# Columbia River Project Water Use Plan

## Lower Columbia River

### Reference: CLBMON #28 (Year 2 and Year 3)

### *Lower Columbia River Adult White Sturgeon Monitoring Program: 2009 & 2010 Investigations Data Report*

### Study Period: January 2009 - December 2010

### BC Hydro and Power Authority

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# EXECUTIVE SUMMARY

White Sturgeon (*Acipenser transmontanus*) in the Canadian section of the lower Columbia River, are one of four populations that were listed as endangered under the Species at Risk Act in 2006. The population has been undergoing recruitment failure for over 40 years and the main causes are still uncertain, though significant changes to the river (flows and habitat) as a result of dam construction are suspected to have contributed. The species was identified during the Water Use Planning (WUP) process as a priority but significant flow alterations on the system were deemed not feasible and as such the system was designated as a working river. As a result, management responses were targeted on collecting baseline data on the population such as spawning locations, spawning activity (timing and frequency), and population level metrics like habitat use, movements, growth, and age class distribution. The general objectives of the early years of this program were to 1) collect mature adult White Sturgeon to contribute to the annual conservation aquaculture program, 2) determine white sturgeon spawning locations, habitat use, and movements through direct (capture) and indirect (telemetry) methods, and 3) collect data related to White Sturgeon spawning including the locations, timing, and frequency through the deployment of egg mats and drift nets.

A significant result of this program was the identification of an additional spawning site in 2010 immediately downstream of Hugh Keenleyside Dam (HLK) and Arrow Lakes Generating Station (ALH). This represents the 3rd known spawning area in addition to spawning that occurs annually at both Waneta and Northport (USA). An additional site has been documented in the vicinity of Kinnaird through the capture of larvae, though the exact location remains uncertain. High survival of eggs incubated *in situ* at several locations in the river indicates the current temperature regime is not limiting survival at this stage. Spawning occurred earlier at Waneta (June-July) compared to samples collected at ALH and Kinnaird (July-August). Spawning typically occurs during the descending limb of the hydrograph after water temperatures exceeded 14 °C. Interestingly, in 2010, 37% of the estimated number of spawning events occurred prior to the peak freshet date on 21 June and almost a week prior to the mean daily water temperatures in the Columbia River system reaching 14 °C. While it is not considered uncommon for the species to spawn on both the ascending and descending limb of the hydrograph, it is considered rare in the lower Columbia River and in particular at the Waneta spawning site, as this has only occurred one other time in the past decade.

Adults tended to select deep slow moving sections of the river that are not currently limited by the operating regime of the system. We found site fidelity was high with the mean time an individual spent at a single location being 0.62 ± 0.21 (mean ± 1 SD). The upper section of the river (e.g., Robson reach) was the highest used section of river by white sturgeon irrespective of the time of year. These results should be incorporated into future sampling programs to ensure adequate spatial representation of the river is maintained.

Results from this program will contribute to determining the potential causes of recruitment failure and will be important for the recovery of White Sturgeon in the lower Columbia River.

The status of the management questions associated with this monitoring project are summarized in Table ES1.

**Table ES1.** CLBMON #28 Status of Lower Columbia River Adult White Sturgeon Monitoring Program Objectives, Management Questions and Hypotheses.

| Management Question | Status |
|---|---|
| What are the abundance trends, population structure and reproductive status of adult White Sturgeon in the lower Columbia River? | - The abundance estimate for adult White Sturgeon remains at 1100 in the Canadian section of the lower Columbia River as estimated by Irvine et al. 2007. In the coming years, a coordinated approach between BC Hydro and biologists in the United States will be conducted using a stratified random sampling approach to develop an accurate baseline number of adults to track against for recovery.<br>- Generally, the population is still dominated by adults only, with limited wild juveniles encountered. Importantly, juveniles released from the conservation aquaculture program are surviving and are represented in a large proportion of the adult captures. These juveniles have extended the estimated extirpation of this population by several decades.<br>- Mature adults are available for use in the broodstock program and individuals have not had to be reused.<br>- Wild spawning has been detected annually, and while numbers of spawning adults are unknown it is estimated that multiple spawning events occur with eggs surviving to hatch. |
| How much spawning occurs annually at known spawning locations, and are there other spawning locations unidentified in the lower Columbia River? | - Spawning occurs annually at the Waneta area, with the number of estimating spawning events varying by year. Egg and larval captures do not correlate to environmental variables like temperature or flows.<br>- Spawning has been identified through egg and larval captures downstream of Hugh Keenleyside Dam and the Arrow Lakes Generating Station. This represents the second known location in the Canadian section of the lower Columbia River, and 3rd for the transboundary reach, and is encouraging for recovery efforts.<br>- An additional spawning location occurs in the vicinity of Kinnaird, though the exact geographical location is unknown. |

| Management Question | Status |
|---|---|
| What is the degree of interaction among sub-populations of sturgeon in the lower Columbia River? | - A spatially balanced longitudinal acoustic receiver array was implemented to track movements of adults year round for the life of this program. Fidelity to specific habitats or locations has been identified as high (>60%). However, individuals have been identified to move throughout the river during the spring and summer months based on subsequent captures or telemetry. Other transboundary movements across the international border have been documented through direct capture and telemetry. Though more detailed movement patterns are being evaluated, further data are required to address the interaction (i.e., spawning) of individuals from different sections of the lower Columba River |
| How do existing river operations affect adult movements, habitat preference, spawning site selection or spawning? | - Spawning related movements have been identified however additional years of data collection are required to address this question. Generally, adults select deeper slower moving sections of the river that do not appear to be limiting under the current operational regime. |

