Columbia River Project Water Use Plan

Columbia River White Sturgeon Management Plan

CLBMON-23A Egg Mat Monitoring Program

Implementation Year 15

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Middle Columbia River White Sturgeon Spawn Monitoring (CLBMON-23A): 2021 Data Report (Year 15)

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Executive Summary

The population of c'm'tus (White Sturgeon) in the Canadian portion of the Columbia River is listed as Endangered under the federal Species at Risk Act. A small portion of this population exists in salt̓ik̓ʷt (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 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:

- Sample to improve understanding of the timing and spatial extent of larval dispersal
- Conduct analyses to assess the risk of eggs or larvae becoming stranded due to hydroelectric operations

In 2021, 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, 671 live eggs, 23 dead eggs and 8 larvae were collected in 2021 using egg mats and 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 three spawning events; Aug 02 – 06, Aug 23 – 25, and Sep 5 2021.

The Arrow Lakes Reservoir elevation was below 437 MASL for the duration of the project, indicating that the survey area was not backwatered by the reservoir during the period when adults were spawning. While stranding risk was not calculated in 2021, egg deposition would have occurred at lower elevations in the absence of backwatering, reducing the risk of stranding.

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The following employees of the **BC Hydro** contributed to this project in 2021-22:

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1.0 Introduction

The Canadian population of *c'm'tus* (White Sturgeon, *Acipenser transmontanus*) in the *nx̌ʷntkʷitkʷ* (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 *snkxy̌ kntn* (Revelstoke) BC. This portion of the *nx̌ʷntkʷitkʷ* 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 27 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 *c'm'tus* 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). Fifteen years of monitoring have been completed in the CLBMON-23A program to date (2007 to 2021). This report describes the methods and results of egg mat and drift net monitoring for CLBMON-23A in 2021 (Year 15).

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 not part of this program but eggs and larvae that were dead after capture were preserved, provided to BC Hydro, and will be used for genetic analyses in the future. Survival of early life stages (key uncertainty #2) cannot be directly measured or estimated using the data provided by this monitoring program. Stranding risk (key uncertainty #3) was assessed by examining river discharge data and ALR surface elevation data for large flow reductions during periods when there were known to be *c'm'tus* 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 Kootenay Sturgeon Hatchery to increase the genetic diversity of the conservation aquaculture program
- Sampling to improve understanding of the timing and spatial extent of larval dispersal

In light of these two objectives, the study design of CLBMON-23A was modified (starting in 2020) from previous years. A modification to attempt to increase the number of progeny collected for conservation aquaculture was to use an adaptive study design, where the sample sites and duration would be adapted during the sampling season based on the timing and location of capture of eggs or larvae. This differed from previous years, where the index sample sites and schedule were set.

This report summarizes the results from the 2021 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

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 2021, the program was focused in the area that all c'm'tus eggs and larvae have been

[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

captured in previous years of this program (RKm 229.9 and 226.3; Wood 2019; Golder and ONA 2020). In an attempt to maximize captures in 2021, sampling was concentrated during the primary spawning and incubation period. Sampling downstream of RKm 226.3 for fall larval dispersal was not conducted in 2021.

2.2 Sampling Equipment

Egg collection mats ('egg mats') and drift nets were used to capture c'm'tus eggs and larvae. This was consistent with all previous years of the monitoring program (Wood 2019; Golder and ONA 2020). 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 bottle). 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 or four-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 September – with egg mats deployed on Jul 22 2021 and retrieved on Sep 14 2021, while drift net were deployed at the beginning, and retrieved at the end, of each sampling session. Sampling was not conducted from Aug 30 – Sept 10 2021 and sampling timing and effort 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 when spawning was detected as a significant reduction in embryo or larval captures were found in the weeks following spawning in previous years. Additional sampling at sites where eggs or larvae were captured was conducted and additional sites were

installed adjacent to (perpendicular to current) or downstream of the capture location when possible. In addition, if significant numbers of eggs or larvae were captured, the session would be extended by one day 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 226.8 and 228.9 between mid-channel and river left as viewed facing downstream (Figure 1). Nine of the twelve sites sampled in 2019 were sampled in 2021 (RKm 226.8M, 227.8M, 227.9L, 228.1M, 228.5L, 228.5M, 228.6M, 228.8L, 228.9M). Exact locations may have been modified slightly in the field depending on river conditions. Similar to 2020, sampling did not occur on river right and further upstream since eggs and larvae were not captured in those 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 – 2021 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.

