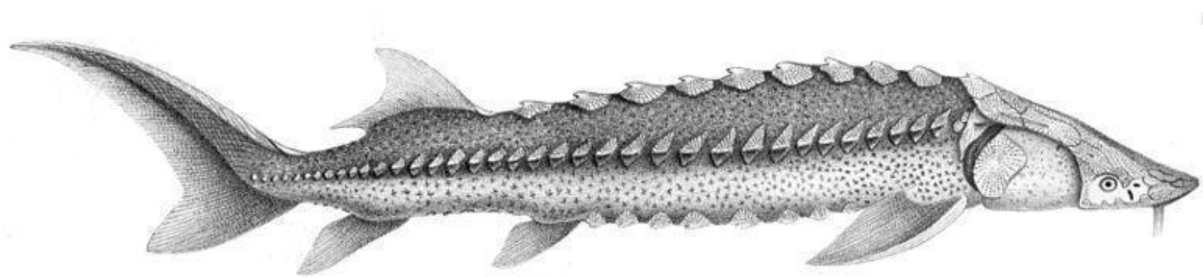
Distribution and Migration of Acoustic-Transmitter Tagged White Sturgeon with Special Regards to Overwintering Habitat in the Lower Fraser River 2017-2018



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DISTRIBUTION AND MIGRATION OF ACOUSTIC-TRANSMITTER TAGGED WHITE STURGEON WITH SPECIAL REGARDS TO OVERWINTERING HABITAT IN THE LOWER FRASER RIVER 2017-2018

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A REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DIPLOMA OF TECHNOLOGY

in

FISH, WILDLIFE AND RECREATION MANAGEMENT
RENEWABLE RESOURCES TECHNOLOGY
SCHOOL OF CONSTRUCTION AND THE ENVIRONMENT

We accept this report as conforming to the required standard

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Supervisor

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Program Head

BRITISH COLUMBIA INSTITUTE OF TECHNOLOGY

MAY 2018

Abstract

The purpose of this study was to track previously acoustic-tagged White Sturgeon to determine seasonal movement patterns in regard to overwintering sites in the lower Fraser River. This study took place from October 2017 to March 2018 from Fort Langley to Mission, British Columbia, Canada. We traversed along a 21-kilometer section of the river by boat while utilizing a VEMCO VR100 hydroacoustic monitoring receiver with an attached omni-directional hydrophone. The hydrophone was suspended into the water and received signals from any tagged White Sturgeon signal within a 500-meter radius. A total of 19 previously-tagged White Sturgeon were observed during the period of the study. A majority of these individuals were located within the two known overwintering sites currently designated by COSEWIC including the mouth of the Stave River and the side channel adjacent to Matsqui Island (Matsqui Slough). A number of White Sturgeon were also observed as an aggregation in the Plumper Reach along the main stem of the Fraser River suggesting a possible newly-discovered overwintering site. Since 2015, only one individual (White Sturgeon 22494) was found to show winter-site fidelity within our study area and this was in the Matsqui Slough. The *furthest distance travelled* from the initial tagging location by an individual in our study was 47.3 km (White Sturgeon 23057), and the minimum distance travelled from the initial tagging location was 15.6 km (White Sturgeon 25421). The greatest *net movement* by one individual from our first observation to the last observation was from White Sturgeon 21853 at approximately 4.58 km. Nine White Sturgeon exhibited no *net movement* as they were observed only once throughout the duration of this study. To better comprehend White Sturgeon movements and habits in the lower Fraser River, we recommend expanding both the geographic length and time duration of the study to identify exactly where each acoustic-tagged White Sturgeon is moving during every season of the year.

KEY WORDS: White Sturgeon, *Acipenser transmontanus*, Fraser River, acoustic transmitter, hydroacoustic, overwintering sites, site fidelity

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Acknowledgements

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1.0 Introduction

1.1 Project Background

Identified nationally as a Canadian Heritage River, the Fraser River has long-been recognized for its significance to British Columbia (BC Parks n.d.). At approximately 1,375 km in length (Newton and Robinson 2007), the Fraser River is the longest watershed entirely contained within this province. With its nutrient-rich water, large flows and broad geographic scope, the Fraser River is home to a variety of fishes and other aquatic animals including White Sturgeon (*Acipenser transmontanus*) (Ministry of Environment n.d.). It is also one of only three major watersheds in North America in which White Sturgeon maintain viable spawning populations, making it a critical habitat for the species (COSEWIC 2012).

The Fraser River drainage includes approximately one-third of the area of the mid-lower part of the province of British Columbia. Downstream of Prince George the direction of flow is largely southwards before veering westward at Hope, wandering through the Fraser Valley area, and into the Salish Sea. The Fraser Valley is part of the lower mainland of British Columbia which extends across the south-western corner of the province, from the Greater Vancouver area to as far east as Hope, BC. This geographic area contains 60 percent of the province's human population and is rapidly growing via development. Modifications to the riverine landscape include changes to the riparian and floodplain along the Fraser River's banks where development is continually expanding and is affecting the sustainability of this aquatic ecosystem (Rosenau and Angelo 2005).

White Sturgeon in the Fraser River were a historically abundant species (COSEWIC 2012). Due to unsustainable harvest through commercial fisheries in the late 1800s and early 1900s, White Sturgeon abundance in the lower Fraser River was significantly reduced, eventually leading to a closure of the commercial harvest in 1994. Today's protected populations have not reached their historical numbers, and over the past 100 years the total population trend for the lower Fraser River has declined over 50 percent (COSEWIC 2012).

Due to the increasing pressures from numerous human activities affecting this species, White Sturgeon in the lower Fraser River were designated as "threatened" by COSEWIC in 2012 (COSEWIC 2012). Under the *Species at Risk Act* (SARA), this population is a Schedule 3 species meaning it has no status and is not protected under SARA because of its socio-economic importance, although it is currently under re-evaluation for future considerations (COSEWIC 2012). Conservation efforts have been developed by several agencies to better understand how to manage White Sturgeon as the Fraser River faces increased levels of urbanization and use by many industries and agriculture.

In order to better understand White Sturgeon in British Columbia, COSEWIC divided populations based on geographic location and genetic characteristics into four Designatable Units (DU's). These DU's included the Upper Kootenay, Upper Columbia, Upper Fraser River (Upper-Middle Fraser, and the Nechako River), and Lower Fraser River (COSEWIC 2012).

In 1995, RL&L Environmental implemented a PIT (Passive Integrated Tag) program on the Fraser River to better understand the population size of White Sturgeon. In 1999-2000, the Fraser River Sturgeon Conservation Society (FRSCS) expanded the program from the RL&L Environmental study and continued their ongoing mark-recapture efforts of White Sturgeon with the objective of achieving a population estimate. As part of this study the FRSCS developed an ongoing program that closely worked with White Sturgeon angling guides on the Fraser River. Guides who volunteer for the program are trained to implant PIT Tags into White Sturgeon, and are then given the appropriate equipment to use on their own in the field (PIT Tags and Scanners). Many guides joined this program as it offered a unique experience for customers wanting to enjoy the thrill of fishing, while promoting conservation as the main focus. When White Sturgeon are caught, they are measured for fork length (FL), girth, and scanned for a PIT Tag. If the scanner does not find a PIT tag, the guides will implant one and record its unique ID number, the location in which it was caught, and its measurements (FL and girth) onto a data sheet that will be given to FRSCS for research (Nelson et al. 2013).

In addition to PIT tagging, the Ministry of Forests, Lands, Natural Resource Operations & Rural Development (FLNRORD) has also initiated a research program using hydroacoustic tags to more-closely assess White Sturgeon movements within the lower Fraser River. By using both mobile and stationary acoustic receivers to track tagged White Sturgeon, the information provided allows agencies the ability to monitor the abundance of individuals using particular areas of the river, and the overall movement of White Sturgeon. The acoustic tagging information also assists in developing current population estimates, discovering important feeding locations, and learning about seasonal habitat areas, especially overwintering sites.

These various methods of study have been used to identify specific areas of the Fraser River in which are essential to the survival of White Sturgeon in the colder winter months. When water temperatures drop below 7 degrees Celsius (mid-fall) White Sturgeon become inactive and gather in overwintering areas (COSEWIC 2012). Using these data, the Committee on the Status of

Endangered Wildlife in Canada (COSEWIC) has designated a number of overwintering sites for White Sturgeon within the Fraser River watershed, two are within our study area (Figure 1).

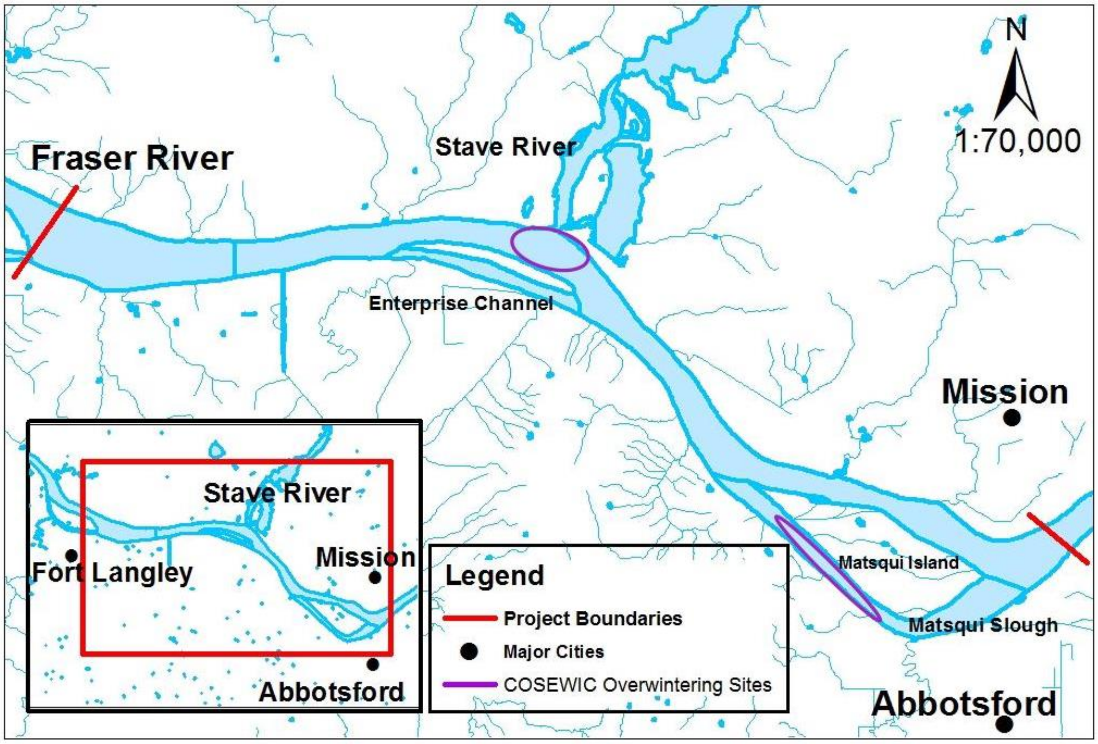

Figure 1. Map of study area in the lower Fraser River including COSEWIC designated White Sturgeon overwintering habitats located within this reach.

The movement of White Sturgeon in the lower Fraser River varies by season. During the summer months White Sturgeon are more active but remain relatively close to feeding areas (RL&L Environmental Services Ltd. 2000). Migration movements begin late fall or early winter as White Sturgeon make their way to overwintering habitats in the lower Fraser River (Nelson et al. 2004). In the winter months these White Sturgeon migrate to deep, low velocity sites to overwinter or "hold" for the season (Fisheries and Oceans Canada 2014). Activity appears to be reduced in the winter as river-discharge rates drop and water temperatures approach zero degrees Celsius. Spawning migrations occur during the timing of the spring freshet (Perrin et al. 2000). White

Sturgeon migration patterns in the lower Fraser River have been tracked using telemetry surveys, and some patterns have been observed to be greater than 100 kilometers (RL&L Environmental Services Ltd. 2000). This is likely due to the propensity of White Sturgeon to move with the seasonal availability of prey in the river, estuary and marine environments, and/or their spawning migrations (Fisheries and Oceans Canada 2014).

The critical White Sturgeon habitats in the lower Fraser River, including riparian areas, have also been extensively modified for anthropogenic uses (e.g., forestry, development, diking, dredging sand and gravel), and conflicts among stakeholders have arisen in regard to how these areas should be utilized (Hatfield et al. 2004). The Fraser River's habitat capacity is being impacted by human activities faster than can be repaired, and pollution is occurring at a faster rate than can be absorbed (Rivershed Society of BC n.d). This river is used by a wide variety of recreationists and commercial industries and is subject to contamination from garbage, solid and liquid waste effluent, and toxic liquids such as motor oil and gasoline spills (Figures 2 and 3). Although these factors exist, much of the habitat still remains functional.

Figure 2. Hydrocarbons floating on the surface of the Fraser River in the Bedford Channel, March 21, 2018.

Figure 3. Containment of a sunken ship near the decommissioned Albion Ferry.

Studies by researchers and biologists can influence agency decisions regarding further development and commercial use of the river, and may have implications for White Sturgeon populations (Fraser River Sturgeon Conservation Society n.d.).

As the Fraser River is home to some of the most vulnerable habitats for many aquatic species, including White Sturgeon, it is imperative for research to continue so we can understand how to better manage their critical habitats (Rosenau and Angelo 2007). By asking these questions and addressing these concerns now, we can help create a future in which these populations are healthy, strong, and naturally sustaining for generations to come.

1.2 Purpose and Objectives

The purpose of our study was to locate previously acoustic-tagged White Sturgeon that resided in the Fraser River from Fort Langley to Mission during our study period. We wanted to determine their seasonal-movement patterns and overwintering sites within a portion of the lower Fraser River known as the Sand Reach (Figure 4). Our surveys were conducted monthly from October 2017 through March 2018, spanning the seasons of late fall, winter, and early spring. We surveyed a 21 kilometer stretch of river located between the Bedford Channel boat launch in Fort Langley to the western side of the Mission Bridge. Surveys were conducted by boat using a Vemco VR100 hydro-acoustic receiver and hydrophone. The data collected provided information on tagged White Sturgeon locations during different months of the year in which we undertook the surveys.

The objectives of our project included:

1. Locate previously tagged sturgeon residing in the project reach during our study period;
2. Observe migration and location patterns of the White Sturgeon that remained in our study area through changes in seasons;
3. Confirm whether White Sturgeon return to the same overwintering sites within our study area over multiple years, based on data collected from previously previous studies conducted by BCIT students in areas which overlapped ours.

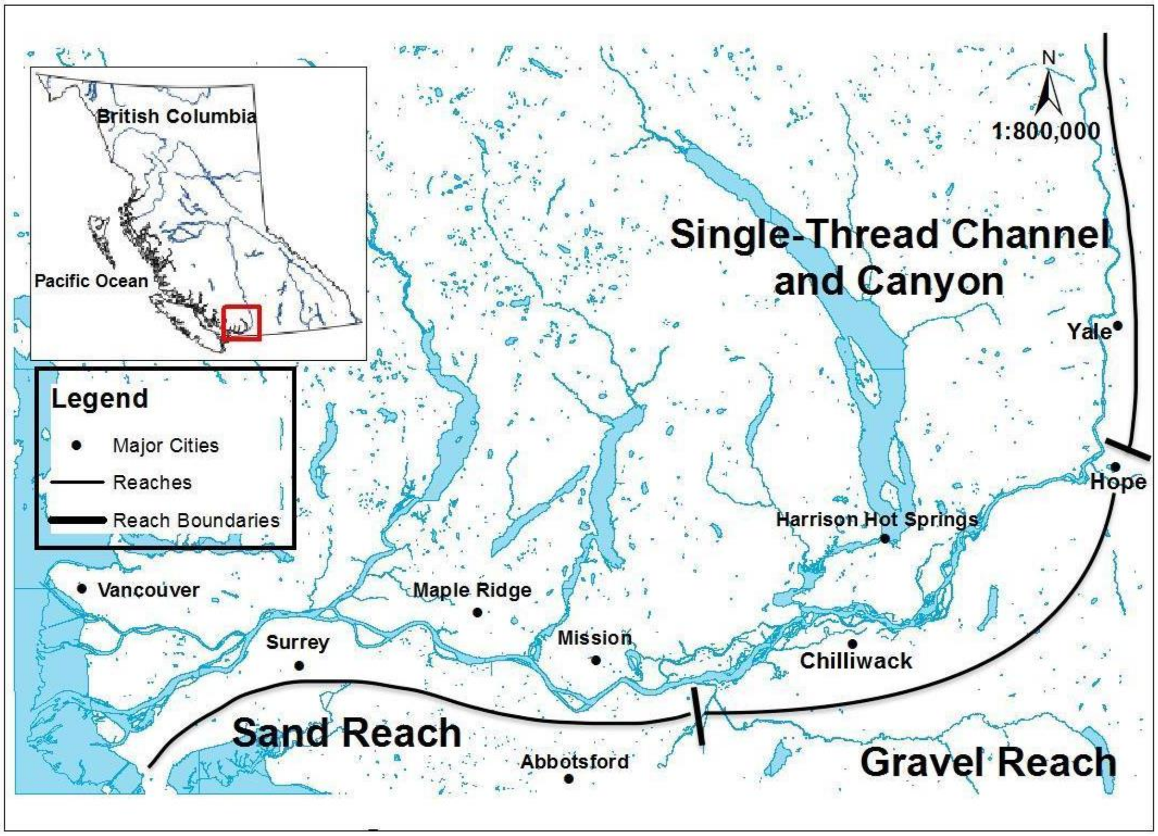

Figure 4. Reaches of the Lower Fraser River. Borders between reaches are delineated with black vertical lines.

