BC Hydro
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Columbia River Project Water Use Plan

COLUMBIA WHITE STURGEON MANAGEMENT PLAN

Reference: CLBMON-21

Mid-Columbia River Juvenile Sturgeon Detection and Habitat Use

Study Period: 2020

Implementation Year: 14 of 16

2020 Technical Report

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CLBMON-21: Mid-Columbia River Juvenile White Sturgeon Detection and Habitat Use

2020 Results

March 2021

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Cover Photo: Upper Photo – Dave Tom (Upper Nicola Indian Band) holding a juvenile White Sturgeon captured in the Middle Columbia River in August 2017. Photo Credit: Evan Smith, Okanagan Nation Alliance. Lower Photo – Juvenile White Sturgeon capture in September 2020. Photo Credit: Eleanor Duifhuis, Okanagan Nation Alliance.

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Executive Summary

White Sturgeon (*Acipenser transmontanus*) in the Columbia River, British Columbia (BC), Canada, were 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 mid-Columbia River (MCR), a section of the Columbia River located between Hugh L. Keenleyside Dam (HLK; Castlegar, BC) and Revelstoke Dam (REV; Revelstoke, BC). In 2006, this population was estimated to be comprised of approximately 52 adult White Sturgeon (37 - 92 individuals at 95% confidence level) that are older than the construction date of HLK Dam (1968).

Since the early 70s, there has been a nearly complete failure to natural recruitment in this population (Hildebrand and Parsley 2013) and in 2007 an experimental conservation aquaculture program was initiated with the objective of evaluating whether either recovery of a self-sustaining or a failsafe population is possible in Arrow Reservoir. A monitoring program (CLBMON-21) was also initiated at this time to evaluate the success of the conservation aquaculture program and determine the survival of fish released. Six management questions were developed for CLBMON-21:

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

These management questions have been assessed in previous years through both direct (capture efforts) and indirect (telemetry) methods, however direct capture has been the primary focus of the program since 2015. This report compares data collected in 2020 to the results of previous years of this program.

A total of nine hatchery-origin juvenile White Sturgeon were captured in 2020. Individuals were caught on setlines in the riverine section of the MCR (Shelter Bay to Greenslide Creek) between Aug 06 2020 and Oct 03 2020. The range in lengths (43.5 – 58.3 cm), weights (0.57 – 1.52 kg), and relative weight (71.85% – 115.98%) of captured sturgeon were similar to previous years. Average annual growth for the 2020 captures (4.96 cm/year, 0.17 kg/year) was lower than the average of all captured sturgeon between 2007 – 2019 (10.34 cm/year; 0.22 kg/year). Five of the individuals caught in 2020 were from the 2015-year class, which has the lowest annual length growth rate (4.33 cm/year) compared to all other year classes (6.39 – 19.52 cm/year).

A total of 50 juvenile White Sturgeon have been captured since the beginning of the CLBMON-21 program, with a single recapture event in 2017. Of these, 18 individuals were captured less than one year after release. Four individuals were captured over five years following release, and one was captured over 10 years after release (caught in 2017). 2020 saw the highest number of juvenile sturgeon captured (nine individuals) since 2014 (11 individuals), which may

be explained by an increase in setline effort in locations with known preferred habitats and targeting effort in the fall.

Concentrating setline effort between Shelter Bay and Greenslide Creek is recommended to maintain or increase capture rates. Continuing "exploratory" sampling in areas with suitable juvenile habitat previously not sampled or under-sampled is also important in this program. Continuing to collect data on the abundance and diversity of potential prey species and as well as juvenile Sturgeon habitat may further describe limiting factors. Telemetry could be utilized on older captured fish to better describe habitat use or help direct capture efforts.

The current state of knowledge for the juvenile White Sturgeon program in the mid-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 Mid-Columbia?	Based on data collected using both acoustic telemetry and direct capture efforts, juvenile White Sturgeon exhibit highest use of riverine habitats near Greenslide Creek (RKm 212) downstream to Shelter Bay (RKm 177) and, to a lesser extent, further south into the Arrow Lakes Reservoir. Few juveniles have been captured downstream of the Beaton Flats area but telemetry and capture data have identified a few individuals further downstream towards Nakusp.
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. 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 favourable. 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 Mid-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 approximately Shelter Bay (RKm 177) to Greenslide Creek (RKm 212).
4. How do hydraulic conditions resulting from dam and reservoir operations relate to habitat	Both REV discharge and ALR elevation 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

Management Question	Status
suitability for juvenile White Sturgeon in the Mid-Columbia?	diminish with downstream distance. High reservoir elevations backwatering the river section results in greater availability of deeper, low velocity habitats further upstream. ALR elevations can influence Sturgeon movements in the river section and attenuate the effects of varying dam discharges.
5. What are the survival rates of juvenile white sturgeon in the mid-Columbia River?	Survival cannot be estimated at this time due to low recapture rates, attributed to a large study area and low capture efficiency. On average for all recaptured fish, total annual growth was 10.34 cm/year in length and 0.22 kg/year in weight. From 2008 – 2016, 16 of 30 fish caught were captured in the same year they were released (over 50%). From 2017 – 2020, only two of the 20 fish caught were captured in the same year they were released (10%). Since 2008, four juvenile sturgeon were captured over five years after release, one after 10 years. At this time additional captures are required to adequately 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 main areas of habitat use by juvenile sturgeon are situated >25 km downstream from REV, where it is unlikely that operational modifications at REV would have influence. At this distance from the dam, large changes in flows are moderated and backwatering from the reservoir likely changes the flow dynamics. The landforms around the preferred area of the Walter Hardman Generating Station and Akolkolex River (RKm 200) constrict the Columbia River, which may be creating conditions that are more suitable to juvenile rearing for at least part of the year. 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 being used by juveniles in this area.

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BC Hydro

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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 within British Columbia (BC), Canada. The population of White Sturgeon in the Canadian 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 occurs within the Arrow Lakes Reservoir (ALR), a section of the mid-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 2020, the estimated population of adult White Sturgeon should be around 28 individuals, calculated with 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.

During the development of the Columbia River Water Use Plan, BC Hydro's Consultative Committee identified knowledge gaps for juvenile White Sturgeon habitat capabilities in the MCR (BC Hydro 2007). Since 2007, BC Hydro has been releasing hatchery-raised juvenile White Sturgeon into the MCR (ONA 2019). CLBMON-21 was developed to monitor the efficacy of the conservation aquaculture program and to investigate juvenile Sturgeon habitat use, habitat availability, and the potential for building a self-sustaining or failsafe population. Upon completion of the 10-year program, data gaps remained as a result of low capture rates, therefore CLBMON-21 was extended for an additional four years with a focus on increasing captures of juvenile White Sturgeon. This report summarizes the findings of Year 14 (2020) of CLBMON-21.

1.1 Management Questions and Hypotheses

Specific management questions as outlined in BC Hydro's Terms of Reference (2007) 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 River?
(6) Can modifications be made to the operations of Revelstoke Dan and/or Arrow Lakes Reservoir to protect or enhance juvenile White Sturgeon habitat?

2.0 Methods

2.1 Study Area

The MCR is a portion of the Columbia River spanning 230 km from REV south to HLK near Castlegar, BC. This portion of the Columbia River encompasses both the Upper and Lower Arrow Lakes Reservoir. While the MCR area is large, the sampling area for this study has been adapted throughout the program in an attempt to optimize capture rates based on results in previous years (see 2.2 Study Design). Sampling was focused on three primary locations in 2020; Revelstoke Reach, Beaton Flats and the Arrow Lake Narrows (Figure 1). Revelstoke Reach is where the majority of previous juvenile White Sturgeon captures have occurred on this program, and it extends from Greenslide Creek to Shelter Bay.

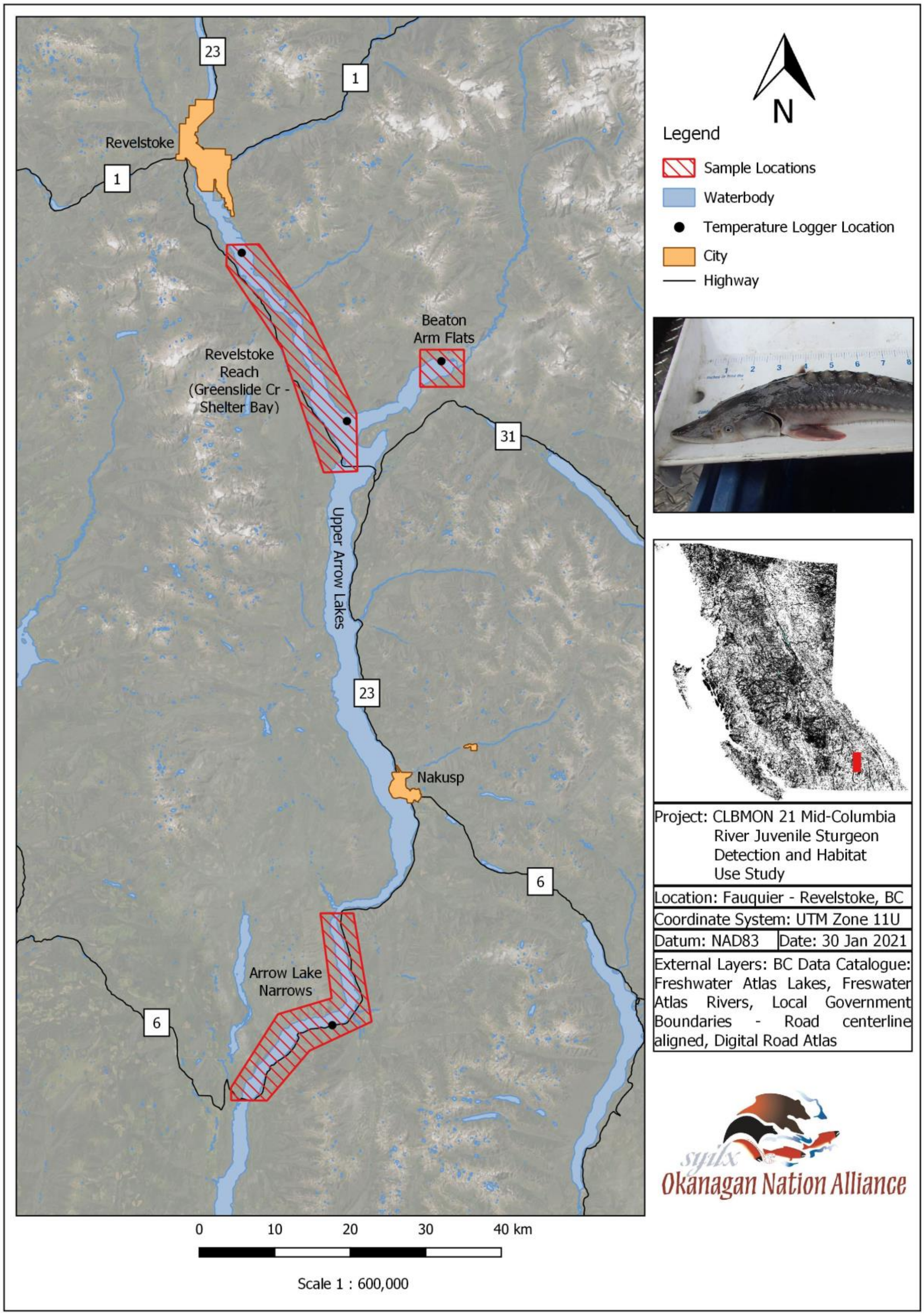

Figure 1. CLBMON-21 study areas in 2020 including temperature logger locations.

2.2 Study Design

Field sampling was designed to increase captures of juvenile White Sturgeon in consideration of previous years' capture successes. Nearly all of the juvenile White Sturgeon captures from this program have been within calm (<0.5 m/s), deep (>10 m) areas with fine substrates with is generally found within the riverine section upstream of Shelter Bay to Greenslide Creek (Golder 2009, ONA 2019). Additionally, the 2012 acoustic positioning study showed that juvenile White Sturgeon movement is concentrated within the thalweg or in floodplain areas associated with the thalweg, and that movement of juvenile White Sturgeon is greatest early to mid-September (Golder and ONA 2013). The 2020 study was comprised of five field sessions sampling three locations:

Session 1A) Jul 04 to Jul 07: Beaton Arm Flats (2 km)

Session 1B) Jul 08 to Jul 10: Arrow Lakes Narrows – Fauquier north to McDonald Creek Provincial Park (30 km)

Session 2) Aug 05 – Aug 12: Revelstoke Reach – Upper Arrow Lakes, Shelter Bay north to Greenslide Creek (35 km)

Session 3) Aug 30 – Sep 05: Revelstoke Reach – Crawford Creek north to Greenslide Creek (20 km)

Session 4) Sep 12 – Sep 19: Revelstoke Reach – Crawford Creek north to Mulvehill Creek (18 km)

Session 5) Sep 26 – Oct 03: Revelstoke Reach – Beaton Arm north to Tank Creek (12 km)

Gillnet (GN) and setline (SL) sites were established for the Revelstoke Reach (200 GN, 200 SL), Beaton Arm Flats (30 GN, 30 SL), and the Arrow Lakes Narrows (30 GN, 30 SL) randomly using the general random tessellation stratified (GRTS; Stevens and Olson 2004) design in R (R Development Core Team). This method provides spatially balanced randomly assigned sample locations. Sites were randomly distributed along the center line of the MCR and distinguished as setline or gillnet sites. Over-sample sites were also created to replace sites that were rejected during sampling due to logistical concerns (depth, velocity, obstructions) to ensure that randomness and spatial segregation were maintained within the study design. The GRTS sites were used as a guideline, and once in the field, sample locations were selected based on targeted water depths (10 – 30 m) and in areas with lower water velocity.

2.3 Field Sampling

2.3.2 Physical Habitat Parameters

Surface water temperatures were measured at each sample site using an onboard depth sounder with accuracy to the nearest 0.1 °C for the first four sessions and to the nearest 1 °C for the last session. Water depths were also recorded from the onboard depth sounder with accuracy to the nearest 0.1 m for the first four sessions and to the nearest 1 m for the last session (differences in temperature and depth accuracy due to different boat and associated equipment). Four Hobo TidbiT v2 temperature data loggers were deployed to record benthic temperatures and were programmed to log every two hours (*Figure 1*; *Table 1*). Loggers were attached to cement blocks, which were marked with line and buoy systems.

Table 1. Location of temperature loggers (UTM Zone 11), including deploy and retrieval dates and water depths, used on CLBMON-21 in 2020.

Location	Easting	Northing	Deploy	Deploy Depth (m)	Retrieve	Retrieve Depth (m)
Arrow Lakes Narrows	433131	5534922	08 Jul 2020	14.8	16 Nov 2020	Not recorded
Revelstoke North (Greenslide Creek)	421140	5637259	05 Aug 2020	14.9	Lost	7.0
Revelstoke South (Shelter Bay)	435063	5614960	05 Jul 2020	14.5	03 Oct 2020	7.1
Beaton Arm	447563	5622892	05 Jul 2020	11.0	01 Oct 202	4.1

The Water Survey of Canada Fauquier Station (Station: 08NE102) was used to obtain Arrow Lakes Reservoir elevation data from 2007 to 2020, particularly between May 01 to October 31 (https://wateroffice.ec.gc.ca/mainmenu/real_time_data_index_e.html). Average daily data from 2020 were compared to the average of the daily means from 2007 to 2019.

Discharge data for the Revelstoke Dam were acquired directly from BC Hydro (BC Hydro unpublished data 2020) – also focusing on the general study period from May 01 to Oct 31. In 2016, data did not include discharge from Oct 09 – 13 and 15 – 31. In 2018, data did not include discharge from Jun 04 – Oct 31. In this report, 2020 data are compared to 2011 – 2019 daily averages (after the implementation of the flow regime change) and exclude 2007 – 2010 data (before the implementation of the flow regime change).

2.3.3 Capture Methods

A number of equipment types have been trialled to sample for juvenile White Sturgeon including angling, tangle nets, trawling, beach seines, set lines, and gillnets, among others (McCabe 1994, Courtier 2010, Glova *et al.* 2010, BC Hydro 2015). This study used gillnets and setlines due to the hydraulic and physical properties of the sites along the Upper Arrow Lakes Reservoir and the Arrow Lakes Narrows. Both sampling methods have been utilized previously for juvenile White Sturgeon with success in the mid- and lower-Columbia Rivers (Golder 2009, 2010, 2011, 2012, Golder and ONA 2013, BC Hydro 2015, ONA 2016, 2017, 2018, 2019, 2020).

Gillnets consisted of a 5.1 cm multi-strand net measuring 3.0 m deep by 30.0 or 45.7 m long. Between three and six gillnets were set each day for a targeted duration of 4 hours to follow SARA permit requirements and minimize impacts on target species and bycatch. Gillnets were deployed at the bottom of the water column with an anchor, float line, and LD-2 float attached to each end of the net. Set and pull times, UTM coordinates, surface water temperatures, minimum and maximum set depths, orientation to flow, and other notable set details were recorded for each set.

Setlines measured 120 m in length and were set with a target of 20 size 6-0 hooks per line spaced 4 m apart. Between four and six setlines were set each afternoon and left overnight for a maximum of 24 hours. An anchor, float line and LD-2 float were attached to both ends of the setline. Barbless 'J' hooks were baited with worms (nightcrawlers). Setlines were oriented perpendicular to the flow whenever possible to increase downstream scent dispersal. As with the gillnets, set and pull times, hook sizes, bait types, UTM coordinates, surface water temperatures, minimum and maximum set depths, orientation to flow, fouled and baitless hooks, and other notable set details were recorded.

2.3.4 Fish Handling

Upon capture, sturgeon were weighed (g) and measured for fork length (mm), photographed, examined for health and external markings (missing scutes) and scanned for a passive integrated transponder (PIT) tag. Handling methods were consistent with those set by the Upper Columbia White Sturgeon Recovery Initiative (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 quickly released to reduce negative impact. All by-catch mortalities were sunk by puncturing the swim bladder. Invasive species (e.g. Common Carp) that were encountered were euthanized and sunk.

Gastric lavage was performed on all captured Sturgeon with the objective of identifying prey and analyzing prey abundance and diversity. Gastric lavage was conducted using a Chapin SureSpray Select 8.0 L pump/bladder and a VWR size 8 standard testing sieve (#140). Samples were collected in glass jars, labelled with the date, site ID, site UTM, Sturgeon weight (g) and fork length (mm), and preserved in denatured ethanol until processing.

2.3.5 Substrate Collection and Analysis

In association with each Sturgeon capture, a substrate sample was collected using a Wildco© Petite Ponar Grab (232 cm^2) to identify habitat type and prey availability. Multiple substrate grabs were performed in some areas to ensure a sufficient sample was collected. The sample was preserved in denatured ethanol, labelled, and stored until processing.

In 2020, ten rock basket samplers were used to identify invertebrate prey availability (*Figure 2*). The 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 on the Middle Columbia River Ecological Productivity Monitoring Program (CLBMON 15b; Perrin *et al.* 2008). The baskets were filled with clean gravel (2.5 to 3.5 cm in size) and locked with cable ties. Rock baskets were deployed in pairs at five locations evenly distributed between Greenslide Creek and Crawford Creek from August 05 – 08, 2020 to October 01 – 02, 2020. A substrate grab was taken near each rock basket to identify substrate type (samples were not retained). Each pair ideally consisted of one rock basket deployed in the floodplains (shallow) and one deployed in the thalweg (deep). 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 a Size 8 standard testing sieve and remaining contents were stored in glass or plastic sample containers with a label and denatured ethanol preservative until processing.

Prior to 2019, invertebrates were only obtained by substrate grabs, which restricted samples to silty or sandy substrates and resulted in low species diversity. In 2020, rock baskets were added to further inform prey availability.