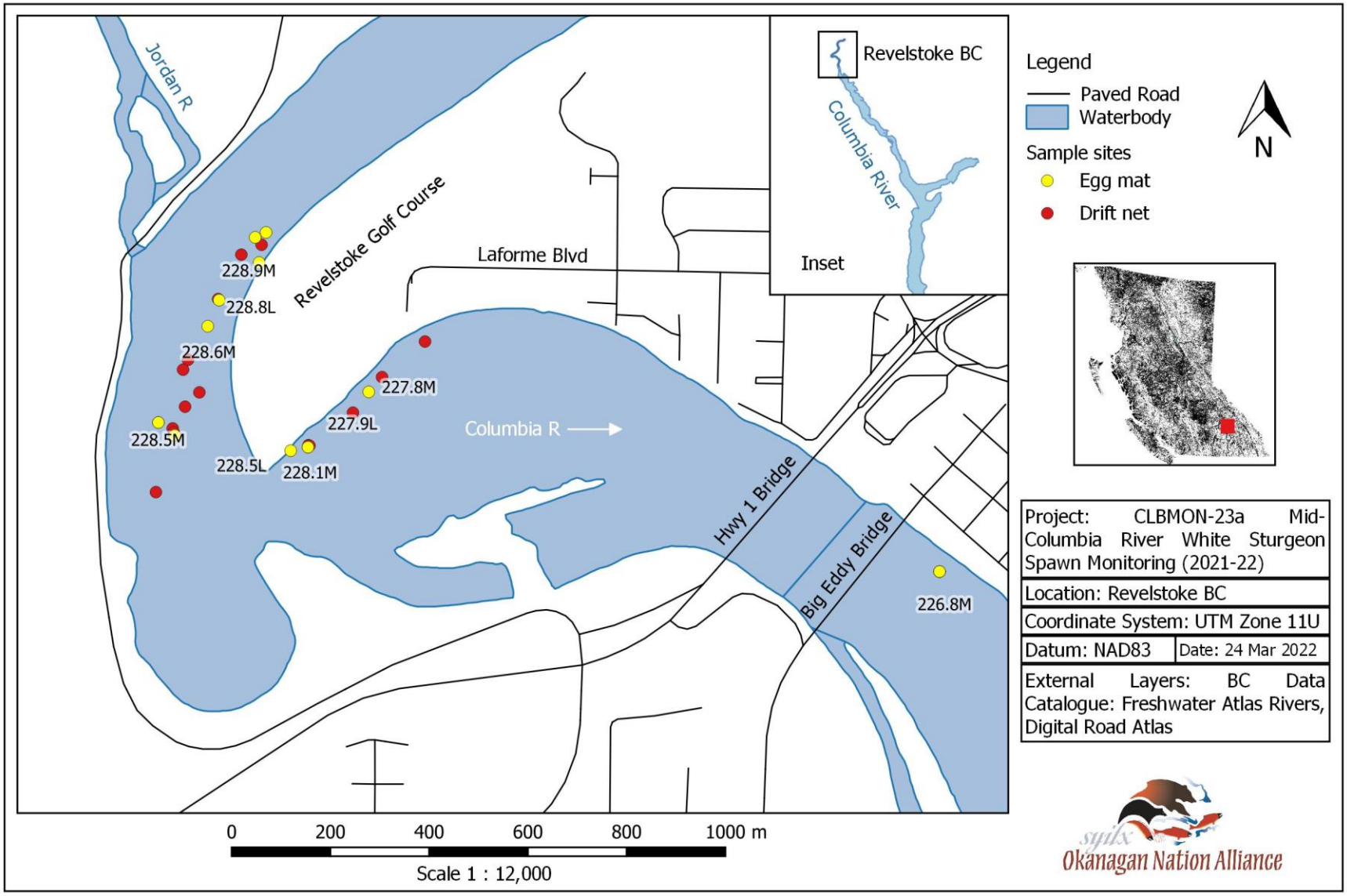

Figure 1. Egg mat and drift net sampling locations for White Sturgeon eggs and larvae in the Mid-Columbia River in 2021. Site names are representative of the river kilometer with "M" (deep) and "L" (shallow) indicating depth.

2.4 Study Period

Sampling activities and the timing of site visits in 2021 relative to the presumed time periods for spawning and early life history phases of c'm'tus were similar to previous years (Table 1). Larval dispersal monitoring was not conducted in 2021.

Table 1. Summary of CLBMON-23A sampling activities in the Mid-Columbia River (MCR) during 2021 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 21 - 23				
2	Egg mat and drift net sampling	Jul 27 - 28				Jul 24 - Aug 1
3	Egg mat and drift net sampling	Aug 03 - 05				
4	Egg mat and drift net sampling	Aug 10 - 11				Aug 7 - 22
5	Egg mat and drift net sampling	Aug 23 - 24				
	No sampling conducted					Aug 28 - Sep 13
6	Egg mat retrieval; drift net sampling	Sep 14 - 15				
	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 *c'm'tus* 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). If large numbers of eggs were captured in one location, a sub-sample of eggs were assigned to specific stages and the remainder grouped into early, middle, or late developmental groups according to the distribution of specific developmental stages. All live eggs and larvae were held in insulated coolers filled with river water and transferred to the Kootenay Sturgeon Hatchery. Any eggs or larvae 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 were obtained from BC Hydro's Columbia Basin Hydrological Database. Two temperature loggers (HOBO TidbiT v2) were deployed to sample water temperature every hour and were secured to sampling set anchors 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)
- Start and end readings of flow meter (drift nets only)
- 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 Data Analyses

Spawn timing (spawning dates) were estimated from the date of egg/larvae collection using the egg/larvae 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 was used to map the location of sample sites and egg and larvae capture locations.

There is some uncertainty in developmental rates of c'm'tus 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 was 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.

2.9 Substrate Dewatering

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. Tracks were recorded at three different discharge / ALR elevation levels in 2021 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

3.0 Results

3.1 Discharge, Reservoir Elevation, and Water Temperature

During sampling in 2021, 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 900 – 1750 m³/s and minimum discharge ranged from 250 – 1350 m³/s.

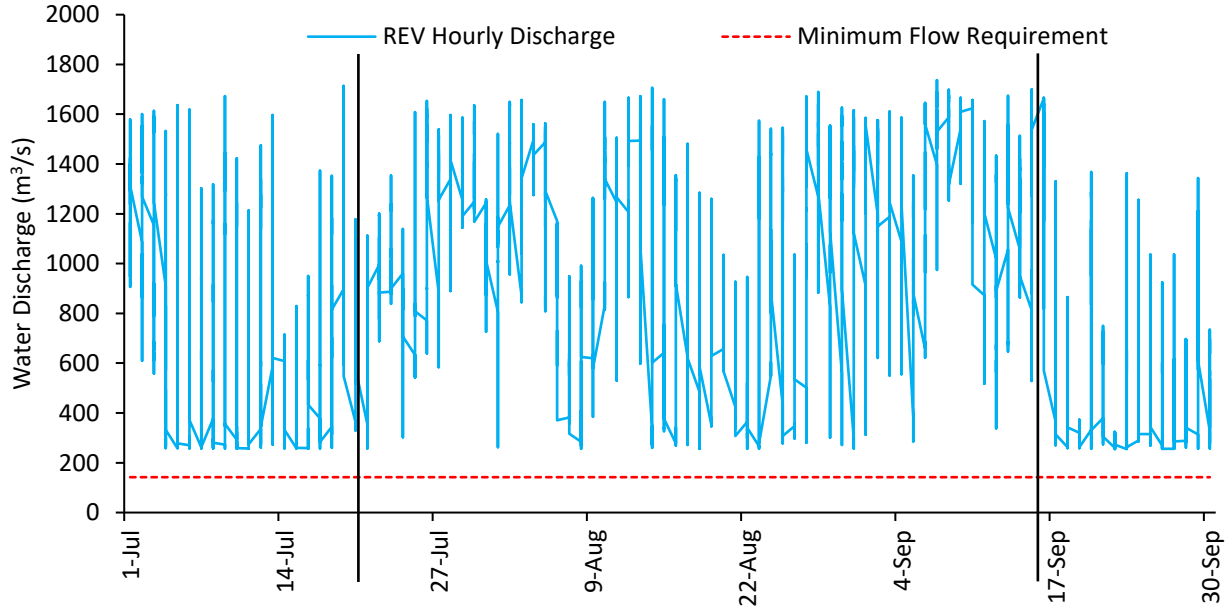

Figure 2. Hourly discharge in the Mid-Columbia River downstream of Revelstoke Dam (REV) in 2021 compared to the minimum flow requirement (142 m^3/s). CLBMON-23A sturgeon monitoring occurred between vertical black lines.

In 2021, ALR water surface elevation was 437.0 MASL at the start of the sample period on Jul 21 2021 and gradually declined to 432.9 MASL by the end of the sample period on Sep 15 2021 (Figure 3). The ALR water surface elevation was only at 437 MASL for the first day of sampling, the level above which the spawning area is backwatered, and was below this level for the remainder of sampling days.