# ACKNOWLEDGEMENTS

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# 1.0 INTRODUCTION

White Sturgeon (*Acipenser transmontanus*) in the Canadian section of the lower Columbia River (LCR), are one of four populations that were listed as endangered under the Species at Risk Act in 2006. The population has been undergoing recruitment failure for over 40 years and the main causes are still uncertain (Gregory and Long 2008). The population has been estimated at 1,157 adults (95% C.I. 414-1899; Irvine et al. 2007) with an additional 2,003 adults (95% C.I. 1093-3223) residing in the LCR from the Canada/US border to Grand Coulee Dam (Howell and McLellan 2007). The population is considered transboundary in nature due to documented movements of fish throughout the system (Howell and McLellan 2006). The current level of natural reproduction is considered to be insufficient for maintaining a self-sustaining population. Based on natural mortality rates and population trajectory calculations this population of White Sturgeon is estimated to become functionally extinct by 2044 (UCWSRI 2002). Accordingly, intervention and monitoring were deemed essential to preclude extinction (UCWSRI 2002; Wood et al. 2007).

The construction of dams on the Columbia River for the purposes of flood control and hydroelectric power has resulted in significant changes to habitat in the river and has had population level impacts on White Sturgeon. These include reduced flows during the sturgeon spawning and incubation periods, the exclusion of pre-impoundment peak freshet events with associated descending hydrograph limbs and increasing water temperatures, the inundation of habitat, and the interruption of natural suspended sediment and associated reduction in total suspended solids (TSS) turbidity during the spawning and incubation periods. One or more of these habitat quality changes may affect adult movements, spawning site selection, spawning timing, or spawning behavior and thereby likely contribute to recruitment failure.

White Sturgeon were identified during the Water Use Planning (WUP) process as a priority species for conservation in the Columbia River, but given the high value of power generation mandated under the Columbia River Treaty (CRT), significant flow alterations on the system were not feasible and as such the system was designated as a working river (Columbia River Water Use Plan Consultative Committee 2005). As a result of this designation, major operational changes in water management are limited to opportunistic high run off events when snowpack levels are high. Thus, management responses targeted on sturgeon need to be focused on non-operational habitat improvements designed to increase spawning and rearing success. A component of implementing these types of improvements requires that baseline data are collected on the population such as spawning locations, spawning activity (timing and frequency), and population level metrics like habitat use, movements, growth, and age class distribution.

Identification of spawning locations, and spawning activity, is an important component of this project as it allows critical spawning habitat to be located, and these areas can either be protected or enhanced as recovery moves forward. Past studies have identified sturgeon spawning sites at two primary locations in the mainstem Columbia, the confluence with the Pend d'Orielle River (Waneta; Golder 2009a) and in vicinity of the town of Northport, Washington (Howell and McLellan 2006). Additional sites are suspected in the Canadian portion of the

Columbia River based on larval captures and adult movements. These include the area near Kinnaird Bridge and downstream (rkm 13.0 to 19.0; Golder 2009a, 2009b), and the area immediately downstream of Hugh Keenleyside Dam (HLK) and the Arrow Lakes Generating Station (ALH; rkm 0.1). These results have demonstrated that there are still spawning locations that are undocumented in the Columbia River, and that the continued monitoring is important to describing adult reproductive ecology and to understanding underlying mechanisms resulting in recruitment failure.

Outside of annual monitoring programs, the sole conservation strategy implemented to date for this population has been restoration through the supplementation of hatchery produced juveniles. The objective of this strategy was to initiate a conservation aquaculture program to supplement wild stocks of White Sturgeon until adequate levels of natural recruitment could be restored. In 2001, a pilot broodstock acquisition program was developed that resulted in the capture of mature adults that were successfully spawned and contributed to the first supplemental year class released (BC Hydro 2009). Since that time, the conservation aquaculture program has been successful in releasing over 114,000 hatchery reared juvenile sturgeon into the lower Columbia River (spring of 2010).

Given that the collection of life history data is an important component of addressing recovery of White Sturgeon and describing the potential causes of recruitment failure the general objectives of the early years of this program were to:

1. Collect mature White Sturgeon to contribute to the annual conservation aquaculture program;
2. Determine White Sturgeon spawning locations, habitat use, and movements through acoustic telemetry; and,
3. Collect data related to White Sturgeon spawning including the locations, timing, and frequency through the deployment of egg mats and drift nets.