2.0 Description of White Sturgeon

2.1 Distributional Characteristics of Fraser River White Sturgeon

The White Sturgeon is considered an ancient fish, surviving two ice ages and remaining virtually unchanged from their first-known emergence nearly 175 million years ago (Ministry of Environment n.d.). White Sturgeon are one of five sturgeon species found in Canada, and reproductively viable populations reside in three major drainages in North America's west coast including the Sacramento River (California), the Columbia River (British Columbia, Oregon, Idaho and Washington), and the Fraser River (British Columbia). Though primarily a freshwater species, some White Sturgeon individuals adapt a marine lifestyle, like its "sister species", the

Green Sturgeon (*Acipenser medirostris)* (Ministry of Environment n.d.). While Green Sturgeon can be found off the west coast of Canada (COSEWIC 2012) and occasionally in the lower Fraser River, the freshwater phases (spawning, early rearing) for populations in North America are only found in streams in Oregon and California, USA. White Sturgeon are frequently found in marine habitats off of the coast of North America, but do not require them to complete their life cycle (Pearson and Healey 2012).

White Sturgeon stocks within the Fraser River watershed were divided into four groups by COSEWIC in 2003 including the Nechako, Upper, Middle and Lower populations (COSEWIC 2012). Though movements between these stock groups are theoretically possible, they are seldom documented (Fraser River Sturgeon Conservation Society 2012). Differences in mitochondrial DNA suggest that the intermixing of stock groups is rare, and these populations typically reproduce independently of each other (Smith et al. 2002).

Due to differences in genetics and physical features amongst the stock groups in the Fraser River, populations were re-assessed by COSEWIC in 2012 into two groups; the Upper and Lower Designatable Units (DU's). These, groups are physically separated by Hells Gate (rkm 220), located within the Fraser Canyon (Nelson et al. 2008). Further, the upstream White Sturgeon were also sub-divided into three sub-DU's because of their genetic and geographic differences (DFO 2016).

The major differences between upstream and downstream populations are thought to be a result of the partial-migration barrier occurring at Hell's Gate (M. Rosenau, fisheries instructor; pers. comm. 2017). The naturally-narrow canyon known as "Hell's Gate" was further constricted when the construction of the Canadian National Railway alongside Hell's Gate caused significant rockslide events in 1914. As a result of the rockslides the canyon gap was partially filled in, narrowing from 91 m to just 23 m (BCIT Commons n.d.). The funnel of turbulent water at Hell's Gate that existed/exists both historically and today may be too difficult for White Sturgeon to navigate in an upstream direction at this location. Based on the absence of White Sturgeon tagged downstream of Hell's Gate having moved above this barrier, upstream movement from the lower Fraser River to areas above Hell's Gate appears to be very rare. This may give the groups of White Sturgeon found in the Fraser River watershed the geographic separation they need to evolve independently (Nelson et al. 2015).

Physical adaptations such as rostrum length, body shape and genetics differ amongst White Sturgeon populations in the Fraser River and have been documented to vary based on their geographic location (RL&L Environmental Services Ltd. 2000). The upper Fraser DU that lives upstream of Hell's Gate are generally subject to faster water currents. In response to this, White Sturgeon appear to have evolved a leaner and more-streamlined body with much longer and narrower rostrums than their lower river counterparts. The Lower Fraser DU, downstream of Hell's Gate, have more-blunt and shorter rostrums, and this appears to be adapted for the slower moving waters in this part of the drainage. We note that both body variations can be found in the lower Fraser River area, but with a much-smaller portion exhibiting the more streamlined bodies; these may be upstream White Sturgeon that have "drifted" downstream into the lower river. These morphological differences suggest movement downstream into the lower reaches by upper-river White Sturgeon may be more common than movement upstream by lower river White Sturgeon. The movement of lower-river White Sturgeon to areas upstream of Hell's Gate would be too difficult and their survival rates would be significantly less due to a lack of appropriate adaptations (RL&L Environmental Services Ltd. 2000).

2.2 White Sturgeon Biology

Fraser River White Sturgeon are the largest freshwater fish species in North America and have been known to grow up to six meters long and weigh over 600 kilograms (Ministry of Environment n.d.). White Sturgeon can also live to be well over 100 years of age. They are classified as a bony fish, but have a skeleton primarily composed of cartilage. The body is long, somewhat "boxy", and covered in dermal denticles including five rows of sharp bony plates called scutes (Figure 5). Scutes line the body for protection against predation and are very sharp as juveniles, but wear down throughout its life. Variation in body colour is common and can range from greenish to grey on the dorsal side, and light-greyish to white on the ventral side. Being a largely-demersal species, this dorsal colouration is used to camouflage into the benthic surface. The rostrum holds a ventrally protruding and toothless mouth adapted for feeding along the bottom (McPhail 2006). A variation in rostrum morphology has been observed among stock groups in the Fraser River, with a more-pointed shape in the upstream areas and a more-rounded shape in the lower river. Small eyes are located dorsally to the mouth and are not used as a primary sensory organ when the water is highly turbid, which it often is in the Fraser River. Living in predominantly murky waters that are difficult to navigate, vision is limited and therefore other senses have been developed to compensate. Examples of these senses include four barbels with chemoreceptors and touch-receptors located on the ventral side of the rostrum, and numerous sensory rosettes located on the underside of their rostrum (Department of Fisheries and Oceans n.d.).

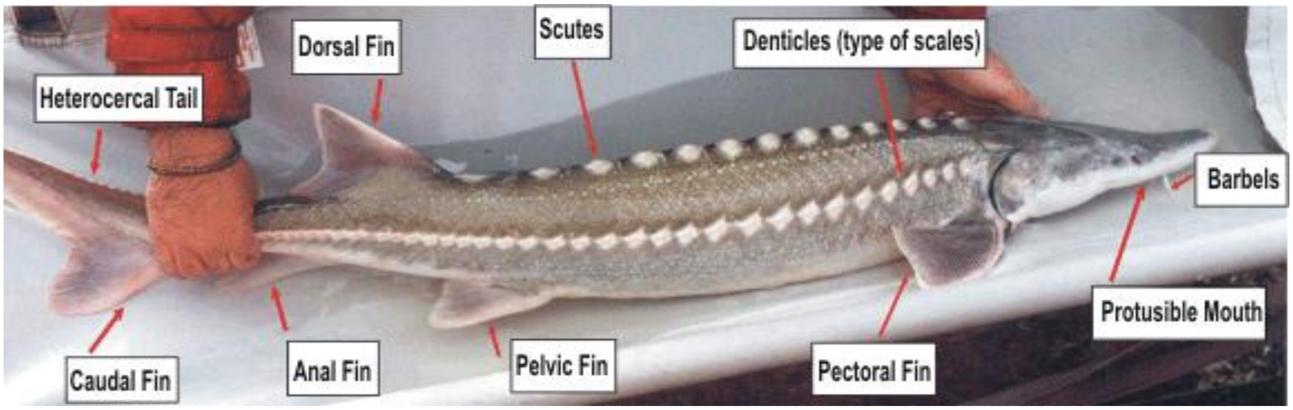

Figure 5. Anatomy of White Sturgeon (Acipenser transmontanus). Image source: Department of Fisheries and Oceans Canada, n.d.

2.3 Reproduction and Spawning Habits

White Sturgeon in the lower Fraser River use different habitats within this river during various stages of their lives. For example, many lower Fraser White Sturgeon spend a large portion of their lives in the Sand Reach (Figure 4) feeding on eulachon (*Thaleichthys pacificus*) which are known to prefer sandy benthic substrates for spawning habitat (Neufeld et al. 2010). The Gravel Reach in the lower Fraser River is used for White Sturgeon spawning grounds, mostly in large side channels behind large islands. Generally, the water in these side channels are faster, and contain clean, larger substrates such as gravels and cobbles which are more suitable for embryo and yolk-sac larvae incubation (Liebe and Sykes 2011, Blood 1997).

White Sturgeon are freshet-adapted spawners (Fraser River Sturgeon Conservation Society n.d.) and spawning typically begins in late spring and extends into early summer when water velocity and volume is high, and water temperatures are between 10 and 18 degrees Celsius (Perrin et al. 2000). White Surgeon are broadcast spawners and have been found to exhibit “homing” behaviours by returning to natal spawning grounds to reproduce (Nelson et al. 2013).

Sexual maturity is achieved very late in life for both sexes. Females in the lower Fraser River do not reproduce until approximately 26 years of age and have a fork length of at least 1.7 meters (Scott and Crossman 1973). Similarly, males mature at approximately ten years of age and a size which averages a fork length of around 1 meter. White Sturgeon are capable of spawning many times throughout their long lives (Hatfield et al. 2004); however, spawning generally does not occur annually and individuals may go several years between spawning events (Fisheries and Oceans Canada 2014).

Female White Sturgeon at maturity are very fecund and up to 3 million eggs can be found in large individuals. Nevertheless, only a small number of these gametes ever successfully survive to adulthood (Ministry of Environment n.d.). Once released from the female body, the eggs become sticky after fertilization. Due to their negative buoyancy, the eggs sink to the bottom where they attach to river substrate and mature into larvae for between five and ten days, and this rate of incubation is temperature dependent (Liebe and Sykes 2011, Fisheries and Oceans Canada 2014). Longer incubation periods may occur where water temperatures are lower (Blood 1997). The young larvae are referred to as “yolk-sac larvae” from one to twelve days post-hatch, and “feeding larvae” from twelve to forty days post-hatch (Fisheries and Oceans 2014). The yolk sac larvae stay embedded in the gravel river bed until they metamorphose into young free-swimming and free-feeding larvae, eventually transforming into free-swimming juvenile White Sturgeon (Ministry of Environment n.d.).

3.0 Study Area

3.1 Study Site Characteristics

The Fraser River drains approximately 21 million hectares of British Columbia's land mass. The river undergoes a wide change in widths and depths during the spring freshet depending on the location and because of the large magnitude of flow changes. Peak discharge occurs in April through July as the snow melts from higher elevations as the season continues (Ferguson and Healey 2009). Large variability in discharge often moves high volumes of coarse woody debris and exposes, or floods, dry bars and banks littered with stumps and logs which provide a wide range of habitat for multiple species in the riverine ecosystem.

3.2 The River Kilometer System

To help orient technicians and scientists working on the lower Fraser River, a geographic-specific measurement of distance is used as a location identifier for this lower Fraser River study. This is referred to as the 'river kilometer system', or 'rkm', and functions by sectioning the river in kilometer-long increments beginning at the confluence of the Fraser River and the Salish Sea (rkm 0) and moving upstream. This system of measurement was developed by RL&L Environmental Services during their studies of White Sturgeon in the late 1990's (Appendix IV). It works similarly to vehicle markers along roadways, except signs are not usually posted along the river itself. Instead, river kilometers are typically denoted on navigation charts and maps, and allows for easier navigation by river users. It has been employed in various research projects and is used by recreational and sport fisheries alike. Our surveys utilized this method to document White Sturgeon sampling locations in order to reference locations to a map (Figure 6). The unit for this measurement is noted as 'rkm' for the remainder of this report.

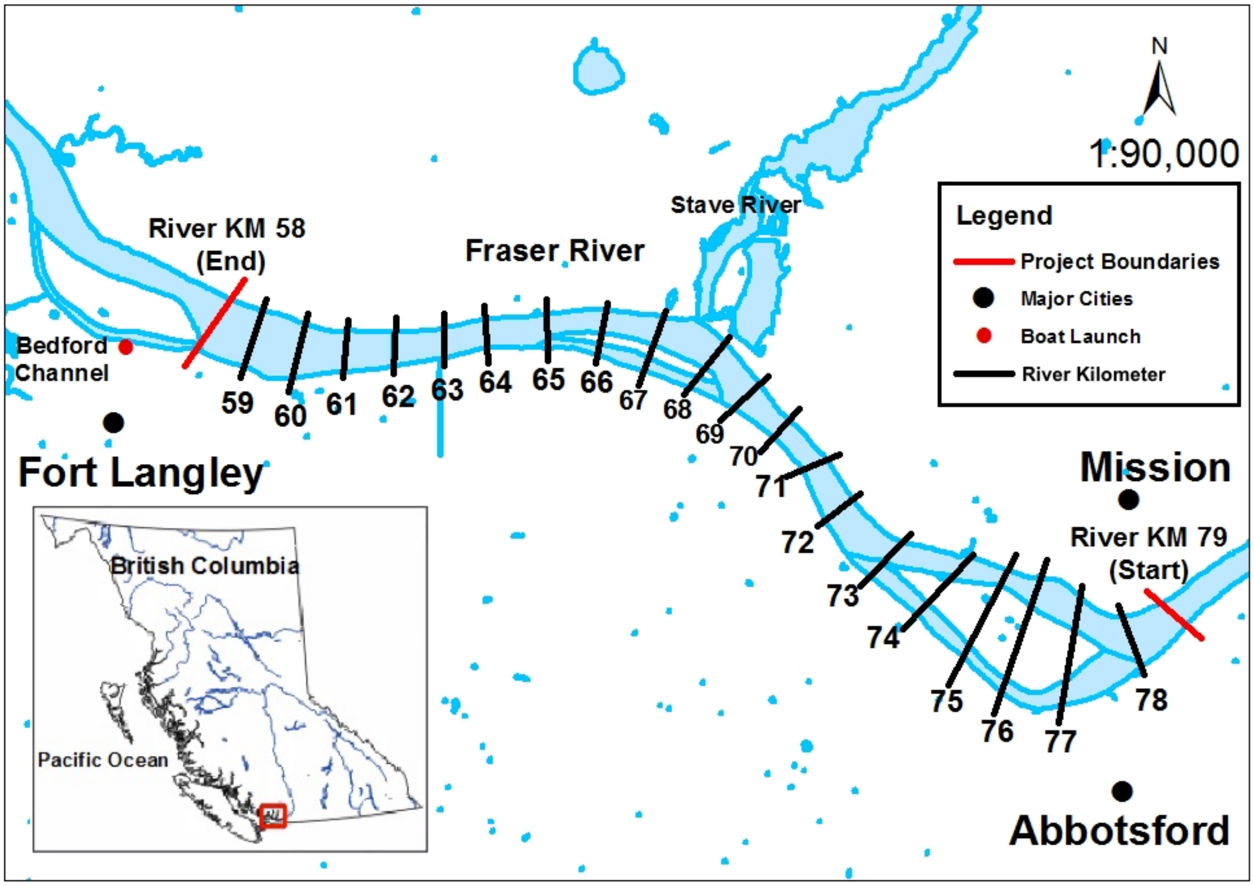

Figure 6. Map of study area location from rkm58 to rkm 79 in the lower Fraser River and river kilometer (rkm) system used for our project area.

The lower Fraser River is the area of our study focus including from the most eastern (upstream) side of the Bedford Landing Channel at Fort Langley (rkm 58) and extending east (upstream) as far as the Mission Bridge (rkm 79) located southwest of Mission (Figure 7).

Our study area of White Sturgeon in the lower Fraser River focuses within the section known as the Sand Reach and this naming is due to the dominance of fine material including sand, silt and clay comprising its benthic surface. The Sand Reach is located downstream of the confluence of the Sumas River where the benthic features change from gravel to a sand-dominated substrate. The Sand Reach is characterized by deeper, slower moving waters and a lower gradient than those immediately upstream.

3.3 Near-Shore Development of the Fraser River

In our study site, there are many fluvial-geomorphic features that may play a role in suitable overwintering habitat. These include three secondary channels (Bedford, Enterprise, and Matsqui Slough) and three islands (McMillan, Matsqui, and Crescent) (Figure 7). The three islands in our study area provide suitably calm waters and deep eddies along their banks, which may be a desired feature for overwintering White Sturgeon (COSEWIC 2012) (Figure 7).

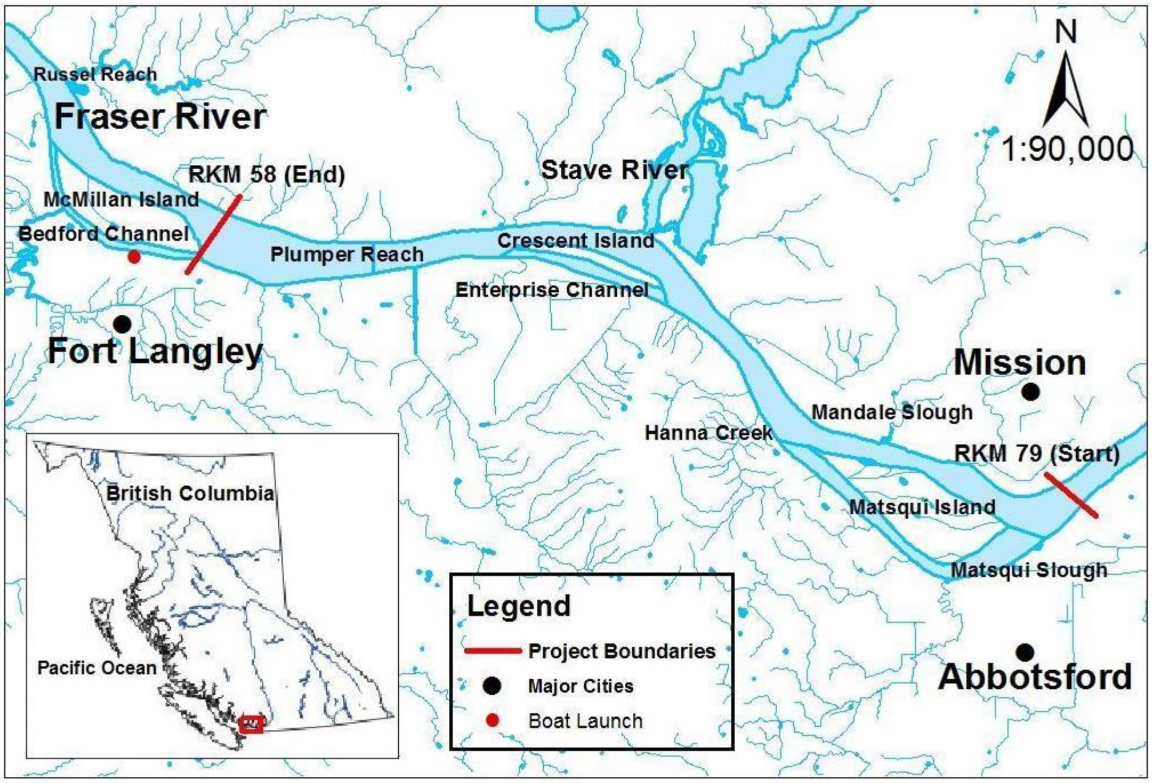

Figure 7. Study site area focusing on river features such as secondary channels, islands, and the confluence of the main stream with tributary streams and sloughs.