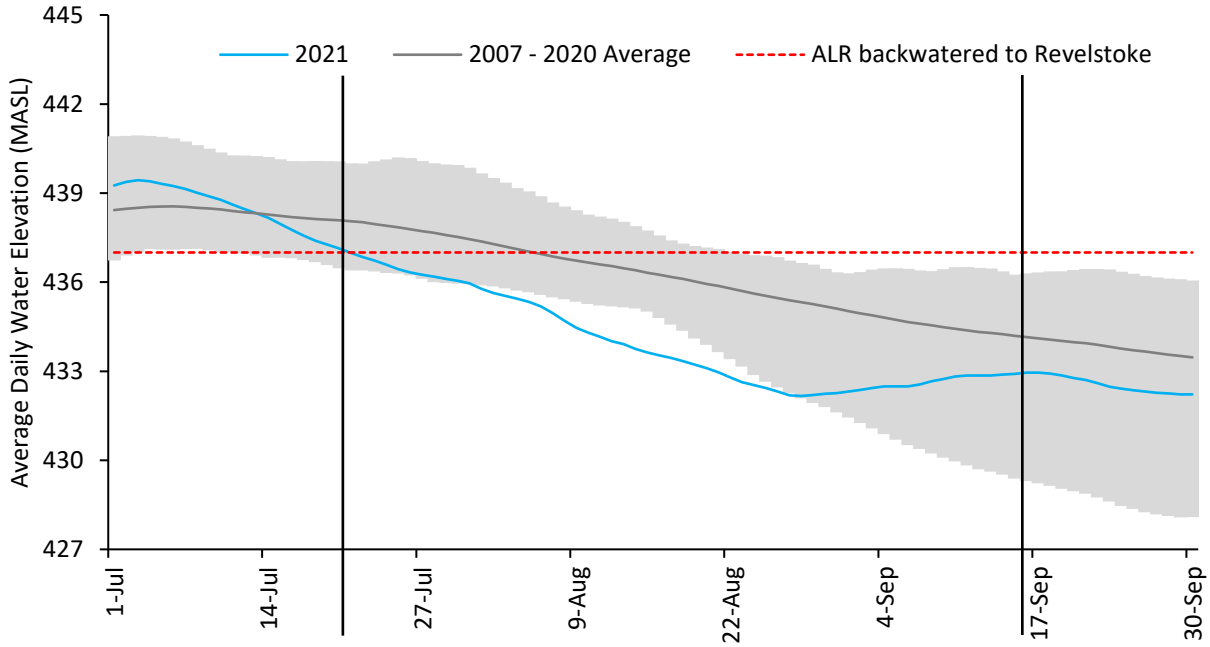

Figure 3. Average daily Arrow Lakes Reservoir (ALR) water surface elevation at Naksup BC from July to September compared to the level at which the reservoir is through to backwater the spawning and incubation area of White Sturgeon near Revelstoke (437 MASL; Hildebrand *et al.* 2014). The greyed area shows the variation in reservoir elevation from 2007 – 2020 (minimum and maximum average daily values). CLBMON-23A sturgeon monitoring occurred between vertical black lines.

Water temperature measured at the spawning area during the sample period averaged 10.6 °C (Figure 4).

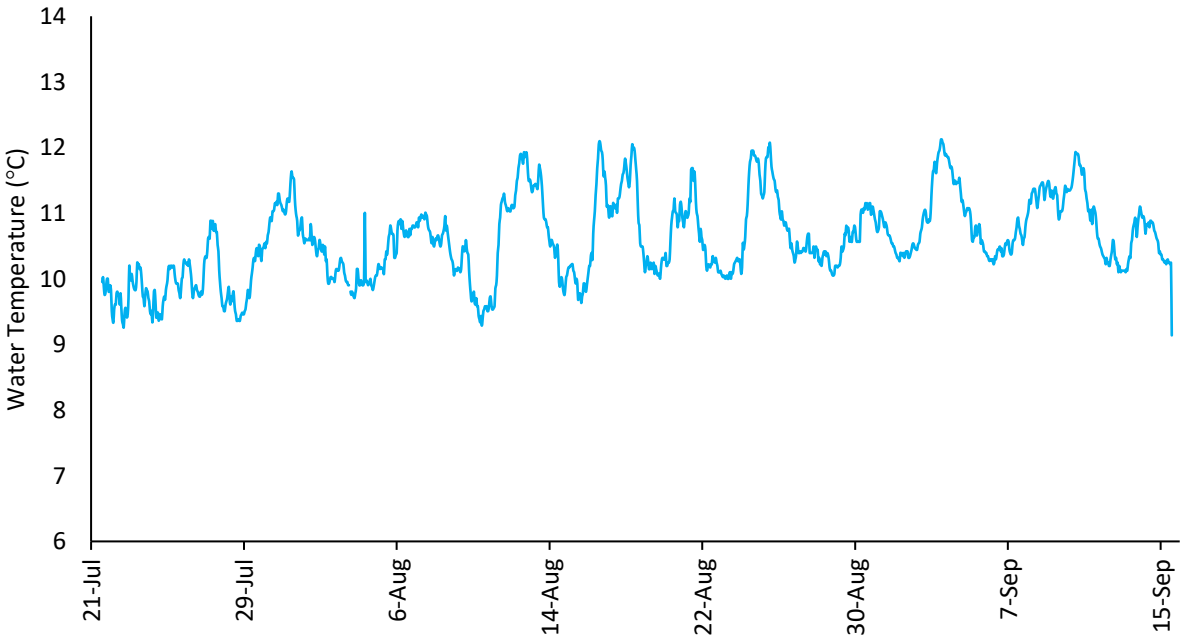

Figure 4. Water temperature in the Mid-Columbia River measured at White Sturgeon spawning areas during CLBMON-23A in 2021.

3.2 Catch and Effort

From Jul 22 – Sep 14 2021, nine sites were sampled with 27 egg mats, one of which was lost, resulting in different expected versus actual egg mat soaking hours (6,378 and ,6280 mat-hours, respectively (Table 2). Through egg mat sampling, one live *c'm'tus* egg was captured at site 228.8L, upstream of Big Eddy (Figure 5). Due to the low capture rate, expected and actual CPUE values were the same (0.001 WSG / 24hr).

Table 2. Expected and actual egg mat sampling effort, catch of White Sturgeon eggs and larvae, and associated Catch-Per-Unit-Effort (CPUE) in the Mid-Columbia River during CLBMON-23A in 2021. Live larvae, dead eggs, and dead larvae were not encountered.

Dates	Effort Expected (mat-hours)	Effort Actual (mat-hours)	# Sites Expected	# Sites Actual	# Live Eggs	CPUE Expected (#/24h)	CPUE Actual (#/24h)
Jul 22 - 27	744	645	7	6	0	0	0
Jul 28 - Aug 03	929	929	6	6	0	0	0
Aug 03 - 10	822	822	6	6	1	0.001	0.001
Aug 10 - 23	2,840	2,840	6	6	0	0	0
Aug 23 - Sep 14	1,043	1,043	2	2	0	0	0