More specific objectives are provided in section 1.2.

## 1.1 Management Hypothesis

While impoundments and water management in the Columbia watershed have contributed to declines in sturgeon recruitment in the lower Columbia River, the precise mechanism(s) remain relatively unclear. Several recruitment failure hypotheses suggest that early life stages, including larval and early feeding phases, appear to be most adversely affected life stage (Gregory and Long 2008). Additionally, other uncertainties regarding recruitment failure exist and could be influenced by spawning site selection, spawning timing, and possible adult behavioral responses related to water management decisions under the CRT.

This monitoring program was designed to provide long term information on adult sturgeon abundance, biological characteristics exhibited under current operation conditions, and reproductive status. In addition, it was designed to include continued baseline data collection on the remaining wild adults, which will be utilized as foundation to evaluate and explore other recovery measures.

Specifically, it will provide data on current adult movements and spawning site selection to assess future management responses, and may also be used to refine current and future recruitment failure hypotheses.

It is intended that future monitoring of the lower Columbia River adult White Sturgeon population may provide key information to help resolve a number of the following outstanding issues identified by the Water Use Plan (WUP) Fisheries Technical Committee (FTC).

1) As the annual average number of spawning events at Waneta appears small relative to the adult population size and the approximate female reproductive cycle, this adult monitoring program may identify additional spawning sites.
2) Changes in movement and spawning behaviour in response to management responses (relative to the baseline established through this monitoring program) may reveal that additional spawning sites (and sub populations) exist in the lower Columbia River.
3) Baseline information acquired through this monitoring program may verify that the abundance of adult sturgeon in the lower Columbia River will not be adversely affected by management response measures.
4) Of equal importance to the maintenance of the remaining sturgeon population; are there sufficient adults to continue the conservation culture program?

The overall approach of this monitoring program is intended to be descriptive rather than experimental in nature and, as such, is designed to provide baseline information that can be used in later years of the program to address the programs management question.

## 1.2 Objectives and Scope

The monitoring program is intended to address a number of uncertainties related to the current status of the population in the lower Columbia River, but it will also provide: (i) input to and assist with the ongoing consideration of recruitment failure hypotheses and the evaluation of the effects of future management efforts on spawning success; and (ii) new information to guide adult broodstock acquisition and assist with adjustments to stocking targets related to the conservation culture program.

The objectives for this program will have been met when:

1) Adult sturgeon life history characteristics including size, growth, age structure, and condition, and population characteristics including abundance and trajectory, mortality rates, genetic status and reproductive potential are quantified with sufficient consistency to describe annual trends.
2) Biological characteristics including spawn monitoring to assess timing and trends, and movements to assess seasonal habitat use and spawning site selection under the current range of operating conditions are adequately defined.

The specific objectives related to the various components of this adult life stage monitoring program are summarized as follows.

### 1.2.1 *Broodstock Acquisition and Population Characteristics*

1. Provide eight to ten late-vitellogenic female and eight to ten mature males for transport to the Kootenay Sturgeon Hatchery;
2. Collect/update information on adult White Sturgeon age structure, growth rates, and population size; and,
3. Provide new information to guide future broodstock acquisition and adjustments to stocking targets related to the conservation culture program.

Biological, mark-recapture and related age structure data accumulated through annual broodstock collection and other on-going research programs will be used to:

1. assess population age structure, abundance, mortality rates, and population trajectories;
2. guide future broodstock acquisition efforts and to guard against future sampling bias (i.e., selected locations and variable effort);
3. provide relative abundance and periodic updates to population estimates of the lower Columbia River White Sturgeon population; and,
4. periodically compared new length frequency data to archived fin ray age analyses to correct for possible aging underestimates.

Data from this program will be analyzed and evaluated on an ongoing basis to drive program decisions or to identify any emerging and imminent threats to the remaining adult population.

### 1.2.2 *Spawn Monitoring*

1. Identify the timing and frequency of annual spawning events at Waneta using egg mats and drift nets to recover spawned White Sturgeon eggs;
2. Provide information on any suspected spawning areas, other than at Waneta;
3. Provide information on trends in the number of discrete spawning events as a measure of population demographics and reproductive potential; and,
4. Provide a baseline for comparison with monitoring of the effects of future management responses.

### 1.2.3 *Movements*

Movements of new and existing acoustically tagged adult White Sturgeon will be monitored using a passive remote receiver array established throughout in the lower Columbia River and, when possible, through mobile tracking to:

1. assist with directing broodstock acquisition efforts;
2. provide new information on suspected staging areas, and other suspected spawning sites throughout the lower Columbia River that may be used during varying ranges of flows; and,

3. provide information on seasonal and annual movements, macro-habitat use and transboundary interactions.

## 1.3 Study Area and Study Period

The study area for both the 2009 and 2010 monitoring program consisted of the lower Columbia River between HLK Dam and the Canada/U.S. Border (just downstream of the Pend O’rielle River confluence; Figure 1). This section of the lower Columbia River is approximately 56 km long. The study area also included a small section (~2.5 km) of the Kootenay River below Brilliant Dam extending to its confluence with the Columbia River. Specific areas of the lower Columbia River sampled under the various components of the program (e.g., broodstock, spawning, etc) are described where they occur below.

