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Columbia White Sturgeon Management Plan

CLBMON-21 – Mid-Columbia River Juvenile Sturgeon Detection and Habitat Use Study

Study Period: 2007 to 2022 Synthesis Report

Implementation Year: 16

BC Hydro and Power Authority

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CLBMON-21: Middle Columbia River Juvenile White Sturgeon Detection and Habitat Use Study – 2007 to 2022 Synthesis Report

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Cover Photo: Juvenile White Sturgeon captured in the Middle Columbia River in August 2017. Photo by Evan Smith, Okanagan Nation Alliance.

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Executive Summary

The population of White Sturgeon (*Acipenser transmontanus*) in the Columbia River in southeastern British Columbia was listed as endangered under the federal Species at Risk Act (SARA) in 2006 due to recruitment failure. One segment of this population resides in the Middle Columbia River (MCR), a section between Hugh L. Keenleyside Dam (HLK; Castlegar, BC) and Revelstoke Dam (REV; Revelstoke, BC) that encompasses the Arrow Lakes Reservoir (ALR). An estimate of 52 adult White Sturgeon (37 - 92 individuals at 95% CI) are thought to remain within the MCR, and all individuals aged were found to be older than the construction date of HLK Dam (1968). The primary reason for recruitment failure in the MCR is unknown as it is uncertain the extent that the area was used historically for all life stages.

In 2005, BC Hydro's Water Use Planning Consultative Committee (WUP CC) recommended a 10-year work plan to better understand juvenile White Sturgeon habitat capabilities in the MCR, and to investigate the potential for either building a self-sustaining or failsafe population in the ALR through releases of juvenile white sturgeon from a conservation aquaculture program. In December 2010, REV implemented minimum flow operations of 142 m^3/s, which coincided with the commissioning of an additional generation unit at Revelstoke Dam (REV5). As a result, the maximum generation discharge capacity of the dam increased from 1,700 m^3/s to 2,124 m^3/s; this was reflected in a mean daily discharge increase of approximately 200 m^3/s. The combined effects of these changes in dam operations are treated as one operational change in this report.

The management questions developed for CLBMON-21 Mid-Columbia River Juvenile White Sturgeon Detection and Habitat Program are:

1. Where are the habitat locations utilized by juvenile Sturgeon in the mid-Columbia?
2. What are the physical and hydraulic properties of this habitat that define its suitability as juvenile Sturgeon habitat?
3. What is the quantity of available habitat meeting these conditions in the mid-Columbia?
4. How do hydraulic conditions resulting from dam and reservoir operations relate to habitat suitability for juvenile White Sturgeon in the mid-Columbia?
5. What are the survival rates of juvenile White Sturgeon in the mid-Columbia?
6. Can modifications be made to the operations of REV and/or ALR to protect or enhance juvenile White Sturgeon habitat?

The program developed using two approaches to evaluate the above objectives:

1. Growth and Survival (2007-2022) – evaluating growth and survival of hatchery-origin sturgeon including. Size at release has generally increased over the 15 years of the program. This study initially focused on the Revelstoke Reach section of the Columbia River (REV to Arrowhead Flats), however has expanded to include the upper Arrow Lakes Narrows and Upper ALR.
2. Habitat Use (2007-2022) – collection of background data on habitat use by juvenile sturgeon and describing the attributes of those habitats. Acoustic telemetry was used to describe sturgeon movements using both large (2007-2010) and fine-scale (2011-2012) receiver arrays. Additional habitat use through direct captures (2007-2022) was used to complement the telemetry data.

CLBMON-21 was initiated in 2007 and at that time focused on acoustic telemetry to locate juvenile and adult White Sturgeon to identify habitat use, and to capture juveniles released by the conservation aquaculture program (marked with passive integrative transponder [PIT] tags) to assess growth and survival. In 2007, a conservation aquaculture program for White Sturgeon was also initiated with the objective of determining whether a failsafe population could be established within the ALR and to evaluate growth and survival of juvenile White Sturgeon. To date, 63,358 juvenile White Sturgeon have been released between Shelter Bay (RKm 177) and Revelstoke BC (RKm 230).

A capture program was run from 2007-2022 using gillnets and setlines throughout the study area in an attempt to recapture released fish. To date, only 79 (<0.01%) individual sturgeon have been captured since release; three individual were recaptured, resulting in a total of 82 sturgeon captures. Of these individuals, 62 were captured over one year after release, 49 of which were captured 2 – 10 years after release. No fish have been captured from the 2010, 2017, 2019, 2020, or 2021 year classes. Growth rates of all MCR juvenile White Sturgeon captured one year or more after release were 6.01 cm / year ± 0.64 cm / year (95% CI; n = 62) and 0.26 kg / year ± 0.04 kg / year (95% CI; n = 61). As a result of low recapture rates of juvenile White Sturgeon, survival estimates could not be determined.

A study design involving three phases of data collection was developed to assess juvenile White Sturgeon habitat use and movements. During the first phase (2007-2010), data on movements and macro-habitat use were obtained from acoustic-tagged juvenile White Sturgeon using both mobile tracking and passive receivers. During this phase, 200 (50 in each year) acoustic-tagged juvenile Sturgeon were released in the upper section of the MCR and data was collected from receivers placed ~5 km apart along the thalweg of the study area. Based on the rapid downstream movements of fish post-release in the first two years, the release sites were distributed at 10 km intervals throughout the upper 50 km of the study area for years 3 and 4. Fish released in less suitable habitat (fast and shallow) upstream habitats (upper 20 km) still exhibited rapid downstream movements until they reached deeper, slower sections while fish released in the lower 30 km had lower rates of movement post-release. Many juveniles used the area between Greenslide Creek (RKm 212) and Arrowhead Flats (Rkm 180) during the summer months and tended to make downstream movements in the fall. The mean net movement of tagged fish was similar in all years, and fish remained within a 21 – 26 km length of the reservoir despite differences in release patterns, which suggests juvenile Sturgeon are selecting for specific habitats. This work also identified that juvenile White Sturgeon in the MCR prefer deep (>10 m), slow moving areas with fine substrates, and tend to be most active at night. Following these results, all hatchery releases were moved to Shelter Bay (rkm 177).

The second phase, implemented in 2011 (Year 5), was to determine the feasibility and best location of a Vemco Positioning System (VPS) array that would describe localized movements and habitat use which was used to inform capture efforts. The data collected from the fine-scale array allowed analysis of movements related to daylight, habitat type, REV discharge, ALR elevation in 2012, and seasons. Tag locations clearly showed that juvenile White Sturgeon have a preference for thalweg areas in all seasons but did use shallow and floodplain sites in summer and fall (when reservoir levels were high). Overall, results from the VPS telemetry array helped refine capture efforts for phase three of data collection by showing that juvenile White Sturgeon used a wider range of depths, and made more frequent, longer, and faster movements in the summer (reservoir is full) compared to spring (reservoir filling) or fall (reservoir emptying).

The third phase of data collection occurred through the whole program and focused on direct captures of individuals to inform habitat use. In 2022, sampling occurred from Aug 12 to Oct 18, and resulted in the capture of 24 juvenile White Sturgeon. This was the greatest number of individuals captured in one year and the greatest diversity of year classes encountered (2006, 2012, 2013, 2014, 2015, 2016, and 2018), although most individuals (9) were from the 2015 year class. Individuals were captured between 3.2 and 15.4 years after release; however the fish captured 15.4 years after release originated from the United States and migrated to the MCR at some point after 2017. Captures in 2022 were from near Arrowhead (RKm 183.4) to upstream of the Walter Hardman Generating Station (RKm 202.6), with 14 captured within a 5.0 km stretch between Wallis Creek to Crawford Creek (RKm 186.7-191.7). All sturgeon captured had gastric lavage performed prior to release to describe prey in the diet and substrate grabs were taken at each capture location to determine substrate type and later analyzed for invertebrate presence. Ten rock baskets were deployed to aid in the identification of potential sturgeon prey presence, each associated with a substrate grab to determine substrate type.

The most common bycatch species in 2022 were Burbot (*Lota lota*), Northern Pikeminnow (*Ptychocheilus oregonensis*), suckers sp. (*Catostomus sp.*), and Peamouth Chub (*Mylocheilus caurinus*). One whitefish (*Prosopium sp.*) was also captured.

The current state of knowledge for the juvenile White Sturgeon program in the Middle-Columbia River with respect to BC Hydro's Management Questions is provided in the table below.

Management Question	Status
1. Where are the habitat locations utilized by juvenile Sturgeon in the Middle-Columbia?	Based on data collected using both acoustic telemetry and direct capture efforts, juvenile White Sturgeon exhibit highest use of riverine habitats near Greenslide Cr. (RKm 212) downstream to Shelter Bay (RKm 177) and, to a lesser extent, further south into the Arrow Lakes Reservoir. To date only a few individuals have been documented further downstream towards Nakusp though sampling effort has been less in this area compared to the upstream riverine area.
2. What are the physical and hydraulic properties of this habitat that define its suitability as juvenile Sturgeon habitat?	Juvenile White Sturgeon use deep (>10 m), low velocity (<0.5 m/s) habitats with fine substrates (sand/silt/clay). This is based primarily on movements of acoustically tagged juveniles (n=250) and general locations of capture (n=82). When releases occurred at the City of Revelstoke (RKm 229, 2007-2012), juveniles were found to move quickly downstream to Mulvehill and Greenslide Creeks, and Akolkolex River areas and further downstream into the reservoir where conditions are more favorable. Accordingly, the release site was moved to Shelter Bay (RKm 177) in 2013 to target release in closer proximity to suitable habitats.
3. What is the quantity of available habitat meeting these conditions in the Middle-Columbia?	The amount of available deeper, slower, habitat for juvenile White Sturgeon varies depending on discharge from REV and backwatering from the ALR. Thalweg habitats are available during all water elevations however the depth of the thalweg varies accordingly. During high water levels, shallows and floodplain habitats become available, though fine-scale

	movement work found that those habitats are used less than the deeper thalweg when both are available. Most juvenile Sturgeon captures have occurred within a 35 km section of river from approximately Shelter Bay (RKm 177) to Greenslide Creek (RKm 212).
4. How do hydraulic conditions resulting from dam and reservoir operations relate to habitat suitability for juvenile White Sturgeon in the Middle-Columbia?	Both REV discharges and ALR operations influence habitat quality and quantity in the MCR. Discharge from REV influences the quantity and type of habitat available in riverine sections; however, the effects diminish with downstream distance and are attenuated by the Greenslide Creek (Rkm 212) area where sturgeon have been found to reside. High reservoir elevations backwatering the river section results in greater availability of deeper, low velocity habitats further upstream. ALR levels can influence sturgeon movements in the river section during the summer when more habitat is available.
5. What are the survival rates of juvenile White Sturgeon in the Middle-Columbia River?	Survival cannot be directly estimated at this time due to low recapture rates, attributed to a large study area and low capture efficiency. However, most of the individuals captured survived at least two years in the MCR (61%), with 7 having survived over 9 years before capture, showing capacity for survival in the MCR. On average, for all fish captured one or more years after release, total annual growth was 6.01 cm / year ± 0.64 cm / year in length and 0.26 kg / year ± 0.04 kg / year in weight. At this time, additional recaptures are required to estimate survival.
6. Can modifications be made to the operations of Revelstoke Dam and/or Arrow Lakes Reservoir to protect or enhance juvenile White Sturgeon habitat?	The implementation of minimum flows (142 cms) at Revelstoke Dam is the only hydroelectric modification since the program began. Based on the preference for deeper (> 10 m) habitats, primarily > 25 km downstream of Revelstoke Dam, it is unlikely the minimum flows significantly improved physical habitat availability. It is unlikely that additional operational improvements or modifications at REV can be made when it concerns physical habitat availability. At this distance from the dam, large changes in flows do not influence flow dynamics to the point where sturgeon avoid the area. The landforms around the preferred area of the Walter Hardman Generation Station and Akolkolex River (RKm 200) constrict the Columbia River, which may be creating conditions that are more suitable to juvenile rearing. In the reservoir, maintaining ALR water elevations at levels that ensure a deep thalweg (425-430 masl) around Greenslide Creek (RKm 212) will maximize the amount of preferred habitat that is currently being used by juveniles in this area.

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1.0 Introduction

White Sturgeon (*Acipenser transmontanus*) are the largest and longest-lived freshwater fish species in North America and are native to the Columbia River drainage in British Columbia (BC), Canada. The population of White Sturgeon in the Upper Columbia River was listed as Endangered under the Canadian Species at Risk Act (SARA) in 2006 due to recruitment failure (DFO 2014). A small segment of the population from the pre-dam era occurs within the Arrow Lakes Reservoir (ALR), a section of the Middle Columbia River (MCR) spanning from the Revelstoke Dam (REV) to the Hugh L. Keenleyside Dam (HLK). 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 2022, the estimated population of adult White Sturgeon may be around 26 individuals, calculated assuming a 97% annual adult survival rate (DFO 2014). There have been no wild juvenile White Sturgeon detected in this section of river, suggesting natural recruitment is not occurring.

In 2007, BC Hydro's Water Use Plan Consultative Committee implemented minimum flow release requirements at REV to 142 m^3/s that coincided with the commissioning of an additional fifth generating unit (REV5) at REV on Dec 20 2010. The addition of REV5 increased the maximum generation discharge capacity of the REV from 1,700 m^3/s to 2,124 m^3/s. The combined effects of the minimum flow release and the increased maximum discharge capacity from REV are collectively referred to as the 'flow regime change'.

As part of the Water License Requirements Program, BC Hydro implemented the MCR Juvenile White Sturgeon Management Plan under the Columbia River Water Use Plan. The purpose was to determine the suitability of the MCR as a second recovery area for White Sturgeon in the Upper Columbia River Basin and to evaluate the potential for a self-sustaining or failsafe population (i.e., a second population supported by supplementation of juvenile White Sturgeon from conservation aquaculture to provide future broodstock or genetic biodiversity in the event of a catastrophic failure of the primary population).

An experimental conservation aquaculture program was initiated in 2007 with releases of hatchery-origin juveniles occurring annually. A monitoring program was developed to investigate juvenile survival, growth, movement, habitat use, and habitat availability to support building a self-sustaining population in this section of the Columbia River. The program has been implemented adaptively, and as the monitoring progressed questions around White Sturgeon movements to preferred habitats and optimal body size at release were incorporated into the study design.

1.1 Management Questions

The management questions defined by the Consultative Committee and associated with CLBMON-21 as per the Terms of Reference and Scope of Services (BC Hydro 2007) are:

1. Where are the habitat locations utilized by juvenile Sturgeon in the MCR?
2. What are the physical and hydraulic properties of this habitat that define its suitability as juvenile Sturgeon habitat?
3. What is the quantity of available habitat meeting these conditions in the MCR?
4. How do hydraulic conditions resulting from dam and reservoir operations relate to habitat suitability for juvenile White Sturgeon in the MCR?
5. What are the survival rates of juvenile White Sturgeon in the Middle Columbia River?

6. Can modifications be made to the operations of REV and/or Arrow Lakes Reservoir to protect or enhance juvenile White Sturgeon habitat?

1.2 Management Hypotheses

Hypotheses for the above management questions have been developed to guide the juvenile White Sturgeon study, and are as follows:

H1: The recruitment of White Sturgeon in Arrow Lakes Reservoir is limited by the quality and quantity of juvenile habitat below Revelstoke Dam.

> **$H1_A$:** Quality and quantity of White Sturgeon juvenile habitat in the MCR is directly related to discharge from the dam.
>
> **$H1_B$:** Quality and quantity of White Sturgeon juvenile habitat in the MCR is directly related to water elevation in Arrow Lakes Reservoir.
>
> **$H1_C$:** Quality and quantity of White Sturgeon juvenile habitat in the MCR is directly related to the interaction between discharge from the dam and water elevation in Arrow Lakes Reservoir.

H2: Quality and quantity of White Sturgeon juvenile habitat in the MCR can be significantly improved through changes in dam and reservoir operations.

$H3_A$: Juvenile White Sturgeon do not survive in the MCR in significant numbers from release as post-hatch larvae to year 1.

$H3_B$: Juvenile White Sturgeon do not survive in the MCR in significant numbers from release as late sub-yearling stage to year 2+ or older.

This report summarizes the key findings of the CLBMON-21 Program since its inception in 2007 to 2022. Additional details are provided in annual reports (Golder 2008, 2009, 2010, 2011, 2012; Golder and ONA 2013; ONA 2016, 2017, 2018, 2019, 2020, 2021), that are referenced collectively as the CLBMON-21 annual report series[1].

1.3 Key Water Use Decision

The key operating decision affected by the results of this monitoring program is the implementation of seasonal flow treatments from Revelstoke Dam. A seasonal flow treatment was to be implemented if age 0+ and 1+ juvenile Sturgeon releases show relatively strong survival during the first 4 years of study (BC Hydro 2007). Results are being used to inform BC Hydro on the value of the 142 m^3/s minimum flow at the end of the review period for the Columbia WUP. The juvenile White Sturgeon monitoring program will provide evidence towards determining if natural recruitment and rearing can be re-established for the MCR White Sturgeon population.

[1] https://www.bchydro.com/toolbar/about/sustainability/environmental_responsibility/water-use-plans/southern-interior/columbia-river/columbia-sturgeon.html

2.0 Methods

The following provides a brief discussion of the methods used over the course of the study program and highlights any changes in methodology that took place. Additional details are provided in the CLBMON-21 annual report series.

2.1 Study Location and Period

The MCR is a portion of the Columbia River spanning 230 km from REV downstream to HLK near Castlegar BC. The MCR includes the ALR (includes the Upper Arrow Lake, Lower Arrow Lake, and Arrow Lakes Narrows) and Revelstoke Reach, defined as the section of the Columbia River from REV downstream to the Beaton Arm (Figure 1). Revelstoke Reach is approximately 50 km in length and varies in width from approximately 150 m at points below Revelstoke Dam (RKm 234.9) to over 2 km at Arrowhead (RKm 184). This section of river is influenced by discharge from REV, experiencing water level changes of over 3.0 – 5.0 m and large daily velocity changes. An additional effect in this area is the filling and draining of the ALR, which dictates the location of the river-reservoir interface throughout the year due to backwatering. Immediately downstream of Revelstoke Reach is the Arrowhead Flats area (described as Beaton Flats in previous CLBMON-21 annual report series), where the Beaton Arm confluences with the MCR (RKm 184 – 180) and is a transitional zone between the river and the deeper ALR. The Beaton Arm extends east 17.9 km to the Incomappleux River. The upstream 3.5 km of the Beaton Arm is characterized by shallow water and is called Beaton Flats (not sampled as a part of CLBMON-21 prior to 2019). The Upper Arrow Lake extends approximately 61 km from the Arrowhead Flats (RKm 180) to the Arrow Lakes Narrows (RKm 119). The entire study area of CLBMON-21 extends from REV downstream into the Arrow Lakes Narrows (157 km in length) and has been split into 17 River Sections, including two sections in the Beaton Arm (Table 1). The CLBMON-21 juvenile White Sturgeon study location and study periods have varied for different components of the study over the years of the program.

Table 1. Middle Columbia River Section descriptions with downstream and upstream river kilometers (RKm).

River Sections	Description	Downstream RKm	Upstream RKm
1	Big Eddy - Rev Dam	228.4	234.9
2	1 km d/s Hwy 1 bridge - Big Eddy	226.1	228.3
3	1 km d/s Wells Creek - 1 km d/s Hwy 1 bridge	220.0	226.0
4	3.5 km d/s Begbie Creek - 1 km d/s Wells Creek	214.1	219.9
5	0.8 km d/s Greenslide Creek - 3.5 km d/s Begbie Creek	209.8	214.0
6	0.7 km u/s Blanket Creek - 0.8 km d/s Greenslide Creek	205.6	209.7
7	0.6 km u/s Walter Hardman - 0.7 km u/s Blanket Creek	201.9	205.5
8	Tree Island - 0.6 km u/s Walter Hardman	197.6	201.8
9	1 km u/s Crawford Creek - Tree Island	192.1	197.5
10	1.5 km d/s Wallis Creek - 1 km u/s Crawford Creek	186.6	192.0
11	Arrowhead - 1.5 km d/s Wallis Creek	182.1	186.5
12	Shelter Bay - Arrowhead	176.9	182.0
13	Nakusp - Shelter Bay	129.1	176.8
14	Arrow Lakes Narrows - Nakusp	119.0	129.0
15	Arrow Lakes Narrows	77.6	118.9
B1	Beaton Arm	2.2	14.3
B2	Beaton Flats	14.4	17.4

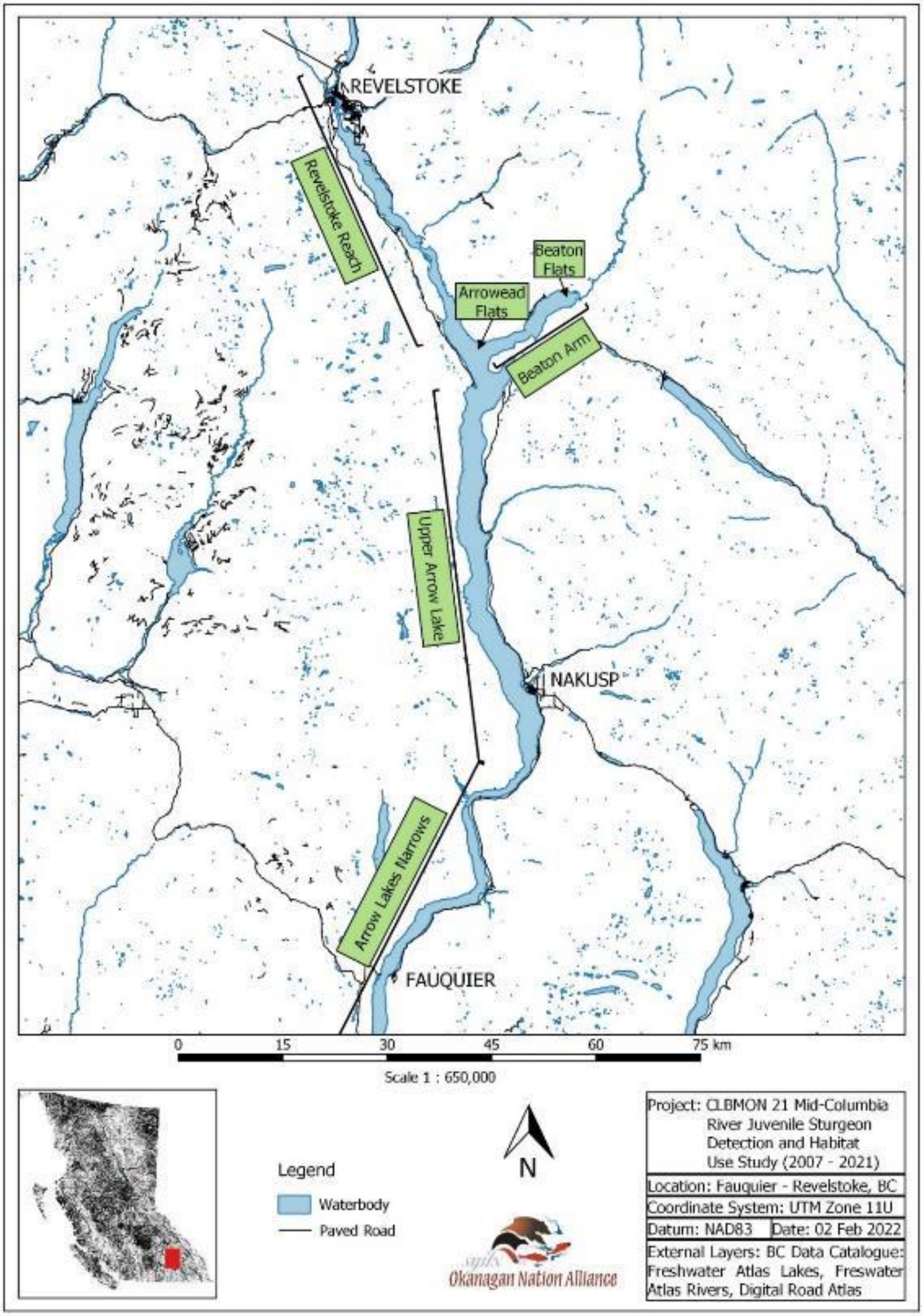

Figure 1. Map of the CLBMON-21 study area in the Middle Columbia River from Revelstoke downstream to Fauquier BC, from 2007 – 2022.

Detailed maps of River Sections, river kilometers, and temperature station locations are available in Appendix A.

2.2 Physical Habitat Parameters

2.2.1 Discharge, Water Temperature, and Reservoir Elevation

Hourly discharge data for the Columbia River at REV were obtained from BC Hydro Power recording stations and water elevation data for ALR were obtained from the Water Survey of Canada (WSC) at Nakusp, BC (Station: 08NE104; WSC 2021). Water temperature data were obtained from various sources. Thermistors were deployed in selected locations within the study area to collect water temperatures representative of the different areas being studied each year (Table 2).

Table 2. Description of temperature stations locations and logger types used throughout CLBMON-21 from 2007 to 2022.

Year	Station	Logger Type
2007, 2009 – 2014	CLBMON-15A Station 6 (RKm 216)	Solinst data loggers
2011 – 2012	VR2W Receiver Stations	Onset StowAway Tidbits™
2013	CLBMON-15A Station 5 (RKm 219.9)	Solinst data loggers
2015	CLBMON-15A Station 3 (RKm 227.9)	
2016	CLBMON-21 Temp Stations (Nakusp, Greenslide Creek, Shelter Bay)	Hobo™ Tidbits
2017	CLBMON-21 Temp Stations (Nakusp, Greenslide Creek, Shelter Bay)	
2018	CLBMON-21 Temp Stations (Greenslide Creek, Shelter Bay)	
2019	CLBMON-21 Temp Stations (Greenslide Creek, Arrowhead Flats, Beaton Flats, Mosquito Creek)	
2020	CLBMON-21 Temp Stations (Greenslide Creek, Arrowhead Flats, Beaton Flats, Burton)	
2021 – 2022	CLBMON-21 Temp Stations (Greenslide Creek, Arrowhead Flats)	

2.2.2 Meso-Habitat Measurements

Over the 16 years of the program, a range of meso-habitat parameters were recorded in the immediate vicinity of where acoustic-tagged juvenile White Sturgeon were detected and at gillnet and setline capture sites (Table 3; Table 4).

Table 3. Instruments used to collect meso-habitat parameters (including available precision and accuracy values) near juvenile White Sturgeon detection and capture sites in during CLBMON-21 from 2007 to 2022.

Parameter	Instrument(s)	Precision	Accuracy
Depth	Boat depth sounder	0.1 m	
Current velocity	Marsh-McBirney electromagnetic flowmeter		± 2 % of reading
Surface water temperature	Alcohol thermometer		± 0.1 °C
	Boat depth sounder	0.1 °C	
	YSI Pro2030	0.1 °C	
Mid-column water sample	Van Dorn sampler		
Turbidity	OrbecoHellige Model 966 portable turbidity meter		0.01 NTU in the lowest range
Water clarity	Secchi disc	0.1 m	
Substrate sample	Ponar Grab sampler or Petite Ponar Grab sampler		
Cover assessment	Underwater video camera		
UTM coordinates	Trimble differential GPS unit		
	Garmin Handheld unit	1 m	± 3 m
Surface dissolved oxygen	YSI Pro2030	0.01 mg/L	± 2 % of the reading or ± 0.2 mg/L, whichever is greater

Table 4. Summary of meso-habitat measurements taken near juvenile White Sturgeon detection and capture sites in the Middle Columbia River during CLBMON-21 from 2007 to 2022.

Study Year	Depth (m)	Water Temperature		Turbidity	Secchi Depth (m)	Current Velocity		Substrate Type	UTM	Dissolved Oxygen
		Surface	Bottom			No. of Locations	Seasonal Data [a]			
2007	√	√		√	√	12 sites		√	√	
2008	√	√							√	
2009	√	√				√			√	
2010	√	√		√	√	32 sites		√	√	
2011	√	√		√		2 sites	√		√	
2012	√	√	√	√	√	32 sites			√	
2013	√	√							√	
2014	√	√						√	√	
2015	√	√						√	√	
2016	√	√	√		√			√	√	
2017	√	√	√		√			√	√	
2018	√	√	√		√			√	√	
2019	√	√							√	
2020	√	√			√			√	√	
2021	√	√			√			√	√	√
2022	√	√			√			√	√	√

[a] Seasonal sampling consisted of sampling once during each session selected to represent the spring summer and fall seasons.

In Year 1 (2007), meso-habitat data were collected near the locations of sonic-tagged White Sturgeon. The boat was equipped with a sounding reel and arm connected to a 45.5 kg lead “fish”. An Aqua-Vu underwater camera and the flowmeter were attached to the “fish” and lowered into the water. Current velocities were obtained at 0.36 m above bottom and at 0.8 and 0.2 of the total depth at the site. In Year 3 (2009), a decision was made to maximize fish capture efforts, therefore habitat data collection was limited to surface water temperature, depth (as determined by the boat depth sounder) and a visual assessment of surface current velocity conducted by observing floating debris moving past a stationary float (from sample gear).

From 2007 to 2010, visual estimates of benthic substrate were obtained using an Aqua-Vu SV-120™ (Aqua-Vu) used to assess the substrate characteristics and cover type and availability at locations where habitat measurements were obtained. The camera was also used for an underwater video survey of Big Eddy on Sep 27 2007 to check for the presence of juvenile White Sturgeon. The Aqua-Vu unit consisted of a compact camera in a plastic housing (equipped with multi-coloured lights), a 30 m cable, and a weather resistant 10 cm^2 monitor.

During most years of the program, the majority of habitat data were collected in the summer period (August to October). In Year 5 (2011), meso-habitat data were collected over three different sample sessions (May, August, and October). In 2012, physical habitat measurements were taken at four representative locations within the study area during VPS downloading sessions near the Walter Hardman Generating Station (August to October; Golder and ONA 2013). From 2013 onwards, habitat related data were collected at juvenile White Sturgeon capture sites.

Water quality parameters collected within the Revelstoke Reach were limited to surface water temperature and turbidity. A standard suite of basic water quality parameters (continuous daily water temperature regimes and routine water quality parameters) was obtained under a separate program (CLBMON-15A Mid-Columbia River Physical Habitat Monitoring).

Benthic substrates were collected at a sub-sample of White Sturgeon capture sites from 2014 to 2022 using a Ponar Grab with a grab capacity of 2,376 cm^3. Grab samples were stored in glass containers with ethanol or isopropyl alcohol preservative until processing. Substrate sample volume was recorded prior to sorting. Samples were sorted using size 105 or 500 micron stainless steel screening depending on sample type. Samples were differentiated by dominant and secondary substrate types (fine-medium-coarse sand/clay/granule/pebbles) and recorded for contents.

2.3 Juvenile White Sturgeon Releases

2.3.1 Conservation Aquaculture

In 2007, the WUP Consultative Committee identified knowledge gaps for recruitment of juvenile White Sturgeon in the MCR (BC Hydro 2007). Following this, a supplemental hatchery program was initiated to release juvenile White Sturgeon annually in the MCR. The Upper Columbia White Sturgeon Recovery Initiative Technical Working Group (UCWSRI-TWG), which is responsible for the White Sturgeon Recovery Plan for the Columbia River upstream of Grand Coulee Dam, was involved in the WLR process and contributed to designing the hatchery program.

Since 2007, juvenile White Sturgeon have been produced from either direct gamete crosses (broodstock; 2007-2014) or from eggs and larvae collected from natural spawning events in the wild. From 2007 to 2014, mature adult White Sturgeon (broodstock) captured in the Lower Columbia River (LCR; HLK to the Canada-US Border) were transported to the Kootenay Trout and Sturgeon Hatchery (KTSH), spawned, and returned to the river. More recently, research has identified that genetic diversity can be increased in supplemental sturgeon progeny by collecting naturally produced eggs and larvae in the wild (Crossman et al. 2011) and this was confirmed for the Columbia population (Jay et al. 2014). This led to a change in the conservation aquaculture program and the broodstock program was ceased in 2014. Juvenile White Sturgeon reared from eggs or larvae captured from natural spawning events are referred to as 'wild origin' juveniles. The first wild origin juveniles (approximately 10 months old) for release in the MCR originated from collections on the Columbia River south of the border in Washington with the objective of testing size at release effects on survival. These were surplus fish to the US juvenile release program and were transported across the border to the KTSH for an additional year of rearing and subsequent release (as 22 month-old fish) in the MCR in 2016-2018. Releases in more recent years have included surplus wild origin progeny from spawning in the lower Columbia River.

Natural spawning of White Sturgeon in Revelstoke has been observed through the capture of eggs and larvae since 1999 during CLBMON-23A. Beginning in 2018, viable eggs and larvae from this stock were sent to the KTSH (89 in 2018, 7 in 2019, 203 in 2020, 679 in 2021, and 20 in 2023; Wood 2019; ONA 2023). A sub-set of these fish were reared to hatchery targets and released at Shelter Bay in following years.

2.3.2 Marking and Tagging

In March of each year, juvenile Sturgeon were individually marked at the KTSH using a Passive Integrated Transponder (PIT) tag into the dorsal musculature at the midpoint between the dorsal and lateral scute line and inferior to the anterior margin of the dorsal fin (Figure 2). All juveniles also received a secondary mark by the removal of selected scutes. Scute removal marking has been conducted since the inception of the White Sturgeon Conservation Aquaculture program to ensure hatchery fish can be identified if PIT tags fail. For hatchery origin fish, scute removal patterns used from 2001 to 2014 involved scutes removed on the fishes left side below the dorsal fin: two scutes removed prior to 2011 and three scutes since 2011, or a combination thereof. Prior to 2011, it was always the first scute and then a second one, taken after counting the number of scutes that corresponded to the year class. For example, a fish born in 2002 would be missing the first and the fourth scutes on the left side. Sturgeon collected in the wild as fertilized embryos or larvae, and then reared in the hatchery before release had a strip of three scutes taken from the right side of the fish directly below the dorsal fin.

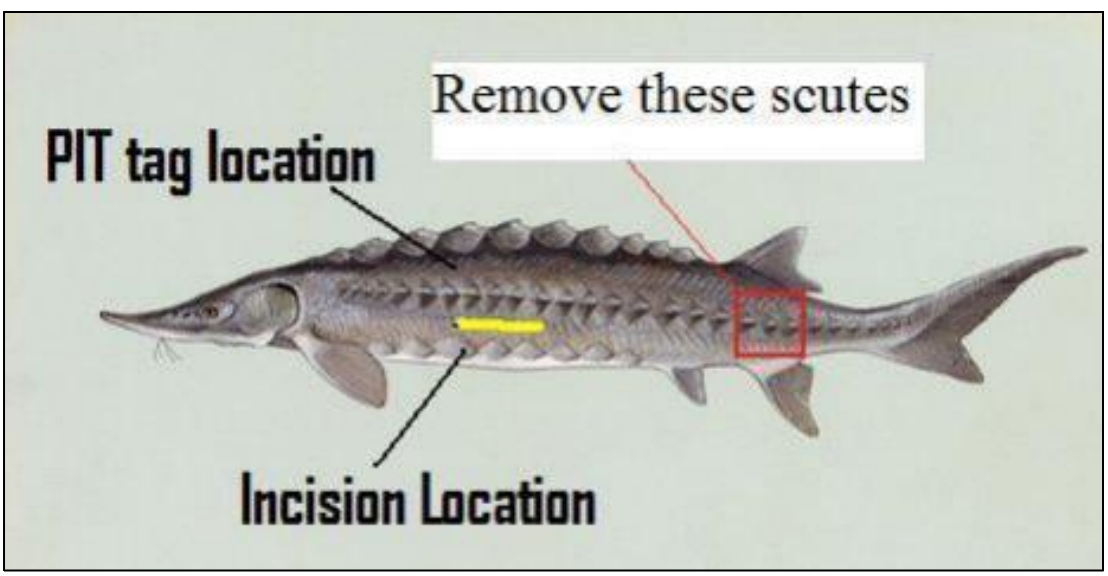

Figure 2. Juvenile White Sturgeon showing the PIT tag location, sonic tag incision location scute removal pattern. Figure from FFSBC (2017).

PIT tag number, scute pattern removal, fork length (cm), weight (g), and fin deformities were recorded for each individual fish at the hatchery in mid-April, as close as possible to their release. This was done to ensure no additional growth occurred in-hatchery that may be attributed to post-release growth. Each individual fish can subsequently be identified to its release location and date of release in addition to family record. Juveniles were transported in Freshwater Fisheries Society of British Columbia (FFSBC) fish transport vehicles according to UCWSRI-TWG transport protocols.

2.3.3 Size at Release Study

The size of fish being released through the conservation aquaculture program has varied over the years to determine the most successful size-at-release for hatchery-raised juveniles. Five different hatchery size target categories have been released within the Revelstoke Reach (Table 5).

Hatchery size target categories were adjusted based on results from capture efforts in the study area, from results from other programs (e.g., lower Columbia River (Crossman et al. 2023), Nechako River, and Kootenai River), and through discussions with the UCWSRI-TWG. From 2007 to 2015, hatchery origin White Sturgeon juveniles were reared at the KTSH to 10 months of age before they were transported to the MCR for release. These 10 month old (~Age-1) fish can be further categorized into small-bodied form (2007-2012; grown to ~ 50-70 g) and large-bodied form (2013-2015; grown to ~ 105 g) fish. Juveniles released in 2016-2021 were reared in the hatchery for either 10 months (~Age-1) or 22 months (~Age-2).

Table 5. Size categories of hatchery release size targets, including age, study years released, and number released for all White Sturgeon released in the Middle Columbia River from 2007 to 2022.

Size Category	Hatchery Release Weight Target (g)	Age at Release	Study Year Released	Number Released
1	n/a	1 to 60 days	2008 – 2010	1,370,749
2	50 – 75	10 months	2007 – 2012	43,078
3	150	10 months	2013 – 2015	15,245
4	350	10 months	2016 – present	1,387
5	700	22 months	2016 – present	3,894
			2007-2022 Total	**1,434,353**

In 2008, the UCWSRI-TWG approved the release of fed and unfed larvae below REV (FFSBC 2010). A dedicated portable hatchery facility, located at the KTSH, housed six three-meter aluminum troughs with four MacDonald jars per trough that contained eggs from Sturgeon broodstock. Approximately 619,480 larvae (fed and unfed combined) from this facility were released at the confluence of the Columbia and Jordan Rivers in 2008 and 260,000 (fed and unfed) larvae were released in 2009. In 2010, 336,270 unfed day-old larvae were released in the upper Revelstoke Reach as part of an experiment to assess the effects of substrate modifications on larval retention and growth (Crossman and Hildebrand 2014). The monitoring described in this report is expected to detect any survival of these larvae to the juvenile life stage.

2.3.4 Release Locations

The location of juvenile White Sturgeon releases was also tested in conjunction with the acoustic-tagged fish movement study. Fifty acoustic-tagged juvenile White Sturgeon were released at single locations in both 2007 and 2008 (Moses Creek and Big Eddy; Table 6) to observe initial dispersal movements. In both years, the fish release was also split into two times of day: 25 fish were released at noon, and 25 fish were released at midnight. In 2009 and 2010, 10 acoustic-tagged juvenile Sturgeon were released at one of five locations: Big Eddy, Begbie Creek, Mulvehill Creek, Tree Island, and Arrowhead during the day.

Table 6. Summary of the release location and time of day study for hatchery juvenile White Sturgeon released in the Middle Columbia River below Revelstoke Dam, 2007 – 2010.

Release Date	Brood Year	RKm	Release Location	Sonic-Tagged?	Release Time	Number of Fish
3-May-07	2006	233	Moses Creek	No	Noon	1,884
					Midnight	2,172
				Yes	Noon	25
					Midnight	25
					2007 Release Total	**4,106**
29-Apr-08	2007	225.8	Centennial Launch	No	Day	600
		228.3	Big Eddy	No	Night	5,884
				Yes	Night	50
					2008 Release Total	**6,534**
23-Apr-09	2008	225.8	Centennial Launch	No	Day	600
		228.3	Big Eddy	No	Night	7,518
				Yes	Day	10
		216	Begbie Creek	Yes	Day	10
		206.1	Mulvehill Creek	Yes	Day	10
		203	Tree Island	Yes	Day	10
		194.1	Arrowhead	Yes	Day	10
					2009 Release Total	**8,168**
23-Apr-10	2009	225.8	Centennial Launch	No	Day	400
		228.3	Big Eddy	No	Night	9,175
22-Apr-10	2009	228.3	Big Eddy	Yes	Day	10
		216	Begbie Creek	Yes	Day	10
		206.1	Mulvehill Creek	Yes	Day	10
		203	Tree Island	Yes	Day	10
		194.1	Arrowhead	Yes	Day	10
					2010 Release Total	**9,625**

The analysis focused on an evaluation of the effect of release sites on subsequent Sturgeon behaviour. Initially, all four years of data were examined; however, during initial exploratory analysis there were sufficient differences in other factors (e.g., reservoir water levels) so Year 1 and Year 2 were excluded from the analysis. The variables examined included: time spent on station and movement magnitude and direction after departing station until relocated. Absolute distance travelled was not used as a fish released at a site near the most upstream VR2W station could not be relocated at an upstream site as there were no more receivers. As this bias also affects relative distance travelled following departure from a VR2W station, the time spent on site after arrival would be a stronger parameter on which to evaluate the effects of release site on subsequent behaviour. The parameters and statistical analysis for the two selected models (Log Time at Station and Standardized Distance Travelled) are described in Golder (2011).

2.4 Juvenile White Sturgeon Movement and General Habitat Use

2.4.1 Study Design

The juvenile White Sturgeon movement study consisted of two components; from 2007 to 2010 (Phase 1), the study focused on larger movements and in 2011 – 2012 (Phases 2 and 3) focused on fine-scale movements. During Phase 1, juvenile White Sturgeon implanted with acoustic tags were tracked using receivers anchored in a linear array every 5 km along the thalweg within the Revelstoke Reach (RKm 229.7 – 179). Mobile acoustic tracking was also conducted in Years 1 to 4 in the Revelstoke Reach during September and October (Table 7). These early studies provided data on large-scale movements (e.g., movements of several kilometres or greater) and identified the general areas and macro-habitats used by these fish but did not identify fine-scale movements or micro-habitats. The low number of captures during this study precluded statistical analyses of survival and life history parameters.

A better understanding of fine-scale movements was desired to contribute to the overall knowledge base, including habitat use during varying ALR water elevations. The objective of Phase 2, implemented in 2011 (Year 5), was to determine the feasibility and best location of the VPS 2D Grid Array that would be used to track fine-scale movements. Phase 3 was implemented in 2012 (Year 6) and involved concentrating all the acoustic receivers into a 3 km section of river near the Walter Hardman Generation Station and Akolkolex River confluence over the period of five months (May to October). The three different phases are described in the following sections.

Table 7. Timing of annual tracking activities for acoustic-tagged juvenile and adult White Sturgeon in the Middle Columbia River from 2007 – 2012. Greyed cells indicated activity during that year.

Year	VR2W Linear Array	Mobile Tracking	VPS 2D Grid Array	Adult Acoustic Tracking [a]
2007	Installed April 2007; RKm 228 to 179	28 Sept – 6 Oct; RKm 223 to 204		Using both VR2W Array and Mobile Tracking
2008	Continuous; RKm 228 to 179	7 Sept – Near Mulvehill Creek; RKm 210 to 205		Using both VR2W Array and Mobile Tracking
2009	Continuous; RKm 228 to 180	18-19 Sept; RKm 202 - 195		
2010	Continuous; RKm 228 to 112	Winter (Feb); RKm 184 to 153 [b]		
2011	Array remove 24 May 2011		Acoustic range testing, 2D array development	
2012			15 May to 30 Oct 2012; RKm 203 to 200	

[a] Due to remnant active acoustic-tagged adult Sturgeon in the study area, acoustic tags were tracked and reported in this program at the same time as juveniles. See Golder 2007.

[b] There was no summer mobile tracking program in 2010. CLBMON-31 submitted mobile tracking results for Sturgeon tags located in Arrow Lake Reservoir during the Burbot tracking program in February.

2.4.2 Passive Acoustic Array

The acoustic receivers used during Phase 1 (2007-2010) were Vemco Ltd. (VR2W) single channel receivers. VR2W receivers were submersible, single channel acoustic receivers that operate at a frequency of 69 kHz and were capable of identifying and decoding Vemco sonic transmitter signals. The receivers were housed in a corrosion resistant cylindrical plastic high-pressure case and incorporate an integral hydrophone. For each tag detection, the date and time was recorded along with the transmitter code. Data were stored in flash memory until downloaded and reinitialized using a VR2W Communications Key, Bluetooth® wireless technology, and a laptop computer running Vemco User Environment (VUE) software. Each VR2W used a Tadiran TL-5930/F lithium 3.6 volt “D” cell battery with an operating life of approximately 15 months. Time was synchronized among receivers during initialization, which matched the time on each receiver to that of the laptop computer.