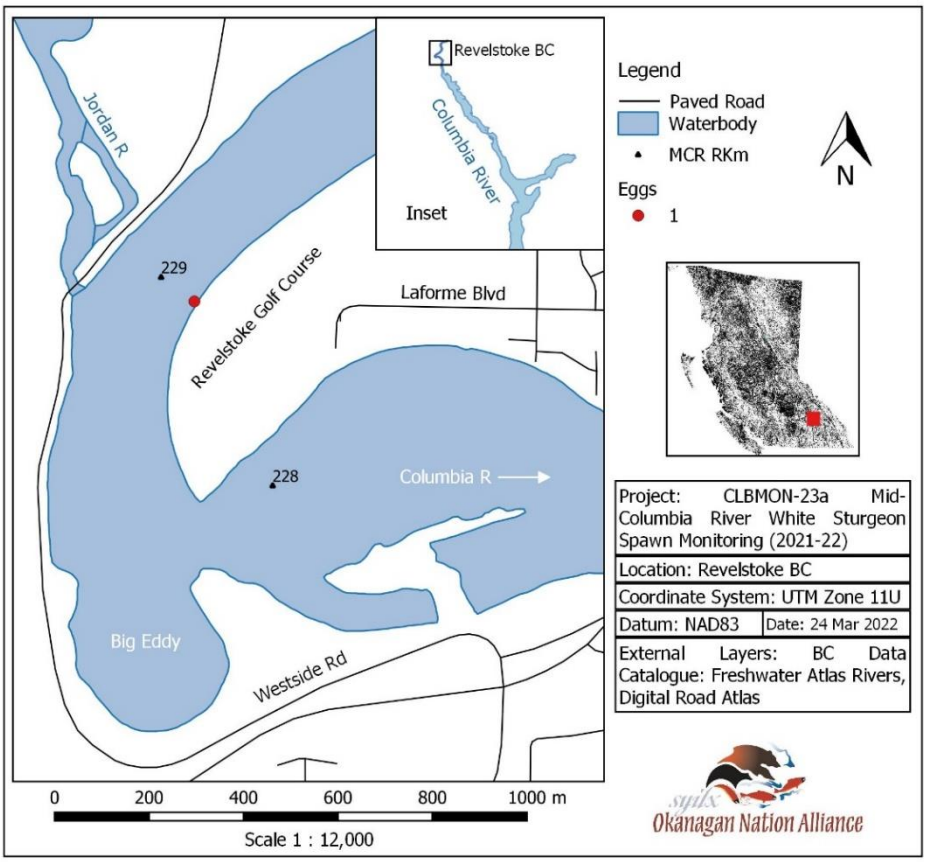

Figure 5. Capture location of White Sturgeon egg via egg mat sampling in the Mid-Columbia River during CLBMON-23A in 2021.

From Jul 21 – Sep 15 2021, eight sites were sampled with 53 drift nets, two of which were damaged and could did not collect any sample, resulting in different expected versus actual drift net soaking hours (579 and 541 net-hours, respectively; Table 3). In total, 25 sets were deployed as day sets (1 – 7 soaking hours) and 28 were set overnight (15 – 22 soaking hours); the two nets that were damaged were overnight sets. A total of 670 live eggs, 23 dead eggs, and 8 live larvae were captured in drift nets in 2021 (702 total; Figure 6). The expected CPUE for drift net sampling was lower than actual CPUE (1.212 WSG/h and 1.295 WSG/h, respectively. As most sturgeon were captured in overnight sets, total actual CPUE for overnight sets was significantly higher than actual CPUE for day sets (1.375 and 0.839 WSG/h, respectively).

Table 3. Expected and actual drift net sampling effort either during the day or overnight, catch of White Sturgeon eggs and larvae, and associated Catch-Per-Unit-Effort (CPUE) in the Mid-Columbia River during CLBMON-23A in 2021.

Dates	Day / Night	Expected Effort (net-hours)	Actual Effort (net-hours)	# of Sets	# Eggs Live (Dead)	# Larvae Live (Dead)	Expected CPUE (#/h)	Actual CPUE (#/h)
Jul 21 - 23	Day	24	24	6	0	0	0	0
	Night	103	103	6	0	0	0	0
Jul 27 - 28	Day	3	3	2	0	0	0	0
	Night	53	53	3	0	0	0	0
Aug 03 - 05	Day	16	16	7	14 (2)	0	1.01	1.01
	Night	129	129	7	69 (4)	0	0.56	0.56
Aug 10 - 11	Day	20	20	6	10 (1)	0	0.54	0.54
	Night	68	68	4	33 (10)	0	0.63	0.63
Aug 23 - 24	Day	18	18	4	41 (0)	0	2.24	2.24
	Night	109	72	6	503 (6)	7 (0)	4.72	7.17
Sep 14 - 15	Day	0	0	0	0	0	0	0
	Night	34	34	2	0	1 (0)	0.03	0.03

The majority (83%) of eggs and larvae were captured at station 228.5M, with 98% of captures occurring within RKm 228 (Table 4).

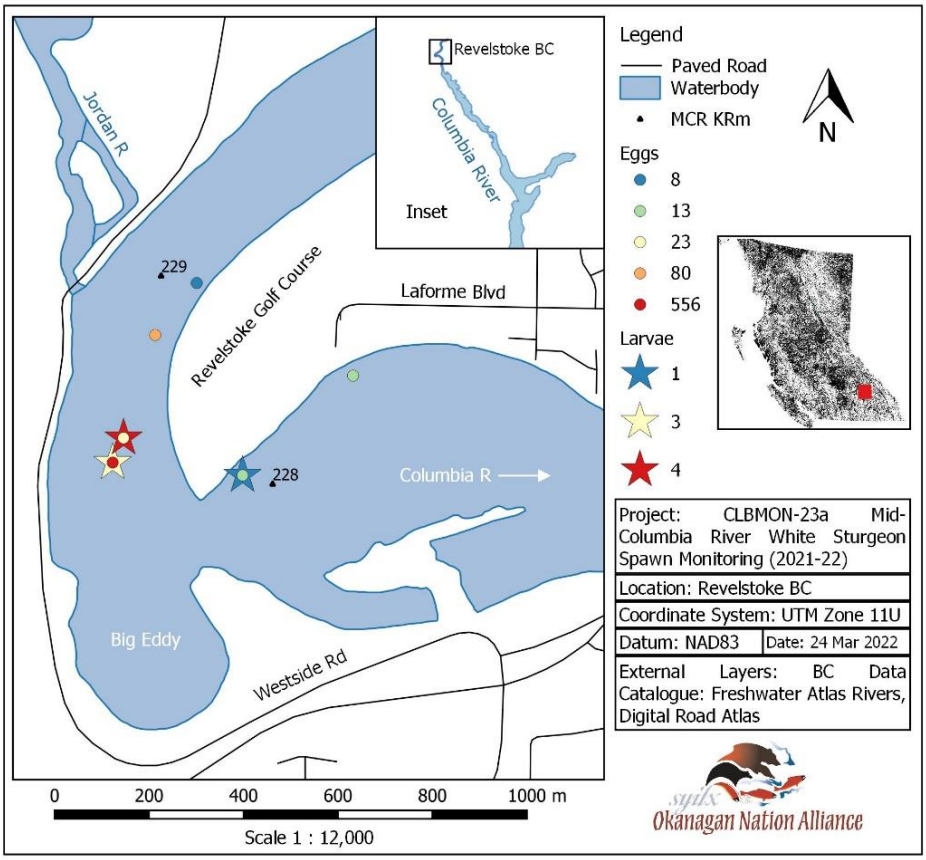

Figure 6. Capture locations of White Sturgeon eggs and larvae via drift net sampling in the Mid-Columbia River during CLBMON-23A in 2021.

Table 4. Temporal and geographical spatial data of egg mat and drift net effort (greyed boxes) including the number of White Sturgeon egg and larvae captures (green boxes). Data collected in the Mid-Columbia River for CLBMON-23A in 2021.

Station	July				August								September		Total
	22	23	27	28	03	04	05	10	11	23	24	25	14	15	
228.9M							1	7							8
228.8L								1							1
228.6M						3	51				26				80
228.5M						12		1	43		42	487		1	586
228.5L															
228.1M						6	3	2	1		2				14
227.9L															
227.8M						1	12								13
226.8M															

Egg mat effort was consistent in early study years (2007 to 2018), with the exception of 2012. When the adaptive study design was integrated in 2019, egg mat effort was decreased (Table 5) as CPUE was generally lower (highest egg mat CPUE was in 2020 at 0.048 WSG/24h), while drift net effort was increased as CPUE was generally higher (highest drift net CPUE was in 2021 at 1.212 WSG/h).