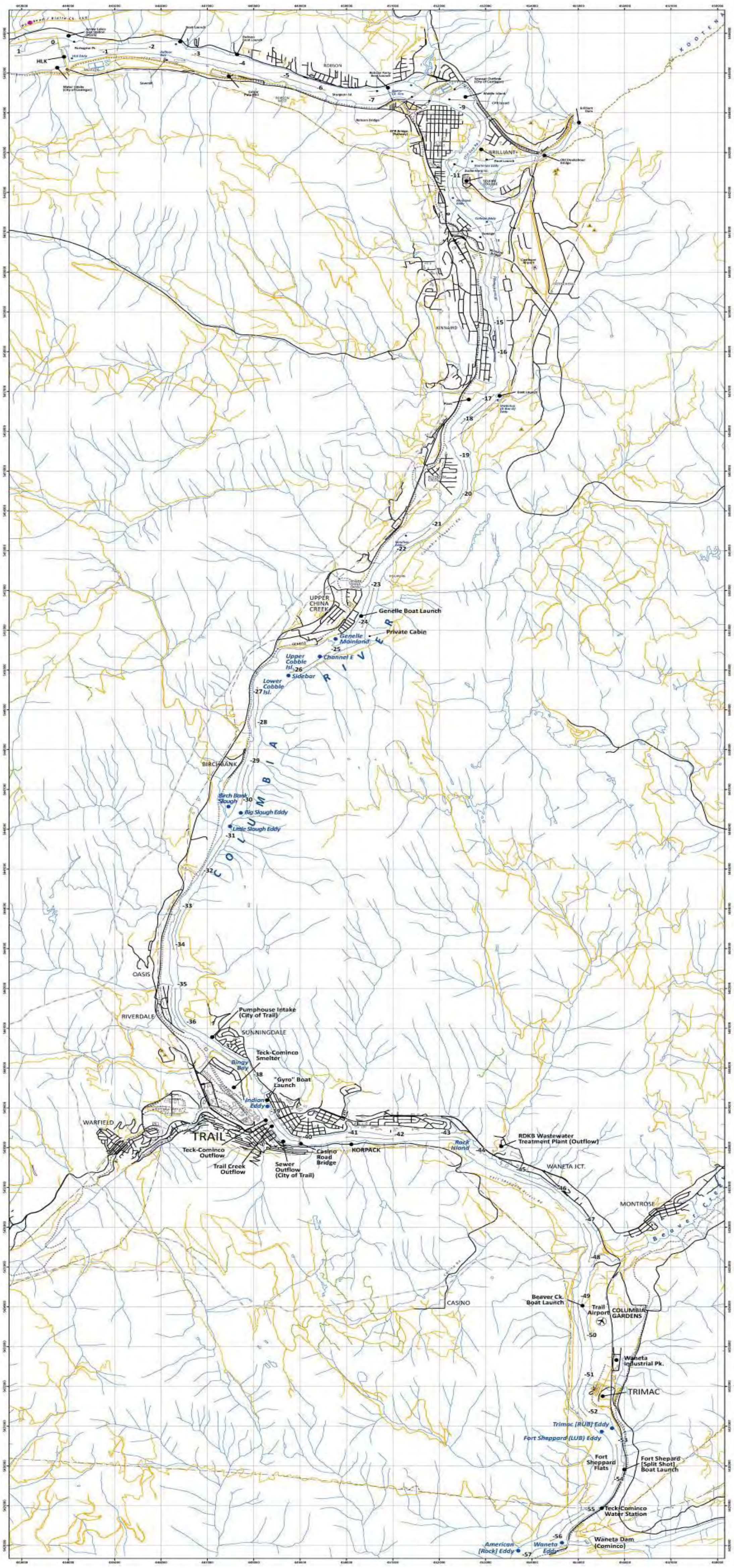

**Figure 1.** Overview of the study area between Hugh Keenlyside Dam (River Kilometer (rkm) 0) and the Canada/US border (rkm 56.5).

# 2.0 METHODOLGY

The monitoring study design follows the recommendations of the WUP FTC and the guidance of the Upper Columbia White Sturgeon Recovery Initiative (UCWSRI) Technical Working Group (TWG) who provided an outline for what they viewed as the components of a lower Columbia adult monitoring program (UCWSRI 2006) during the development of the Columbia WUP. The program is divided into data collection during broodstock acquisition, spawn monitoring, movement studies, and a suite of population characteristics including age structure analyses, population size estimation and genetics assessments. These are described separately below.