Our study area of the lower Fraser River includes a portion of the Plumper Reach (Figure 7). This section of our study area contains long expanses of log booms which are stored and transferred along our study area, resulting in vessel traffic from tugboat operations (Figure 8).

Figure 8. Tugboat operations often frequent the waters of the Fraser River.

Another fluvial feature of importance to White Sturgeon and within our study area includes the Stave River which flows into the Fraser River east of Maple Ridge (Figure 7). The water that flows from the Stave River into the Fraser River passes through or over the hydro-electric dam at Hayward Lake just upstream of the confluence.

At the confluence of the Stave River and Fraser River, pockets of significant depths have been documented to provide crucial overwintering habitats (COSEWIC 2012). In addition to the Stave River, an abundance of secondary channels, streams, and sloughs also exist throughout our study area. While White Sturgeon often use fast moving flows for spawning, they may also use slower, sandy-bottomed, secondary channels for rearing or overwintering (Ministry of Environment n.d). Within our study site, such secondary channel conditions are found in areas comprising the Mandale Slough and Hanna Creek confluences with the Fraser River (Figure 7). These locations have the potential to provide critical rearing habitat for use by both juvenile and adult White Sturgeon.

4.0 Methods

4.1 Tracking Surveys

We tracked acoustic-tagged White Sturgeon in the lower Fraser River that had been previously fitted with tags by the Ministry of FLNRORD from October 2017 to March 2018. The field days were scheduled on every mid-month Wednesday, from October 2017 to March 2018, depending on weather conditions. Tide schedules and wind warnings were checked the night before, and again in the mornings of surveys, to ensure the safety of group members. If the tide was too low or wind gusts were too high, tracking was postponed until the following Saturday. Each field day began at 8:00 am in Fort Langley at the Bedford Landing boat launch. A 16-foot Hourston Glasscraft runabout was deployed and driven at full speed to the upstream boundary of the study area at the Highway 11 bridge at Mission (Figure 6). Tracking surveys involved deploying a hydrophone into the water and slowly traversing downstream the Fraser River on an approximately 45-degree angle to the stream bank, and following a zig-zagging tack, at no faster than five kilometers per hour (Figure 9). This is the maximum recommended speed while using a Vemco VR100 hydroacoustic receiver, as engine noise can interfere with the ability of the hydrophone to "hear" signals from the tagged White Sturgeon if the motor is revving too high. The receiver can detect White Sturgeon that are located within a radius of approximately 500 meters of the hydrophone (E. Stoddard, FLNRORD biologist; pers. comm.) The duration of tracking for each session took approximately six hours from the Mission Bridge to the Bedford Landing boat launch. In assessing secondary channels; the Matsqui Slough was surveyed first, the hydrophone was removed from the water, and then the boat was navigated back up river at a normal speed to the main stem of the Fraser River where downstream tracking was resumed in the main channel. Due to the hydrophone being fragile, it was retrieved from the water during transport at high speeds and re-deployed prior to the start of each new traverse.

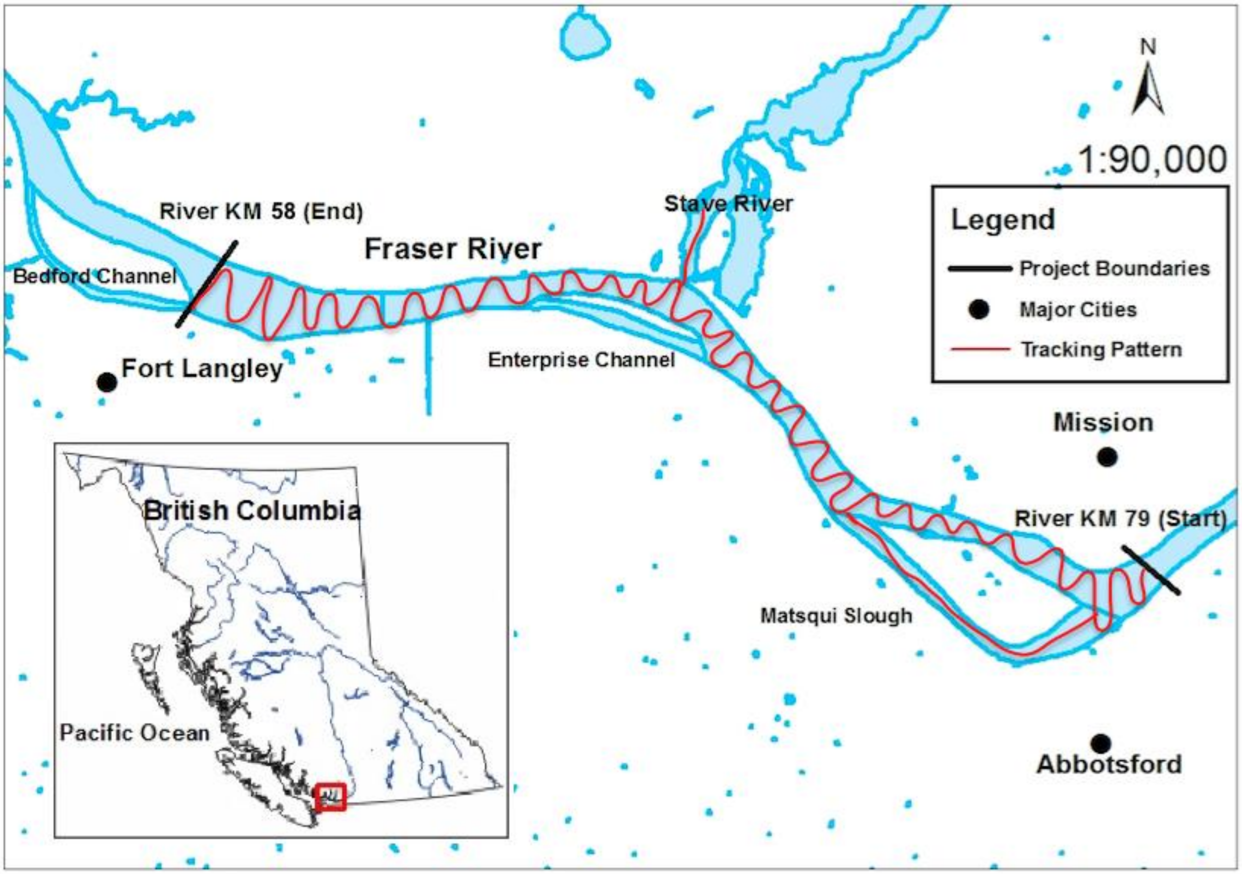

Figure 9. Generalized diagrammatic description of on-water navigational patterns used in our study site when tracking White Sturgeon.

The Vemco VR100 hydroacoustic receiver was wired to an omni-directional hydrophone which was attached to the side of the boat using a wire tie. During operation the hydrophone was lowered into the water to obtain sound signals (Figure 10). The complete apparatus was attached to a weight to counteract buoyancy and allow for it to sink to the desired depth. The depth appropriate for Fraser River flow rate and the speed of the boat was approximately three meters into the water (E. Stoddard, FLNRORD biologist; pers. comm.), off the starboard side of the boat, behind the driver.

Figure 10. Placement of the Vemco VR100 hydroacoustic tag reader in the boat behind the driver (starboard side) while tracking White Sturgeon in the Fraser River.

The hydroacoustic tags which have been implanted in the White Sturgeon during an earlier sampling period, provide signals in three-minute intervals. This long duration between signals extends the battery life for up to 10 years (E. Stoddard, FLNRORD biologist; pers. comm.). Once the hydrophone receives a signal from a tag, the frequency would be transmitted to the Vemco VR100 receiver, indicating the presence of a tagged White Sturgeon. The receiver would then log its own GPS position at the time of detection, along with the individual's unique identification code, the date, time, signal frequency, and signal decibel. All data collected by the VR100 was stored and later used for analysis.

Signals detected from a tagged White Sturgeon have a unique code number associated with a particular hydroacoustic tag. Each of these individuals were also tagged with a Passive Integrated Transponder (PIT) tag with another unique code number as well. To date, approximately 60,000 PIT tags have been implanted into White Sturgeon by sport fishing guides and other volunteers of the Fraser River Sturgeon Conservation Society (FRSCS). The British Columbia Ministry of FLNRORD had surgically implanted 175 hydroacoustic tags by the time of our survey (E. Stoddard, FLNRORD biologist, pers. comm.).

4.2 Data Transfer and Analysis

Transfer of Vemco VR100 Data and Storage

All field data obtained via the VR100 hydroacoustic receiver were uploaded to a stationary computer following all tracking surveys. The Vemco receiver is only compatible with desktop computers equipped with the VR100HS software management program, provided through the Vemco website. This software must be installed on the desktop prior to data transfer. Upon upload from the Vemco VR100, the software program will appear on the desktop monitor and extraction will occur though selecting “File” and “Get all data.” Once this action is complete, a spreadsheet generated by the VR100HS software will open displaying the data that had been recorded throughout the field day. The data that are seen on this spreadsheet exhibits the date, time, channel number, Frequency (kHz), type of tag receiver, code space, identification number of the hydroacoustic tag, signal strength in decibels, gain mode, gain decibels, latitude and longitude. These variables that were found within the spreadsheet help define where and when the White Sturgeon signals in our study area were found. These data were examined and information regarding latitude, longitude, date, time and identification number of the hydroacoustic tag were extracted to record monthly movements during tracking sessions. All data were saved into a single Excel “database” for the duration of the project.

Map Making

After the tracking sessions were completed, these data from the Vemco VR100 were uploaded into an .xlsx Excel Spreadsheet for organizational purposes. Each selection of data was then uploaded to Google Earth and given a filename that was specific to each White Sturgeon hydroacoustic tag ID number. Each observation of an individual was assigned a specific coloured pin to show the difference in location between months of tracking. Once all observations for a White Sturgeon were labelled by to the correct colour, the file was then exported as a KML, and imported into ArcMap to create location maps for each individual located.

Calculating Net Movement and Furthest Distance Travelled

Once the locations of observation for each individual White Sturgeon had been imported and colour-coordinated as a location in Google Earth, we were able to calculate the movements seen among tracking sessions using Google Earth's measurements tools. Some individuals were located more than once per day and we chose the location of first detection to use for measurement purposes. All calculations were then put into a table where we determined "*net movemen*t" and "*furthest distance travelled*". *Net movement* represents the overall observed movements by each individual on a month-by-month basis, from detection point to detection point and the represented values summed. *Furthest distance travelled* was also determined by identifying the furthest location away we observed the individual from their initial tag location (provided by FLNRORD). Both *net movement* and *furthest distance travelled* can provide insight on how far each individual can move and where we may expect to see them in the lower Fraser River at any given time, based on the season and food availability for each region.

5.0 Results

During the extent of our study on the Fraser River from October 18th, 2017 to March 21st, 2018, a total of 19 acoustic tagged White Sturgeon were located (Appendix VIII - XXVI).

We determined *furthest distance travelled* for 17 of the 19 White Sturgeon, but were unable to integrate tagging data and calculate the *furthest distance travelled* for two White Sturgeon, 23057 and 25069. These individuals were tagged as part of a separate project and the original tagging data were not provided by the study managers.

The average *furthest distance travelled* for 17 of 19 observed White Sturgeon was 29.8 km. White Sturgeon 21862, with a fork length of 193cm, (Appendix XVI) travelled the furthest distance, at approximately 47.3 km. White Sturgeon 25421(Appendix XXIV) with a fork length of 151cm travelled the shortest distance at 15.6 km and was only observed once throughout our study.

Net movement was determined for all 19 White Sturgeon, and the average distance travelled was 0.54km. White Sturgeon 21853 with a fork length of 193 cm (Appendix XVI) had the most *net movement* at approximately 4.58 km. Nine White Sturgeon exhibited no *net movement* as they were only observed once and the sum of inter-monthly travel accumulation was not determined.

Out of the 19 White Sturgeon we observed, only nine individuals were located once (19410, 19406, 19414, 25057, 25069, 25414, 25421, 25436, 25437). The remaining 10 White Sturgeon had recurring appearances over the six monthly sessions. Of these 10 individuals there were four that were located twice (16051, 21862, 22493, 22494), two were located three times (16052, 22497) and four White Sturgeon were located four times (16053, 19411, 19413, 21853). Over half of the White Sturgeon observed (10 individuals) displayed minimal movement as they were recorded within the same proximity over multiple months. The other nine individuals were only observed once throughout the study, with five of them located in the month of October. Additionally, October and December were the months with the greatest tracking tag encounters, because for both months we recorded nine uniquely tagged White Sturgeon. November, January and March were also productive as we observed six White Sturgeon in each of these months. The month which displayed the least number of White Sturgeon detected was February with only three individuals observed.

Over the fall-winter duration of our study, we observed aggregations of White Sturgeon at three major spots within our study area (Figure 11). Two of these locations were previously identified as overwintering sites designated by COSEWIC: the confluence of the Stave River and the Matsqui Slough side channel. A third location in what's known as the Plumper Reach, which lies west of the overwintering site at the Stave River (Figure 11) revealed similar and frequent use of the available habitat when compared to the other known overwintering sites.

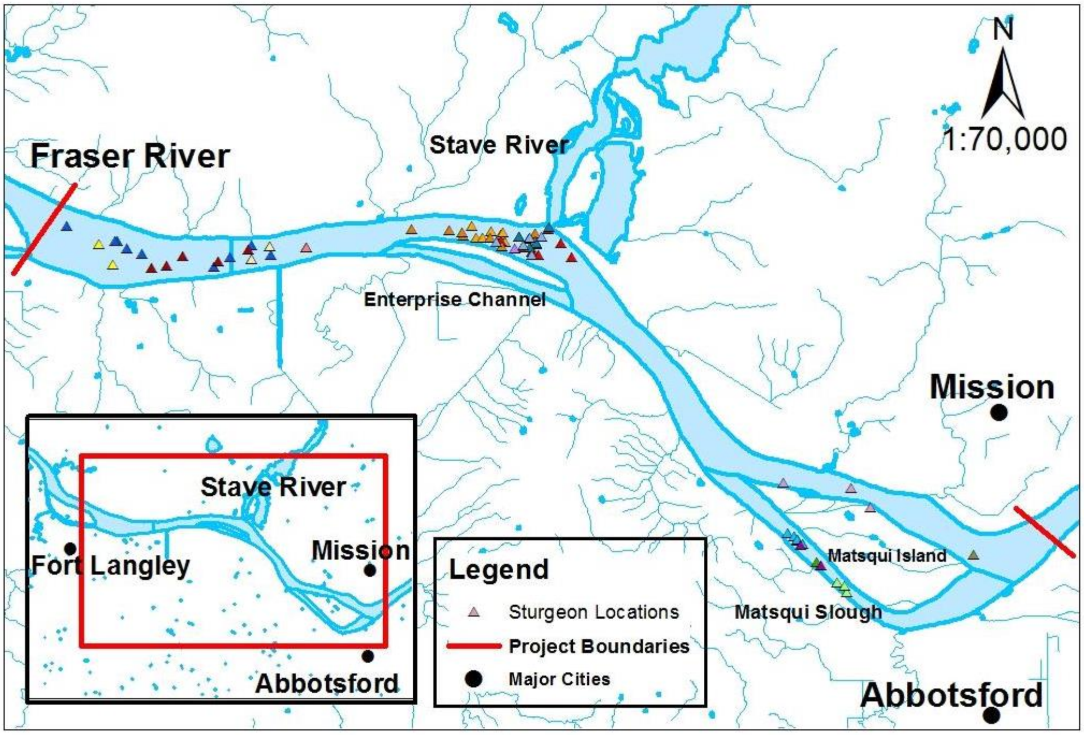

Figure 11. Locations of all observed White Sturgeon during the 2017/2018 tracking study. Each colour of a triangle indicates observations of a different individual.

Table 1. Tagged White Sturgeon Parameters, including distances travelled; FL = fork length, NM = Net movement, TNM = Total Net movement for each White Sturgeon, "0" indicates the month when an individual White Sturgeon was first observed; the subsequent number if present, represents the distance it travelled from the first sighting during the study.