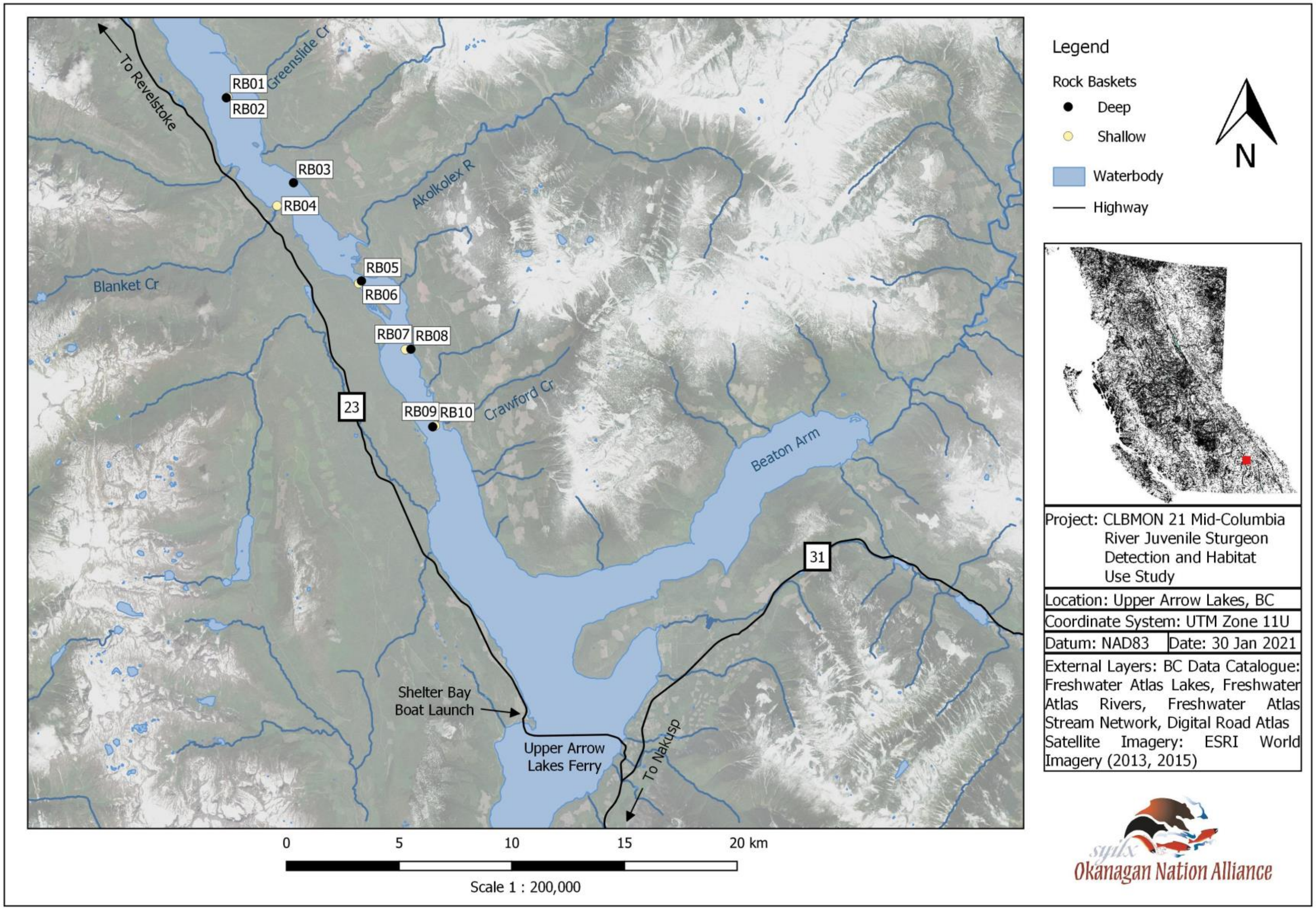

Figure 2. Rock basket locations in the Upper Arrow Lakes Reservoir from Crawford Creek north to Greenslide Creek, 2020.

2.4 Data Analysis

Data management and descriptive statistics were completed using Microsoft Excel.

2.4.1 Sturgeon Data Analyses

Catch-per-unit-effort (CPUE) was calculated by gear type in each year as follows (Equations 1-4):

(1) Gillnet effort – net-unit

$$\boldsymbol{net-unit} = \left(\frac{\boldsymbol{a}}{\boldsymbol{100\ m^2}}\right) \times \left(\frac{\boldsymbol{t}}{\boldsymbol{24\ h}}\right)$$

where,
$a = net\ area\ (length \times width)$
$t = time$

(2) Gillnet CPUE

$$\boldsymbol{CPUE^G} = \frac{\boldsymbol{WSG}}{\boldsymbol{net-unit}}$$

where,
$WSG = number\ of\ juvenile\ White\ Sturgeon\ caught$
$net-unit = gillnet\ effort$

(3) Setline effort – hook-hour

$$\boldsymbol{hook-hour} = \mathrm{h} \times \mathrm{t}$$

where,
$h = number\ of\ hooks\ baited\ and\ set$
$t = time$

(4) Setline CPUE

$$\boldsymbol{CPUE^S} = \frac{\boldsymbol{WSG}}{100\ hook-hours}$$

where,
$WSG = number\ of\ juvenile\ White\ Sturgeon\ caught$
$hook-hour = setline\ effort$

Biological data collected and analyzed in this report included fork length (mm) and weight (g). The relationship between length and weight was estimated by graphing the lengths and weights of all captured sturgeon in excel and adding an exponential trendline. Excel automatically determined the coefficients of this equation through the graph and displayed the estimated coefficients and R^2, which indicated the fit of the trendline to the data (an R^2 near 1 indicated good fit). This equation will continue to be refined as subsequent data is collected (Equation 5):

(5) Length-Weight Relationship

$$\mathbf{W} = \boldsymbol{\alpha} \times \boldsymbol{e}^{(\boldsymbol{\beta} \times \boldsymbol{L})}$$

where,
$W = weight\ of\ juvenile\ White\ Sturgeon\ caught\ (kg)$
$L = length\ of\ juvenile\ White\ Sturgeon\ caught\ (cm)$
$\alpha\ \&\ \beta = Excel\ estimated\ coefficients$
$e = base\ of\ the\ natural\ logarithms$

Sturgeon were aged by determining year class from the PIT tag data. 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 between release and capture and multiplying by 365. Relative weight was calculated using the weight-specific standard-weight from Beamesderfer (1993) described below (Equations 6-7):

(6) Relative Weight (Wr)

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

$where,$
$W = weight\ of\ juvenile\ White\ Sturgeon\ caught\ (kg)$
$W_S = length - specific\ standard - weight\ value$

(7) Length-Specific Standard-Weight Value (W_S)

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

$where,$
$\alpha = 2.735^{-6}$
$\beta = 3.232$
$L = length\ of\ juvenile\ White\ Sturgeon\ caught\ (cm)$

2.4.2 Bycatch

Bycatch were recorded by species and set sample type. This allowed for mortality rates (number or mortalities divided by total number caught and multiplied by 100%) to be compared between species of interest and set sample type.

2.4.3 Invertebrates and Substrate

All analyses of preserved samples were completed by ONA staff in January 2021. Invertebrates were identified, measured for length, and enumerated using a dissecting microscope (Motic SMZ-143 Series) and the Guide to Common Freshwater Invertebrates of North America (Voshell 2002). Invertebrates were analysed from all three sample types: (1) gastric lavage, (2) substrate grab, and (3) rock basket. Identification and abundance measures are reported rather than diversity indices due to a general lack of taxa identified within samples. Substrate grab samples were also described by primary and secondary substrate types, and volumes were estimated.

3.0 Results

3.1 Physical Habitat Parameters

Benthic water temperatures at three tidbit locations were recorded for the duration of the sampling season. The “Revelstoke North” temperature logger (north of Greenslide Creek) was not recovered. The highest benthic temperatures recorded were in the “Arrow Lakes Narrows” (average 12.9 °C, range 10.6 – 16.7 °C; *Figure 3*), and the lowest temperatures were at “Revelstoke South” (north of Shelter Bay; average 10.4 °C, range 5.7 – 12.3 °C; *Figure 3*).

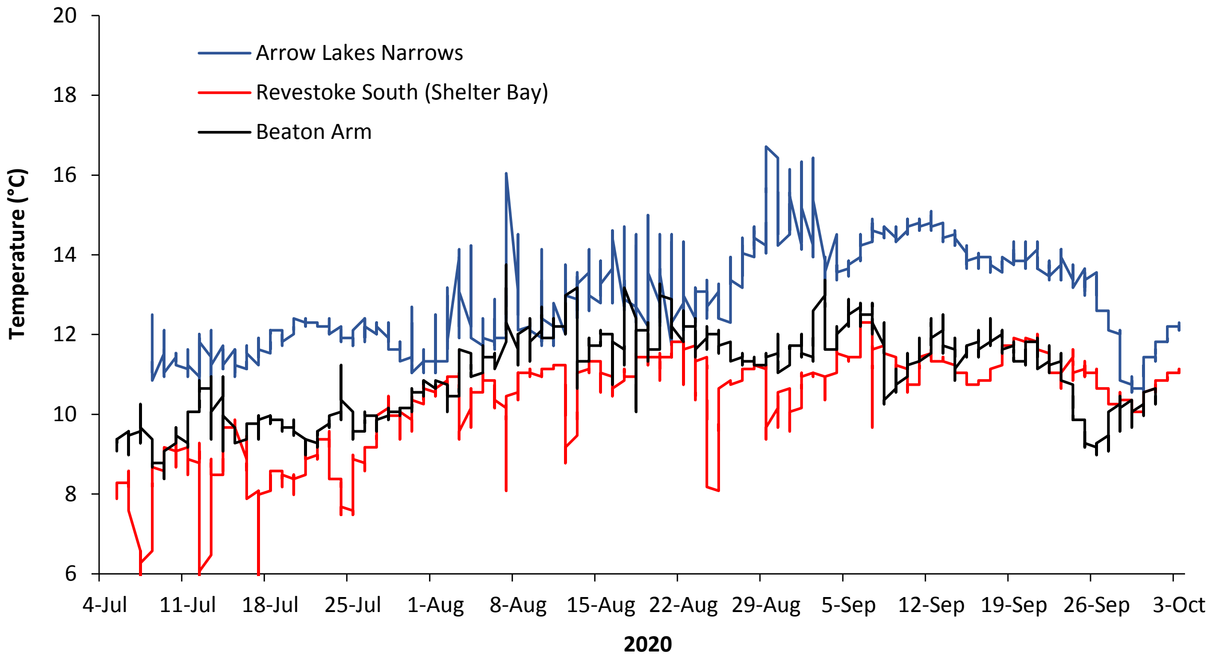

Figure 3. Benthic water temperature (°C) from Jul 05 to Oct 03 2020 at Arrow Lakes Narrows, Revelstoke South (north of Shelter Bay), and Beaton Arm Flats.

The highest water surface temperatures recorded (20.0 °C) were in the Revelstoke Reach on Aug 05 2020 during gillnet retrieval at around 16:00. At that time, benthic temperature recorded from the “Revelstoke South” logger was 10.8 °C. Mean surface temperatures during individual sessions ranged from 10.0 – 16.1 °C, while associated benthic temperatures ranged from 9.5 – 11.3 °C (*Figure 4*). During the last two sessions, average surface temperatures were lower than benthic temperatures measured at the “Revelstoke South” Tidbit (*Figure 4*).

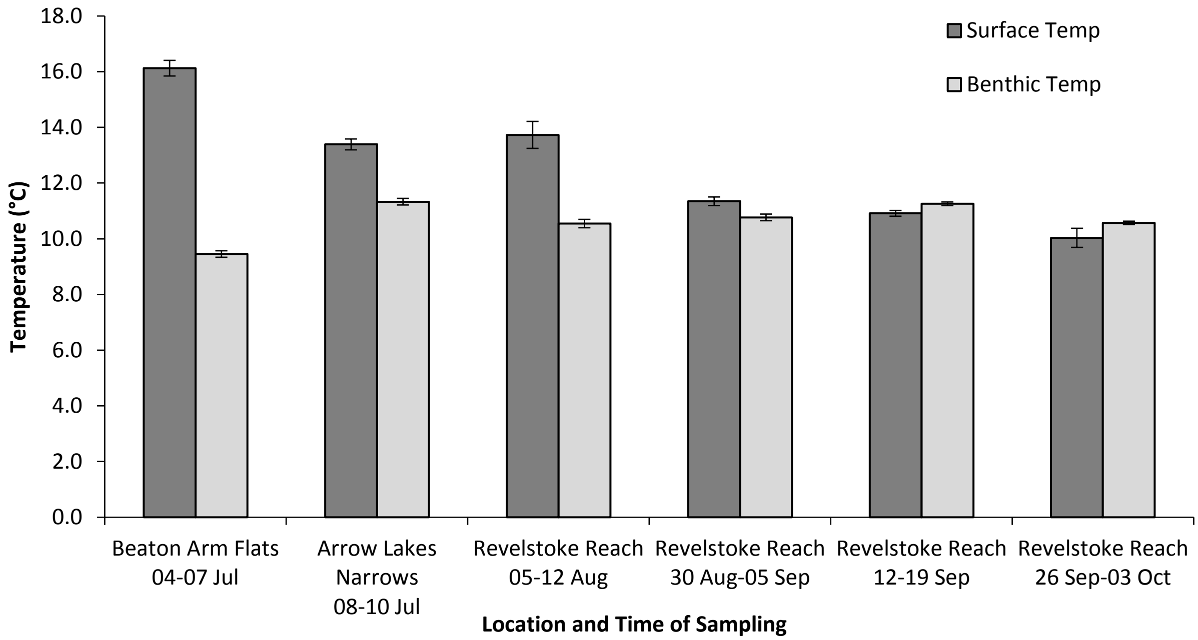

Figure 4. Average surface and benthic water temperatures (mean ± 95% CI) in Beaton Arm, Arrow Lake Narrows, and Revelstoke Reach during sampling sessions.

Reservoir elevations (meters above sea level, MASL) measured at Fauquier in 2020 were similar to the average for previous years (2007 – 2019) from May 01 to Oct 31 (*Figure 5*). The trend in previous years showed reservoir levels peaking in late-June to mid-July. In 2020, reservoir peaked at Fauquier on Jul 04 (439.68 MASL) then declined steadily and reached the fall minimum on Oct 05 2020 (433.35 MASL), two days after field sampling was completed.

Mean daily discharge (m^3/s), including spill discharge, recorded at REV was highly variable throughout the study period (*Figure 6*). In 2020, discharge rates were notably lower in May and higher in July compared to the long-term average (2011-2019). During the study period in 2020, discharge was lowest on Jul 07 at 22:00 (174. 37 m^3/s) and highest on Jul 29 at 11:00 (2284.24 m^3/s).

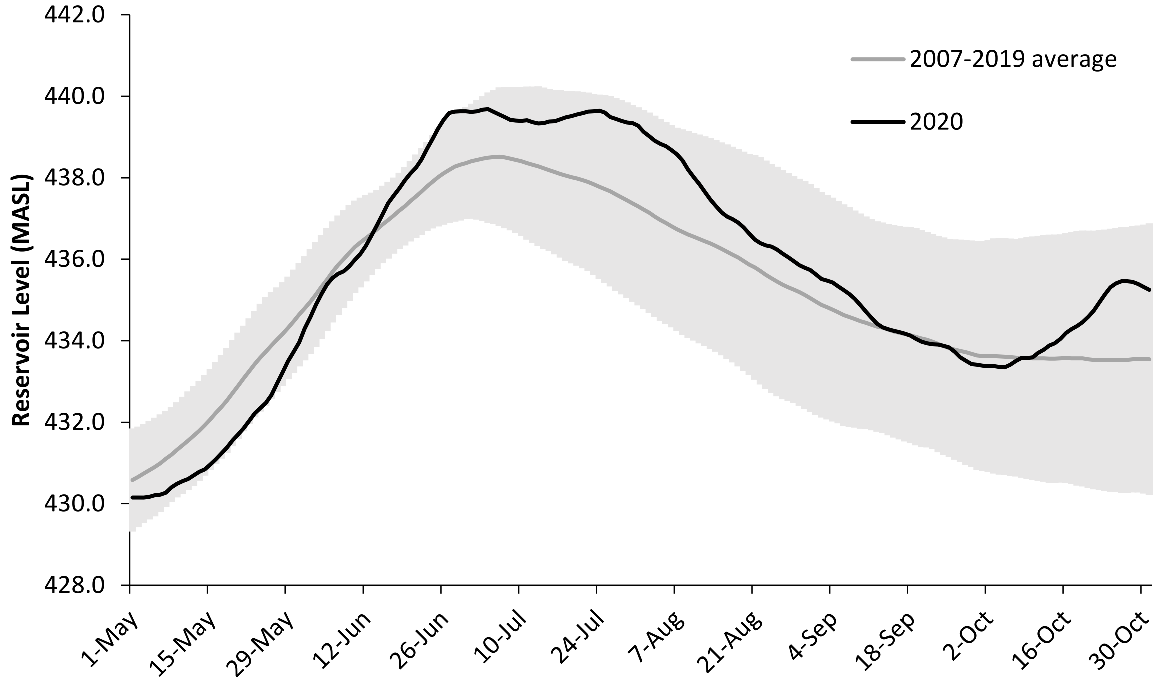

Figure 5. Mean daily reservoir level (meters above sea level; MASL) recorded at Fauguier, BC from May 01 to Oct 31 comparing 2020 elevation to the average from 2007 – 2019 ± SD (data from Government of Canada 2021).

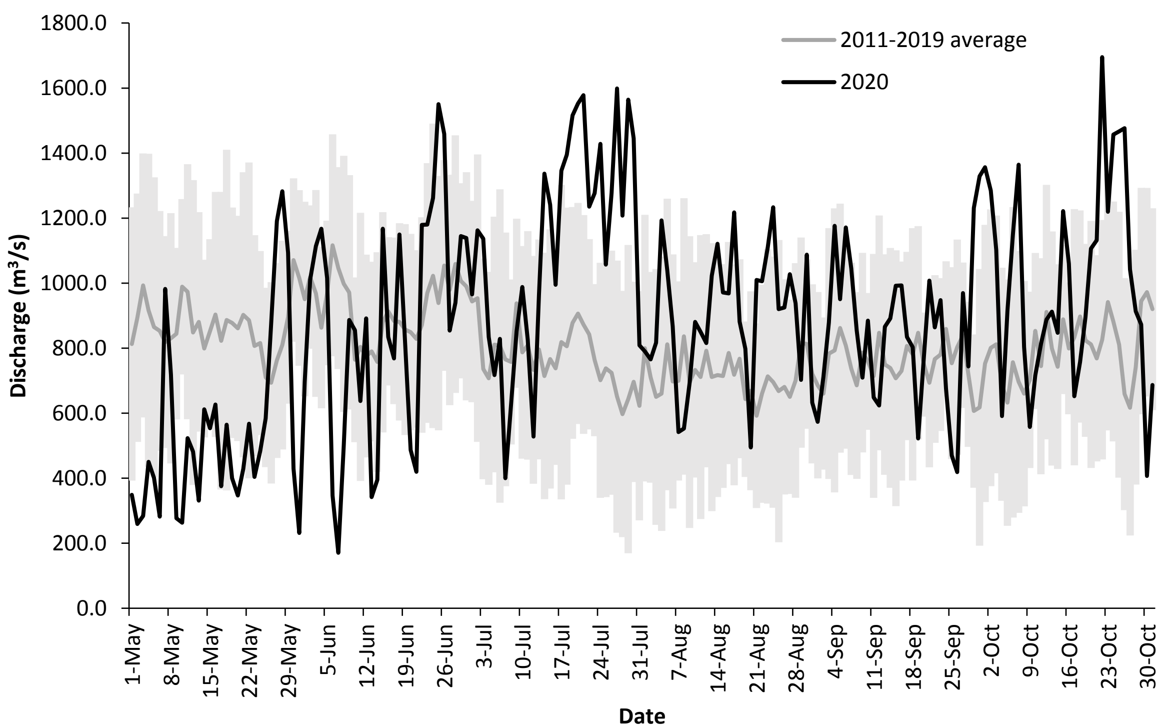

Figure 6. Mean daily discharge (m^3/s) recorded at the Revelstoke Dam from May 01 to Oct 31 comparing 2020 to the average from 2011 – 2019 ± SD (BC Hydro unpublished data 2020).

3.2 Field Sampling Effort

In 2020, 38 days were spent sampling a total of 268 sites (86 gillnets, 182 setlines). GRTS sites were sampled in the Narrows and Revelstoke Reach, but due to the depth of water in the Beaton Arm, sites were found opportunistically in areas of shallow water (10 – 30 m). Some GRTS sites were sampled multiple times over different sessions in the Revelstoke Reach due to the amount of time spent in the area.

Total gillnet effort in 2020 was lower compared to 2018 and 2019 seasons (*Table 2*) due to the difficulty of setting gillnets within the thalweg section of the Revelstoke Reach. Setline effort in 2020 was higher than both 2018 and 2019 (1.5 and 2.1 time higher, respectively) as four full sessions were conducted in that area, with up to six setlines being set per day (*Table 3*).

Table 2. Summary of gillnet effort in the MCR for CLBMON-21 from 2018 to 2020.

Year	Location	Total net-units	Total WSG caught	CPUE
2018	**Revelstoke Reach**	**25.06**	**0**	**0**
2019	Beaton Arm	1.98	0	0
	Arrow Lakes Narrows	10.73	0	0
	Revelstoke Reach	13.64	0	0
	Total	**26.34**	**0**	**0**
2020	Beaton Arm Flats	1.92	0	0
	Arrow Lakes Narrows	1.68	0	0
	Revelstoke Reach	16.04	0	0
	Total	**19.64**	**0**	**0**

Table 3. Summary of setline effort in the MCR for CLBMON-21 from 2018 to 2020.

Year	Location	Total hook-hours	Total WSG caught	CPUE
2018	**Revelstoke Reach**	**44379.66**	**2**	**0.005**
2019	Beaton Arm	4252.03	0	0
	Arrow Lakes Narrows	13079.75	0	0
	Revelstoke Reach	32211.23	2	0.006
	Total	**49543.02**	**2**	**0.004**
2020	Beaton Arm Flats	8476.15	0	0
	Arrow Lakes Narrows	4725.00	0	0
	Revelstoke Reach	67823.52	9	0.013
	Total	**81024.67**	**9**	**0.011**

3.3 Sturgeon Captures

A total of nine juvenile White Sturgeon were captured in 2020 (*Table 4*; *Figure 7*). All Sturgeon were captured on setlines in the riverine section of the MCR between Shelter Bay and Greenslide Creek. All captured Sturgeon possessed PIT tags and were of hatchery origin. CPUE in the Revelstoke Reach in 2020 was higher than both 2018 and 2019 (2.6 and 2.2 times higher, respectively; *Table 3*).

Table 4. White Sturgeon capture location (UTM 11U) data in 2020.