In April 2007, prior to the first release of acoustic-tagged juvenile White Sturgeon below REV, 18 remote telemetry receivers were deployed in a linear array within the MCR (passive acoustic array; Golder 2008). This passive array, located from RKm 233 (Moses Creek) to RKm 180 (Arrowhead Flats) was in constant operation until spring 2011, although the configuration changed over time. By 2010, the passive acoustic array consisted of 19 VR2W stations; 11 stations were located between Big Eddy (RKm 228.3) and Arrowhead (RKm 184), 5 were located in the Arrowhead Flats and mouth of Beaton Arm area, and 3 were located at the Narrows (Burton area, RKm 112 – 110). The design of the array allowed collection of large-scale movements and general timing of movements within the study area after fish release. Two hundred sonic-tagged juvenile White Sturgeon (50 each in 2007, 2008, 2009, and 2010) were released into the MCR. The life expectancy of these tags was less than one year, so tags released the previous year had expired prior to the release of fish the following year.

Preferred locations for passive acoustic receiver deployment were areas with low water velocities and smooth channel bottom configurations to reduce background noise and interference from islands or underwater obstructions and help prevent damage or loss of the units. Prior to deployment, VR2Ws were checked *in situ* using a reference tag to confirm their operation. VR2Ws were deployed such that their position in the water column was below the thermocline depth during the summer, as water density changes can interfere with acoustic signal reception.

2.4.3 Mobile Tracking

Mobile tracking surveys were conducted to identify locations that acoustic-tagged juveniles were utilizing in sections of river between the VR2W stations, as well as determining sites to sample for specific preferred habitat parameters. Tracking was conducted from a boat using a Vemco VR28T acoustic receiver and towed V-fin. In areas with fast current, the boat was allowed to drift in the middle of the channel to reduce noise from the engine that could interfere with the reception of the acoustic tag signals. In areas where the river channel was narrow, mobile tracking was conducted by towing the V-fin in the middle of the channel. In areas where the river channel was wider, a “zigzag” pattern was followed, with priority given to coverage of the thalweg.

When an acoustic-tagged juvenile was detected, the directional hydrophone data provided by the receiver were used to “zero in” on the fish. When a strong signal was received indicating close proximity to the tagged fish, the boat was anchored in position over the fish, the location marked using a Garmin 12 GPS unit, and habitat data were obtained. Underwater video surveys (Section 3.3.5) and gillnet sampling (Section 3.4.1) also were conducted in association with mobile tracking surveys.

During a separate WUP project (CLBMON-31), LGL Limited conducted mobile tracking surveys for acoustic-tagged Burbot (*Lota lota*) from Feb 08 – 11 2010. The surveys were focused within the ALR; though juvenile White Sturgeon were also detected (Robichaud et al. 2010) and the detection data supplied to this program.

2.4.4 Fine-Scale Movement Array

Range testing was completed for all three phases of the acoustic tag tracking program to assess the tag detection efficiency of the receivers. Range testing involved in-situ movements at different distances around VR2W receivers using a tester acoustic tag, either lowered in place and held stationary, or towed by a boat. For the fine-scale array, the efficiency of tag detections within the VPS was tested on May 03 and 14 2012. Drag tests were conducted by suspending a test tag (Vemco V9-2x) from a boat at approximately 3 m depth and moving through the VPS array either by drifting or under power. Drop tests were conducted by affixing a test tag to an anchored float line and deploying the tag (Vemco V9-2x) at a location for a period of time. A drop test was conducted within a receiver triangle and at the edge of a receiver triangle. Upon completion of the testing, the downloaded data were submitted to Vemco Ltd. for post-processing. The resulting estimated positions indicated VPS effectiveness of 55-78% (Golder and ONA 2013), which is considered at or above the expected rate of positioning success (Vemco analyst, pers. comm.). Specific details regarding range testing activities and results can be found in the CLBMON-21 annual report series. The results from the range testing study informed the Fine-Scale Movement Array.

The purpose of the 2012 (Year 6) monitoring program was to deploy a VPS array in the MCR to monitor the seasonal (spring, summer, and fall) movements of 50 acoustic-tagged juvenile White Sturgeon released within the array. The array configuration was based on results from the 2011 feasibility assessment and recommendations from Vemco technical advisors, as well as previous studies, which indicated high use of this area by acoustic-tagged hatchery juvenile White Sturgeon (Golder 2008, 2009, 2010, 2011). The specific objectives were:

1. To describe fine-scale movements (< 10 m positional accuracy) and associated habitat use by juvenile White Sturgeon and determine if there is a relationship between the movements observed and variables of daylight, flow, and seasonal changes in ALR water surface elevation and
2. Use the movement data obtained to recommend refinements to future capture programs to obtain data on juvenile White Sturgeon life history, population abundance and survival metrics.

The preliminary receiver and reference tag locations within the VPS array were pre-determined in the office in consultation with Vemco Ltd. and plotted on aerial photos of the study area. Twenty-six telemetry receivers were deployed on May 01 and 02 2012. The pre-selected locations of many receivers had to be adjusted from the original array design because portions of the study area were de-watered at this time due to low ALR water levels. To expand coverage of the array into recently inundated habitats, three additional receiver stations (R27, R28, and R29) were deployed on Sep 19 2012. The calculation of a fish's position within the array required detection by a minimum of three co-located receivers. To facilitate triangulation of fish positions, receivers were deployed in a triangular pattern with a target distance of 300 m between receivers along the "sides" of each triangle. Reference tags (n = 3) were deployed on May 01 2012 and were placed within three of the VPS triangles to provide redundancy (i.e., to test the receivers' positional accuracy of tags at known positions).

The study area consists primarily of deep, low velocity habitat, and is constricted at the downstream end, which facilitates the identification of tagged fish moving downstream and out of the study area. The study area is far enough downstream of Revelstoke Dam for diel discharge effects to be attenuated, although some minor changes in water velocity and water surface elevations can occur. Individual receivers within the VPS array consisted of an anchor, float line, the VR2W receiver, and a float. Receivers were affixed to the float lines approximately 2 m off the bottom using heavy-duty cable ties and submerged with the hydrophone pointing up. A small subsurface float attached to the float line above the receiver maintained the vertical position of the receiver and kept it off the river bottom. Synchronization tags (sync tags) were affixed to the float line approximately 1 m above the receivers. Sync tags were necessary within the VPS array for receiver time synchronization; if a receiver could not be time synced with at least one other receiver, it was not used for signal positioning.

Three additional receiver stations were deployed in the fall to expand coverage of the array into recently inundated habitats. The calculation of a fish's position within the array required detection by a minimum of three co-located receivers. To facilitate triangulation of fish positions, receivers were deployed in a triangular pattern with a target distance of 300 m between receivers along the "sides" of each triangle. Sync tags were necessary within the VPS array for receiver time synchronization; if a receiver could not be time synced with at least one other receiver, it was not used for tag positioning.

2.4.5 Dispersal and General Movements

Total, upstream, downstream, and net movements were calculated for acoustic-tagged juvenile White Sturgeon released in the MCR in 2009 and 2010 (Golder 2011). The movements analyzed were defined as:

1. Total movement: sum of all detected movements, regardless of direction,
2. Upstream movement: sum of all detected movements in an upstream direction,
3. Downstream movement: sum of all detected movements in a downstream direction and,
4. Net movement: distance between the furthest upstream and furthest downstream locations a fish was detected (i.e., a representation of the range of a particular fish or group of fish).

To assess differences in post-release dispersal patterns of acoustic-tagged juvenile White Sturgeon, two release strategies have been employed in the MCR:

- 2007 and 2008, acoustic-tagged fish were released at or above Big Eddy (RKm 228.3) and
- 2009 and 2010, acoustic-tagged fish were released in groups of 10 fish at 10 km intervals between Big Eddy (RKm 228. 3) and Arrowhead (RKm 184).

2.4.6 General Macro-Habitat Use

General macro-habitat selection by acoustic-tagged juvenile White Sturgeon was examined by calculating the number of tag days (one tag day = one fish detected at a particular station for any portion of a particular day) at VR2W stations in the MCR in 2010 (Golder 2011). This provided data on the temporal (days used) and spatial (the area within approximately 500 m of a particular receiver) use of macro-habitats in the vicinity of the receiver locations. However, since past studies have shown that acoustic tag detection ranges in the MCR can vary substantially on a daily or seasonal basis (Golder 2006), the tag day data likely represented the minimum period that a tagged fish was present in the area of a particular receiver.

2.4.7 Statistical Analyses of Movement

A summary of the methods used to analyze the movement data obtained from the acoustic telemetry receivers is provided. Additional details are provided in the annual report (Golder 2011).

Juvenile White Sturgeon movement data from 2007 to 2010 were condensed from several million detections from the VR2W receivers to several thousand records that identified the time and location of fish when they first arrived at a station and when they moved out of detection range. For example, if a fish was detected 100 times by a VR2W station and not detected at another station during that time, these 100 detections were reduced to two records - when the fish arrived and when the fish moved out of range (the first and last detection).

The time spent near each station between movements and the direction, magnitude, and rate of movements were calculated. The time spent at station parameter has advantages in that it is not dependent upon the location of potential relocation sites, which could bias interpretation of movement data collected after a fish left a particular site. The selected model used release site, month and an interactive term between month and release site as the independent variable (Equation 1).

Equation 1. Model used to determine the time juvenile White Sturgeon spent at a station in the Middle Columbia River.

$$Log(Time\ and\ Station) = B0 + B1\ (Release\ Site) + B3\ (Release\ Site\ x\ Month) + e$$

$$where,$$
$$e = normally\ distributed\ error\ term\ with\ u = 0$$

The net mean distance moved and the mean residence time at station were selected as the dependent variables after exploratory graphical analyses of the data.

The influence of time of day on movements was examined among seasons and years. Movement frequencies were summarized by hour, month, and year. For the purposes of this analysis, only those fish that left the vicinity of one receiver (departure) and were subsequently detected at another receiver (arrival) were used to represent an actual movement. The onset of the movement was defined as the time that a fish was last detected at the departure receiver. Data from fish that simply “disappeared” from one receiver but were either never relocated or were subsequently relocated at the same receiver were not used since these data may simply have reflected daily differences in the detection range of the receiver.

The hourly discharge rate from REV was used to calculate the average flow in the relationship between flows and fish movements.

Diel patterns of light intensity (solar radiation) were estimated using the SOPOS (Solar Position) model available at the National Renewable Energy Laboratory’s Measurement and Instrument Data Center (http://www.nrel.gov/midc/solpos/solpos.html). Extraterrestrial Global Horizontal Solar Irradiance values (W / m^2) were extracted for further analyses. The model was run using 10-minute intervals to predict solar radiation at Revelstoke BC. After examining the frequency distribution of solar irradiance for each year at the onset of movement, the lack of variation during daylight resulted in the decision to convert these data to a binary variable where 0 = dark and 1 = light. The binary variable was used in subsequent analyses.

The effect of release location on the movements of acoustic-tagged juvenile White Sturgeon was analyzed for Years 3 and 4 (2009 and 2010) and not Years 1 and 2 (2007 and 2008) due to placement of receivers and a larger dataset from more release sites spread over the entire study area. The two release strategies were not otherwise comparable. To provide additional information on the effect of release location on subsequent dispersal patterns and habitat selection, acoustic-tagged fish were released in groups of ten fish at five locations approximately 10 km apart:

- Big Eddy (RKm 228.3),
- Near Begbie Creek (RKm 216),
- Near Mulvehill Creek (RKm 206.1),
- Near Tree Island (RKm 194.1), and
- Near Arrowhead (RKm 184).

2.4.8 Movement GLM Model Development

A general linear regression model was developed that included standardized distance travelled after the onset of movement as the dependent variable and independent variables of: daylight (binary day/night), hourly Revelstoke discharge at time of movement initiation, hourly ALR water surface elevation at Nakusp, month, year, and release site. All variables were categorical except for Revelstoke discharge (Q in m^3/s) and ALR water surface elevations (masl). AIC_c scores for a set of plausible models were used to select the final model with AIC_c weights calculated for the set of models used in the analysis (model details are described in Golder 2011). Hourly ALR water surface elevations (m above sea level; masl) at Nakusp were used as an independent variable in the analysis.

2.4.9 Fine-Scale Array Location Analysis

The VPS is based on the principle of range difference positioning (also known as time-difference-of-arrival [TDOA], hyperbolic positioning, and multi-lateration). If a signal transmitted by the object to be located is detected by two receivers at two different times, the difference between the arrival times was converted into a range difference, using information collected in the testing phase during Year 5 (2011) of the program. In 2-D positioning, each range difference was defined as a hyperbola along which the acoustic signal may be found. By using the overlap of multiple hyperbolas, from different receiver locations, the 2-D position was estimated. For further data analysis details refer to Golder and ONA (2013).

The accuracy of the HPE (horizontal positioning error) values as descriptors of positioning error was examined using sync and reference tags, for which the true position of the tag is known. The error between the VPS estimated position and the true position was defined as HPEm (measured horizontal position error). The relationship between HPE and HPEm values for sync and reference tags was examined to describe error in the estimated positions of tagged fish. Generally, when HPE values were at or below 7, more than 95% of the empirical error values (HPEm) were smaller than the HPE value. Applying this to VPS-generated tagged White Sturgeon locations, the HPE values reported with estimates of tag positions could be viewed as liberal estimates of positioning error, as they will likely overestimate the actual position error in at least 95% of the cases while HPE ≤ 7.

Using the cumulative proportion plot, three HPE values were chosen (HPE = 5, 6, and 7) as the most desirable combination of fine-scale positional accuracy. A sensitivity analysis was then conducted to determine the most appropriate cut-off value among these three candidates and its effect on the results. Based on the results of the sensitivity analysis and the cumulative distribution, a threshold HPE value of 7 was chosen, and all tag locations with HPE > 7 were omitted from all subsequent analyses.

2.4.10 Analyses of Fine-Scale Movement Data

Over the VPS study area, maximum depths in the thalweg area were typically > 10 m (range between approximately 8 and 21 m). Maximum depths in the floodplain area over the same period were typically from 5 to 10 m (range between approximately 1 and 16 m) and maximum depths in the shallows area were typically < 5 m (range between approximately 1 and 11 m).

To describe fish movements relative to habitat and environmental variables, the following metrics were determined for each White Sturgeon tag location:

- Minimum distance traveled from previous tag location (m),
- Movement speed from previous tag location (m/s),
- The time of day (i.e., day or at night); defined using sunrise and sunset times for each day of the study as obtained from https://aa.usno.navy.mil/data/RS_OneYear,
- The season:
    - Spring (May 15 – Jun 20),
    - Summer (Jun 21 – Sep 20), or
    - Fall (Sep 21 – Oct 30),
- The month, since sample periods in spring and fall were considerably shorter than in the summer, monthly analysis was considered to provide better insight into temporal changes in behaviour,
- Whether ALR was:
    - Filling,
    - Full,
    - Emptying, or
    - Stable,
- What the ALR water surface elevation (masl) stage was:
    - Low (430.34 – 433.74 masl)
    - Moderate (433.75 – 437.13 masl), or
    - High (437.14 – 440.53 masl), and
- The habitat classification where the fish was positioned:
    - The old river channel thalweg (defined as below the 424.0 masl contour)
    - The old river floodplain (defined as within the 424.1 – 429.0 masl contours), or
    - The reservoir shallows (defined as between the 429.0 to 440.5 masl contours).

The last metric was used to assign fish position to a defined geomorphic feature and as an indirect means of assessing fish depth selection. The geodetic elevations of these macro-habitat divisions were obtained from Canadian Hydrographic Service chart datum (Chart 3058, Columbia River, Arrowhead to Blanket Creek, 1991), scanned and digitized using ArcGIS 10.1. These data were then used to develop depth ranges for the three channel types over the May 30 to Oct 30 2012 monitoring period. The old pre-regulation river channel (thalweg area) provides the greatest depths available in all seasons and since this habitat remains wetted throughout the year, would exhibit the greatest benthic productivity. The floodplain area represents the historical river floodplain that would have been inundated during typical spring freshet levels but is now flooded by reservoir filling during the spring and remains wetted until late fall. The reservoir shallows area represents the area above the historical active floodplain that is now flooded during the late spring to early fall period due to reservoir filling.

The study area was divided into the three habitat classifications and each tag position was categorized into one of these habitat types. To provide confidence intervals for the assignment of habitat type to a fish position, the distance from every estimated fish position to each elevation contour was calculated. The associated HPE values (HPE ≤ 7) were used as liberal 95% confidence intervals, as suggested by the results of quantile regression of synchronization and reference tag HPEm versus HPE. For each fish position, the distance from the position to the nearest habitat classification elevation contour line was compared to the HPE values associated with the VPS position estimate. If distance from the contour line was greater than the HPE, the fish was assigned to the type of habitat it was positioned in (thalweg, floodplain, or shallow). If the distance from the contour line was smaller than the HPE value, the habitat assignment was considered uncertain and was not assigned to a specific habitat classification.

The study area includes the mouth of the Akolkolex River, a major tributary to Revelstoke Reach, which represents a potential source of food (i.e., benthic drift) for juvenile White Sturgeon. This potential food source may serve to attract juvenile White Sturgeon into the shallow bay at the river-reservoir confluence. The depths in the bay were typically < 5 m in the spring and fall periods and < 10 m in the summer at peak ALR levels of 440.5 masl. To describe the extent of movement between the main VPS array and the large shallow bay at the mouth of the Akolkolex River, fish positions using detections at the three receivers closest to the river mouth (R27, R28, and R08) were summarized. All detections at one of the three receivers were categorized by time of day (day or night) and season (spring, summer, or fall). In addition, detections were categorized based on whether the fish remained within the VPS array near the Akolkolex (continually detected on at least one of the three receivers), left the VPS array (presumably moved into the Akolkolex Bay area) for more than 0.5 h, or returned into the VPS array after leaving for longer than 0.5 h.

2.4.11 Underwater Video Surveys

In 2007 and 2009, an Aqua-Vu SV-120™ (Aqua-Vu) was used to assess the substrate characteristics and cover types and availability at locations where habitat measurements were obtained (Golder 2008, 2010). The Aqua-Vu unit consisted of a compact camera in a plastic housing (equipped with multi-coloured lights), a 30 m cable, and a weather resistant 10 cm^2 monitor. The camera was also used for an underwater video survey of Big Eddy in 2007 to check for the presence of juvenile White Sturgeon. In 2009, The Aqua-Vu camera was used to look for juvenile White Sturgeon presence at multiple locations in the Revelstoke Reach.

2.5 Juvenile White Sturgeon Capture Efforts to Estimate Growth and Survival

2.5.1 Study Design

The objective of the juvenile White Sturgeon capture program was to estimate the growth and survival of fish released from the conservation aquaculture program. Golder led the program for the first four years (2007 – 2010) with capture and habitat assessment components limited to Revelstoke Reach, between Shelter Bay and REV (RKm 179 – 233). Capture efforts were closely informed by movement monitoring results (Table 8). Capture activities for juvenile White Sturgeon were conducted from mid-August to mid-October with the exception of one overnight set at Mulvehill Creek (RKm 207.2) from Mar 12 – 13 2008 (

Table 9).

In 2013, ONA became the program lead and conducted an abbreviated sampling period from the last week of September to the first week of October with sample sites from the Arrow Lakes Narrows to Arrowhead Flats (RKm 116 – 183). BC Hydro complimented sampling effort with additional capture activities in early October from Wallis Creek upstream to Greenslide Creek (RKm 187 – 212). In 2014 and 2015, the sampling period was extended earlier in the year, from mid-July to mid-October, while the study location included sites from the Arrow Lakes Narrows upstream to Greenslide Creek (RKm 113 – 211). In 2014 and 2015, BC Hydro conducted sampling in late September to early October from upstream of Tank Creek to Greenslide Creek (RKm 194 – 210). In 2016 and 2017, the study period was expanded to include sampling effort from early June to late September (

Table 9). For these years, the upstream extent of the study location was Greenslide Creek (RKm 210) and included a more concentrated effort along the shoreline of the Upper Arrow Lake downstream to McDonald Creek (RKm 119). In 2016, effort extended into the Beaton Arm (Beaton RKm 8), while in 2017, effort extended into the Arrow Lakes Narrows to upstream of Burton BC (RKm 98). The study area in 2018 was limited to the Revelstoke Reach, from Arrowhead Flats upstream to Greenslide Creek (RKm 180 – 211) and sampling period ranged from late August to late September. In 2019 and 2020, the sampling period ranged from early July to early October and included sampling effort (1) from Fauquier BC to McDonald Creek (RKm 79 – 118), (2) from Shelter Bay to Greenslide Creek (RKm 177 – 211), and (3) in the Beaton Arm. In 2021, the sampling period was from mid-August to late September and sampling effort was again limited to between Shelter Bay and Greenslide Creek (RKm 117 – 213). In 2022, the sampling period was from mid-August to mid-October and as in 2021, occurred from Shelter Bay to Greenslide Creek (RKm 177 – 211).

Table 8. Site distribution of juvenile White Sturgeon capture effort by year and for each River Section of the Middle Columbia River (1 – 15) and Beaton Arm (B1 – B2), including downstream (d/s) and upstream (u/s) river kilometer (RKm). Capture effort conducted (grey shaded cells) from 2007 to 2022 by Golder Associates Inc., Okanagan Nation Alliance, and BC Hydro. Effort not conducted in 2011 and 2012.

River Section	RKm d/s	RKm u/s	2007	2008	2009	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	228.4	234.9														
2	226.1	228.3														
3	220.0	226.0														
4	214.1	219.9														
5	209.8	214.0														
6	205.6	209.7														
7	201.9	205.5														
8	197.6	201.8														
9	192.1	197.5														
10	186.6	192.0														
11	182.1	186.5														
12	176.9	182.0														
13	129.1	176.8														
14	119.0	129.0														

15	77.6	118.9														
B1	2.2	14.3														
B2	14.4	17.4														

Table 9. Seasonal distribution of juvenile White Sturgeon capture effort by year and for each month quarter (1 = 1st – 8th; 2 = 9th – 16th; 3 = 17th – 24th; 4 = 25th – the last day of the month). Capture effort conducted (grey shaded cells) from 2007 to 2022 by Golder Associates Inc., Okanagan Nation Alliance, and BC Hydro. Effort not conducted in 2011 and 2012.

Month	Quarter	2007	2008	2009	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Mar	**2**														
Jun	1														
	2														
	3														
	4														
Jul	1														
	2														
	3														
	4														
Aug	1														
	2														
	3														
	4														
Sep	1														
	2														
	3														
	4														
Oct	1														
	2														
	3														

2.5.2 Equipment

Gillnets were chosen as the primary method for initial sampling based on the success of this method to capture juvenile White Sturgeon in the Transboundary Reach (Columbia River between HLK and Grand Coulee Dam). Gillnet sites were selected based on gear limitation (i.e., lower velocity habitats where gillnets can be fished effectively) and the presence of habitat types (deep, slow moving eddies) known to be used by juvenile White Sturgeon in the LCR (Golder 2007). Gillnets were also deployed in the immediate vicinity of where acoustic-tagged juvenile White Sturgeon were located during mobile tracking surveys. Based on the results of other juvenile White Sturgeon monitoring programs in the Columbia River (i.e., Keenleyside Reach and the Roosevelt Reach; Golder 2007; Howell and McLellan 2013) sampling was focused on the thalweg, but shallower areas were also sampled to assess juvenile use of these habitats. Capture sessions were not conducted in 2011 and 2012 (Years 5 and 6) to focus efforts on the fine-scale movement study.

During 2014 to 2022 (Years 8 to 16), sampling sites were generated using the generalized random tessellation stratified (GRTS; Stevens and Olsen 2004) method design in the statistical package R (R Development Core Team 2013). This method provided spatially balanced, randomly chosen, sampling locations, distributed along the centerline MCR and Beaton Arm, and assigned a sampling gear type (gillnet or setline). Extra sites were also generated, that allowed for substitutions of sites that were rejected in the field due to logistical concerns (depth, velocity, obstructions) to ensure that randomness and spatial representation were maintained with the study design. The generated GRTS sites were used as a guideline, and once in the field, near shore sample locations were selected perpendicular to the centerline at targeted water depths (10 – 30 m). From 2014 to 2021, 200 gillnet and 200 setline sites were generated. In 2022, only 200 setline sites were generated as gillnets were not utilized.

2.5.2.1 Gillnets

Gillnets were 5.1 cm stretch measure monofilament, horizontal nets, but net dimensions varied over the course of the program.

All years of gillnet effort have used monofilament, horizontal gillnets with a mesh size of 5.1 cm, with the exceptions of 2008 (also used mesh sizes of 10.2 and 15.2 cm) and 2009 (also used a mesh size of 7.6 cm). From 2007, nets measured 15.2 m long by 1.8 m deep (27.9 m^2) and 45.7 m long by 1.8 m deep (83.6 m^2). In 2008, the smaller nets were replaced by larger nets measuring 30.5 m long and 1.8 m deep (55.7 m^2). From 2009 to 2015, nets measured 91.5 m long by 1.8 m deep (167.2 m^2). In 2016 and 2017, six different nets were used with varying dimensions; additional deeper nets were added as well measuring 91.5 m long by 3.0 m deep (278.7 m^2). These deep nets were used in 2017 and 2018 before they were cut in half to reduce potential for field worker injury. From 2019 to 2021 the same nets were in use, measuring 45.7 m long by 3.0 m deep (139.4 m^2) and 30.5 m long by 3.0 m deep (92.9 m2). Gillnets were deployed at the bottom of the water column, with a float and float line and anchors attached to each end of the net. Habitat measurements were recorded at each gillnet site (see Section 2.2.2).

Because of the potential risks of injury or mortality to adult White Sturgeon and in consideration of the endangered status of the population, overnight gillnet sets were not used in 2007 (Year 1) of the study. Based on the lack of capture success using daytime gillnets in 2007, the SARA sampling permit was amended to allow the use of overnight gillnets (with a target 12 hour set duration) in areas where adult White Sturgeon were not likely to be present. During 2008 (Year 2) sampling, gillnets were initially deployed overnight, but direct mortality of Bull Trout (*Salvelinus confluentus*) capture in these overnight sets was high (Golder 2009). Due to this high bycatch mortality, gillnet sampling in 2009 and 2010 was changed to short nighttime duration sets of approximately four hours, which reduced bycatch mortality. Both full overnight and short duration nighttime gillnets were used in 2010. From 2013 to 2021, four or five gillnets would typically be set out each day in the morning and retrieved mid-afternoon, with a target soak time of four hours. Occasionally, sections of net were damaged, generally due to submerged woody debris. These nets were repaired, replaced, or the percent broken was noted to properly alter effort results. A list of UTM coordinates for all gillnet sites are provided in the CLBMON-21 annual report series.

In 2022, gillnets were not deployed due to a lack of recent White Sturgeon captures (since 2017), risk to bycatch (e.g. Bull Trout), and issues with damage and entanglement (generally associated with high flows).

2.5.2.2 Setlines

In 2009 (Year 3), baited setlines were tested as an additional method to gillnetting for capturing juvenile White Sturgeon. Setlines were used in other sturgeon programs and were able to be deployed longer than gillnets (up to 24 hours rather than 4-hour sets for gillnets; BC Hydro 2022). Setlines were originally deployed similar to gillnets, but fewer in number (e.g. eight gillnets and two setlines per night).

Setlines initially consisted of 90 m mainline with 30 hooks spaced 3 m apart, an anchor, float line, and an LD-2 float affixed to each end. The mainline was marked at 3 m intervals to ensure that hooks were spaced evenly along the length of each setline during deployment. During Session 1 in 2009, barbless halibut hooks that were smaller (size 10, 11, and 12) than normally used (e.g., 14-0 to 20-0; Crossman et al. 2023) for sturgeon baited with worms, roe bags, or Kokanee (*Oncorhynchus nerka*) were clipped to the setlines. Based on a lack of captures using these hooks, smaller barbless "J" hooks (size 6 and 7) baited with worms, roe bags, Kokanee, Mountain Whitefish (*Prosopium williamsoni*) or Burbot were used in Session 2. Setlines were deployed perpendicular to the current to increase downstream scent dispersal and were fished overnight. Fishing setlines overnight was initially conducted within a specific session, not randomized over the entire study area.

Setlines became the main sample method used in 2013 to 2022 (Years 7 to 16) due to lower bycatch mortality compared to gillnetting. Each day, five to eight setlines were deployed (up to 12 per day in 2022). Setlines ranged from 50 to 120 m in length with 10 – 20 size 5 or 6 barbless "J" hooks per line baited with worms (night crawlers). The mainline was marked at 4 m intervals to ensure hooks were evenly spaced on the line. Setlines were set in the afternoon perpendicular to the flow, left to fish overnight, and pulled the following morning. An anchor, float line and LD-2 float were attached to either end of the setlines.

Habitat measurements were recorded at each site (see Section 2.2.2). In addition, hook size and number, bait type, and the number of baited, baitless, fouled, and lost hooks upon retrieval were recorded. A list of UTM coordinates for setline sites are provided in the CLBMON-21 annual report series.

2.5.2.3 Gear Efficacy Testing

In 2016, due to low capture rates in previous study years, additional gear testing to compare efficacy of gear types was conducted from May 02 to 06. The testing was concurrent with the juvenile White Sturgeon release at Shelter Bay (May 03 and 05) to optimize the chances of capture while the density of juvenile White Sturgeon was still high near the release site.

Gear efficacy testing was conducted using 4 hour gillnet sets and overnight setline sets. Gillnets measuring 91.5 m long by 3.0 m deep (278.7 m^2) were deployed at the bottom of the water column perpendicular to the shoreline. For setlines, different size hooks (4, 5, and 6) and bait types (shrimp, Kokanee, and worms) were tested on setlines to test preference in prey items and recruitment to different sizes of gear. Hook sizes and bait types were differentiated on each setline clip using coloured electrical tape. Hook sizes and bait types were also randomized on each setlines.

A total of ten gillnet sets and five overnight setline sets were sampled during this test. Gillnets were set for an average duration of four hours, except for three gillnet sets that were left sampling for 24 hours due to emergency boat issues.

2.5.3 Fish Handling

Captured White Sturgeon were weighed to the nearest 0.1 kg, measured for fork length to the nearest 0.1 centimeter, photographed, examined for health and external markings (missing scutes), and scanned for the presence of a PIT tag. Handling methods were consistent with those set by the UCWSRI in the Upper Columbia River Adult White Sturgeon Capture, Transport and Handling Manual (2006). All bycatch were identified to species, measured for length, and, if in good condition, released. One juvenile White Sturgeon captured was sacrificed for stomach content analysis and the digestive tract fixed in 10% formalin in 2010 (Golder 2011).

2.5.3.1 Gastric Lavage

In 2016, gastric lavage was attempted on two of the captured White Sturgeon with the objective of flushing the individual's stomach to identify prey items (Crossman et al. 2016). In 2017 to 2022, all captured sturgeon were lavaged except one that was capture in an unplanned overnight gillnet set in 2017. To reduce handling stress, this fish was only weighed and measured.

Gastric lavages were conducted using a Chapin SureSpray Select 8.0 L pump/bladder and a VWR size 8 standard testing sieve (#140). Food items collected were placed in jars, preserved with ≥ 90% ethanol, and labelled with the following information: date of collection, collection site, site UTM's, sturgeon FL (cm), and sturgeon weight (kg).

2.5.3.2 Fin Clip

In 2022, dorsal fin clips were collected for DNA analysis. A section of dorsal fin (roughly 1 cm x 1 cm) was cut with sterilized scissors, following the contours of the fin, and placed in a coin envelope to dry using forceps. Envelopes were labelled with the following information: date of collection, collection site, site UTM's, unique White Sturgeon identification number, PIT tag number, fork length (cm), and weight (kg).

2.5.4 Capture Effort and CPUE

Catch per unit effort (CPUE) was calculated for each year as total juvenile White Sturgeon captures per effort depending on gear type. Gillnet hours were calculated to compare different gillnet lengths, with and without damage panels, over the years of the program. Gillnet soaking hours (Net-Units; NU) were calculated using the area of the gillnet fishing and time soaking. Setline hook-hours (Hook-Hours; HH) were calculated based on the number of hooks set with bait and time and did not take into consideration how many retrieved were baitless, baited, broken, or lost. This method was standardized across all years of data.

Gillnet soaking hours were calculated using Equation 2 and setline soaking hours were calculated using Equation 3.

Equation 2. Gillnet soaking hours (Net-Units) calculated using gillnet fishing area and time fishing.

$$Soaking\ Hours = \left(\frac{A}{100\ m^2}\right) \times \left(\frac{T}{24\ h}\right) \times D$$

$$\begin{aligned} &where, \\ &A = net\ length\ (m) \times net\ depth\ (m) \\ &T = soak\ time\ (hours) \\ &D = intact\ net\ (\%) \end{aligned}$$

Equation 3. Setline hook – hours calculated using number of hooks set and time fishing.

$$Hook - Hours = \#\ hooks\ set\ \times T$$

$$where,$$
$$T = time\ (hours)$$

2.5.5 Relative Weight

The relative weight index (Wr) is a commonly used method for comparing the body condition of different fish populations of the same species (Murphy et al. 1991; Beamesderfer 1993). The relative weight index is expressed as a percent and is modelled on the 75th percentile weight data of the species' entire geographic range, therefore a Wr of 100% would represent a White Sturgeon in better condition than 75% of the fish that were used as the basis for developing the length-specific standard weight value (Equation 4). Relative weight is not affected by size-at-age, but rather provides an indication of condition based on length and weight. Because researchers often use different methods to measure the length of White Sturgeon and only fork length data were available from previously released hatchery juveniles, relative weights were calculated using fork during this program.

Equation 4. Relative weight index equation

$$Wr = \left(\frac{W}{W_S}\right) \times 100$$

$$where,$$
$$Wr = relative\ weight$$
$$W = individual\ weight\ (kg)$$
$$W_S = length - specific\ standard - weight\ value$$

For this report, the W_S used for calculating Wr was from Beamesderfer (1993; Equation 5).

Equation 5. Beamesderfer (1993) equation

$$W_S = \alpha \times L^{\beta}$$

$$where,$$
$$\alpha = 2.735^{-6}$$
$$L = individual\ fork\ length\ (cm)$$

This growth relationship was calculated using growth information from 15 populations of White Sturgeon from the Fraser, Sacramento, and Columbia Rivers (Beamesderfer 1993).

2.5.6 Growth

Total and annual growth (fork length [cm] and weight [kg]) were calculated for each individual and combined into mean growth metrics by age and year class. Total growth was calculated by subtracting the size at release (length and weight) from the capture size. Annual growth was calculated by dividing the total growth by the number of days since release and multiplying by 365 days. The assumption for annual growth is the total daily growth is constant between release and recapture; growth may vary seasonally and / or with size, but this assumption allows for the comparison of fish captured after more than one year after release.

2.5.7 Survival

To date, capture and recapture rates are too low to enable an estimate of survival. Low capture rates were attributed to a large study area and low capture efficiency. A larger number of recaptures are required to effectively estimate survival. Survival was qualitatively assessed by looking at the number of years at large a fish had been at large at the time of capture as an indication of survival potential.

2.5.8 Diet Analysis

The numbers of individual prey items within each taxon represented in the foregut were counted. Only foregut contents were enumerated and identified. Hindgut contents were not relied upon for accurate taxonomic identification, as digestive processes made identification efforts difficult.

Benthic substrates were physically collected at a subsample of sturgeon capture sites from 2014 to 2018 using a Petite Ponar Grab (232 cm^2) and were stored in glass containers with ethanol preservative until processing. Samples were sorted using size 105 to 500 micron stainless steel screening depending on sample type. All invertebrates in the sorted samples were stored in micro-centrifuges tubes with ethanol preservative. Invertebrates were identified to preliminary taxonomic order in the Freshwater Invertebrates of North American (Voshell 2002). In 2019, substrate grabs were not taken in association with sturgeon capture locations. In 2020, it became standard to take benthic grabs at sturgeon capture locations after individual fish processing (preferably the same day) and preserve samples for later analysis similar to that described above.

As benthic grabs were not seen to effectively sample larger substrate types (i.e., large gravel or shale), in 2019 to 2022, rock baskets were deployed (10 each year) in the Revelstoke Reach to identify a wider array of invertebrates potentially available to juvenile sturgeon. Rock basket samplers consisted of a wire “chicken barbeque” basket measuring 30 cm x 14 cm x 14 cm (planar surface area = 0.042 m^2), previously used in the Middle Columbia River Ecological Productivity Monitoring Program (CLBMON-15b; Perrin et al. 2008). The baskets were filled with clean gravel (size range of 2.5 – 2.5 cm) and closed with cable ties. Rock baskets were deployed near the beginning of annual sturgeon capture effort and retrieved during the last session. Upon retrieval, the basket and rocks were placed into a 5-gallon pail filled with water and scrubbed to loosen invertebrates. The water was processed through the same sieve used for benthic grab samples and remaining contents were preserved with denatured ethanol until processing. Benthic grabs were taken at each rock basket location to determine substrate type, but samples were not preserved. At each rock basket, date and time of deploy and retrieval were recorded along with location, water depth, secchi depth, dissolved oxygen, conductivity, substrate characterization (from benthic grab), and other comments including if the station had to be moved.

2.5.9 Incidental Catch

All incidentally captured species were identified, measured (fork length; mm), and, depending on species, weighed (grams). Several species (particularly salmonids) were scanned for the presence of a PIT tag that may have been applied during concurrently sampling programs in the study area (CLBMON-16; Golder et al. 2019). Individuals were also scanned to identify tags applied to hatchery juvenile White Sturgeon that may have been predated upon. From 2008 to 2010, scale and otolith samples were collected from Bull Trout that succumbed to sampling, as well as reviewing stomach contents for evidence of juvenile White

Sturgeon. Since 2019, most salmonids and Burbot that succumbed to sampling had their stomach contents examined for evidence of sturgeon.

2.6 Adult White Sturgeon Movement

2.6.1 Mobile Tracking

Monitoring adult White Sturgeon equipped with acoustic tags was added as a minor component of CLBMON-21 to increase the data obtained from the previous adult program (Golder 2006) and was only conducted in the first year of the program. In an attempt to detect movements of acoustic-tagged adult White Sturgeon into the Revelstoke spawning area and to understand habitat use, mobile tracking surveys using a Sonotronics receiver were conducted from Aug 16 and Sep 04 2007 and again in 2008 between Revelstoke Dam and Big Eddy (Golder 2008; Golder 2009). Mobile tracking was discontinued as all adult tags were past the battery life expectations.

2.6.2 Passive Array Detection

Of the 26 adult White Sturgeon implanted with acoustic tags in ALR since 1997, six Vemco coded pingers and one Sonotronics tag (Code 5-5-5) were potentially still functional (Golder 2006; Golder 2008). Four adult White Sturgeon in the ALR were expected to still have functional acoustic tags during the 2008 spawning period. The VR2W passive array was checked for detections as long as the array was deployed (four years). Further details on adult White Sturgeon detection during the CLBMON-21 program can be found in Golder (2008; Golder 2009).

3.0 Results

3.1 Physical Habitat Parameters

3.1.1 Discharge and Reservoir Elevations

Mean daily discharge levels (cubic meters per second; m^3/s) recorded at REV showed different trends when grouped before the REV5 flow regime change (Years 1 to 4; 2007 to 2010; pre-flow regime change) and after the flow regime change (beginning Year 5 – 2011; post-flow regime change). During the pre-flow regime change, mean daily discharge averages from REV ranged from 450 to 1050 m^3/s, with longer periods of lower discharge, (corresponding to reduced power demand) in July and August (Figure 3). Pre-flow regime change, during the White Sturgeon spawning period (late July to early August), REV operations experienced variable mean daily discharge averages between 500 and 900 m^3/s. During the post-flow regime change, mean daily discharge averages from REV ranged from 600 and 1100 m^3/s (Figure 3). Post-flow regime change, during the White Sturgeon spawning period, REV operations experienced variable mean daily discharge averages between 730 and 980 m^3/s, which were similar to pre-flow regime change daily mean discharges. Juvenile sturgeon were generally captured in mid- to late September when mean daily discharge averages were less variable and similar between pre- and post-flow regime changes.

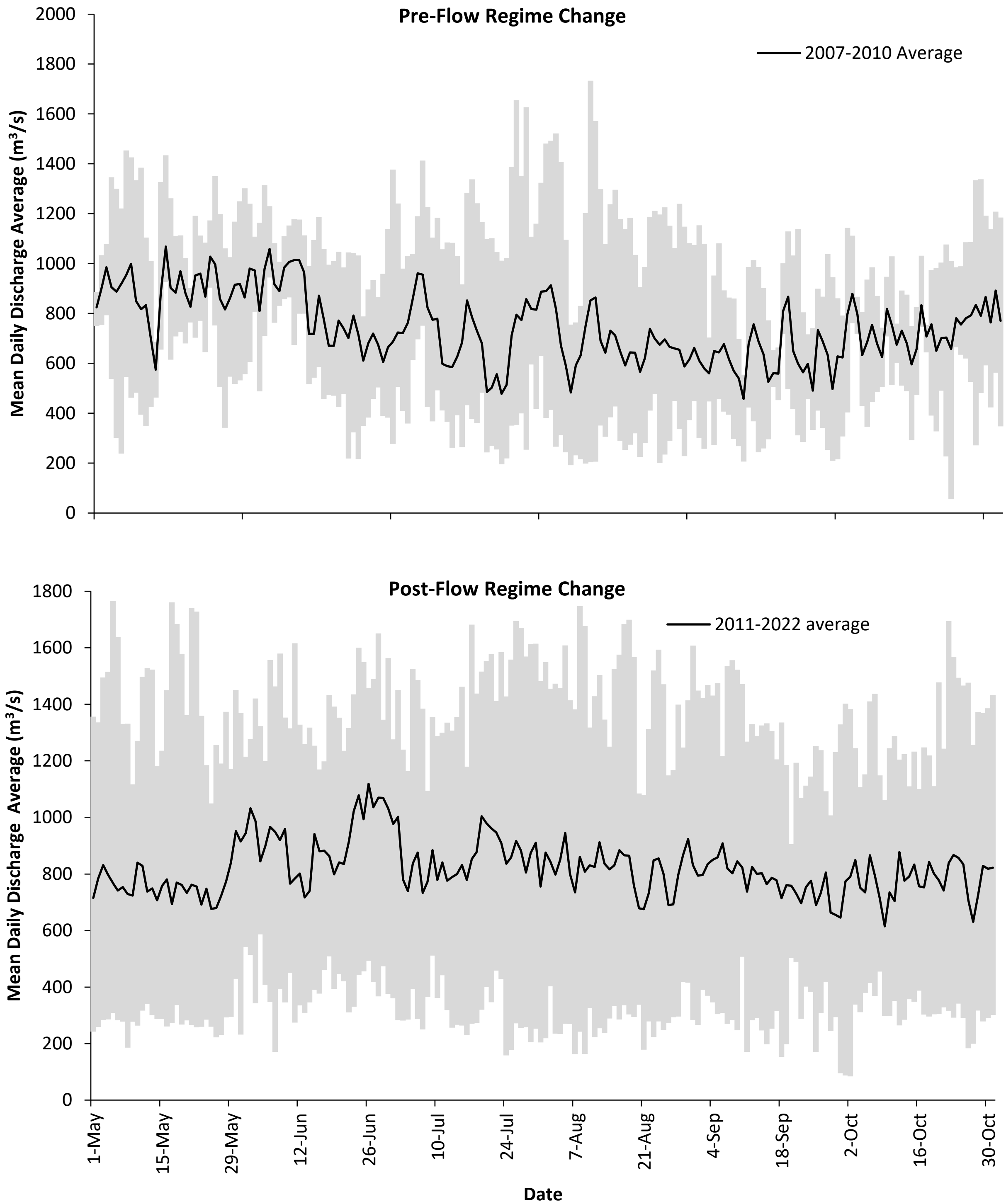

Figure 3. Revelstoke Dam daily discharge average (mean ± min and max average data) during the CLBMON-21 study period before the implementation of flow regime change (2007 to 2010; top graph) and after the implementation of flow regime change (2011 to 2022; bottom graph). Unpublished data from BC Hydro.

ALR water surface elevations (meters above sea level, masl) from 2007 to 2022 during the May to October study period varied greatly in regards to summer peaks and fall reductions (Figure 4). Reservoir elevations peak between early June to early August and, over the program study years, were highest from Jul 04 – Aug 01 2012 (440.6 masl peak on Jul 22 2012). Reservoir elevations then experience reductions, but do not generally bottom out until after the study period ends in October.