Acoustic Tag ID	Date Tagged	Season Tagged	Capture Location (rkm)	Capture Location (Lat)	Capture Location (Long)	FL (cm)	GR (cm)	FTD (km)	NM Oct (km)	NM Nov (km)	NM Dec (km)	NM Jan (km)	NM Feb (km)	NM Mar (km)	TNM (km)
16051	23-Nov-17	Fall	67	49.17062	-122.42896	151	59	8.46	-	-	0	0.12	-	-	0.12
16052	23-Nov-17	Fall	67	49.17103	-122.42958	172	73	7.35	-	-	0	-	0.32	0.22	0.54
16053	23-Nov-17	Fall	67	49.17103	-122.42958	175	71	0.93	-	-	0	0.16	0.55	0.67	1.38
19406	25-Oct-13	Fall	91	49.13912	-122.17222	176	69.5	29.4	0	-	-	-	-	-	0
19410	25-Oct-13	Fall	94	49.14341	-122.12896	219	84	29.3	-	-	0	-	-	-	0
19411	25-Oct-13	Fall	93	49.14179	-122.14095	173	64.5	25	-	0	0.54	0.3	-	-	0.84
19413	28-Apr-14	Spring	P1	49.23311	-122.76272	160	56	36	-	-	0	0.52	-	0.38	0.9
19414	11-Jul-14	Summer	22	49.16678	-122.96994	202	87	38.2	0	-	-	-	-	-	0
21853	25-Nov-15	Fall	94	49.14517	-122.13093	193	79	33.3	0	1.39	0.29	0.21	-	2.69	4.58
21862	10-Feb-16	Winter	114	49.22283	-121.90159	193	80	48.2	0	0.58	-	-	-	-	0.58
22493	10-Sep-15	Summer	109	49.21871	-121.94395	157	58	42.8	-	-	0	0.34	-	-	0.34
22494	2-Oct-15	Fall	97	49.14501	-122.08352	193.5	77	23	-	-	-	-	0	0.51	0.51
22497	2-Oct-15	Fall	94	49.14747	-122.12367	188	72	32.5	-	0	1.14	0.36	-	-	1.5
25057	5-May-14	Spring	M	M	M	M	M	-	0	-	-	-	-	-	0
25069	7-May-14	Spring	M	M	M	M	M	-	0	-	-	-	-	-	0
25414	26-Sep-14	Fall	95	49.14856	-122.12574	174	70	26.3	-	0	-	-	-	-	0
25421	31-Oct-14	Fall	84	49.14387	-122.25472	151	59	15.7	-	-	-	-	-	0	0
25436	22-Jan-15	Winter	94.5	49.14327	-122.11847	191	74	16.5	0	-	-	-	-	-	0
25437	22-Jan-15	Winter	94.5	49.14327	-122.11847	183	65	18.8	0	-	-	-	-	-	0

6.0 Discussion

Project Goals

The goals of this project were to locate previously tagged White Sturgeon in the lower Fraser River, observe their migration and movement patterns in our study reach over the 2017-18 fall-winter seasons, and to confirm whether White Sturgeon return to the same overwintering sites within our study area over multiple years, based on data collected from previously previous studies conducted by BCIT students in areas which overlapped ours. This included examining our data, and comparing it to these earlier studies in order to determine if White Sturgeon exhibit overwintering site fidelity over multiple years.

Movement Observations

During the months of October to January 2017-2018, we observed White Sturgeon at an average rate of 7.8 individuals per field day. We note that only two of the eight individuals observed in October were never seen again in our study. Clearly these White Sturgeon are still moving around at these early periods in our assessment. Of interest, in the month of February and March 2018, the number of located White Sturgeon fell to an average of 4.5 individuals per day. We hypothesize that a decrease in the water temperature and stream velocity during the coldest winter months may prompt White Sturgeon to temporarily migrate to unknown overwintering sites outside of our zone of study, where they remain in semi-torpor. Clearly, some of the individuals moved back into the study area after February so there must be some movement in the winter period. Nevertheless, it is not clear why there was a drop in observations for these end-of-winter months.

We predict that if our study continued into the spring, we may have had the opportunity to sight individuals seen in the fall sessions, or those not detected outside of our study area, as they pass through our study site during their spring migration to spawning or feeding areas. In particular, increased movements in the late winter-spring (Table 1) could also be a result of White Sturgeon seeking critical food sources such as populations of Eulachon which begin to spawn during the spring months within the lower Fraser River.

Confirmation of Use of COSEWIC Overwintering Sites

We have gathered observations that provide support for COSEWIC's designation of overwintering habitats located within our study area. Of the White Sturgeon we observed, they were not spread homogeneously along river but were located in discrete congregations at three main locations (Figure 12). There is enough research about White Sturgeon to establish an understanding that the same spawning and overwintering sites are being used every year (including those mentioned above), and that they also perform annual seasonal foraging migrations in response to food availability (Nelson et al. 2000). In our study area we have also observed a potential new overwintering site along the main stem of the Fraser River in the Plumper Reach, just upstream of McMillan Island (Figure 12). This site exhibits some similar characteristics to the mouth of the Stave River and Matsqui Slough side channel overwintering sites, which includes deep holes and slower-moving currents. White Sturgeon prefer this type of habitat over the winter months as the deep holes and slower currents allow them to conserve valuable energy during a period in which they have less food availability (DFO 2016).

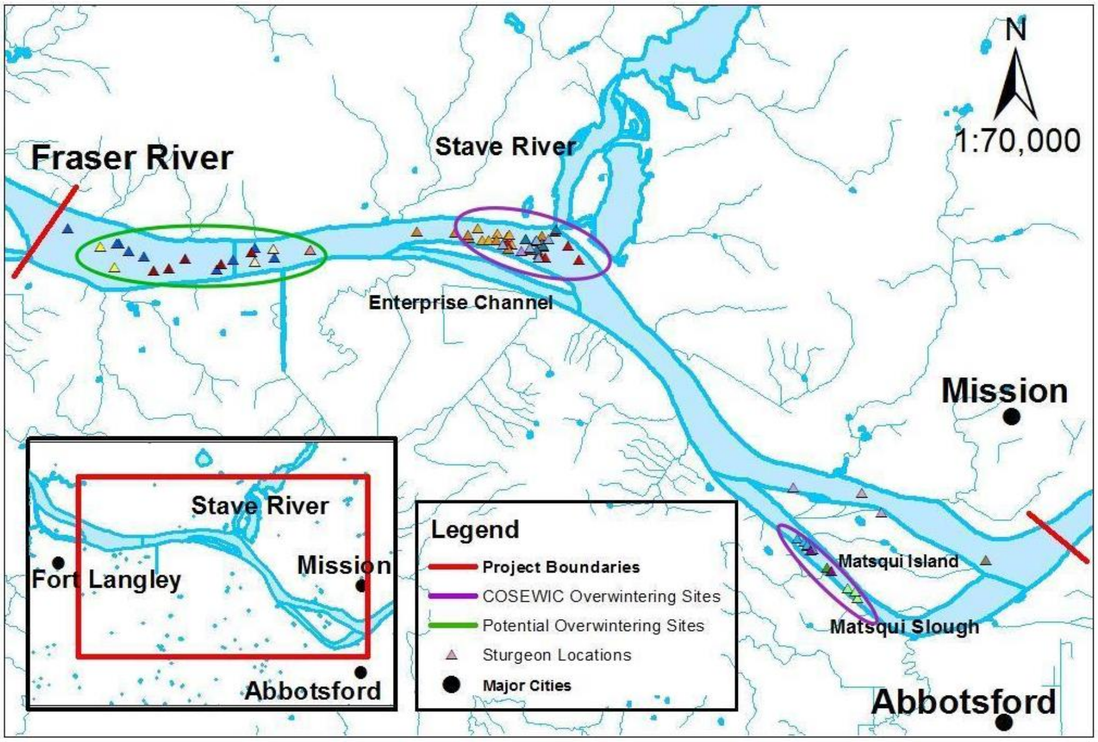

Figure 12. Individual White Sturgeon locations during the 2017/2018 study supports previously designated COSEWIC overwintering sites and may suggest a potential new site.

Overwintering Site Fidelity

The third goal of our project was to determine whether or not individual White Sturgeon choose to utilize the same overwintering sites over multiple years. To determine site fidelity in our study reach we compared individual White Sturgeon data we observed to those observed in the 2015 - 2016 BCIT study (Guinchard et al. 2016). Though the 2015-2016 study reach did not match ours exactly, Reach 1 of their study encompassed the eastern side of ours, from the confluence of the Stave River extending to the eastern tip of Matsqui Island. By comparing our data to those collected in the 2015 study, we were able to determine nine individuals who were located during both studies (19410, 19413, 21853, 22493, 22494, 25414, 25421, 25436, 25437). Of these nine individuals, only one (White Sturgeon 22494) was found to show site fidelity in the Matsqui Slough.

Using these data has allowed us to hypothesize that though White Sturgeon clearly do accumulate in particular overwintering sites in consecutive years, however, perhaps White Sturgeon as individuals are somewhat opportunistic and will utilize any available overwintering habitat in the general area in which they occur and which they find suitable.

6.1 Study Limitations

Physical Factors

There were a number of physical factors affecting our study and the ability to track White Sturgeon in the lower Fraser River between Fort Langley and Mission. Some of these factors included inclement weather, such as intense winds and heavy rains. This had an effect on the consistency of tracking days in regard to the original goal of utilizing field days on a Wednesday in the middle of each month. Other physical factors such as tides, river currents, debris, and shallow depths also affected the safety of the crew and limited the time in which we could begin and end our tracking days. Similarly, due to an unpredictable variation in the depths of the water in the Enterprise Channel, we were unable to enter and track in this area even though it is possible that White Sturgeon may utilize the channel. Although there were safety hazards while performing work on a body of water, we followed all safety protocols to make sure we were never in danger.

Tracking Days

Considering our limited tracking days, the movements and migrations of some individuals (19410, 19414, 25057, 25069, 25414, 25421, 25436, 25437) were only observed once. As these individuals were not located again, it is likely that these particular White Sturgeon are utilizing habitat outside our boundaries.

Understanding the full extent of real-time movements was difficult because our data were only collected once a month. Thus the values for total net movement observed are not particularly representative of overall movement. Furthermore, it is possible that previously-tracked White Sturgeon who were outside of our study area during our tracking days could have returned during the dates which tracking did not take place. In contrast, individuals who were seen throughout the months by us, may have also left for a duration of time and returned. Ultimately, the movements of White Sturgeon are likely influenced by seasonal changes to conditions of their habitats and to determine a complete understanding of movements for each individual, a more thorough tracking study would be needed.

Acoustic Tags

The Vemco acoustic tags implanted into the White Sturgeon are set to emit a signal only once every three minutes. This allows for a longer-than-usual battery life of the tags, and therefore a longer tracking study. However, as there is a three-minute gap between the signals, it is possible that the signal may not have been emitted at the time in which it was within the 500m maximum range of the hydrophone. That is, it is possible that we might have moved too quickly through the signal zone and missed tagged individuals that were in the area. This could affect our observations if the hydrophone was not have been able to track certain individuals that could have been within its range due to this time delay (E. Stoddard, FLNRORD biologist; pers. comm.).

Another difficulty that we encountered is that the tag delays can cause uncertainty in determining location of the individuals and result in inaccuracy of the readings. This means that when a signal is received by the hydrophone, the White Sturgeon could be at any location within the 500-meter radius. In order to pinpoint the White Sturgeon accurately, we would have had to stay a considerable amount of time at each location due to the long delay between signals. This creates some difficulty when trying to determine exact locations of the signal in terms of mapping, as the actual location of the tagged White Sturgeon may not necessarily be accurate by a distance of up to 500 meters for a single emitted signal.

Interference to the hydrophone may also prevent it from receiving signals from tagged White Sturgeon (VR100 User Manual 2017). As the hydrophone relies on sounds waves, it can be easily interrupted by sonar equipment, river traffic, as well as our own engine noise. These interruptions may prevent tag signals from reaching the hydrophone, limiting the extent of the data (E. Stoddard, FLNRORD biologist; pers. comm.).

There is also the possibility of acoustic tag failure, as it has recently been documented on November 22, 2017. In this particular case, a previously tagged White Sturgeon was recaptured at the confluence of the Stave River (rkm 67) on November 25, 2017, but the tag was not emitting a signal. We verified this by holding both our hydrophone and a stationary receiver to the side of the recaptured individual, with a result of no signal being received (Erin Stoddard, FLNRORD fisheries biologist, pers. comm.). Though this was the first documented case of acoustic tag failure, it is possible that there may be more White Sturgeon in the Ft. Langley to Mission area that had acoustic tags that malfunctioned resulting in unobserved individuals in our study locations. Thus, potential location observations for some individuals that had acoustic tags, and were within our study area, may have been missed because the equipment may not have been properly sending out signals.

6.2 Recommendations

For future British Columbia Institute of Technology; Fish, Wildlife, and Recreation studies looking at movement and locations of acoustic tagged White Sturgeon in the lower Fraser River we recommend including additional tracking days to the study as compared to ours. For subsequent work it would be beneficial to have at least a bi-weekly level of effort versus only once per month as undertaken in our work. This would allow for more comprehensive information in terms of White Sturgeon locations, and a more-precise idea of their movement habits. In addition, by having a bi-weekly tracking routine, it might shed light on where White Sturgeon are coming from, how long they have been in the area, and why they may or may not remain in any particular location.

Ultimately, expanding both the geographic length and time duration of the study would be the most effective way to collect more precise data of White Sturgeon in the lower Fraser River. By increasing these factors in the study area, we would be able to see exactly where each acoustic-tagged White Sturgeon is moving during every season of the year. Unfortunately, this could be a very expensive endeavor and probably beyond the scope of ability for BCIT students.
FLNRORD has already set stationary receivers at intervals throughout the lower Fraser River and

is collecting this data in real time. For the purpose of this future projects, it may be beneficial to request access to this data to pinpoint where White Sturgeon who pass through the areas of study are moving to and corroborate that information with student study results.

7.0 Conclusions

The Fraser River is facing serious challenges to its habitats and ecosystem sustainability in terms of existing commercial, recreational, agriculture and urban development features in its waters and along its banks. All of these factors pose potential risks to the well-being and longevity of the White Sturgeon that inhabit these waters. Though the population of White Sturgeon in the lower Fraser River is not listed as endangered under SARA, it is currently being re-evaluated by COSEWIC to determine whether a more-rigorous listing is necessary to protect it and its habitats. We suggest the continuation of this telemetry study to monitor how populations of White Sturgeon use the sites examined in our work, and others, in the coming years. Continuing with this study could allow students and other researchers to detect changes in the seasonal movement patterns of White Sturgeon in this area, and the level of use in both the known and potential overwintering sites. Additional studies in this area could provide insight into the health of the overall ecosystems within the lower Fraser River, and the effects of anthropogenic factors on specific areas. This would allow for better understanding of the population dynamics of White Sturgeon in the lower Fraser River and give conservationists and fisheries' managers the knowledge they need to better-protect their habitats.

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Appendices

Appendix I

Field Data Form

<u>Field Data Form</u>
Project: Project: Distribution and Migration of Acoustic-Transmitter Tagged White Sturgeon with Regards to Overwintering Habitat in the Lower Fraser, 2017/2018
Personnel: Shane Steele, Mackenzie Mercer, Sarah Jackson
Boat Info: 16' Hourston Glasscraft, with a 40HP Yamaha
Date:
Time In:
Time Out:
Water Temperatures:
River Conditions:
Boat Traffic Density:

Field Notes:

List of Tracked White Sturgeon		
Fish no.	**Acoustic Tag #**	**River Location Details**

Appendix II

Emergency Contact Info

Group Members:	Project Manager:	Project Sponsor:	Project Duration:
Sarah Jackson, Mackenzie Mercer, Shane Steele	*Dr. Marvin Rosenau*	*Erin Stoddard (main contact); The Ministry of Forest, Lands, Natural Resource Operations and Rural Development (FLNRORD)*	*October 2017-April 2018*

Project Details

- **Project Title:** Distribution and Migration of Acoustic-Transmitter Tagged White Sturgeon with Regards to Overwintering Habitat in the Lower Fraser River 2017-2018
- **Location of Activities**: Approximately 21 kilometer stretch of the Fraser River from the boat launch at the Bedford Landing Channel in Fort Langley, and as far east as the Mission Bridge
- **Description of Activities:** Using a boat to track White Sturgeon

Field Work Personnel

Field Work Personnel Names

- **Name:** Sarah Jackson
  Contact Number: (519)719-3179
  Pleasure Craft Operator Card Number: 3000742111
- **Name:** Mackenzie Mercer
  Contact Number: (250)650-2500
  Pleasure Craft Operator Card Number: 5046239674
- **Name:** Shane Steele
  Contact Number: (604)996-8062
  Pleasure Craft Operator Card Number: 306660439

First Aid/Medical Emergency contacts

First Aid/ Closest Medical Facility:
Contact Number:
Mission Memorial Hospital

- Address: 7324 Hurd St, Mission BC V2V 3H5
- Phone: 604-826-626

Ridge Meadows Hospital

- Address: 11666 Laity St, Maple Ridge BC V2X 7G5
- Phone: 604-463-4111

Local Search and Rescue:
Contact Number:

- Mission Search and Rescue (MSAR)
  604-826-9727
- Ridge Meadows Search and Rescue (RMSAR)
  604-463-4891

Local Police:

Contact Number:

- Emergency # dial 911
- For non-emergency calls phone
  Langley detachment; 604-532-3200
  Mission detachment; 604-826-7161

Personnel with First Aid training & level:

- Mackenzie Mercer - Occupational First Level One

Transportation

- **Transportation Names of Drivers:** Shane Steele, Sarah Jackson, Mackenzie Mercer
- **Owner of Vehicle Used to Tow Boat**: Shane Steele
- **Vehicle Type:** 2007 Ford F-150 & 1998 Jeep Cherokee Sport

Boat operation

List of Equipment:

• Bailing Buckets	• Life Jackets (3)
• Spare Gas	• Compass, Charts, Garmin GPS
• Oars & Paddles	• Cell Phones
• Radio	• Knife
• First Aid Kit	• Flashlight and Flares
• Horn/Whistle	• VR100 Hydroacoustic Tag Reader

Hazards

Local Hazards:

- Murky Water Resulting in Poor Visibility of Underwater Debris
- Low Side Channels Due to Low Tides
- Floating Logs and Garbage
- Weather

Appendix III

Fraser River White Sturgeon Research Project

BCIT Students in the Fish, Wildlife and Recreation program working in association with Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD).

Purpose:
To Record the Distribution and Migration Patterns of Acoustic-Transmitter Tagged White Sturgeon with Regards to Overwintering Habitat in the Lower Fraser River.
Time:
From __________________A.M. to ___________________P.M.