Table 5. Summary of annual expected effort, White Sturgeon egg and larvae captures, and associated Catch-Per-Unit-Effort (CPUE) in the Mid-Columbia River during CLBMON-23A from 2007 to 2021.

Year	Egg Mats				Drift Nets				Total
	Egg Mats Deployed	Effort (hours)	# WSG	CPUE (# / 24 h)	Drift Nets Deployed	Effort (hours)	# WSG	CPUE (# / h)	
2021	27	6378	1	0.004	53	578.6	701	1.212	702
2020	30	4215	1	0.048	67	825.5	230	0.300	231
2019	82	11569	2	0.004	52	148.5	10	0.070	12
2018	140	23068	6	0.01	71	387.2	93	0.24	99
2017	143	23263	7	0.01	66	379.5	2	0.01	9
2016	140	22771	1	0.001	55	341.6	0	0	1
2015	132	21560	0	0	60	311.0	0	0	0
2014	123	20850	19	0.02	64	375.9	38	0.10	57
2013	135	20019	2	0.002	67	424.3	0	0	2
2012	61	8773	0	0	28	106.8	8	0.07	8
2011	128	22169	30	0.03	23	61.2	18	0.30	48
2010	96	20514	0	0	15	67.4	0	0	0
2009	115	18860	36	0.05	22	65.3	47	0.70	83
2008	164	27009	4	0.004	6	12.6	4	0.30	8
2007	136	25818	0	0.000	8	24.7	0	0	0
Total			109				1151		1260

3.3 Developmental Staging and Estimated Spawn Timing

Based on capture dates, water temperature, and egg / larvae stages, three spawning event were detected in 2021 (Table 6). The estimated dates of spawning were

(1) Aug 02 – 06
(2) Aug 23 – 25
(3) Sep 04

It is possible spawning took place over a few days, which can occur depending on factors such as water temperature. Larval sturgeon captured from Aug 24 – 25 were not staged, and may have been from the first spawning event, or potentially a separate spawning event.

Table 6. Estimated White Sturgeon spawn dates based on developmental stages (Parsely *et al.* 2011; Dettlaff *et al.* 1993) of eggs and larvae captured in the Mid-Columbia River during CLBMON-23A in 2021. 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 04	Eggs	22	3 – 15 / 12 – 21	0 – 58	Aug 02 – 04
Aug 05	Eggs	67	4 – 17 / 13 – 22	3 – 75	Aug 02 – 05
Aug 10	Eggs	11	25 – 30 / 24 – 26	107 – 128	Aug 05 – 06
Aug 11	Eggs	43	29 – 32 / 26	128	Aug 06
Aug 24	Eggs	65	1 – 9 / 11 – 17	0 – 22	Aug 23 – 24
	Larvae	5			
Aug 25	Eggs	485	2 – 10 / 12 – 18	0 – 27	Aug 24 – 25
	Larvae	2			
Sep 15	Larvae	1	36 / >27	~ 228	~ Sep 05

3.4 Substrate Dewatering

Neither sturgeon eggs nor larvae were documented during stranding surveys in 2021. ALR surface elevation slowly lowered in each consecutive week; and the study area was not backwatered by the ALR during the study period, with the exception of the first day when ALR elevation was at 437 MASL. The largest dewatered area was recorded on Aug 08 2021, when discharge was dropping and the ALR elevation had receded (Figure 7). Hourly discharge values do not account for the lag time between REV the downstream study site.

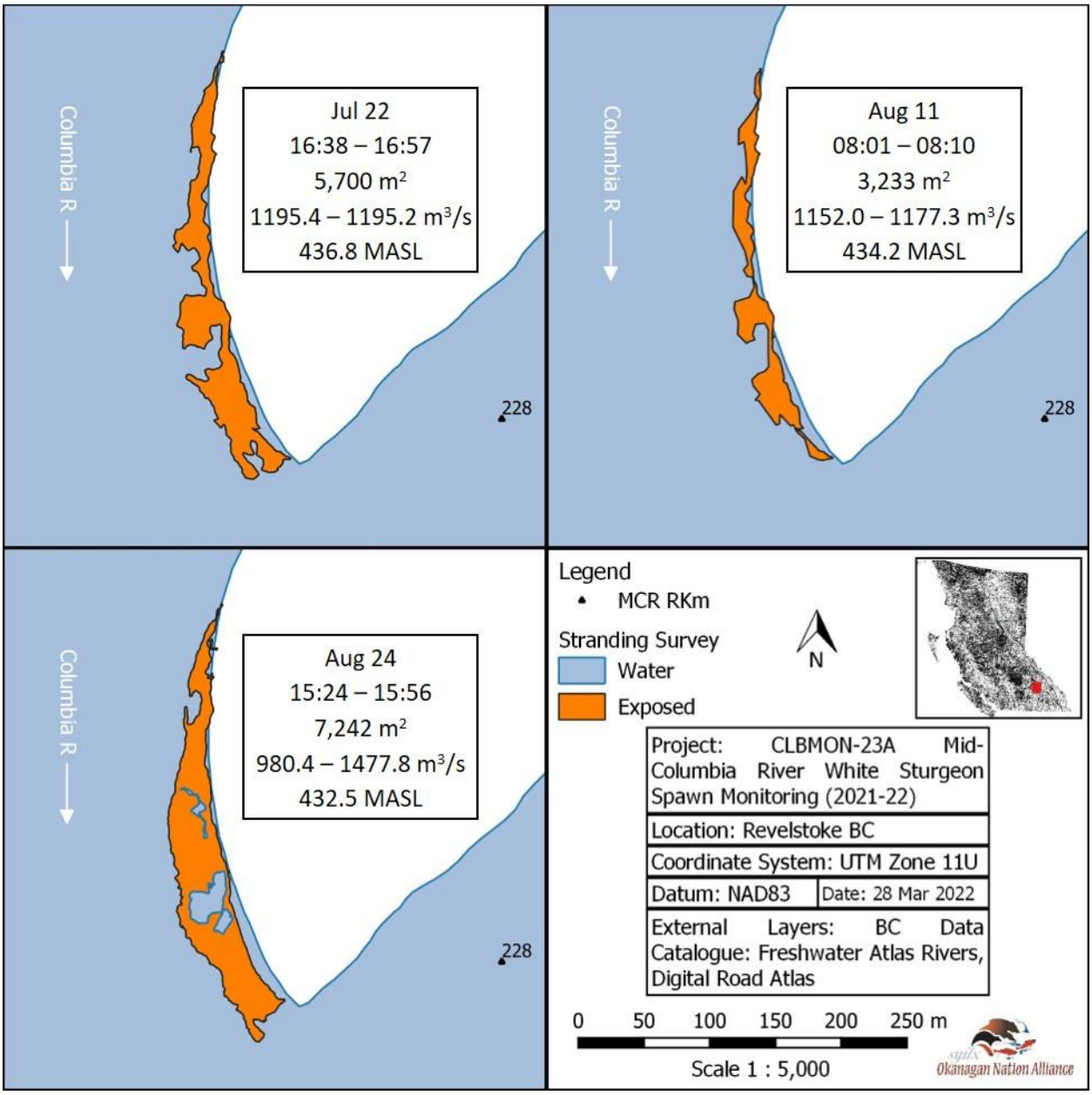

Figure 7. Dewatered areas in the Mid-Columbia River at the gravel / cobble bar corner near Big Eddy, Revelstoke BC during CLBMON-23A in 2021. Each map shows the date, time, exposed area (m^2), discharge from Revelstoke Dam (m^3/s), and Arrow Lakes Reservoir elevation (MASL).