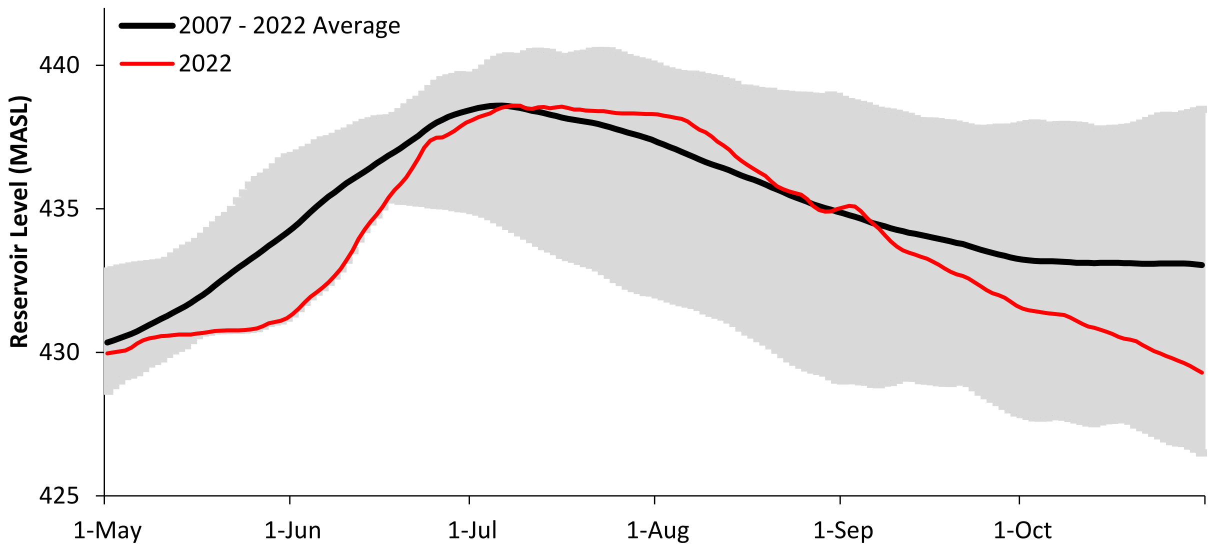

Figure 4. Reservoir elevation (masl) of the Arrow Lakes Reservoir at Nakusp BC from May 01 to Oct 31 for the 2007 to 2022 CLBMON-21 study periods, excluding 2019 as it was unavailable. Greyed area shows the variability of the data over all study years. Hydrometric data from the Government of Canada Water Office website.

3.1.1.1 Reservoir Elevations during Movement Studies

The peak reservoir elevation for Years 1 to 4 (2007 to 2010) ranged from 437.0 to 439.8 masl during the dispersal and general movement study, while the peak reservoir elevation during the fine-scale movement study in Year 6 (2012) reached a high of 440.5 masl.

In 2012, reservoir elevation in ALR (measured at the BC Hydro gauge at Nakusp BC) were near average from January to the end of May, increased to above the 10 year maximum in July and August, and were slightly above average during the fall (Figure 5). This general pattern was similar to that observed in past study years (2007 to 2010), except that during 2012, the peak reservoir elevation was higher. During the 2012 filling period, ALR levels increased by approximately 10 m from mid-May (430.3 masl) to early July (440.5 masl) and then declined approximately 6 m from late July to early October.

Over the study period, maximum measured depths in the thalweg area were typically > 10 m (range between approximately 8 to 21 m; Figure 5). Maximum depths in the floodplain area over the same period were typically 5 to 10 m (range between approximately 1 and 16 m) and maximum depths in the shallows area were typically < 5 m (range between approximately 1 and 11 m).

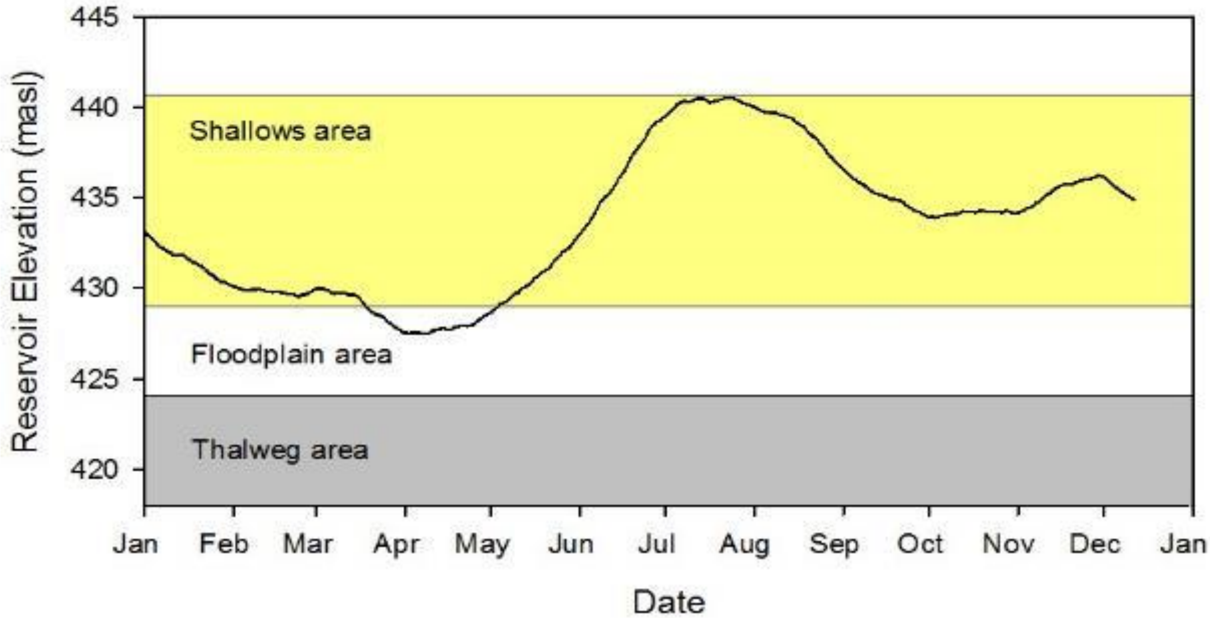

Figure 5. Mean 2012 daily water elevation (masl) of the Arrow Lakes Reservoir, and the resultant depths at the three habitat classifications (thalweg, floodplain, shallows) available near the Walter Hardman Generation Station for the CLBMON-21 fine-scale movement study. Graph from Golder and ONA (2013).

3.1.2 Water Temperatures

As warming temperatures have been observed to correlate to increased sturgeon movements (this study), the effect of the REV5 flow regime changes on the downstream water temperatures and monitored temperatures in the ALR was reviewed. Main daily water temperatures over the May 01 to Oct 30 period were calculated separately for the pre-flow regime change (2007 to 2010) and post-flow regime change (2011 to 2022;

Figure 6). In general, both periods had similar water temperature patterns with increases during the summer months. Temperature peaks were evident in 2009, 2010, and 2016, which may be attributed to either reductions in ALR levels, or changes in the water layer REV intakes are drawing from (i.e., epilimnion, metalimnion, hypolimnion).

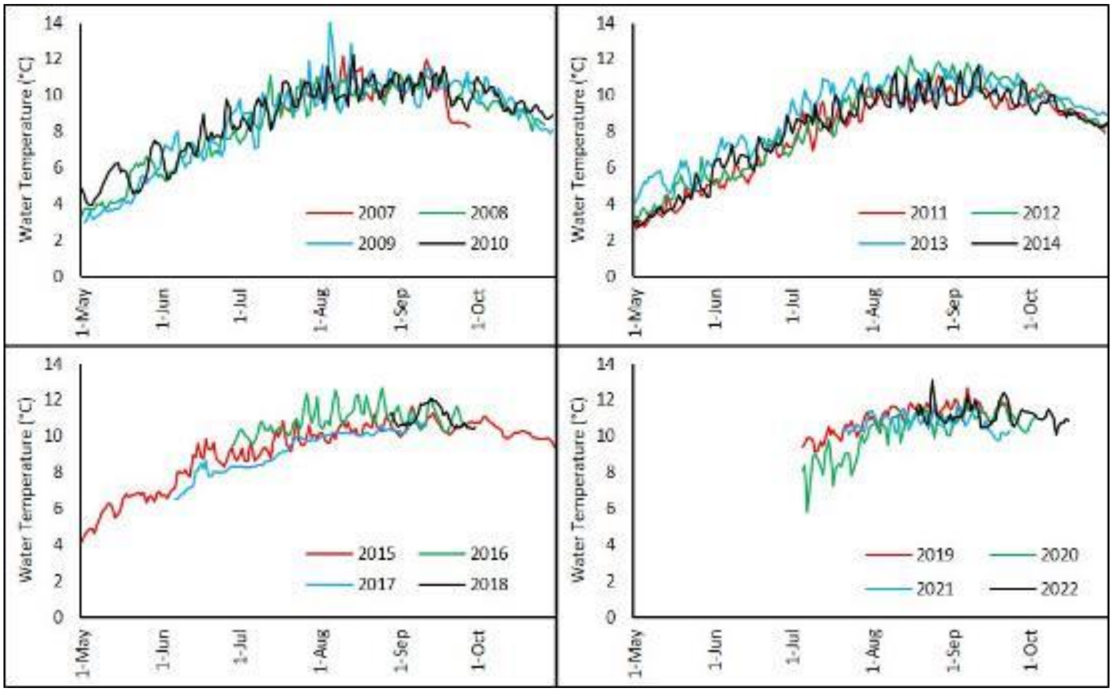

Figure 6. Revelstoke Reach average daily water temperature during the CLBMON-21 study period before the implementation of flow regime change (2007 to 2010; top left graph) and after the implementation of flow regime change (2011 to 2022; top right and bottom graphs). Data for 2007 and 2009 to 2014 are from Station 6 (CLBMON-15), data for 2008 are from Station 5 (CLBMON-15a), data for 2015 are from Station 3 (BC Hydro unpublished data), data for 2016 to 2018 are from portable thermistors moored seasonally downstream from Greenslide Creek, data for 2019, 2021, and 2022 are from temperature tid-bit loggers installed seasonally downstream from Greenslide Creek, and data from 2020 are from a temperature tid-bit logger installed seasonally at Arrowhead Flats.

In 2018, moored temperature thermistors programmed to record hourly were deployed at two locations within the ALR at an average water depth of 10.8 m. Loggers were deployed on Aug 28 2018 and retrieved on Sep 30 2018 (Figure 7). Water temperatures ranged from 10 – 12.5 °C at Greenslide Creek and from 8.5 – 12.9 °C at Shelter Bay. Temperature oscillation patterns were evident at both stations – in a previous ALR limnology study, Pieters et al. (1998) observed similar temperature oscillations, even at depths of over 30 m. Pieters et al. (1998) suggested that large windstorms create patterns of 'internal seiche': lower density warmer water being pushed to one side by the wind combined with the Coriolis effect, starting a 'rocking' of the water layers back and forth as the system tries to equilibrate.

Shorter term variations in temperature over a few hours were also recorded, potentially indicating that flow through the reservoir is turbulent. These variations are likely associated with changes in weather patterns and variations in the passage through the system (Pieters et al. 1998). As water temperature can have a strong influence on sturgeon movement, these temperature swings may affect sturgeon movement behaviour in the reservoir in shallow areas (< 30 m depth).

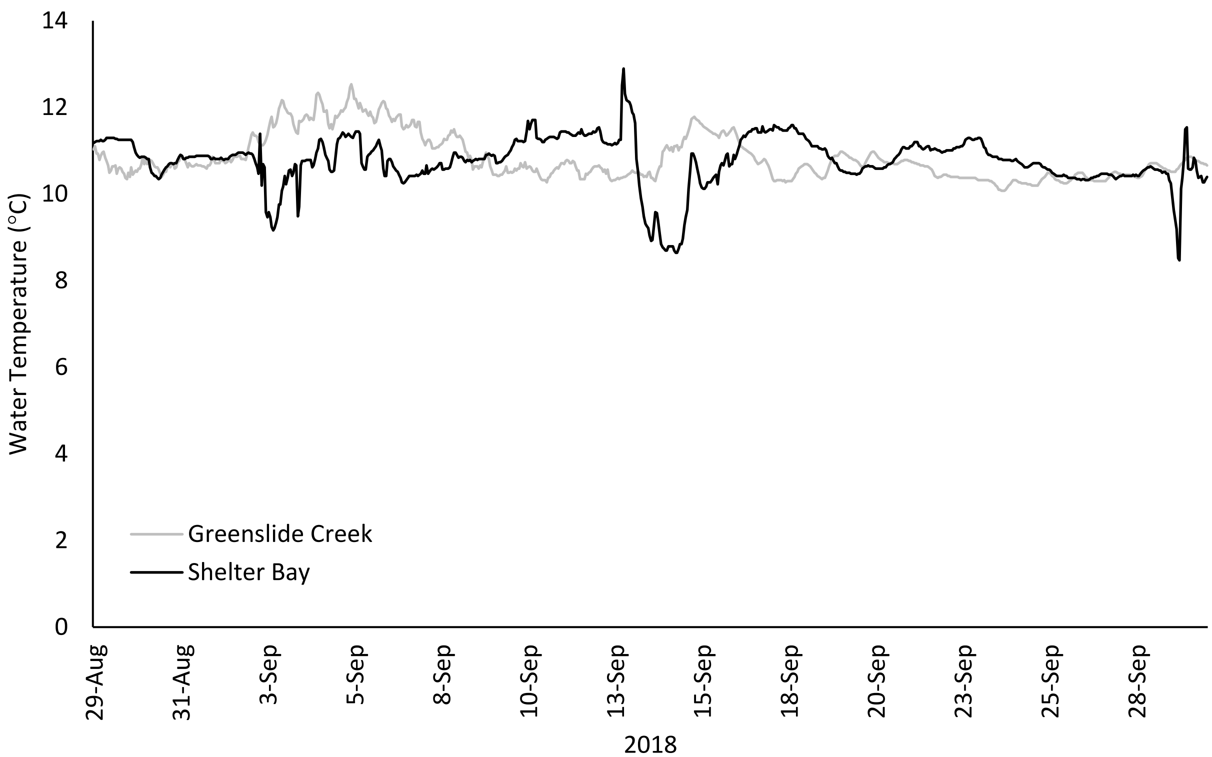

Figure 7. Greenslide Creek and Shelter Bay average water temperature during the CLBMON-21 study period in 2018. Graph from ONA (2019).

3.1.3 Meso-Habitat Measurements

In general, surface water velocities in the study area were low (< 1 m/s) at all sites and sampling dates, but varied seasonally, with the highest velocities during August. Bottom water velocities at the meso-habitat measurement stations associated with the gear that captured juvenile White Sturgeon ranged from 0.0 to 1.0 m/s (Golder 2010). Habitat conditions at juvenile sturgeon capture locations were similar throughout the years, and averaged a water depth of 12.2 m and water temperature of 10.8 °C. A summary of meso-habitat conditions taken at sturgeon capture locations can be found in Appendix B.

Turbidity was typically low (≤ 3 NTU) at all sites except during the one July sampling session (6 NTU) when ALR elevations rose and inundated the exposed shallower sections with predominantly silt-sand substrates (Figure 8Figure 8). Secchi depths (ranged from 2.1 to 5.1 m) supported the general seasonal pattern of water clarity as indicated by the turbidity data.

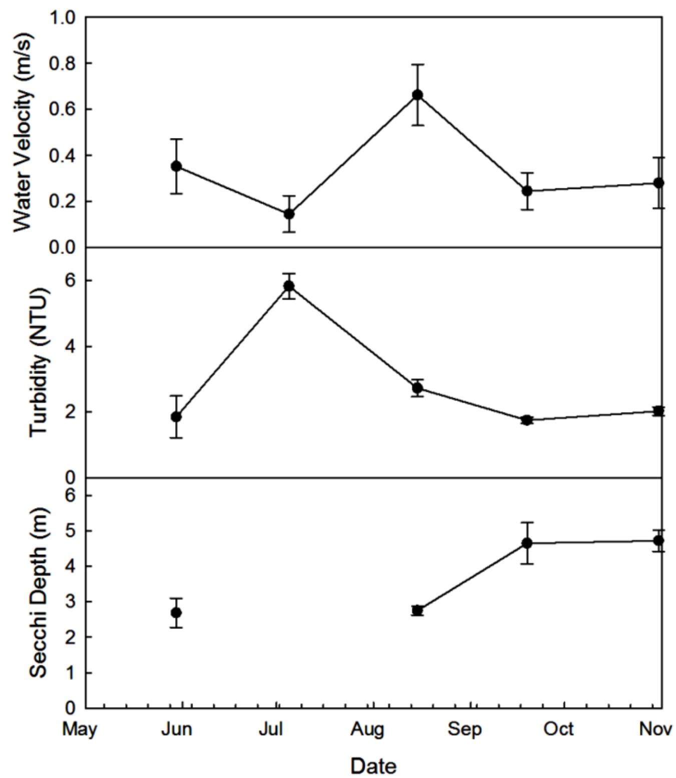

Figure 8. Physical habitat variables measured at four locations within the Middle Columbia River CPS study area at approximately monthly intervals between May 30 and Oct 30 2012. Black dots represent the mean values and horizontal bars are standard deviations. Graph from Golder and ONA (2013).

3.2 Juvenile Sturgeon Releases

An important aspect of the CLBMON-21 program has been to evaluate juvenile growth and survival after release from the hatchery, as well as describe the availability and suitability of habitat for juvenile White Sturgeon in the ALR. These data gaps have been investigated through monitoring of juveniles following release using acoustic telemetry or by direct capture.

3.2.1 Larval Releases

Under a different program (CLBWORKS-24) the BC Hydro WUP required the release of larval White Sturgeon (under 60 days old) into the upper Revelstoke Reach (Table 10). From 2008 to 2009, larval White Sturgeon were to either a stage just before hatchery feeding would commence (unfed larvae), or after a few weeks of feeding had occurred (fed larvae; FFSBC 2011). These larvae were released at the confluence of the Jordan River and the Columbia River.

In 2010, larval releases also occurred as part of an experiment to assess the effects of substrate modifications in the White Sturgeon spawning area below REV on larval retention and growth (Table 10). One day old unfed larvae were raised at the KTSH then transported to the MCR for release over modified (clean coarse materials placed on the river bottom) and unmodified (natural riverbed) substrates (Crossman and Hildebrand 2014).

Table 10. Summary of unfed and fed larvae from the Kootenay Trout and Sturgeon Hatchery and release locations in the Middle Columbia River.

Study Year	Date of Release	Release Location	River Kilometer	No. Juvenile Sturgeon Released	Larval Stage	Number of Families
2008	4-Jul	Jordon River mouth	229	335,631	unfed	2
	25-Jul	Jordon River mouth	229	283,848	fed	
2009	5-Jul	Jordon River mouth	229	180,000	unfed	1
	8-Aug	Jordon River mouth	229	80,000	fed	
2010	3-Jul	Revelstoke Spawning Area - Control Site (first release)	228.5	168,135	unfed	6
	3-Jul	Revelstoke Spawning Area - Control Site (second release)	228.5	168,135	unfed	
	@	Centennial Park	225.2	155,000	fed	
		Total Released		**1,370,749**		

Results from this study demonstrated that modifications to embedded substrates at known White Sturgeon spawning locations can enhance conditions required for hiding at the yolk sac larvae stage (Crossman and Hildebrand 2014). Fed larvae also were released in 2010 at the Centennial Park boat launch in the Revelstoke town site (Table 10).

All of the ~1.3 million larvae released in the MCR were unmarked. No unmarked juveniles have been captured during the sampling program.

3.2.2 Juvenile Releases

In total, 63,358 juvenile PIT-tagged juvenile White Sturgeon have been released into the MCR from 2007 to 2022 (Table 11). The number of juveniles released annually between REV and Shelter Bay has varied between 244 and 9,575 individuals. Between 2007 and 2012, the annual releases included 50 acoustic-tagged fish (250 fish in total; Table 12).

Table 11. Summary of PIT-tagged juvenile White Sturgeon including origin, release date, location, number released, and average length (mm) and weight (g). Acoustically-tagged individuals not included.

Stock / Release Year	Year Class	Origin of Juveniles	Hatchery Growth Release Target	Release Date	Release Location	River Kilo-metre	No. Juvenile Sturgeon Released	Average length (mm)	Average weight (g)
2007	2006	Hatchery	1	3-May	Moses Creek- Day	233.0	1,884	19.9	59
					Moses Creek- Night	233.0	2,172		
2008	2007	Hatchery	1	29-Apr	Big Eddy	228.3	5,884	20.0	61
					Centennial Launch	225.8	600		
2009	2008	Hatchery	1	23-Apr	Big Eddy	228.3	7,518	20.8	67
					Centennial Launch	225.8	600		
2010	2009	Hatchery	1	23-Apr	Big Eddy	228.3	9,175	21.6	81
					Centennial Launch	225.8	400		
2011	2010	Hatchery	1	20-Apr	Shelter Bay	177.0	7,578	20.0	55
					Centennial Launch	225.8	500		
2012	2011	Hatchery	1	8-May	Shelter Bay	177.0	6,517	22.2	81
2013	2012	Hatchery	2	8-May	Shelter Bay	177.0	5,944	27.4	159
2014	2013	Hatchery	2	8-May	Shelter Bay	177.0	3,288	28.0	202
2015	2014	Hatchery	2	5-May	Shelter Bay	177.0	6,013	27.2	144
2016	2014	Wild	4	3-May	Shelter Bay	177.0	750	40.3	451
				5-May	Shelter Bay	177.0	575	39.6	442
2017	2015	Wild	4	7-May	Shelter Bay	177.0	1,589	38.0	313
2018	2016	Wild	4	8-May	Shelter Bay	177.0	977	39.5	423
2019	2018	Wild	3	7-May	Shelter Bay	177.0	540	37.6	385.5
				8-Aug	Shelter Bay	117.0	183	36.0	327.5
2020	2019	Wild	4	6-May	Shelter Bay	117.0	212	35.3	329.9
				17-Jul	Shelter Bay	117.0	32	36.0	326.3
2021	2014	Wild	6	12-May	Shelter Bay	177.0	4	58	1100
	2019	Wild	5	12-May	Shelter Bay	177.0	1	49	896
	2019	Wild	5	12-May	Shelter Bay	177.0	2	42	404
	2020	Wild	4	12-May	Shelter Bay	177.0	278	40	385
2022	2021	Wild	4	18-May	Centennial Launch	231.0	15	37.5	368.1
	2021	Wild	4	18-May	Shelter Bay	177.0	104	43	612.1
	2021	Wild	4	6-Sep	Shelter Bay	177.0	172	39.8	461
			Total juvenile White Sturgeon released – all years				**63,358**		

Table 12. Summary of acoustic-tagged juvenile White Sturgeon origin, release date, release location, number of juveniles released and average length (mm) and weight (g).

Study Year	Origin of Juvenile	Date of Release	Release Location	RKm	No. Juvenile Sturgeon Released	Average Length (mm)	Average Weight (g)
2007	Hatchery	3-May	Moses Creek	233.0	50	31.0	211.0
2008	Hatchery	29-Apr	Big Eddy	228.3	50	31.6	229.2
2009	Hatchery	23-Apr	Big Eddy	228.3	10	35.1	280.9
			Begbie Creek	216.0	10		
			Mulvehill Creek	206.1	10		
			Tree Island	194.1	10		
			Arrowhead	184.0	10		
2010	Hatchery	22-Apr	Big Eddy	228.3	10	31.5	244.8
			Begbie Creek	216.0	10		
			Mulvehill Creek	206.1	10		
			Tree Island	194.1	10		
			Arrowhead	184.0	10		
2011	No acoustic-tagged juveniles released						
2012		15-May	Akolkolex/ Walter Hardman	203.0	50	32.0	250.0
Total acoustic-tagged juvenile White Sturgeon released – all years					**250**		

3.2.3 Size at Release

The release size of juvenile White Sturgeon has changed over the 16 years of the program. To observe the effects of size at release, five hatchery release target categories were released over the study period. Target release size categories for all fish released have yet to be finalized and results will be included in the 2023-2024 report.

Due to low recaptures of fish released into the MCR, it has been difficult to determine the effect of size at release on expected survival, excluding 2016 and later data. Four hatchery released juvenile White Sturgeon were captured in 2010, for a total of ten fish captured during the 2007 to 2010 study. Of note, four of the ten juveniles captured have been fish equipped with sonic tags at release. These fish were larger at release (230 – 390 g) compared to fish released without a sonic tag (40 – 120 g) and grew faster (15.18 ± 3.06 mm / year and 362 ± 292 g / year) compared to fish without sonic tags (9.08 ± 2.51 mm / year and 81 ± 57 g / year). This may suggest that size at release may influence survival in the MCR but requires further evaluation through capture efforts to confirm if more recent year classes, released at larger sizes, are surviving better.

3.3 Juvenile White Sturgeon Movements and General Habitat Use

At the onset of this program, a fine-scale telemetry study was implemented to track daily movements of acoustically-tagged juvenile White Sturgeon with the objective of investigating movement and habitat use. This study was divided into two components: a longer-range dispersal and general movement study (2007-2010), and a fine-scale telemetry study to track daily movements over three seasons at a section of river that was associated with high juvenile White Sturgeon detection (2011-2012). As well, mobile tracking for adult White Sturgeon with acoustic tags that were still active from a previous monitoring program were recorded in this program.

3.3.1 Passive Array Detection

Movements of acoustic-tagged juvenile White Sturgeon in the study area were continuously monitored by the CR2W linear array from May 2007 to November 2010 (see Golder 2011 for additional details). All 200 acoustic-tagged juvenile White Sturgeon released between REV between 2007 to 2010 were detected at least once by the array. In total, 3,106,943 detections have been recorded by the array since April 2007. Of these 1,965,248 detections were juvenile White Sturgeon, 48,795 were adult White Sturgeon, 1,091,771 were Burbot (tagged in 2009 and 2010 in the MCR as part of a separate study program, CLBMON-31), and 1,129 were considered false detections (i.e., noise). The approximately 2 million juvenile White Sturgeon detections were reduced down to 2,705 (as described in Golder 2011) for the statistical analyses of movement data. The percentage of false presence tag IDs (i.e., noise) recorded by the array was 0.04%, a very low frequency compared to detections accepted as valid.

The number of detections of acoustic-tagged juvenile White Sturgeon recorded in 2010 (450,955) was less than that recorded in 2009 (757,687), but more than in 2008 (402,279) and 2007 (354,327). The greater number of detections in 2009 was initially thought to result from the five release locations that year, compared to one release location in each of 2007 and 2008 (Golder 2010); however, other potential reasons may include natural variation of the much greater number of tagged Burbot detections in 2010 (1,048,307) compared to 2009 (43,464) that reduced the number of juvenile White Sturgeon tags that could successfully be coded out by the receivers.

3.3.2 Dispersal for Release Locations

Dispersal patterns of acoustic-tagged White Sturgeon were observed by comparing single release upstream locations that were used in 2007 and 2008 with multiple release locations (spaced approximately every 10 km) covering the entire Revelstoke Reach, used in 2009 and 2010. In April of 2008, 2009, and 2010, downstream dispersal was apparent at all stations (Golder 2011). In 2008, when all acoustic-tagged juveniles were released at Big Eddy, fish were detected as far downstream as Station 212.0 (near Greenslide Creek) within 2 days of release. A similar pattern was apparent in May 2007, when all acoustic-tagged juveniles were released at Moses Creek (RKm 233). These fish exhibited rapid downstream movement past the seven most upstream VR2W stations (Stations 232.3 to 212.0), then spent more time in the vicinity of the CR2W stations in the deeper, lower velocity habitats near Mulvehill Creek (RKm 207.4) and downstream. A similar pattern was observed in May 2008, as fish released in Big Eddy continued their downstream dispersal, and then began to spend more time near Mulvehill Creek and downstream areas.

In 2009 and 2010, acoustic-tagged juvenile White Sturgeon were released in groups of ten fish at approximately 10 km intervals in the MCR between Big Eddy and Arrowhead (Table 12). The general post-release dispersal pattern of acoustic-tagged juveniles released at the two most upstream locations (Big Eddy, RKm 228.3 and ear Begbie Creek, RKm 215) was characterized by rapid downstream movements through the riverine section of the MCR to deeper areas with lower water velocities (Golder 2011). These downstream movements were fastest and occurred over the longest distances for fish released at Big Eddy. After these initial movements, the speed and distance travelled decreased and fish generally spent longer periods of time in particular areas. These dispersal patterns (especially for fish released at Big Eddy) were similar to those of fish released at Big Eddy in 2009 (n – 10) and 2008 (n – 50) and upstream at Moses Creek (RKm 233) in 2007 (n = 50).

The dispersal patterns of fish released in 2010 at the three downstream locations (near Mulvehill Creek, RKm 206.1, Tree Island, RKm 194.1, and Arrowhead, RKm 184) were more variable (Golder 2011). A portion of these fish moved rapidly downstream shortly after release, while other remained in the vicinity of their release location. Several fish released at Arrowhead moved upstream within a few weeks of release.

Of the 50 sonic-tagged juveniles released in 2010, 13 (26%) were not detected after May 17 (24 days after release). These fish were represented by fish from each release location: Big Eddy (n = 2), near Begbie Creek (n = 3), near Mulvehill (n = 1), near Tree Island (n = 4), and Arrowhead (n = 3). This was a higher "early disappearance" rate than the eight (16%) sonic-tagged juveniles released in 2009, but less than the 17 (34%) released in 2008 and the 18 (36%) released in 2007 that were not detected after one month post-release (Golder 2010). The number of sonic-tagged juveniles not detected after one month post-release in 2009 was reduced because three fish that were not detected by the CR2W array after May 11 2009 were later detected between acoustic receiver locations during mobile tracking surveys. Many of the fish were last detected at the downstream end of the study area, located in the upper ALR.

3.3.3 Effect of Release Sites

There were significant differences in distances moved among release sites (Figure 9). Movements in April and May were generally downstream while there was a general tendency to move upstream after June, although sample sizes (number of detections of tagged fish) decreased, which resulted in greater uncertainty. The Begbie Creek release location (RKm 216) had individuals that were more likely to move upstream in the fall.

With the top ranked models (AICc weights >0.1), arrival time (day/night), year, REV discharge (Q), and ALR water surface elevation influenced the time spent on station (Table 13; Golder 2011). As there were considerable covariation in the variables month and ALR water surface elevation, the temporal component may contain changes in behaviour related to water levels or discharge. Time spent on site generally increased each month and varied by release site. All years were pooled for the selected model (Figure 10; Golder 2011). Average time spent on station in 2007 was significantly less than in the other years, so the data from fish released at Moses Creek (RKm 232.3) may not reflect site differences, but rather differences among years.

Overall, fish tended to move upstream more often and to stay longer on station during the course of the summer and into the fall. Fish released at RKm 216 tended to be more likely to move upstream and stay on site longer than fish released at other sites. Fish released at the most upstream and downstream sites would be biased to move downstream or upstream, respectively, because of the lack of receivers beyond these release locations (Golder 2011).

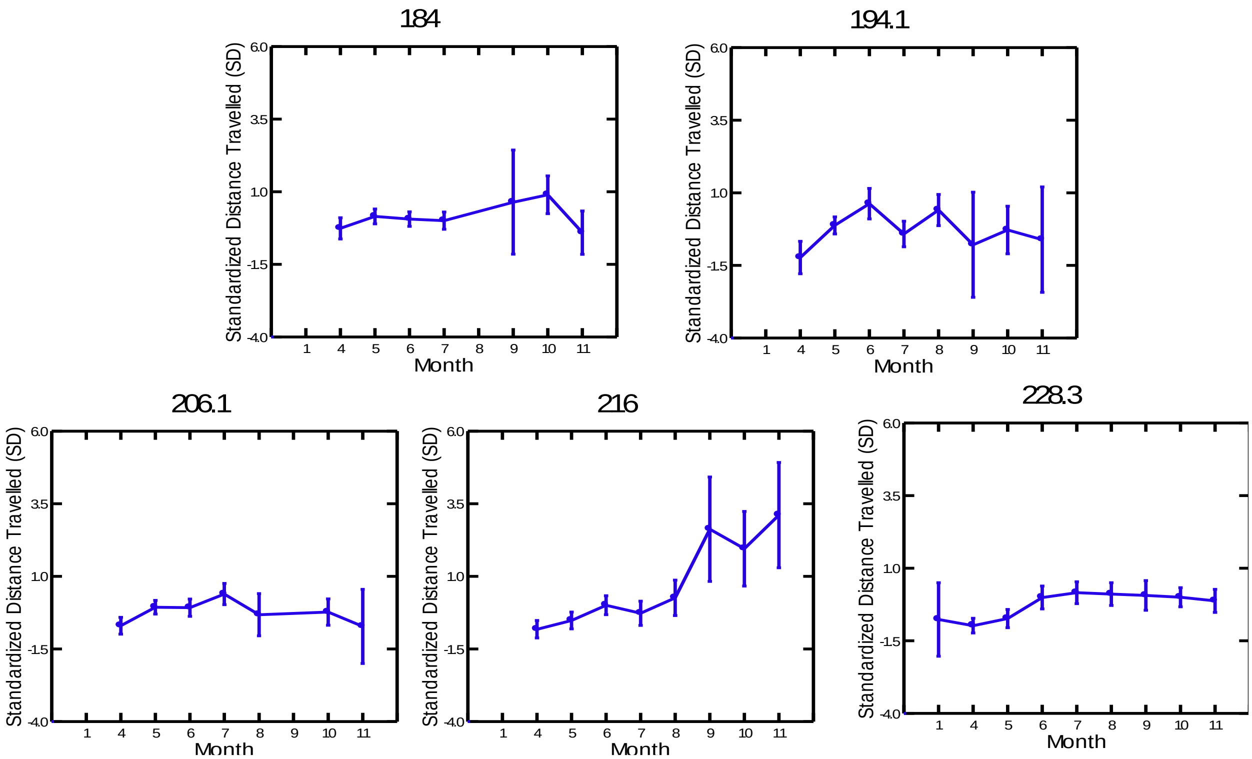

Figure 9. Least Square Means of the standardized distance travelled variable of the selected model of acoustic-tagged juvenile White Sturgeon in the middle Columbia River by month of detection for fish from the five release locations (River kilometre numbers at the top of each graph). Values reflect standardized net distances (positive = upstream movement; negative = downstream movement). The data are from the 2009 and 2010 study years combined. Error bars are SE of the least square means from the general linear model. Graph from Golder (2011).

Table 13. AICc ranking of candidate models for predicting Log of Time at Station after arrival of an acoustic-tagged juvenile White Sturgeon at a station in the MCR. Independent variables are categorical except for REV discharge and Arrow Lakes Reservoir water surface elevation. Table from Golder (2011).

Dependent Variable	Multiple R^2	AIC_c Weight	AIC_c	Independent Variables						
				Release Site	Year	Month	Month x Release Site	Daylight (Day/ Night)	ALR Water Surface Elevation	REV Discharge
Log Time at Station	**0.2**	**0.294**	**4965.268**	**x**		**x**	**x**			
	0.202	0.241	4965.663	x		x	x		x	
	0.201	0.171	4966.352	x		x	x	x		
	0.201	0.11	4967.236	x		x	x			x
	0.2	0.102	4967.387	x	x	x	x			
	0.202	0.082	4967.809	x		x	x	x		x
	0.12	>0.001	5010.165	x		x				
	0.122	>0.001	5011.163	x		x		x		x
	0.121	>0.001	5011.171	x		x				x
	0.121	>0.001	5011.199	x		x		x		
	0.123	>0.001	5013.156	x	x	x		x		x
	0.131	>0.001	5041.358	x			x			

Although the trends described are statistically significant, the overall selected models explained only a small amount of the variability observed (R2 ~ 0.2; Golder 2011). Other variables examined for effect on juvenile White Sturgeon movements included: solar radiation (day/night), REV hourly discharge, and ALR water surface elevations. Although there were some slight statistical significance to these parameters (ALR water surface elevations was the strongest), the relationship was confounded by the temporal correlation with fish growth and explained very little of the variability observed in movement patterns. Although thousands of relocations were observed at the various stations, the bulk of the data was from a small number of individuals.

In addition, the dependent variable used (the magnitude and direction of movements and time spent on station) do not have obvious biological interpretations, i.e., is less movement or upstream movement better than more frequent movement or downstream movement? A plausible interpretation is that the extended time spent on station indicated the presence of preferred habitat and food resources, whereas upstream or downstream movements could have indicated that the individual was required to more actively search for food. However, the influence of other factors (e.g., fish in poor condition tend to migrate less frequently) cannot be discounted.

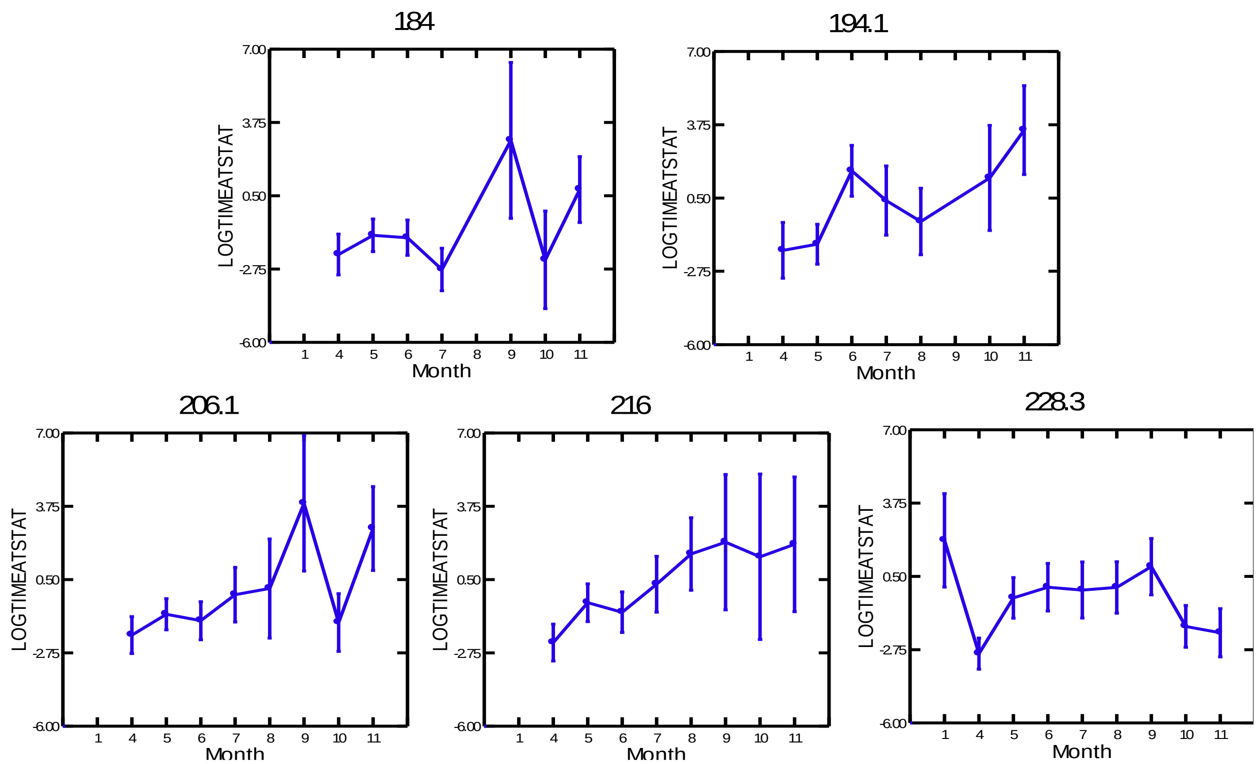

Figure 10. Least Square Means of the Log (Time at Station) by acoustic-tagged juvenile White Sturgeon in the middle Columbia River over each month (River kilometre numbers at the top of each graph). The data are from the 2009 and 2010 study years combined. Graph from Golder (2011).

3.3.4 Movements and Macro-Habitat Use

The number of tag days recorded at each VR2W station from 2007 to 2010 provided an indirect indication of rearing use of macro-habitats by juvenile White Sturgeon in the MCR. Macro-habitat in this context is defined as the sum of all meso- or micro-habitat types within the detection range of the station. The presence of a tagged juvenile White Sturgeon in the vicinity of the station, even if only transitory, was considered as a use of available habitats within that area. Insufficient data were collected on habitat parameters occupied by individual fish to categorize habitats on smaller spatial scales.

The mean net movement of sonic-tagged juvenile White Sturgeon, an indication of the length of river used (or the range of these fish), was similar in all four study years despite the differences in release patterns (Table 14). This suggests an active selection for deeper, lower velocity habitat and an apparent avoidance of higher velocity habitats in the MCR. The sonic-tagged juveniles remained within an approximate 21 to 26 km length of river/reservoir. The movement of one fish downstream of the VR2Ws in the Arrowhead Flats area was confirmed by its detection at the Narrows; however, undetected movements downstream of this area likely occurred, which could have resulted in an increase in net and total movements. Additionally, undetected movements within the study area could also have occurred.

Table 14. Mean net movement of acoustic-tagged juvenile White Sturgeon after released in the Middle Columbia River, 2007 to 2010.

Year	Mean net movement (km)	Range (km)	S.D.	Number of detections (±SD)
2007	23.9	0 - 52.3	16.2	7,087 (± 23,133)
2008	25.7	0 – 48.3	15.3	8,046 (± 11,455)
2009	21.4	2.6 – 68.3	14.1	15,154 (± 21,361)
2010	21.7	0 - 104	18.2	9,019 (± 19,552)

The average total distance moved by acoustic-tagged juvenile White Sturgeon varied between 2007 and 2010 but was highest in 2008 (49.1 km; Table 15). Mean total movements were lowest in 2009, which may be related to the low ALR elevations in 2009 (compared to 2007-08 and 2010). The statistical analysis of movements determined that ALR water surface elevations were a significant variable that affected net movement.

Table 15. Mean total movement of acoustic-tagged juvenile White Sturgeon after released in the middle Columbia River, 2007 to 2010.

Year	Mean Total Movement (km)	Range (km)	S.D.	Number of detections (±SD)
2007	44.1	0 – 214.3	46.5	7,087 (± 23,133)
2008	49.1	0 – 237.1	49.6	8,046 (± 11,455)
2009	37.9	2.6 – 136.0	30.3	15,154 (± 21,361)
2010	47.1	0 – 296.1	57.5	9,019 (± 19,552)

On average, the 50 acoustic-tagged juveniles released in 2010 moved approximately twice as far downstream (31 km) as upstream (16 km). Seven fish were detected more than 1.3 km upstream of their release location. One fish was detected at the Narrows (RKm 112; 68 km downstream of Arrowhead Flats and 104 km downstream of its release location), which is out of the study area. Eighteen juveniles did not exhibit any upstream movement, although nine of these fish were not detected after May 9, 2010 (18 days after their release).

Habitat use was higher at the lower end of the Robson Reach (Arrowhead Flats / Tree Island areas; RKm 180-195) in Spring (June) in years that water elevations were low (2009 and 2010). In years that spring water elevations were high (2007 and 2008), habitat use was higher further north near Mulvehill Creek (RKm 207.4) and the Akolkolex River / Blanket Creek areas (RKm 200-203.5). Similarly, use of the Tree Island area (RKm 195) was higher in summer (July/August) 2009 and 2010 when water levels remained low.

From 2007 to 2010, the stations where the highest use (measured as tag days on site) by sonic-tagged juvenile White Sturgeon was recorded were located between Station 212.0 (upstream of Greenslide Creek) and Station 195.0 (Tree Island area; 56% of total tag days), and the Arrowhead Flats area (RKm 180; 14% of total tag days; Figure 11Figure 11). High use of the area between Stations 212.0 and 195.0 occurred during all study years (63% of total tag days in 2007, 71% in 2008, 43% in 2009, and 51% in 2010; Golder 2011). The multiple release locations in 2009 and 2010 resulted in lower overall use (47%) of this area than the single upstream release locations used in 2007 and 2008 (68%).