#	Date	Set ID	Easting	Northing	Water Depth (m)	Surface Water Temp (°C)	PIT Tag #
1	6-Aug-20	SL14	422084	5637575	12.5	12.0	900026000543100
2	9-Aug-20	SL142	422458	5633840	17.9	12.6	900026000541498
3	13-Sep-20	DSL142	422164	5634156	11.0	10.1	900026000541211
4	17-Sep-20	DSL75	427339	5629100	12.7	11.1	900026000543455
5	18-Sep-20	DSL95	428994	5627515	14.5	11.4	900254000083275
6	18-Sep-20	DSL4	428997	5626454	14.4	11.5	989001006617501
7	18-Sep-20	DSL4	429022	5626435	14.4	11.5	989001006616329
8	27-Sep-20	ESL2	433851	5616137	12.0	13.4	900026000540965
9	3-Oct-20	ESL64	429016	5624003	10.5	10.0	900254000137719

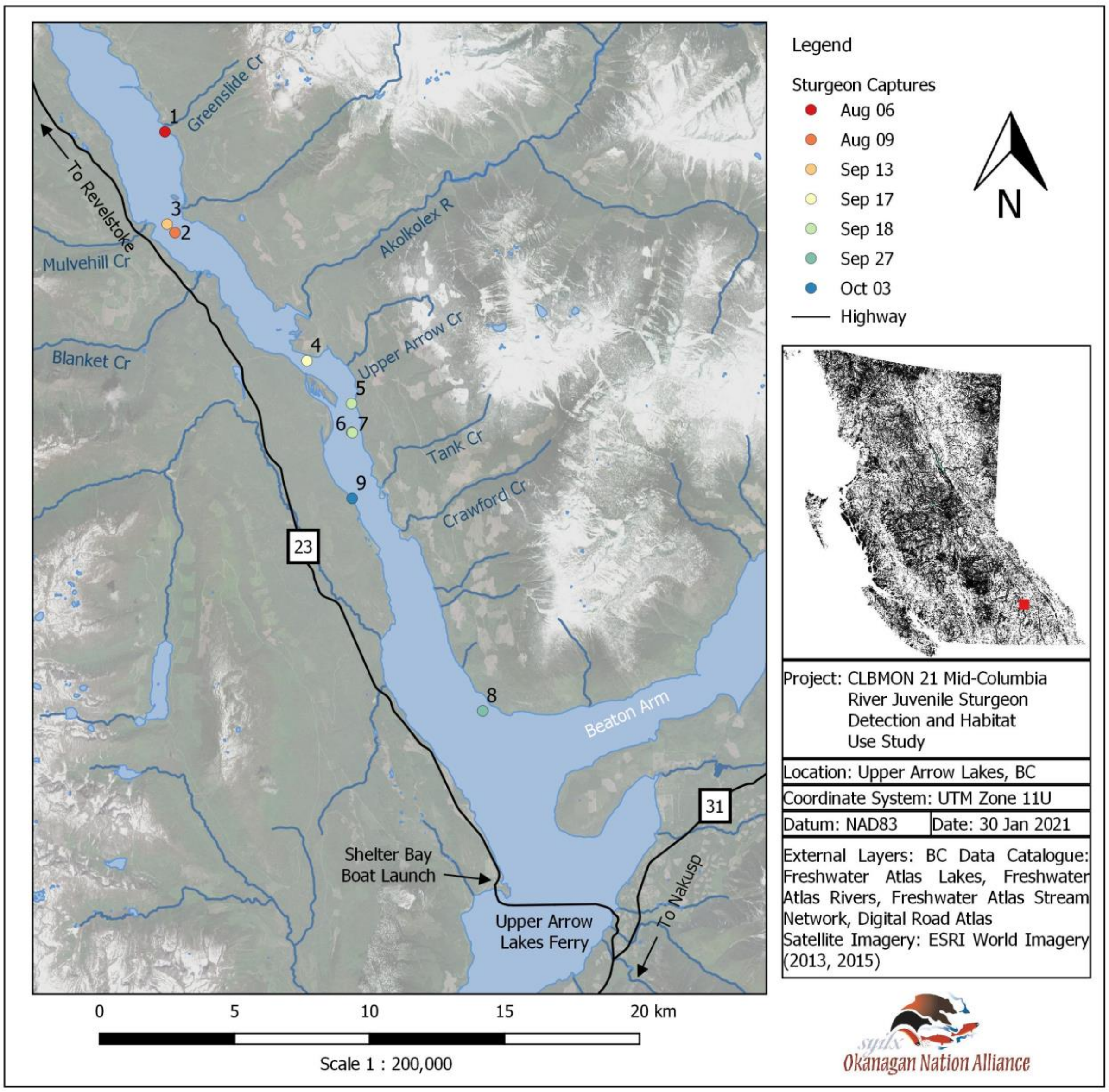

Figure 7. Juvenile White Sturgeon capture locations by number and date in 2020.

3.3.1 Sturgeon Size and Growth

Physical measurements of the nine sturgeon captured in 2020 were compared to release data to calculate total and annual growth (*Table 5*). Sturgeon were captured between 1.1 to 5.4 years after initial release. Growth for these individuals averaged 4.96 cm/year and 0.19 kg/year, lower than averages for all years combined (10.34 cm/year and 0.22 kg/year). The relative weight (Wr) of sturgeon captured in 2020 averaged 98.29% (8.99% 95% CI); all previous captures averaged 95.80% (5.00% 95% CI).

Table 5. Release and growth data for juvenile White Sturgeon caught in 2020.

Release Data				Capture Data			Growth / Year		Relative Weight (Wr)
Year Class	Date	Length (cm)	Weight (kg)	Date	Length (cm)	Weight (kg)	Length (cm)	Weight (kg)	
2015	9-May-17	37.5	0.37	6-Aug-20	44.3	0.57	2.09	0.06	99%
2015	9-May-17	36.0	0.44	9-Aug-20	47.7	0.60	3.59	0.05	82%
2015	9-May-17	45.0	0.59	13-Sep-20	56.8	1.27	3.52	0.20	99%
2015	9-May-17	36.0	0.33	17-Sep-20	52.0	1.05	4.76	0.22	109%
2014	7-May-17	32.0	0.25	18-Sep-20	49.8	0.97	5.28	0.21	116%
2018	7-May-19	36.0	0.31	18-Sep-20	44.5	0.61	6.21	0.22	106%
2018	8-Aug-19	35.0	0.32	18-Sep-20	43.5	0.57	7.62	0.23	106%
2015	9-May-17	36.0	0.32	27-Sep-20	58.3	1.52	6.58	0.35	109%
2014	7-May-15	28.5	0.17	3-Oct-20	55.5	1.13	4.99	0.18	95%

The lengths and weights of the nine individuals captured in 2020 were similar to those captured in previous years (*Figure 8*). With the addition of these nine Sturgeon, the R^2 increased from 0.9258 (in 2019) to 0.9264 (in 2020) and the length-weight relationship can be described by the following formula:

$$\mathbf{W} = \mathbf{0.0209} \times \boldsymbol{e}^{(\mathbf{0.0713} \times \boldsymbol{L})}$$

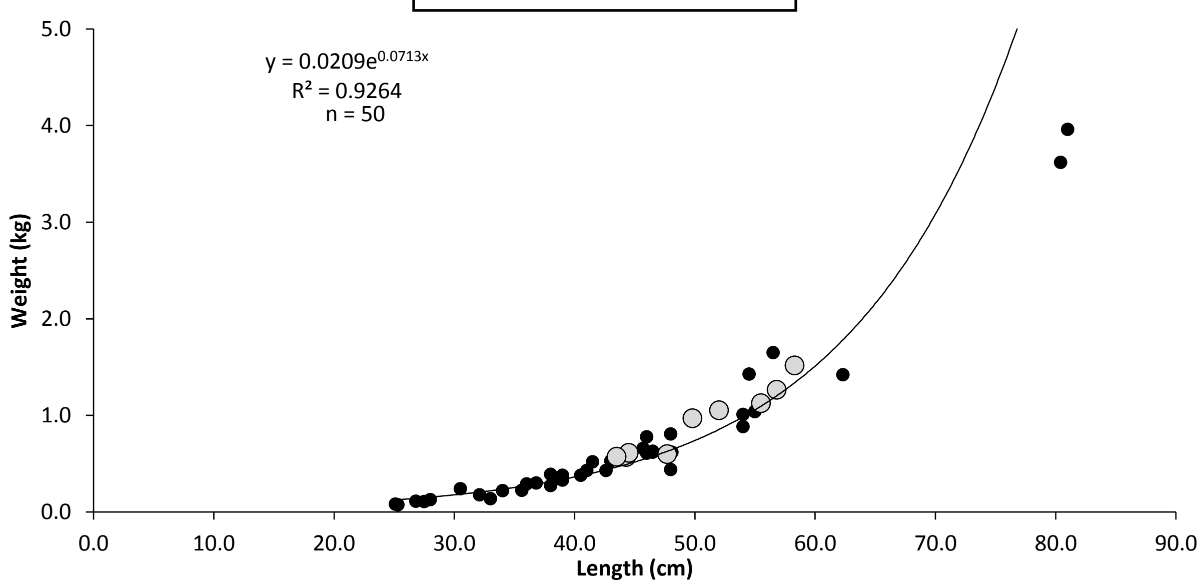

Figure 8. Length-weight relationship for juvenile White Sturgeon caught during CLBMON21 from 2008 -2019 (black dots) and 2020 (grey dots). Data collected by Golder Associates Ltd. and Okanagan Nation Alliance (ONA 2019, 2020).

Two sturgeon from the 2014-year class showed the highest annual increase in length of 34.2 and 54.4 cm/year compared to other year classes (***Error! Reference source not found.***); these are extrapolated growth rates as they were recaptured 128 and 141 days after release, respectively. Sturgeon from the 2017, 2014, and 2008-year classes had the highest annual increase in weight of 0.9, 0.8, and 0.7 kg/year, respectively (*Figure 10*). The mean annual growth for all sturgeon is 10.34 cm/year ± 9.31 (range: 0.00 – 54.36 cm/year) and 0.22 kg/year ± 0.21 (range: -0.17 – 0.89 kg/year).

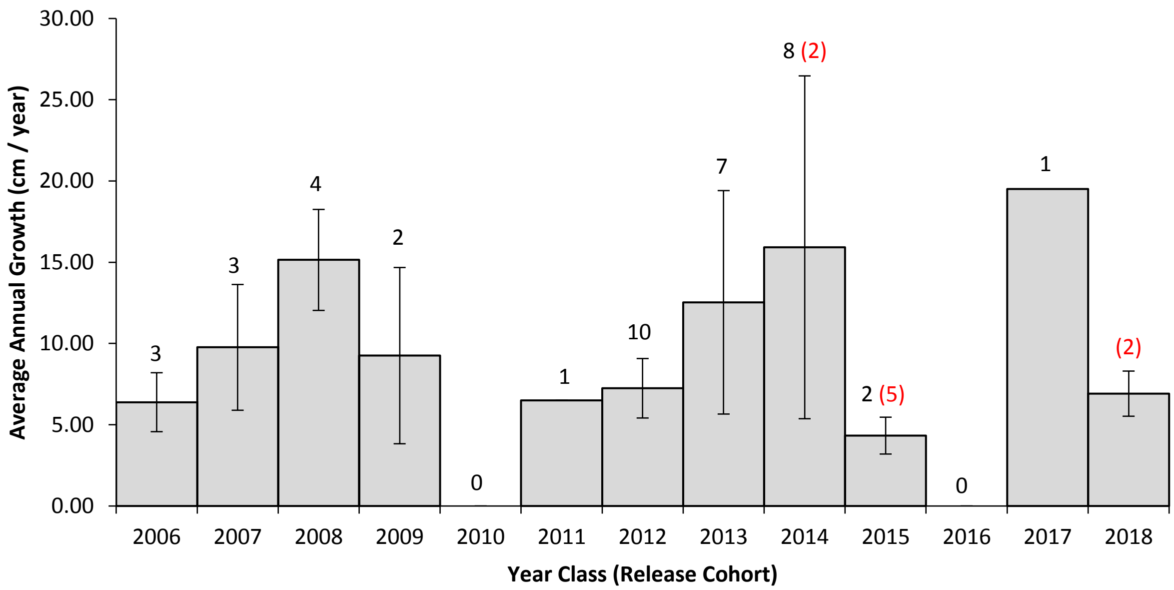

Figure 9. Increase in total length (cm) per year of juvenile White Sturgeon by release year inclusive of all captures during CLBMON-21 from 2008 – 2019 (black text) and 2020 (red text). Data collected by Golder Associates Ltd. and Okanagan Nation Alliance (ONA 2019, 2020).

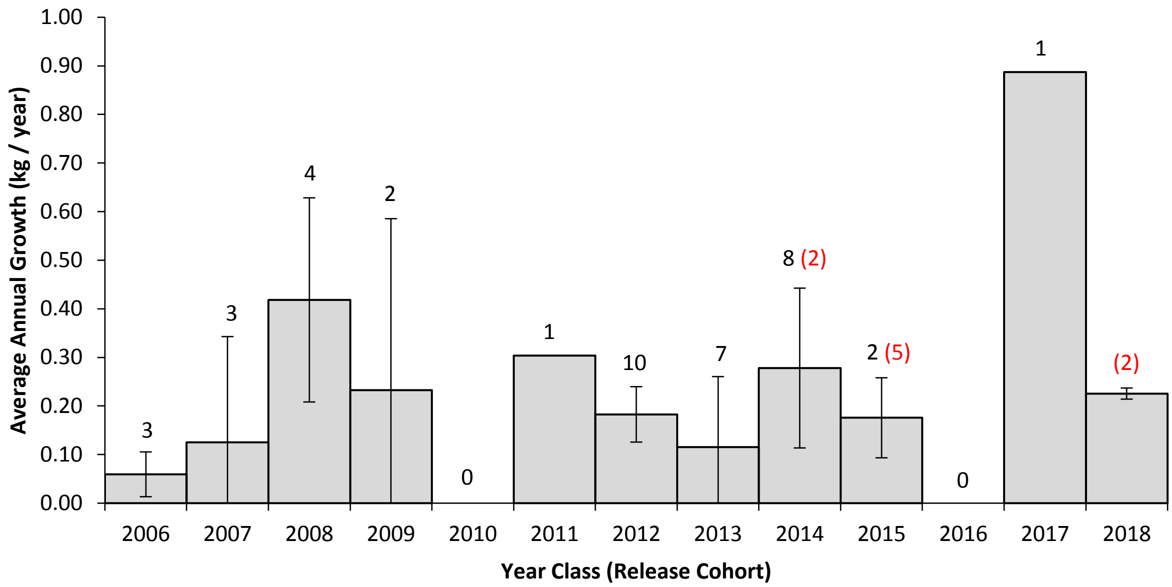

Figure 10. Increase in total weight (kg) per year of juvenile White Sturgeon by release year inclusive of all captures during CLBMON-21 from 2008 – 2019 (grey squares) and 2020 (red squares). Data collected by Golder Associates Ltd. and Okanagan Nation Alliance (ONA 2019, 2020).

3.3.2 Habitat Use

All juvenile White Sturgeon caught in 2020 were in the riverine section of the MCR between Shelter Bay and Greenslide Creek (Revelstoke Reach). Capture locations had water depths between 10.5 – 17.9 m, surface water temperatures between 10.1 – 13.0 °C, and benthic temperatures between 10.6 – 11.5 °C. Average water depth and temperatures were compared between sampling locations, with Revelstoke Reach having the shallowest sets and the coolest surface temperatures (*Table 6*).

Table 6. Comparison of water depth and temperature between locations sampled during CLBMON-21 in 2020.

Location	Sturgeon Capture?	Mean Gillnet Depth (m)	Mean Gillnet Surface Temp (°C)	Mean Setline Depth (m)	Mean Setline Surface Temp (°C), when recorded	Mean Benthic Temp (°C) Jul 08 – Oct 01 2020
Beaton Arm Flats	No	11.9	16.1	11.4	16.1	11.0
Arrow Lakes Narrows	No	12.4	13.4	10.8	13.4	12.9
Revelstoke Reach	Yes	12.3	13.0	11.6	11.1	10.4

3.4 Bycatch

Gillnet bycatch in 2020 included only 39 fish of six species: Bull Trout (BT; *Salvelinus confluentus*), Kokanee (KO; *Oncorhynchus nerka*), Mountain Whitefish (MW; *Prosopium williamsoni*), Lake Whitefish (LW; *Coregonus clupeaformis*), Northern Pikeminnow (NSC; *Ptychocheilus oregonensis*), and Peamouth Chub (PCC; *Mylocheilus caurinus*). Rainbow Trout

(RB; *Oncorhynchus mykiss*) were not encountered as bycatch in 2020. Gillnet bycatch mortality rate was reduced by 8.15% from 2019 to 2020 (*Table 7*).

Setline bycatch in 2020 included 157 fish of six species: Burbot (BB; *Lota lota*), Longnose Sucker (LSU; *Catostomus catostomus*), Largescale Sucker (CSU; *Catostomus macrocheilus*), MW, NSC, and PCC. Setline bycatch mortality rate was reduced by 23.8% from 2019 to 2020. Several fish caught appeared to have been stomach contents, as they were hooked through the body and appeared to be partially digested. These were still recorded as mortalities.

Mortality rate was broken down to show the difference between sampling type (setline and gillnet) and species of concern to this project (BT and BB; *Table 7*).

Table 7. Bycatch mortality by sampling type (setline and gillnet), species of concern (BT and BB), and remaining species during CLBMON21 in 2020.

Parameter	# Caught	# Mortality	Mortality Rate (%)
Setline	122	22	18.5%
Gillnet	39	7	17.9%
BT	6	3	50.0%
BB	122	22	18.0%
Remaining Species	68	11	16.2%
Total	**196**	**36**	**18.4%**

3.5 Invertebrate and Stomach Analyses

Gastric lavage was conducted on eight of the nine Sturgeon captured, five of which had identifiable stomach contents (*Table 8*). The most abundant prey species were from the Order Mysida (9-19 mm in length), found in all five stomachs. The only other prey species identified were Diptera (3-9 mm in length), found in two stomachs.

Eight substrate grabs were collected in association with nine sturgeon encounters, as two juvenile sturgeon were captured on the same setline. Three grabs were attempted near the second sturgeon capture (Aug 09 2020) and all were unsuccessful, potentially indicating substrate too large or embedded to be sampled with the Ponar. Substrate grabs resulted in highly variable sample volumes that did not seem to be related to sediment type. Sediment where sturgeon were captured was primarily sand, however the Sturgeon caught furthest downstream, on Sep 27 2020, was in silty substrate.

Four of the seven successful substrate grabs had identifiable benthic invertebrates. Diptera were found in all four samples (1-9 mm in length) and Oligochaeta were found in three samples (4-10 mm). The substrate grab with the most abundant and largest Diptera individuals was associated with the sturgeon that had over 30 individual Diptera in its stomach.

Table 8. Stomach contents and associated substrate grabs for each juvenile White Sturgeon (WSG) caught in the MCR during CLBMON21 in 2020.

WSG LAVAGE				**SUBSTRATE GRAB**				
WSG #	**Lavage Contents**	**#**	**Size (mm)**	**Substrate Type and % Composition**	**Sample Volume (cm^3)**	**Sample Contents**	**#**	**Size (mm)**
1	- Diptera - Mysida	34 13	3-9 12-19	Sand (100%)	623	- Diptera - Oligochaeta	11 1	4-9 5
2	Empty			Substrate grab unsuccessful				

3	- Mysida	1	16	Coarse gravel (75%) Coarse sand (25%)	52	None		
4	- Mysida	19	14-17	Sand (100%)	83	- Diptera - Oligochaeta	1 1	6 4
5	Empty			Sand (100%)	133	None		
6	- Mysida	21	10-15	Sand (70%) Silt (28%) Organic Matter (2%)	51	None		
7	- Diptera - Mysida	3 51	3-5 9-15					
8	Empty			Silt (100%)	255	- Diptera - Oligochaeta	14 2	1-4 8-10
9	Lavage not conducted			Sand (100%)	212	- Diptera	3	1-2

Rock basket retrieval was conducted on Oct 01 and 02, 2020. Diptera were the most abundant invertebrate identified (n = 484), followed by Oligochaeta (n = 12), and Platyhelminthes (n = 5). One Trichoptera and one Arachnida were also identified. A full list of invertebrates identified (abundance and life stage) by rock basket is listed (*Table 9*), along with a representative photo (*Figure 11*).

Table 9. Summary of invertebrates collected from Rock Baskets during CLBMON21 in 2020.