During the stranding survey on Aug 24 2021 from 08:30 – 08:50, several fish species were identified including Redside Shiners (*Richardsonius balteatus*), Kokanee (*Oncorhynchus nerka*), and suckers (*Catostomidae* sp.; Figure 8). At 07:00, REV discharge was 870.2 m^3/s and increased by 09:00 to 1138.3 m^3/s. Kokanee fry and Redside Shiners were encountered as stranded fish in the exposed substrate, and adult suckers were viewed in isolated pools. As REV discharge began to increase after the stranding survey, the isolated pools were reconnected with the MCR mainstem.

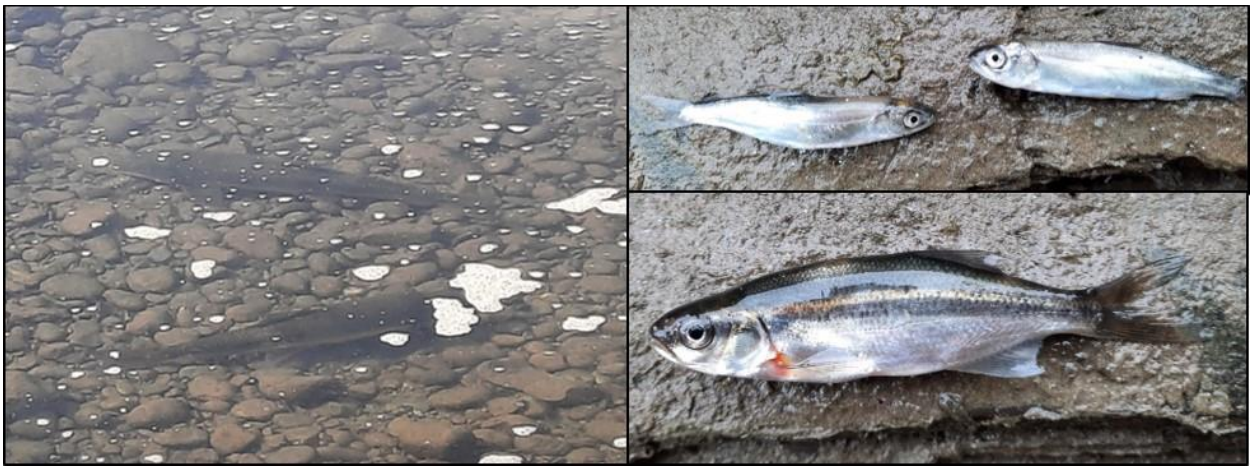

Figure 8. Fish encountered during stranding surveys in the Mid-Columbia River during CLBMON-23A in 2021. Adult suckers (*Catostomidae* sp.; left) were in isolated pools; Kokanee fry (*Oncorhynchus nerka*; top right) and Redside Shiners (*Richardsonius balteatus*; bottom right) were stranded in exposed substrate.

4.0 Discussion and Recommendations

Three *c'm'tus* spawning events were documented in the MCR in 2021, estimated to have taken place between Aug 02 and Sep 05 2021. In previous years of the program, spawning dates have ranged between July 21 and August 28 and the number of spawning events detected has ranged between 0 – 6. Spawning has now been detected in 15 of the 20 years that monitoring has been conducted in the MCR. As adult sturgeon are intermittent spawners, there may be more than the calculated 27 remaining in the MCR. On-going genetics work on collected sturgeon eggs and larvae will give an indication of the number of adult sturgeon that have contributed to collected progeny.

A total of 702 *c'm'tus* progeny were captured in 2021, the largest number captured in all years of this program. Drift nets captured all larvae and all but one of the eggs 2021; most on overnight sets. This can likely be attributed to the adaptive methodology utilized in this year where crews extended sampling at locations where progeny were captured. For example, the crew was scheduled to check egg mats and deploy drift nets on Aug 3 and 4, but extended the sampling period to Aug 5 as 22 eggs were captured Aug 4. The subsequent day of sampling on Aug 5 resulted in a capture of 67 sturgeon eggs. Sampling was extended on a second occasion to Aug 25 and resulted in a total capture of 485 eggs and 2 larvae. In previous years of the program, crews have followed a set schedule and sampled set locations. Maintaining an adaptive schedule is recommended to increase capture success in future years of the program.

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 2021 can be used to update Management Questions 2, 4 and 5:

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 analysis was updated to include 2020 conditions, however 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.

Management Question 4: What is the most effective method for monitoring spawning of White Sturgeon?

The most effective methods for monitoring *c'm'tus* 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 1151 using drift nets (0.28 CPUE). In 2020 and 2021, the increase in drift net effort, especially those sampled over night, resulted in the highest number of captures in all years of the program. Going forward, overnight drift net sets should be prioritized to maximize captures in the MCR.

This data report is intended to detail the methods and results of monitoring in 2021. 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).

5.0 References

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Appendix A – 2021 Data

Table 7. Egg mat data from CLBMON-23A in 2021.