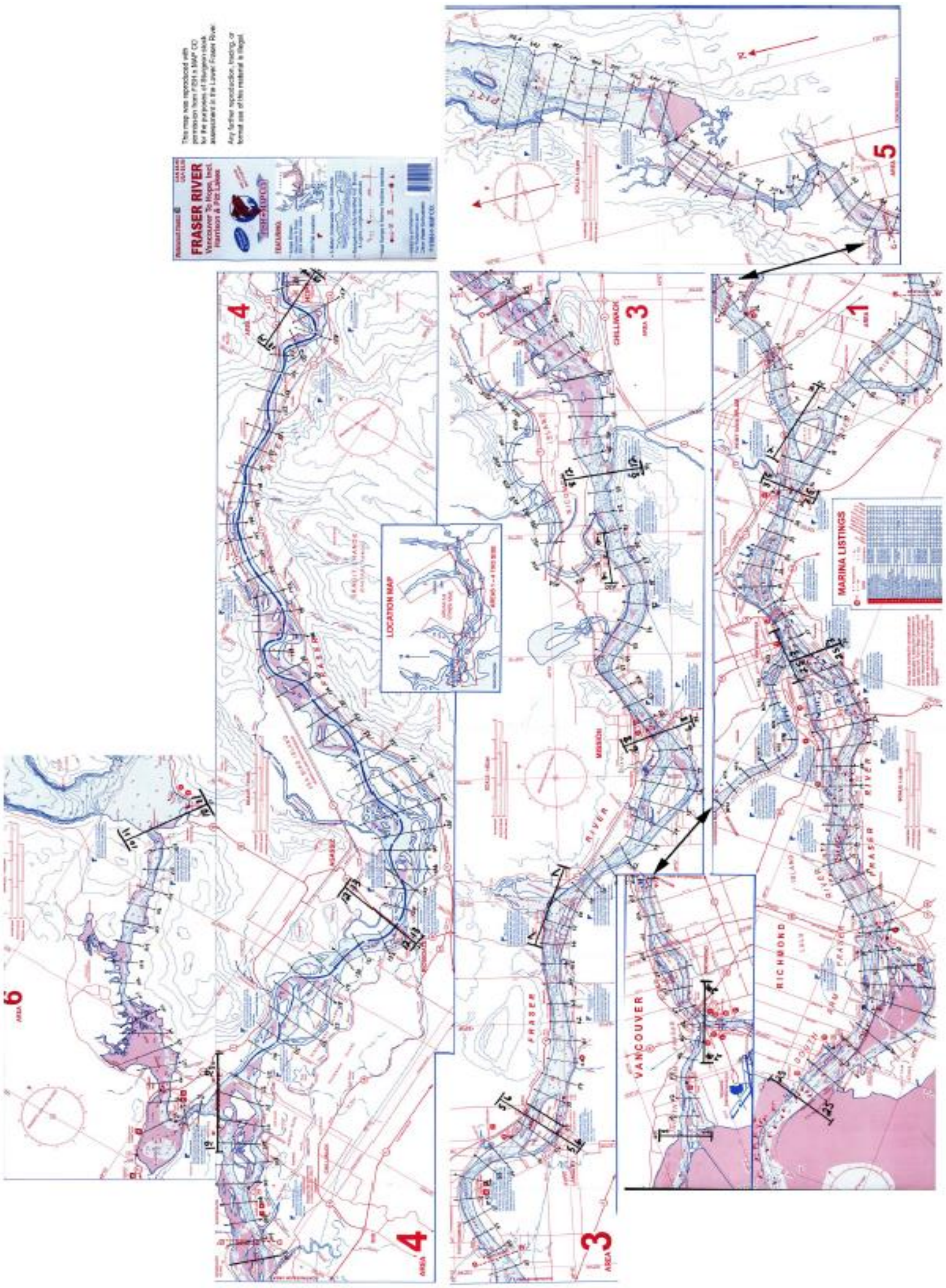
Contact Information

Sarah Jackson
(519)719-3179
Mackenzie Mercer
(250)650-2500
Shane Steele
(604)996-8062

If any Questions or Concerns arise, please feel free to contact us with the phone numbers provided above.

Appendix IV

RL&L Environmental Services river kilometer system map of the lower Fraser River (page below)



Appendix V

Table 2. White Sturgeon length/weight/age proportion reference chart. Created and provided by FLNRORD.

Lower Fraser White Sturgeon Length/Weight/Age Chart

Fork Length (in.)	Fork Length (cm)	Weight (lbs)	Weight (kgs)	Age (yrs)
5.7-10	14.5-20		0.03-0.06	0
8.2-10.6	20.9-26.8		0.06-0.1	1
9.0-12.6	22.8-31.9		0.1-0.2	2
11.0-11.5	28.0-29.3		0.2-0.3	3
17.8	45.0	1.1	0.50	~4
20.9	53.0	1.8	0.83	~5
22.0	56.0	2.0	0.90	~5
24.8	63.0	3.5	1.6	~6
37	94	15	7	9
39	99	17	8	10
41	104	20	9	11
43	109	23	10	12
45	114	27	12	12
47	119	31	14	13
49	124	35	16	14
51	130	39	18	15
53	135	44	20	16
55	140	49	22	17
57	145	55	25	17
59	150	61	28	18
61	155	67	30	20
63	160	74	34	17, 20&21
65	165	82	37	16&21
67	170	90	41	23
69	175	98	45	24
71	180	107	49	25
73	185	116	53	26
75	191	126	57	27
77	196	137	62	29
79	201	148	67	30
81	206	159	72	32
83	211	172	78	33
85	216	185	84	35
87	221.5 (97.5G)	198 - 267*	90 - 121*	36 - 40
89	226	212	96	38
91	231	227	103	40
93	236	243	110	42
94	239 (110G*)	259 - 326*	117 - 148*	43 - 62
96	244.5 (95.5G*)	266* - 276	121* - 125	70
98	249	294	134	
99	251 (102G)	303	138	
100	254	312	142	
102	259	332	151	
103	262 (114G)	334	152	77
104	264	352	160	
116	295	372	169	
118	300	394	179	

*girth and weight of the fish measured

Appendix VI

Table 3. White Sturgeon data collection throughout the year-long study.

Date	Time	Chan	Freq(kHz)	Type	Code Space	ID		Sgnl(dB)	Gain	Mode	Latitude	Longitude
2017-10-18	22:44:58	1	69	Coded Pinger	A69-9001	21853		61	Manual	48	49.17259	-122.53922
2017-10-18	22:34:44	1	69	Coded Pinger	A69-1303	19406		36	Manual	48	49.16967	-122.53146
2017-10-18	22:29:29	1	69	Coded Pinger	A69-1303	19406		42	Manual	48	49.16638	-122.52827
2017-10-18	22:13:13	1	69	Coded Pinger	A69-1303	19414		38	Manual	48	49.1676	-122.51009
2017-10-18	21:59:48	1	69	Coded Pinger	A69-9001	25069		43	Manual	48	49.16723	-122.49501
2017-10-18	21:56:17	1	69	Coded Pinger	A69-9001	25069		41	Manual	48	49.16921	-122.49074
2017-10-18	21:20:30	1	69	Coded Pinger	A69-9001	21862		49	Manual	48	49.17144	-122.44746
2017-10-18	21:16:16	1	69	Coded Pinger	A69-9001	21862		42	Manual	48	49.17111	-122.44453
2017-10-18	21:10:16	1	69	Coded Pinger	A69-9001	21862		55	Manual	48	49.17028	-122.43777
2017-10-18	21:07:45	1	69	Coded Pinger	A69-9001	21862		63	Manual	48	49.1689	-122.43496
2017-10-18	19:41:47	1	69	Coded Pinger	A69-9001	25057		48	Manual	48	49.13139	-122.36801
2017-10-18	19:29:59	1	69	Coded Pinger	A69-9001	25437		42	Manual	48	49.13047	-122.35173
2017-10-18	19:24:28	1	69	Coded Pinger	A69-9001	25437		54	Manual	48	49.12741	-122.34726
2017-10-18	17:53:20	1	69	Coded Pinger	A69-9001	25436		58	Manual	48	49.11978	-122.32255
2017-10-18	17:48:27	1	69	Coded Pinger	A69-9001	25436		59	Manual	48	49.12195	-122.32083
2017-11-15	52:34.2	1	69	Coded Pinger	A69-9001	21853		45	Manual	48	49.17013	-122.5276
2017-11-15	43:42.3	1	69	Coded Pinger	A69-9001	21853		29	Manual	48	49.16807	-122.52134
2017-11-15	39:49.0	1	69	Coded Pinger	A69-9001	22497		46	Manual	48	49.16589	-122.51908
2017-11-15	12:47.9	1	69	Coded Pinger	A69-9001	22497		32	Manual	48	49.16867	-122.49583
2017-11-15	32:49.4	1	69	Coded Pinger	A69-9001	21862		35	Manual	48	49.17178	-122.45647
2017-11-15	19:20.3	1	69	Coded Pinger	A69-9001	21862		51	Manual	48	49.1707	-122.44412
2017-11-15	10:43.2	1	69	Coded Pinger	A69-9001	25414		53	Manual	48	49.16967	-122.4362
2017-11-15	10:06.5	1	69	Coded Pinger	A69-1303	19411		46	Manual	48	49.16974	-122.43531
2017-11-15	07:09.3	1	69	Coded Pinger	A69-9001	21862		59	Manual	48	49.17061	-122.4313
2017-11-15	05:59.4	1	69	Coded Pinger	A69-9001	25414		57	Manual	48	49.17084	-122.42964
2017-11-15	05:10.2	1	69	Coded Pinger	A69-1303	19411		58	Manual	48	49.17096	-122.42845
2017-11-15	03:11.1	1	69	Coded Pinger	A69-9001	21862		52	Manual	48	49.1704	-122.42793
2017-11-15	01:20.3	1	69	Coded Pinger	A69-9001	25414		46	Manual	48	49.17028	-122.42838
2017-11-15	00:25.7	1	69	Coded Pinger	A69-1303	19411		42	Manual	48	49.17002	-122.42857
2017-11-15	56:13.4	1	69	Coded Pinger	A69-9001	25414		61	Manual	48	49.16904	-122.42987
2017-11-15	55:17.0	1	69	Coded Pinger	A69-1303	19411		45	Manual	48	49.1687	-122.43018

2017-11-15	48:19.1	1	69	Coded Pinger	A69-9001	21862		45	Manual	48	49.1697	-122.42701
2017-11-15	46:39.7	1	69	Coded Pinger	A69-9001	25414		30	Manual	48	49.17046	-122.42534
2017-11-15	17:42.6	1	69	Coded Pinger	A69-9001	21862		50	Manual	48	49.1709	-122.42696
2017-11-15	12:43.1	1	69	Coded Pinger	A69-1303	19411		48	Manual	48	49.16803	-122.4278
2017-11-15	12:06.1	1	69	Coded Pinger	A69-9001	25414		42	Manual	48	49.1676	-122.42773
2017-11-15	42:50.1	1	69	Coded Pinger	A69-1303	19413		53	Manual	48	49.12083	-122.36258
2017-12-16	21:54:33	1	69	Coded Pinger	A69-9001	21853		66	Manual	30	49.16906	-122.52496
2017-12-16	21:44:33	1	69	Coded Pinger	A69-9001	22497		56	Manual	30	49.1663	-122.51538
2017-12-16	21:40:52	1	69	Coded Pinger	A69-9001	22497		55	Manual	30	49.16775	-122.51144
2017-12-16	21:15:41	1	69	Coded Pinger	A69-1303	19410		55	Manual	30	49.16897	-122.48193
2017-12-16	20:43:22	1	69	Coded Pinger	A69-9001	16053		54	Manual	30	49.17026	-122.43947
2017-12-16	20:40:01	1	69	Coded Pinger	A69-9001	16053		50	Manual	30	49.17108	-122.43468
2017-12-16	20:36:35	1	69	Coded Pinger	A69-9001	22493		57	Manual	30	49.17036	-122.43089
2017-12-16	20:32:58	1	69	Coded Pinger	A69-9001	22493		54	Manual	30	49.16863	-122.42823
2017-12-16	20:31:33	1	69	Coded Pinger	A69-1303	19411		55	Manual	30	49.16922	-122.42674
2017-12-16	20:26:52	1	69	Coded Pinger	A69-1303	19411		61	Manual	30	49.17149	-122.42379
2017-12-16	20:26:17	1	69	Coded Pinger	A69-9001	22493		53	Manual	30	49.17182	-122.42366
2017-12-16	20:06:25	1	69	Coded Pinger	A69-1303	19411		43	Manual	30	49.16936	-122.4207
2017-12-16	17:59:27	1	69	Coded Pinger	A69-9001	16052		59	Manual	30	49.12295	-122.36543
2017-12-16	17:56:49	1	69	Coded Pinger	A69-1303	19413		49	Manual	30	49.12246	-122.36474
2017-12-16	17:56:29	1	69	Coded Pinger	A69-9001	16052		68	Manual	30	49.12241	-122.36465
2017-12-16	17:52:43	1	69	Coded Pinger	A69-9001	16052		64	Manual	30	49.1217	-122.36353
2017-12-16	17:41:03	1	69	Coded Pinger	A69-9001	16051		66	Manual	30	49.11516	-122.35337
2018-01-17	21:14:40	1	69	Coded Pinger	A69-9001	21853		55	Manual	48	49.1702	-122.52724
2018-01-17	20:58:25	1	69	Coded Pinger	A69-9001	22497		46	Manual	48	49.16678	-122.50294
2018-01-17	20:19:43	1	69	Coded Pinger	A69-9001	16053		55	Manual	48	49.16967	-122.43427
2018-01-17	20:00:34	1	69	Coded Pinger	A69-9001	22493		44	Manual	48	49.16943	-122.42664
2018-01-17	19:57:45	1	69	Coded Pinger	A69-1303	19411		45	Manual	48	49.16755	-122.42621
2018-01-17	19:52:20	1	69	Coded Pinger	A69-1303	19411		37	Manual	48	49.16714	-122.41831
2018-01-17	18:15:42	1	69	Coded Pinger	A69-1303	19413		31	Manual	48	49.11891	-122.36024
2018-01-17	18:09:37	1	69	Coded Pinger	A69-9001	16051		27	Manual	48	49.11557	-122.35532
2018-01-17	18:06:42	1	69	Coded Pinger	A69-9001	16051		36	Manual	48	49.11413	-122.35294

Appendix VII

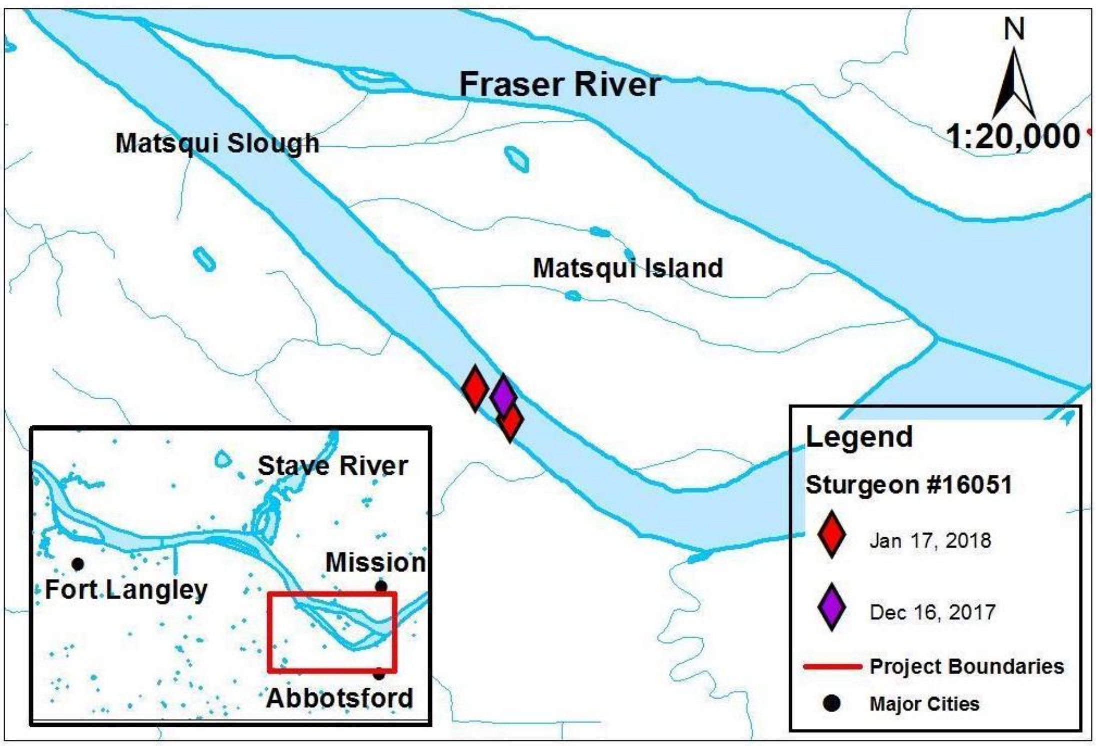
Table 4. White Sturgeon observed by date and hydroacoustic tag number, within our study site on the Fraser River.

Acoustic Tag Number	PIT Tag Number	Tracking Days Located					
		October 18, 2017	November 15, 2017	December 16, 2017	January 17, 2018	February 28, 2018	March 21, 2018
16051	48685E2E40			✓	✓		
16052	431138650C			✓		✓	✓
16053	Missing Data			✓	✓	✓	✓
19406	0A140A4242	✓	✓				
19410	0A140A422C			✓			
19411	6C00054229	✓	✓	✓	✓		
19413	4B027E2316		✓	✓	✓		✓
19414	4C3A192900	✓					
21853	0A181B1D6E	✓	✓	✓	✓		✓
21862	4A0B602E37	✓	✓				
22493	6C00051746			✓	✓		
22494	490C7F2E55					✓	✓
22497	0A13093D0A		✓	✓	✓		
25057	422F282E56	✓					
25069	4230237F3F	✓					
25414	4864575423		✓				
25421	4C39772208						✓
25436	4214165B6A	✓					
25437	152209291A	✓					

Appendix VIII

Movement patterns for White Sturgeon 16051 over the 2017-2018 tracking season.