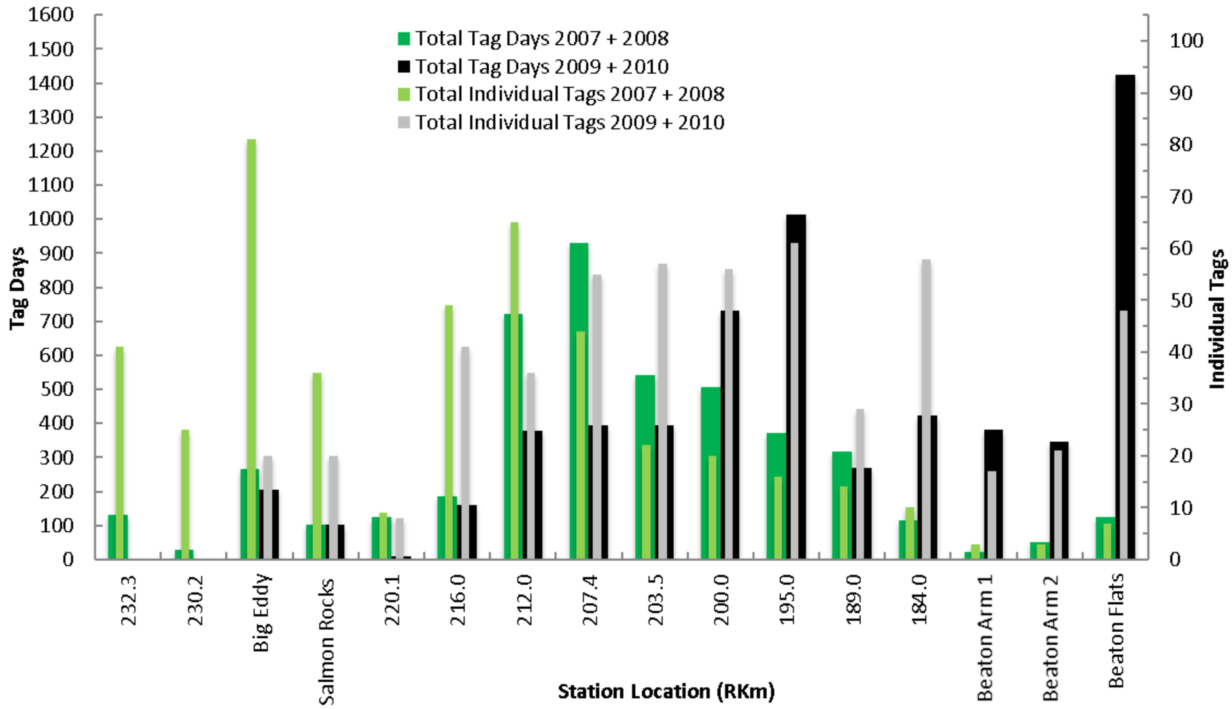

Figure 11. Total tag days and total individual tags recorded of acoustic-tagged juvenile White Sturgeon movements in the middle Columbia River for 2007 and 2008 fish (single release location at RKm 233) and 2009 and 2010 fish grouped (5 release locations spread from Big Eddy to RKm 184) recorded in the middle Columbia River, 2007 to 2010. Graph from Golder (2011); Arrowhead Flats referred to as Beaton Flats.

The highest overall use occurred at Arrowhead Flats (14% of total tag days; Figure 11). This was due to a greater use of this area in 2009 and 2010 (23%) than in 2007 and 2008 (3%; Golder 2011). Use of the areas from Blanket Creek (Station 203.5) upstream was greater in 2007 and 2008 (67%), whereas use of the areas from the Akolkolex River (Station 200.0) downstream was greater in 2009 and 2010 (74%).

The macro-habitat conditions in the areas where the most tag days were recorded were similar in terms of depth, velocity, and substrate (Golder 2011). These areas were characterized by depths in excess of 10 m (and often 15 m), water velocities of less than 0.5 m/s, and substrates composed mainly of fines. These areas exhibited more lentic conditions for longer periods, as opposed to upstream areas that exhibited lotic conditions for longer periods of the year.

3.3.5 Movement Out of Study Area/Post-release Mortality

In 2007, five acoustic-tagged juvenile White Sturgeon moved steadily downstream after release, apparently past the Arrowhead Flats stations and out of the study area. In 2008, four acoustic-tagged fish exhibited the same movement pattern (Golder 2009). The detection of eight acoustic-tagged juveniles downstream of the Arrowhead Flats VR2W stations during mobile tracking in 2009 provided further verification that some hatchery-released juveniles move beyond the study area. In 2010, 30 tags were last located in either Arrowhead or Arrowhead Flats receiver stations at the downstream end of the Revelstoke Reach over the study period. The size and depth of ALR downstream of the study area (approximately 180 km long) presents substantial logistical difficulties in terms of monitoring juvenile White Sturgeon and their use of the reservoir.

The fate of acoustic-tagged juveniles remains unknown. Results from 2009 suggested that a portion of tag "disappearance" is due to fish moving downstream beyond coverage of the VR2W array. In 2007 and 2008, the relatively high proportion of tags that were not detected beyond one month post-release (36% and 34%, respectively) suggested potential post-release mortality (Golder 2009), though high ALR levels in 2008 could have allowed fish more river width to move undetected past the receiver array stations. However, this proportion was substantially lower in 2009 (16%), due in part to mobile tracking surveys that located three acoustic-tagged juveniles that had not been detected by the VR2W array for approximately 5 to 7 months. The four potential reasons for the disappearance of some tags shortly after release are:

1. Movement out of the study area (outside range of acoustic receivers).
2. The fish remain in portions of the study area that are out of all acoustic receiver station's detection range (for example, one tag was located by mobile tracking after disappearing from station data).
3. Post-release mortality (for example, fish dies in between stations or at stations and tag does not move any further for the year).
4. Occasional equipment malfunction or battery failure that may be responsible for tags disappearing, which is impossible to confirm without relocating tag.

It is possible that tag "disappearance" is due partly to all of these reasons. Additional VR2Ws were deployed in the Burton area (approximately 80 km downstream of the study area at a narrow point in ALR) in 2009. In 2010, one fish was identified at the Narrows station, but it was not possible to determine if this fish continued downstream or returned to ALR. Sampling in 2014 to 2017 was extended to the entire upper Arrow Lake basin. During these four years only one juvenile fish was captured in the ALR in a gillnet on the west shoreline at RKm 124.0 in June 2017 (Appendix C).

3.3.6 Diel Movement Analyses

Diel movements during Years 1 to 4 (2007 to 2010) were predominantly initiated during the periods of darkness from 21:00 until 06:00 (Figure 12). Downstream movements were more frequent than upstream movements (not illustrated), but both followed the same diel pattern. This pattern has been observed in each of the four years of the study (Golder 2008, 2009, 2010).

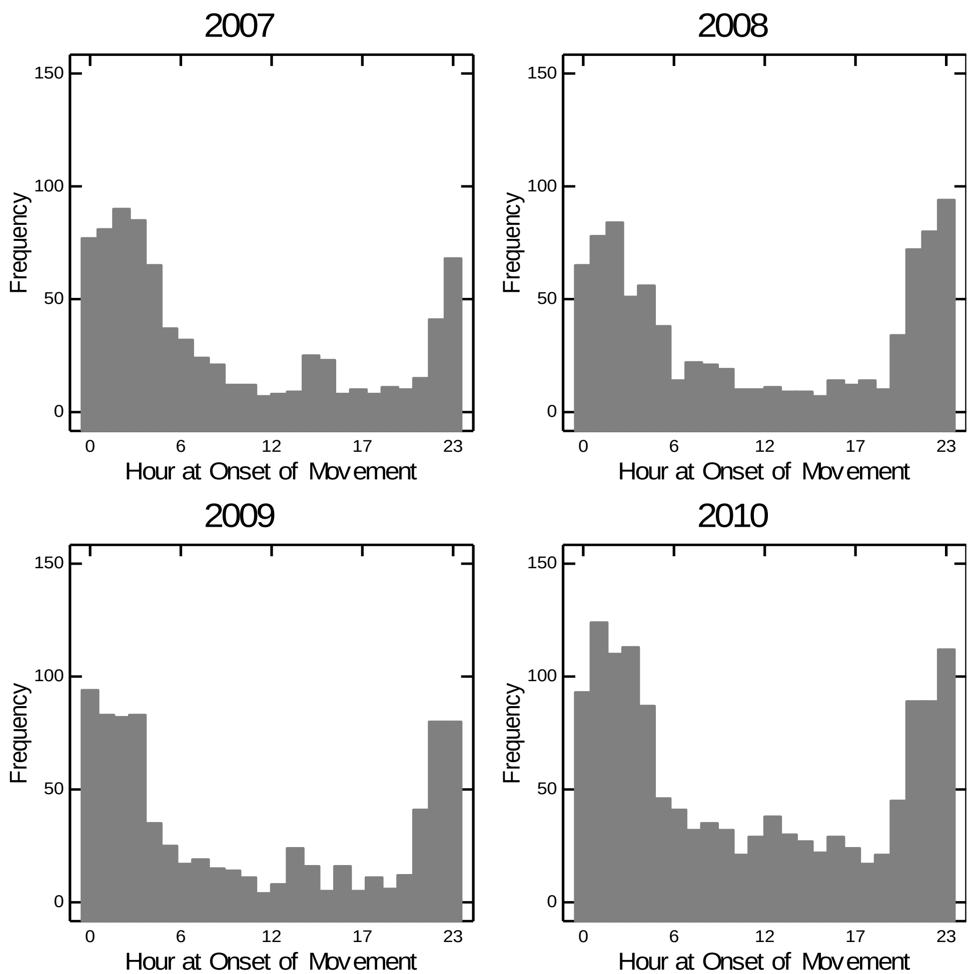

Figure 12. Frequency of the onset of movements by hour of the day (0 = midnight) of acoustic-tagged juvenile White Sturgeon in the Middle Columbia River, 2007 to 2010. Graph from Golder (2011).

Examination of the frequency distribution of light intensity [hourly diel solar radiation patterns (watts/m^2) measured at Revelstoke BC] at the onset of movements did not indicate any variability in movements during daylight as a result of light intensity (Golder 2011). Consequently, daylight was used as a binary variable (day/night) during subsequent analyses.

3.3.7 Revelstoke Dam Discharge

Annual hourly average discharge (Q in m^3/s) from REV between 2007 and 2010 was also examined as it was related to the hour at the onset of movement (Figure 13Figure 13; Golder 2011). The recorded flows at the onset of movements were less during 2010 and 2009 than 2008, and less in 2008 than 2007.

The REV discharge variable was positively related to downstream movement but was of minor significance. The results indicated that release site significantly affected movements, but only in the context of a particular month. The inclusion of an interactive term significantly improved the model but also was essential to evaluation of seasonal changes in behavior (Golder 2011).

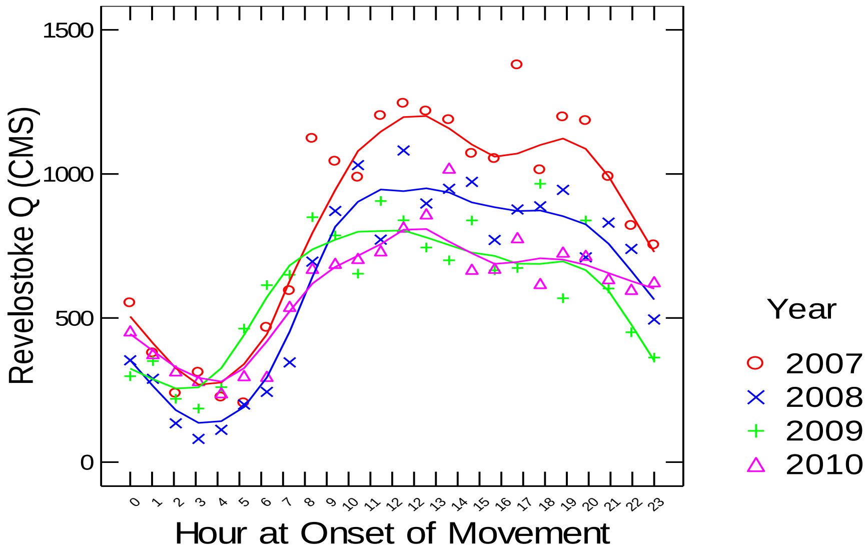

Figure 13. Annual hourly average discharge (m3/s) from Revelstoke Dam vs. hour of the day in the middle Columbia River, 2007 to 2010. Curve fitting the data is from LOWESS (tension = 0.25). Graph from Golder (2011).

3.3.8 Fine-scale Array Detection

In total, 202,186 tag positions were calculated based on data collected during study period (May 15 – Oct 30 2012). Out of the total dataset, 21% of the total number of tag positions had HPE ≤ 5, 60% had HPE ≤ 6, and 71% had HPE ≤ 7 (HPE defined in Section 2.4.9). In the restricted dataset (HPE ≤ 7) HPE values ranged from 2.5 to 7, with a mean of 5.3 and a median of 5.5. Once the first two weeks of data were removed to eliminate acclimation movements, the dataset included 128,601 tag positions estimated between May 29 and Oct 30 2012.

Sensitivity analyses indicated little difference between HPE cutoff values of 5 and 6 (Golder and ONA 2013). However with a HPE cutoff value of 7, a few cases emerged where estimated swimming speed was high (> 2 m/s), as to be expected with lower positioning accuracy.

Using HPE values as a 95% confidence interval for fish positioning (Section 2.4.9), only 3.1% of the fish assigned to the thalweg were less than the HPE distance from the nearest floodplain/thalweg contour line; i.e., the position's confidence interval overlapped the thalweg/floodplain contour line in 3.1% of the cases. Therefore, 96.9% of White Sturgeon positions were assigned to the thalweg stratum. Out of the fish positions assigned to the floodplain, 5.6% were less than the HPE distance from the shallows/floodplain contour line; therefore, 94.4% were assigned to the floodplain stratum. Out of the fish positions assigned to the shallow stratum, only 0.1% was less than the HPE distance from the shallows/floodplain contour line, and therefore, could have been in deeper water than estimated.

3.3.9 Fine-scale Movements

The data collected from the fine-scale array allowed analysis of movement patterns as related to daylight, habitat type, REV discharge effects at the study area, ALR elevation for 2012, and seasons. Half of the 50 acoustic-tagged juvenile White Sturgeon that were released into the vicinity of the VPS array on May 15 2012 were only recorded during the spring session and were absent from the VPS study area in the summer and fall. Of the remaining 25 juveniles that stayed within range of the VPS system for more than two weeks, 12 fish left before the beginning of the summer. Thirteen individuals were present in the area during the summer, and only five were recorded in the fall. Throughout the May 29 to Oct 30 2012 study period, juvenile White Sturgeon spent 0.03% to 25.3% of the time within the VPS array (mean = 4.8 ± 6.0%, median = 6.6%).

3.3.10 Meso-habitat Movements of RKm 203 to RKm 200

The fine-scale array allowed for detailed movement monitoring of tagged White Sturgeon within a high use habitat area of RKm 203 to RKm 200 near Walter Hardman Generation Station. Tag locations by time of day, season, and habitat depth classification (Figure 14) clearly showed that juvenile White Sturgeon were found in shallow and floodplain sites in summer and fall but rarely in spring. Minimum distances traveled between consecutive positions within the array were usually less than 100 m throughout the study period (mean ± SD = 5.4 ± 10.6 m, median = 2.3 m). In the summer, minimum traveled distances were slightly longer than in the spring, with more cases of 50 to 100 m distances traveled between tag locations (spring: mean ± SD = 3.8 ± 6.9 m, median = 2.4 m; summer: mean ± SD = 6.04 ± 11.2 m, median = 2.8 m).

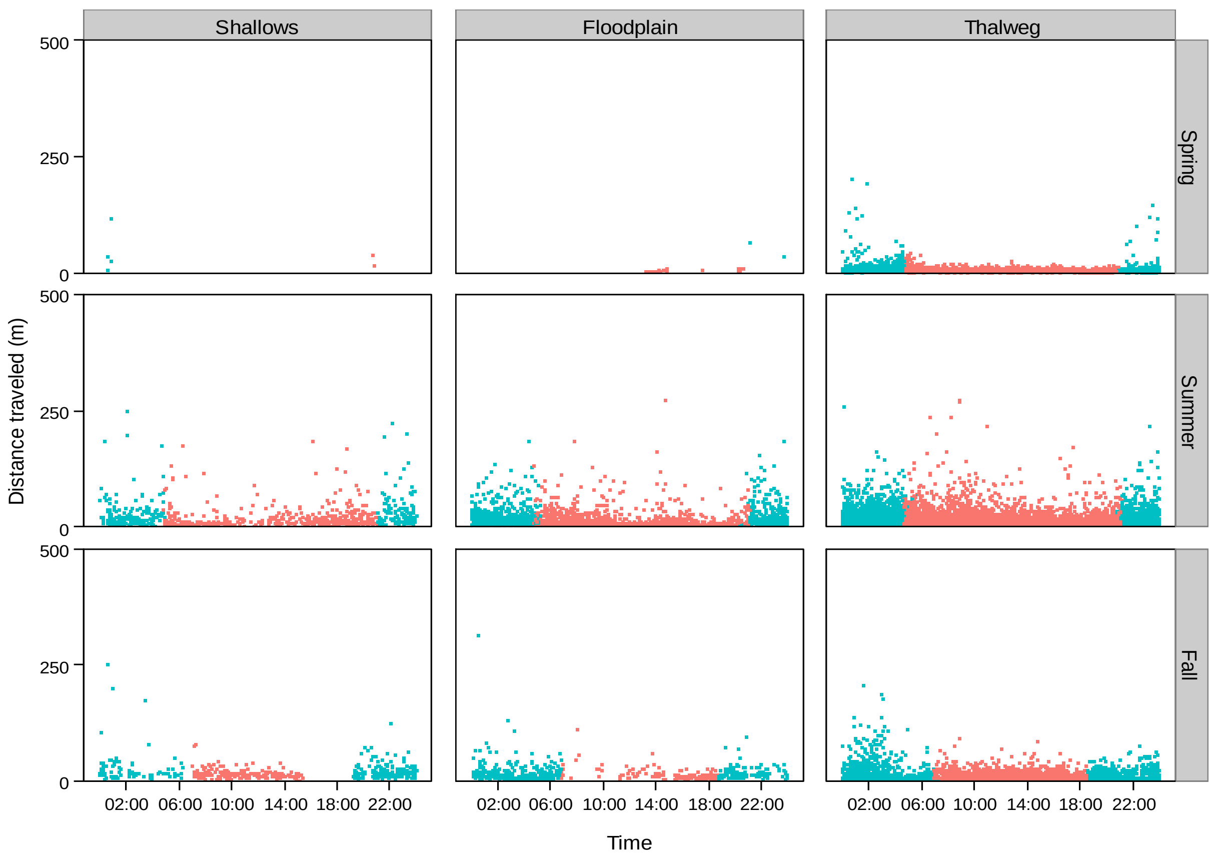

Figure 14. Minimum distance traveled between positions (m) of White Sturgeon juveniles in the VPS array, plotted by time of day, season, and habitat classification (thalweg, floodplain or shallows). Figure from Golder and ONA (2013).

Minimum movement speeds changed seasonally, with highest rates estimated in the summer, in comparison to spring and fall months (Table 16). Estimated minimum movement speeds were 0.02 ± 0.03 m/s (mean ± SD, median = 0.01 m/s) in spring time, 0.03 ± 0.06 m/s (mean ± SD, median = 0.02 m/s) in summer time, and 0.02 ± 0.05 m/s (mean ± SD, median = 0.01 m/s) in the fall. Movement speeds were similar between nighttime and daytime. For example, in fish located in the thalweg at night time, swimming speed was 0.02 ± 0.05 m/s (mean ± SD, median = 0.01 m/s), while daytime swimming speed was 0.02 ± 0.04 m/s (mean ± SD, median = 0.01 m/s).

Table 16. Summary statistics of minimum movement speed (m/s) of juvenile White Sturgeon, separated by day/night, season, and habitat type (thalweg, floodplain, shallows); values are means ± standard deviations. Table from Golder and ONA (2013).

Habitat Classification	Spring (m/s)	Summer (m/s)	Fall (m/s)
Thalweg	0.04 ± 0.1	0.09 ± 0.48	0.02 ± 0.05
Floodplain	0.08 ± 0.17	0.30 ± 0.99	0.09 ± 0.07
Shallows	0.11 ± 0.10	0.18 ± 0.35	0.1 ± 0.05

When examining fine-scale data, juvenile White Sturgeon used shallow water under all ALR elevations (Figure 15). The longest, most consistent movements traveled in the shallows were observed when the reservoir was emptying. In the thalweg, the majority of the traveled distances were typically short (25th, 50th, and 75th quantiles of 0, 0.9, 2.1, and 4.9 m; Golder and ONA 2013).

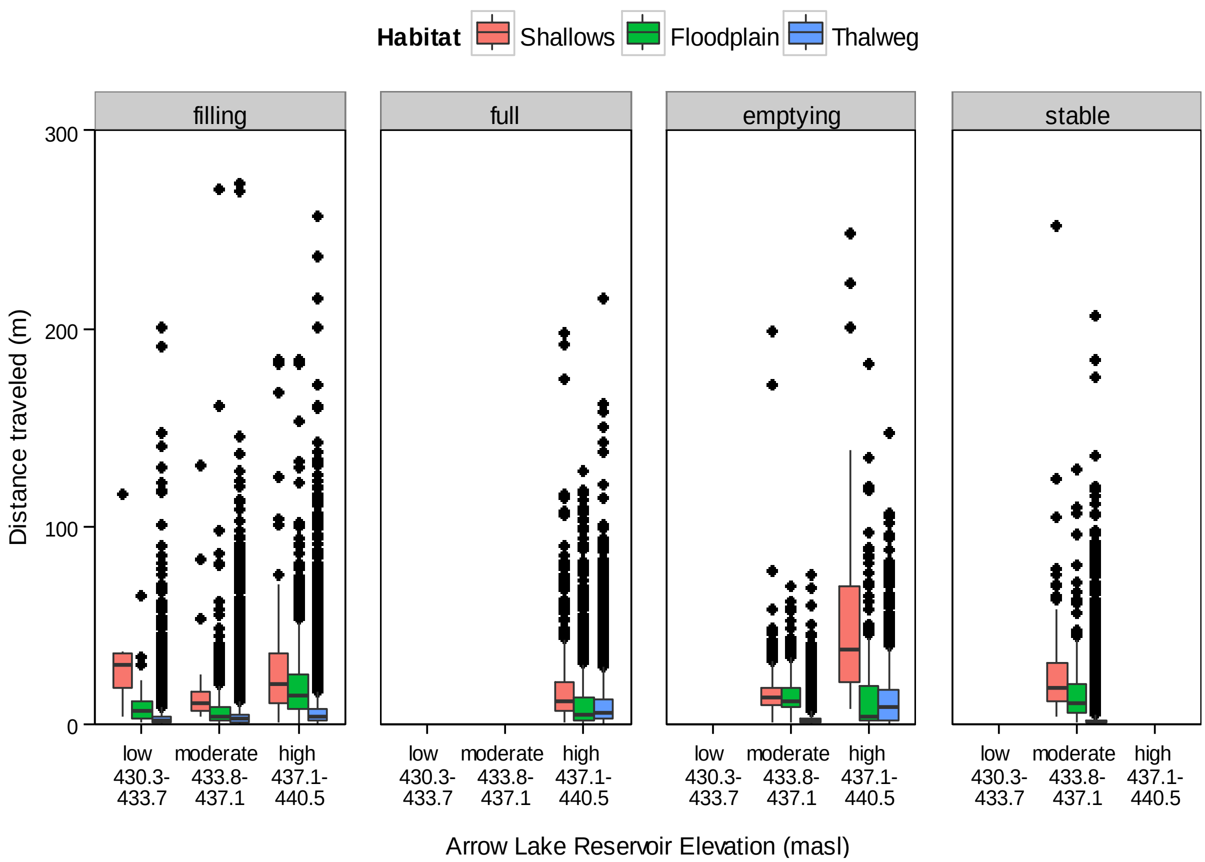

Figure 15. Minimum distance traveled between tag positions (m), separated by habitat classification (thalweg, floodplain or shallows), ALR elevation (low, moderate, and high), and ALR status (filling, full, emptying, and stable). Each box represents the 25th and 75th quantiles (bottom and top lines, respectively), and the median (middle, bold line); whiskers extend to 1.5 times the interquartile distance; outliers are shown as individual points. Figure from Golder and ONA (2013).

Seasonal differences in fish locations were apparent (Figure 16). During springtime, movements were usually restricted to the thalweg. In comparison, in summer and fall the fish took advantage of the increasing amount of habitat and were detected further from the thalweg. However, there was considerable individual variability in habitat use (described in Golder and ONA 2013). For example, in the summer, the White Sturgeon with tag numbers WSG34 and WSG38 remained in the thalweg, while WSG19, WSG23, WSG26, and WSG30 had wider distributions. In the fall, WSG01 and WSG41 utilized the shallows, while WSG25 and WSG30 remained in the thalweg.

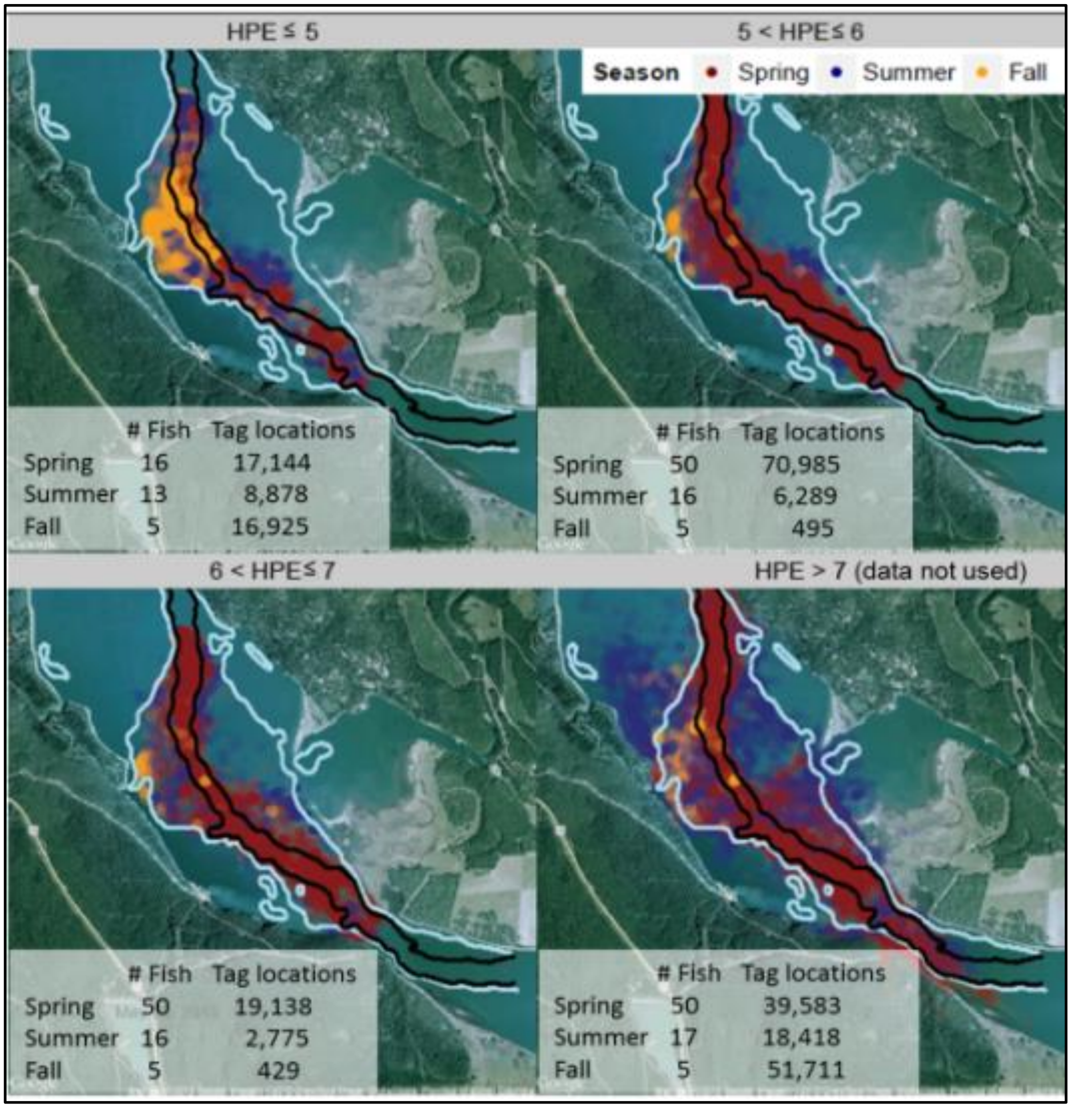

Figure 16. Positions of juvenile White Sturgeon within the VPS array. Panels show the positions included using various horizontal position cut-off (HPE) values. Point colour corresponds to season, and colour strength corresponds to use, with more solid colours representing heavier use. The thalweg is between the black lines, and floodplain is in between the black and light-blue lines. The number of fish and positions in each season within each HPE stratum are provided. Fish positions were plotted as partly transparent, to show differences between areas used rarely (transparent) and often (solid). Maps are based on Google Earth maps, taken Dec-31-2001, when ALR elevation at Nakusp was approximately 423 m. Only positions obtained from the third week post-release and onward are included. Figure from Golder and ONA (2013).

The extent of minimum daily movement (daily distance traveled by individual fish) varied by season and habitat type (Figure 17). In the spring, the majority of the recorded daily movement was less than 2 km, and 11 out of the 13 recorded fish remained in the thalweg. In the summer, the extent of fish movements increased, with daily movements up to 5 km; similar numbers of fish were recorded in the thalweg and the floodplain area, and 12 fish were recorded in the shallows, where they moved up to 2.5 km per day. In the fall, the patterns of movement appeared to be similar to those in the spring, although direct comparison was difficult due to the quickly decreasing sample size over time (only five juveniles were recorded in the thalweg in the fall).

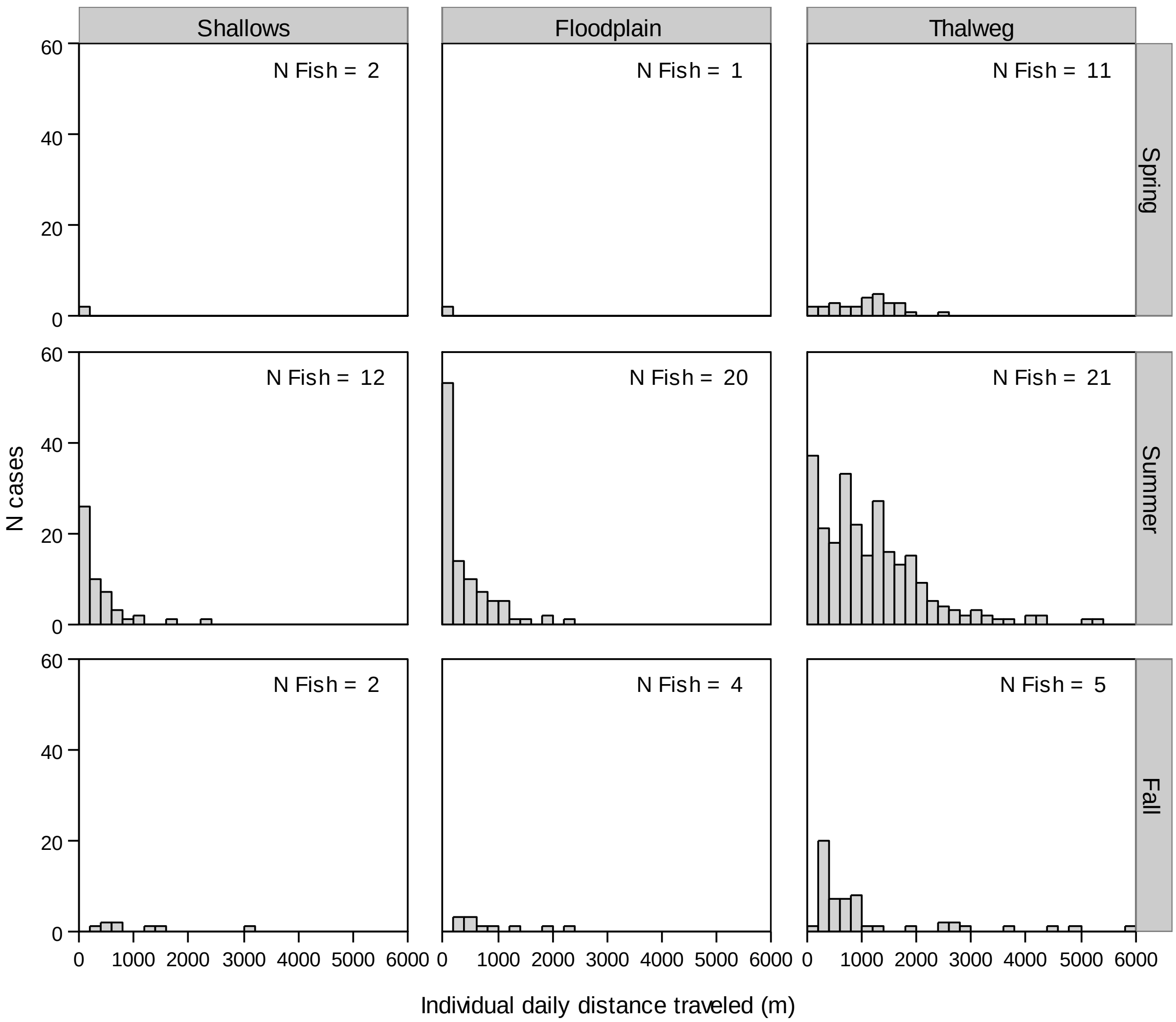

Figure 17. Histogram of minimum daily distances traveled by individual juvenile White Sturgeon, by season and habitat classification. (shallows, floodplain or thalweg). The number of fish (N cases) within each stratum is provided; plots include only positions that were at most 0.5 h apart. Figure from Golder and ONA (2013).

The total movement (minimum distance travelled throughout study period) ranged between 117 m and 50 770 m (median = 13 849 m). The minimum distance travelled by the five White Sturgeon that remained in the VPS area throughout the entire study ranged from 4872 m (WSG25) to 44 816 m (WSG41).

The breakdown of movement by month, rather than season, indicated that the shift between spring and summer behaviours occurred in late June, since early-mid June was classified as spring, when fish exhibited the majority of movement in the thalweg (Figure 17), whereas the total distribution of June movements shows increased use of shallows and thalweg (Figure 18). A decrease in use of non-thalweg habitat occurred in October. In September, juvenile White Sturgeon traveled over 2,000 m in the floodplain and shallow areas compared to October when only two movements, both at or below 500 m, were observed (Figure 17). The shifts in behaviour in late June and (likely) early October suggest that the division by season used in this analysis is appropriate.

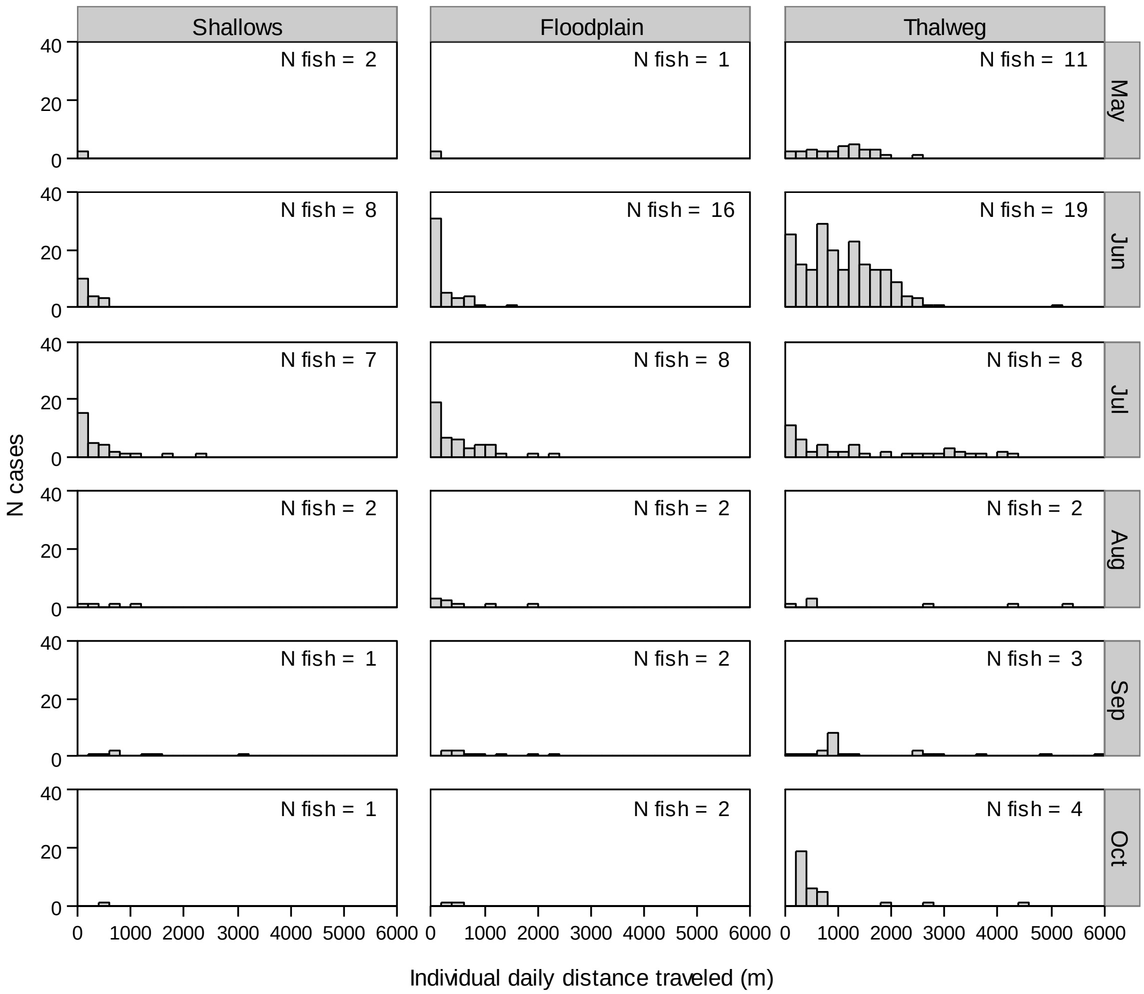

Figure 18. Histograms of daily distances traveled by individual juvenile White Sturgeon, classified by month (May to October) and habitat. The number of fish within each stratum is provided on each panel. Note that the period shown for May only includes May 29 - 31; plots include only positions that were at most 0.5 h apart. Figure from Golder and ONA (2013).

The division of time spent in different habitat classifications by month rather than by season provided similar findings (Figure 18). The shift from thalweg-only positions to use of floodplain and shallow habitats occurred in late June; throughout the summer, all three habitats were used, although juvenile White Sturgeon still spent the longest periods of time in the thalweg. In October, a shift from the floodplains and shallows to the thalweg occurred. Even though the number of fish observed in the array was similar between September and October, the amount of time spent in the shallows and floodplain decreased considerably, while the length of time spent in the thalweg increased (Figure 19). Based on a visual assessment of plotted data, there were no clear relationships between traveled distance or movement speed and REV discharge throughout the study period.

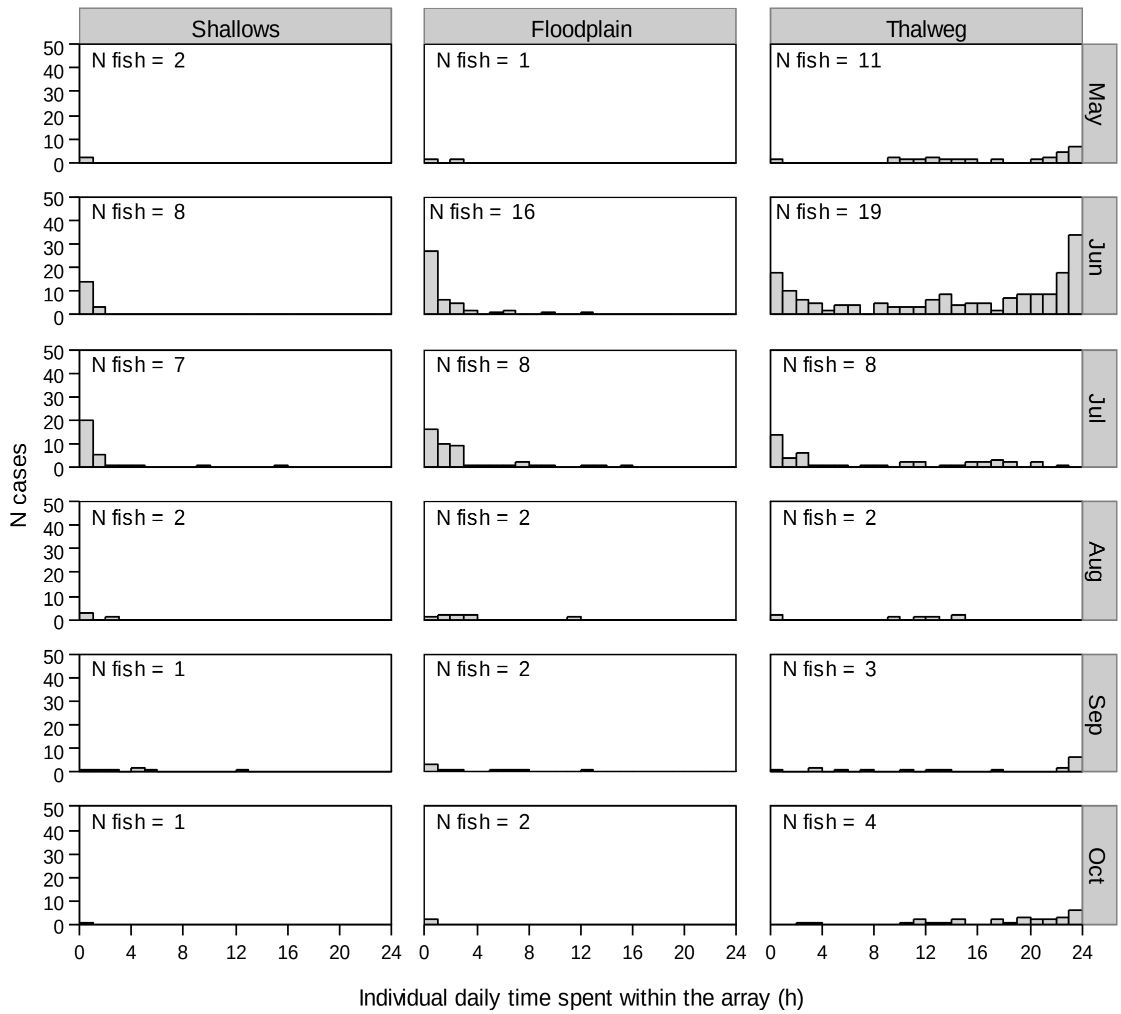

Figure 19. Histograms of daily lengths of time spent by individual juvenile White Sturgeon within each habitat classification in each month. The number of fish recorded within each stratum is provided within the panels. Note that the period shown for May only includes May 29 - 31; plots include only positions that were at most 0.5 h apart). Figure from Golder and ONA (2013).

3.3.11 Akolkolex Bay Use

Juvenile White Sturgeon were found in the Akolkolex Bay area more often in daytime than nighttime. The majority of the fish recorded near the mouth of the Akolkolex were categorized as fish that remained near the array, since the periods between tag locations were less than 0.5 h. A considerably lower number were categorized as fish that left or returned into the array area. The frequency of fish leaving the VPS array by the mouth of the Akolkolex ranged from 80 cases in springtime (52 daytime, 28 nighttime), and 75 cases in the fall (44 daytime, 31 nighttime). The frequency of return of fish into the array in the Akolkolex area was similar to the frequency of fish leaving the array (Golder and ONA 2013). Overall, the results indicate that juvenile White Sturgeon did not foray into the Akolkolex River Bay very often, since the majority of fish remained within the VPS array. However, when fish did leave the array and enter the bay area, they were more likely to do so during daytime than nighttime.

3.4 Juvenile White Sturgeon Capture Efforts to Estimate Growth and Survival

3.4.1 Capture Effort

Effort has varied for both gillnets and setlines over the 16 years that fish sampling activities occurred (Table 17). For the first four years of the study, the fishing effort was focused at locations where acoustic-tagged fish were detected and in areas considered to have a high probability of encountering a White Sturgeon (e.g., the channel thalweg, sandy flats) and areas where tagged White Sturgeon were previously captured. Both full overnight (n = 52) and short duration night time (n = 64) gillnets were used in 2010. During 2014 to 2022, a GRTS stratified sampling design was introduced to ensure random coverage in the Revelstoke Reach and the upper ALR to determine if juvenile White Sturgeon were using other habitat types and locations. Effort was increased in these years with the objective of capturing sufficient numbers of juvenile White Sturgeon to determine growth and survival metrics. Even with this increased level of effort, few juvenile White Sturgeon have been captured; however, over the last three years setline CPUE has increased. Details on within-year gillnetting and setline activity are available in the CLBMON-21 annual report series. Details on 2022 fish sampling effort and results are located in Appendix D.

Table 17. Gillnet effort (Net-Units = NU) and setline effort (Hook-Hours = HH), number of juvenile White Sturgeon (WSG) captured, and catch-per-unit-effort (CPUE; higher values indicated by darker shades) from 2007 to 2022. Data collected from the Middle Columbia River by Golder Associates Inc., Okanagan Nation Alliance, and BC Hydro.