## 2.1 Physical Parameters

### 2.1.1 *Discharge*

Discharge records for the entire Columbia River (combined HLK and ALH discharges from Arrow Lakes Reservoir; Kootenay River; and, the Pend d'Orielle River) at the Canada United States border were obtained from BC Hydro power records. Individual discharge records from Arrow Reservoir (combined HLK and ALH), Brilliant Dam on the Kootenay River and Waneta Dam on the Pend d'Oreille River were also obtained from BC Hydro power records. Discharge data were recorded at one minute intervals and averaged hourly in cubic meters per second (cms), cubic feet per second (cfs), and in thousands of cubic feet per second (kcfs) of passage flow.

Typically, the metric discharge measurement (cms) is used to discuss and present results of volumetric flow rates in technical reports and scientific publications; however, the non-metric discharge measurements of kcfs (typically used to describe flow rates of large magnitude) and cfs are more readily used by water planners and biologists to discuss flows from hydroelectric facilities. As such, all three units of measure (cms, cfs and kcfs) are also presented and referenced within the discussion section of this study report.

### 2.1.2 *Water Temperature*

Water temperature data for the 2009 and 2010 study period were collected at four locations on the Columbia River including immediately downstream of HLK, in Kinnaird Eddy, in Waneta Eddy, and in the Kootenay River downstream of Brilliant Dam. Water temperatures were recorded hourly at each location using thermographs (Vemco Minilogs, accurate to +0.1°C). Long-term water temperature monitoring stations are also maintained at Genelle, Birchbank, and Rivervale on the mainstem Columbia River and are available as alternatives should a monitoring station be lost or vandalized.

## 2.2 Adult Capture and Broodstock Acquisition

### 2.2.1 *Study Design*

Previous sampling efforts for adult White Sturgeon in the lower Columbia River (e.g., broodstock collection; BC Hydro 2007; BC Hydro 2008), mark recapture and basic life history studies for population estimation (Hildebrand et al. 1999; Irvine et al. 2007) and acoustic tagging (Golder 2002 and 2006b) have focused on areas of known concentrations in order to maximize catch per unit effort given the short-term nature of the projects and budgetary limitations associated with many of the past studies. Since this WLR study is closely linked to the other two lower Columbia River monitoring programs (CLBMON 29 and CLBMON 30), and as all three projects are considered long term (10 years) it is critical that sampling is designed to address both spatial and temporal factors across all years and to maintain consistency with related programs. Furthermore, it has been suggested that White Sturgeon in the lower Columbia River exhibit high site fidelity (Hildebrand et al. 1999; van Poorten and McAdam 2010). Documented site fidelity further indicates the importance of ensuring that sampling strategies encompass the entire spatial distribution of habitats occurring throughout the entire lower Columbia River. Consistency between sampling designs is even more important given the transboundary nature of the population (Hildebrand et al. 1999; Irvine et al. 2007) and allows for direct comparison of results in future years. The stratified random sampling design described below is also being used by the Washington Department of Fish and Wildlife (WDFW) from the Canadian-United States (US) border on the Columbia River to Grand Coulee Dam. This design is used on the US side of the Columbia River for both adult and juvenile sampling efforts.

In order to ensure a spatially balanced sampling design, the lower Columbia River study area has been stratified into 5 equal zones (each 11.2 km in length; see Figures 2a, 2b, 2c, 2d, 2e). Sampling effort is randomly distributed with equal probability within and across each of the zones. We used a generalized random-tessellation stratified (GRTS) design developed by Stevens and Olsen (2004) to assign sampling locations within each river zone. This was conducted with the statistical package R (Program R, version 2.9.0) using the library packages spsurvey and sp, provided by the United States Environmental Protection Agency. The library package spsurvey allows a user to input data/criteria needed for a GRTS sampling design. We developed shapefiles (i.e., geo-referenced maps) for each river zone using ArcMap (ESRI version 10.0). Each river zone shapefile can be imported in to spsurvey and sampling sites can be randomly generated with equal probability and distribution. The locations of each of the sequentially randomly generated sampling sites are output as coordinates in Universal Transverse Mercator (UTM) format for visual display on maps and for importing into handheld global positioning system (GPS) devices used for field application.