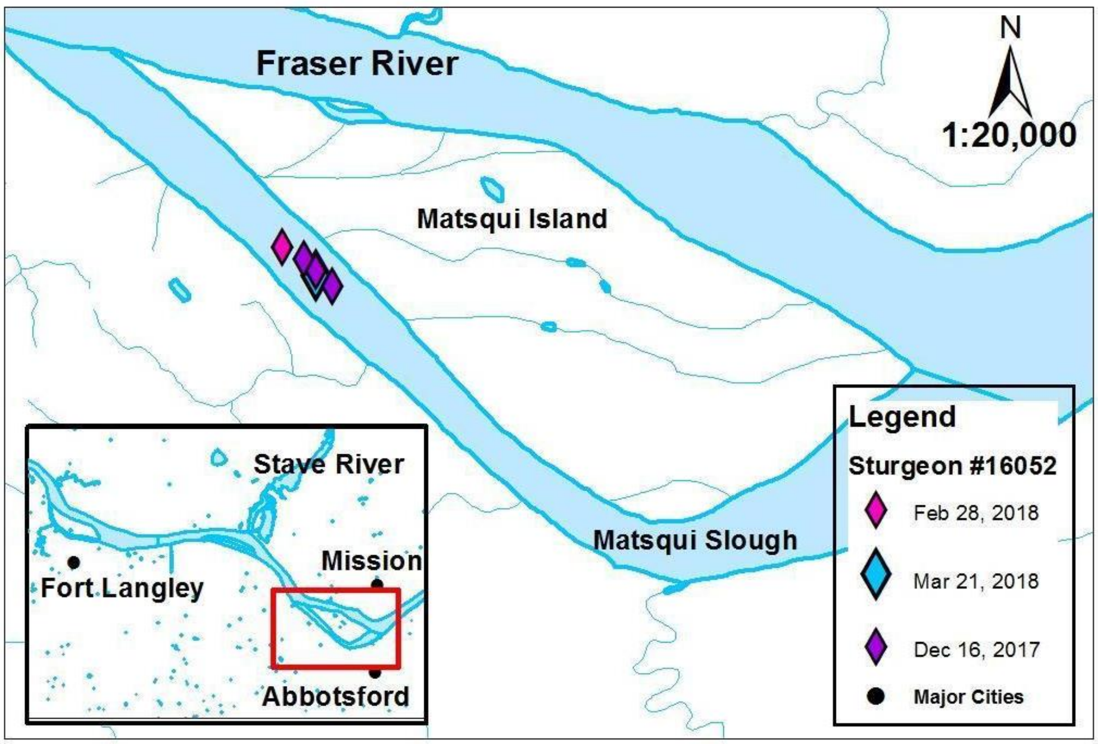
White Sturgeon 16051 was tagged in November 2017 at the confluence of the Stave River (rkm 67). It was located in the Matsqui Slough at rkm 75 in both December 2017 and January 2018 tracking sessions (Table 4 - Appendix VII). The total net distance travelled for all observations during the length of our study was 0.12km.



Appendix IX

Movement patterns for White Sturgeon 16052 over the 2017-2018 tracking season.

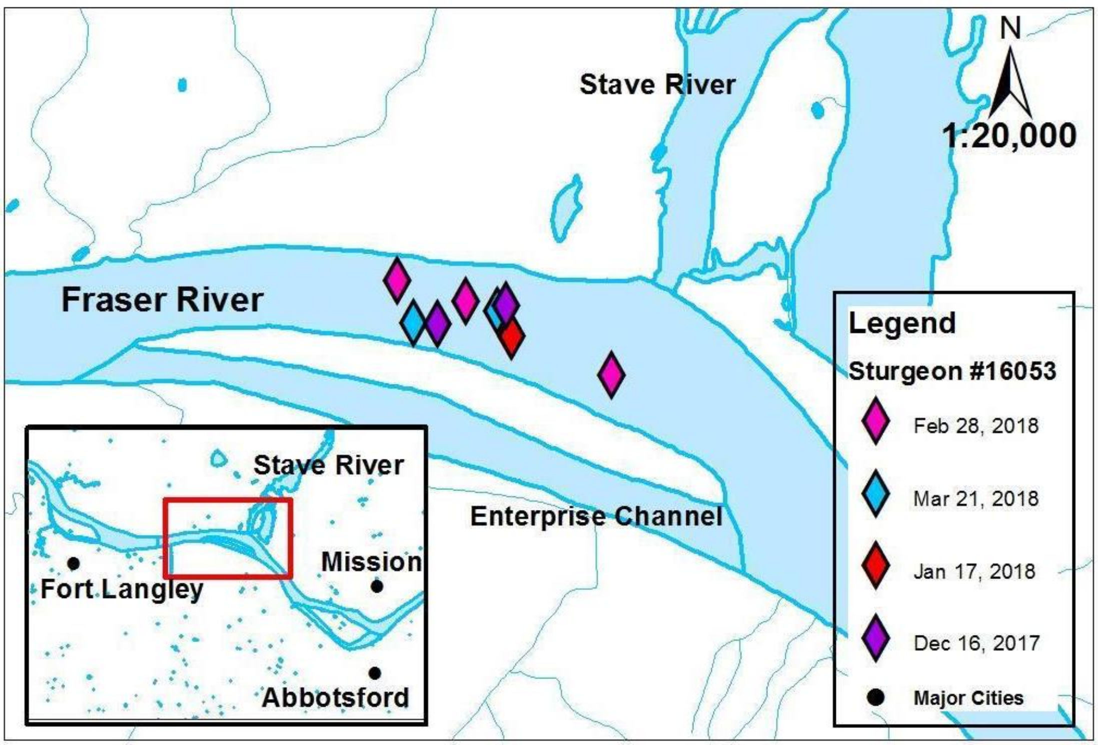
White Sturgeon 16052 was tagged in November 2017 at the confluence of the Stave River (rkm 67). It was observed in the Matsqui Slough during the December tracking session (rkm 74). It was not observed during the month of January, but returned to the same site for the months of February and March (Table 4 - Appendix VII). The total net distance travelled for all observations during the length of our study was 0.54km.



Appendix X

Movement patterns for White Sturgeon 16053 over the 2017-2018 tracking season.

White Sturgeon 16053 was tagged in November 2017 at the confluence of the Stave River (rkm 67). It was observed in all of the following tracking sessions (December, January, February and March) at the confluence of the Stave River (Table 4 - Appendix VII). The total net distance travelled for all observations during the length of our study was 1.38km.



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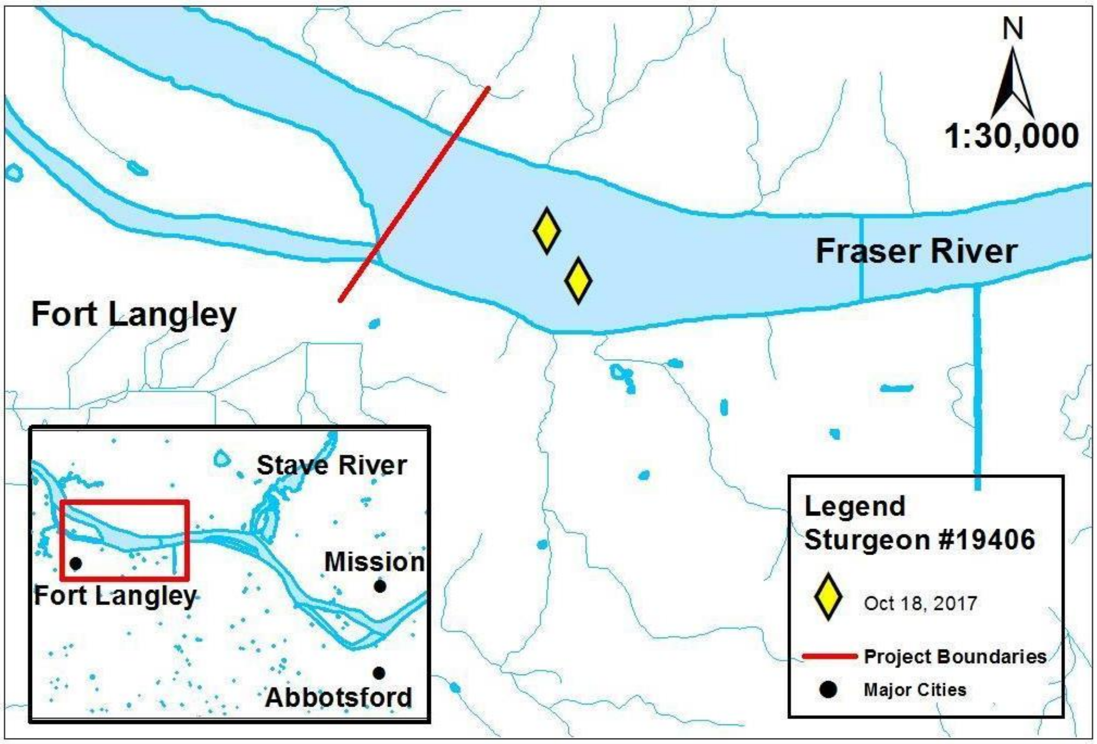
Appendix XI

Movement patterns for White Sturgeon 19406 over the 2017-2018 tracking season.

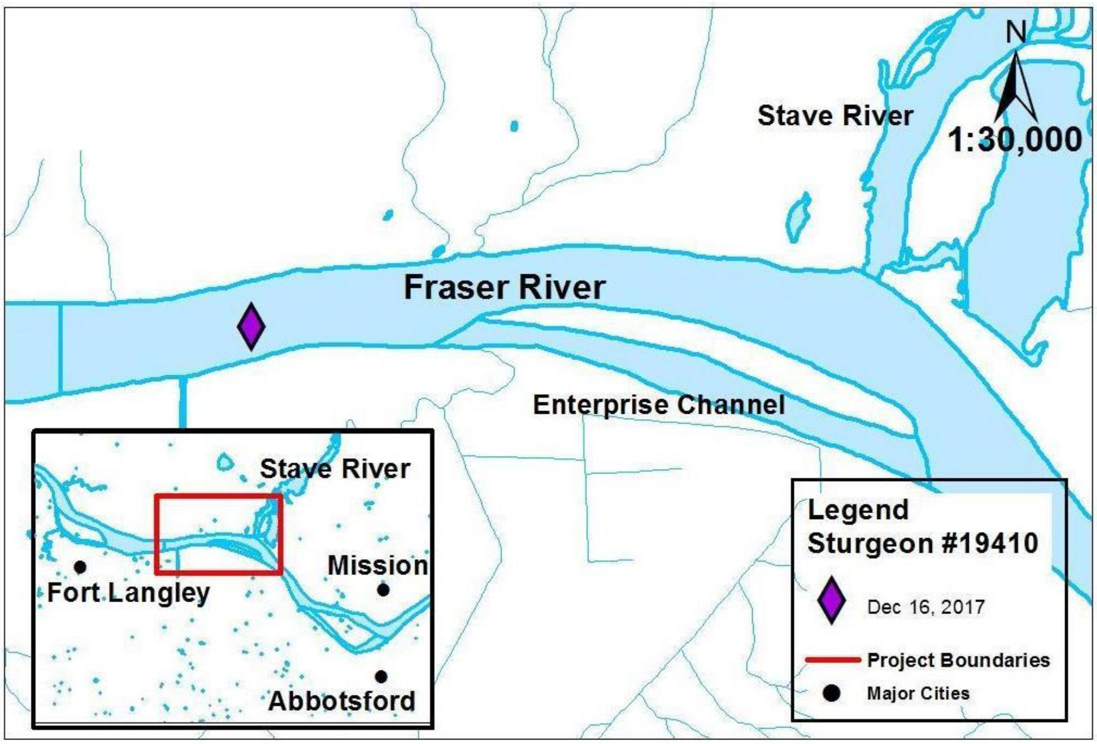
White Sturgeon 19406 was tagged in October 2013 at rkm 90, near the confluence of the Sumas River. It was located during the October 2017 tracking session in the western portion of the Plumper Reach, just upstream of McMillan Island at rkm 60. It was not observed again after October 2017 (Table 4 - Appendix VII). The total net distance travelled for all observations during the length of our study was 0 km.



Appendix XII

Movement patterns for White Sturgeon 19410 over the 2017-2018 tracking season.

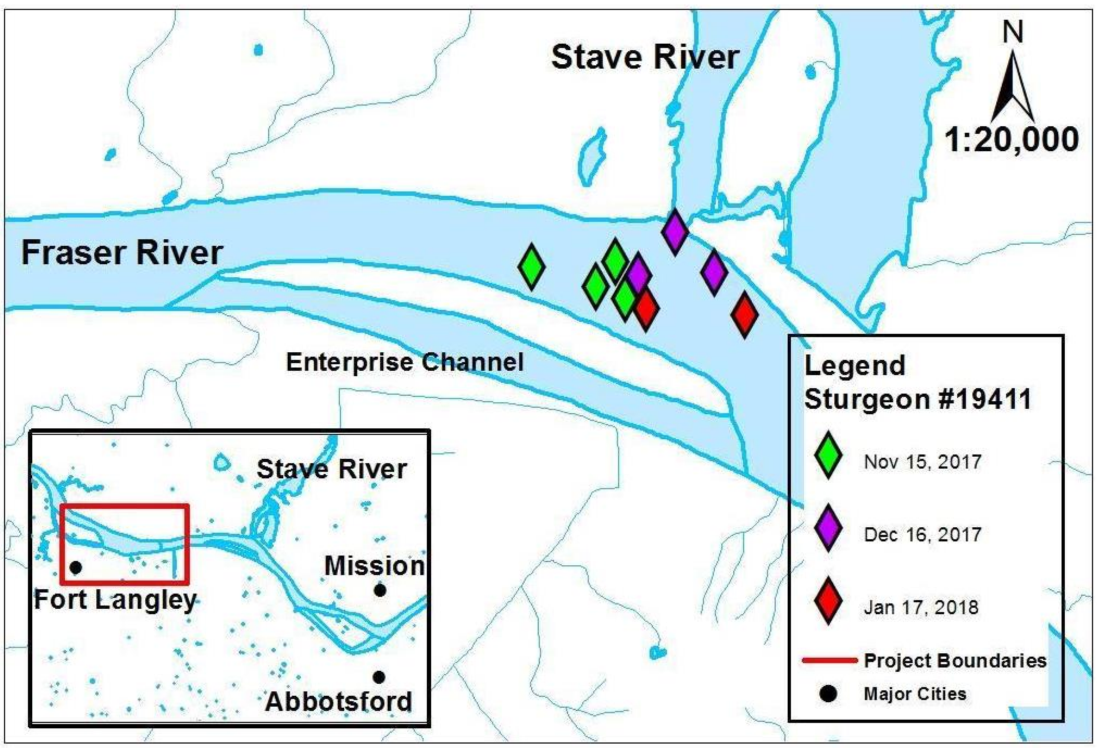
White Sturgeon 19410 was tagged in October 2013 at rkm 93, near the confluence of the Sumas River. It was observed only during the December 2017 tracking session in the Plumper Reach at rkm 64, near the Confluence of the Stave River (Appendix VII). The total net distance travelled for all observations during the length of our study was 0 km.



Appendix XIII

Movement patterns for White Sturgeon 19411 over the 2017-2018 tracking season.

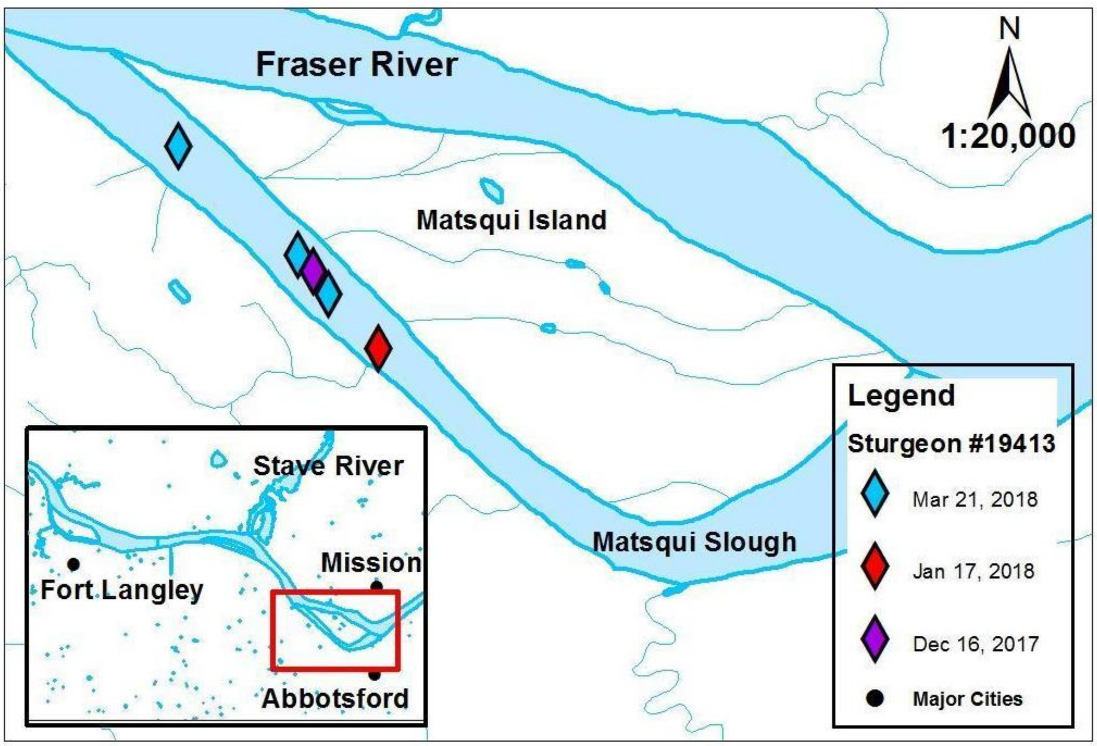
White Sturgeon 19411 was tagged in October 2013 at rkm 92, near the confluence of the Sumas River. We first observed it at the Stave River confluence during the November 2017 tracking session (rkm67). Since then, 19411 has been located in the same area during December and January, but was absent from both tracking sessions in February and March (Table 4 - Appendix VII). The total net distance travelled for all observations during the length of our study was 0.84 km.