Study Year	Gillnet Effort				Setline Effort				Total WSG
	Soak Time (Hours)	Effort (NU)	WSG	CPUE (WSG / NU)	Soak Time (Hours)	Effort (HH)	WSG	CPUE (WSG / 100 HH)	
2007	71.3	2.1							0
2008	642.2	22.3	4	0.180					4
2009	521.4	36.3	2	0.055	54.6	1085.1			2
2010	1041.0	72.5	4	0.055	470.0	14100.5			4
2011	No capture effort undertaken - Sonic tracking range testing								
2012	No capture effort undertaken - 2D sonic array tracking								
2013	121.9	8.5			900.7	14368.5			0
2014 [a]	365.2	25.4	7	0.275	2620.4	53192.5	4	0.008	11
2015	704.4	49.1	1	0.020	3289.2	66534.4			1
2016	914.4	82.4			4810.5	96140.7	8	0.008	8
2017	743.2	59.1	3	0.051	5156.9	101496.0	5	0.005	8
2018	332.8	25.0			2242.4	44379.7	2	0.005	2
2019	478.9	26.3			2458.6	49084.0	2	0.004	2
2020	378.9	19.6			4054.5	81024.7	9	0.011	9
2021	231.8	12.0			2969.4	58502.7	7	0.012	7
2022					6661.6	133231.0	24	0.018	24
Total	**6547.3**	**440.8**	**21**	**0.048**	**35688.6**	**713139.8**	**61**	**0.009**	**82** [b]

[a] 2014 gillnet efforts in Sep were estimated to have 3:15 average soaking times at 20 sites
[a] 2014 setline efforts in Sep were estimated to have 20:48 average soaking times at 22 sites
[b] 2017 and 2022 within-year re-capture event included

Juvenile White Sturgeon have not been captured in the Beaton Arm, although sampling effort in this area has been relatively low (Table 18). Juvenile White Sturgeon have been encountered most often in River Section 9: 1 km upstream of Crawford Creek (RKm 192.1) upstream to Tree Island (RKm 197.5). River Section 6: 0.7 km upstream of Blanket Creek (RKm 205.6) upstream to 0.8 km downstream of Greenslide Creek (RKm 209.7) saw the second highest juvenile White Sturgeon captures (Table 18). Maps of capture locations, effort, and CPUE by River Section can be found in Appendix E.

Table 18. Gillnet effort (Net-Units = NU) and setline effort (Hook-Hours = HH), number of juvenile White Sturgeon (WSG) captured, and catch-per-unit-effort (CPUE; higher values indicated by darker shades) by River Section from 2007 to 2022; excluding September 2014 effort and capture data as location data were lacking. Data collected from the Middle Columbia River (1 – 15) and Beaton Arm (B1 – B2) by Golder Associates Inc., Okanagan Nation Alliance, and BC Hydro.

River Section	Gillnet Effort				Setline Effort				Total WSG
	Soak Time (Hours)	Effort (NU)	WSG	CPUE (WSG / NU)	Soak Time (Hours)	Effort (HH)	WSG	CPUE (WSG / 100 HH)	
1	8.4	0.1							0
2	15.1	0.6							0
3	39.1	1.5							0
4	57.5	3.6							0
5	226.1	10.9	4	0.366	595.6	12103.5	1	0.008	5
6	753.1	37.4	4	0.107	3967.6	78884.8	6	0.008	10
7	357.7	25.3	1	0.040	3910.9	77420.6	8	0.010	9
8	517.2	34.3	1	0.029	3998.4	79035.0	8	0.010	9
9	695.8	47.4	4	0.084	4146.0	81486.3	10	0.012	14
10	536.7	35.8	1	0.028	3901.3	77435.6	14	0.018	15
11	603.0	41.6			3860.1	78894.8	11	0.014	11
12	697.7	49.1	1	0.020	1728.6	35783.5	1	0.003	2
13	1075.4	84.8			5698.4	114376.9			0
14	495.1	38.2	1	0.026	1612.7	32648.6			1
15	301.4	18.5			1235.7	24469.4			0
B1	89.8	7.2			43.5	826.4			0
B2	58.9	3.1			532.3	10622.5			0
Total	**6527.9**	**439.4**	**17**	**0.039**	**35231.0**	**703987.7**	**59**	**0.008**	**76***

* 2017 and 2022 within-year re-capture event included

Juvenile White Sturgeon captures have also varied depending on sample timing, with 70% of captures occurring between Sep 01 and Oct 31, and 51% of captures occurring solely in September. Although effort has not been prioritized between Oct0 9 and 16 (Month Quarter = Oct 2), the capture of sturgeon resulted in the highest CPUE for both gillnet and setline effort compared to all other sample time periods (Table 19). Effort from Sep 17 to 24 (Month Quarter = Sep 3) has been relatively high for both gillnets and setlines and has resulted in the highest juvenile White Sturgeon captures overall.

Table 19. Gillnet effort (Net-Units = NU) and setline effort (Hook-Hours = HH), number of juvenile White Sturgeon (WSG) captured, and catch-per-unit-effort (CPUE; higher values indicated by darker shades) by month quarter (quarter 1 is the 1st – 8th, 2 is the 9th – 16th, 3 is the 17th – 24th, and 4 is the 25th – the last day of the month) from 2007 to 2022. Data collected from the Middle Columbia River by Golder Associates Inc., the Okanagan Nation Alliance, and BC Hydro.

Quarter Month	Gillnet Effort				Setline Effort				Total WSG
	Soak Time (Hours)	Effort (NU)	WSG	CPUE (WSG / NU)	Soak Time (Hours)	Effort (HH)	WSG	CPUE (WSG / 100 HH)	
Mar 2	25.5	0.9							0
No capture effort undertaken from Apr - May and Nov - Feb									
Jun 1	145.9	13.5			839.5	16744.2			0
Jun 2					722.7	13956.8			0
Jun 3	60.7	5.7			415.1	8279.3			0
Jun 4	253.0	20.4	1	0.049	581.8	11618.0			1
Jul 1	240.4	17.5			1286.2	25616.8			0
Jul 2	226.9	17.3			1353.2	27455.7			0
Jul 3	140.3	10.6			699.8	13913.7			0
Jul 4	166.5	11.7			747.6	14905.3			0
Aug 1	218.6	15.4			1012.0	20262.9	1	0.005	1
Aug 2	494.3	33.2			3642.5	72581.8	9	0.012	9
Aug 3	448.1	32.6	3	0.092	3142.4	62996.1	2	0.003	5
Aug 4	469.5	33.4			2780.8	55999.3	9	0.016	9
Sep 1	423.4	23.4	3	0.128	2963.6	58886.9	4	0.007	7
Sep 2	1389.6	92.0	3	0.033	3320.1	66365.8	7	0.011	10
Sep 3	831.4	48.5	6	0.124	5940.2	118582.1	16	0.013	22
Sep 4	482.4	29.1			2492.1	50446.0	3	0.006	3
Oct 1	456.7	30.3	4		2068.2	40024.2	2	0.005	6
Oct 2	74.4	5.2	1	0.193	1118.1	23251.7	7	0.030	8
Oct 3					562.7	11253.3	1	0.009	1
Total	**6521.8**	**439.9**	**21**	**0.048**	**35688.6**	**713139.7**	**61**	**0.009**	**82***

* 2017 and 2022 within-year re-capture event included

3.4.2 Juvenile White Sturgeon Captures

Over the 16 years of the program, all juvenile White Sturgeon have been captured within a 32.7 km stretch of river, from Shelter Bay (RKm 178.1) to just upstream of Greenslide Creek (RKm 210.8), with the exception of the sturgeon caught downstream of Nakusp BC at RKm 124.1 (Table 20). In 2021, effort was limited to the eight River Sections within the Revelstoke Reach (River Section 5 to 12) and had the highest capture location variability (63% of sections sampled experienced captures). In 2015, although ten River Sections were sampled, only one section experienced a capture, the lowest of all years that experienced at least one capture. Interestingly, in 2022, 14 captures occurred in River Section 10, which had been sampled over 11 previous years and only resulted in two captures. A map of capture locations can be found in Appendix C.

Timing of effort and captures has varied between years (Table 20 and Table 21). In 2022, White Sturgeon were captured in seven of eight month quarters sampled (capture rate of 88%) resulting in the highest variable capture timing of all study years. All other years experienced more condensed capture timing in relation to sampling effort. In 2015, capture timing was the least variable (White Sturgeon were captured in one of nine sampled month quarters; 11%) of all years with one white sturgeon capture.

Table 20. Number of juvenile White Sturgeon (WSG) caught (numbers with green shaded cells) by River Section (descriptions in Section 2.1). Annual effort (grey shaded cells; GN = gillnet; SL = setline) and capture data collected from 2007 to 2022 (sampling not conducted in 2011 or 2012) by Golder Associates Inc., Okanagan Nation Alliance, and BC Hydro.

River Section	U/S RKm	D/S RKm	2007	2008	2009		2010		2013		2014		2015		2016		2017		2018		2019		2020		2021		2022	Total WSG Captures
			GN	GN	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	SL	
1																												**0**
2	228.4	228.4																										**0**
3	226.1	226.1																										**0**
4	220	220																										**0**
5	214.1	214.1		3			1																	1				**5**
6	209.8	209.8		1			2				2	1				1		1		1				2		1		**12**
7	205.6	205.6			1							2				4						1					1	**9**
8	201.9	201.9									2					1		3						1		1	2	**10**
9	197.6	197.6			1						2	1				2	2	1		1		1		4		1		**16**
10	192.1	192.1					1				1																14	**16**
11	186.6	186.6																						1		3	7	**11**
12	182.1	182.1											1													1		**2**
13	176.9	176.9																										**0**
14	129.1	129.1															1											**1**
15	119	119																										**0**
B1	77.6	77.6																										**0**
B2	2.2	2.2																										**0**
Total WSG Captures			**0**	**4**	**2**	**0**	**4**	**0**	**0**	**0**	**7**	**4**	**1**	**0**	**0**	**8**	**3***	**5**	**0**	**2**	**0**	**2**	**0**	**9**	**0**	**7**	**24***	**82**

*2017 and 2022 within-year re-capture event is included

Table 21. Number of juvenile White Sturgeon (WSG) caught (numbers with green shaded cells) by year and month quarter (period 1 is the 1st – 8th, 2 is the 9th – 16th, 3 is the 17th – 24th, and 4 is the 25th – the last day of the month). Annual effort (grey shaded cells; GN = gillnet; SL = setline) and capture data collected from 2007 to 2022 (sampling not conducted in 2011 or 2012) by Golder Associates Inc., Okanagan Nation Alliance, and BC Hydro.

Month	Period	2007	2008	2009		2010		2013		2014		2015		2016		2017		2018		2019		2020		2021		2022	Total WSG Captures
		GN	GN	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	GN	SL	SL	
Mar	**2**																										**0**
Jun	1																										**0**
	2																										**0**
	3																										**0**
	4															1											**1**
Jul	1																										**0**
	2																										**0**
	3																										**0**
	4																										**0**
Aug	1																						1				**1**
	2																						1		1	7	**9**
	3			2						1															1	1	**5**
	4																3		1						2	3	**9**
Sep	1											1			2	2	2									2	**9**
	2		2			1									2				1		1		1				**8**
	3		2							4	2				2						1		4		3	4	**22**
	4														2								1				**3**
Oct	1					3				1	1												1				**6**
	2									1	1															6	**8**
	3																									1	**1**
Total WSG Captures		**0**	**4**	**2**	**0**	**4**	**0**	**0**	**0**	**7**	**4**	**1**	**0**	**0**	**8**	**3***	**5**	**0**	**2**	**0**	**2**	**0**	**9**	**0**	**7**	**24***	**82**

*2017 and 2022 within-year re-capture event is included

3.4.3 Gear Efficacy Testing

Gear efficacy testing was conducted following the 2016 juvenile release at Shelter Bay. Gillnets set in daytime for four hours did not capture any juvenile White Sturgeon. Three unplanned overnight gillnets sets captured 16 juvenile White Sturgeon with no mortalities. This suggested juvenile sturgeon movements increased during nighttime hours, a conclusion that was supported by movement data collected using the fine-scale array (Section 3.3.8), as well as captures from other unplanned overnight gillnet sets. Setlines did not capture any White Sturgeon during the gear efficacy testing. White Sturgeon captured during the gear efficacy testing were not used in other analyses.

3.4.4 Growth and Condition

All growth and condition results exclude fish captures “2017-8” and “2022-16”, as they were caught within the same year and had the same measurements. Individual 2022_14 (outlier on the following graphs) was initially released in the United States in 2007 (2006 year class) and encountered in 2015 and 2017 at Kettle Falls, WA. This individual did not have an acoustic tag and therefore movement timing into Canada and through the navigational lock at HLK Dam is unknown. This individual’s growth and relative weight may not be comparable to individuals released and reared in the MCR.

MCR juvenile White Sturgeon growth was best described using the power function equation below (R^2 = 0.98; Equation 6; Figure 20):

Equation 6. MCR juvenile White Sturgeon growth.

$$W = 3 \times 10^{-6} \times L^{3.2406}$$

$where,$
$W = White\ Sturgeon\ weight\ (kg)$
$L = White\ Sturgeon\ length\ (cm)$

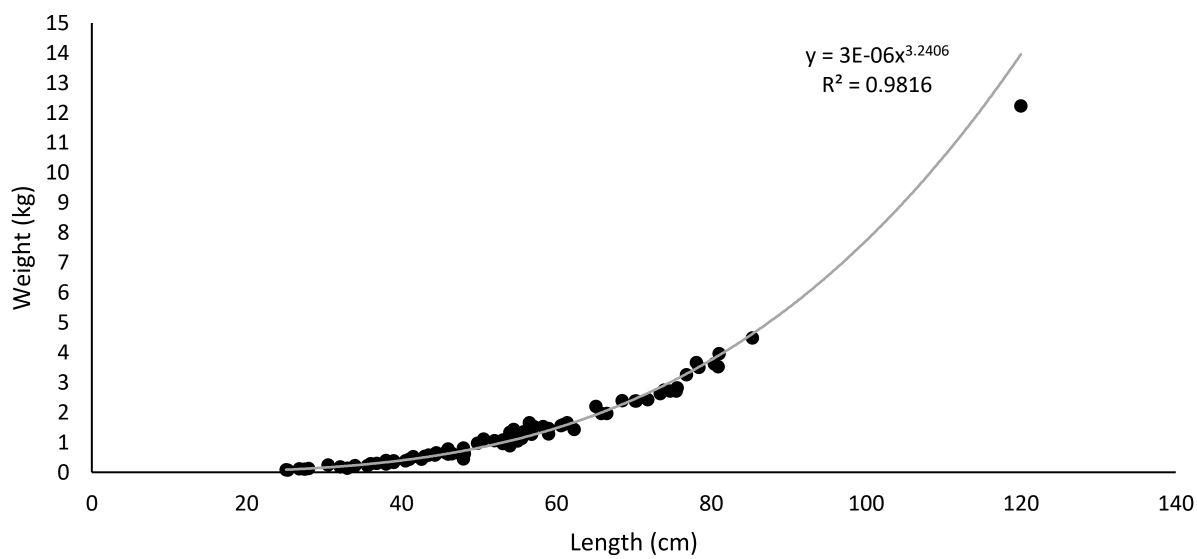

Figure 20. Length-weight regression of juvenile White Sturgeon captured in the Middle Columbia River between 2007 and 2022 (n = 79). Data collected by Golder Associates Inc., Okanagan Nation Alliance, and BC Hydro.

Relative weights for juvenile White Sturgeon captured in the MCR ranged from 59.3% to 140.0% (Figure 21). The average relative weight for all the MCR juvenile Sturgeon captured between 2007 and 2022 was 98.6% +/- 3.0%, which is higher than the 85.7% +/- 7.4% reported in the first four years of sampling (Golder 2011).

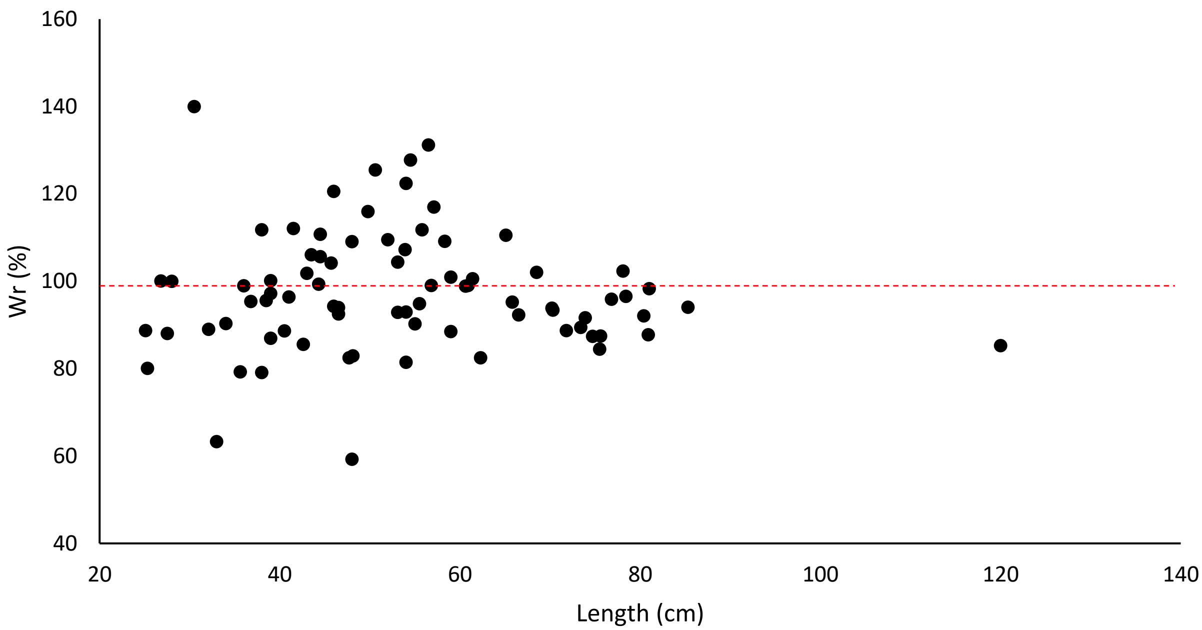

Figure 21. Plot of relative weight (Wr) compared to 100% for juvenile White Sturgeon captured in the Middle Columbia River from 2007 to 2022 (n = 79). Data collected by Golder Associates Inc., Okanagan Nation Alliance, and BC Hydro.

Length and weight measurements and growth calculations of all White Sturgeon captured during Years 1 to 16 (2007-2022) were split into three categories depending on the time between release and capture (< 1 year, 1 year, > 2 years). This was done as fish captured less than two years after release appeared to have higher growth rates on average (particularly length) and were more variable (standard deviation) even with more data points (n values; Figure 22).

Since 2007, 18 out of 80 (22%) juvenile White Sturgeon have been captured within one year of release, 13 (16%) were captured one year after release, and the remainder (49; 62%) were captured two year or more after release (Figure 22).

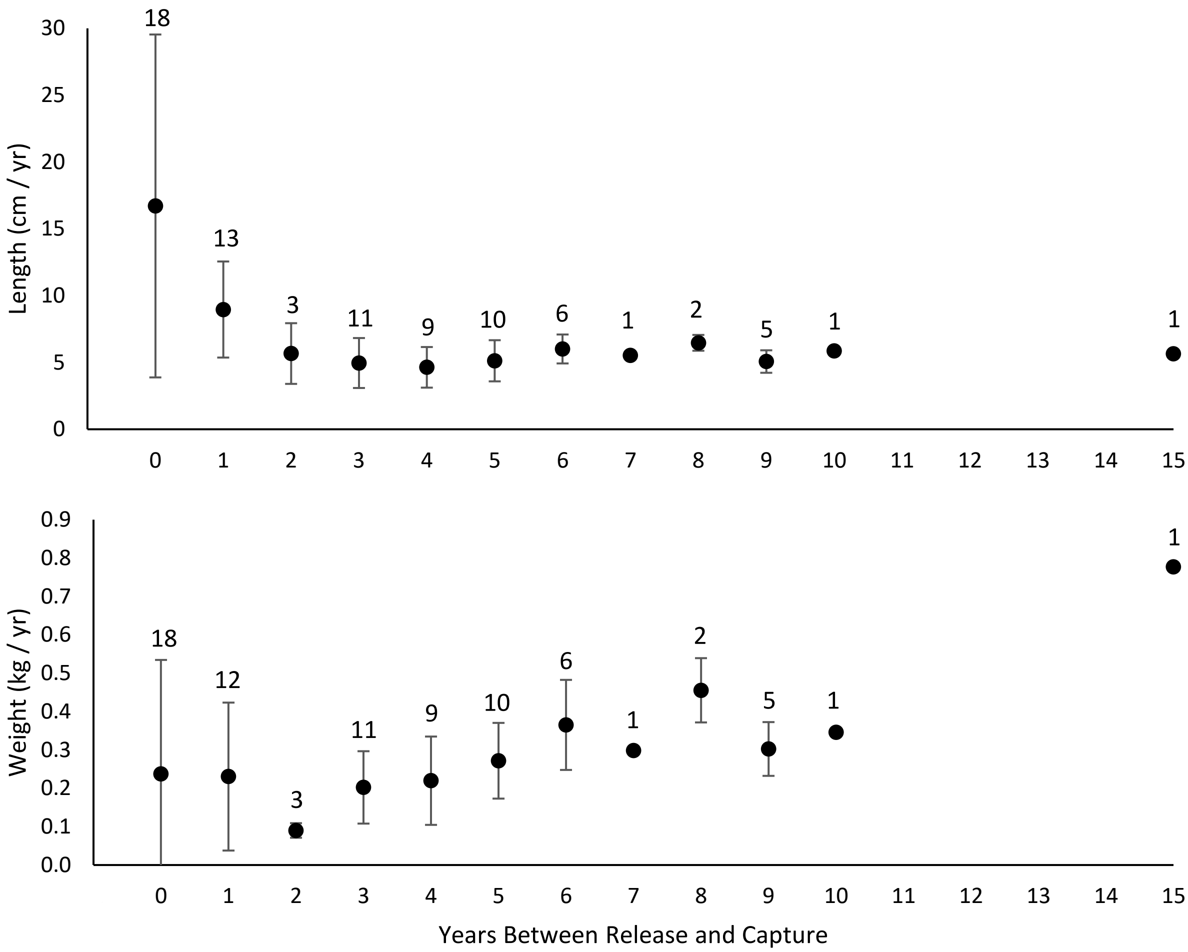

Figure 22. Growth measures for juvenile White Sturgeon compared to number of years between release and capture in the Middle Columbia River during CLBMON-21 from 2007-2022. Data collected by Golder Associates Inc., Okanagan Nation Alliance, and BC Hydro.

Since 2007, there have been no captures from the 2010, 2017, 2019, 2020, or 2021 year classes. Representation of captured year classes varied from a low of one from year class 2011 (0.02% capture rate) to a high of 19 from year class 2015 (1.20% capture rate).

The average length and weight of fish captured within one year of release were 37.03 cm ± 3.15 cm (95% CI) and 0.33 kg ± 0.09 kg (95% CI). When captured, they had grown an average of 6.39 cm ± 2.28 cm (95% CI) and 0.09 kg ± 0.05 kg (95% CI). Captured fish appeared to have similar relative weights (94.46% ± 8.29%) compared to fish capture one year after release (94.84% ± 5.97), but lower than fish caught two years or more after release (99.23% ± 3.51%). Annual growth rates for fish captured less than one year after release were not calculated as results are extrapolated from a small time-frame and do not accurately show growth for a full year.

Average annual growth (mean ± 95% confidence interval) of fish captured one year after release was 8.96 cm / year ± 1.95 cm / year (95% CI) and 0.23 kg / year ± 0.11 kg / year (95% CI); while fish captured two years or more after release grew 5.22 cm / year ± 0.42 cm / year (95% CI) and 0.27 kg / year ± 0.04 kg /

year (95% CI). Of all the MCR juvenile White Sturgeon that were captured one year or more after release, average annual growth was 6.01 cm / year ± 0.64 cm / year (95% CI; n = 62) and 0.26 kg / year ± 0.04 kg / year (95% CI; n = 61).

One individual was captured in 2021 (2021_2; 59.0 cm and 1.46 kg) and re-captured in 2022 (2022_3; 60.6 cm and 1.56 kg). This was the first inter-year re-capture of the project and allowed for additional growth measures to be assessed. This individual grew 16.0 cm and 0.92 kg over 4.3 years (3.74 cm / year and 0.22 kg / year) to its first capture and 1.60 cm and 0.10 kg over 1.0 year to its re-capture in 2022.

Average fork length (cm; mean ± 95% confidence interval) of juveniles captured in the MCR during 2022 was 69.51 ± 6.04 cm. Since 2008, there appeared to have been a positive increase in capture fork length, however this increase was not significant. Average fork length of juveniles in the MCR by capture year have been consistently lower than juveniles from the Lower Columbia River (102.6 ± 28.1 cm SD to 160 ± 41.5 cm SD from 2013 to 2019; BC Hydro 2022).

Average weight (kg; mean ± 95% confidence interval) of juveniles captured in the MCR during 2022 was 2.72 ± 0.93 kg. Since 2008, there appeared to have been a positive increase in capture weight, however this increase was not significant. Average weight of juveniles in the MCR by capture year have been consistently lower than juveniles from the Lower Columbia River (9.0 ± 11.9 kg SD to 40.2 ± 25.1 kg SD from 2013 to 2019; BC Hydro 2022).

Average relative weight (%; mean ± 95% confidence interval) of juveniles captured in the MCR during 2022 was 98.8 ± 4.4 %. Average relative weight has not significantly changed over capture years in the MCR, but appear to be higher than juveniles from the Lower Columbia River (78.3 ± 7.3 % SD to 88.9 ± 10.3 % SD from 2013 to 2019; BC Hydro 2022).

3.4.5 Survival

Survival has not been estimated due to low recapture rates, which are attributed to a large study area and low capture efficiency. Additional recaptures are required to adequately address the survival question.

3.4.6 Diet

Stomach contents were analyzed to determine juvenile White Sturgeon prey utilization in the MCR. Stomach contents in juvenile White Sturgeon sampled have remained similar between years. Samples from 2010, and 2016-2022 were composed of:

- Mysis diluviana, an introduced freshwater shrimp species,
- Chironomide, non-biting midges,
- Sphaeriidae, pea clams or fingernail clams,
- Gastropoda, snails and
- Unidentifiable fish (spinal column, flesh, and internal organs; skin and head not present).

White Sturgeon are difficult to gastric lavage for a complete stomach content analysis. Crossman et.al. (2016) compared gastric lavage to a complete stomach removal in the lower Columbia River in Canada and observed that on average, gastric lavage obtains 67% of the actual stomach contents. In 2017, the one recaptured juvenile White Sturgeon was gastric lavaged twice over a four-day period. Both samples contained large numbers of mysid shrimp, which indicated active feeding between capture events in September.

The decapod *Mysis diluviana* was abundant in some sections of the MCR study area (Arrowhead Flats and downstream of Walter Hardman) during underwater video surveys in 2009 (Golder 2010). Mysids are a key component of the diet of juvenile White Sturgeon downstream of HLK (Golder 2009b) and based on the stomach contents of lavaged fish in 2016-2022, are an important food source to MCR fish as well. Mysids were also the largest invertebrate identified, ranging from 9 – 20 mm during 2019 to 2022 analyses. Oligochaeta were the second largest invertebrate identified (1 – 16 mm), but individuals have not been identified in lavage samples. Chrionomidae were the second most common prey item identified in lavage samples and were generally small (3 – 9 mm), with the exception of an 18 mm individual in identified 2021.

Ponar Grab substrate samples were taken at both White Sturgeon capture locations as well as representative habitat locations from 2016-2022. The primary taxon identified in these substrate samples since 2014 was Chironomidae, followed by Oligochaeta. From 2019-2022, 22 ponar grabs have been conducted, 17 resulting in positive invertebrate identifications (Table 22).

Rock baskets resulted in more species identified and total individual invertebrates collected, all rock baskets resulted in the positive identification of at least one invertebrate (one rock basket was lost in 2019 and is not included in number of samples analysed). Similar to substrate grabs, Chironomidae were the most abundant (Table 22). Full rock basket results are available in Appendix F.

Table 22. Number of invertebrates identified by sample type, including the number of samples analysed and the number of samples with positive invertebrate identification. Data collected from the Middle Columbia River during CLBMON-21 from 2019 – 2022.

	Sample Type	**Lavage**	**Ponar Grab**	**Rock Basket**
	Samples Analysed	17	14	29
	Samples with Invertebrates	9	10	29
Invertebrate Taxon	Oligochaeta		36	82
	Hirudinea			4
	Mysis	146		
	Chironomidae	97	50	586
	Heptageniidae			1
	Ephemerellidae			8
	Trichoptera			52
	Culcidae			1
	Hydrachnidia			2
	Sphaeriidae	2	1	1
	Platyhelminthes			55

3.4.7 Incidental Catch

Bycatch summaries for Years 1 to 16 of the program can be found in the CLBMON-21 annual report series. Data for Year 16 (2022) are provided in Appendix D. Over the years the most common bycatch species captured in gillnets were Bull Trout, Mountain Whitefish, Lake Whitefish (*Coregonus clupeaformis*), Peamouth Chub (*Mylocheilus caurinus*), Kokanee, and Northern Pikeminnow (*Ptychocheilus oregonensis*).

Setline bycatch consisted mainly of Burbot; in past years, Burbot mortality on setlines was high due to the depth of setline sets and resultant swim bladder ruptures when the lines were retrieved. Fewer mortalities occurred when Burbot were captured in the shallower Revelstoke Reach. To reduce Burbot mortality, setlines in recent years were not set at depths greater than 25 m and were retrieved at a slow rate. Other common species captured on setlines were suckers (*Catostomus sp.*), Northern Pikeminnow, and Peamouth Chub. Most Peamouth Chub encountered on setlines were dead and partially digested, and therefore assumed to be prey items of Burbot. One Common Carp (*Cyprinus carpio*) was captured on a setline in 2021 and removed from the system as it is a non-native species.

Boat electrofishing was conducted in the upper section of the MCR (from REV down to RKm 224) from 2001 to 2019 for a different sampling program (CLBMON-16). A total of three White Sturgeon have been observed during that program; one juvenile (Oct 30 2009 at Big Eddy; ~ 80 cm total length) and two adults (Sep 13 2001 at the spawning area adjacent the Revelstoke golf course and Oct 25 2018 near the rock groyne downstream of the City of Revelstoke boat launch) (Golder et al. 2019; MCR Fish Indexing Database).

3.5 Adult White Sturgeon Movement

3.5.1 Mobile Tracking

Acoustic mobile tracking surveys using a Sonotronics receiver were conducted to monitor spawning movements of acoustic-tagged adult White Sturgeon into the Revelstoke spawning area from below Revelstoke Dam to Big Eddy (2007 MCR juvenile White Sturgeon study, five times between Aug 16 and Sep 04 2007; Golder 2008). No adult White Sturgeon were detected during these mobile tacking surveys or by the VR2W array receivers located in the vicinity of the Revelstoke spawning area (Big Eddy and upstream). During 2008, none of the adult tags were detected within the ALR or Revelstoke Reach during the mobile tracking session (Golder 2009).

3.5.2 VR2W Linear Array Detection

Five of the six adult White Sturgeon equipped with Vemco coded pingers were detected by the VR2W array (Golder 2008). The furthest upstream detection of an acoustic-tagged adult in 2007 was at RKm 195.0 in August, but this fish subsequently moved back downstream to RKm 180 (Arrowhead Flats; Table 23). The acoustic-tagged adults did not display typical spawning movements and as such, the movements detected were likely feeding related. The lack of detections from January to March 2008 was believed to be due to issues with the VR2W stations moving un-expectantly from their original locations in the Arrowhead Flats area, as well as the general lack of movement exhibited by White Sturgeon during the winter months. Most of these fish were captured and tagged in lower ALR in 2002 and 2003. The fish that were not detected during the present study may have moved back downstream to that area.

Table 23. Locations and number acoustic-tagged adult White Sturgeon detected in the MCR, April to December 2007. Table from Golder (2008).

VR2W Station Locations [a] (RKm)	**Number of Adult White Sturgeon Detected/Month**								
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
195.0					1				
189.0		1	1	1	1	1			
184.0		1	2	1	3	1	2		
Arrowhead Flats/ Arm Area	3	3	2	1	2	3	4	3	3

[a] See Golder 2008 for receiver locations; the 5 VR2Ws in the Arrowhead Flats and mouth of Beaton Arm area were combined in this table.

4.0 Discussion

4.1 Management Questions

4.1.1 Where are the habitat locations utilized by juvenile White Sturgeon in the Middle Columbia River?

To date, the results of CLBMON-21 indicate that habitat preferences of juvenile White Sturgeon vary depending on the time of year and corresponding water levels as there were defined seasonal differences in meso-habitat use and movements within the MCR. In spring, juvenile White Sturgeon were detected almost exclusively in the thalweg. During summer months, juveniles were detected in all three meso-habitat areas (thalweg, floodplain, and shallows), although habitat use was primarily in the thalweg and floodplain habitats during summer. In the fall, the highest usage was again recorded in the thalweg, although limited use of the available floodplain also was observed. The low use of non-thalweg areas in the fall by juvenile White Sturgeon may suggest other factors such as temperature may affect habitat use in that period.

Seasonal variation in the use of thalweg habitats has also been observed in juvenile White Sturgeon in the Lake Roosevelt Reservoir (McLellan et al. 2011, Howell and McLellan 2013). In that area, the probability of occupancy in the thalweg, based on models using VPS telemetry data, was high in the spring (86%) and winter (71%) and lower in the summer (33%). Although there are distinct seasonal trends in juvenile White Sturgeon habitat use patterns in the MCR, the small number of fish left in the study area by fall limited the strength of conclusions presented here.

The 2009 movement studies indicated the Arrowhead Flats area (RKm 180-182) had the highest use by tagged Sturgeon (by total tag days); this may suggest a decrease in available habitat upstream at ALR elevations of 434-436 masl. In contrast, juvenile White Sturgeon showed increased use of areas near Mulvehill Creek (RKm 207) during the higher ALR elevations in summer and fall of 2008, when water elevations remained near 439 masl for an extended period. In 2007 and 2010, high use habitat was located between Blanket Creek (RKm 203.1) and Akolkolex River (RKm 200.0) when ALR elevations were approximately 436 to 438 masl. ALR elevations may help to identify high use locations that can direct future capture efforts.

The analysis of fish movement near the Akolkolex River mouth did provide some information on White Sturgeon use of shallow habitat in the MCR outside of the VPS array. Throughout all three seasons, the majority of estimated positions were classified as fish that remained within the VPS array near the Akolkolex River mouth. Use of the Akolkolex Bay area was likely to be higher during daytime, since the daytime counts of fish that left the VPS array (presumably into the Akolkolex Bay area) were higher than nighttime counts of similar behaviour throughout all three seasons. Further analysis of the data would be needed to determine if the daytime movement was in the morning, mid-day or evening, as the juveniles potentially move into the shallows to feed.

4.1.2 What are the physical and hydraulic properties of this habitat that define its suitability as juvenile White Sturgeon habitat?

Within the MCR, juvenile White Sturgeon appear to prefer calm (<0.5 m/s), deep (average capture set depth of 11.5 – 12.8 m; total capture set depth ranged from 4.7 – 21.4 m) areas with fine substrates (clay and sand). While preference was for the deeper thalweg, use of floodplain and shallow habitats occurred in late June within the positional array. In October, a shift from using the floodplains and shallows back to mainly using thalweg habitat occurred (Golder and ONA 2013). The timing of these movement patterns generally follows the spring increase and fall decrease in water surface elevations of ALR.

Several studies suggest that the assumption of juvenile White Sturgeon mostly occupying benthic habitats is reasonable. In a study in Lake Roosevelt Reservoir, McLellan et al. (2011) found that depth measurements of tagged adult and juvenile White Sturgeon typically corresponds to the total depth at the location. Diet analyses of juvenile White Sturgeon in the LCR and Lake Roosevelt showed a high proportion of benthic invertebrates, which also suggested benthic orientation of juveniles (Crossman et al. 2016; Parsley et al. 2010). However, juvenile White Sturgeon in the ALR are known to forage on mysid shrimp that are known to make vertical diel migrations within the water column. The diel movement analysis conducted in 2009 (Golder 2010) indicates that juveniles are more active at night, which may indicate: 1) juvenile White Sturgeon may feed higher in the water column when foraging on mysids or 2) that mysid shrimp could have moved into shallower benthic areas during nighttime hours.

4.1.3 What is the quantity of available habitat meeting these conditions in the Middle Columbia River?

All White Sturgeon captures have been between RKm 178.1-210.7 with the exception of one individual captured near Nakusp at RKm 124.1. The dispersal analysis identified that juvenile White Sturgeon made rapid movements downstream to the riverine section of the river (RKm 207-212) following release at upstream sites (Big Eddy [RKm 228.3] and Moses Creek [RKm 233]) and upstream following release at Arrowhead (RKm 184). Available habitat in the preferred riverine section varies throughout the year depending on water elevations as a result of operations at REV and backwatering from the ALR. However, this section of river is generally deeper, has finer substrates and has available eddy habitat (slower water) compared to the upstream habitat (RKm 212 and upstream). The program to date has not quantified the availability of meso-habitat that is preferred by juvenile White Sturgeon in the MCR but given that juveniles are selecting calm (<0.5 m/s), deep (>10 m) areas with fine substrates within the MCR it is not expected that habitat is limiting. Habitat suitability as measured through food availability remains uncertain throughout the reservoir.

4.1.4 How do hydraulic conditions resulting from dam and reservoir operations relate to habitat suitability for juvenile White Sturgeon in the Middle Columbia River?

In general, habitat use for juvenile White Sturgeon is concentrated in the thalweg (< 10 m) of the riverine section in the MCR (RKm 190-212). Throughout the year, dam and reservoir operations alter the amount and type of habitat available in this section of river; when water elevations are high, the thalweg becomes deeper and other habitats including floodplain and shallows become available. When water elevations are low, the thalweg is the primary habitat available for juvenile White Sturgeon. Juvenile White Sturgeon movements and habitat use generally coincide with habitat availability; they increase as water levels increase, and become more concentrated during low water elevations.

Studies on juvenile White Sturgeon in other areas of the upper Columbia River Basin have shown a preference for depths greater than 10 m (Golder 2009, McLellan et al. 2011), which suggests depth is a factor in influencing seasonal habitat selection by juveniles in the MCR; additional habitat data would be required to test this hypothesis. The only observed trend in fish behaviour related to reservoir elevation (i.e., emptying, filling, full, or stable) was that distances traveled in the shallow habitat type were greater during the emptying phase of ALR than during the stable or filling reservoir phases (Golder and ONA 2013).

Juvenile White Sturgeon also utilize the downstream section of the Revelstoke Reach study area in the vicinity of the river-reservoir transition zone where the effects of REV discharge fluctuations are attenuated by ALR elevations. Similarly, White Sturgeon juveniles are found at the transition zone in higher numbers in Lake Roosevelt Reach during sampling (Howell and McLellan 2013). Further work that summarizes key locations preferred by juvenile White Sturgeon at different ALR elevations could help understand how to target habitat restoration projects in the future.

4.1.5 What are the survival rates of juvenile White Sturgeon in the Middle Columbia River?

Recapture rates of juveniles in the MCR have been low in all years of sampling (total individual captures = 78 of 63, 358 released juvenile fish; 2007-2022) excluding two fish recaptured in the same session, one recaptured in subsequent sampling events, and one fish immigrating to the study area. The capture of individuals up to 10 years after release (including four captured over 9 years after release in 2022) does indicate the capacity for sturgeon to survive in the MCR; however, the lack of recaptures precludes estimating year class-specific survival. Individual 2022_14 was captured over 15 years after release and migrated over 300 km from Kettle Falls to access habitat in the MCR.

Juvenile White Sturgeon CPUEs in the MCR ranged from 0.0 to 0.275 fish/net-hour for gillnets and 0.0 to 0.018 fish/hook-hour for setlines. These rates are very low compared to capture rates recorded for similar juvenile White Sturgeon monitoring programs elsewhere in the Columbia drainage. For example, efforts in the Columbia River below HLK monitoring program using setlines have recorded CPUE values of 0.133 and 0.188 in the spring and fall stock assessments in 2019, respectively (BC Hydro 2020). In the Kootenay River and Kootenay Lake in 2019, one-hour daytime gillnet lines produced a CPUE of 2.0 fish/net-hour (Stephenson et al. 2020). Complimentary setline efforts had recorded CPUE values of 0.07 and 0.13 in the spring and fall sampling sessions in 2019, respectively (Stephenson et al. 2020).

Mean relative weight for all the MCR juvenile sturgeon captured to date is 97.5% +/- 3.0%, which may indicate that growth is near normal for those individuals that were captured. This finding does not support a hypothesis that food resources are limiting growth and survival of juvenile White Sturgeon in the MCR. The mean relative weights of juvenile White Sturgeon in the Lower Columbia River in 2019 (W_r = 77.8 – 82.3%; riverine habitat; BC Hydro 2020) were lower than in the MCR total average for that year (W_r = 95%; reservoir habitat). This is similar to findings reported by Millar and Beckman (1992) who reported that juveniles in the reservoir upstream of Bonneville Dam had higher mean growth for the first 7 year classes than juveniles captured in the riverine section below Bonneville Dam.

This program has not yet recaptured any of the juveniles released in the 2010, 2017, 2019, 2020, or 2021 years classes. The program has also not captured any untagged fish that might have been released from the hatchery as larvae or recruiting from wild spawning events. Therefore, the effects of releasing early life-stage or larger juveniles on growth and survival cannot be determined at this time.

In order to address juvenile survival in this program, a substantial increase in captures and/or further understanding of mechanisms influencing sources of mortality is needed. Increasing sampling effort and targeting areas of previous capture in all seasons should help to capture more juvenile White Sturgeon. Efforts to reduce bycatch mortality, especially for Bull Trout, have limited the duration of sets and sampling locations depending on time of year (see Golder 2010). However, setlines can be easily used in the riverine section between Shelter Bay and Greenslide Creek and are less likely to capture Bull Trout.

4.1.6 Can modifications be made to the operations of Revelstoke Dam and/or Arrow Lakes Reservoir to protect or enhance juvenile White Sturgeon habitat?

Based on captures and movements of acoustic-tagged individuals, juvenile White Sturgeon prefer the section of the MCR between Greenslide Creek (RKm 212) to Shelter Bay (RKm 177) and downstream. During very low ALR levels, this section of river can experience substantial daily fluctuations in water levels and velocities resulting from REV operations. However, based on the results to date in this program, juvenile White Sturgeon that reside in this area utilize deep, slow moving habitats associated with the thalweg of the Columbia River. These deep-water habitats are less prone to effects of REV discharge variations. Therefore, at present, there are no specific modifications to REV operations that could protect or enhance juvenile habitats.

Juvenile White Sturgeon in the Snake River downstream of Hells Canyon Dam in Idaho were studied for changes in oxygen respiration and movement over the range of discharge flows (Geist et al. 2005). The overall trend was for swim speeds and oxygen consumption to be less during lower, stable flows, but the differences between seasons were related to temperature and daylight factors. Higher flows from load shaping were shown to restrict juvenile Sturgeon movement but did not increase oxygen consumption, likely due to morphological and behaviour adaptions of living in high flow habitats

Macro-habitats with similar depth, velocity, and substrate characteristics as that selected by the 79 individual juvenile White Sturgeon captured during this study program, is abundant in the ALR throughout the year and in the MCR during periods of high ALR levels. The results of the first four years of study (2007 to 2010) indicate that juvenile White Sturgeon rarely use the upstream portion of the study area, where Revelstoke Dam and ALR operations have the greatest influence on habitat availability and suitability. Depths and velocities in the river/reservoir transition zone, where many juveniles have been detected, would be influenced to a lesser degree, however this influence would decrease with increased downstream distance from Revelstoke Dam.