#	Depth	Substrate Type and % Composition	Contents	Life Stage	#	Size (mm)
1	Shallow	Silt (70%) Sand (20%) Organic Matter (10%)	- Diptera - Diptera	Larva Pupa	253 3	3-6 3
2	Deep	Silt (80%) Organic Matter (20%)	- Diptera - Flatworm	Larva -	2 1	6 2
3	Deep	Sand (100%)	- Diptera - Platyhelminthes - Oligochaeta	Adult - -	1 2 2	3 1-5 3-6
4	Shallow	Silt (50%) Organic Matter (50%)	- Diptera - Diptera - Oligochaeta	Larva Pupa -	4 3 6	3 3 6-10
5	Deep	Sand (100%)	- Diptera - Platyhelminthes - Oligochaeta	Larva - -	38 1 1	1-3 5 5
6	Shallow	Sand (90%) Silt (10%)	- Diptera - Trichoptera - Arachnida	Larva Larva -	65 1 1	1-4 2 4
7	Shallow	Silt (70%) Sand (25%) Organic Matter (5%)	- Diptera - Diptera - Diptera	Larva Pupa Adult	47 1 1	1-3 2 3
8	Deep	Sand (90%) Organic Matter (10%)	- Diptera - Platyhelminthes - Oligochaeta	Larva - -	4 1 3	1-3 2 3-5
9	Deep	Silt (80%) Sand (20%)	- Diptera	Larva	17	1-4
10	Shallow	Silt (100%)	- Diptera - Diptera	Larva Pupa	44 1	1-3 3

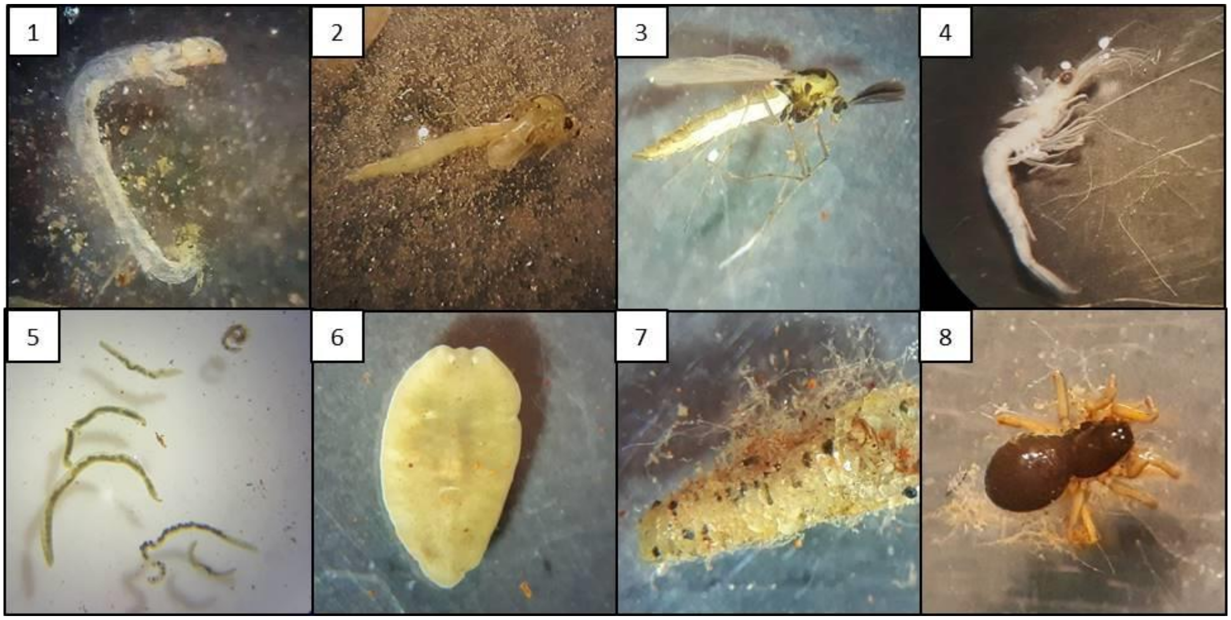

Figure 11. Photo inventory of invertebrates found during CLBMON21 in 2020 lab analysis (1) Diptera - larva, (2) Diptera - pupa, (3) Diptera - adult, (4) Mysida, (5) Oligochaeta, (6) Platyhelminthes, (7) Trichoptera, and (8) Arachnida.

4.0 Discussion

Since 2013, the primary objective of CLBMON-21 has been to maximize juvenile White Sturgeon captures in the MCR to determine survival rates for juveniles released from the conservation aquaculture program (BC Hydro 2007). Despite low capture rates in all study years, data collected have contributed to the current state of knowledge on distribution, habitat use, and growth rates.

4.1 Management Questions

Although the capture rate in 2020 was higher compared to recent previous years, the lack of recaptures limits any assessment beyond that previously stated in the 2019 synthesis report (ONA 2019). Results from 2020 that contribute to selected management questions are discussed below.

(1) Where are the habitat locations utilized by juvenile Sturgeon in the Middle Columbia?

Juvenile sturgeon were captured from August to October 2020 in the thalweg of the riverine section of the MCR (Shelter Bay to Greenslide Creek), consistent with most captures in past years. Juvenile Sturgeon were not captured in the Arrow Lakes Narrows or the Beaton Arm Flats. The four sessions conducted in the Revelstoke Reach did not always cover the same geographical locations; and although it would appear that sturgeon were caught further downstream in the fall, distribution of sampling effort may be a contributing factor. Setline effort during the second, third, and fourth sessions were concentrated from Greenslide Creek downstream to Tank Creek. Setlines were only deployed downstream of Tank Creek during the last session (Sep 26 – Oct 03), where the sturgeon closest to Shelter Bay was encountered.

(2) What are the physical and hydraulic properties of this habitat that define its suitability as juvenile Sturgeon habitat?

Sturgeon in 2020 were captured at depths between 10.5 – 17.9 m (average = 13.3 m), similar to previous captures at depths between 7.0 – 18.3 m (average = 12.2 m). Water velocities were only formally recorded for sturgeon captures in 2010 (average = 0.2 m/s), but "low flow" areas are prioritized to increase sturgeon encounters and reduce entanglement of sampling gear.

(3) What is the quantity of available habitat meeting these conditions in the Middle Columbia?

As identified in the 2019 synthesis report (ONA 2019), juveniles appear to be selecting calm (<0.5 m/s), deep (>10 m) habitats with fine substrates within the MCR. Depending on discharge from REV and ALR water level elevations, this type of habitat can be limiting. Results from fieldwork conducted in 2020 further support this.

(4) How do hydraulic conditions resulting from dam and reservoir operations relate to habitat suitability for juvenile White Sturgeon in the mid-Columbia?

Throughout these studies, Sturgeon appear to prefer the thalweg of the riverine section of the Revelstoke Reach of the MCR (from Greenslide Creek) downstream to the river-reservoir transition zone (near Shelter Bay). Dam and reservoir operations directly influence the availability of water depths within Revelstoke Reach, which would subsequently dictate the depth of the thalweg and availability of shallow water habitats.

(5) What are the survival rates of juvenile White Sturgeon in the Middle Columbia River?

Both capture and recapture rates of juveniles in the MCR remain low. There were no recaptures in 2020, limiting any insight to survival rates. The individuals captured in 2020 also had low annual growth rates relative to individuals caught in previous years. Before 2016, all sturgeon (n = 22) were captured less than 2.5 years after release. Since 2016, 28 sturgeon have been caught (excluding one same-year recapture event), 13 of which were captured 3 – 5 years after release, 3 of which were captured 5 – 10 years after release, and 1 capture over 10 years after release. These data indicate that there is capacity for survival of hatchery-released sturgeon in the MCR, however whether they are able to reach maturity within this system cannot yet be determined.

(6) C*an modification be made to the operations of Revelstoke Dam and/or Arrow Lakes Reservoir to protect or enhance juvenile White Sturgeon habitat?*

The deep-water, thalweg habitats that juvenile sturgeon appear to be prioritizing are less prone to fluctuations in REV operations even when reservoir elevations are low. At present, there are no specific recommended modifications to REV operations that could protect or enhance juvenile Sturgeon habitats.

4.2 Substrates and Invertebrates

In 2020, 105 Mysida and 37 Diptera were recovered from five lavage samples, a large increase to the single Mysid recovered in 2019. Stomach contents were at minimum 3 mm in length, invertebrates identified under the microscope from substrate grabs and rock baskets were commonly less than 2 mm. This may indicate that Sturgeon are selecting prey based on size, although smaller stomach contents may be more quickly digested, not flushed out during the lavage, or degrade before positive identification.

A study in the Canadian Lower Columbia River (downstream of HLK Dam) identified 16 different taxa in juvenile White Sturgeon stomachs (Crossman *et al*. 2016). In that study, Mysida were identified as an important food source for juvenile Sturgeon. Gastropoda, Diptera, and Trichoptera were the next three most dominant prey taxa (Crossman *et al*. 2016). To date, MCR juvenile sturgeon appear to be utilizing the same food sources, when present in the area. Diptera are often found in substrate grabs and rock baskets, and in turn, occasionally found in lavage samples of juvenile sturgeon in the MCR. Gastropoda have not been identified in recent years in substrate grabs or rock baskets, and Trichoptera only rarely encountered; neither were identified in lavage samples from the MCR. As Mysida occupy the water column, rather than substrate, they have not been encountered through either substrate grabs or rock basket sampling.

Information regarding Mysida densities in the MCR have been collected in association with the Arrow Lakes Reservoir Nutrient Restoration Program (Schindler *et al*. 2007; Bassett *et al*. 2020) but are limited to the Upper and Lower Arrow Lakes, and do not include the riverine section where juvenile sturgeon are most commonly encountered. In the 2020 report, Basset *et al*. (2020) indicated Mysida densities in the Upper Arrow Lake Reservoir in 2019 increased from 2018, and was above the long-term 1997-2019 average. Data relating to Mysida densities during the 2020 season have yet to be reported. General Mysida population trends in the Arrow Lakes Reservoir may be correlated with Mysida availability in the riverine section of the MCR, but this is untested.

This was the second year rock baskets were deployed to monitor the benthic macroinvertebrate community available as prey species to juvenile sturgeon in the MCR. Rock baskets may have provided habitat for invertebrates not representative of local substrate, and potentially caused immigration and/or emigration of invertebrates as a result. There was no direct correlation between substrate type and identified invertebrate communities, however in general, shallow sites were more silty, and deep sites were more sandy. There were more individual benthic invertebrates identified in shallow sets (n = 430) than deep sets (n = 73), however the dataset was too small to show confidence. In addition, two factors seemed to greatly influence identification rate between samples: (1) amount of interstitial material and (2) size of invertebrates.

In 2020, some rock baskets had high volumes of fine silty and organic material within the sample, potentially resulting in lower identification rates compared to 2019 (when all rock basket samples had very little volume) and between other rock basket samples in 2020. In addition, a high number of Diptera were less than 2 mm in length and not readily visible without magnification, but were found in great numbers when analysed under the microscope. Due to large volumes, samples were spread out in a large white tray and invertebrates and potential invertebrates were separated and verified under the microscope. Although in 2020, over 500 individual invertebrates were identified in ten rock baskets (over four times the amount identified in 2019 from nine rock baskets), it is likely the identification rate was lower due to larger volumes of interstitial material.

Substrate grabs had fewer invertebrates compared to rock baskets; however the information they provide may be more directly relevant to juvenile sturgeon, the habitat they chose, and the food sources available.

5.0 Recommendations

The following recommendations are presented in two sections: (1) recommendations from the technical forum held for the Mid-Columbia White Sturgeon Management Plan in December 2018 (BC Hydro 2018) and (2) recommendations based on the results from this year of the program:

1. 2018 Technical Forum Recommendations (BC Hydro 2018):
    - 1.1 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.
        - i. Direct capture remains critical with a focus on Beaton Flats and pilot sampling of deeper habitats (>30 m). Consultation is required with MFLNRORD on bycatch mortalities
        - ii. Consider telemetry 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 focussed on recaptured fish that have survived for several years following release.
        - iii. Review eDNA experimental work done by UVIC/UBC/BC Hydro to determine if it could be a future tool to help guide direct sampling efforts.
    - 1.2 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.
        - i. Deploy rock baskets to sample invertebrate prey types and density (this was conducted in 2019-2020, but may be expanded in future years and should be paired with substrate grabs).
        - ii. Conduct plankton tows to determine seasonal and diel plankton (primarily mysids) availability.
2. Recommendations from Year 14 (2020):
    - 1.1 Conduct a literature review on juvenile Sturgeon diet sample methods and analyses and apply methods for direct comparisons. For example, determine whether prey diversity is limiting in the MCR compared to similar systems, and determine the importance of prey diversity on growth of juvenile Sturgeon.
    - 1.2 Increase the number of substrate grabs throughout the Revelstoke Reach to better understand substrate types and availability. A sub-set of these may be further analysed for invertebrate identification, abundance and diversity.

Substrate type may be correlated to benthic invertebrate prey densities and total availability for juvenile sturgeon.

1.3 Record benthic water velocity at Sturgeon capture locations. Higher precision data would better inform juvenile habitat preference in the MCR and may enable the development of recommendations for operations at REV.

1.4 Conduct plankton tows to determine Mysida availability to fill data gap in the Revelstoke Reach.

1.5 Apply the HECRAS model developed in CLBMON15a to the Revelstoke Reach section of the MCR to assesses substrate availabilities by type at various REV discharge flows and reservoir elevations.

6.0 Literature Cited

Bassett, M., Arndt, S., and Schindler, E. 2020. Arrow Lakes Reservoir Nutrient Restoration Program. Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Fish & Wildlife Compensation Program – Section. Prepared with financial support of Fish and Wildlife Compensation Program & Arrow Lakes Power Corporation. 20 p.

BC Hydro. 2007. Columbia River Project Water Use Plan Monitoring Program Terms of Reference, Columbia River White Sturgeon Management Plan: CLBMON-21 Mid Columbia River juvenile White Sturgeon detection and habitat program and tracking of existing sonic-tagged sturgeon.

BC Hydro. 2015. Lower Columbia River Juvenile Detection Program (CLBMON-29). Years 4 and 5 Data Report. Report by BC Hydro, Castlegar, BC. 82 p. +1 app.

BC Hydro. 2018. Mid Columbia River White Sturgeon Technical Forum – Summary and Action Items. Memo produced by BC Hydro, 4 p.

BC Hydro unpublished data 2019 provided by James Crossman, Senior Environmental Coordinator, via email on Feb 20 2020.

Beamesderfer, R. C. 1993. A standard weight (Ws) equation for White Sturgeon. California Fish and Game. 79:63–69.

Courtier, J. 2010. 2009 Assessment of Juvenile Nechako White Sturgeon. Report prepared for the Ministry of Environment. Prince George, BC. 29 p. + 3 app.

Crossman, J., Jay, K., and Hildebrand, L. 2016. Describing the Diet of Juvenile White Sturgeon in the Upper Columbia River Canada with Lethal and Nonlethal Methods. North American Journal of Fisheries Management; 36: 421-432.

Department of Fisheries and Oceans Canada (DFO). 2014. Recovery strategy for White Sturgeon (*Acipenser transmontanus*) in Canada [Final]. In Species at Risk Act Recovery Strategy Series. Ottawa: Fisheries and Oceans Canada. 252 p.

Ghosh, D. and Biswas, J.K. 2015. Macroinvertebrate diversity indices: A quantitative bioassessment of ecological health status of an oxbow lake in Eastern India. Journal of Advances in Environmental Health Research 2015; 3(2): 78-90. Accessed from: https://www.academia.edu/16503931/Macroinvertebrate_diversity_indices_A_quantitative_bioassessment_of_ecological_health_status_of_an_oxbow_lake_in_Eastern_India

Glova, G., Nelson, T., English, K., and Mochizuki, T. 2010. Investigations of Juvenile White Sturgeon Abundance and Habitat Use in the Lower Gravel Reach of the Lower Fraser River, 2009-2010. LGL Environmental Research Associates. Prepared for Fraser River Sturgeon Conservation Society. 23 p. + 1 app.

Golder Associates Ltd. 2006. Upper Columbia White Sturgeon Stock Monitoring and Data Management Program: Synthesis Report, 1 November 2003 - 31 March 2006. Report prepared for British Columbia Ministry of Environment, Nelson, B.C. Golder Report No. 05-1480-025F: 55 p. + 2 app. + plates

Golder Associates Ltd. 2009 Monitoring of juvenile White Sturgeon habitat use and movements of sonic-tagged sturgeon: 2008 investigations. Report prepared for BC Hydro, Revelstoke, B.C. Golder Report No. 08 1480-0030F: 34 p. + 3 app.

Golder Associates Ltd. 2010. Middle Columbia River juvenile White Sturgeon monitoring: 2009 Investigations. Report prepared for BC Hydro, Castlegar, B.C. Golder Report No. 09-1480-0045F: 47 p. + 3 app.

Golder Associates Ltd. 2011. Middle Columbia River juvenile White Sturgeon monitoring: 2010 Investigations. Report prepared for BC Hydro, Castlegar, B.C. Golder Report No. 10-1492-0113F: 47 p. + 4 app.

Golder Associates Ltd. 2012. Middle Columbia River juvenile White Sturgeon monitoring: 2011 investigations. Report prepared for BC Hydro, Castlegar, B.C. Golder Report No. 11-1492-0035F: 22 pp. + 2 app. Golder and ONA; 2017. CLBMON-16 Middle Columbia River Fish Population Indexing Database. For BC Hydro, Castlegar, BC. Data from 2001 to 2017 sample years.

Golder and Okanagan Nation Alliance 2013. Middle Columbia River juvenile White Sturgeon monitoring: 2012 investigations. Report prepared for BC Hydro, Castlegar, BC. Golder Report No. 12-1492-0053: 42 p. + 2 app.

Government of Canada 2021. Environment and Climate Change Canada Real-time and Historical Hydrometric Data web sites. Accessed from: https://wateroffice.ec.gc.ca/mainmenu/real_time_data_index_e.html and https://water office.ec.gc.ca/mainmenu/historical_data_index_e.html

Hildebrand, L. R. and Parsley, M. 2013. Upper Columbia White Sturgeon Recovery Plan – 2012 Revision. Prepared for the Upper Columbia White Sturgeon Recovery Initiative. 129 p + 1 app. Available at: www.uppercolumbiasturgeon.org

Mandaville, S. M. 2002. Benthic Macroinvertebrates in Freshwaters-Taxa Tolerance Values, Metrics, and Protocols. Project H-1. Soil & Water Conservation Society of Metro Halifax. Appendix A: 58 p.

McCabe Jr., G.T. 1994. Report D: Objectives 1 & 2. National Marine Fisheries Service, Northwest Fisheries Science Center. Seattle, WA. 21 pp.

Okanagan Nation Alliance (ONA). 2016. CLBMON21: Mid-Columbia River Juvenile White Sturgeon Monitoring – 2015 Report. Prepared for BC Hydro, Castlegar, BC. 26 p. + 3 app.

Okanagan Nation Alliance (ONA). 2017. CLBMON21: Mid-Columbia River Juvenile White Sturgeon Monitoring – 2016 Investigations. Report prepared for BC Hydro, Castlegar, BC. 27 p. + 3 app.

Okanagan Nation Alliance (ONA). 2018. CLBMON21: Mid-Columbia River Juvenile White Sturgeon Detection and Habitat Use Program – 2007 to 2017 Synthesis Report. Okanagan Nation Alliance Report prepared for BC Hydro, Castlegar, BC. 84 p. + 2 app.

Okanagan Nation Alliance (ONA). 2019. CLBMON21: Mid-Columbia River Juvenile White Sturgeon Detection and Habitat Use Program – 2007 to 2018 Synthesis Report. Okanagan Nation Alliance Report prepared for BC Hydro, Castlegar, BC. 84 p. + 5 app.

Okanagan Nation Alliance (ONA) 2020. CLBMON21: Mid-Columbia River Juvenile White Sturgeon Detection and Habitat Use Program – 2019. Okanagan Nation Alliance Report prepared for BC Hydro, Castlegar, BC. 24 p. + 2 app

Perrin, C.J., L. Westcott, and D. Schmidt. 2008. Middle Columbia River ecological productivity monitoring, 2007. Report prepared by Golder Associates and Limnotek Research and Development Inc. for BC Hydro. 59 p.

Schindler, E. U., Vidmanic, L., Sebastian, D., Andrusak, H., Scholten, G., Woodruff, P., Sockner, J., Ashley, K. I., and Andrusak, G. F. 2007. Chapter 1 Introduction – Arrow Lakes Reservoir Fertilization Experiment, Years 6 and 7 (2004 and 2005) Report. Fisheries Project Report No. RD 121 2007. Fish and Wildlife Science and Allocation, Ministry of Environment, Province of British Columbia. 14 p. Accessed from: http://a100.gov.bc.ca/pub/acat/documents/r11393/ALRFertilizationExperiment,Years6and7-Schindleret_1197929691716_8e248a68ce5aa62397a394c4935821a961e1d998cc8.pdf

Stevens, D. L. and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association. 99(465): 262-278.

Upper Columbia White Sturgeon Recovery Initiative (UCWSRI). 2006. Upper Columbia River adult White Sturgeon capture, transport, and handling manual. Prepared by Golder Associates Ltd. 20p + app.

Voshell, Jr., J. Reese. 2002. A Guide to Common Freshwater Invertebrates of North America. The McDonald & Woodward Publishing Company. Granville, Ohio. Tenth Printing (2014).