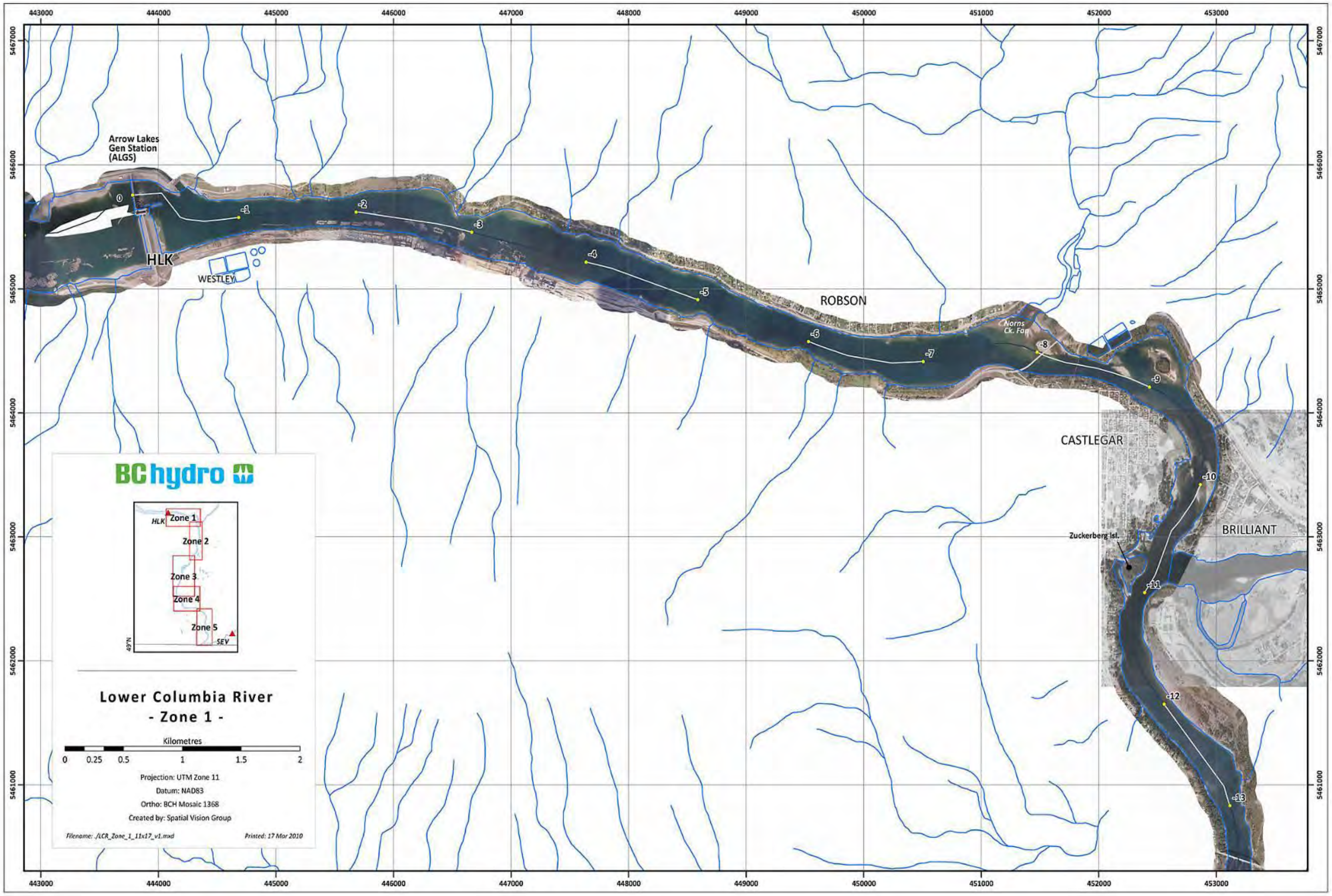

**Figure 2a.** Stratified sampling zone 1 for adult White Sturgeon capture efforts on the lower Columbia River.

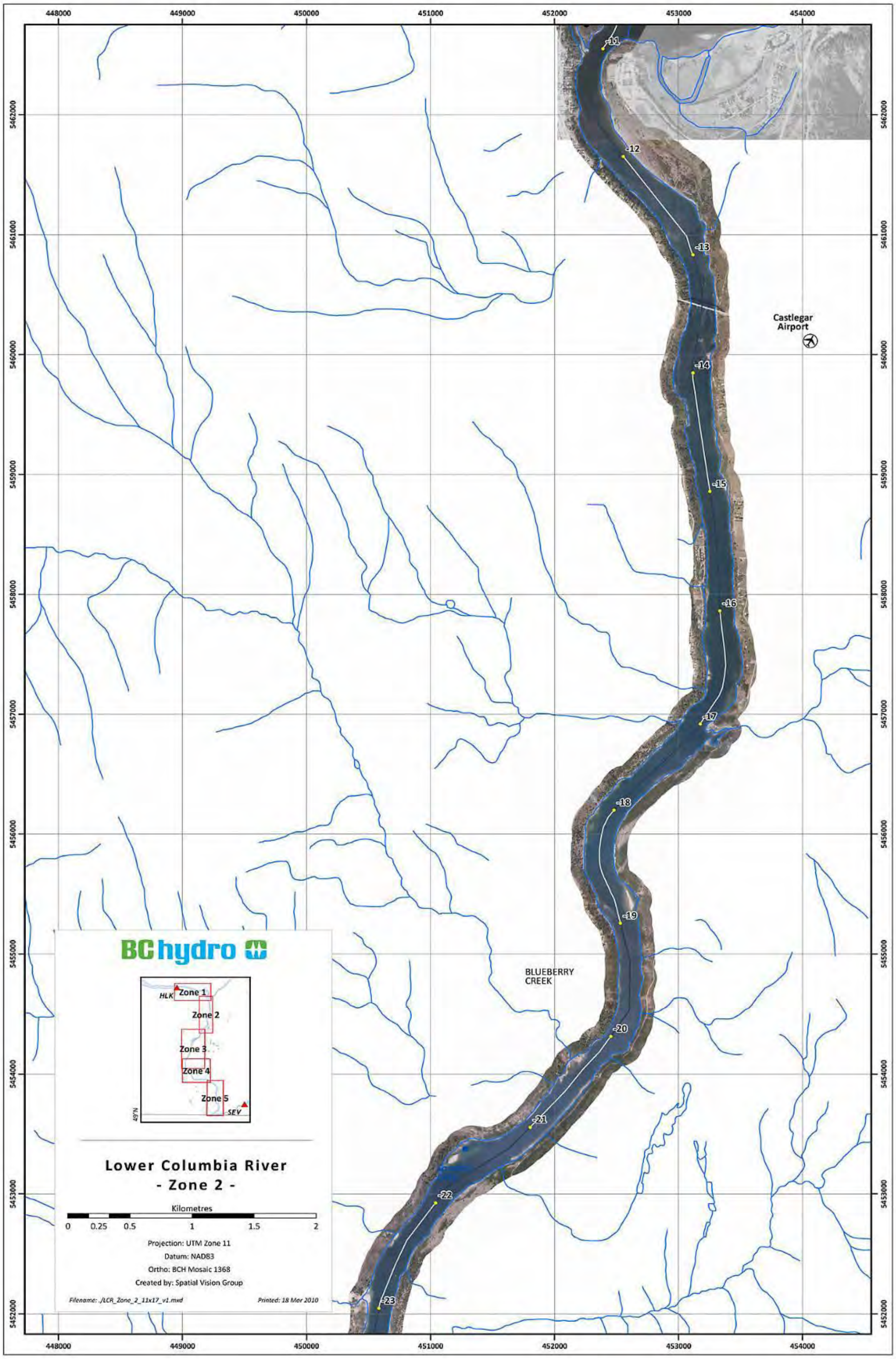