5.0 Recommendations

The following recommendations are a result of the technical forum held for the Mid-Columbia White Sturgeon Management Plan in December 2018 (BC Hydro 2018):

- The primary uncertainty remaining in this program is survival of fish released from the conservation aquaculture program. As well, larger sizes at release have been tested over the course of the program, with the largest release sizes only occurring in recent years. Additional sampling is required to assess survival and evaluate the effects of size at release on survival.
    - Direct capture remains critical with a focus on Arrowhead Flats.
    - Consider telemetry as a tool to understand habitat use and movements if efforts to directly capture juveniles are not successful. Could provide additional distribution data for older larger sturgeon if encountered and the recommendation is that application of telemetry in the future is focused on recaptured fish that have survived for several years following release.
    - Review eDNA experimental work done by UVic/UBC/BC Hydro to determine if it could be a tool in the future to help guide direct sampling efforts or understand habitat use.
- Further assess food availability and distribution for juvenile White Sturgeon in all habitat types and throughout the year in the riverine section of the MCR.
    - Conduct plankton tows to determine seasonal and diel plankton (primarily mysids) availability

6.0 Literature Cited

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Appendix A – Detailed Maps of River Kilometers, White Sturgeon Release Sites, and Temperature Stations

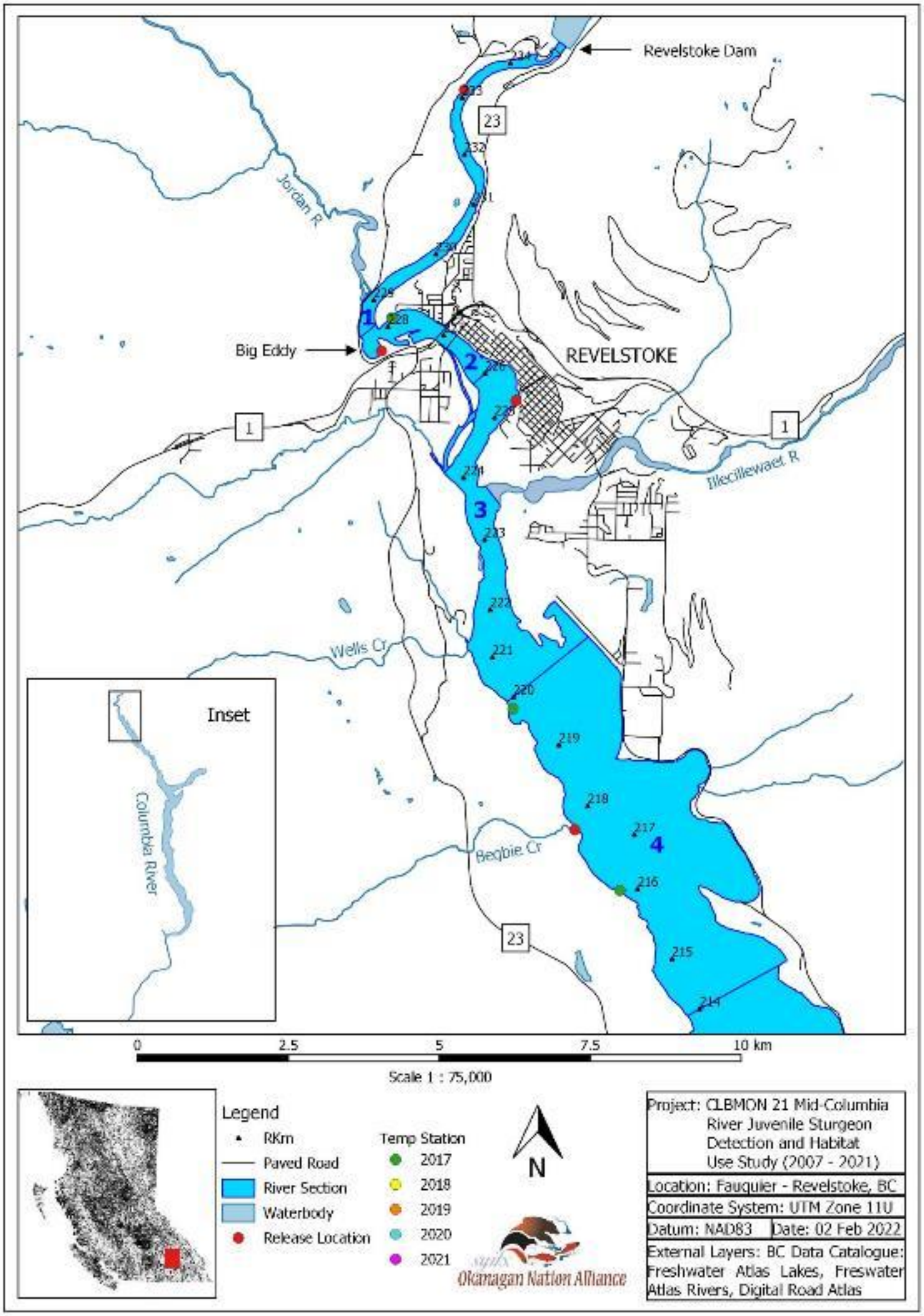

Figure 23. Juvenile White Sturgeon release locations (2007 – 2022) and temperature stations (2017 – 2022) from 3.5 km downstream of Begbie Creek to Revelstoke Dam. Data collected by BC Hydro, Golder Associates Ltd., and Okanagan Nation Alliance.

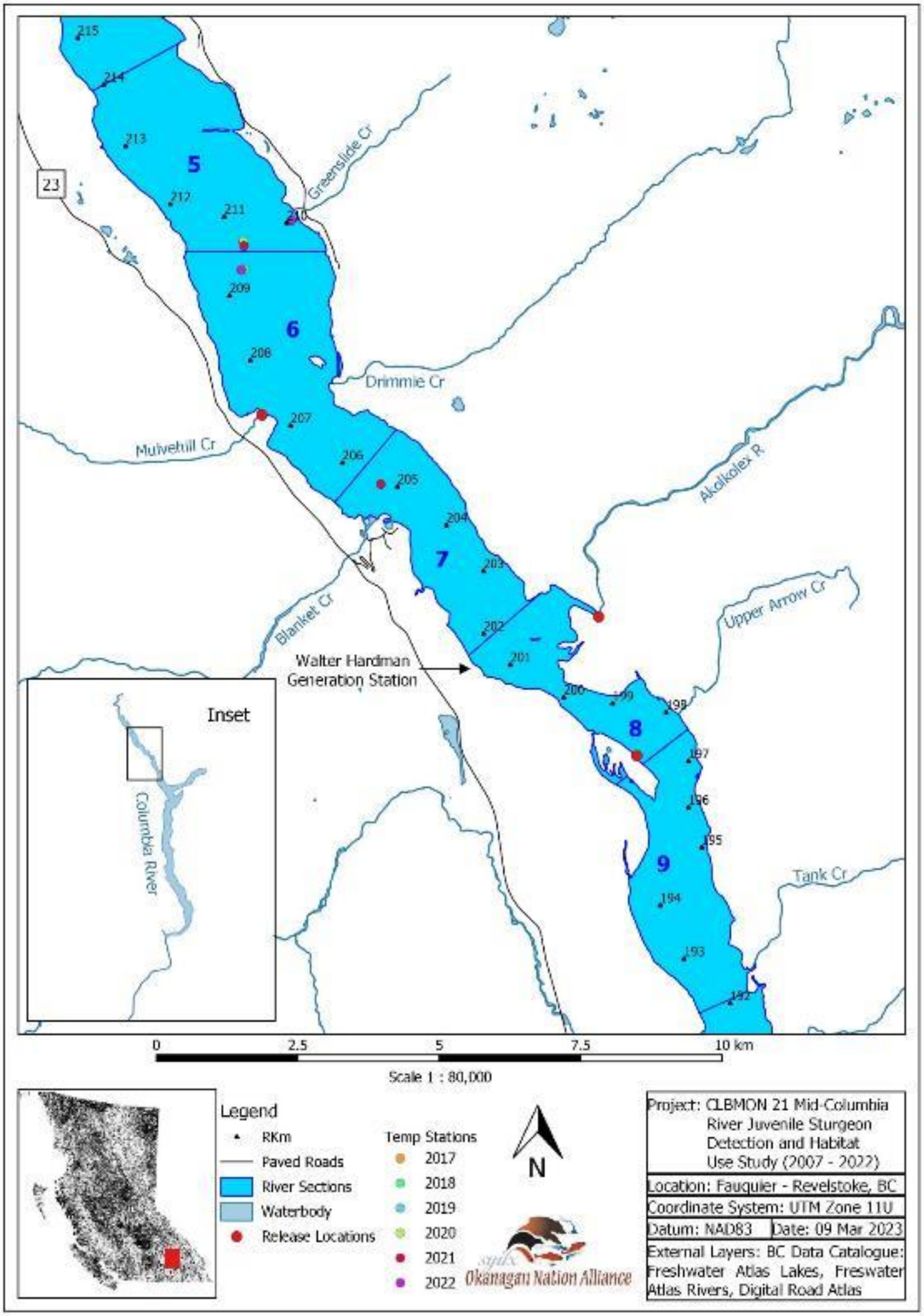

Figure 24. Juvenile White Sturgeon release locations (2007 – 2022) and temperature stations (2017 – 2022) from 1 km upstream of Crawford Creek to 3.5 km downstream of Begbie Creek. Data collected by BC Hydro, Golder Associates Ltd., and Okanagan Nation Alliance.

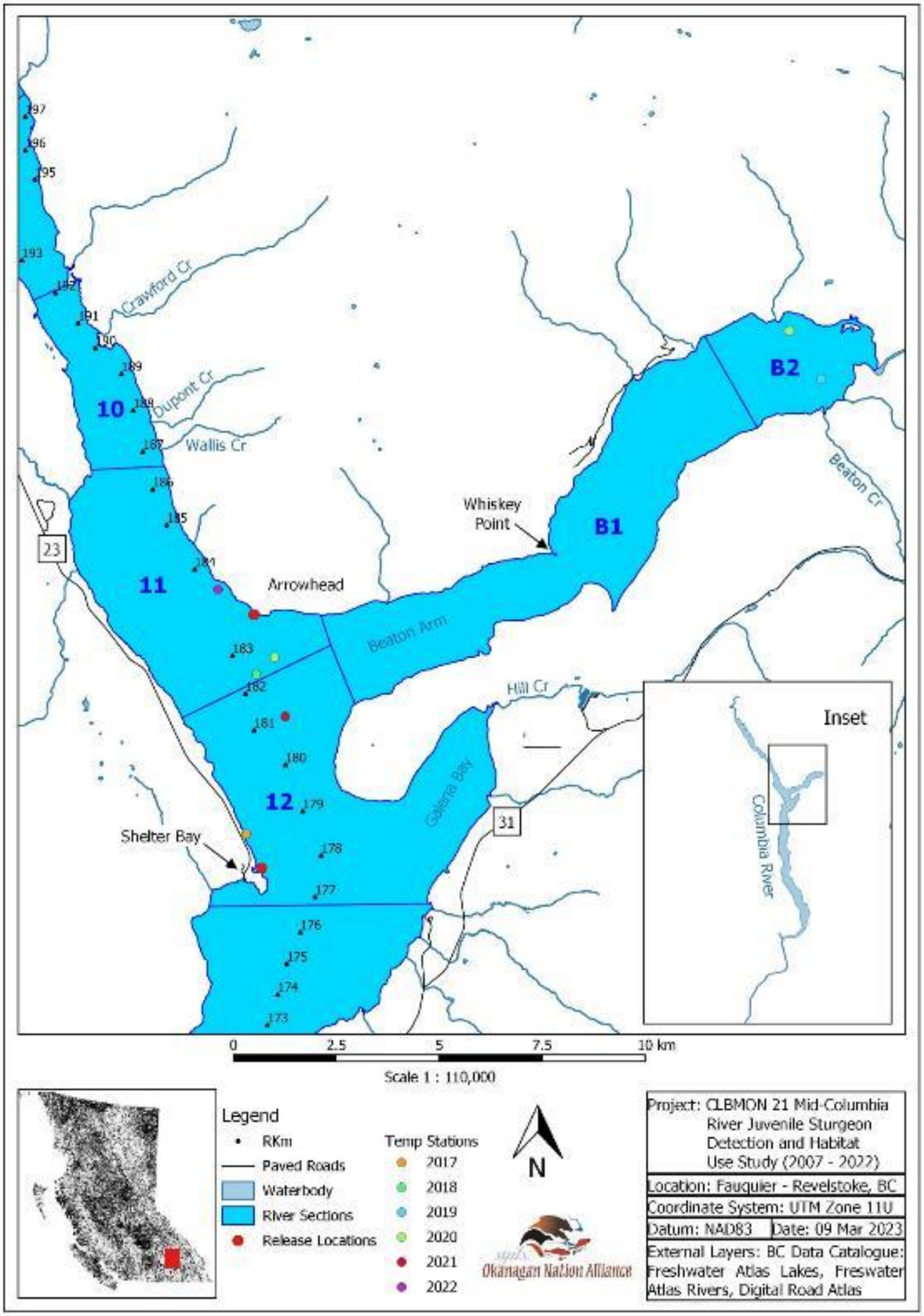

Figure 25. Juvenile White Sturgeon release locations (2007 – 2022) and temperature stations (2017 – 2022) from Shelter Bay to 1 km upstream of Crawford Creek and the Beaton Arm. Data collected by BC Hydro, Golder Associates Ltd., and Okanagan Nation Alliance.

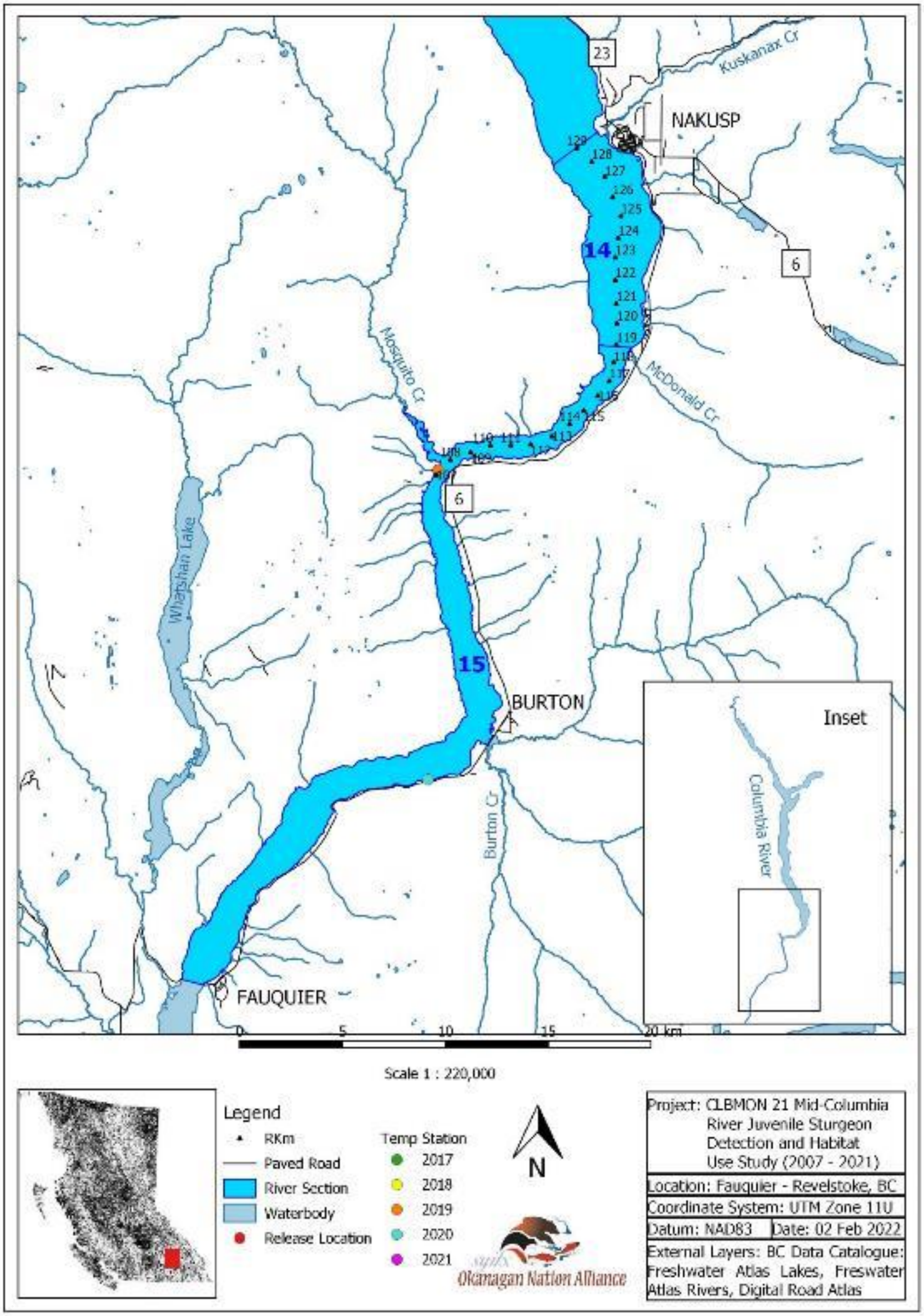

Figure 26. Juvenile White Sturgeon release locations (2007 – 2022) and temperature stations (2017 – 2022) from the Arrow Lakes Narrows to Nakusp. Data collected by BC Hydro, Golder Associates Ltd., and Okanagan Nation Alliance.

Appendix B – Summary of Habitat Conditions Measured at Juvenile White Sturgeon Capture Locations

Table 24. Summary of habitat conditions measured at juvenile White Sturgeon capture locations in the Middle Columbia River from 2008 – 2022 during CLBMON-21. Data collected by BC Hydro, Golder Associates Ltd., and Okanagan Nation Alliance.

Year	RKm	Water Temp (°C)	Average Water Depth (m)	Secchi Depth (m)	Mean Velocity	Substrate	Turbidity	Contents in Substrate Sample
2008-1	207.4	-	18.3					
2008-2	210.2	-	10.1					
2008-3	210.6	-	10.9					
2008-4	210.8	-	11.8					
2009-1	192.5	-	16.4					
2009-2	202.2	-	11.1					
2010-1	205.9	10.5	14.3	3.5	0.28	fines/SG	-	
2010-2	210.5	10.5	7.7		0.2	fines	4.2	
2010-3	206.4	10	13.4		0.17	fines	2.9	
2010-4	190.7	10.5	13.1	3.95	0.18	fines/some OD	2.4	
2014-1	196.2	-	-			Sand		None
2014-2	192.0	-	-			Sand		Biting Midge
2014-3	195.4	-	-			Clay (sand)		Biting Midge
2014-4	196.0	-	-			Sand		None
2014-5	200.1	-	-			Pebbles (Sand)		None
2014-6	207.7	-	-			Sand		None
2014-7	208.5	-	-			Sand		6 Non-biting Midges
2014-8	207.5	-	-			Sand (Clay)		None
2014-9	208.0	10	10.8			Sand (Pebble)		Non-Biting Midge and Larvae
2014-10	206.0	10.1	8.9			Sand		3 red Non-Biting Midgets
2014-11	199.5	10.3	11.7					
2015-1	177.8	11.2	9			Clay		None
2016-1	205.5	10.5	10.8			Sand		None
2016-2	207.5	11	9.5			Pebbles (Sand)		Biting Midge
2016-3	195.5	9.8	10			Sand		None
2016-4	195.5	9.8	10					
2016-5	205.5	10.6	8.3			Sand (Pebble)		None
2016-6	205.5	10.6	8.3					
2016-7	201.5	9.5	7					
2016-8	202.6	9.5	6.3					
2017-1	124.1	15.4	13.6			Clay (Sand)		None
2017-2	199.5	10.1	15.5			Sand		1 Caddisfly
2017-3	192.8	12.2	15.3			Sand (Clay)		None
2017-4	192.8	12.2	15.3			Sand (Clay)		None
2017-5	193.0	11.1	17			Sand (Pebbles)		None
2017-6	199.4	11.7	15.8			Sand		None
2017-7	205.8	10.6	15.2			Sand		None
2017-8	200.7	11.5	13.7			Sand (Clay)		None
2018-1	193.2	11.4	15.1	3		Coarse sand		1 Diptera
2018-2	207	10.5	15.5			Medium sand		Nothing
2019-1	204.8	12	9.6					
2019-2	196	12.3	13.0					
2020-1	210	12	12.4			Coarse sand (medium sand)		Midges & 1 aquatic worm
2020-2	206.6	12.6	18.2					None
2020-3	207	10.1	10.6			Coarse gravel (coarse sand)		1 midge & 1 aquatic worm
2020-4	199.4	11.1	12.7	3		Coarse sand (fine gravel)		
2020-5	196.3	12.1	14.6			Medium sand (fine gravel)		

Year	RKm	Water Temp (°C)	Average Water Depth (m)	Secchi Depth (m)	Mean Velocity	Substrate	Turbidity	Contents in Substrate Sample
2020-6	194.8	11.8	15.2			Medium sand (silt)		
2020-7	194.8	11.8	15.2			Medium sand (silt)		
2020-8	183.5	13	10.0			Silt (fine sand)		Midges & aquatic worms
2020-9	192.5	10	10.5			Fine gravel (coarse sand)		Midges
2021-1	185	17.1	14.6			Medium sand (fine sand)		Aquatic worms
2021-2	192.6	11.1	13.1			Medium sand (silt)		Midges & aquatic worms
2021-3	185	11.9	11.1			Silt (fine sand)		Midges & aquatic worms
2021-4	186.4	12.1	11.1			Fine sand (silt)		1 midge & 1 aquatic worm
2021-5	199.4	10.2	10.2			Medium sand (fine sand)		None
2021-6	208.4	10.6	5.3			Coarse sand (fine gravel)		Midges, aquatic worms, and 1 fingernail clam
2021-7	181	12.4	12.4			Silt (clay)		1 midge & aquatic worms
2022-1	184.9	13.2				Silt		Midges, aquatic worms, 1 hydrozoa & 1 fingernail clam
2022-2	186.8	11.7				Silt, (medium sand), ((medium gravel))		Aquatic worms
2022-3	186.8	11.7						
2022-4	186.3	11.7				Silt, (fine sand), ((OM))		Aquatic worms
2022-5	187.9	11.6				Medium sand, (fine sand), ((OM))		1 midge
2022-6	189.2	11.7				Silt, (fine gravel), ((medium sand))		Midges, aquatic worms
2022-7	201.7	11				Coarse sand, (fine gravel), ((silt))		Midges & aquatic worms
2022-8	202.6	11.3				Coarse sand, (medium sand), ((silt)		1 midge, 1 aquatic worm
2022-9	186.7	11.6				Silt, (fine sand), ((OM))		Midges & aquatic worms
2022-10	186.7	11.6						
2022-11	190.1	11.5				Medium sand, coarse sand		None
2022-12	191	11.8				Medium sand, (OM), ((silt))		1 hydrozoa
2022-13	185.9	12.1				Fine sand, (medium sand), ((silt))		1 midge & 2 aquatic worms
2022-14	190.6	11.2				Fine sand, (silt)		Aquatic worms
2022-15	191.3	11.3				Medium sand, (silt)		None
2022-16	200.3	11.9				Coarse sand, (medium sand), ((medium gravel))		1 midge, 1 aquatic worm
2022-17	186.2	12.2				Fine sand, (silt), ((OM))		1 midge, 1 aquatic worm
2022-18	183.4	13.3				Silt, (fine sand)		Midges & aquatic worms
2022-19	184.1	11.9				Silt, (fine sand)		Midges & aquatic worms
2022-20	189.6	10.8				Fine sand , (silt), ((OM))		1 snail, aquatic worms
2022-21	190	10.8				Medium sand, (fine sand)		None
2022-22	190	10.8				Medium sand, (silt)		None
2022-23	191.7	10.7				Medium sand, (silt)		None
2022-24	184	10.7				Silt, (fine sand), ((OM))		Midges & aquatic worms

Appendix C – Location Map of Juvenile White Sturgeon Captures (2007 – 2022)

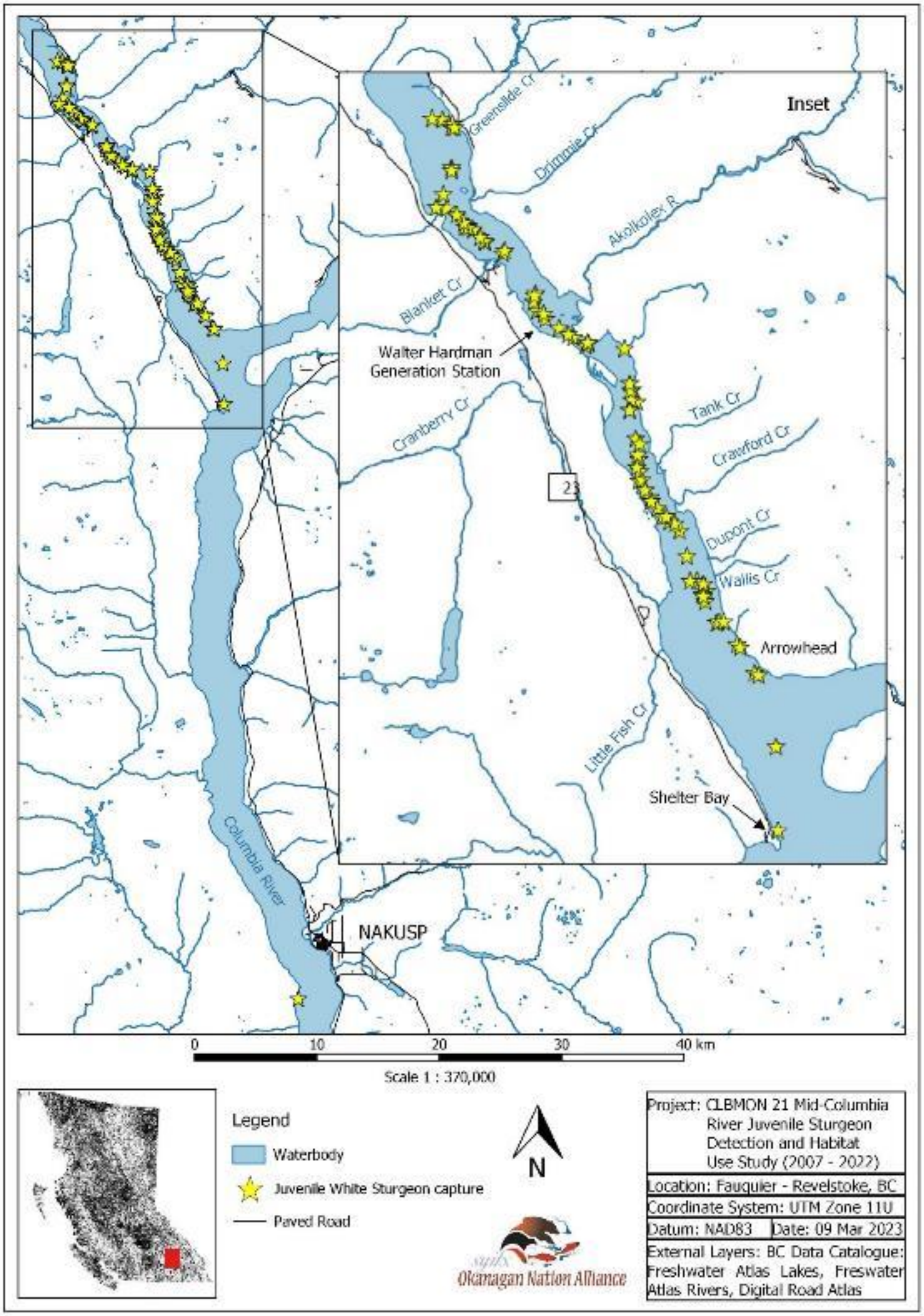

Figure 27. Locations of all juvenile White Sturgeon captures in the Middle Columbia River during CLBMON-21 from 2007 to 2022. Data collected by BC Hydro, Golder Associates Ltd., and Okanagan Nation Alliance.

Appendix D – 2022 Sample Data

Appendix D1 – 2022 Setline Data

Table 25. Setline sample site data collected in the Middle Columbia River during CLBMON-21 in 2022, with juvenile White Sturgeon captures highlighted in yellow and sets soak times over 24 hours highlighted in red.

Set #	Site	Easting	Northing	Weather	Orientation to Flow	Depth Min (m)	Depth Max (m)	Set Date	Set Time	Set Water Temp (°C)	Pull Date	Pull Time	Pull Water Temp (°C)	Soak Time (Hours)	# of Hooks	Total # WSG
1	ASL027	434449	5613420	cloud	parallel	14.2	14.3	12-Aug-22	15:55	18.2	13-Aug-22	13:03	16.5	21.1	20	0
2	ASL030	434383	5613785	cloud	parallel	12.3	12.7	12-Aug-22	16:05	18.5	13-Aug-22	13:29	17.3	21.4	20	0
3	ASL033	434380	5614397	cloud	parallel	11.6	12.0	12-Aug-22	16:14	18.4	13-Aug-22	13:40	17.6	21.4	20	0
4	ASL036	434140	5615088	cloud	parallel	15.0	16.0	12-Aug-22	16:22	19.3	13-Aug-22	13:58	18.2	21.6	20	0
5	ASL039	433712	5615267	cloud	parallel	11.0	11.6	12-Aug-22	16:29	18.2	13-Aug-22	14:05	18.1	21.6	20	0
6	ASL042	433172	5615722	cloud	parallel	11.7	12.3	12-Aug-22	16:37	18.0	13-Aug-22	14:18	17.9	21.7	20	0
7	ASL045	433030	5616155	cloud	parallel	9.9	10.3	12-Aug-22	16:43	18.8	13-Aug-22	14:39	17.9	21.9	20	0
8	ASL048	433227	5616773	cloud	parallel	12.6	13.3	12-Aug-22	16:49	18.5	13-Aug-22	14:50	18.4	22.0	20	0
9	ASL052	433395	5617161	sun	perpendicular	15.4	16.7	13-Aug-22	11:25	18.4	14-Aug-22	10:37	15.6	23.2	20	0
10	ASL055	432757	5617484	sun	perpendicular	15.0	15.4	13-Aug-22	11:31	18.4	14-Aug-22	10:59	16.4	23.5	20	0
11	ASL058	432683	5618178	sun	perpendicular	12.2	14.8	13-Aug-22	11:40	17.8	14-Aug-22	11:30	15.6	23.8	20	1
12	ASL061	432284	5618228	sun	perpendicular	17.8	18.8	13-Aug-22	11:48	17.0	14-Aug-22	12:30	15.6	24.7	20	0
13	ASL064	432110	5618876	sun	parallel	15.3	15.8	13-Aug-22	12:03	15.9	14-Aug-22	15:34	15.4	27.5	20	0
14	ASL067	431777	5619267	sun	perpendicular	16.1	16.8	13-Aug-22	12:12	14.8	14-Aug-22	14:51	14.7	26.7	20	1
15	ASL070	431586	5619777	sun	perpendicular	14.2	15.6	13-Aug-22	12:20	13.2	14-Aug-22	13:49	13.5	25.5	20	2
16	ASL073	431711	5620293	sun	perpendicular	14.8	15.8	13-Aug-22	12:29	13.4	14-Aug-22	13:37	13.9	25.1	20	0
17	ASL077	431194	5620728	Sun/smoke	perpendicular	13.2	15.2	14-Aug-22	9:50	12.1	15-Aug-22	9:40	12.0	23.8	20	1
18	ASL080	431008	5621336	Sun/smoke	perpendicular	15.1	16.2	14-Aug-22	9:58	12.2	15-Aug-22	10:11	12.1	24.2	20	0
19	ASL083	430946	5621755	Sun/smoke	perpendicular	11.3	16.8	14-Aug-22	10:06	12.3	15-Aug-22	10:28	12.1	24.4	20	1
20	ASL086	430601	5622128	Sun/smoke	perpendicular	15.8	16.2	14-Aug-22	10:15	12.5	15-Aug-22	11:00	12.6	24.8	20	0
21	ASL089	430313	5622542	Sun/smoke	perpendicular	12.0	16.9	14-Aug-22	12:48	13.9	15-Aug-22	11:09	12.6	22.4	20	0
22	ASL092	429896	5622903	Sun/smoke	perpendicular	14.8	15.6	14-Aug-22	12:57	13.4	15-Aug-22	11:19	12.1	22.4	20	0
23	ASL095	429455	5623317	Sun/smoke	perpendicular	14.7	17.4	14-Aug-22	13:06	13.9	15-Aug-22	13:36	13.7	24.5	20	0
24	ASL098	429207	5624188	Sun/smoke	perpendicular	16.3	16.7	14-Aug-22	13:16	14.4	15-Aug-22	13:43	13.8	24.5	20	0
25	ASL102	429392	5624706	Sun/smoke	perpendicular	15.4	16.2	14-Aug-22	16:05	13.0	15-Aug-22	14:04	12.4	22.0	20	0
26	ASL105	429311	5625108	Sun/smoke	perpendicular	15.1	15.6	14-Aug-22	16:14	13.8	15-Aug-22	14:15	12.1	22.0	20	0
27	ASL108	429183	5625508	Sun/smoke	perpendicular	12.2	13.0	14-Aug-22	16:23	12.6	15-Aug-22	14:21	12.1	22.0	20	0
28	ASL111	429307	5626221	Sun/smoke	perpendicular	12.4	13.3	14-Aug-22	16:32	12.8	15-Aug-22	14:30	11.9	22.0	20	0
29	ASL114	429059	5626430	cloud	oblique	14.5	15.7	15-Aug-22	11:56	12.1	16-Aug-22	9:30	11.6	21.6	20	0
30	ASL117	429003	5626931	cloud	oblique	14.3	14.9	15-Aug-22	12:04	12.0	16-Aug-22	9:36	11.3	21.5	20	0
31	ASL120	428926	5627495	cloud	perpendicular	15.5	16.1	15-Aug-22	12:11	11.8	16-Aug-22	9:47	11.2	21.6	20	0
32	ASL123	428952	5628216	cloud	parallel	12.8	13.4	15-Aug-22	12:21	12.0	16-Aug-22	9:56	11.2	21.6	20	0
33	ASL127	428869	5628630	cloud	parallel	15.2	15.4	15-Aug-22	12:28	11.8	16-Aug-22	10:05	11.2	21.6	20	0
34	ASL130	428122	5629109	cloud	perpendicular	12.7	13.2	15-Aug-22	12:38	12.0	16-Aug-22	10:12	11.6	21.6	20	0

35	ASL133	427526	5628964	cloud	parallel	13.0	15.4	15-Aug-22	15:08	13.0	16-Aug-22	12:41	11.6	21.6	20	0
36	ASL136	427344	5629229	cloud	oblique	9.0	10.8	15-Aug-22	15:14	11.5	16-Aug-22	12:50	11.2	21.6	20	0
37	ASL139	426645	5629256	cloud	oblique	15.7	16.0	15-Aug-22	15:22	12.2	16-Aug-22	12:59	12.8	21.6	20	0
38	ASL142	426375	5629795	cloud	perpendicular	13.7	14.3	15-Aug-22	15:29	13.9	16-Aug-22	13:08	12.1	21.7	20	0
39	ASL145	425713	5630027	cloud	perpendicular	14.5	17.0	15-Aug-22	15:37	12.5	16-Aug-22	13:20	12.4	21.7	20	0
40	ASL148	425603	5630322	cloud	oblique	11.9	13.4	15-Aug-22	15:44	13.0	16-Aug-22	13:31	12.3	21.8	20	1
41	ASL152	425204	5631039	sun	parallel	13.5	13.9	16-Aug-22	10:45	11.4	17-Aug-22	9:36	11.8	22.9	20	1
42	ASL155	425144	5631436	sun	perpendicular	11.8	12.7	16-Aug-22	10:53	11.1	17-Aug-22	10:11	11.7	23.3	20	0
43	ASL158	425268	5632026	sun	parallel	11.6	13.4	16-Aug-22	11:01	11.3	17-Aug-22	10:21	11.6	23.3	20	0
44	ASL161	425060	5632437	sun	perpendicular	12.0	16.2	16-Aug-22	11:08	11.7	17-Aug-22	10:31	12.0	23.4	20	0
45	ASL164	424085	5632550	sun	oblique	13.7	14.4	16-Aug-22	11:16	11.1	17-Aug-22	10:46	12.5	23.5	20	0
46	ASL167	424110	5633003	sun	perpendicular	9.0	9.7	16-Aug-22	11:24	11.3	17-Aug-22	10:58	12.1	23.6	20	0
47	ASL170	423349	5633119	sun	parallel	14.7	15.2	16-Aug-22	14:34	11.4	17-Aug-22	12:44	11.6	22.2	20	0
48	ASL173	423075	5633237	sun	oblique	15.7	16.2	16-Aug-22	14:43	11.3	17-Aug-22	12:55	11.2	22.2	20	0
49	ASL177	422570	5633878	sun	oblique	8.5	10.6	16-Aug-22	14:51	11.1	17-Aug-22	13:03	11.3	22.2	20	0
50	ASL180	422109	5633941	sun	oblique	10.9	12.9	16-Aug-22	14:59	11.1	17-Aug-22	13:44	11.4	22.8	20	0
51	ASL183	421641	5634317	sun	parallel	9.8	10.5	16-Aug-22	15:06	11.4	17-Aug-22	13:53	11.4	22.8	20	0
52	ASL186	420758	5635015	sun	perpendicular	12.4	13.4	16-Aug-22	15:15	11.2	17-Aug-22	14:05	11.2	22.8	20	0
53	ASL166	423946	5632695	sun	oblique	12.8	13.8	17-Aug-22	11:27	11.5	18-Aug-22	13:50	11.6	26.4	20	0
54	ASL169	423608	5633028	sun	parallel	11.7	13.7	17-Aug-22	11:36	11.2	18-Aug-22	13:38	11.6	26.0	20	0
55	ASL172	423044	5633391	sun	parallel	13.7	14.9	17-Aug-22	11:44	11.2	18-Aug-22	13:25	11.6	25.7	20	0
56	ASL175	422590	5633618	sun	parallel	11.9	13.3	17-Aug-22	11:53	11.2	18-Aug-22	13:11	11.4	25.3	20	0
57	ASL178	422413	5633985	sun	parallel	10.0	10.3	17-Aug-22	12:01	11.3	18-Aug-22	12:59	11.5	25.0	20	0
58	ASL181	421938	5634323	sun	parallel	12.2	13.0	17-Aug-22	12:08	11.3	18-Aug-22	12:49	11.5	24.7	20	0
59	ASL191	421599	5635984	sun	perpendicular	7.2	7.4	17-Aug-22	14:37	14.9	18-Aug-22	10:49	12.6	20.2	20	0
60	ASL194	422147	5636481	sun	perpendicular	7.4	7.7	17-Aug-22	14:47	15.4	18-Aug-22	10:38	15.5	19.9	20	0
61	ASL197	422275	5637235	sun	perpendicular	6.0	8.1	17-Aug-22	14:56	18.6	18-Aug-22	10:27	14.7	19.5	20	0
62	ASL200	421801	5637832	sun	perpendicular	7.2	8.6	17-Aug-22	15:06	19.6	18-Aug-22	10:17	13.9	19.2	20	0
63	ASL150	425257	5630505	sun	perpendicular	11.1	12.3	18-Aug-22	11:25	12.0	19-Aug-22	9:33	12.6	22.1	20	0
64	ASL147	425726	5630048	sun	parallel	15.7	16.7	18-Aug-22	11:35	12.6	19-Aug-22	9:43	12.5	22.1	20	0
65	ASL144	426093	5629794	sun	perpendicular	12.0	12.3	18-Aug-22	11:42	12.8	19-Aug-22	9:54	12.1	22.2	20	0
66	ASL141	426550	5629494	sun	parallel	12.0	12.3	18-Aug-22	11:51	13.1	19-Aug-22	10:05	12.6	22.2	20	0
67	ASL138	426753	5629256	sun	oblique	14.5	15.0	18-Aug-22	14:28	13.4	19-Aug-22	11:18	12.1	20.8	20	0
68	ASL134	427421	5629068	sun	perpendicular	14.9	16.3	18-Aug-22	14:35	12.9	19-Aug-22	11:28	12.5	20.9	20	0
69	ASL131	428050	5628705	sun	oblique	13.3	13.6	18-Aug-22	14:45	12.0	19-Aug-22	11:39	12.1	20.9	20	0
70	ASL128	428473	5628402	sun	oblique	11.9	12.3	18-Aug-22	14:52	12.0	19-Aug-22	11:46	12.4	20.9	20	0
71	ASL106	429164	5625255	cloud	oblique	12.4	13.3	19-Aug-22	10:33	12.1	20-Aug-22	9:21	13.0	22.8	20	0
72	ASL103	429275	5624775	cloud	parallel	15.0	15.3	19-Aug-22	10:40	12.1	20-Aug-22	9:31	13.1	22.9	20	0
73	ASL100	429402	5624410	cloud	perpendicular	13.7	14.1	19-Aug-22	10:47	12.1	20-Aug-22	9:41	12.9	22.9	20	0
74	ASL097	429356	5623741	cloud	perpendicular	13.9	16.0	19-Aug-22	10:55	12.8	20-Aug-22	10:00	13.1	23.1	20	0

75	ASL094	429836	5623251	cloud	oblique	10.8	11.2	19-Aug-22	12:58	12.7	20-Aug-22	10:09	12.9	21.2	20	0
76	ASL091	429846	5622706	cloud	perpendicular	15.1	15.4	19-Aug-22	12:54	12.9	20-Aug-22	10:23	12.6	21.5	20	0
77	BSL025	433877	5612675	sun/cloud	perpendicular	12.3	12.9	28-Aug-22	10:37	15.8	29-Aug-22	9:26	15.3	22.8	20	0
78	BSL029	433739	5613317	sun/cloud	perpendicular	13.3	13.5	28-Aug-22	10:46	16.2	29-Aug-22	9:40	15.7	22.9	20	0
79	BSL032	433887	5613796	sun/cloud	perpendicular	11.6	11.7	28-Aug-22	10:55	16.7	29-Aug-22	9:49	16.0	22.9	20	0
80	BSL035	434118	5614955	sun/cloud	parallel	10.8	13.8	28-Aug-22	11:10	17.1	29-Aug-22	10:01	16.5	22.9	20	0
81	BSL038	434013	5615452	sun/cloud	parallel	10.3	13.4	28-Aug-22	11:20	16.9	29-Aug-22	10:15	17.1	22.9	20	0
82	BSL041	433966	5615781	sun/cloud	oblique	12.1	14.0	28-Aug-22	11:27	17.1	29-Aug-22	10:30	17.4	23.1	20	0
83	BSL044	433884	5616123	sun/cloud	perpendicular	13.7	14.1	28-Aug-22	13:09	17.2	29-Aug-22	12:45	18.2	23.6	20	0
84	BSL047	433702	5616474	sun/cloud	perpendicular	15.5	16.1	28-Aug-22	13:16	17.2	29-Aug-22	13:02	19.7	23.8	20	0
85	BSL050	432970	5617230	sun/cloud	perpendicular	12.7	13.1	28-Aug-22	13:26	17.3	29-Aug-22	13:12	17.9	23.8	20	0
86	BSL054	432855	5617514	sun/cloud	perpendicular	13.8	14.1	28-Aug-22	13:33	17.2	29-Aug-22	13:22	17.4	23.8	20	0
87	BSL057	432514	5617854	sun/cloud	perpendicular	14.2	15.4	28-Aug-22	13:40	16.6	29-Aug-22	13:31	17.6	23.9	20	0
88	BSL060	432321	5618248	sun/cloud	perpendicular	14.3	15.3	28-Aug-22	13:47	15.8	29-Aug-22	13:40	17.8	23.9	20	0
89	BSL063	432255	5618756	sun	perpendicular	12.3	13.0	29-Aug-22	11:09	16.1	30-Aug-22	9:33	14.5	22.4	20	0
90	BSL066	431838	5619132	sun	perpendicular	13.7	14.1	29-Aug-22	11:19	14.8	30-Aug-22	9:42	12.3	22.4	20	0
91	BSL069	431840	5619659	sun	oblique	13.6	14.2	29-Aug-22	11:26	15.0	30-Aug-22	9:59	13.3	22.6	20	2
92	BSL072	431442	5620096	sun	oblique	11.5	12.7	29-Aug-22	11:33	13.6	30-Aug-22	10:58	12.6	23.4	20	0
93	BSL075	431464	5620626	sun	perpendicular	12.5	13.4	29-Aug-22	11:40	12.9	30-Aug-22	11:09	12.7	23.5	20	0
94	BSL079	430495	5621145	sun	oblique	11.4	12.0	29-Aug-22	11:48	12.9	30-Aug-22	11:16	12.7	23.5	20	0
95	BSL082	430740	5621566	sun	perpendicular	11.3	12.1	29-Aug-22	14:15	13.7	30-Aug-22	13:15	13.2	23.0	20	0
96	BSL085	430627	5622038	sun	parallel	13.8	14.2	29-Aug-22	14:22	13.7	30-Aug-22	13:23	12.5	23.0	20	0
97	BSL088	430183	5622307	sun	perpendicular	13.3	13.7	29-Aug-22	14:30	13.1	30-Aug-22	13:39	13.7	23.2	20	1
98	BSL091	429973	5622821	sun	perpendicular	12.8	13.5	29-Aug-22	14:36	12.8	30-Aug-22	14:10	12.8	23.6	20	0
99	BSL094	429555	5623192	sun	perpendicular	14.5	15.5	29-Aug-22	14:44	12.7	30-Aug-22	14:20	12.8	23.6	20	0
100	BSL097	429546	5623778	sun	perpendicular	11.9	12.2	29-Aug-22	14:51	13.0	30-Aug-22	14:38	11.7	23.8	20	0
101	BSL100	429315	5624630	sun	perpendicular	13.7	14.0	30-Aug-22	12:07	12.1	31-Aug-22	9:46	11.9	21.7	20	0
102	BSL104	429220	5624897	sun	parallel	13.6	13.8	30-Aug-22	12:13	11.8	31-Aug-22	9:53	11.7	21.7	20	0
103	BSL107	429188	5625326	sun	oblique	11.8	11.9	30-Aug-22	12:19	11.7	31-Aug-22	10:04	11.7	21.8	20	0
104	BSL110	429382	5625672	sun	perpendicular	14.6	15.0	30-Aug-22	12:26	11.9	31-Aug-22	10:12	11.6	21.8	20	0
105	BSL113	429144	5626499	sun	oblique	11.9	12.4	30-Aug-22	12:33	12.9	31-Aug-22	10:21	11.7	21.8	20	0
106	BSL116	429074	5626784	sun	oblique	11.0	12.5	30-Aug-22	12:40	12.5	31-Aug-22	10:33	12.0	21.9	20	0
107	BSL119	428999	5627160	sun	oblique	12.0	12.7	30-Aug-22	15:17	11.9	31-Aug-22	12:07	11.9	20.8	20	0
108	BSL122	428999	5628042	sun	oblique	14.3	15.4	30-Aug-22	15:25	11.8	31-Aug-22	12:15	12.8	20.8	20	0
109	BSL125	428995	5628226	sun	parallel	11.8	12.0	30-Aug-22	15:30	11.4	31-Aug-22	12:24	12.5	20.9	20	0
110	BSL129	428557	5629018	sun	parallel	12.8	14.0	30-Aug-22	15:38	11.6	31-Aug-22	12:33	12.4	20.9	20	0
111	BSL132	427897	5629034	sun	oblique	11.0	11.2	30-Aug-22	15:46	11.7	31-Aug-22	12:42	11.7	20.9	20	0
112	BSL135	427388	5629105	sun	parallel	13.5	14.0	30-Aug-22	15:54	11.2	31-Aug-22	12:52	11.5	21.0	20	0
113	BSL138	426453	5629510	sun	parallel	11.5	11.6	31-Aug-22	11:12	12.2	1-Sep-22	9:58	12.4	22.8	20	0
114	BSL141	426291	5629733	sun	perpendicular	11.6	11.9	31-Aug-22	11:18	12.6	1-Sep-22	10:07	12.1	22.8	20	0