Appendix A – Sample Site Location Maps

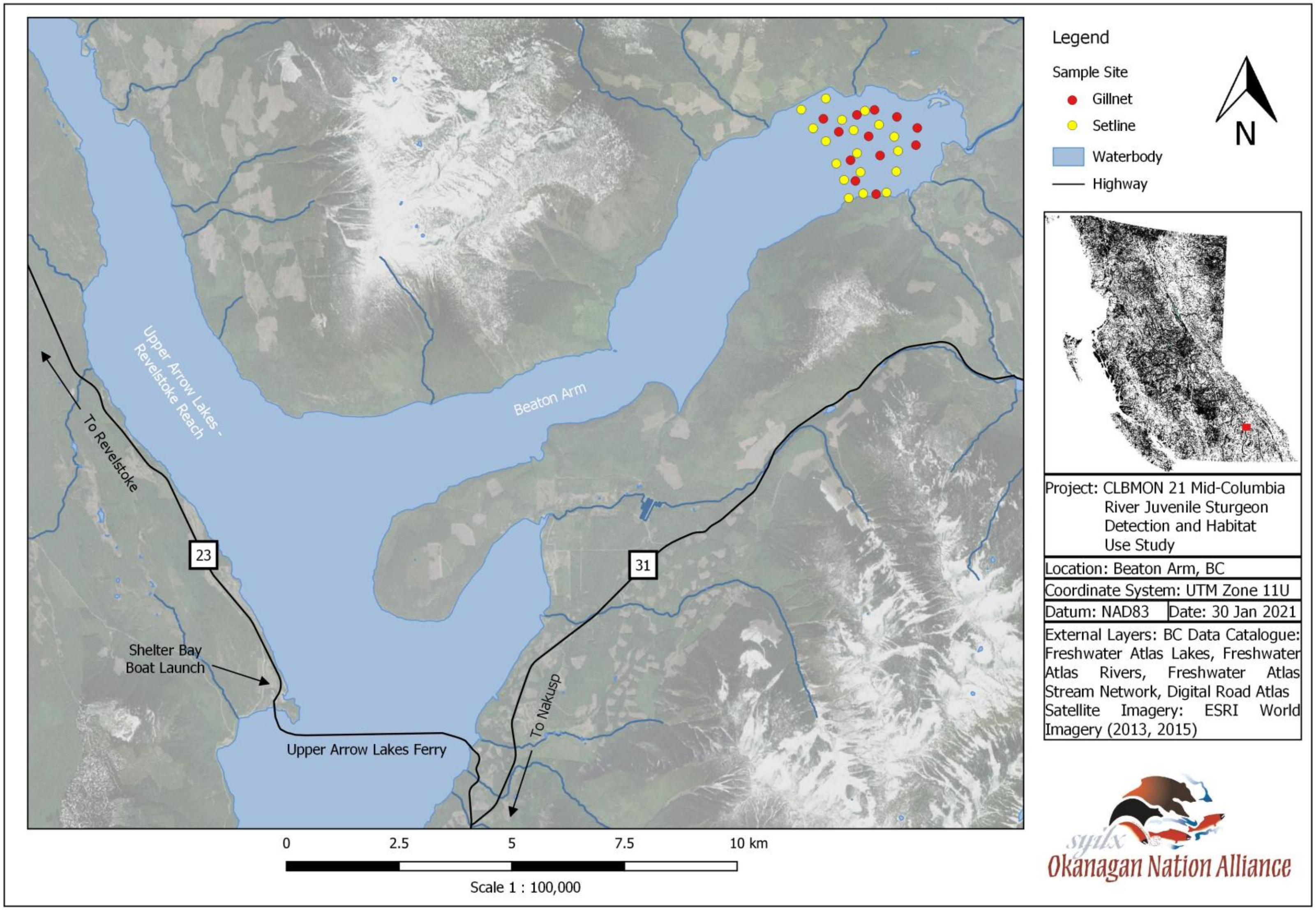

Figure 12. Field session 1A in the Beaton Arm showing gillnet and setline sample sites during CLBMON21, Jul 04 – 07 2020.

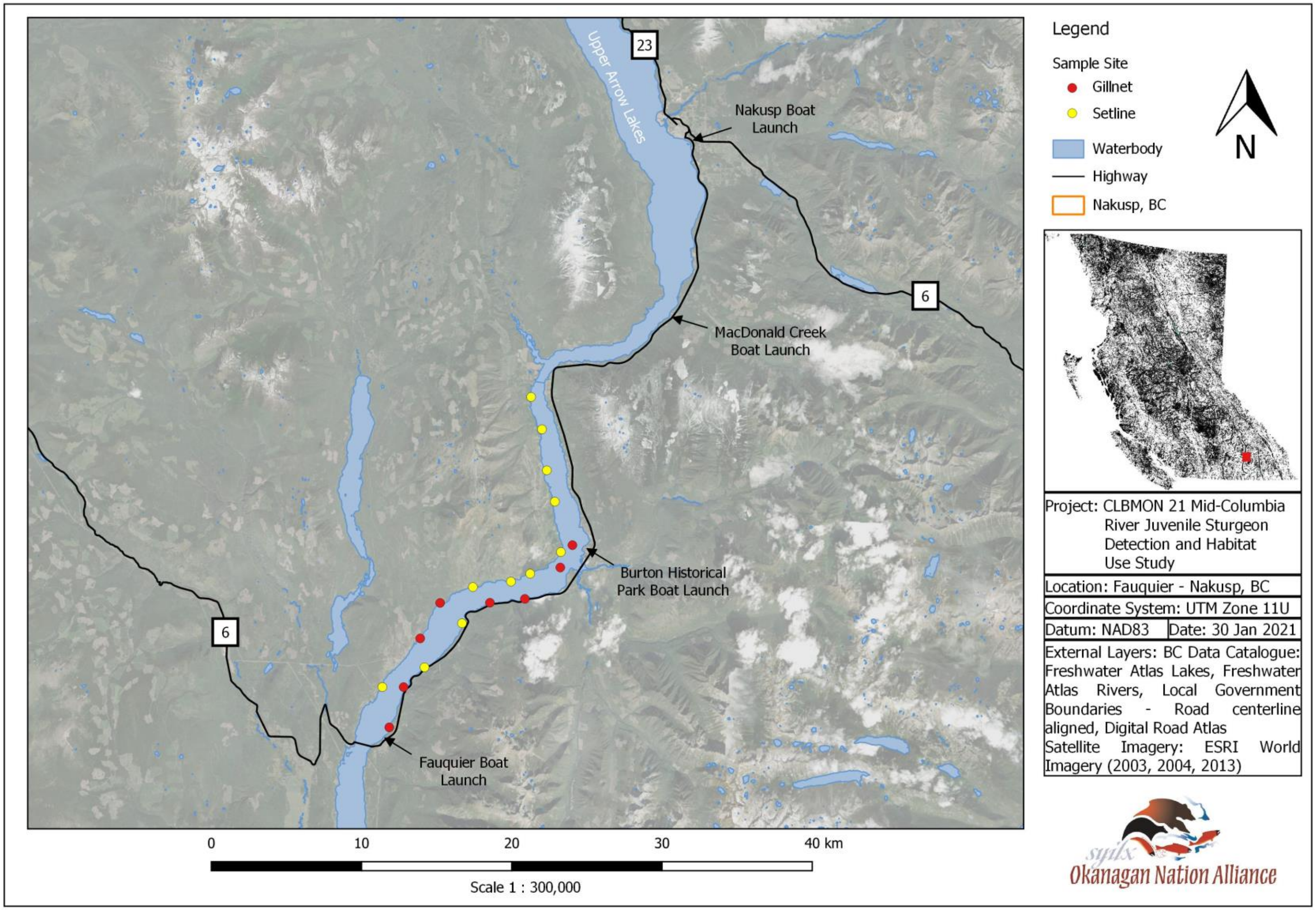

Figure 13. Field session 1B in the Arrow Lake Narrows showing gillnet and setline sample sites during CLBMON21, Jul 08 – 10 2020.

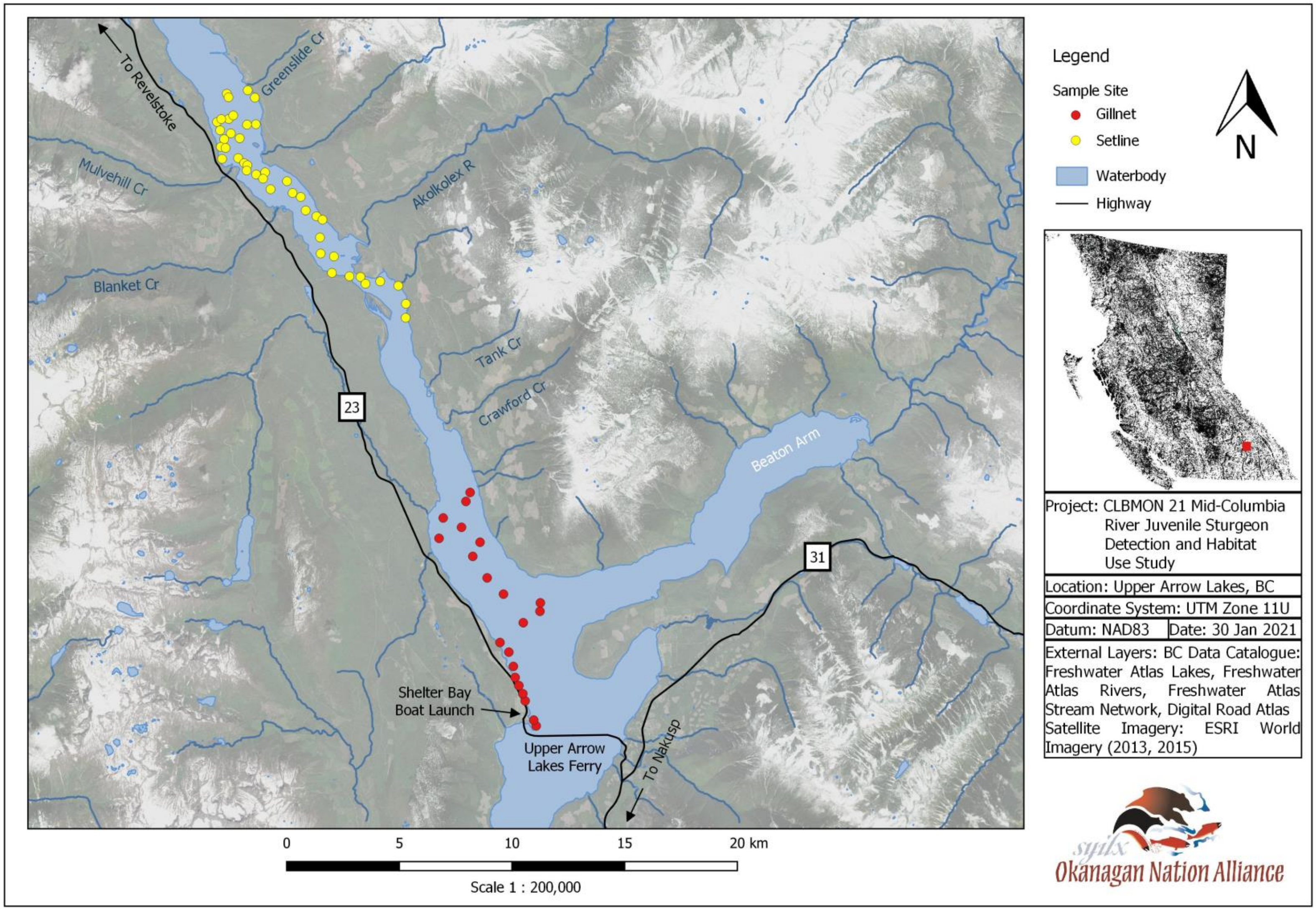

Figure 14. Field session 2 in the Revelstoke Reach from Shelter Bay to Greenslide Creek showing gillnet and setline sample sites during CLBMON21, Aug 05 – Sep 12 2020.

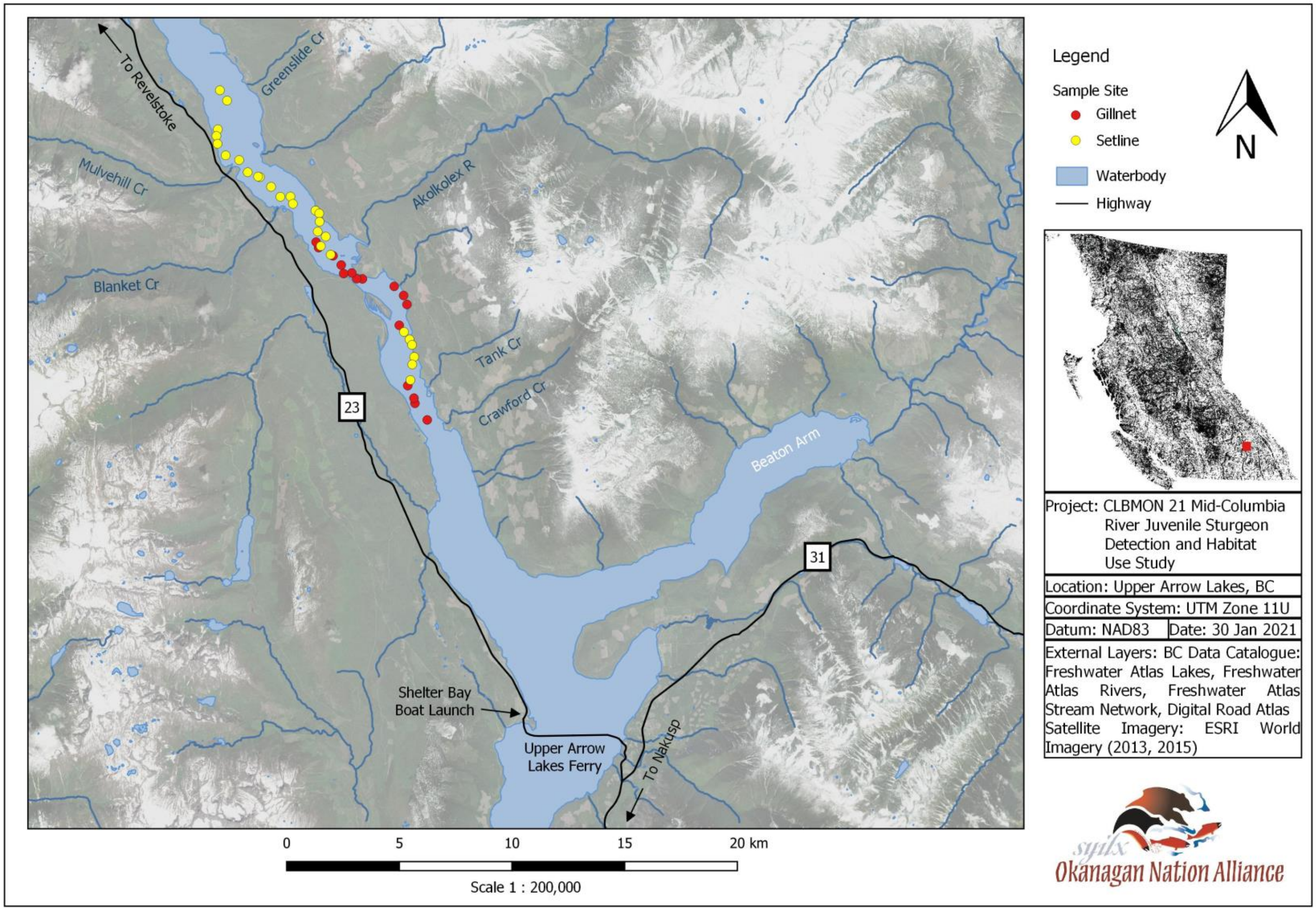

Figure 15. Field session 3 in the Revelstoke Reach from Crawford Creek to Greenslide Creek showing gillnet and setline sample sites during CLBMON21, Aug 30 – Sep 05 2020.

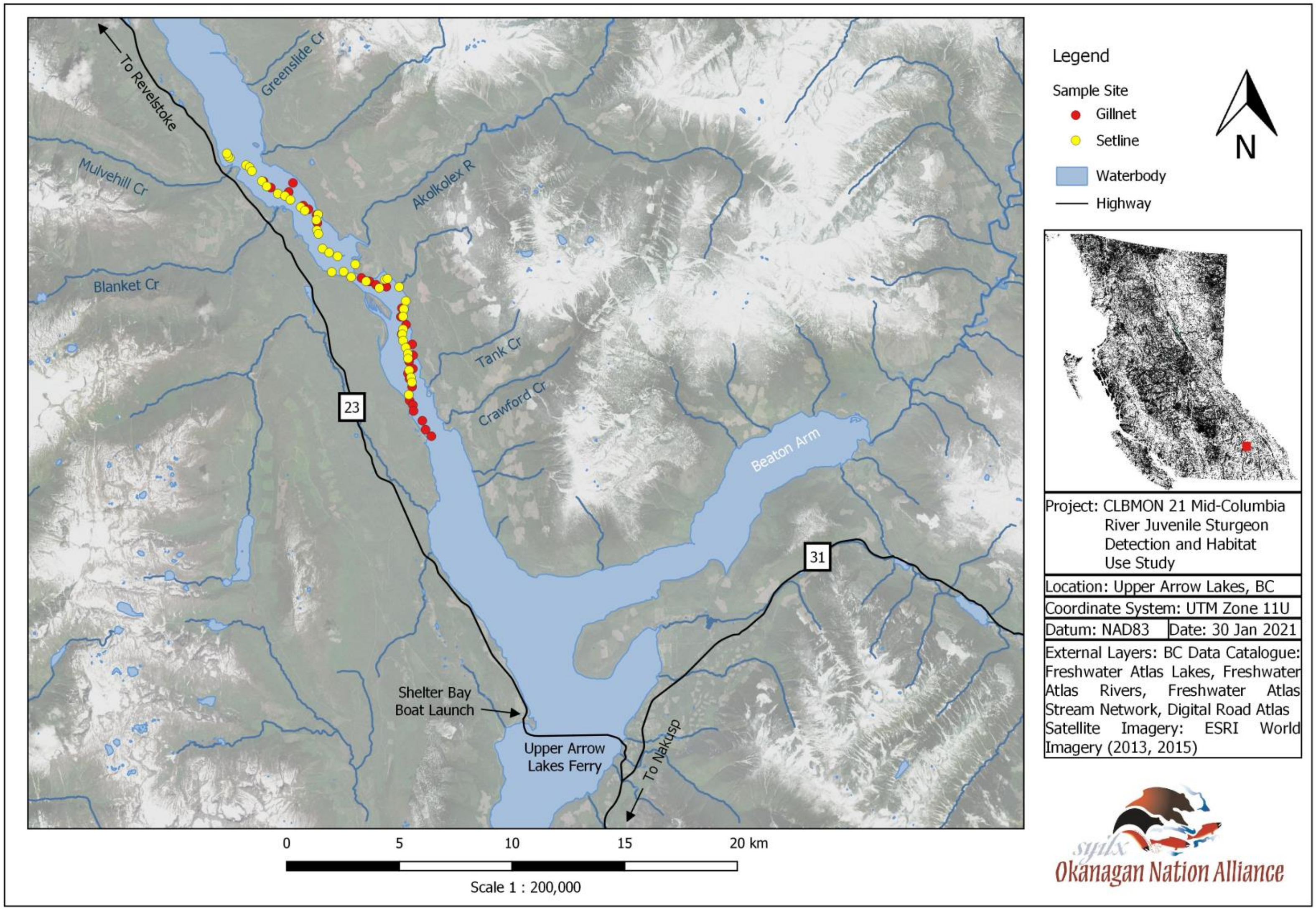

Figure 16. Field session 4 in the Revelstoke Reach from Crawford Creek to Mulvehill Creek showing gillnet and setline sample sites during CLBMON21, Sep 12 – 19 2020.

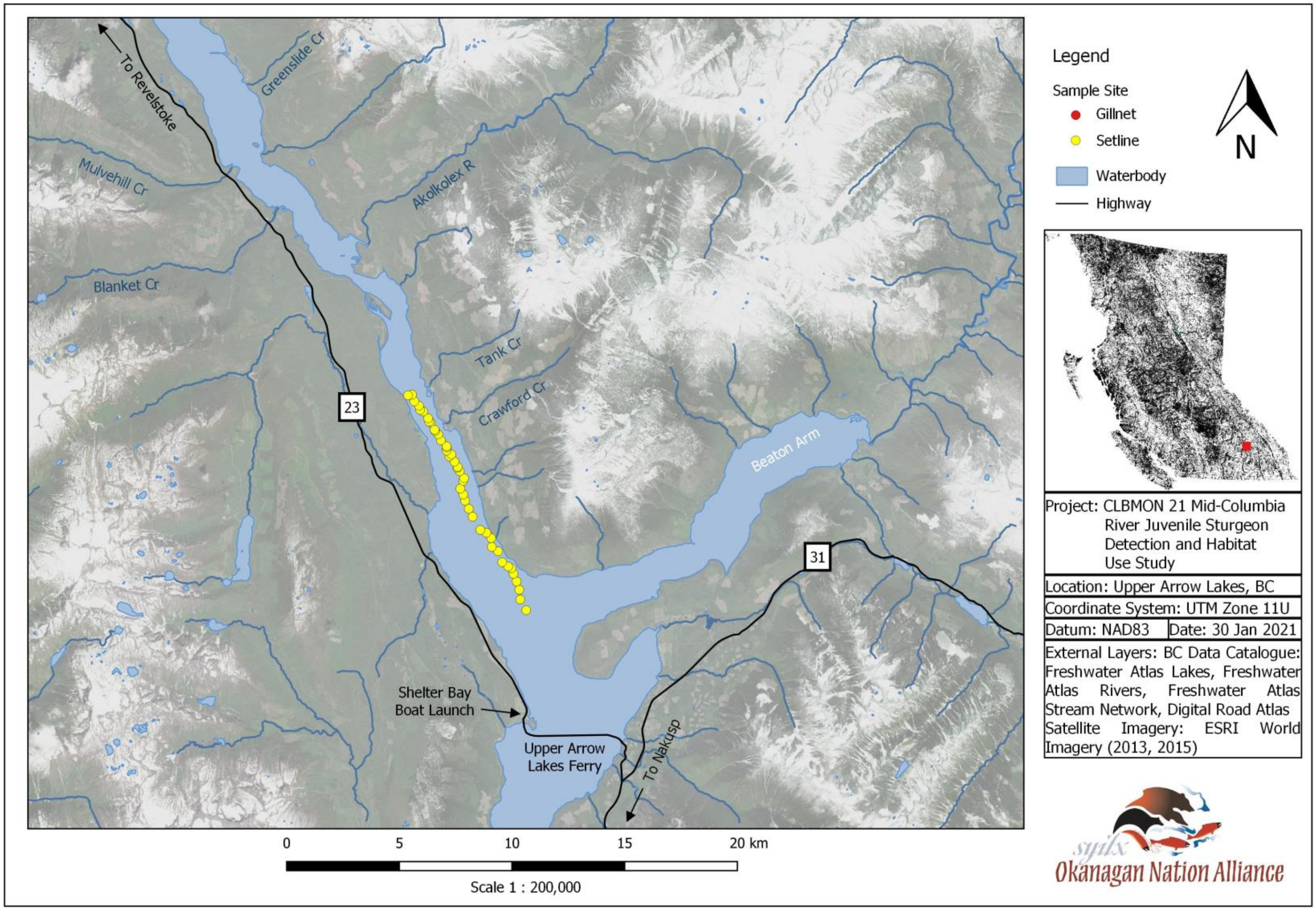

Figure 17. Field session 5 in the Revelstoke Reach from the Beaton Arm to Tank Creek showing gillnet and setline sample sites during CLBMON21, Sep 26 – Oct 03 2020.