Appendix XIV

Movement patterns for White Sturgeon 19413 over the 2017-2018 tracking season.

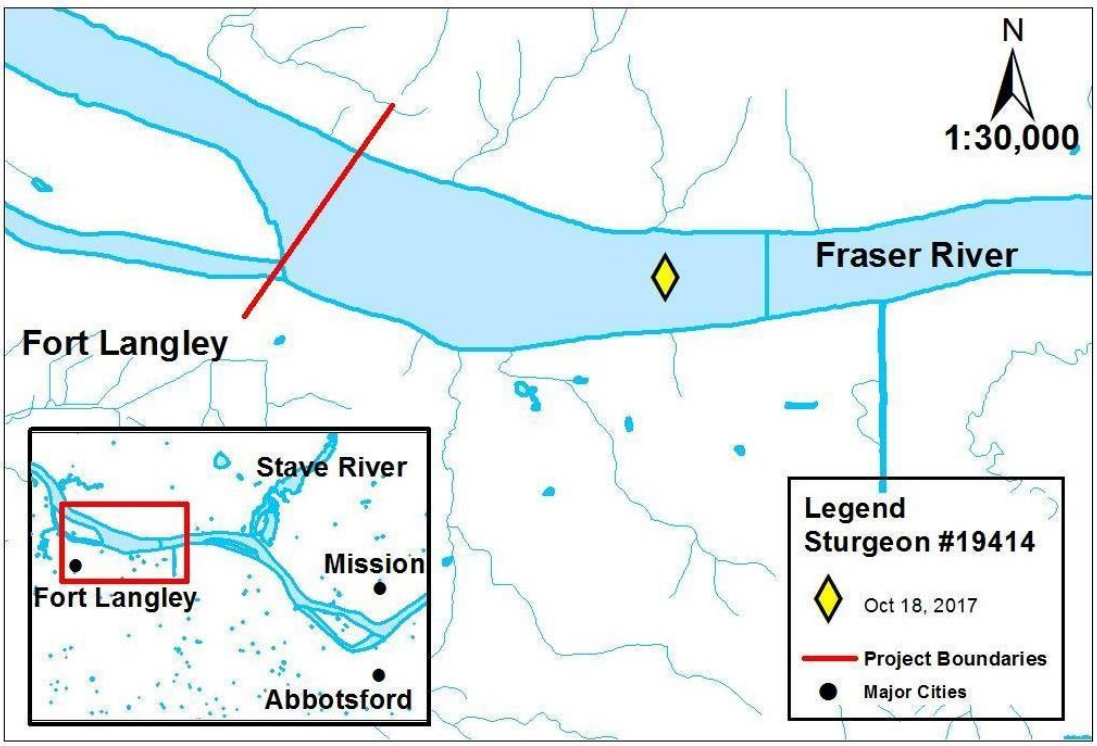
White Sturgeon 19413 was tagged in the Pitt River on April 2014, approximately 1 rkm upstream from the confluence with the Fraser River (rkm 68). We first located it during the December 2017 tracking session in the Matsqui Slough at rkm 74 and was again detected in January and March, in the same location (Table 4 - Appendix VII). The total net distance travelled for all observations during the length of our study was 0.9km.



Appendix XV

Movement patterns for White Sturgeon 19414 over the 2017-2018 tracking season.

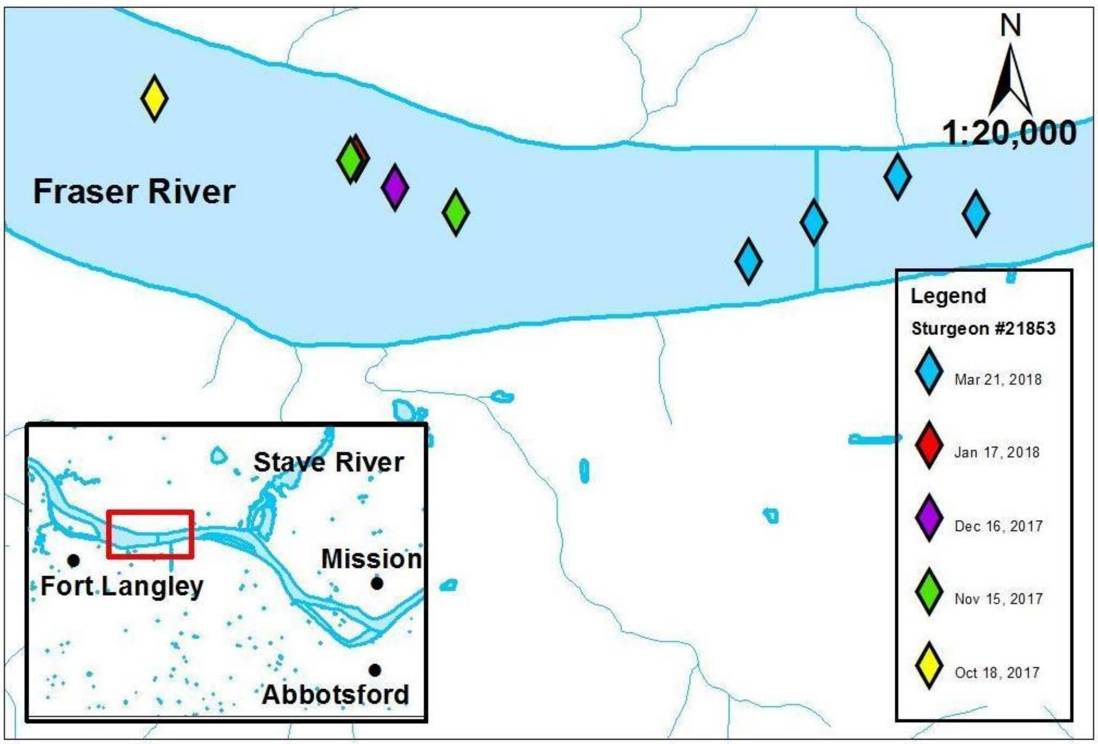
White Sturgeon 19414 was tagged in July 2014 at rkm 21, near Annacis Island, under the Alex Fraser Bridge. We only observed it during the October 2017 tracking session at rkm 61, in the Plumper Reach (Table 4 - Appendix VII). Because we only observed this individual once during the length of our study the total net distance travelled was 0 km.



Appendix XVI

Movement patterns for White Sturgeon 21853 over the 2017-2018 tracking season.

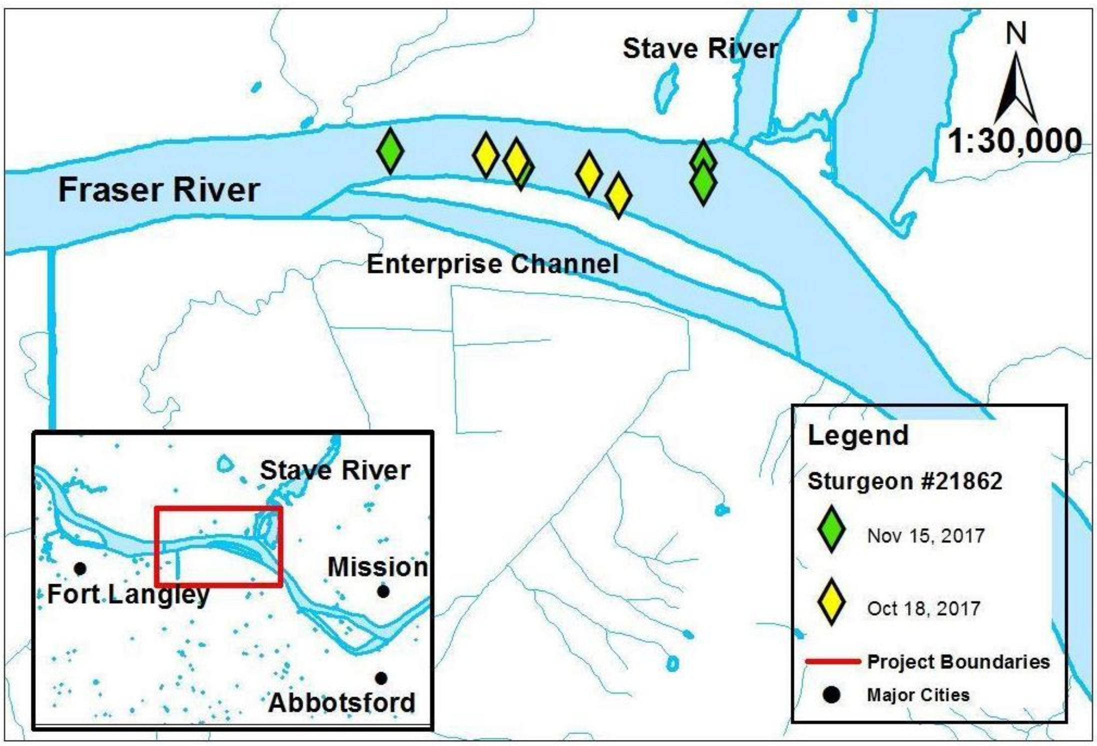
White Sturgeon 21853 was tagged in November 2015 at rkm 93 near the confluence of the Vedder River. We first observed it during the October 2017 tracking session at rkm 59 in the Plumper Reach. It was detected in the same general location during all consecutive tracking sessions, other than in February (Table 4 - Appendix VII). The total net distance travelled for all observations during the length of our study was 4.58 km.



Appendix XVII

Movement patterns for White Sturgeon 21862 over the 2017-2018 tracking season.

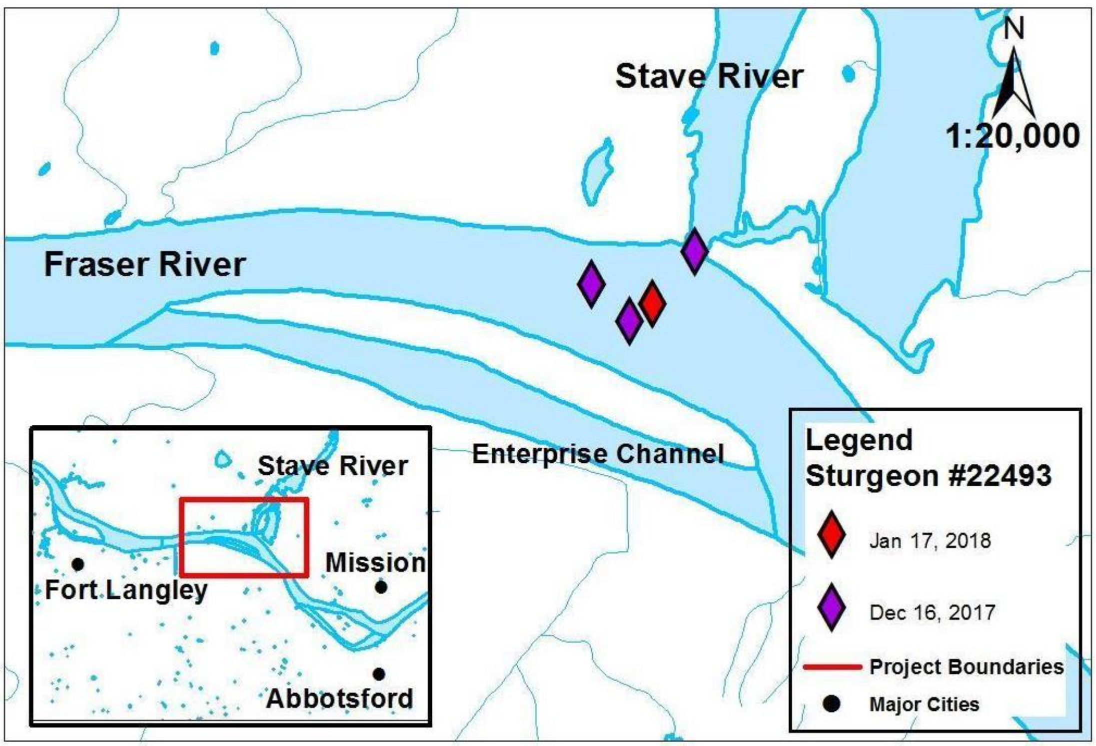
White Sturgeon 21862 was tagged in February 2016 at rkm 114, near the confluence of the Harrison River. We first observed it during the October 2017 tracking session at the confluence of the Stave River and Fraser River (rkm 67). It was detected in the same location in November, and since then it was not located again (Table 4 - Appendix VII). The total net distance travelled for all observations during the length of our study was 0.58 km.



Appendix XVIII

Movement patterns for White Sturgeon 22493 over the 2017-2018 tracking season.

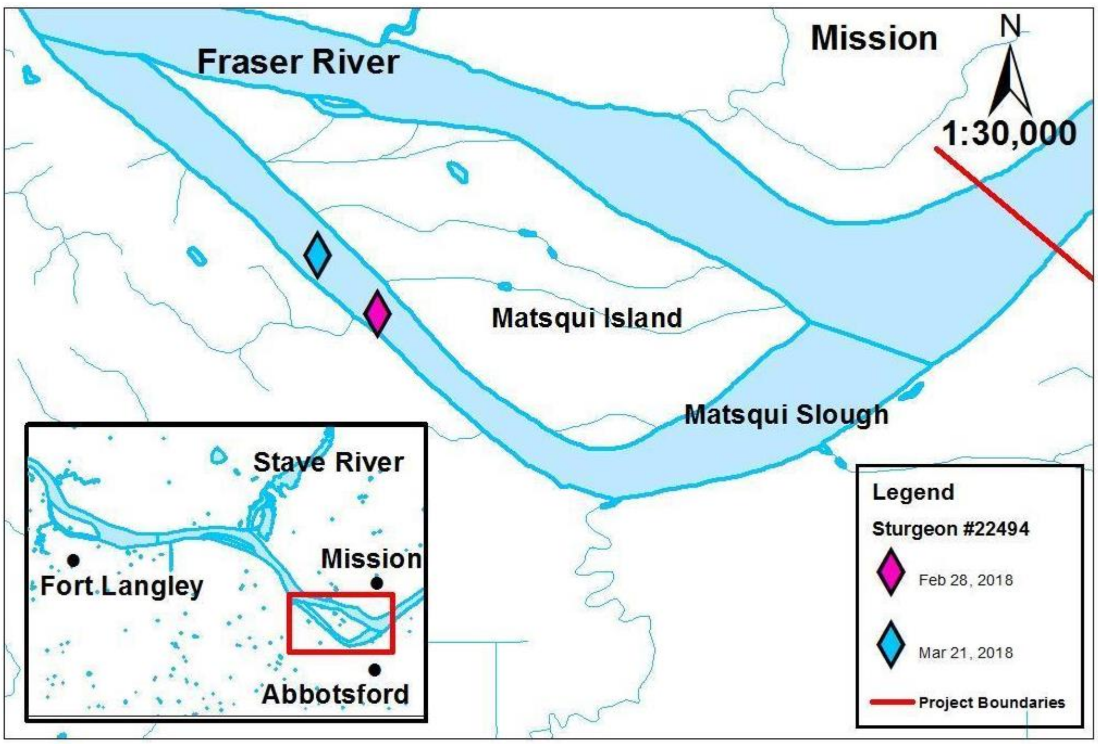
White Sturgeon 22493 was tagged in September 2015 at rkm 110, near the confluence of the Harrison River. We first located it in December 2017 at the confluence of the Stave and Fraser Rivers (rkm 67). It was observed again in January 2018 in the same location (Table 4 - Appendix VII). The total net distance travelled for all observations during the length of our study was 0.34 km.



Appendix XIX

Movement patterns for White Sturgeon 22494 over the 2017-2018 tracking season.