115	BSL144	426063	5629818	sun	oblique	12.1	12.3	31-Aug-22	11:25	12.3	1-Sep-22	10:13	12.2	22.8	20	0
116	BSL147	425764	5630106	sun	parallel	10.4	10.8	31-Aug-22	11:31	11.8	1-Sep-22	10:21	12.3	22.8	20	0
117	BSL150	425356	5630570	sun	parallel	11.5	11.8	31-Aug-22	11:39	12.1	1-Sep-22	10:28	12.2	22.8	20	0
118	BSL154	425204	5631290	sun	perpendicular	11.3	11.9	31-Aug-22	11:49	11.9	1-Sep-22	10:37	12.5	22.8	20	0
119	BSL157	425155	5631796	sun	oblique	10.8	11.4	31-Aug-22	13:28	12.6	1-Sep-22	13:02	12.8	23.6	20	0
120	BSL160	425030	5632303	sun	parallel	10.2	12.3	31-Aug-22	13:36	14.2	1-Sep-22	13:10	14.1	23.6	20	0
121	BSL163	424259	5632494	sun	parallel	11.3	11.6	31-Aug-22	13:45	11.9	1-Sep-22	13:20	11.8	23.6	20	0
122	BSL166	423933	5632819	sun	parallel	10.1	11.3	31-Aug-22	13:52	11.7	1-Sep-22	13:28	11.6	23.6	20	0
123	BSL169	423712	5632934	sun	oblique	11.8	12.7	31-Aug-22	13:58	11.7	1-Sep-22	13:38	11.5	23.7	20	0
124	BSL172	422972	5633369	sun	parallel	13.8	14.0	31-Aug-22	14:05	11.5	1-Sep-22	13:48	11.4	23.7	20	0
125	BSL199	421022	5637435	sun	parallel	9.5	9.7	1-Sep-22	11:21	11.6	2-Sep-22	9:55	11.6	22.6	20	0
126	BSL197	420877	5636905	sun	perpendicular	6.9	7.9	1-Sep-22	11:31	11.1	2-Sep-22	10:08	11.1	22.6	20	0
127	BSL196	421289	5636729	sun	perpendicular	8.6	9.7	1-Sep-22	11:39	11.4	2-Sep-22	10:21	11.3	22.7	20	0
128	BSL194	420996	5636275	sun	perpendicular	10.1	11.3	1-Sep-22	11:47	11.1	2-Sep-22	10:37	11.1	22.8	20	0
129	BSL193	421522	5636353	sun	oblique	6.8	7.3	1-Sep-22	11:56	11.5	2-Sep-22	10:54	11.3	23.0	20	0
130	BSL191	421359	5635909	sun	perpendicular	6.9	7.4	1-Sep-22	12:04	11.3	2-Sep-22	11:03	11.7	23.0	20	0
131	BSL189	421684	5635674	sun	oblique	6.4	7.4	1-Sep-22	14:26	13.0	2-Sep-22	13:08	14.1	22.7	20	0
132	BSL188	420687	5635390	sun	parallel	12.9	16.0	1-Sep-22	14:36	11.5	2-Sep-22	13:20	11.4	22.7	20	0
133	BSL185	421199	5634941	sun	oblique	8.7	9.8	1-Sep-22	14:46	11.4	2-Sep-22	13:37	12.4	22.9	20	0
134	BSL182	421932	5634373	sun	parallel	6.7	8.9	1-Sep-22	14:56	11.5	2-Sep-22	13:54	11.5	23.0	20	0
135	BSL179	422224	5634097	sun	parallel	11.3	11.8	1-Sep-22	15:04	11.4	2-Sep-22	14:05	11.4	23.0	20	0
136	BSL175	422715	5633687	sun	parallel	10.7	11.8	1-Sep-22	15:14	11.4	2-Sep-22	14:30	11.4	23.3	20	0
137	BSL161	424751	5632446	sun	perpendicular	10.2	11.0	2-Sep-22	11:44	12.6	3-Sep-22	9:54	12.1	22.2	20	0
138	BSL158	425198	5632030	sun	parallel	13.7	14.2	2-Sep-22	11:52	12.4	3-Sep-22	10:03	11.7	22.2	20	0
139	BSL155	425348	5631426	sun	perpendicular	11.8	12.2	2-Sep-22	11:59	13.1	3-Sep-22	10:11	11.7	22.2	20	0
140	BSL152	425246	5631054	sun	parallel	10.7	12.2	2-Sep-22	12:06	12.7	3-Sep-22	10:19	11.9	22.2	20	0
141	BSL149	425508	5630377	sun	parallel	10.6	11.1	2-Sep-22	12:15	12.4	3-Sep-22	10:29	12.3	22.2	20	0
142	BSL146	425801	5630003	sun	oblique	13.3	13.6	2-Sep-22	12:21	13.4	3-Sep-22	10:38	12.0	22.3	20	0
143	BSL093	429758	5622931	sun	oblique	14.2	14.5	2-Sep-22	15:21	11.9	3-Sep-22	12:57	14.4	21.6	20	1
144	BSL089	430301	5622330	sun	oblique	14.3	14.8	2-Sep-22	15:30	12.1	3-Sep-22	13:44	14.0	22.2	20	0
145	BSL086	430633	5622031	sun	perpendicular	14.3	15.0	2-Sep-22	15:37	12.1	3-Sep-22	13:53	12.9	22.3	20	0
146	BSL083	430818	5621570	sun	perpendicular	12.7	13.5	2-Sep-22	15:43	12.2	3-Sep-22	14:03	12.8	22.3	20	0
147	BSL080	431041	5621280	sun	oblique	13.3	13.9	2-Sep-22	15:50	12.3	3-Sep-22	14:12	13.1	22.4	20	0
148	BSL077	431363	5620644	sun	parallel	12.7	13.1	2-Sep-22	15:56	11.9	3-Sep-22	14:21	12.5	22.4	20	0
149	BSL074	431430	5620210	smoke	perpendicular	12.6	13.0	3-Sep-22	11:32	12.3	4-Sep-22	9:27	17.1	21.9	20	0
150	BSL071	431772	5620037	smoke	perpendicular	13.5	13.9	3-Sep-22	11:39	14.8	4-Sep-22	9:37	17.7	22.0	20	0
151	BSL068	431802	5629515	smoke	parallel	13.8	14.3	3-Sep-22	11:46	16.0	4-Sep-22	9:46	17.5	22.0	20	0
152	BSL064	431905	5618928	smoke	perpendicular	13.1	14.9	3-Sep-22	11:53	14.8	4-Sep-22	9:56	17.9	22.1	20	1
153	BSL061	432379	5618462	smoke	perpendicular	12.4	13.6	3-Sep-22	12:02	16.3	4-Sep-22	10:33	18.5	22.5	20	0
154	BSL058	432510	5618066	smoke	parallel	14.3	14.8	3-Sep-22	12:09	17.1	4-Sep-22	10:43	18.3	22.6	20	0

155	CSL052	433279	5616961	sun/wind	oblique	10.4	10.8	17-Sep-22	11:08	12.9	18-Sep-22	9:24	13.5	22.3	20	0
156	CSL055	432861	5617550	sun/wind	oblique	12.0	12.3	17-Sep-22	11:18	12.1	18-Sep-22	9:35	13.1	22.3	20	0
157	CSL059	432441	5618129	sun/wind	oblique	11.9	12.7	17-Sep-22	11:28	12.1	18-Sep-22	9:46	11.8	22.3	20	0
158	CSL062	432238	5618636	sun/wind	perpendicular	10.4	10.9	17-Sep-22	11:38	12.1	18-Sep-22	9:55	11.2	22.3	20	0
159	CSL065	432047	5619107	sun/wind	perpendicular	10.8	11.4	17-Sep-22	11:45	12.0	18-Sep-22	10:04	11.1	22.3	20	0
160	CSL068	431861	5619430	sun/wind	oblique	11.7	12.3	17-Sep-22	11:53	11.3	18-Sep-22	10:18	11.1	22.4	20	0
161	CSL071	431663	5619969	sun/wind	parallel	11.8	12.1	17-Sep-22	13:44	11.5	18-Sep-22	12:27	11.4	22.7	20	0
162	CSL074	431497	5620349	sun/wind	oblique	10.8	11.7	17-Sep-22	13:52	11.4	18-Sep-22	12:34	11.4	22.7	20	0
163	CSL077	431265	5620844	sun/wind	oblique	10.8	11.2	17-Sep-22	14:02	11.4	18-Sep-22	12:42	11.4	22.7	20	0
164	CSL080	430975	5621288	sun/wind	perpendicular	10.2	11.8	17-Sep-22	14:13	9:36	18-Sep-22	12:53	11.6	22.7	20	0
165	CSL084	430703	5621867	sun/wind	parallel	11.8	12.0	17-Sep-22	14:20	11.4	18-Sep-22	13:01	11.6	22.7	20	0
166	CSL087	430389	5622268	sun/wind	oblique	12.0	12.4	17-Sep-22	14:33	11.5	18-Sep-22	13:12	11.5	22.7	20	0
167	CSL090	430028	5622647	sun/wind	perpendicular	11.5	11.9	18-Sep-22	11:08	11.4	19-Sep-22	9:56	11.6	22.8	20	1
168	CSL093	429798	5623122	sun/wind	perpendicular	9.2	11.1	18-Sep-22	11:16	11.4	19-Sep-22	10:48	11.5	23.5	20	1
169	CSL096	429501	5623316	sun/wind	parallel	13.1	13.6	18-Sep-22	11:26	11.5	19-Sep-22	11:21	11.8	23.9	20	0
170	CSL099	429279	5623930	sun/wind	parallel	12.1	12.5	18-Sep-22	11:34	11.5	19-Sep-22	11:30	11.6	23.9	20	0
171	CSL102	429336	5624576	sun/wind	oblique	9.8	11.1	18-Sep-22	11:42	11.4	19-Sep-22	11:41	11.4	24.0	20	0
172	CSL105	429308	5625035	sun/wind	oblique	11.1	11.9	18-Sep-22	11:48	11.5	19-Sep-22	11:50	11.5	24.0	20	0
173	CSL109	429296	5625812	sun/wind	perpendicular	11.3	12.2	18-Sep-22	13:55	11.6	19-Sep-22	13:27	11.4	23.5	20	0
174	CSL112	429249	5626333	sun/wind	perpendicular	8.6	9.5	18-Sep-22	14:02	11.6	19-Sep-22	13:35	11.4	23.6	20	0
175	CSL115	429153	5626889	sun/wind	oblique	4.5	6.8	18-Sep-22	14:10	11.3	19-Sep-22	13:46	11.3	23.6	20	0
176	CSL118	429076	5627223	sun/wind	perpendicular	10.9	11.4	18-Sep-22	14:16	11.6	19-Sep-22	13:53	11.6	23.6	20	0
177	CSL121	429007	5627834	sun/wind	oblique	12.8	13.4	18-Sep-22	14:24	11.6	19-Sep-22	14:02	11.5	23.6	20	0
178	CSL124	429116	5628235	sun/wind	perpendicular	9.6	13.8	18-Sep-22	14:32	11.8	19-Sep-22	14:14	11.3	23.7	20	0
179	CSL127	428872	5628762	cloud	perpendicular	13.3	16.5	19-Sep-22	12:06	11.4	20-Sep-22	10:30	12.0	22.4	20	0
180	CSL130	428328	5629216	cloud	perpendicular	10.4	12.2	19-Sep-22	12:14	11.3	20-Sep-22	10:41	11.9	22.5	20	0
181	CSL134	427293	5629118	cloud	perpendicular	10.2	11.5	19-Sep-22	12:22	11.3	20-Sep-22	10:49	12.1	22.5	20	0
182	CSL137	426908	5629063	cloud	perpendicular	12.0	12.2	19-Sep-22	12:27	11.4	20-Sep-22	10:59	12.1	22.5	20	0
183	CSL140	426520	5629526	cloud	perpendicular	9.4	10.4	19-Sep-22	12:33	11.5	20-Sep-22	11:10	12.2	22.6	20	1
184	CSL143	426288	5629825	cloud	perpendicular	9.4	10.1	19-Sep-22	12:38	11.5	20-Sep-22	12:12	12.2	23.6	20	0
185	CSL146	425742	5629986	cloud	perpendicular	10.9	12.9	19-Sep-22	14:26	11.6	20-Sep-22	14:38	12.4	24.2	20	0
186	CSL149	425546	5630284	cloud	perpendicular	7.2	9.1	19-Sep-22	14:33	11.6	20-Sep-22	14:54	12.4	24.4	20	0
187	CSL152	425258	5631103	cloud	perpendicular	9.9	10.4	19-Sep-22	14:39	11.7	20-Sep-22	15:03	12.4	24.4	20	0
188	CSL155	425320	5631472	cloud	oblique	10.2	10.3	19-Sep-22	14:46	11.9	20-Sep-22	15:10	12.3	24.4	20	0
189	CSL159	425237	5632079	cloud	oblique	11.3	11.7	19-Sep-22	14:52	11.7	20-Sep-22	15:20	12.4	24.5	20	0
190	CSL162	424484	5632412	cloud	parallel	8.4	9.8	19-Sep-22	14:58	11.8	20-Sep-22	15:33	12.3	24.6	20	0
191	CSL199	422221	5637443	sun	parallel	5.3	5.8	20-Sep-22	13:28	11.9	21-Sep-22	10:12	11.9	20.7	20	0
192	CSL196	422366	5637130	sun	parallel	3.1	5.2	20-Sep-22	13:38	12.0	21-Sep-22	10:21	11.9	20.7	20	0
193	CSL193	422296	5636827	sun	parallel	4.4	4.8	20-Sep-22	13:45	12.1	21-Sep-22	10:28	11.9	20.7	20	0
194	CSL190	422211	5636344	sun	perpendicular	4.3	5.4	20-Sep-22	13:53	12.1	21-Sep-22	10:39	12.2	20.8	20	0

195	CSL187	421208	5635484	sun	oblique	4.6	5.0	20-Sep-22	14:07	12.1	21-Sep-22	10:47	11.9	20.7	20	0
196	CSL184	421027	5634929	sun	oblique	6.2	6.6	20-Sep-22	14:15	12.1	21-Sep-22	10:55	12.1	20.7	20	0
196	CSL180	422305	5634000	sun	parallel	8.4	8.8	20-Sep-22	16:16	12.3	21-Sep-22	13:04	12.4	20.8	20	0
198	CSL177	422577	5633761	sun	parallel	9.6	11.4	20-Sep-22	16:21	12.3	21-Sep-22	13:19	12.3	21.0	20	0
199	CSL174	422882	5633398	sun	parallel	11.7	12.2	20-Sep-22	16:28	12.3	21-Sep-22	13:27	12.4	21.0	20	0
200	CSL171	423471	5633042	sun	parallel	12.0	12.8	20-Sep-22	16:34	12.2	21-Sep-22	13:37	12.3	21.1	20	0
201	CSL168	423870	5632833	sun	parallel	9.8	10.3	20-Sep-22	16:41	12.2	21-Sep-22	13:45	12.4	21.1	20	0
202	CSL165	424132	5632616	sun	parallel	8.2	8.4	20-Sep-22	16:48	12.2	21-Sep-22	13:54	12.3	21.1	20	0
203	CSL154	425208	5631165	sun	parallel	9.3	9.4	21-Sep-22	11:41	12.6	22-Sep-22	9:30	12.6	21.8	20	0
204	CSL151	425155	5630837	sun	oblique	7.9	9.1	21-Sep-22	11:47	12.6	22-Sep-22	9:38	12.6	21.9	20	0
205	CSL148	424921	5630446	sun	parallel	7.8	7.9	21-Sep-22	11:54	12.3	22-Sep-22	9:45	12.6	21.9	20	0
206	CSL145	425907	5630347	sun	oblique	5.4	5.7	21-Sep-22	12:05	12.5	22-Sep-22	9:53	12.6	21.8	20	0
207	CSL141	426004	5629787	sun	perpendicular	8.7	8.9	21-Sep-22	12:11	12.5	22-Sep-22	10:00	12.6	21.8	20	0
208	CSL138	426427	5629407	sun	parallel	9.6	9.8	21-Sep-22	12:18	12.5	22-Sep-22	10:15	12.6	22.0	20	0
209	CSL135	427487	5629052	sun	parallel	10.8	11.7	21-Sep-22	15:16	12.6	22-Sep-22	11:55	12.9	20.7	20	0
210	CSL132	427791	5629074	sun	oblique	9.3	9.8	21-Sep-22	15:22	12.5	22-Sep-22	12:03	12.9	20.7	20	0
211	CSL129	428301	5629288	sun	perpendicular	5.6	6.9	21-Sep-22	15:30	12.7	22-Sep-22	12:10	13.0	20.7	20	0
212	CSL126	428514	5629001	sun	parallel	9.1	9.9	21-Sep-22	15:37	12.5	22-Sep-22	12:19	13.1	20.7	20	0
213	CSL123	428787	5628888	sun	parallel	6.8	14.5	21-Sep-22	15:44	12.5	22-Sep-22	12:25	13.0	20.7	20	0
214	CSL120	428881	5628500	sun	parallel	9.6	10.2	21-Sep-22	15:53	12.5	22-Sep-22	12:34	13.1	20.7	20	0
215	CSL082	430727	5621508	cloud	perpendicular	9.0	9.2	22-Sep-22	11:01	12.6	23-Sep-22	9:18	12.8	22.3	20	0
216	CSL085	430652	5622109	cloud	perpendicular	11.6	12.3	22-Sep-22	11:12	12.6	23-Sep-22	9:28	12.8	22.3	20	0
217	CSL088	430291	5622482	cloud	perpendicular	12.0	12.7	22-Sep-22	11:18	12.8	23-Sep-22	9:37	12.8	22.3	20	0
218	CSL091	429786	5622800	cloud	perpendicular	11.7	12.5	22-Sep-22	11:27	12.8	23-Sep-22	9:46	12.6	22.3	20	0
219	CSL095	429491	5623270	cloud	perpendicular	12.4	13.2	22-Sep-22	11:34	12.9	23-Sep-22	9:55	12.6	22.4	20	0
220	CSL098	429209	5623978	cloud	perpendicular	11.1	13.3	22-Sep-22	11:41	12.9	23-Sep-22	10:03	12.7	22.4	20	0
221	CSL101	429396	5624670	cloud	perpendicular	10.3	11.5	22-Sep-22	13:47	12.9	23-Sep-22	12:09	12.6	22.4	20	0
222	CSL104	429399	5625060	cloud	perpendicular	11.4	11.8	22-Sep-22	13:54	12.8	23-Sep-22	12:18	12.6	22.4	20	0
223	CSL107	429437	5625308	cloud	perpendicular	8.5	12.6	22-Sep-22	14:01	12.8	23-Sep-22	12:27	12.4	22.4	20	0
224	CSL110	429407	5625672	cloud	parallel	13.9	14.9	22-Sep-22	14:09	12.8	23-Sep-22	12:37	12.5	22.5	20	0
225	CSL113	428952	5626663	cloud	oblique	11.8	12.5	22-Sep-22	14:18	13.0	23-Sep-22	12:49	12.5	22.5	20	0
226	CSL116	428843	5626875	cloud	perpendicular	5.5	12.5	22-Sep-22	14:25	13.0	23-Sep-22	12:58	12.5	22.6	20	0
227	CSL079	430939	5621098	cloud	oblique	8.7	9.0	23-Sep-22	10:47	12.8	24-Sep-22	9:38	12.4	22.9	20	0
228	CSL076	431473	5620759	cloud	oblique	10.9	12.0	23-Sep-22	10:55	12.6	24-Sep-22	9:47	12.4	22.9	20	0
229	CSL073	431457	5620187	cloud	parallel	9.9	10.1	23-Sep-22	11:03	12.7	24-Sep-22	9:55	12.4	22.9	20	0
230	CSL070	431837	5619937	cloud	oblique	10.6	11.3	23-Sep-22	11:14	12.8	24-Sep-22	10:04	12.4	22.8	20	0
231	CSL066	432059	5619293	cloud	oblique	10.4	11.3	23-Sep-22	11:21	12.7	24-Sep-22	10:17	12.4	22.9	20	1
232	CSL063	432036	5618810	cloud	parallel	13.2	13.8	23-Sep-22	11:29	12.7	24-Sep-22	10:51	12.5	23.4	20	0
233	DSL025	434682	5613057	sun	perpendicular	11.6	11.8	12-Oct-22	10:20	12.7	13-Oct-22	9:04	13.0	22.7	20	0
234	DSL028	434863	5613554	sun	perpendicular	9.7	9.8	12-Oct-22	10:28	12.9	13-Oct-22	9:13	13.0	22.8	20	0

235	DSL031	435100	5613966	sun	oblique	8.5	9.2	12-Oct-22	10:39	13.0	13-Oct-22	9:21	13.0	22.7	20	0
236	DSL034	435370	5614360	sun	perpendicular	7.6	9.9	12-Oct-22	10:47	13.2	13-Oct-22	9:29	13.1	22.7	20	0
237	DSL037	435807	5614784	sun	perpendicular	8.0	8.9	12-Oct-22	10:55	13.6	13-Oct-22	9:39	13.1	22.7	20	0
238	DSL040	435049	5615444	sun	perpendicular	9.0	9.3	12-Oct-22	12:10	14.1	13-Oct-22	11:08	13.1	23.0	20	0
239	DSL043	434825	5615586	sun	perpendicular	9.3	10.1	12-Oct-22	12:16	14.0	13-Oct-22	11:16	13.4	23.0	20	0
240	DSL046	434004	5616047	sun	perpendicular	9.3	9.7	12-Oct-22	12:27	14.0	13-Oct-22	11:25	13.5	23.0	20	1
241	DSL050	433385	5616796	sun	perpendicular	8.5	9.6	12-Oct-22	12:37	14.0	13-Oct-22	12:18	13.6	23.7	20	0
242	DSL053	433166	5617286	sun	perpendicular	9.5	9.8	12-Oct-22	12:47	13.1	13-Oct-22	12:25	13.1	23.6	20	1
243	DSL065	432064	5618950	sun	perpendicular	9.9	11.1	13-Oct-22	10:21	10.3	14-Oct-22	9:19	10.8	23.0	20	0
244	DSL068	431803	5619393	sun	perpendicular	9.5	10.1	13-Oct-22	10:27	10.3	14-Oct-22	9:28	10.8	23.0	20	0
245	DSL071	431715	5620005	sun	perpendicular	9.1	9.8	13-Oct-22	10:33	10.3	14-Oct-22	9:37	10.8	23.1	20	0
246	DSL075	431274	5620677	sun	perpendicular	8.6	9.2	13-Oct-22	10:40	10.4	14-Oct-22	9:47	10.8	23.1	20	0
247	DSL078	431318	5620969	sun	oblique	8.6	9.5	13-Oct-22	10:48	10.3	14-Oct-22	9:57	10.7	23.2	20	0
248	DSL081	431030	5621531	sun	perpendicular	10.4	11.2	13-Oct-22	13:50	10.7	14-Oct-22	12:21	10.7	22.5	20	0
249	DSL084	430744	5622005	sun	perpendicular	10.1	11.1	13-Oct-22	13:58	10.7	14-Oct-22	11:34	10.8	21.6	20	1
250	DSL087	430393	5622317	sun	parallel	10.1	10.6	13-Oct-22	14:05	10.7	14-Oct-22	12:32	10.8	22.5	20	1
251	DSL090	429777	5622929	sun	oblique	9.5	10.1	13-Oct-22	14:13	10.7	14-Oct-22	13:12	10.8	23.0	20	1
252	DSL093	429616	5623335	sun	perpendicular	7.8	9.1	13-Oct-22	14:19	10.8	14-Oct-22	13:43	10.7	23.4	20	1
253	DSL118	428945	5627007	sun/cloud	perpendicular	8.3	8.5	14-Oct-22	10:40	10.6	15-Oct-22	9:36	10.6	22.9	20	0
254	DSL121	429101	5627930	sun/cloud	perpendicular	8.3	10.6	14-Oct-22	10:47	10.7	15-Oct-22	9:45	10.6	23.0	20	0
255	DSL125	428945	5628397	sun/cloud	perpendicular	7.6	9.5	14-Oct-22	10:55	10.6	15-Oct-22	9:59	10.6	23.1	20	0
256	DSL128	428864	5628655	sun/cloud	perpendicular	10.6	11.5	14-Oct-22	11:00	10.6	15-Oct-22	10:24	10.7	23.4	20	0
257	DSL131	427943	5628800	sun/cloud	parallel	6.8	8.0	14-Oct-22	11:10	10.8	15-Oct-22	10:35	10.5	23.4	20	0
258	DSL134	427261	5629130	sun/cloud	perpendicular	7.4	9.8	14-Oct-22	15:00	11.3	15-Oct-22	12:22	10.9	21.4	20	0
259	DSL137	427024	5629222	sun/cloud	perpendicular	4.6	8.6	14-Oct-22	15:06	11.1	15-Oct-22	12:30	10.8	21.4	20	0
260	DSL140	426492	5629516	sun/cloud	perpendicular	6.8	7.5	14-Oct-22	15:11	11.1	15-Oct-22	12:39	11.0	21.5	20	0
261	DSL143	426259	5629829	sun/cloud	perpendicular	7.3	8.2	14-Oct-22	15:17	11.3	15-Oct-22	12:51	11.1	21.6	20	0
262	DSL146	425618	5630205	sun/cloud	perpendicular	7.6	8.4	14-Oct-22	15:23	11.1	15-Oct-22	12:58	11.0	21.6	20	0
263	DSL171	423428	5633078	sun	parallel	8.7	10.1	15-Oct-22	11:18	10.8	16-Oct-22	9:39	11.0	22.4	20	0
264	DSL175	422750	5633642	sun	parallel	6.3	9.2	15-Oct-22	11:26	10.8	16-Oct-22	9:50	10.8	22.4	20	0
265	DSL178	422364	5633926	sun	parallel	7.7	8.3	15-Oct-22	11:33	10.8	16-Oct-22	10:00	10.8	22.5	20	0
266	DSL181	421928	5634289	sun	parallel	8.8	9.2	15-Oct-22	11:40	10.8	16-Oct-22	11:06	10.9	23.4	20	0
267	DSL184	421601	5634497	sun	parallel	10.4	13.8	15-Oct-22	11:47	10.6	16-Oct-22	11:16	10.8	23.5	20	0
268	DSL187	420871	5635053	sun	oblique	4.0	4.8	15-Oct-22	13:36	11.0	16-Oct-22	11:25	10.9	21.8	20	0
269	DSL190	421368	5635659	sun	oblique	2.4	3.4	15-Oct-22	13:47	10.9	16-Oct-22	11:34	10.7	21.8	20	0
270	DSL193	421374	5636417	sun	parallel	2.8	4.2	15-Oct-22	13:59	11.1	16-Oct-22	11:43	10.8	21.7	20	0
271	DSL167	423934	5632867	sun	oblique	6.3	6.8	16-Oct-22	10:24	11.0	17-Oct-22	9:32	10.8	23.1	20	0
272	DSL164	424157	5632477	sun	perpendicular	7.1	9.1	16-Oct-22	10:31	11.1	17-Oct-22	9:43	10.8	23.2	20	0
273	DSL161	424711	5632508	sun	perpendicular	4.2	5.8	16-Oct-22	10:38	11.1	17-Oct-22	9:50	10.9	23.2	20	0
274	DSL157	425167	5631780	sun	perpendicular	6.6	7.5	16-Oct-22	10:45	11.1	17-Oct-22	10:01	10.8	23.3	20	0

275	DSL154	425324	5631343	sun	perpendicular	7.7	8.3	16-Oct-22	10:52	11.1	17-Oct-22	10:08	11.0	23.3	20	0
276	DSL151	425235	5630928	sun	perpendicular	7.4	8.0	16-Oct-22	13:49	11.4	17-Oct-22	11:58	10.9	22.2	20	0
277	DSL148	425547	5630309	sun	perpendicular	6.8	8.1	16-Oct-22	13:57	11.5	17-Oct-22	12:06	10.9	22.2	20	0
278	DSL145	425857	5630000	sun	parallel	5.9	8.1	16-Oct-22	14:02	11.4	17-Oct-22	12:12	10.9	22.2	20	0
279	DSL142	426472	5629670	sun	perpendicular	7.4	9.2	16-Oct-22	14:10	11.8	17-Oct-22	12:20	11.0	22.2	20	0
280	DSL139	426873	5629276	sun	oblique	6.9	7.4	16-Oct-22	14:16	12.0	17-Oct-22	12:30	11.0	22.2	20	0
281	DSL107	429164	5625262	sun	perpendicular	6.8	7.5	17-Oct-22	11:19	10.8	18-Oct-22	9:18	10.8	22.0	20	0
282	DSL104	429258	5624884	sun	oblique	9.0	9.5	17-Oct-22	11:25	10.8	18-Oct-22	9:33	11.0	22.1	20	0
283	DSL101	429332	5624571	sun	perpendicular	9.3	9.7	17-Oct-22	11:30	10.9	18-Oct-22	9:46	11.0	22.3	20	0
284	DSL098	429210	5624094	sun	perpendicular	9.6	10.0	17-Oct-22	11:36	10.9	18-Oct-22	9:58	11.0	22.4	20	0
285	DSL095	429497	5623391	sun	perpendicular	8.3	9.6	17-Oct-22	11:41	10.9	18-Oct-22	10:05	10.9	22.4	20	0
286	DSL092	429998	5622800	sun	perpendicular	7.0	8.0	17-Oct-22	13:45	11.0	18-Oct-22	11:36	11.0	21.9	20	0
287	DSL089	430088	5622397	sun	perpendicular	8.3	10.0	17-Oct-22	13:50	10.9	18-Oct-22	11:47	10.9	22.0	20	0
288	DSL086	430530	5621978	sun	perpendicular	8.7	9.4	17-Oct-22	13:56	11.0	18-Oct-22	11:55	10.9	22.0	20	0
289	DSL082	430960	5621649	sun	perpendicular	10.2	11.2	17-Oct-22	14:04	11.0	18-Oct-22	12:02	11.1	22.0	20	0
290	DSL079	431194	5621130	sun	oblique	8.6	9.5	17-Oct-22	14:10	11.0	18-Oct-22	12:09	11.0	22.0	20	0
291	DSL061	432379	5618462	sun	oblique	7.1	7.5	18-Oct-22	10:42	10.8	19-Oct-22	9:30	10.7	22.8	20	0
292	DSL057	432544	5617933	sun	oblique	10.1	11.0	18-Oct-22	10:50	10.8	19-Oct-22	9:41	10.6	22.9	20	0
293	DSL054	432917	5617401	sun	perpendicular	9.1	9.4	18-Oct-22	10:59	10.9	19-Oct-22	9:52	10.6	22.9	20	0
294	DSL051	433318	5617215	sun	oblique	9.7	9.8	18-Oct-22	11:07	10.9	19-Oct-22	10:00	10.6	22.9	20	1
295	DSL048	433578	5616675	sun	parallel	10.9	11.7	18-Oct-22	11:15	11.0	19-Oct-22	10:41	10.6	23.4	20	0

Appendix D2 – 2022 Setline Bycatch

Table 26. Setline bycatch in the Middle Columbia River during CLBMON-21 in 2022, including juvenile White Sturgeon captures highlighted in yellow and sets with no fish caught (NFC) as grey-shaded cells.

Set	Site	Pull Date	Species	Life Stage	Quantity	Live	Dead	Length Min (mm)	Length Max (mm)	Weight Min (g)	Weight Max (g)	Comments
1	ASL027	8/13/2022	BB	A	5	1	4	503	743			
1	ASL027	8/13/2022	BB	J	1	1	0	375	375			
2	ASL030	8/13/2022	BB	A	4	4	0	518	680			
3	ASL033	8/13/2022	BB	A	5	4	1	478	640			
4	ASL036	8/13/2022	BB	A	7	7	0	530	612			
4	ASL036	8/13/2022	LSU	A	1	1	0	404	404			
5	ASL039	8/13/2022	NSC	A	1	1	0	341	341			
5	ASL039	8/13/2022	BB	A	2	2	0	544	592			
6	ASL042	8/13/2022	BB	A	3	3	0	482	646			
7	ASL045	8/13/2022	BB	A	5	2	3	427	615			
7	ASL045	8/13/2022	NSC	A	2	2	0	304	381			
8	ASL048	8/13/2022	NSC	A	1	1	0	359	359			
8	ASL048	8/13/2022	BB	A	3	0	3	625	642			
9	ASL052	8/14/2022	BB	A	2	0	2	594	642			
10	ASL055	8/14/2022	BB	A	2	0	2	523	628			
11	ASL058	8/14/2022	WSG	J	1	1	0	739	739	2744	2744	
12	ASL061	8/14/2022	NFC									
13	ASL064	8/14/2022	BB	A	2	2	0	493	910			left hook in to increase survival potential
14	ASL067	8/14/2022	WSG	J	1	1	0	658	658	1960	1960	
15	ASL070	8/14/2022	WSG	J	1	1	0	734	734	2620	2620	
15	ASL070	8/14/2022	WSG	J	2	2	0	606	606	1560	1560	
16	ASL073	8/14/2022	BB	A	3	2	1	469	581			
17	ASL077	8/15/2022	WSG	J	1	1	0	781	781	3664	3664	
18	ASL080	8/15/2022	NFC									
19	ASL083	8/15/2022	WSG	J	1	1	0	614	614	1655	1655	
19	ASL083	8/15/2022	BB	A	1	1	0	595	595			
20	ASL086	8/15/2022	BB	A	1	1	0	434	434			
21	ASL089	8/15/2022	NFC									
22	ASL092	8/15/2022	NFC									
23	ASL095	8/15/2022	NFC									
24	ASL098	8/15/2022	NFC									
25	ASL102	8/15/2022	NFC									
26	ASL105	8/15/2022	NFC									
27	ASL108	8/15/2022	NFC									
28	ASL111	8/15/2022	NFC									
29	ASL114	8/16/2022	BB	A	2	2	0	421	503			

30	ASL117	8/16/2022	BB	A	2	2	0	462	566			
30	ASL117	8/16/2022	NSC	A	1	0	1	312	312			Was stomach contents
31	ASL120	8/16/2022	NFC									
32	ASL123	8/16/2022	NFC									
33	ASL127	8/16/2022	NFC									
34	ASL130	8/16/2022	BB	J	1	0	1	361	361			
35	ASL133	8/16/2022	BB	A	1	1	0	519	519			
36	ASL136	8/16/2022	BB	A	2	2	0	545	685			
36	ASL136	8/16/2022	LSU	A	1	1	0	403	403			
37	ASL139	8/16/2022	BB	A	2	2	0	473	516			
38	ASL142	8/16/2022	BB	A	1	0	1	459	459			
39	ASL145	8/16/2022	NFC									
40	ASL148	8/16/2022	WSG	J	1	1	0	531	531	1074	1074	
41	ASL152	8/17/2022	WSG	J	1	1	0	651	651	2198	2198	
42	ASL155	8/17/2022	BB	A	1	1	0	558	558			
43	ASL158	8/17/2022	NFC									
44	ASL161	8/17/2022	BB	A	1	0	1	614	614			
44	ASL161	8/17/2022	BB	J	1	1	0	362	362			
44	ASL161	8/17/2022	NSC	A	2	2	0	332	334			
45	ASL 164	8/17/2022	CSU	A	1	1	0	431	431			
46	ASL167	8/17/2022	CSU	A	1	1	0	449	449			
47	ASL170	8/17/2022	NFC									
48	ASL173	8/17/2022	NFC									
49	ASL177	8/17/2022	CSU	A	1	1	0	431	431			
50	ASL180	8/17/2022	NFC									
51	ASL183	8/17/2022	NFC									
52	ASL186	8/17/2022	NFC									
53	ASL166	8/18/2022	NFC									
54	ASL169	8/18/2022	BB	A	1	0	1	446	446			
55	ASL172	8/18/2022	NFC									
56	ASL175	8/18/2022	NFC									
57	ASL178	8/18/2022	NFC									
58	ASL181	8/18/2022	CSU	A	1	1	0	401	401			
59	ASL191	8/18/2022	BB	A	1	1	0					Self release
59	ASL191	8/18/2022	LSU	A	1	1	0	424	424			
60	ASL194	8/18/2022	NFC									
61	ASL197	8/18/2022	NSC	A	1	1	0	316	316			
62	ASL200	8/18/2022	NFC									
63	ASL150	8/19/2022	NSC	A	3	3	0	344	345			
63	ASL150	8/19/2022	BB	A	1	1	0	566	566			
64	ASL147	8/19/2022	NSC	A	1	1	0					Self release
64	ASL147	8/19/2022	BB	A	1	1	0	425	425			

65	ASL144	8/19/2022	BB	A	1	1	0	456	456			
66	ASL141	8/19/2022	BB	J	1	1	0	320	320			
67	ASL138	8/19/2022	NFC									
68	ASL134	8/19/2022	NSC	A	1	1	0	341	341			
69	ASL131	8/19/2022	NFC									
70	ASL128	8/19/2022	LSU	A	1	1	0	412	412			
71	ASL106	8/20/2022	NFC									
72	ASL103	8/20/2022	BB	A	1	1	0	643	643			
73	ASL100	8/20/2022	NSC	A	1	1	0	308	308			
74	ASL097	8/20/2022	NSC	A	1	1	0	304	304			
75	ASL094	8/20/2022	NSC	A	1	1	0	308	308			
76	ASL091	8/20/2022	BB	A	2	2	1	438	438			1 self release
77	BSL025	8/29/2022	BB	A	2	0	2	435	516			
78	BSL029	8/29/2022	BB	A	1	1	0	550	550			
79	BSL032	8/29/2022	BB	A	4	3	1	469	545			
80	BSL035	8/29/2022	BB	A	2	1	1	527	560			
80	BSL035	8/29/2022	NSC	A	1	1	0	338	338			
81	BSL038	8/29/2022	BB	A	3	1	2	550	618			
81	BSL038	8/29/2022	NSC	A	1	1	0	341	341			
82	BSL041	8/29/2022	BB	A	3	2	1	484	640			
83	BSL044	8/29/2022	BB	A	2	0	2	545	589			
84	BSL047	8/29/2022	BB	A	6	2	4	507	615			
85	BSL050	8/29/2022	NFC									
86	BSL054	8/29/2022	BB	A	1	1	0	508	508			
87	BSL057	8/29/2022	BB	A	1	1	0	473	473			
88	BSL060	8/29/2022	NFC									
89	BSL063	8/30/2022	NFC									
90	BSL066	8/30/2022	NFC									
91	BSL069	8/30/2022	WSG	J	1	1	0	853	853	4480	4480	Hooked through gill plate
91	BSL069	8/30/2022	WSG	J	1	1	0	768	768	3251	3251	
92	BSL072	8/30/2022	CSU	A	1	1	0	429	429			
93	BSL075	8/30/2022	NSC	A	1	1	0	344	344			
94	BSL079	8/30/2022	BB	A	1	1	0	485	485			
95	BSL082	8/30/2022	NFC									
96	BSL085	8/30/2022	NFC									
97	BSL088	8/30/2022	WSG	J	1	1	0	506	506	1105	1105	
97	BSL088	8/30/2022	BB	A	1	1	0	500	500			
97	BSL091	8/30/2022	BB	J	1	1	0	376	376			
98	BSL091	8/30/2022	BB	A	2	1	1	539	596			
99	BSL094	8/30/2022	NFC									
100	BSL097	8/30/2022	NFC									
101	BSL100	8/31/2022	NFC									

102	BSL104	8/31/2022	NFC									
103	BSL107	8/31/2022	NFC									
104	BSL110	8/31/2022	NFC									
105	BSL113	8/31/2022	NFC									
106	BSL116	8/31/2022	NFC									
107	BSL119	8/31/2022	NFC									
108	BSL122	8/31/2022	NFC									
109	BSL125	8/31/2022	NFC									
110	BSL129	8/31/2022	NFC									
111	BSL132	8/31/2022	NFC									
112	BSL135	8/31/2022	NFC									
113	BSL138	9/1/2022	BB	J	1	1	0	344	344			
113	BSL138	9/1/2022	BB	A	1	1	0	586	586			
113	BSL138	9/1/2022	CSU	A	1	1	0	397	397			
114	BSL141	9/1/2022	BB	A	1	1	0	510	510			
114	BSL141	9/1/2022	BB	J	1	1	0	356	356			
115	BSL144	9/1/2022	NFC									
116	BSL147	9/1/2022	BB	A	1	1	0	444	444			
117	BSL150	9/1/2022	NFC									
118	BSL154	9/1/2022	NFC									
119	BSL157	9/1/2022	NFC									
120	BSL160	9/1/2022	NSC	A	1	1	0	348	348			
121	BSL163	9/1/2022	NFC									
122	BSL166	9/1/2022	NFC									
123	BSL169	9/1/2022	NFC									
124	BSL172	9/1/2022	NFC									
125	BSL199	9/2/2022	NFC									
126	BSL197	9/2/2022	CSU	A	1	1	0	435	435			
126	BSL197	9/2/2022	NSC	A	2	2	0	531	531			self release
127	BSL196	9/2/2022	NSC	A	1	1	0	356	356			
128	BSL194	9/2/2022	LSU	A	1	1	0	373	373			
129	BSL193	9/2/2022	NSC	A	1	1	0	340	340			
129	BSL193	9/2/2022	BB	A	1	0	1	531	531			
130	BSL191	9/2/2022	CSU	A	1	0	1	463	463			
131	BSL189	9/2/2022	BB	A	1	0	1	445	445			
131	BSL189	9/2/2022	LSU	A	2	2	0	409	410			
131	BSL189	9/2/2022	NSC	A	1	1	0	323	323			
132	BSL188	9/2/2022	NSC	A	1	1	0	406	406			
133	BSL185	9/2/2022	BB	A	1	0	1	424	424			
133	BSL185	9/2/2022	PCC	A	1	0	1	223	223			Was stomach contents - body hooked
134	BSL182	9/2/2022	BB	A	3	2	1	495	758			
135	BSL179	9/2/2022	NFC									

136	BSL175	9/2/2022	NFC									
137	BSL161	9/3/2022	NFC									
138	BSL158	9/3/2022	NFC									
139	BSL155	9/3/2022	NFC									
140	BSL152	9/3/2022	BB	A	2	2	0	495	590			
140	BSL152	9/3/2022	CSU	A	1	1	0	434	434			
141	BSL149	9/3/2022	BB	A	1	0	1	468	468			
142	BSL146	9/3/2022	NSC	A	1	1	0	410	410			
143	BSL093	9/3/2022	BB	A	2	2	0	454	553			
143	BSL093	9/3/2022	WSG	J	1	1	0	784	784	3499	3499	
144	BSL089	9/3/2022	BB	J	1	1	0	384	384			
144	BSL089	9/3/2022	BB	A	1	1	0	538	538			
145	BSL086	9/3/2022	BB	A	2	2	0	453	585			
146	BSL083	9/3/2022	BB	A	1	1	0	468	468			
147	BSL080	9/3/2022	BB	A	1	1	0	451	451			
148	BSL077	9/3/2022	NFC									
149	BSL074	9/4/2022	NFC									
150	BSL071	9/4/2022	BB	A	2	2	0	462	624			
151	BSL068	9/4/2022	NFC									
152	BSL064	9/4/2022	BB	A	1	1	0	542	542			
152	BSL064	9/4/2022	WSG	J	1	1	0	539	539	1158	1158	
153	BSL061	9/4/2022	NFC									
154	BSL058	9/4/2022	NFC									
155	CSL052	9/18/2022	NFC									
156	CSL055	9/18/2022	BB	A	1	1	0	553	553			
157	CSL059	9/18/2022	NFC									
158	CSL062	9/18/2022	NFC									
159	CSL065	9/18/2022	PCC	A	1	0	1	246	246			Was stomach contents
160	CSL068	9/18/2022	NFC									
161	CSL071	9/18/2022	BB	A	1	1	0	514	514			
162	CSL074	9/18/2022	NFC									
163	CSL077	9/18/2022	NFC									
164	CSL080	9/18/2022	NFC									
165	CSL084	9/18/2022	NFC									
166	CSL087	9/18/2022	BB	A	1	1	0	519	519			
167	CSL090	9/19/2022	WSG	J	1	1	0	1200	1200	12230	12230	
168	CSL093	9/19/2022	NSC	A	2	1	1	428	544			
168	CSL093	9/19/2022	WSG	J	1	1	0	685	685	2392	2392	
169	CSL096	9/19/2022	NFC									
170	CSL099	9/19/2022	BB	A	1	0	1	610	610			
171	CSL102	9/19/2022	CSU	A	1	1	0	437	437			
172	CSL105	9/19/2022	NFC									

