.1	3.0	0	0	2.45	-
1	228.5M	200	413212	5651398	25-Jul-22	14:15	556726	25-Jul-22	17:00	784855	8.9	9.2	2.8	0	0	2.75	-
1	228.1M	201	413436	5651350	25-Jul-22	14:25	987641	25-Jul-22	17:18	260501	8.9	9.3	4.2	0	0	2.88	-
1	228.6M	205	413210	5651394	25-Jul-22	17:02	726493	26-Jul-22	8:25	384961	9.2	9.4	2.4	0	0	15.38	-
1	228.1M	201	-	-	25-Jul-22	17:20	384961	26-Jul-22	9:09	887370	9.3	9.4	3.6	0	0	15.82	-
1	228.6M	204	-	-	25-Jul-22	17:40	260503	26-Jul-22	10:51	473070	9.4	9.4	1.7	0	0	17.18	-
2	228.6M	204	-	-	2-Aug-22	13:31	384962	2-Aug-22	15:57	652999	10.3	10.2	1.9	0	0	2.43	-
2	228.5M	206	-	-	2-Aug-22	14:32	88776	2-Aug-22	16:15	209789	10.2	10.2	2.3	0	0	1.72	-
2	228.1M	201	-	-	2-Aug-22	15:01	473095	2-Aug-22	16:55	694943	10.3	10.2	3.5	0	0	1.90	-
2	228.6M	204	-	-	2-Aug-22	15:58	887428	3-Aug-22	8:55	533754	10.2	9.4	1.9	0	0	16.95	-
2	228.5M	206	-	-	2-Aug-22	16:17	653004	3-Aug-22	8:15	979843	10.2	9.4	2.2	0	0	15.97	-
2	228.1M	201	-	-	2-Aug-22	16:58	209798	3-Aug-22	9:15	167029	10.2	9.3	3.5	0	0	16.28	-
2	228.9M	209	413391	5651802	2-Aug-22	17:18	694150	3-Aug-22	7:48	401567	10.2	9.5	4.4	0	0	14.50	-
3	228.6M	215	413222	5651430	8-Aug-22	12:26	167030	8-Aug-22	15:55	656119	9.7	9.6	2.3	0	0	3.48	-
3	228.5M	215	-	-	8-Aug-22	16:23	656128	9-Aug-22	8:26	354739	9.7	9.7	2.6	0	0	16.05	-
3	228.6M	216	413242	5651464	8-Aug-22	16:28	992166	9-Aug-22	7:52	119149	9.6	9.7	1.9	0	0	15.40	-
3	228.9M	209	-	-	-	-	553750	-	-	-	-	-	-	-	-	N/A	-
3	228.1M	201	-	-	8-Aug-22	16:43	564720	9-Aug-22	9:28	446370	9.5	9.7	4.2/3.8	0	0	16.75	-
4	228.9M	209	-	-	-	-	-	-	-	-	-	-	-	-	-	N/A	-
4	228.6M	216	-	-	15-Aug-22	12:54	N/A	15-Aug-22	16:14	N/A	10.0	10.6	1.5	0	0	3.33	-
4	228.5M	215	-	-	15-Aug-22	13:23	N/A	15-Aug-22	16:37	N/A	10.0	10.6	2.1	0	0	3.23	-
4	228.1M	250	413479	5651385	15-Aug-22	13:42	N/A	15-Aug-22	15:11	N/A	10.1	10.3	4.0	1	0	1.48	3
4	228.6M	216	-	-	15-Aug-22	16:15	2937	16-Aug-22	11:08	469790	10.6	10.6	1.5	0	0	18.88	-
4	228.5M	215	-	-	15-Aug-22	16:38	354790	16-Aug-22	10:46	452770	10.6	10.4	2.1	0	0	18.13	-
4	228.9M	252	413369	5651766	15-Aug-22	17:10	390571	16-Aug-22	7:54	603526	10.5	10.5	4.2	0	0	14.73	-
4	227.8M	214	-	-	15-Aug-22	17:20	119165	16-Aug-22	8:38	714310	10.5	10.6	3.4	0	0	15.30	-
4	228.9M	252	-	-	16-Aug-22	7:55	N/A	16-Aug-22	12:59	N/A	10.6	10.7	3.9	0	0	5.07	-
4	227.8M	256	413510	5651424	16-Aug-22	8:39	603543	16-Aug-22	13:23	88285	10.6	10.7	3.5	0	0	4.73	-
4	228.5M	215	-	-	16-Aug-22	10:47	714310	16-Aug-22	13:51	33755	10.5	10.5	1.5	0	0	3.07	-
4	228.6M	257	413202	5451390	16-Aug-22	11:55	469790	16-Aug-22	14:10	720702	10.6	10.8	2.8	0	0	2.25	-
4	228.9M	252	-	-	16-Aug-22	13:00	452780	16-Aug-22	14:24	617986	10.6	108.0	3.8	0	0	1.40	-
4	228.9M	258	413340	5651725	16-Aug-22	15:23	617980	17-Aug-22	10:33	708962	10.8	10.5	3.9	0	0	19.17	-