Session	Station	Easting	Northing	Set Date	Set Time	Pull Date	Pull Time	Set Temp	Pull Temp	Depth (m)	Number of WSG Eggs	Number of WSG Larvae	Egg / Larvae Stage	Set Retrieved	comments
1	227.9L	413406	5651337	22-Jul-21	11:30	27-Jul-21	14:40	10.5	12.5	-	0	0	-	y	Depth sounder broken; set slipped
1	228.8L	413342	5651718	22-Jul-21	12:30	27-Jul-21	13:01	9.7	12.1	-	0	0	-	y	Depth sounder broken
1	228.5L	413171	5651368	23-Jul-21	8:30	27-Jul-21	13:40	10.2	11.2	-	0	0	-	y	Depth sounder broken
1	227.8M	413564	5651456	23-Jul-21	9:07	27-Jul-21	15:03	10.3	12.3	-	0	0	-	y	Depth sounder broken
1	228.1M	-	-	23-Jul-21	9:44	27-Jul-21	14:10	10.4	11.3	-	0	0	-	y	Depth sounder broken
1	228.6M	413238	5651589	23-Jul-21	10:37	27-Jul-21	13:20	10.5	10.9	-	-	-	-	n	Depth sounder broken; unable to retrieve set (egg mat came off line)
1	228.9M	413334	5651769	23-Jul-21	10:43	27-Jul-21	12:39	10.3	12.5	-	0	0	-	y	Depth sounder broken
2	228.8L	-	-	27-Jul-21	13:18	3-Aug-21	14:59	10.9	9.6	-	0	0	-	y	Depth sounder broken; pull depth = 2.1 m
2	227.9L	-	-	27-Jul-21	15:40	3-Aug-21	14:25	11.2	9.8	-	0	0	-	y	Depth sounder broken; pull depth = 2.7 m
2	227.8M	-	-	28-Jul-21	8:27	3-Aug-21	13:55	10.3	9.8	-	0	0	-	y	Depth sounder broken; pull depth = 3.3 m
2	228.1M	-	-	28-Jul-21	9:48	3-Aug-21	14:12	11.1	9.8	-	0	0	-	y	Depth sounder broken; pull depth = 3.2 m
2	228.6M	413261	5651642	28-Jul-21	10:31	3-Aug-21	14:44	9.9	9.7	-	0	0	-	y	Depth sounder broken; pull depth 3.7 m
2	228.9M	413356	5651779	28-Jul-21	10:37	3-Aug-21	13:15	10	9.8	-	0	0	-	y	Depth sounder broken; pull depth 3.4 m
3	227.9L	-	-	3-Aug-21	14:36	10-Aug-21	13:29	9.7	9.5	2.3	0	0	-	y	
3	228.8L	-	-	3-Aug-21	15:10	10-Aug-21	13:11	9.6	9.5	2.9	1	0	25?	y	Possibly tampered with, rope coiled on shore; surrounded by Didymo, difficult to stage; pictures 573-583
3	228.6M	-	-	5-Aug-21	8:53	10-Aug-21	12:25	10.1	9.4	3.1	0	0	-	y	Mat fouled on buoy line, came up vertical and flipped mid-column
3	228.1M	-	-	5-Aug-21	9:31	10-Aug-21	12:04	10.2	9.6	2.5	0	0	-	y	
3	228.9M	-	-	5-Aug-21	10:18	10-Aug-21	12:51	10.2	9.8	3.8	0	0	-	y	
3	227.8M	-	-	5-Aug-21	10:41	10-Aug-21	11:33	10.4	9.4	3.3	0	0	-	y	
4	228.8L	-	-	10-Aug-21	13:24	23-Aug-21	12:40	9.4	9.9	2.4	0	0	-	y	
4	227.9L	-	-	10-Aug-21	14:42	14-Sep-21	14:25	9.6	9.7	3.3	0	0	-	y	
4	228.5M	-	-	11-Aug-21	11:46	23-Aug-21	16:21	11.1	10.1	2	0	0	-	y	
4	228.6M	-	-	11-Aug-21	12:13	23-Aug-21	13:32	11.2	9.9	3.2	0	0	-	y	
4	228.1M	-	-	11-Aug-21	12:18	23-Aug-21	12:10	11.1	9.9	1.7	0	0	-	y	
4	227.8M	-	-	11-Aug-21	12:21	14-Sep-21	15:16	11.1	9.9	3	0	0	-	y	
5	228.8L	-	-	23-Aug-21	13:28	14-Sep-21	15:50	9.9	10.1	2.8	0	0	-	y	
5	226.8M	-	-	24-Aug-21	7:36	14-Sep-21	16:30	10.8	10	1.5	0	0	-	y	

Table 8. Drift net data from CLBMON-23A in 2021.

Session	Station	Easting	Northing	Set Date	Set Time	Set Flow Reading	Pull Date	Pull Time	Pull Flow Reading	Set Temp	Pull Temp	Depth (m)	Number of Eggs	Number of Larvae	WSG Stage	Set Retrieved	Comments
1	228.6M	413198	5651521	21-Jul-21	16:32	879670	22-Jul-21	8:40	994792	9.7	10.5	4	0	0		y	Slipped ~ 57 m
1	228.5M	413138	5651394	21-Jul-21	16:40	950312	22-Jul-21	9:08	376912	9.5	10.3	4.8	0	0		y	Slipped ~ 85 m; hole in cup
1	228.1M	413441	5651344	21-Jul-21	16:46	769492	22-Jul-21	9:33	596087	9.8	10.4	2.5	0	0		y	
1	227.8M	413532	5651414	22-Jul-21	8:26	413532	22-Jul-21	12:40	984699	10.4	9.8	-	0	0		y	Depth sounder broken; 1 KO; 12 UNIDS (1 preserved)
1	228.6M	413188	5651501	22-Jul-21	8:41	994792	22-Jul-21	14:19	403647	10.5	10.1	-	0	0		y	Depth sounder broken; 6 UNIDS; slipped ~ 12 m
1	228.5M	413133	5651253	22-Jul-21	9:11	376912	22-Jul-21	14:46	110364	10.5	9.8	-	0	0		y	Depth sounder broken; slipped 183 m; redeployed
1	228.1M	413442	5651348	22-Jul-21	9:34	526902	22-Jul-21	13:25	936150	10.4	10.1	-	0	0		y	Depth sounder broken; 4 UNIDS (1 egg)
1	227.8M	-	-	22-Jul-21	12:41	596105	22-Jul-21	15:08	858052	9.8	9.7	-	0	0		y	Depth sounder broken; 7 UNIDS
1	228.1M	413444	5651347	22-Jul-21	13:26	984699	22-Jul-21	15:34	325009	10.1	9.8	-	0	0		y	Depth sounder broken; 1 UNID egg
1	228.6M	413167	5651382	22-Jul-21	14:20	936156	23-Jul-21	8:24	64979	10.1	10.2	-	0	0		y	Depth sounder broken; 25 UNIDS; slipped
1	227.8M	-	-	22-Jul-21	15:09	110364	23-Jul-21	9:04	172934	9.7	10.3	-	0	0		y	Depth sounder broken; may have slipped; 6 UNIDS
1	228.1M	-	-	22-Jul-21	15:35	403641	23-Jul-21	9:42	659062	9.8	10.4	-	0	0		y	Depth sounder broken; 31 UNIDS
2	228.9M	413306	5651734	27-Jul-21	12:39	64985	27-Jul-21	15:22	102252	12.5	11.4	-	0	0		y	Depth sounder broken; 1 UNID larvae
2	228.6M	413192	5651426	27-Jul-21	13:30	172932	27-Jul-21	13:34	204416	10.9	10.9	-	0	0		y	Depth sounder broken; Slipped, removed before entering Big Eddy
2	228.6M	413259	5651644	27-Jul-21	15:23	204418	28-Jul-21	10:20	493529	11.4	9.9	-	0	0		y	Depth sounder broken; hole in cup
2	228.1M	-	-	27-Jul-21	15:54	102254	28-Jul-21	9:45	130754	10.6	11.1	-	0	0		y	Depth sounder broken; 14 UNIDS (1 egg)
2	227.8M	-	-	27-Jul-21	15:59	325060	28-Jul-21	8:26	869212	10.6	10.3	-	0	0		y	Depth sounder broken; 50 UNIDS (3 egg casings)
3	228.5M	413169	5651374	3-Aug-21	12:30	493548	3-Aug-21	12:41	517723	9.8	9.8	3.9	0	0		y	Slipped 120 m, removed before entering Big Eddy
3	228.9M	413221	5651455	3-Aug-21	13:16	517723	4-Aug-21	8:25	986091	9.7	9.9	2.8	0	0		y	Slipped; snagged