**Figure 2b.** Stratified sampling zone 2 for adult White Sturgeon capture efforts on the lower Columbia River.

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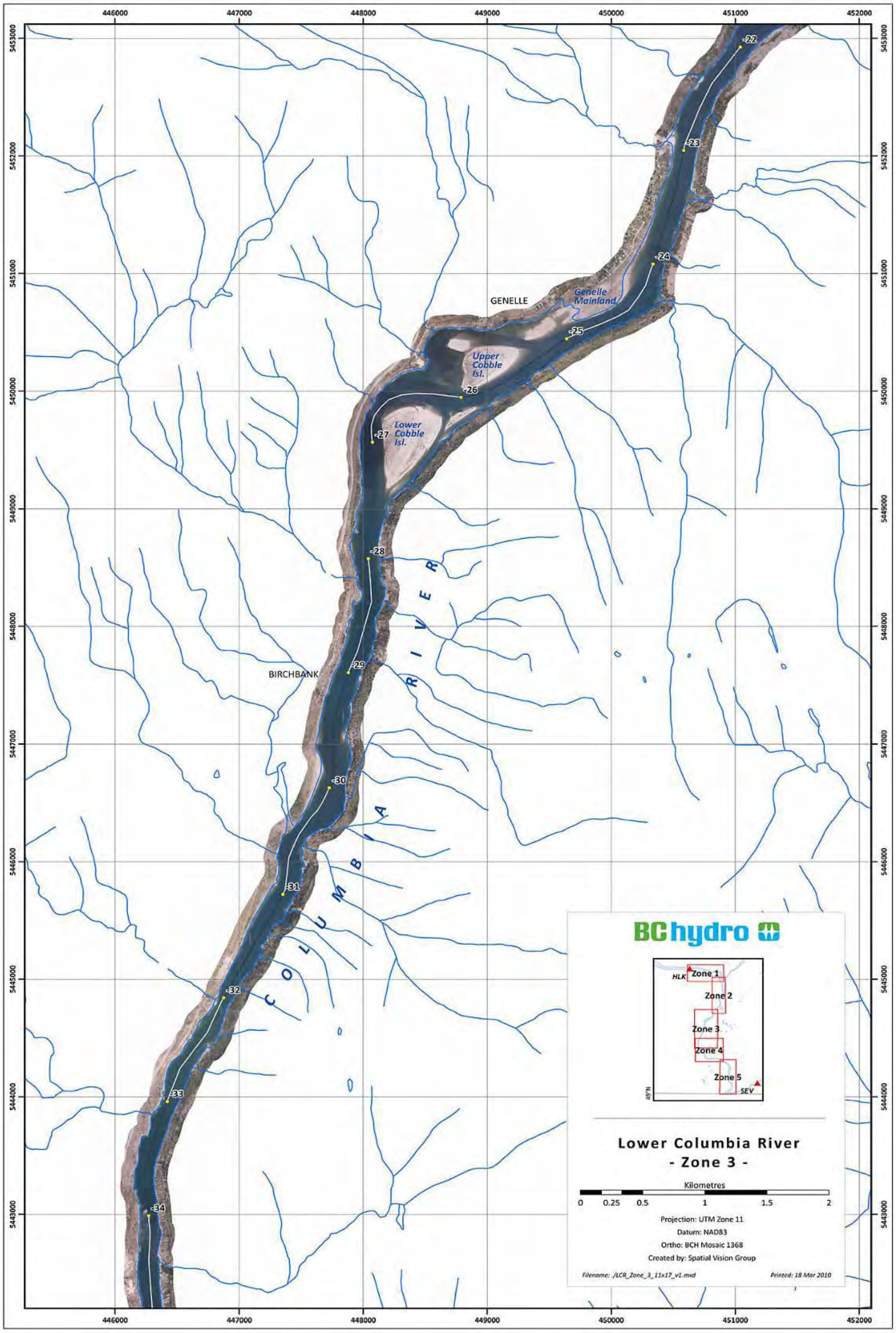