Appendix B – Sample Site Information

Table 10. Gillnet sample site data collected during CLBMON21 in 2020, with sets soak times over four hours highlighted in red.

Set #	Session	Site	Location			Orientation to Flow	Depth (m)		Set Date	Set Time	Set Water Temp (°C)	Pull Date	Pull Time	Pull Water Temp (°C)	Soak Time (Hours)	Total WSG	Gillnet Area (m2)
			Zone	Easting	Northing		Min	Max									
1	1	BA01GN	11	448552	5622019	parallel	6.3	7.1	7/4/2020	10:55	14.7	7/4/2020	13:32	16.6	2.6	0	92.9
2	1	BA02GN	11	448582	5622400	parallel	6.3	6.9	7/4/2020	11:01	14.2	7/4/2020	13:37	15.8	2.6	0	139.4
3	1	BA03GN	11	448131	5622646	parallel	8.7	9.4	7/4/2020	11:10	15.4	7/4/2020	13:45	16.7	2.6	0	139.4
4	1	BA04GN	11	447634	5622800	parallel	9.2	11.0	7/4/2020	11:17	14.8	7/4/2020	13:58	15.0	2.7	0	139.4
5	1	BA05GN	11	447670	5620933	perpendicular	15.0	15.7	7/5/2020	10:40	14.3	7/5/2020	14:16	15.7	3.6	0	139.4
6	1	BA06GN	11	447757	5621789	perpendicular	13.5	14.1	7/5/2020	10:48	14.8	7/5/2020	14:08	16.2	3.3	0	139.4
7	1	BA07GN	11	447503	5622215	parallel	10.9	11.2	7/5/2020	10:54	14.8	7/5/2020	13:58	16.4	3.1	0	139.4
8	1	BA08GN	11	447243	5622690	perpendicular	11.6	12.0	7/5/2020	11:01	15.3	7/5/2020	13:45	16.4	2.7	0	92.9
9	1	BA09GN	11	446499	5622603	perpendicular	13.4	13.7	7/6/2020	10:46	17.1	7/6/2020	14:20	18.4	3.6	0	92.9
10	1	BA10GN	11	446841	5622315	parallel	13.7	15.0	7/6/2020	10:51	16.6	7/6/2020	14:12	18.8	3.4	0	139.4
11	1	BA11GN	11	447101	5621685	perpendicular	14.7	15.1	7/6/2020	11:00	16.8	7/6/2020	14:05	17.9	3.1	0	139.4
12	1	BA12GN	11	447210	5621226	parallel	15.3	16.4	7/6/2020	11:05	16.2	7/6/2020	13:56	18.0	2.9	0	139.4
13	1	NA01GN	11	423437	5526208	oblique	10.7	13.4	7/8/2020	9:35	13.2	7/8/2020	13:03	13.4	3.5	0	139.4
14	1	NA02GN	11	424392	5528888	oblique	12.5	13.6	7/8/2020	9:46	13.3	7/8/2020	13:15	13.5	3.5	0	139.4
15	1	NA03GN	11	425495	5532126	oblique	9.2	17.8	7/8/2020	9:56	12.4	7/8/2020	13:36	12.2	3.7	0	139.4
16	1	NA04GN	11	426820	5534484	oblique	8.9	11.4	7/8/2020	10:07	13.5	7/8/2020	13:47	13.8	3.7	0	92.9
17	1	NA05GN	11	430136	5534497	perpendicular	13.4	16.6	7/9/2020	9:20	14.0	7/9/2020	14:14	14.1	4.9	0	92.9
18	1	NA06GN	11	432461	5534753	oblique	12.7	17.2	7/9/2020	9:28	13.5	7/9/2020	13:59	13.9	4.5	0	139.4
19	1	NA07GN	11	434818	5536840	parallel	5.7	7.3	7/9/2020	9:36	13.1	7/9/2020	13:46	13.6	4.2	0	139.4
20	1	NA08GN	11	435626	5538328	perpendicular	13.4	14.0	7/9/2020	9:44	12.8	7/9/2020	13:37	13.5	3.9	0	139.4
21	2	GN111	11	434883	5609383	oblique	4.5	16.6	8/5/2020	10:17	17.0	8/5/2020	15:49	18.8	5.5	0	92.9
22	2	GN199	11	434774	5609642	perpendicular	6.7	14.3	8/5/2020	10:23	17.0	8/5/2020	15:58	20.0	5.6	0	139.4
23	2	GN4	11	434393	5610494	perpendicular	7.4	12.0	8/5/2020	10:31	17.7	8/5/2020	16:10	20.0	5.7	0	139.4
24	2	GN23	11	434289	5610813	perpendicular	7.4	16.8	8/6/2020	10:02	18.7	8/6/2020	17:20	17.1	7.3	0	139.4
25	2	GN75	11	434114	5611171	perpendicular	9.8	15.6	8/6/2020	10:10	18.8	8/6/2020	17:05	15.3	6.9	0	92.9
26	2	GN135	11	433949	5611532	perpendicular	9.7	17.4	8/6/2020	10:20	18.9	8/6/2020	16:59	16.7	6.7	0	139.4
27	2	GN87	11	433869	5612021	perpendicular	17.1	17.3	8/7/2020	10:25	16.1	8/7/2020	16:49	17.0	6.4	0	92.9
28	2	GN39	11	433668	5612655	perpendicular	16.3	17.1	8/7/2020	10:35	17.1	8/7/2020	16:41	16.8	6.1	0	139.4
29	2	GN123	11	433276	5613081	parallel	12.3	13.1	8/7/2020	10:45	17.7	8/7/2020	16:31	16.9	5.8	0	139.4

Set #	Session	Site	Location			Orientation to Flow	Depth (m)		Set Date	Set Time	Set Water Temp (°C)	Pull Date	Pull Time	Pull Water Temp (°C)	Soak Time (Hours)	Total WSG	Gillnet Area (m2)
			Zone	Easting	Northing		Min	Max									
30	2	GN27	11	434308	5613959	perpendicular	14.4	14.7	8/8/2020	10:38	17.1	8/8/2020	17:10	15.3	6.5	0	92.9
31	2	GN91	11	435050	5614466	parallel	14.3	14.9	8/8/2020	10:48	17.1	8/8/2020	17:01	15.6	6.2	0	139.4
32	2	GN43	11	435067	5614841	perpendicular	12.1	12.8	8/8/2020	10:55	17.1	8/8/2020	16:53	15.6	6.0	0	139.4
33	2	GN171	11	433431	5615227	parallel	13.5	14.9	8/9/2020	10:23	15.6	8/9/2020	16:23	19.0	6.0	0	139.4
34	2	GN198	11	432706	5615948	perpendicular	11.3	11.8	8/9/2020	10:31	15.5	8/9/2020	16:15	17.0	5.7	0	92.9
35	2	GN79	11	432068	5616902	perpendicular	9.8	11.7	8/9/2020	10:39	15.2	8/9/2020	16:03	16.6	5.4	0	139.4
36	2	GN127	11	432391	5617529	perpendicular	9.1	11.0	8/10/2020	10:27	17.2	8/10/2020	15:07	18.9	4.7	0	139.4
37	2	GN59	11	430572	5617702	parallel	10.8	10.9	8/10/2020	10:37	14.0	8/10/2020	15:12	16.7	4.6	0	92.9
38	2	GN183	11	431569	5618192	oblique	10.2	10.7	8/10/2020	10:45	16.4	8/10/2020	15:17	18.6	4.5	0	139.4
39	2	GN154	11	430756	5618606	perpendicular	8.7	8.9	8/11/2020	10:49	16.5	8/11/2020	14:45	16.2	3.9	0	139.4
40	2	GN190	11	431764	5619339	parallel	17.2	18.0	8/11/2020	11:00	16.4	8/11/2020	14:58	17.7	4.0	0	92.9
41	2	GN26	11	431951	5619737	perpendicular	7.6	9.9	8/11/2020	11:07	16.4	8/11/2020	15:06	18.0	4.0	0	139.4
42	3	GN6	11	430047	5622955	perpendicular	10.1	13.4	8/30/2020	9:53	11.1	8/30/2020	13:34	11.2	3.7	0	139.4
43	3	GN50	11	429503	5623691	perpendicular	13.1	14.4	8/30/2020	10:00	11.1	8/30/2020	13:45	10.9	3.8	0	139.4
44	3	GN130	11	429459	5623921	parallel	13.4	13.9	8/30/2020	10:07	11.1	8/30/2020	13:54	11.1	3.8	0	139.4
45	3	GN82	11	429183	5624475	perpendicular	13.4	17.1	8/30/2020	10:16	11.0	8/30/2020	14:05	11.1	3.8	0	92.9
46	3	GN81	11	428806	5627152	perpendicular	13.5	14.5	8/31/2020	10:38	11.1	8/31/2020	16:23	11.1	5.8	0	139.4
47	3	GN169	11	429149	5628075	parallel	10.9	12.0	8/31/2020	10:47	10.5	8/31/2020	16:12	11.1	5.4	0	139.4
48	3	GN145	11	429000	5628473	perpendicular	14.3	15.8	8/31/2020	11:05	11.1	8/31/2020	16:04	11.1	5.0	0	139.4
49	3	GN153	11	428582	5628878	perpendicular	11.5	13.4	8/31/2020	11:12	10.4	8/31/2020	15:57	11.1	4.8	0	92.9
50	3	GN189	11	427173	5629209	perpendicular	9.6	11.8	9/3/2020	11:24	11.4	9/3/2020	15:32	11.1	4.1	0	139.4
51	3	GN25	11	426919	5629218	perpendicular	10.8	13.2	9/3/2020	11:32	11.4	9/3/2020	15:21	11.4	3.8	0	139.4
52	3	GN21	11	426700	5629473	parallel	12.6	13.2	9/3/2020	11:42	11.2	9/3/2020	15:10	11.6	3.5	0	139.4
53	3	GN73	11	426341	5629446	perpendicular	13.2	13.6	9/3/2020	11:49	11.3	9/3/2020	14:58	11.6	3.2	0	92.9
54	3	GN69	11	426233	5629826	perpendicular	13.2	13.4	9/4/2020	10:35	11.3	9/4/2020	14:31	12.9	3.9	0	92.9
55	3	GN93	11	425869	5630235	perpendicular	9.4	10.1	9/4/2020	10:43	11.2	9/4/2020	14:52	12.9	4.2	0	139.4
56	3	GN193	11	425227	5630595	perpendicular	10.4	13.6	9/4/2020	10:55	10.9	9/4/2020	15:00	12.1	4.1	0	139.4
57	3	GN105	11	425118	5630845	perpendicular	11.1	13.0	9/4/2020	11:04	11.0	9/4/2020	15:08	11.4	4.1	0	139.4
58	4	DGN156	11	422784	5633533	parallel	13.7	14.2	9/12/2020	10:41	10.7	9/12/2020	14:52	10.5	4.2	0	139.4
59	4	DGN8	11	423107	5633258	perpendicular	14.5	14.8	9/12/2020	10:49	10.7	9/12/2020	15:02	10.6	4.2	0	139.4
60	4	DGN120	11	424091	5633466	perpendicular	6.7	7.0	9/12/2020	11:04	11.4	9/12/2020	15:11	12.7	4.1	0	92.9

Set #	Session	Site	Location			Orientation to Flow	Depth (m)		Set Date	Set Time	Set Water Temp (°C)	Pull Date	Pull Time	Pull Water Temp (°C)	Soak Time (Hours)	Total WSG	Gillnet Area (m2)
			Zone	Easting	Northing		Min	Max									
61	4	DGN68	11	423904	5633065	parallel	6.8	7.0	9/12/2020	11:13	11.4	9/12/2020	15:20	12.1	4.1	0	139.4
62	4	DGN180	11	424546	5632460	perpendicular	9.2	10.8	9/13/2020	10:37	10.6	9/13/2020	14:54	10.4	4.3	0	139.4
63	4	DGN76	11	424778	5632298	perpendicular	9.4	10.8	9/13/2020	10:46	10.5	9/13/2020	15:03	10.3	4.3	0	139.4
64	4	DGN148	11	425138	5632052	parallel	11.2	12.0	9/13/2020	10:54	10.7	9/13/2020	15:13	10.5	4.3	0	92.9
65	4	DGN149	11	425176	5631696	perpendicular	11.2	11.6	9/13/2020	11:02	10.4	9/13/2020	15:35	10.4	4.6	0	139.4
66	4	DGN165	11	427131	5629249	perpendicular	8.4	8.7	9/15/2020	10:16	10.2	9/15/2020	13:43	10.2	3.5	0	92.9
67	4	DGN189	11	427488	5629096	perpendicular	12.0	13.9	9/15/2020	10:24	10.1	9/15/2020	13:50	10.2	3.4	0	139.4
68	4	DGN133	11	427776	5628952	perpendicular	10.9	11.4	9/15/2020	10:30	10.1	9/15/2020	14:07	10.2	3.6	0	139.4
69	4	DGN153	11	428237	5628864	perpendicular	7.9	8.8	9/15/2020	10:37	10.1	9/15/2020	14:18	10.2	3.7	0	139.4
70	4	DGN113	11	428923	5627911	parallel	9.6	11.2	9/16/2020	10:27	10.5	9/16/2020	14:35	11.1	4.1	0	92.9
71	4	DGN129	11	428877	5627529	perpendicular	10.6	12.2	9/16/2020	10:34	10.5	9/16/2020	14:45	10.7	4.2	0	139.4
72	4	DGN81	11	429107	5627176	perpendicular	12.0	13.1	9/16/2020	10:41	10.5	9/16/2020	14:52	11.4	4.2	0	92.9
73	4	DGN177	11	428912	5626760	perpendicular	14.2	16.3	9/16/2020	10:49	10.4	9/16/2020	15:02	12.0	4.2	0	139.4
74	4	DGN97	11	429380	5626307	perpendicular	9.0	10.8	9/16/2020	10:56	10.3	9/16/2020	15:18	10.8	4.4	0	139.4
75	4	DGN65	11	429420	5625821	parallel	13.7	15.8	9/17/2020	10:01	11.0	9/17/2020	14:12	12.0	4.2	0	92.9
76	4	DGN109	11	429244	5625545	parallel	11.6	11.8	9/17/2020	10:09	11.0	9/17/2020	14:22	12.3	4.2	0	139.4
77	4	DGN197	11	429409	5625227	perpendicular	13.8	14.2	9/17/2020	10:17	10.9	9/17/2020	14:31	11.4	4.2	0	139.4
78	4	DGN114	11	429192	5625017	perpendicular	13.2	13.9	9/17/2020	10:24	10.9	9/17/2020	14:41	11.6	4.3	0	92.9
79	4	DGN34	11	429263	5624780	perpendicular	14.1	14.5	9/17/2020	10:30	11.0	9/17/2020	14:51	11.8	4.4	0	92.9
80	4	DGN82	11	429375	5624425	perpendicular	12.7	13.4	9/17/2020	10:37	10.9	9/17/2020	15:00	11.5	4.4	0	139.4
81	4	DGN130	11	429266	5623820	perpendicular	14.2	16.0	9/18/2020	10:00	11.5	9/18/2020	15:02	11.4	5.0	0	139.4
82	4	DGN186	11	429413	5623619	perpendicular	12.8	13.7	9/18/2020	10:05	11.3	9/18/2020	15:17	11.4	5.2	0	139.4
83	4	DGN118	11	429443	5623353	perpendicular	14.3	16.0	9/18/2020	10:10	11.4	9/18/2020	15:30	11.7	5.3	0	92.9
84	4	DGN6	11	429829	5622919	parallel	13.7	14.0	9/18/2020	10:16	11.3	9/18/2020	15:38	11.6	5.4	0	92.9
85	4	DGN74	11	429972	5622524	perpendicular	13.0	13.7	9/18/2020	10:22	11.4	9/18/2020	15:53	11.5	5.5	0	139.4
86	4	DGN146	11	430234	5622232	parallel	9.4	11.6	9/18/2020	10:28	11.5	9/18/2020	16:00	11.6	5.5	0	92.9

Table 11. Setline sample site data collected during CLBMON21 in 2019, with juvenile White Sturgeon captures highlighted in yellow and sets soak times over 24 hours highlighted in red.

Set #	Session	Site	Location			Orientation to Flow	Depth (m)		Set Date	Set Time	Set Water Temp (°C)	Pull Date	Pull Time	Pull Water Temp (°C)	Soak Time (Hours)	WSG Catch
			Zone	Easting	Northing		Min	Max								
1	1	BA01SL	11	447421	5622781	perpendicular	9.9	10.6	7/4/2020	12:44	15.6	7/5/2020	11:03	15.6	22.3	0
2	1	BA02SL	11	447733	5622472	parallel	9.9	11.0	7/4/2020	12:52	15.6	7/5/2020	11:23	15.6	22.5	0
3	1	BA03SL	11	448072	5622206	parallel	9.7	11.7	7/4/2020	13:00	14.8	7/5/2020	11:38	15.2	22.6	0
4	1	BA04SL	11	448156	5621890	perpendicular	11.0	13.0	7/4/2020	13:07	16.5	7/5/2020	11:43	15.2	22.6	0
5	1	BA05SL	11	448116	5621435	perpendicular	14.2	14.5	7/4/2020	13:15	15.7	7/5/2020	11:52	14.9	22.6	0
6	1	BA06SL	11	447900	5620969	perpendicular	14.6	15.0	7/4/2020	13:23	15.5	7/5/2020	12:00	14.7	22.6	0
7	1	BA07SL	11	447382	5620944	perpendicular	14.9	15.5	7/5/2020	12:51	15.0	7/6/2020	11:22	15.8	22.5	0
8	1	BA08SL	11	447322	5621420	oblique	14.9	16.0	7/5/2020	12:59	15.7	7/6/2020	11:30	15.9	22.5	0
9	1	BA09SL	11	447247	5621840	parallel	13.5	14.0	7/5/2020	13:06	15.8	7/6/2020	11:53	17.0	22.8	0
10	1	BA10SL	11	447170	5622351	parallel	10.9	11.4	7/5/2020	13:15	16.3	7/6/2020	12:03	16.9	22.8	0
11	1	BA11SL	11	446912	5622580	parallel	11.4	12.7	7/5/2020	13:27	16.3	7/6/2020	12:12	17.3	22.8	0
12	1	BA12SL	11	446554	5623053	parallel	9.3	10.2	7/5/2020	13:35	16.8	7/6/2020	12:25	17.7	22.8	0
13	1	BA13SL	11	446008	5622808	parallel	12.7	13.2	7/6/2020	13:12	17.1	7/7/2020	14:33	14.4	25.4	0
14	1	BA14SL	11	446271	5622393	parallel	14.0	15.0	7/6/2020	13:19	17.5	7/7/2020	14:42	15.8	25.4	0
15	1	BA15SL	11	446554	5622107	parallel	13.7	15.0	7/6/2020	13:26	17.8	7/7/2020	15:00	15.7	25.6	0
16	1	BA16SL	11	446787	5621610	parallel	15.7	16.1	7/6/2020	13:35	17.5	7/7/2020	15:14	15.6	25.7	0
17	1	BA17SL	11	446958	5621250	parallel	15.7	16.3	7/6/2020	13:42	17.9	7/7/2020	15:22	15.7	25.7	0
18	1	BA18SL	11	447061	5620846	perpendicular	15.2	16.4	7/6/2020	13:49	17.9	7/7/2020	15:38	16.4	25.8	0
19	1	NA01SL	11	431535	5535904	parallel	18.4	19.7	7/8/2020	12:02	11.8	7/9/2020	9:57	12.9	21.9	0
20	1	NA02SL	11	429002	5535539	perpendicular	8.9	18.9	7/8/2020	12:15	12.8	7/9/2020	10:09	13.1	21.9	0
21	1	NA03SL	11	428279	5533130	oblique	16.1	17.9	7/8/2020	12:28	13.3	7/9/2020	10:21	13.9	21.9	0
22	1	NA04SL	11	425784	5530201	perpendicular	8.1	17.9	7/8/2020	12:44	13.1	7/9/2020	10:34	14.1	21.8	0
23	1	NA05SL	11	422978	5528888	oblique	13.0	19.9	7/8/2020	12:55	12.8	7/9/2020	10:47	13.5	21.9	0
24	1	NA06SL	11	432814	5536427	perpendicular	10.1	18.1	7/9/2020	12:02	13.1	7/10/2020	9:25	13.2	21.4	0
25	1	NA07SL	11	434857	5537870	perpendicular	15.3	18.9	7/9/2020	13:25	12.6	7/10/2020	10:28	13.0	21.1	0
26	1	NA08SL	11	434459	5541223	perpendicular	11.6	16.3	7/9/2020	13:12	13.5	7/10/2020	10:16	13.9	21.1	0
27	1	NA09SL	11	433923	5543304	perpendicular	12.3	12.7	7/9/2020	13:01	13.3	7/10/2020	10:08	14.2	21.1	0
28	1	NA10SL	11	433597	5546034	perpendicular	11.9	20.1	7/9/2020	12:51	13.7	7/10/2020	9:57	14.6	21.1	0
29	1	NA11SL	11	432875	5548182	perpendicular	9.8	19.8	7/9/2020	12:40	14.0	7/10/2020	9:48	14.6	21.1	0