Session	Station	Easting	Northing	Set Date	Set Time	Set Flow Reading	Pull Date	Pull Time	Pull Flow Reading	Set Temp	Pull Temp	Depth (m)	Number of Eggs	Number of Larvae	WSG Stage	Set Retrieved	Comments
3	227.8M	-	-	3-Aug-21	13:57	869223	3-Aug-21	15:30	67023	9.8	9.7	4.1	0	0		y	3 UNIDS; meter fouled at deploy; slipped
3	228.1M	-	-	3-Aug-21	15:24	659034	4-Aug-21	9:27	630120	9.8	10.1	3.5	6	0	3 – 5	y	3 UNIDS; eggs = stage 4 (1), stage 5 (1), stage 3 (1)
3	227.8M	413591	5651486	3-Aug-21	17:32	130756	4-Aug-21	8:48	741301	9.7	10	4.2	0	0		y	Slipped
3	227.8M	413678	5651558	4-Aug-21	8:51	986104	4-Aug-21	12:46	448572	9.9	10	3.9	1	0	14*	y	Egg = difficult to stage due to algae on membrane, could be dead
3	228.5M	-	-	4-Aug-21	10:34	630120	4-Aug-21	13:40	741599	10	9.9	2.5	12	0	8 – 15	y	Photos: #472-496, 472-475
3	228.1M	-	-	4-Aug-21	10:50	66987	4-Aug-21	14:35	581312	9.9	10.1	2.5	0	0		y	
3	228.6M	-	-	4-Aug-21	11:28	858086	4-Aug-21	11:38	874920	9.9	9.8	3.8	3	0	6	y	Velocity meter failed at deploy; slipped, removed before entering Big Eddy
3	228.9M	413347	5651754	4-Aug-21	11:44	741400	4-Aug-21	14:55	96670	9.8	10.1	4.1	0	0		y	
3	228.6M	-	-	4-Aug-21	13:41	448590	5-Aug-21	8:50	738477	9.9	10.1	2.2	51	0	8 – 17	y	Stage photos begin at #508 (3 photos of each egg, 10 eggs photographed); eggs = stage 17 (4), stage 8 (1), stage 9 (1), stage 12 (2), stage 13 (1), stage 16 (1); 35 UNIDS
3	228.1M	-	-	4-Aug-21	14:36	741591	5-Aug-21	9:27	627570	10.1	10.2	2.4	3	0	4 – 14	y	Stage photos 545-553; eggs = stage 4 (1), stage 12 (1), stage 14 (1) dead?
3	228.9M	-	-	4-Aug-21	14:50	581315	5-Aug-21	10:17	647676	10.1	10.2	3.9	1	0	12	y	Photo 555 & 554
3	227.8M	-	-	4-Aug-21	15:12	874918	5-Aug-21	10:40	24702	10.1	10.4	3.6	12	0	12 – 16	y	Stage photos = 558-572; stage 16 (1), stage 12 (3); very little of gravel bar on 4-Aug-21, not worth walking
4	227.8M	-	-	10-Aug-21	11:31	738480	10-Aug-21	15:07	36283	9.4	9.5	3.4	0	0		y	YOY BB in net, alive; I UNID
4	228.1M	-	-	10-Aug-21	12:05	199960	10-Aug-21	15:58	569672	9.6	9.7	2.6	2	0	27	y	Flow meter fouled at deploy; 4 UNIDS; photos = 598-604
4	228.5M	-	-	10-Aug-21	12:27	24707	10-Aug-21	16:37	381093	9.4	9.6	2.1	1	0	28	y	photos 619-627
4	228.9M	-	-	10-Aug-21	12:52	627585	10-Aug-21	16:57	183830	9.8	9.8	4.2	7	0	27 – 29, 30?	y	Photos: 628-641; stage 27 (2), 28 (2), 29 (2), 30 (1)
4	228.6M	-	-	10-Aug-21	15:00	No flow meter	11-Aug-21	7:56	-	9.6	10.5	3.7	0	0		y	Slipped; cod piece almost completely ripped off cup - picture (642)

Session	Station	Easting	Northing	Set Date	Set Time	Set Flow Reading	Pull Date	Pull Time	Pull Flow Reading	Set Temp	Pull Temp	Depth (m)	Number of Eggs	Number of Larvae	WSG Stage	Set Retrieved	Comments
4	228.1M	-	-	10-Aug-21	15:50	36272	11-Aug-21	9:55	262257	9.7	10.9	3.7	1	0		y	5 UNIDS; WSG egg too decayed to stage
4	228.5M	-	-	10-Aug-21	16:48	569650	11-Aug-21	8:17	899225	9.6	10.6	2.4	42	0	29 – 32	y	4 of alive eggs are out of gel coating; 21 UNIDS; 1 YOY CC; photos: 642-658; stage 32 (1), 31 (3), 30 (1), 29 (1)
4	228.9M	-	-	10-Aug-21	16:59	381094	11-Aug-21	10:32	350801	9.8	11.0	4.3	0	0		y	Flow meter fouled at deploy; 2 UNIDS
4	228.6M	-	-	11-Aug-21	8:13	183850	11-Aug-21	11:25	650125	10.6	11.1	3.0	0	0		y	
4	228.5M	-	-	11-Aug-21	10:28	899223	11-Aug-21	11:45	25592	11	11.1	1.8	1	0	30	y	Photos = 657-662; minimal gravel exposed and Big Eddy Bar on Aug 11 at 1110 m^3/s (09:40)
5	226.8M	414720	5651092	23-Aug-21	12:00	350781	23-Aug-21	14:08	587113	10	10	2.3	0	0		y	
5	228.1M	414720	5651092	23-Aug-21	12:13	262247	23-Aug-21	15:10	740584	9.9	10.0	2.3	0	0		y	
5	228.1M	414720	5651092	23-Aug-21	15:10	587129	24-Aug-21	12:30	198394	10	11.0	2.6	1	1	9	y	
5	228.6M	-	-	23-Aug-21	16:02	740584	24-Aug-21	9:05	50459	10.1	10.8	3.6	0	0		y	
5	226.8M	-	-	23-Aug-21	16:07	25613	24-Aug-21	7:34	109605	10.1	10.8	2.3	-	-		n	Night; end of cup missing, no sample
5	228.5M	-	-	23-Aug-21	16:21	650119	24-Aug-21	8:15	942340	10.1	10.9	2.1	23	4	3 – 9	y	Night; net on side; stage 3 (6), stage 4 (11), stage 5 (4), stage 7 (1), stage 9 (8)
5	228.6M	-	-	24-Aug-21	8:06	109605	24-Aug-21	14:33	987646	10.8	11.8	2.6	26	0	1 – 9	y	4 or 5 out of membrane; stage 1 (5), stage 2 (17), stage 7 (1), stage 8 (2), stage 9 (1)
5	228.5M	-	-	24-Aug-21	8:16	50459	24-Aug-21	15:04	881195	10.9	11.8	1.4	15	0	1 – 9	y	Stage 1 (2), stage 2 (6), stage 3 (2), stage 3 (1), stage 4 (2), stage 5 (2), stage 8 (1), stage 9 (2)
5	228.6M	-	-	24-Aug-21	14:34	198382	25-Aug-21	12:20	556702	11.8	11.9	2.7	-	-		n	Sock off D ring from (picture) frame bent
5	228.5M	-	-	24-Aug-21	15:05	942573	25-Aug-21	8:57	291910	11.8	11.8	1.4	485	2	2 – 10	y	Hard to age/stage due to Didymo
6	228.5M	-	-	14-Sep-21	14:23	881210	15-Sep-21	8:18	400359	10.6	10.2	2.4	0	1	36	y	1 UNID larvae; pics 100-0733-100-0734
6	227.8M	-	-	14-Sep-21	17:09	291894	15-Sep-21	9:14	88740	10.6	10.2	3.4	0	0		y	