4	228.6M	257	-	-	16-Aug-22	15:29	720710	17-Aug-22	10:08	288236	10.6	10.5	2.2	0	0	18.65	-
4	228.5M	259	413198	5651309	16-Aug-22	15:33	33770	17-Aug-22	9:24	53930	10.7	10.4	3.1	1	0	17.85	16
4	228.1M	260	413438	5651354	16-Aug-22	15:41	88263	17-Aug-22	8:07	422534	10.6	10.4	3.2	0	0	16.43	-
4	227.8M	214	-	-	17-Aug-22	8:04	N/A	17-Aug-22	12:29	N/A	10.4	10.8	3.5	0	0	4.42	-
4	228.6M	257	-	-	17-Aug-22	10:09	422533	17-Aug-22	12:47	666396	10.5	10.8	2.1	0	0	2.63	-
4	228.9M	262	413329	5651710	17-Aug-22	10:34	288236	17-Aug-22	13:05	532157	10.5	10.9	3.6	0	0	2.52	-
4	228.5M	263	413204	5651366	17-Aug-22	11:38	708955	17-Aug-22	14:03	34275	10.6	10.9	3.0	6	0	2.42	12, 14

Session	Station	WP	UTM Zone 11 U		Set			Pull			Temperature (°C)		Depth	No. WSG Eggs	No. WSG Larvae	Soak Time (hrs)	Stage of WSG
			Easting	Northing	Date in	Time in	Flow Meter Reading	Date out	Time out	Flow Meter Reading	Set	Pull					
4	227.8M	214	-	-	17-Aug-22	12:30	53933	17-Aug-22	15:15	108733	10.8	10.9	3.8	0	0	2.75	-
4	228.6M	257	-	-	17-Aug-22	13:02	666396	17-Aug-22	15:56	86673	10.9	11.1	2.2	0	0	2.90	-
4	228.5M	264	413204	5651340	17-Aug-22	15:03	34270	18-Aug-22	9:22	474765	10.9	10.8	3.0	1	0	18.32	15
4	228.1M	260	-	-	17-Aug-22	15:11	554968	18-Aug-22	7:49	246605	10.9	10.9	3.8	5	0	16.63	15
4	228.6M	257	-	-	17-Aug-22	15:57	108732	18-Aug-22	9:47	1868	10.9	10.9	2.2	0	0	17.83	-
5	228.6M	257	-	-	23-Aug-22	13:04	N/A	23-Aug-22	16:08	N/A	10.5	11.7	2.0	0	0	3.07	-
5	228.1M	268	413448	5651362	23-Aug-22	13:30	N/A	23-Aug-22	15:15	N/A	10.9	11.1	3.6	1	0	1.75	24
5	228.6M	257	-	-	23-Aug-22	16:09	N/A	24-Aug-22	8:45	N/A	11.7	13.6	2.2	1	0	16.60	26
5	228.5M	270	413217	5651422	23-Aug-22	16:32	N/A	24-Aug-22	9:30	N/A	11.8	13.1	2.5	0	0	16.97	-
5	227.8M	214	-	-	23-Aug-22	16:40	N/A	24-Aug-22	7:38	N/A	11.8	13.4	4.3	3	0	14.97	24
5	227.8M	214	-	-	24-Aug-22	7:39	N/A	24-Aug-22	11:30	N/A	13.4	13.3	4.0	1	0	3.85	25
5	228.6M	257	-	-	24-Aug-22	8:44	N/A	24-Aug-22	12:11	N/A	13.6	13.2	1.7	0	0	3.45	-
5	228.9M	271	413308	5651675	24-Aug-22	9:22	N/A	24-Aug-22	12:21	N/A	13.1	13.4	3.1	0	0	2.98	-
5	228.5M	272	413186	5651387	24-Aug-22	9:58	N/A	24-Aug-22	12:50	N/A	14.0	13.2	3.6	0	0	2.87	-
5	228.1M	274	413390	5651314	24-Aug-22	10:47	N/A	24-Aug-22	13:55	N/A	13.5	13.3	2.7	0	0	3.13	-
5	228.6M	257	-	-	24-Aug-22	12:12	N/A	24-Aug-22	14:20	N/A	13.2	13.3	1.9	0	0	2.13	-
5	228.9M	271	-	-	24-Aug-22	12:22	N/A	24-Aug-22	14:36	N/A	13.4	13.3	3.0	0	0	2.23	-
5	227.8M	214	-	-	24-Aug-22	12:44	N/A	24-Aug-22	15:07	N/A	13.3	13.1	3.8	0	0	2.38	-
5	228.6M	257	-	-	24-Aug-22	15:43	N/A	25-Aug-22	8:01	N/A	13.1	11.5	2.4	0	0	16.30	-
5	228.5M	275	413208	5651380	24-Aug-22	15:45	N/A	25-Aug-22	8:34	N/A	13.0	11.5	2.9	0	0	16.82	-
5	228.1M	276	413427	5651350	24-Aug-22	15:51	N/A	25-Aug-22	7:42	N/A	13.1	11.7	4.3	0	0	15.85	-