173	CSL109	9/19/2022	BB	A	3	3	0	493	820			
174	CSL112	9/19/2022	BB	A	1	1	0	475	475			
175	CSL115	9/19/2022	NFC									
176	CSL118	9/19/2022	NFC									
177	CSL121	9/19/2022	NFC									
178	CSL124	9/19/2022	NFC									
179	CSL127	9/20/2022	NFC									
180	CSL130	9/20/2022	BB	A	1	1	0	735	735			
181	CSL134	9/20/2022	NFC									
182	CSL137	9/20/2022	NFC									
183	CSL140	9/20/2022	WSG	J	1	1	0	1200	1200	12230	12230	
184	CSL143	9/20/2022	BB	A	1	1	0	612	612			
184	CSL143	9/20/2022	PCC	A	1	0	1	223	223			Was stomach contents, partially digested
185	CSL146	9/20/2022	NFC									
186	CSL149	9/20/2022	NSC	A	1	1	0	290	290			
186	CSL149	9/20/2022	BB	A	1	0	1	546	546			
187	CSL152	9/20/2022	NFC									
188	CSL155	9/20/2022	NFC									
189	CSL159	9/20/2022	BB	A	1	1	0	534	534			
190	CSL162	9/20/2022	CSU	A	2	2	0	466	471			
191	CSL199	9/21/2022	NSC	A	1	1	0	395	395			
192	CSL196	9/21/2022	LSU	A	1	1	0	415	415			
193	CSL193	9/21/2022	NSC	A	1	1	0	388	388			Hooked in left eye but remained attached
194	CSL190	9/21/2022	CSU	A	1	1	0	396	396			Hooked in front of dorsal fin, left side
194	CSL190	9/21/2022	NSC	A	1	1	0	340	340			
195	CSL187	9/21/2022	LSU	A	1	1	0	409	409			
196	CSL184	9/21/2022	CSU	A	1	1	0	408	408			
197	CSL180	9/21/2022	NFC									
198	CSL177	9/21/2022	BB	J	1	1	0	340	340			
199	CSL174	9/21/2022	NFC									
200	CSL171	9/21/2022	LSU	A	1	1	0	388	388			
201	CSL168	9/21/2022	NFC									
202	CSL165	9/21/2022	CSU	A	2	2	0	442	448			
203	CSL154	9/22/2022	CSU	A	1	1	0	410	410			
204	CSL151	9/22/2022	NFC									
205	CSL148	9/22/2022	NFC									
206	CSL145	9/22/2022	NFC									
207	CSL141	9/22/2022	NSC	A	1	1	0	298	298			
208	CSL138	9/22/2022	NFC									

209	CSL135	9/22/2022	CSU	A	1	1	0					Self-release
210	CSL132	9/22/2022	NFC									
211	CSL129	9/22/2022	NFC									
212	CSL126	9/22/2022	NSC	A	1	1	0	313	313			
213	CSL123	9/22/2022	NFC									
214	CSL120	9/22/2022	NFC									
215	CSL082	9/23/2022	NFC									
216	CSL085	9/23/2022	CSU	A	1	1	0	433	433			
217	CSL088	9/23/2022	NFC									
218	CSL091	9/23/2022	NFC									
219	CSL095	9/23/2022	NFC									
220	CSL098	9/23/2022	NFC									
221	CSL101	9/23/2022	BB	J	1	1	0	357	357			
221	CSL101	9/23/2022	BB	A	1	1	0	423	423			
222	CSL104	9/23/2022	NFC									
223	CSL107	9/23/2022	NFC									
224	CSL110	9/23/2022	BB	A	1	1	0	645	645			
224	CSL110	9/23/2022	NSC	A	1	1	0	345	345			
225	CSL113	9/23/2022	NFC									
226	CSL116	9/23/2022	NFC									
227	CSL079	9/24/2022	BB	A	1	1	0	589	589			
227	CSL079	9/24/2022	LSU	A	1	1	0	384	384			
228	CSL076	9/24/2022	NFC									
229	CSL073	9/24/2022	CSU	A	1	1	0	456	456			
229	CSL073	9/24/2022	BB	A	1	0	1	544	544			
230	CSL070	9/24/2022	NFC									
231	CSL066	9/24/2022	WSG	J	1	1	0	665	665	1965	1965	
232	CSL063	9/24/2022	BB	A	1	1	0	560	560			
233	DSL025	10/13/2022	PCC	A	1	0	1	235	235			Was stomach contents
234	DSL028	10/13/2022	BB	A	1	1	0	550	550			
234	DSL028	10/13/2022	NSC	A	1	1	0	460	460			
235	DSL031	10/13/2022	NFC									
236	DSL034	10/13/2022	NFC									
237	DSL037	10/13/2022	BB	A	2	1	1	520	800			
238	DSL040	10/13/2022	BB	A	1	1	0	600	600			
239	DSL043	10/13/2022	BB	A	1	1	0	630	630			
240	DSL046	10/13/2022	WSG	J	1	1	0	558	558	1350	1350	
240	DSL046	10/13/2022	NSC	A	1	1	0	465	465			
241	DSL050	10/13/2022	CSU	A	1	1	0	360	360			
242	DSL053	10/13/2022	WSG	J	1	1	0	756	756	2820	2820	
243	DSL065	10/14/2022	BB	A	1	1	0	550	550			
243	DSL065	10/14/2022	NSC	A	1	1	0	445	445			

244	DSL068	10/14/2022	NFC									
245	DSL071	10/14/2022	BB	A	1	1	0	700	700			
246	DSL075	10/14/2022	BB	J	1	1	0	380	380			
246	DSL075	10/14/2022	BB	A	1	1	0	450	450			
247	DSL078	10/14/2022	NFC									
248	DSL081	10/14/2022	NFC									
249	DSL084	10/14/2022	WSG	J	1	1	0	809	809	3515	3515	
249	DSL084	10/14/2022	NSC	A	3	2	1	340	445			
249	DSL084	10/14/2022	LSU	A	3	3	0	425	450			
249	DSL084	10/14/2022	BB	A	1	1	0	800	800			
250	DSL087	10/14/2022	WSG	J	1	1	0	540	540	1330	1330	
251	DSL090	10/14/2022	WSG	J	1	1	0	590	590	1280	1280	
251	DSL090	10/14/2022	BB	A	1	1	0	490	490			
251	DSL090	10/14/2022	NSC	A	1	1	0	440	440			
252	DSL093	10/14/2022	WSG	J	1	1	0	702	702	2380	2380	
252	DSL093	10/14/2022	BB	A	1	1	0	-	-			Self-release
253	DSL118	10/15/2022	BB	A	1	1	0	600	600			
254	DSL121	10/15/2022	BB	J	1	1	0	362	362			
255	DSL125	10/15/2022	BB	A	3	1	2	498	710			
255	DSL125	10/15/2022	CSU	A	1	1	0	475	475			
256	DSL128	10/15/2022	BB	J	3	1	2	365	385			
256	DSL128	10/15/2022	CSU	A	2	2	0	435	498			
257	DSL131	10/15/2022	NFC									
258	DSL134	10/15/2022	BB	A	1	1	0	560	560			
258	DSL134	10/15/2022	CSU	A	1	1	0	442	442			
259	DSL137	10/15/2022	BB	A	1	1	0	430	430			
260	DSL140	10/15/2022	BB	A	1	1	0	700	700			
260	DSL140	10/15/2022	LW	A	1	1	0	452	452			
261	DSL143	10/15/2022	BB	J	1	1	0	395	395			
261	DSL143	10/15/2022	BB	A	1	1	0	487	487			
262	DSL146	10/15/2022	CSU	A	1	1	0	411	411			
263	DSL171	10/16/2022	CSU	A	1	1	0	400	400			
264	DSL175	10/16/2022	CSU	A	1	1	0	410	410			
264	DSL175	10/16/2022	BB	A	2	2	1	455	650			
265	DSL178	10/16/2022	BB	A	1	0	1	430	430			
265	DSL178	10/16/2022	NSC	A	1	1	0	380	380			
266	DSL181	10/16/2022	BB	A	3	3	0	410	600			
266	DSL181	10/16/2022	NSC	A	1	1	0	430	430			
267	DSL184	10/16/2022	BB	A	1	1	0	490	490			
268	DSL187	10/16/2022	CSU	A	2	2	0	392	398			
269	DSL190	10/16/2022	NFC									
270	DSL193	10/16/2022	NFC									
271	DSL167	10/17/2022	CSU	A	3	3	0	440	445			self release

272	DSL164	10/17/2022	BB	J	2	2	0	345	365			
273	DSL161	10/17/2022	CSU	A	1	1	0	460	460			
274	DSL157	10/17/2022	LSU	A	1	1	0	372	372			
275	DSL154	10/17/2022	CSU	A	1	1	0	390	390			
276	DSL151	10/17/2022	CSU	A	1	1	0	425	425			
277	DSL148	10/17/2022	NFC									
278	DSL145	10/17/2022	BB	J	1	0	1	330	330			
279	DSL142	10/17/2022	NFC									
280	DSL139	10/17/2022	NSC	A	1	1	0	335	335			
280	DSL139	10/17/2022	BB	J	1	1	0	370	370			
281	DSL107	10/18/2022	CSU	A	2	2	0	441	445			
282	DSL104	10/18/2022	BB	A	2	2	0	510	598			
282	DSL104	10/18/2022	NSC	A	1	0	1	525	525			
283	DSL101	10/18/2022	BB	A	2	2	0	498	750			
283	DSL101	10/18/2022	BB	J	1	0	1	380	380			
283	DSL101	10/18/2022	LSU	A	3	3	0	412	440			Body hooked behind right pectoral fin
284	DSL098	10/18/2022	CSU	A	2	2	0	453	460			
284	DSL098	10/18/2022	NSC	A	1	1	0	410	410			
284	DSL098	10/18/2022	BB	A	1	1	0	410	410			
284	DSL098	10/18/2022	BB	J	1	1	0	352	352			
285	DSL095	10/18/2022	BB	A	1	1	0	430	430			
286	DSL092	10/18/2022	NSC	A	1	1	0	-	-			Self-release
286	DSL092	10/18/2022	LSU	A	1	1	0	-	-			Self-release
287	DSL089	10/18/2022	LSU	A	3	3	0	380	485			
287	DSL089	10/18/2022	NSC	A	2	2	0	385	495			
288	DSL086	10/18/2022	BB	A	1	1	0	415	415			
289	DSL082	10/18/2022	LSU	A	1	1	0	412	412			
290	DSL079	10/18/2022	LSU	A	1	1	0	405	405			
290	DSL079	10/18/2022	CSU	A	2	2	0	430	455			
291	DSL061	10/19/2022	NFC									
292	DSL057	10/19/2022	CSU	A	3	3	0	396	455			
292	DSL057	10/19/2022	BB	A	1	1	0	430	430			
293	DSL054	10/19/2022	CSU	A	3	3	0	460	490			
293	DSL054	10/19/2022	NSC	A	1	1	0	528	528			
294	DSL051	10/19/2022	WSG	J	1	1	0	718	718	2420	2420	
294	DSL051	10/19/2022	BB	A	1	1	0	505	505			
295	DSL048	10/19/2022	CSU	A	1	1	0	458	458			
295	DSL048	10/19/2022	BB	A	1	0	1	605	605			

Appendix E – Maps of Sampling Effort and Juvenile White Sturgeon Captures by River Section (2007 – 2022)

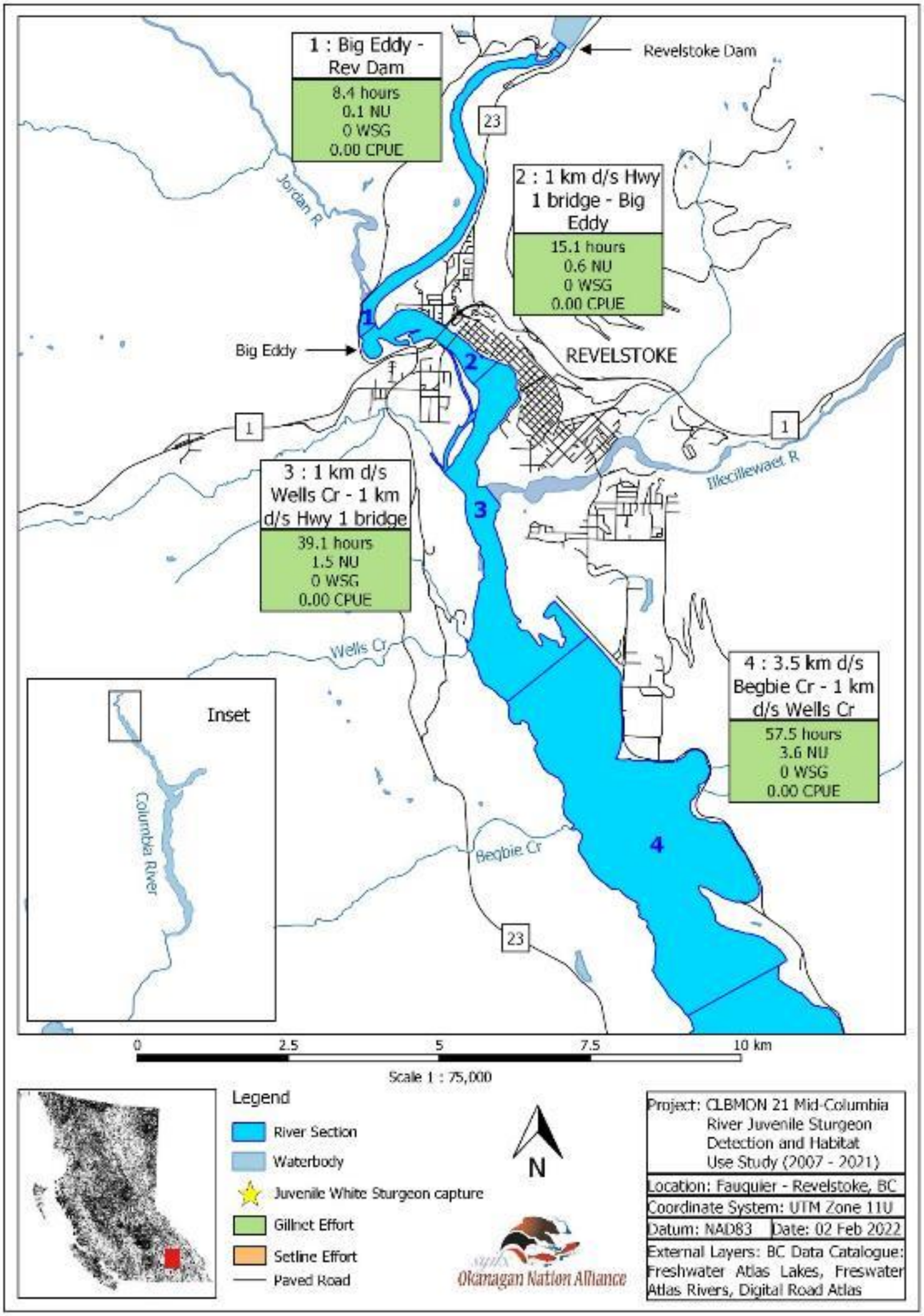

Figure 28. Juvenile White Sturgeon capture locations, effort, and associated catch-per-unit-effort (CPUE) from 3.5 km downstream of Begbie Creek to Revelstoke Dam (2007 – 2022). Data collected by BC Hydro, Golder Associates Ltd., and Okanagan Nation Alliance.

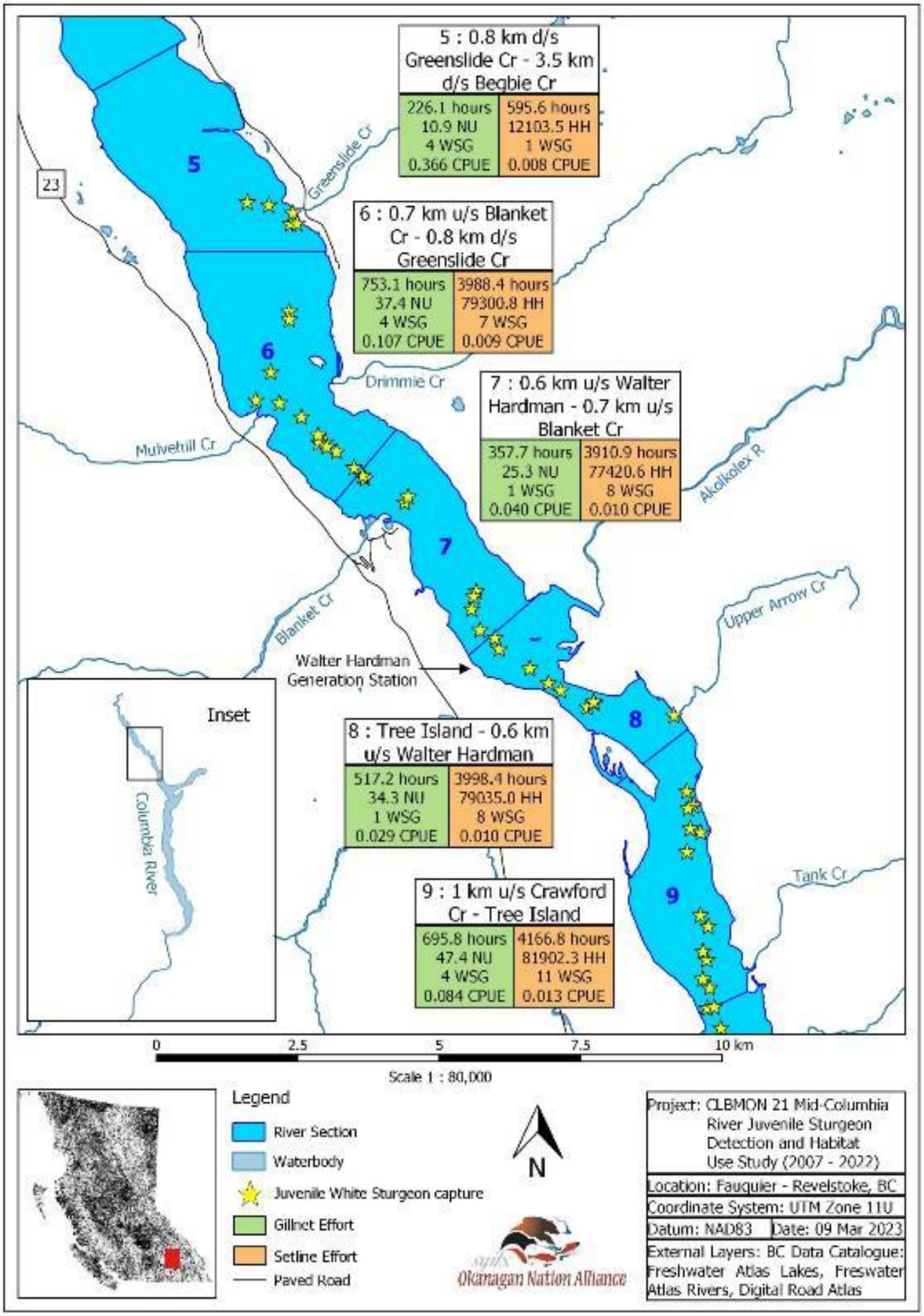

Figure 29. Juvenile White Sturgeon capture locations, effort, and associated catch-per-unit-effort (CPUE) from 1 km upstream of Crawford Creek to 3.5 km downstream of Begbie Creek (2007 – 2022). Data collected by BC Hydro, Golder Associates Ltd., and Okanagan Nation Alliance.

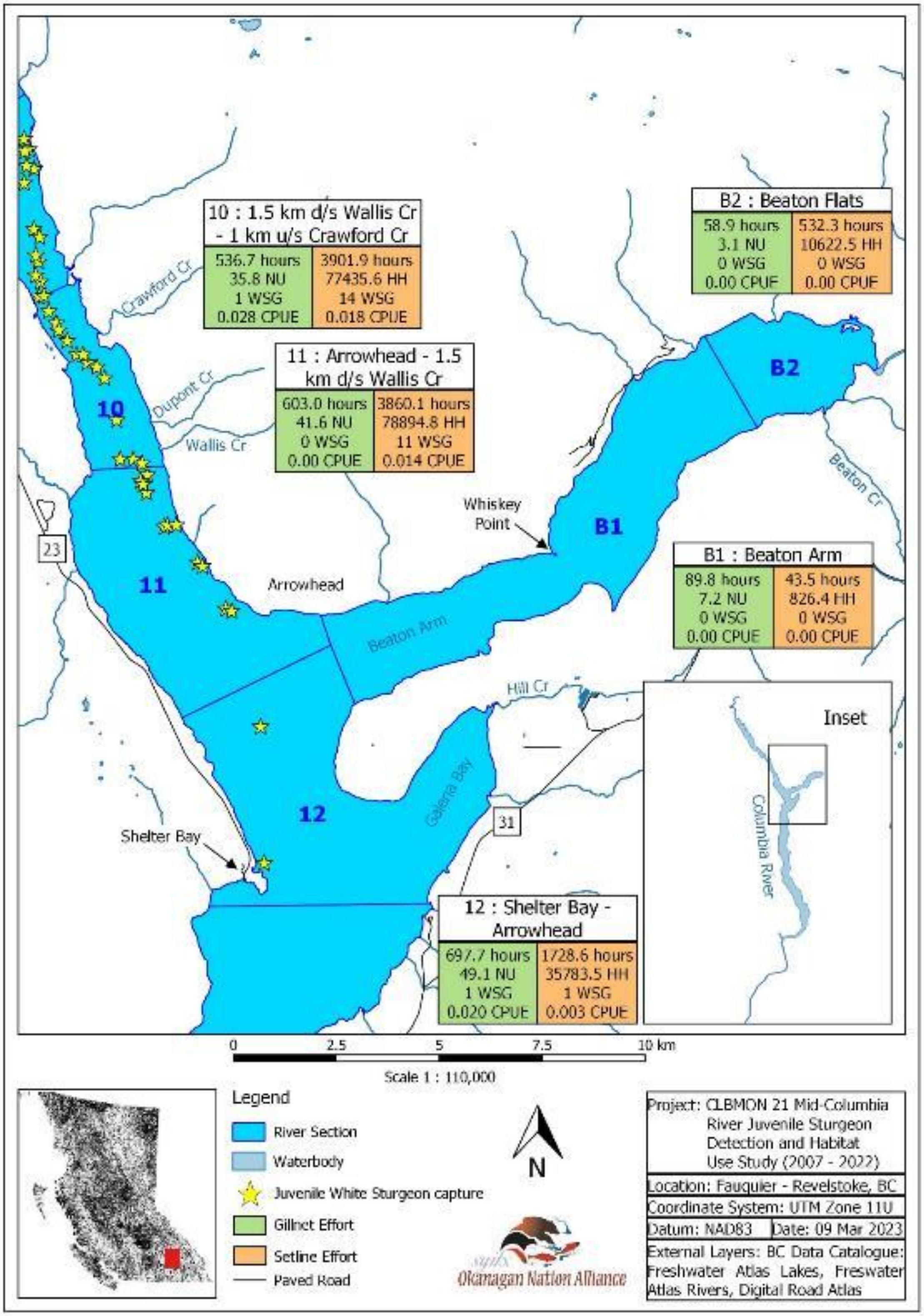

Figure 30. Juvenile White Sturgeon capture locations, effort, and associated catch-per-unit-effort (CPUE) from Shelter Bay to 1 km upstream of Crawford Creek and the Beaton Arm (2007 – 2022). Data collected by BC Hydro, Golder Associates Ltd., and Okanagan Nation Alliance.

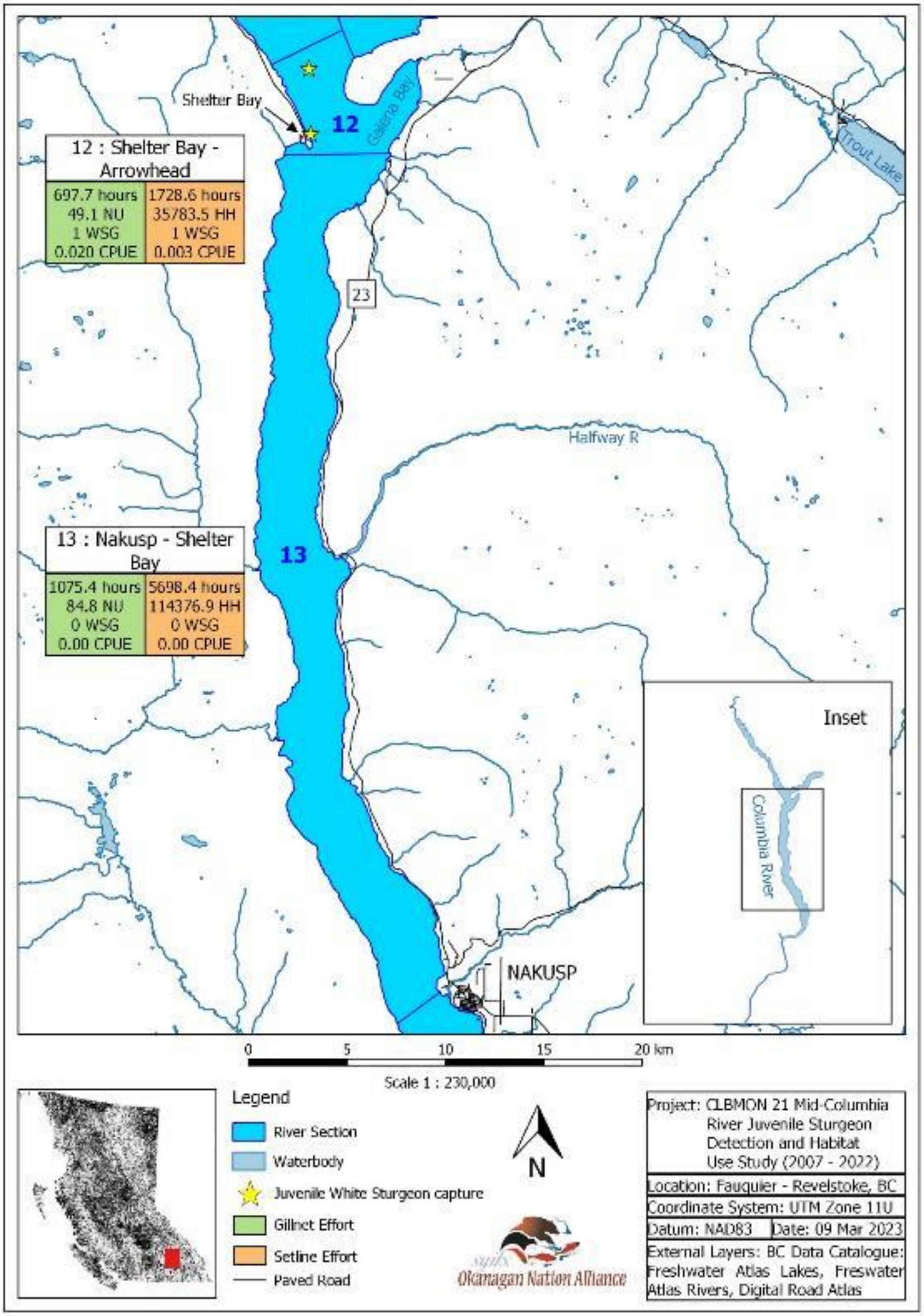

Figure 31. Juvenile White Sturgeon capture locations, effort, and associated catch-per-unit-effort (CPUE) from Nakusp to Arrowhead (2007 – 2022). Data collected by BC Hydro, Golder Associates Ltd., and Okanagan Nation Alliance.

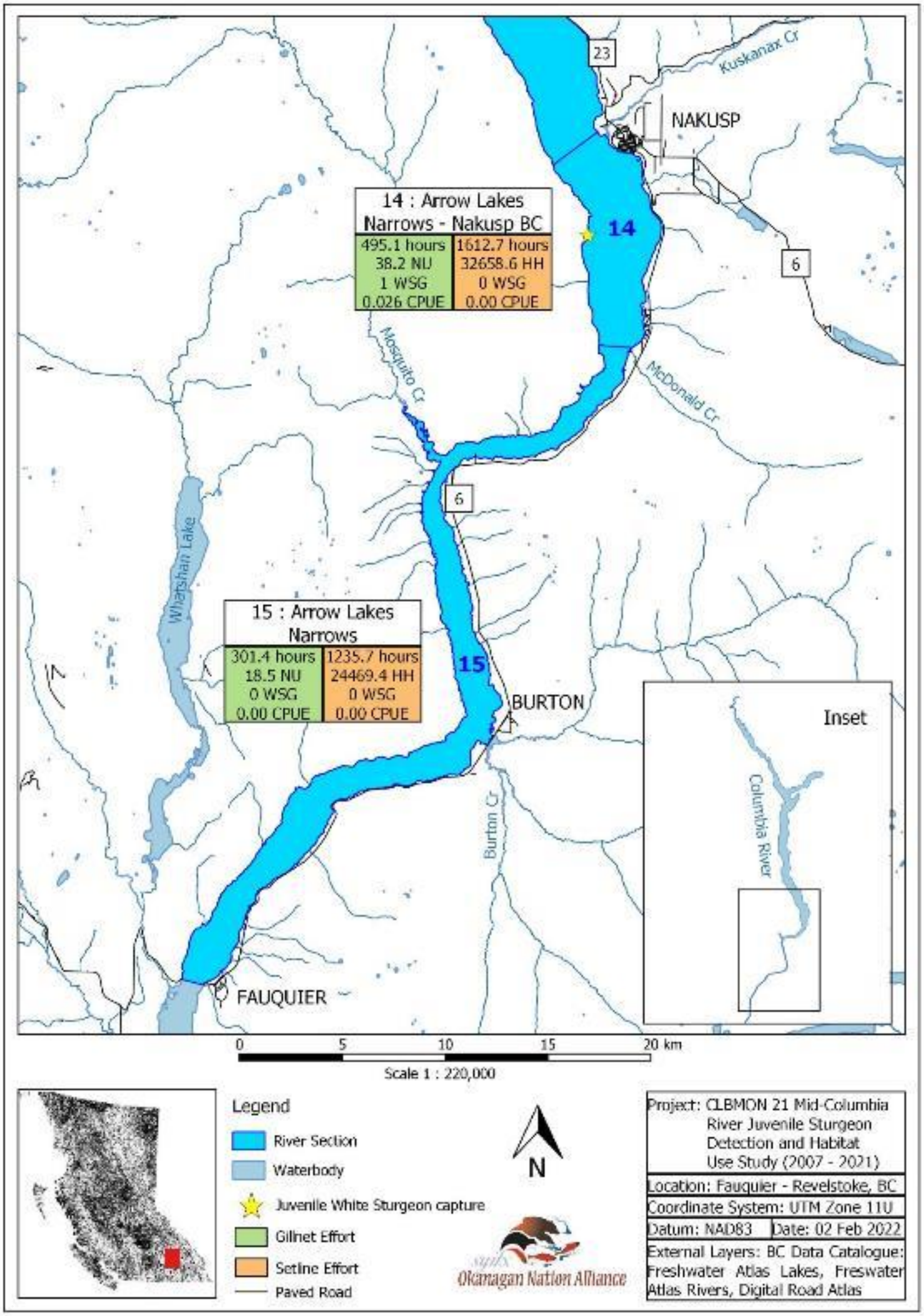

Figure 32. Juvenile White Sturgeon capture locations, effort, and associated catch-per-unit-effort (CPUE) from the Arrow Lakes Narrows to Nakusp (2007 – 2022). Data collected by BC Hydro, Golder Associates Ltd., and Okanagan Nation Alliance.

Appendix F – Map of Rock Basket Sample Locations and Data Summary

Appendix F1 – Rock Basket Locations

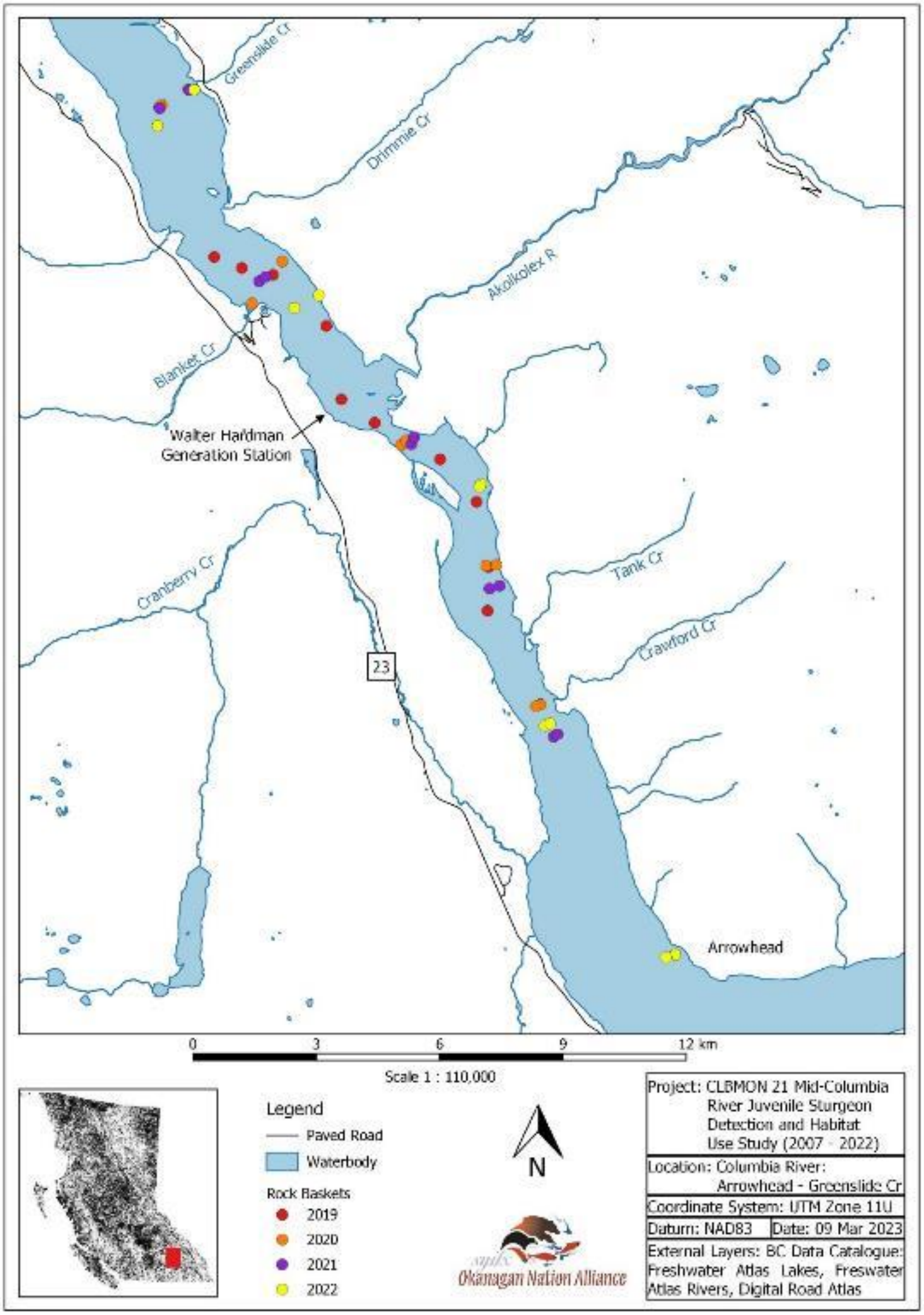

Figure 33. Locations of rock baskets for benthic invertebrate monitoring in the Middle Columbia River during CLBMON-21 from 2019 to 2022. Data collected Okanagan Nation Alliance.

Appendix F2 – Rock Basket Data

Table 27. Summary data for rock baskets monitored in the Middle Columbia River from 2019 – 2021 during CLBMON-21. Data collected Okanagan Nation Alliance.

Year	ID	Easting	Northing	Set Date	Set Depth (m)	Set Ponar	Pull Date	Pull Depth (m)	Pull Ponar	Contents
2019	2019_RB_01_S	422472	5633573	5-Jul-19	5.7		24-Sep-19			Aquatic worms (7) Midges (35) Flatworms (1)
2019	2019_RB_02_D	423148	5633304	5-Jul-19	15.9		24-Sep-19			Flatworms (3)
2019	2019_RB_03_S	423905	5633136	5-Jul-19	9.0	Lost during retrieval				
2019	2019_RB_04_D	425202	5631895	5-Jul-19	17.1		24-Sep-19			Midges (1) Flatworms (5)
2019	2019_RB_05_D	425568	5630109	5-Jul-19	18.0		24-Sep-19			Flatworms (1)
2019	2019_RB_06_D	426380	5629537	5-Jul-19	15.8		24-Sep-19			Flatworms (2)
2019	2019_RB_07_S	427970	5628650	5-Jul-19	8.5		24-Sep-19			Aquatic worms (3) Mayflies (1) Flatworms (5)
2019	2019_RB_08_D	428854	5627616	5-Jul-19	12.0		24-Sep-19			Flatworms (11)
2019	2019_RB_09_D	429144	5626030	5-Jul-19	11.6		24-Sep-19			Flatworms (2)
2019	2019_RB_10_S	429123	5624966	5-Jul-19	7.5		19-Sep-19	3.4		Aquatic worms (17) Leeches (3) Midges (17) Water mites (1) Flatworms (3)
2020	2020_RB_01_S	421379	5637387	5-Aug-20	5.8	Silt (70%), sand (20%), OM (10%)	2-Oct-20	1.9		Midges (256)
2020	2020_RB_02_D	421140	5637259	5-Aug-20	14.9	Silt (80%), OM (20%)	2-Oct-20	7.0		Aquatic worms (1) Midges (2)
2020	2020_RB_03_D	424123	5633459	5-Aug-20	11.2	Sand (100%)	2-Oct-20	5.5		Aquatic worms (2) Midges (1) Flatworms (2)
2020	2020_RB_04_S	423484	5632550	5-Aug-20	4.8	Silt (50%), terrestrial veg (50%)	2-Oct-20	4.2		Aquatic worms (6) Midges (7)
2020	2020_RB_05_D	427120	5629130	6-Aug-20	16.8	Sand (100%)	2-Oct-20	10.0		Aquatic worms (1) Midges (38) Flatworms (1)
2020	2020_RB_06_S	427005	5628984	6-Aug-20	6.5	Sand (90%), silt (10%)	2-Oct-20	3.7		Midges (65) Caddisflies (1) Water mites (1)

Year	ID	Easting	Northing	Set Date	Set Depth (m)	Set Ponar	Pull Date	Pull Depth (m)	Pull Ponar	Contents
2020	2020_RB_07_S	429014	5626110	8-Aug-20	6.2	Silt (70%), sand (25%), OM (5%)	1-Oct-20	3.7		Midges (49)
2020	2020_RB_08_D	429339	5626105	8-Aug-20	15.8	Sand (90%), OM (10%)	1-Oct-20	10.0		Aquatic worms (3) Midges (4) Flatworms (1)
2020	2020_RB_09_D	430301	5622641	8-Aug-20	12.9	Silt (80%), sand (20%)	1-Oct-20	7.5		Midges (17)
2020	2020_RB_10_S	430525	5622721	8-Aug-20	5.9	Silt (100%)	1-Oct-20	2.7		Midges (45)
2021	2021_RB_01_S	421850	5637642	21-Jul-21	10.0	Coarse gravel (52 mm b-axis) (50%), fine sand (30%), veg (didymo) (20%)	23-Sep-21	5.0	Silt (80%), OM (20%)	Aquatic worms (12) Midges (2) Mayflies (1) Flatworms (1)
2021	2021_RB_01_D	421147	5637187	21-Jul-21	12.0	Silt (80%), OM/WD (15%), fine sand (5%)	23-Sep-21	8.0	Fine sand (90%), OM (10%)	Aquatic worms (17) Midges (27) Mayflies (1) Mosquitoes (1)
2021	2021_RB_02_S	423727	5633090	21-Jul-21	10.0	Fine sand (80%), fine/med gravel (20%)	22-Sep-21	10.6	Silt (90%), fine sand (10%)	Fingernail clams (1) Flatworms (3)
2021	2021_RB_02_D	423566	5632978	21-Jul-21	16.0	Med sand (90%), silt (5%), WD (5%)	22-Sep-21	11.3	Med sand (100%)	Aquatic worms (1) Mayflies (2) Flatworms (1)
2021	2021_RB_03_S	427334	5629192	21-Jul-21	10.0	Fine sand (95%), WD (5%)	24-Sep-21	5.4	Med sand (100%)	Caddisflies (4)
2021	2021_RB_03_D	427269	5629017	21-Jul-21	16.0	Veg (50%), WD (50%)	24-Sep-21	11.4	Cobble (90%), fine sand (8%), OM (2%)	Aquatic worms (9) Midges (2) Mayflies (2)
2021	2021_RB_04_S	429172	5625505	21-Jul-21	10.0	Silt (80%), fine sand (10%), coarse sand (5%), fine gravel (5%)	22-Sep-21	5.9	Silt (95%), fine gravel (5%)	Aquatic worms (2) Flatworms (13)
2021	2021_RB_04_D	429415	5625572	21-Jul-21	19.4	Coarse gravel (20 mm b-axis) (100%)	22-Sep-21	15.0	Med sand (100%)	Midges (1) Mayflies (1) Caddisflies (47)
2021	2021_RB_05_S	430825	5621963	21-Jul-21	8.0	Silt (70%), med sand (30%)	24-Sep-21	2.9	Silt (100%)	Midges (18) Mayflies (1)
2021	2021_RB_05_D	430729	5621905	21-Jul-21	17.0	Med sand (100%)	24-Sep-21	12.2	Fine sand (80%), med sand (20%)	Aquatic worms (1)
2022	2022_RB_01_D	421098	5636765	18-Aug-22	12.0		16-Oct-22	5.3	OM (99%), fine sand (1%)	Midge (2) Hydrozoa (1)
2022	2022_RB_01_S	421990	5637635	18-Aug-22	8.2		16-Oct-22	2.5	Medium sand (70%), OM (30%)	Midge (6) Hydrozoa (8)

Year	ID	Easting	Northing	Set Date	Set Depth (m)	Set Ponar	Pull Date	Pull Depth (m)	Pull Ponar	Contents
										Stonefly (1) Mayfly (2)
2022	2022_RB_02_D	424425	5632331	16-Aug-22	15.6		17-Oct-22	9.5	Medium sand (91%), OM (6%), coarse sand (3%)	Flatworms (11) Aqautic worms (4) Hydrozoa (3)
2022	2022_RB_02_S	425020	5632639	16-Aug-22	12.0		17-Oct-22	6.4	Medium sand (98%), fine gravel (2%)	Snail (1) Midges (2) Mayfly (3) Abundant hydrozoa
2022	2022_RB_03_D	428959	5628043	18-Aug-22	16.5		17-Oct-22	10.4	Fine sand (75%), medium sand (15), OM (10)	Flatworms (6) Hydrozoa (9)
2022	2022_RB_03_S	428930	5627987	18-Aug-22	12.4		17-Oct-22	6.3	Medium sand (90%), fine sand (5%), coarse sand (5%)	Snail (1) Midge (1) Flatworms (11) Aquatic worms (3)
2022	2022_RB_04_D	430514	5622177	19-Aug-22	15.5		18-Oct-22	9.9	Medium sand (94%), fine gravel (3%), OM (3%)	Abundant hydrozoa
2022	2022_RB_04_S	430642	5622224	19-Aug-22	12.0		18-Oct-22	4.7	Medium sand (50%), fine sand (40%), OM (10%)	Abundant hydrozoa Midges (5)
2022	2022_RB_05_D	433687	5616605	19-Aug-22	17.5		13-Oct-22	12.2	Coarse sand (50%), medium sand (49%), OM (1%)	Abundant hydrozoa Mayfly (1)
2022	2022_RB_05_S	433466	5616533	19-Aug-22	12.5		13-Oct-22	6.6	Medium sand (60%), OM (20%), medium gravel (B axis = 11mm) (20%)	Abundant hydrozoa