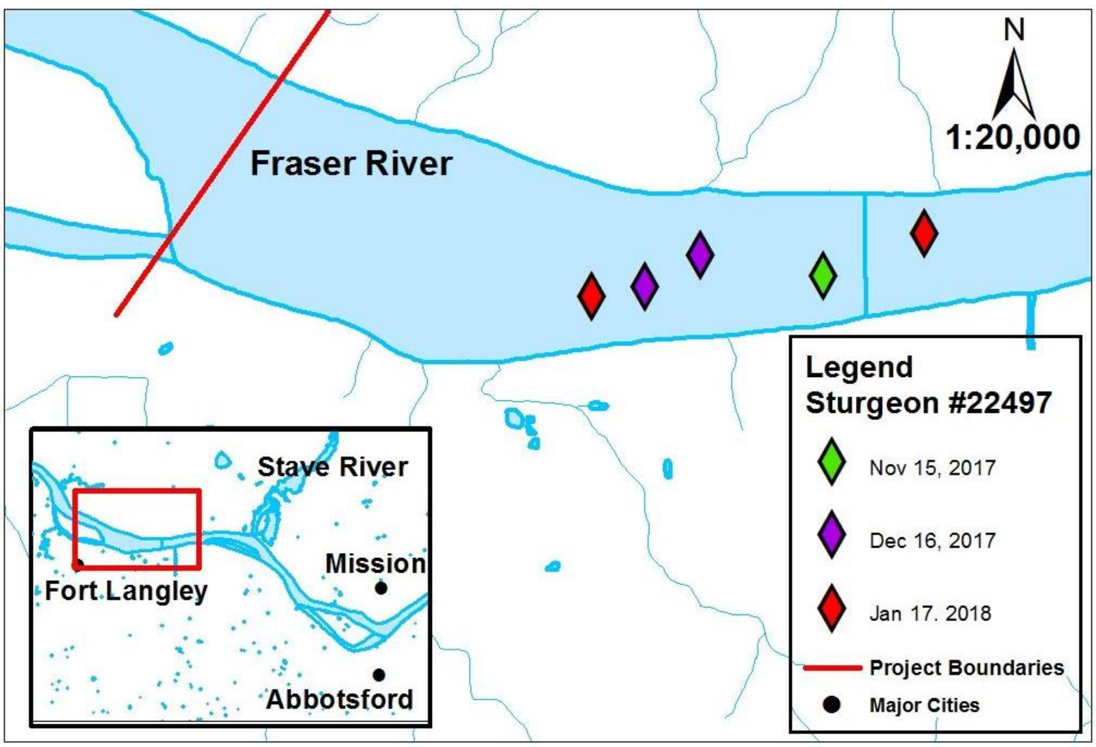
White Sturgeon number 22494 was tagged October 2015 at rkm 95, near the confluence of the Vedder River. We first observed it the Matsqui Slough at rkm 74 in February of 2018. During the length of our study, this White Sturgeon remained in the same location for the tracking session in March (Table 4 - Appendix VII). The total net distance travelled for all observations during the length of our study was 0.51 km.



Appendix XX

Movement patterns for White Sturgeon 22497 over the 2017-2018 tracking season.

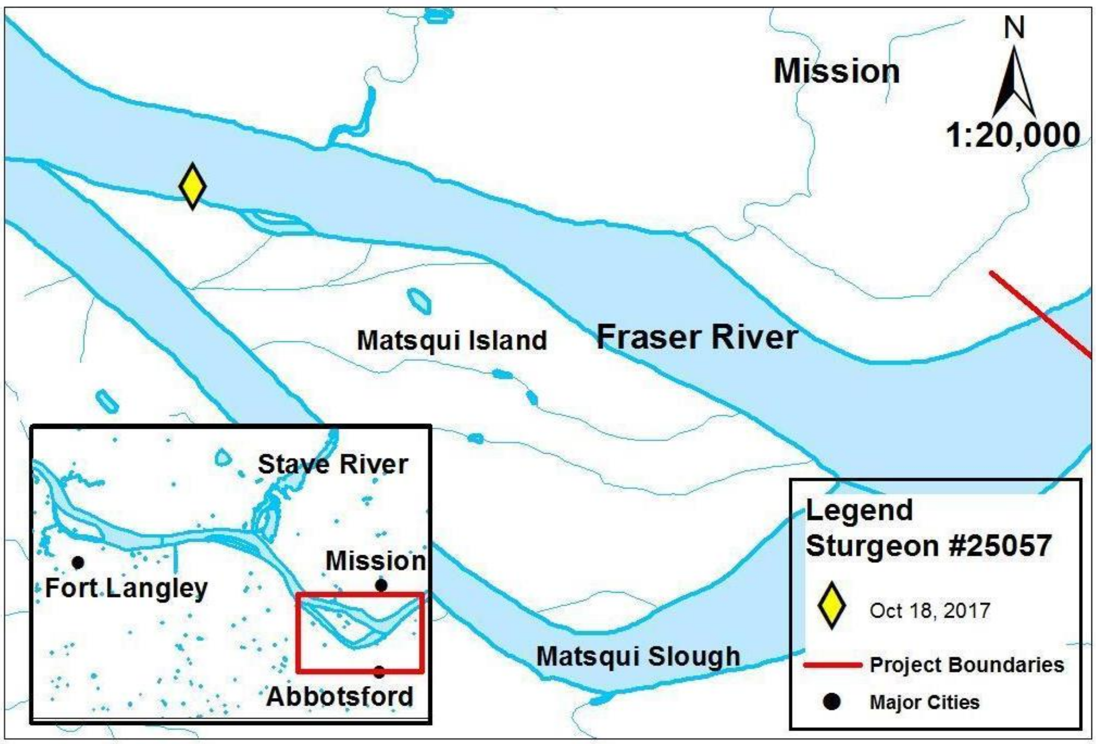
White Sturgeon 22497 was tagged in October 2015 at rkm 93, near the confluence of the Stave River. We first located it in November 2017 along the Plumper Reach, east of McMillan Island at rkm 60. It was located in the same locations in December and January. It was not observed again after this time (Table 4 - Appendix VII). The total net distance travelled for all observations during the length of our study was 1.5 km.



Appendix XXI

Movement patterns for White Sturgeon 25057 over the 2017-2018 tracking season.

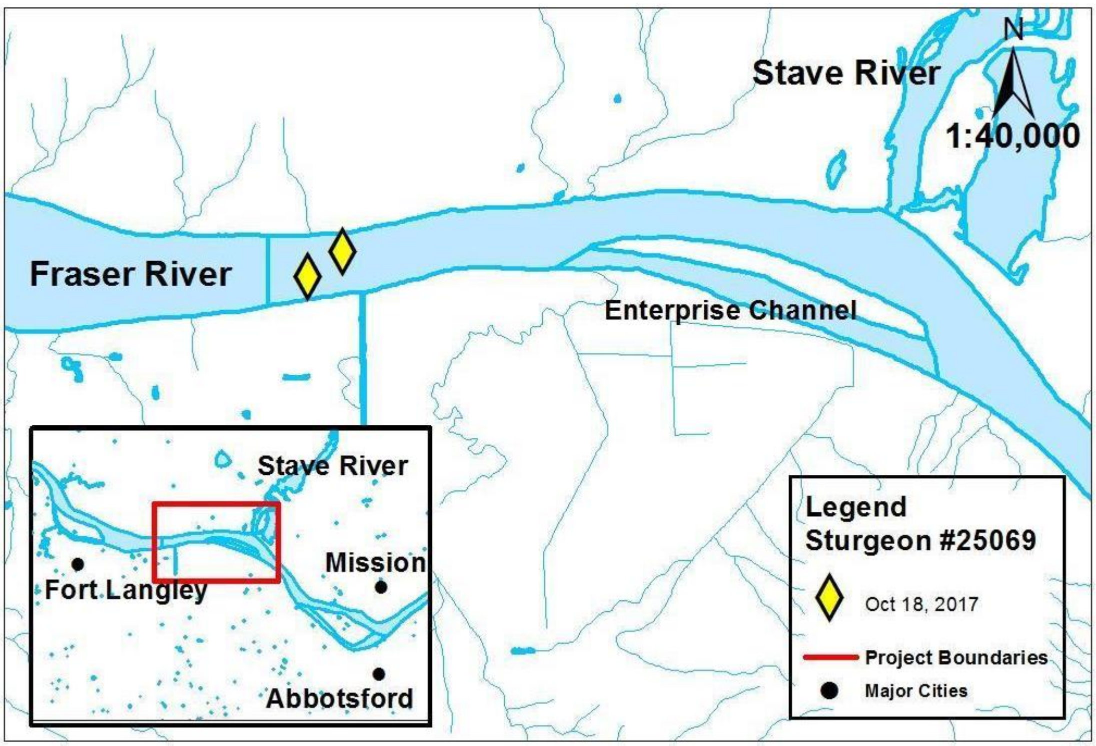
White Sturgeon 25057 was tagged in May 2014, but no location was provided by the people who had performed the tagging. It was only located during the October tracking session in the mainstem of the Fraser near the western tip of Matsqui Island at rkm 74 (Table 4 - Appendix VII). Because we only observed this individual once during the length of our study the total net distance travelled was 0 km.



Appendix XXII

Movement patterns for White Sturgeon 25069 over the 2017-2018 tracking season.

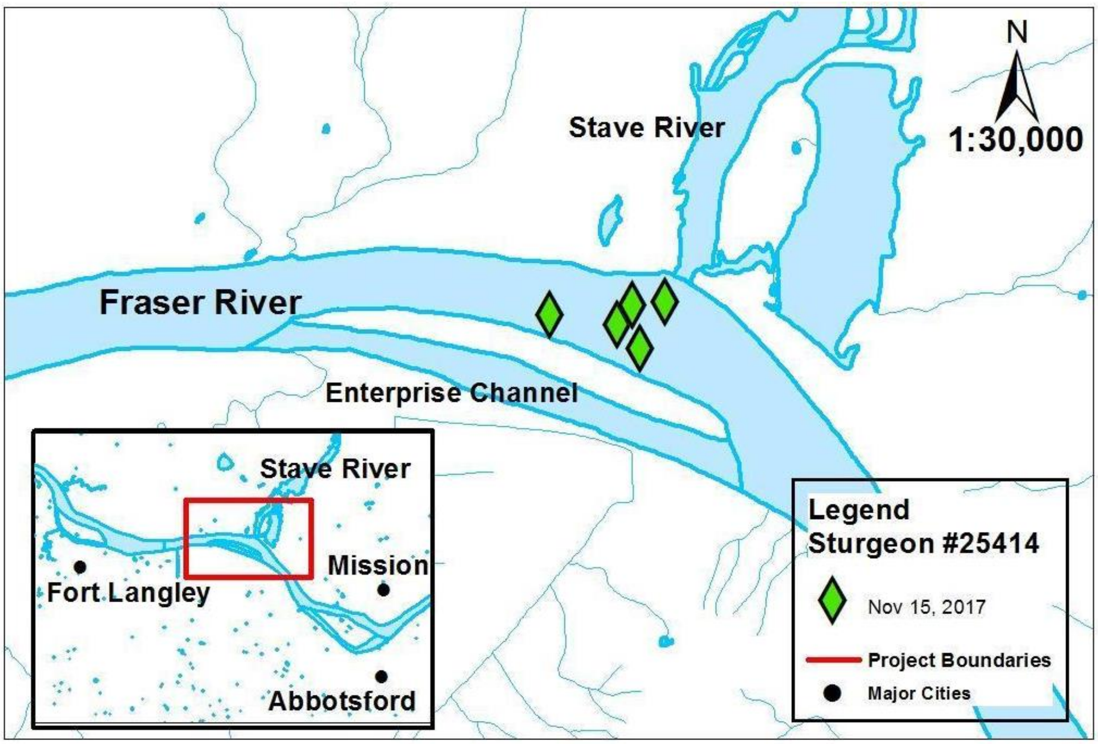
White Sturgeon 25069 was tagged in May 2014, but no location was provided by the taggers. We only observed it in October 2017 at rkm 63, along the Plumper Reach, near the confluence of the Stave River (Table 4 - Appendix VII). Because we only observed this individual once during the length of our study the total net distance travelled was 0 km.



Appendix XXIII

Movement patterns for White Sturgeon 25414 over the 2017-2018 tracking season.

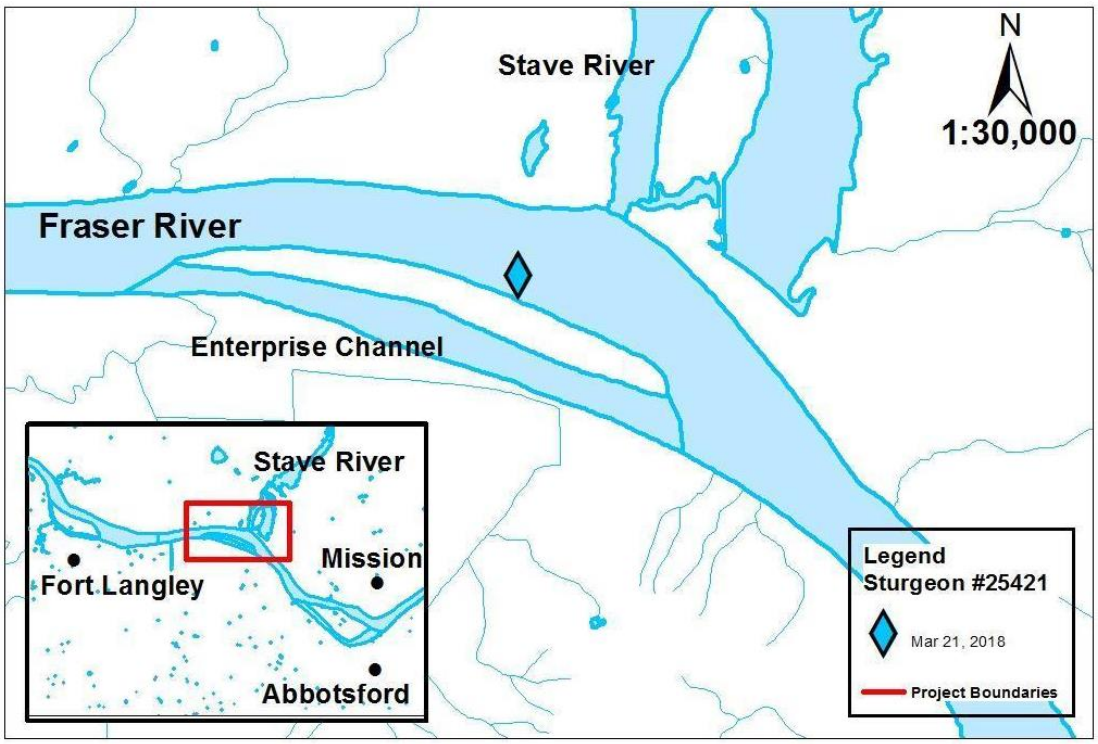
White Sturgeon 25414 was tagged in September 2014 at rkm 93, near the confluence of the Sumas River. We only observed this White Sturgeon during the month of November, at the confluence of the Stave River (rkm 67) (Table 4 - Appendix VII). Because we only observed this individual once during the length of our study the total net distance travelled was 0 km.



Appendix XXIV

Movement patterns for White Sturgeon 25421 over the 2017-2018 tracking season.

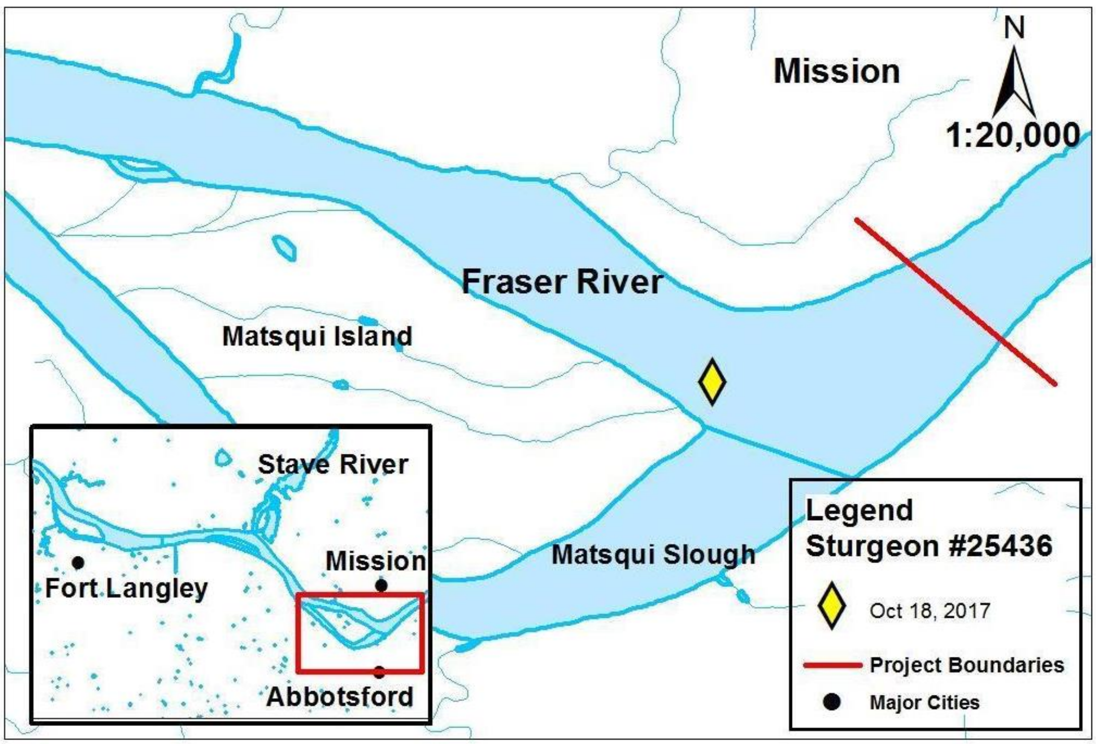
White Sturgeon 25421 was only observed during the month of March 2018, at the confluence of the Stave and Fraser Rivers (rkm 67). This White Sturgeon was originally tagged at the Hatzic Eddy, in October of 2014 (Table 4 - Appendix VII). Because we only observed this individual once during the length of our study the total net distance travelled was 0 km.



Appendix XXV

Movement patterns for White Sturgeon 25436 over the 2017-2018 tracking season.

White Sturgeon 25436 was tagged in January 2015 at rkm 95, near the confluence of the Sumas River. We only observed it in the month of October at rkm 77 in the mainstem of the Fraser River, along the eastern tip of Matsqui Island (Table 4 - Appendix VII). Because we only observed this individual once during our study, the total net distance travelled was 0 km.



Appendix XXVI

Movement patterns for White Sturgeon 25437 over the 2017-2018 tracking season.

White Sturgeon 25437 was tagged in January 2015 at rkm 95, near the confluence of the Vedder River. We only observed it in the month of October 2017, at rkm 76 in the mainstem of the Fraser River, along the central part of Matsqui Island (Table 4 - Appendix VII). Because we only observed this individual once during the length of our study the total net distance travelled was 0 km.