Set #	Session	Site	Location			Orientation to Flow	Depth (m)		Set Date	Set Time	Set Water Temp (°C)	Pull Date	Pull Time	Pull Water Temp (°C)	Soak Time (Hours)	WSG Catch
			Zone	Easting	Northing		Min	Max								
30	2	SL171	11	421155	5637422	perpendicular	8.1	9.5	8/5/2020	12:33	13.0	8/6/2020	11:09	10.4	22.6	0
31	2	SL138	11	421232	5637265	perpendicular	5.3	5.9	8/5/2020	12:43	14.8	8/6/2020	11:21	10.1	22.6	0
32	2	SL14	11	422084	5637575	parallel	11.9	12.9	8/5/2020	13:44	19.4	8/6/2020	11:34	12.0	21.8	1
33	2	SL194	11	422400	5637249	perpendicular	9.5	12.4	8/5/2020	13:53	17.3	8/6/2020	12:34	12.1	22.7	0
34	2	SL70	11	421242	5636306	perpendicular	10.7	11.4	8/5/2020	14:22	14.9	8/6/2020	12:49	10.7	22.5	0
35	2	SL126	11	420722	5636169	perpendicular	10.9	14.0	8/5/2020	14:33	11.4	8/6/2020	13:00	9.9	22.5	0
36	2	SL30	11	421440	5636460	parallel	11.3	11.5	8/6/2020	13:56	11.5	8/7/2020	11:36	12.6	21.7	0
37	2	SL90	11	420910	5636297	oblique	11.1	13.8	8/6/2020	14:08	11.1	8/7/2020	12:00	13.1	21.9	0
38	2	SL42	11	420858	5635802	parallel	14.4	15.1	8/6/2020	14:17	10.1	8/7/2020	12:28	11.1	22.2	0
39	2	SL174	11	421334	5635664	parallel	11.8	12.2	8/6/2020	14:59	11.1	8/7/2020	12:38	12.9	21.7	0
40	2	SL106	11	421038	5635404	perpendicular	10.8	11.7	8/6/2020	15:11	11.0	8/7/2020	12:49	13.1	21.6	0
41	2	SL58	11	422445	5636068	perpendicular	8.7	11.4	8/6/2020	15:21	12.2	8/7/2020	13:00	12.3	21.7	0
42	2	SL182	11	422051	5636050	perpendicular	11.8	12.3	8/7/2020	14:22	13.1	8/8/2020	11:38	12.5	21.3	0
43	2	SL115	11	421728	5635450	parallel	10.8	12.6	8/7/2020	14:39	12.1	8/8/2020	11:47	12.5	21.1	0
44	2	SL19	11	420885	5635065	perpendicular	10.8	13.2	8/7/2020	14:50	12.1	8/8/2020	11:56	10.9	21.1	0
45	2	SL163	11	421098	5635018	oblique	13.3	14.8	8/7/2020	15:05	12.6	8/8/2020	12:08	12.1	21.1	0
46	2	SL158	11	420947	5634534	parallel	16.1	16.3	8/7/2020	15:17	11.2	8/8/2020	12:25	11.5	21.1	0
47	2	SL3	11	421658	5634569	oblique	10.2	12.2	8/7/2020	15:43	10.3	8/8/2020	12:35	10.8	20.9	0
48	2	SL198	11	421926	5634346	perpendicular	12.3	17.9	8/8/2020	13:53	10.3	8/9/2020	11:14	11.7	21.4	0
49	2	SL131	11	422069	5634255	perpendicular	9.9	17.0	8/8/2020	14:03	10.2	8/9/2020	11:22	11.6	21.3	0
50	2	SL78	11	422036	5634017	perpendicular	8.9	19.3	8/8/2020	14:11	11.4	8/9/2020	11:36	12.3	21.4	0
51	2	SL142	11	422458	5633840	parallel	17.9	18.4	8/8/2020	14:30	10.4	8/9/2020	12:00	12.6	21.5	1
52	2	SL46	11	422856	5633936	parallel	6.8	10.3	8/8/2020	15:31	10.7	8/9/2020	12:35	13.2	21.1	0
53	2	SL110	11	422762	5633653	parallel	10.9	12.4	8/8/2020	15:39	10.4	8/9/2020	12:45	12.5	21.1	0
54	2	SL54	11	423095	5633185	perpendicular	17.7	18.1	8/9/2020	14:10	11.0	8/10/2020	11:15	11.0	21.1	0
55	2	SL102	11	423825	5633542	parallel	10.6	11.4	8/9/2020	14:21	12.2	8/10/2020	11:24	13.6	21.1	0
56	2	SL146	11	424073	5633021	parallel	10.5	11.4	8/9/2020	14:50	13.7	8/10/2020	11:32	13.0	20.7	0
57	2	SL166	11	424435	5632842	perpendicular	10.5	10.8	8/9/2020	14:57	14.5	8/10/2020	11:46	13.2	20.8	0
58	2	SL74	11	424656	5632248	perpendicular	9.3	10.7	8/9/2020	15:06	12.6	8/10/2020	11:57	11.8	20.9	0
59	2	SL66	11	425135	5631985	parallel	14.4	16.2	8/9/2020	15:17	13.2	8/10/2020	12:05	13.4	20.8	0
60	2	SL27	11	425401	5631834	parallel	13.2	14.0	8/10/2020	13:05	11.1	8/11/2020	11:36	11.6	22.5	0
61	2	SL123	11	425289	5631046	perpendicular	14.0	15.8	8/10/2020	13:15	12.0	8/11/2020	11:46	12.1	22.5	0

Set #	Session	Site	Location			Orientation to Flow	Depth (m)		Set Date	Set Time	Set Water Temp (°C)	Pull Date	Pull Time	Pull Water Temp (°C)	Soak Time (Hours)	WSG Catch
			Zone	Easting	Northing		Min	Max								
62	2	SL195	11	425319	5630334	perpendicular	13.0	13.7	8/10/2020	13:34	13.4	8/11/2020	12:00	12.5	22.4	0
63	2	SL59	11	425907	5630204	oblique	12.4	13.0	8/10/2020	13:44	12.6	8/11/2020	12:08	13.1	22.4	0
64	2	SL91	11	425819	5629474	parallel	9.7	12.3	8/10/2020	13:55	12.9	8/11/2020	12:24	11.2	22.5	0
65	2	SL51	11	426597	5629325	perpendicular	16.6	17.2	8/10/2020	14:05	12.8	8/11/2020	12:33	11.2	22.5	0
66	2	SL39	11	427084	5629296	perpendicular	11.6	12.8	8/11/2020	13:38	12.2	8/12/2020	11:04	10.9	21.4	0
67	2	SL135	11	427307	5628994	parallel	11.6	16.8	8/11/2020	13:45	11.1	8/12/2020	11:12	11.1	21.5	0
68	2	SL7	11	427960	5629097	perpendicular	15.1	15.9	8/11/2020	13:55	11.4	8/12/2020	11:23	11.3	21.5	0
69	2	SL103	11	428765	5628903	parallel	19.7	20.4	8/11/2020	14:04	12	8/12/2020	11:33	11.5	21.5	0
70	2	SL147	11	429101	5628106	parallel	14.1	19.8	8/11/2020	14:13	11.1	8/12/2020	11:45	11.0	21.5	0
71	2	SL95	11	429090	5627484	parallel	15.9	18.0	8/11/2020	14:22	11.1	8/12/2020	11:59	11.4	21.6	0
72	3	SL79	11	429019	5626857	oblique	12.7	14.4	8/30/2020	12:36	11	8/31/2020	11:20	11.1	22.7	0
73	3	SL4	11	429262	5626525	oblique	10.0	12.2	8/30/2020	12:44	11.1	8/31/2020	11:29	11.1	22.8	0
74	3	SL111	11	429370	5626283	parallel	7.9	10.2	8/30/2020	12:54	10.9	8/31/2020	11:41	10.4	22.8	0
75	3	SL144	11	429469	5625749	parallel	4.0	10.8	8/30/2020	13:03	10.7	8/31/2020	11:49	10.4	22.8	0
76	3	SL16	11	429384	5625415	oblique	15.4	18.8	8/30/2020	13:10	11.1	8/31/2020	11:56	10.9	22.8	0
77	3	SL160	11	429302	5624722	parallel	15.2	16.0	8/30/2020	13:21	11.1	8/31/2020	12:09	11.1	22.8	0
78	3	SL62	11	422624	5633723	oblique	15.2	15.6	8/31/2020	14:50	10.8	9/1/2020	14:01		23.2	0
79	3	SL26	11	423120	5633293	perpendicular	14.8	15.9	8/31/2020	15:05	10.4	9/1/2020	14:20		23.3	0
80	3	SL86	11	423532	5632853	perpendicular	9.1	11.3	8/31/2020	15:16	10.3	9/1/2020	15:00		23.7	0
81	3	SL10	11	423977	5632862	parallel	11.2	12.1	8/31/2020	15:25	10.8	9/1/2020	15:10		23.8	0
82	3	SL122	11	424089	5632541	perpendicular	12.5	14.8	8/31/2020	15:33	10.4	9/1/2020	15:27		23.9	0
83	3	SL22	11	425090	5632239	parallel	13.2	14.5	8/31/2020	15:44	12.1	9/1/2020	15:42		24.0	0
84	3	SL46B	11	422542	5633746	parallel	15.0	16.2	9/2/2020	14:03	11.0	9/3/2020	12:42	10.8	22.7	0
85	3	SL131B	11	422083	5633939	oblique	3.4	12.2	9/2/2020	14:10	11.2	9/3/2020	12:32	10.8	22.4	0
86	3	SL158B	11	421703	5634481	parallel	8.9	22.9	9/2/2020	14:40	11.0	9/3/2020	12:18	10.3	21.6	0
87	3	SL19B	11	421103	5634688	parallel	11.9	12.6	9/2/2020	14:52	11.1	9/3/2020	12:09	11.9	21.3	0
88	3	SL171B	11	420849	5637576	perpendicular	8.4	10.6	9/3/2020	13:55	11.4	9/4/2020	11:32	12.1	21.6	0
89	3	SL14B	11	421166	5637118	parallel	11.2	11.8	9/3/2020	14:09	10.6	9/4/2020	11:46	11.1	21.6	0
90	3	SL70B	11	420758	5635844	oblique	10.2	11.3	9/3/2020	14:25	11.1	9/4/2020	11:58	11.8	21.6	0
91	3	SL42B	11	420695	5635551	parallel	11.0	12.0	9/3/2020	14:33	10.7	9/4/2020	12:06	11.6	21.6	0
92	3	SL106B	11	420743	5635203	perpendicular	12.2	15.8	9/3/2020	14:41	11.2	9/4/2020	12:14	11.9	21.6	0
93	3	SL118	11	425255	5632116	perpendicular	13.4	15.2	9/4/2020	13:25	12.0	9/5/2020	10:50	12.5	21.4	0

Set #	Session	Site	Location			Orientation to Flow	Depth (m)		Set Date	Set Time	Set Water Temp (°C)	Pull Date	Pull Time	Pull Water Temp (°C)	Soak Time (Hours)	WSG Catch
			Zone	Easting	Northing		Min	Max								
94	3	SL6	11	425188	5631308	perpendicular	12.0	14.3	9/4/2020	13:41	12.4	9/5/2020	11:07	12.4	21.4	0
95	3	SL139	11	425272	5631747	oblique	13.5	14.2	9/4/2020	13:53	11.9	9/5/2020	10:58	12.8	21.1	0
96	3	SL11	11	425544	5631087	parallel	9.5	9.8	9/4/2020	14:05	11.5	9/5/2020	11:18	12.6	21.2	0
97	3	SL167	11	425325	5630667	parallel	11.8	14.2	9/4/2020	14:14	11.9	9/5/2020	11:27	13.3	21.2	0
98	3	SL15	11	425763	5630285	perpendicular	9.9	10.4	9/4/2020	14:23	13.1	9/5/2020	11:40	13.3	21.3	0
99	4	DSL115	11	421282	5634583	perpendicular	10.6	11.3	9/12/2020	12:54	11.1	9/13/2020	11:20	10.1	22.4	0
100	4	DSL163	11	421209	5634668	perpendicular	10.4	11.6	9/12/2020	13:03	12.1	9/13/2020	11:27	10.1	22.4	0
101	4	DSL3	11	421157	5634777	oblique	8.9	11.0	9/12/2020	13:14	12.1	9/13/2020	11:37	10.8	22.4	0
102	4	DSL131	11	422010	5634257	perpendicular	11.0	11.4	9/12/2020	13:22	10.7	9/13/2020	11:54	10.1	22.5	0
103	4	DSL142	11	422164	5634156	perpendicular	9.8	11.3	9/12/2020	13:31	10.6	9/13/2020	12:05	10.1	22.6	1
104	4	DSL110	11	422270	5633992	perpendicular	10.7	11.4	9/12/2020	13:43	10.6	9/13/2020	12:55	10.1	23.2	0
105	4	DSL94	11	422712	5633548	oblique	13.2	14.2	9/13/2020	13:51	10.3	9/14/2020	12:20	9.9	22.5	0
106	4	DSL54	11	422928	5633314	parallel	10.8	12.4	9/13/2020	14:01	10.4	9/14/2020	12:30	9.9	22.5	0
107	4	DSL154	11	423416	5632995	oblique	13.4	16.2	9/13/2020	14:13	10.2	9/14/2020	12:42	9.9	22.5	0
108	4	DSL86	11	423736	5632891	parallel	13.2	14.0	9/13/2020	14:22	10.2	9/14/2020	14:13	9.9	23.9	0
109	4	DSL10	11	423977	5632718	parallel	11.8	12.3	9/13/2020	14:32	10.2	9/14/2020	14:22	9.9	23.8	0
110	4	DSL122	11	424437	5632392	parallel	10.8	12.6	9/13/2020	14:44	10.4	9/14/2020	14:32	9.9	23.8	0
111	4	DSL74	11	424619	5632241	parallel	5.0	10.1	9/14/2020	13:36	9.9	9/15/2020	10:50	10.1	21.2	0
112	4	DSL118	11	425205	5632068	perpendicular	11.4	15.1	9/14/2020	13:50	10.4	9/15/2020	11:01	10.6	21.2	0
113	4	DSL6	11	425132	5631819	parallel	10.9	11.3	9/14/2020	13:57	10.1	9/15/2020	11:08	10.3	21.2	0
114	4	DSL27	11	425159	5631371	parallel	5.6	10.2	9/14/2020	14:56	10.0	9/15/2020	11:17	10.3	20.4	0
115	4	DSL175	11	425220	5631209	parallel	11.4	12.1	9/14/2020	15:03	10.4	9/15/2020	11:25	10.8	20.4	0
116	4	DSL167	11	425402	5630552	perpendicular	10.5	11.7	9/14/2020	15:14	10.6	9/15/2020	11:39	10.7	20.4	0
117	4	DSL15	11	425694	5630374	perpendicular	8.0	8.7	9/15/2020	12:49	10.6	9/16/2020	11:12	10.7	22.4	0
118	4	DSL59	11	426071	5630211	perpendicular	6.8	8.9	9/15/2020	13:00	10.7	9/16/2020	11:21	11.0	22.4	0
119	4	DSL43	11	425813	5629515	parallel	8.9	9.8	9/15/2020	13:11	10.5	9/16/2020	11:31	10.6	22.3	0
120	4	DSL99	11	426336	5629533	parallel	11.0	11.3	9/15/2020	13:19	11.0	9/16/2020	11:46	11.0	22.5	0
121	4	DSL51	11	426673	5629292	parallel	13.0	14.0	9/15/2020	13:27	11.3	9/16/2020	12:00	10.6	22.6	0
122	4	DSL35	11	426857	5629857	parallel	11.0	11.3	9/15/2020	13:36	10.4	9/16/2020	12:11	11.0	22.6	0
123	4	DSL75	11	427339	5629100	parallel	12.6	12.8	9/16/2020	13:35	10.6	9/17/2020	10:54	11.1	21.3	1
124	4	DSL23	11	427921	5628806	parallel	6.0	10.0	9/16/2020	13:45	10.6	9/17/2020	11:36	11.1	21.9	0
125	4	DSL7	11	428176	5629183	perpendicular	11.6	11.8	9/16/2020	13:57	11.1	9/17/2020	11:47	11.1	21.8	0

Set #	Session	Site	Location			Orientation to Flow	Depth (m)		Set Date	Set Time	Set Water Temp (°C)	Pull Date	Pull Time	Pull Water Temp (°C)	Soak Time (Hours)	WSG Catch
			Zone	Easting	Northing		Min	Max								
126	4	DSL191	11	428282	5629216	parallel	12.8	13.1	9/16/2020	14:05	10.7	9/17/2020	11:57	11.3	21.9	0
127	4	DSL103	11	428805	5628852	perpendicular	15.3	16.8	9/16/2020	14:18	10.6	9/17/2020	12:08	11.7	21.8	0
128	4	DSL147	11	429097	5628226	perpendicular	13.6	16.8	9/16/2020	14:27	11.1	9/17/2020	12:17	11.4	21.8	0
129	4	DSL47	11	429009	5627867	parallel	15.1	16.0	9/17/2020	13:25	11.5	9/18/2020	11:17	11.6	21.9	0
130	4	DSL95	11	428972	5627546	parallel	14.1	14.8	9/17/2020	13:32	11.5	9/18/2020	11:29	12.1	22.0	1
131	4	DSL143	11	428979	5626978	perpendicular	12.4	12.8	9/17/2020	13:40	11.4	9/18/2020	12:19	11.7	22.7	0
132	4	DSL159	11	428940	5626755	perpendicular	13.2	15.4	9/17/2020	13:46	11.4	9/18/2020	12:28	11.5	22.7	0
133	4	DSL4	11	428975	5626474	perpendicular	14.4	16.0	9/17/2020	13:53	11.8	9/18/2020	12:38	11.8	22.8	2
134	4	DSL151	11	429098	5626162	perpendicular	10.7	16.0	9/17/2020	14:01	12.1	9/18/2020	13:31	11.6	23.5	0
135	4	DSL80	11	429192	5625892	perpendicular	10.8	12.6	9/18/2020	14:09	11.5	9/19/2020	10:14	11.4	20.1	0
136	4	DSL128	11	429200	5625676	parallel	10.4	10.8	9/18/2020	14:16	11.5	9/19/2020	10:28	11.3	20.2	0
137	4	DSL32	11	429248	5625156	perpendicular	13.9	14.7	9/18/2020	14:24	11.5	9/19/2020	10:44	11.4	20.3	0
138	4	DSL160	11	429326	5624844	oblique	13.6	14.0	9/18/2020	14:32	11.4	9/19/2020	10:57	11.4	20.4	0
139	4	DSL96	11	429365	5624624	perpendicular	13.8	14.6	9/18/2020	14:39	11.4	9/19/2020	11:10	11.5	20.5	0
140	4	DSL112	11	429231	5624069	perpendicular	13.9	14.2	9/18/2020	14:49	11.4	9/19/2020	11:24	11.4	20.6	0
141	5	ESL137	11	434439	5614517	parallel	12	15	9/26/2020	12:24	12	9/27/2020	13:10	13	24.8	0
142	5	ESL77	11	434178	5614988	parallel	12	12	9/26/2020	12:38	12	9/27/2020	13:23	13	24.8	0
143	5	ESL93	11	434131	5615421	perpendicular	9	12	9/26/2020	12:52	12	9/27/2020	13:37	13	24.8	0
144	5	ESL109	11	434013	5615788	perpendicular	10	12	9/26/2020	13:31	12	9/27/2020	14:44	13	25.2	0
145	5	ESL2	11	433875	5616129	perpendicular	8	12	9/26/2020	12:40	12	9/27/2020	14:59	13	26.3	1
146	5	ESL114	11	433781	5616379	perpendicular	12	14	9/26/2020	13:49	12	9/27/2020	15:51	13	26.0	0
147	5	ESL5	11	433641	5616451	parallel	11	12	9/27/2020	14:10	13	9/28/2020	11:57	12	21.8	0
148	5	ESL117	11	433374	5616643	perpendicular	10	13	9/27/2020	14:19	13	9/28/2020	12:02	12	21.7	0
149	5	ESL169	11	433191	5617126	perpendicular	11	11	9/27/2020	14:30	13	9/28/2020	12:10	12	21.7	0
150	5	ESL129	11	432911	5617324	parallel	11	11	9/27/2020	16:22	13	9/28/2020	13:19	12	21.0	0
151	5	ESL177	11	432885	5617715	perpendicular	12	13	9/27/2020	16:31	13	9/28/2020	13:33	12	21.0	0
152	5	ESL81	11	432673	5617950	perpendicular	11	13	9/27/2020	16:40	13	9/28/2020	13:47	12	21.1	0
153	5	ESL17	11	432404	5618076	parallel	14	15	9/28/2020	12:41	9	9/29/2020	11:04	9	22.4	0
154	5	ESL56	11	432061	5618661	parallel	12	14	9/28/2020	12:53	9	9/29/2020	11:18	9	22.4	0
155	5	ESL156	11	431894	5619010	perpendicular	11	13	9/28/2020	13:30	9	9/29/2020	11:26	9	21.9	0
156	5	ESL192	11	431728	5619367	parallel	9	12	9/28/2020	14:13	9	9/29/2020	12:30	9	22.3	0
157	5	ESL76	11	431648	5619645	perpendicular	11	13	9/28/2020	14:24	9	9/29/2020	12:39	9	22.3	0

Set #	Session	Site	Location			Orientation to Flow	Depth (m)		Set Date	Set Time	Set Water Temp (°C)	Pull Date	Pull Time	Pull Water Temp (°C)	Soak Time (Hours)	WSG Catch
			Zone	Easting	Northing		Min	Max								
158	5	ESL24	11	431516	5619906	perpendicular	10	11	9/28/2020	14:32	9	9/29/2020	12:46	9	22.2	0
159	5	ESL120	11	431643	5620246	perpendicular	11	12	9/29/2020	11:55	9	9/30/2020	9:45	9	21.8	0
160	5	ESL52	11	431682	5620366	oblique	5	12	9/29/2020	12:06	9	9/30/2020	10:05	9	22.0	0
161	5	ESL100	11	431489	5620678	perpendicular	12	13	9/29/2020	12:14	9	9/30/2020	10:14	9	22.0	0
162	5	ESL188	11	431385	5620828	parallel	11	12	9/29/2020	13:15	9	9/30/2020	11:12	9	22.0	0
163	5	ESL36	11	431400	5620868	perpendicular	12	13	9/29/2020	13:25	9	9/30/2020	11:25	9	22.0	0
164	5	ESL180	11	431254	5621104	parallel	12	13	9/29/2020	13:34	9	9/30/2020	11:32	9	22.0	0
165	5	ESL172	11	431035	5621333	oblique	12	12	9/30/2020	10:39	9	10/1/2020	10:32	9	23.9	0
166	5	ESL132	11	431119	5621425	oblique	11	13	9/30/2020	10:49	9	10/1/2020	10:42	9	23.9	0
167	5	ESL20	11	430905	5621596	parallel	12	13	9/30/2020	10:58	9	10/1/2020	10:49	9	23.9	0
168	5	ESL164	11	430911	5621735	parallel	11	12	9/30/2020	12:19	9	10/1/2020	11:44	9	23.4	0
169	5	ESL116	11	430907	5621785	oblique	5	12	9/30/2020	12:25	9	10/1/2020	11:53	9	23.5	0
170	5	ESL8	11	430652	5622050	parallel	12	12	9/30/2020	12:34	9	10/1/2020	12:01	9	23.5	0
171	5	ESL92	11	430536	5622316	parallel	10	11	10/1/2020	11:22	9	10/2/2020	10:16	9	22.9	0
172	5	ESL176	11	430400	5622463	perpendicular	9	12	10/1/2020	11:30	9	10/2/2020	10:28	9	23.0	0
173	5	ESL140	11	430373	5622519	perpendicular	8	10	10/1/2020	11:37	9	10/2/2020	10:35	9	23.0	0
174	5	ESL108	11	430196	5622852	parallel	8	8	10/1/2020	12:47	9	10/2/2020	11:20	9	22.6	0
175	5	ESL60	11	430130	5622883	perpendicular	8	9	10/1/2020	12:50	9	10/2/2020	11:25	9	22.6	0
176	5	ESL184	11	430087	5623026	parallel	7	9	10/1/2020	13:01	9	10/2/2020	11:33	9	22.5	0
177	5	ESL12	11	429870	5623329	parallel	5	8	10/2/2020	10:55	9	10/3/2020	9:49	9	22.9	0
178	5	ESL124	11	429735	5623401	parallel	8	9	10/2/2020	11:03	9	10/3/2020	9:57	9	22.9	0
179	5	ESL28	11	429684	5623584	oblique	8	8	10/2/2020	11:12	9	10/3/2020	11:06	9	23.9	0
180	5	ESL196	11	429474	5623776	perpendicular	10	11	10/2/2020	12:02	9	10/3/2020	10:15	10	22.2	0
181	5	ESL64	11	429375	5624076	oblique	10	11	10/2/2020	12:10	9	10/3/2020	10:28	10	22.3	1
182	5	ESL112	11	429194	5624046	perpendicular	10	13	10/2/2020	12:18	9	10/3/2020	11:06	10	22.8	0

Appendix C – All Sturgeon Captures

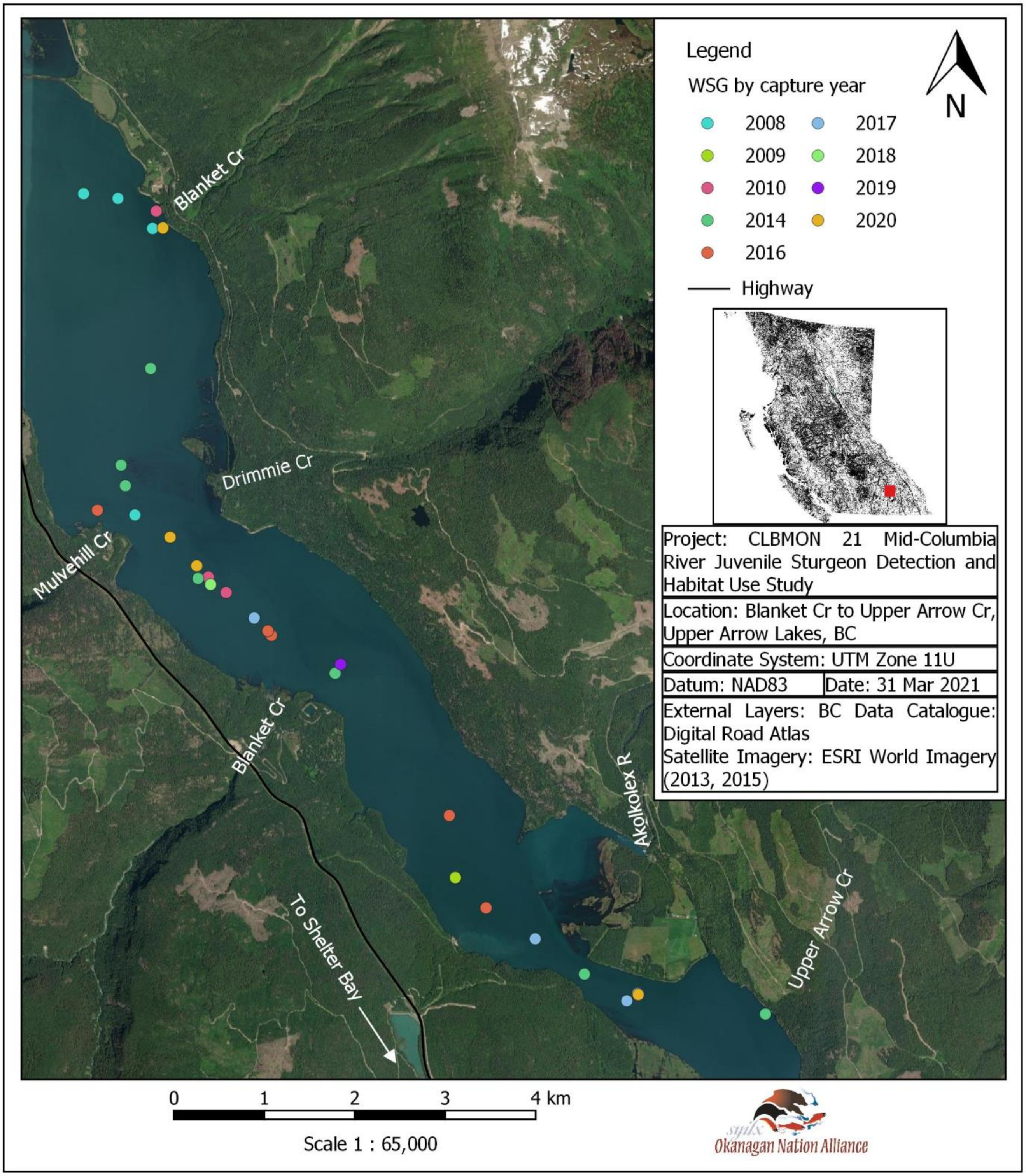

Figure 18. Juvenile White Sturgeon captures from CLBMON-21 (Blanket Cr downstream to Upper Arrow Cr) in the Upper Arrow Lakes for all years. Data collected by Golder Associates Ltd. and Okanagan Nation Alliance (ONA 2019, 2020).

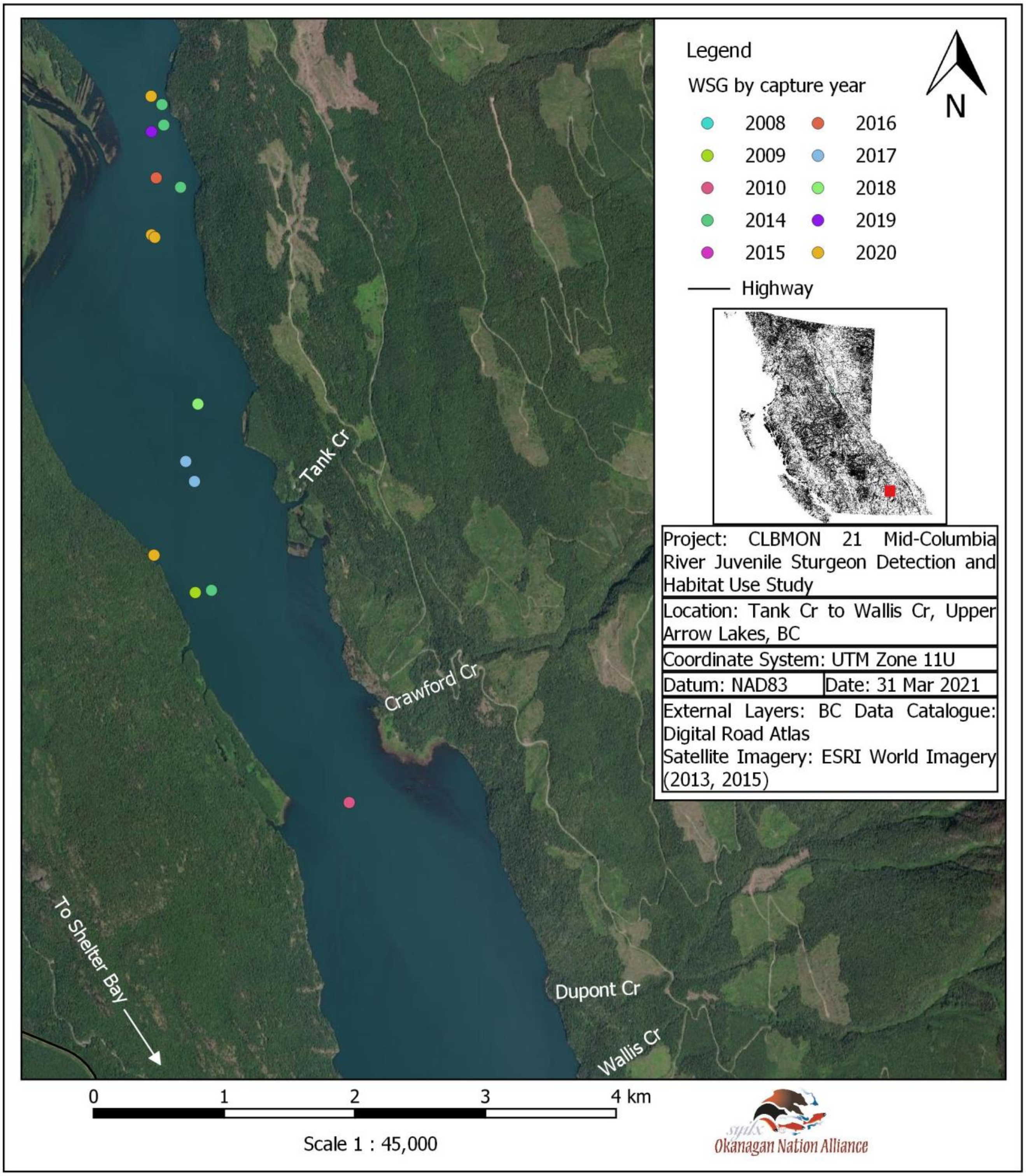

Figure 19. Juvenile White Sturgeon captures from CLBMON-21 (upstream of Tank Cr downstream to Wallis Cr) in the Upper Arrow Lakes for all years. Data collected by Golder Associates Ltd. and Okanagan Nation Alliance (ONA 2019, 2020).

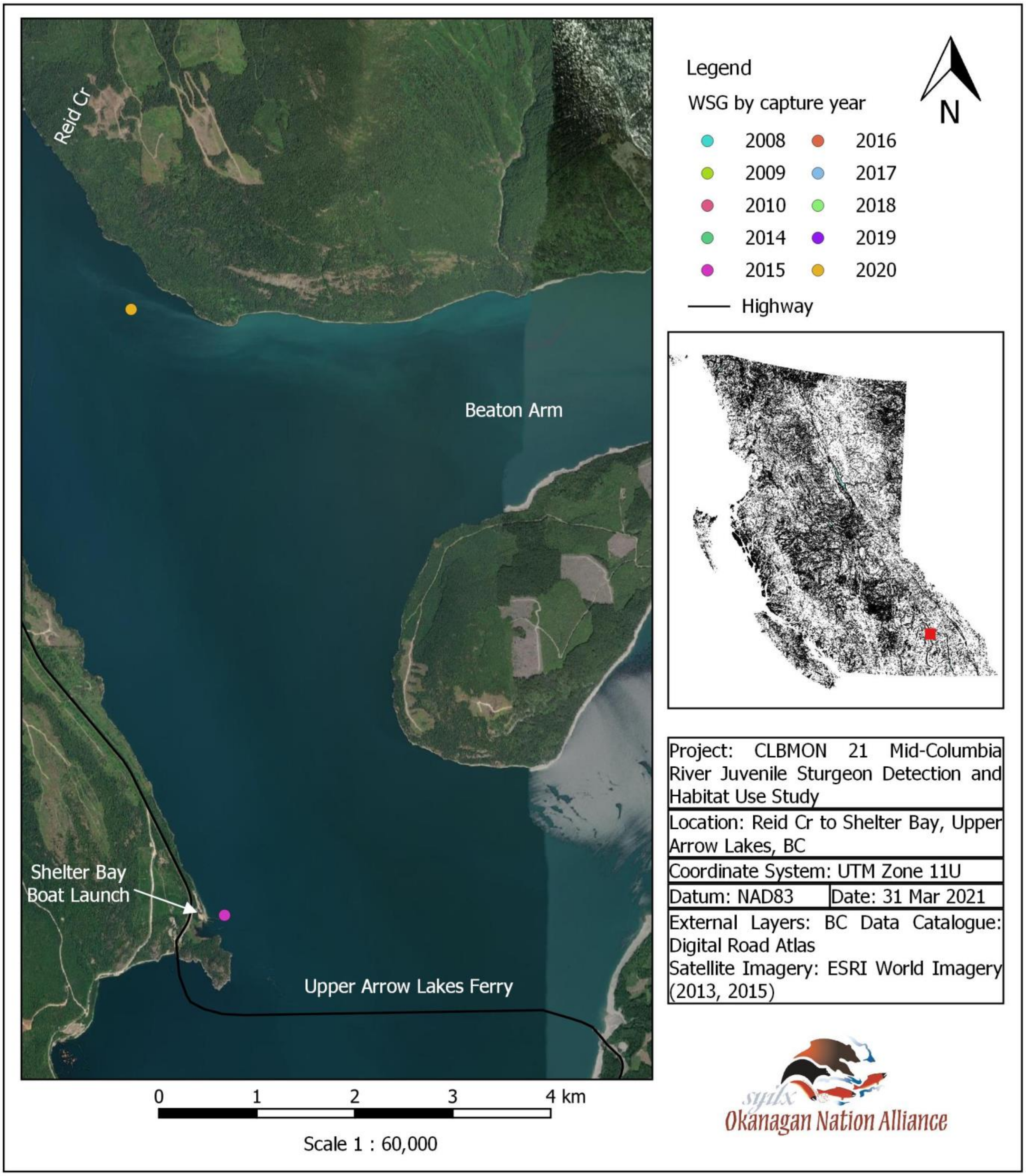

Figure 20. Juvenile White Sturgeon captures from CLBMON-21 (Reid Cr downstream to Shelter Bay) in the Upper Arrow Lakes for all years. Data collected by Golder Associates Ltd. and Okanagan Nation Alliance (ONA 2019, 2020).

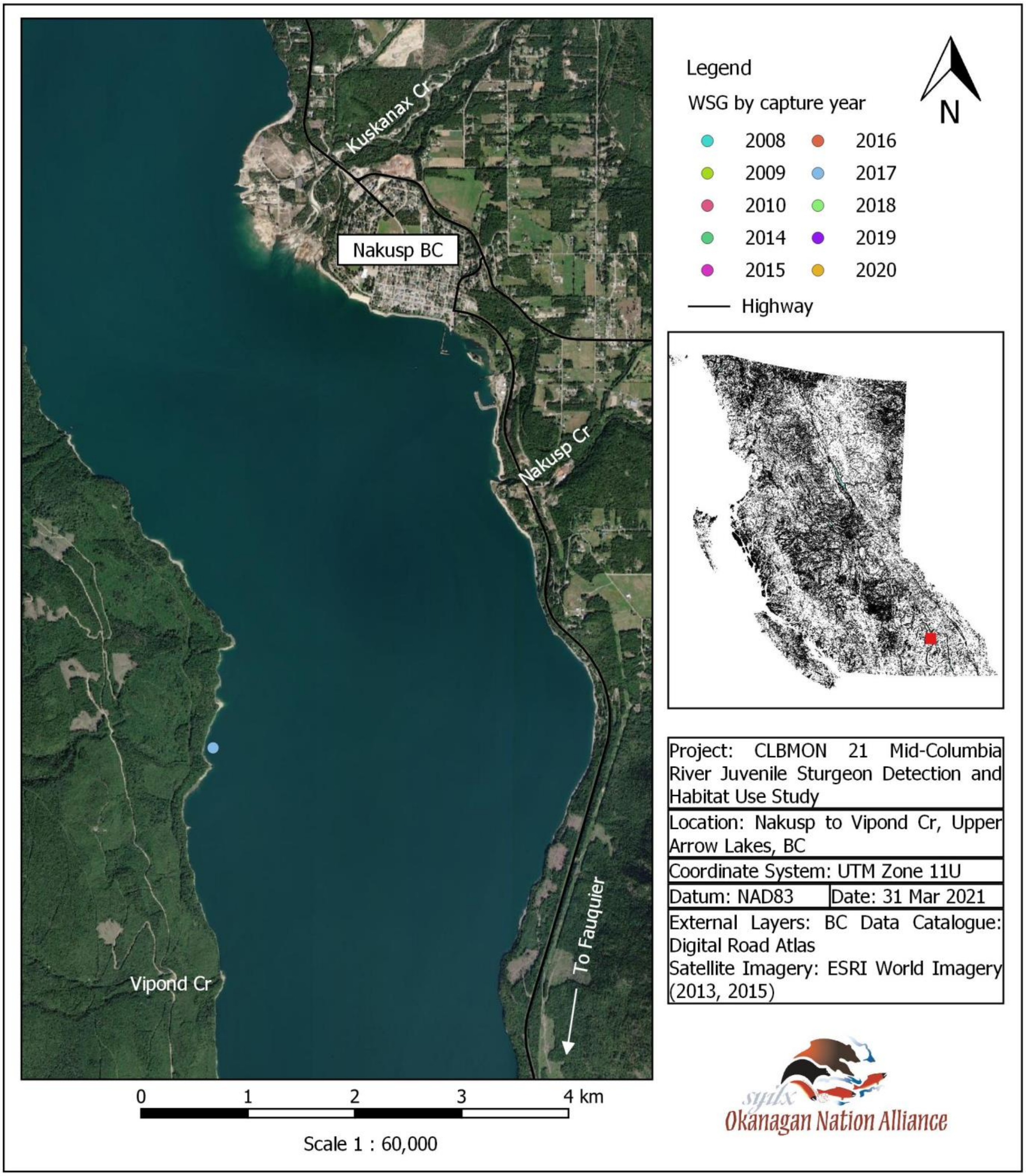

Figure 21. Juvenile White Sturgeon captures from CLBMON-21 (Nakusp BC downstream to Vipond Cr) in the Upper Arrow Lakes for all years. Data collected by Golder Associates Ltd. and Okanagan Nation Alliance (ONA 2019, 2020).