**Figure 2c.** Stratified sampling zone 3 for adult White Sturgeon capture efforts on the lower Columbia River.

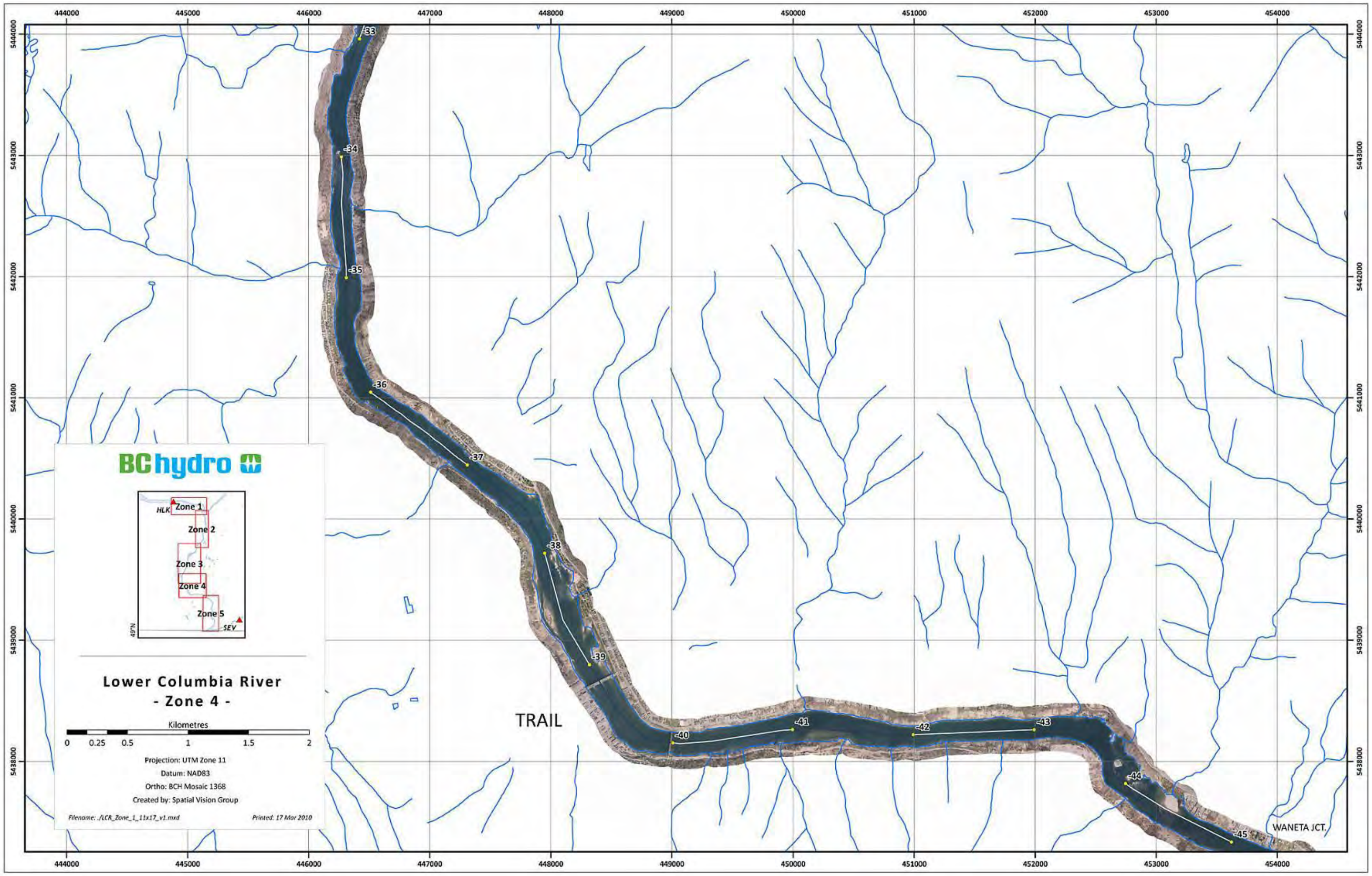

**Figure 2d.** Stratified sampling zone 1 for adult White Sturgeon capture efforts on the lower Columbia River.

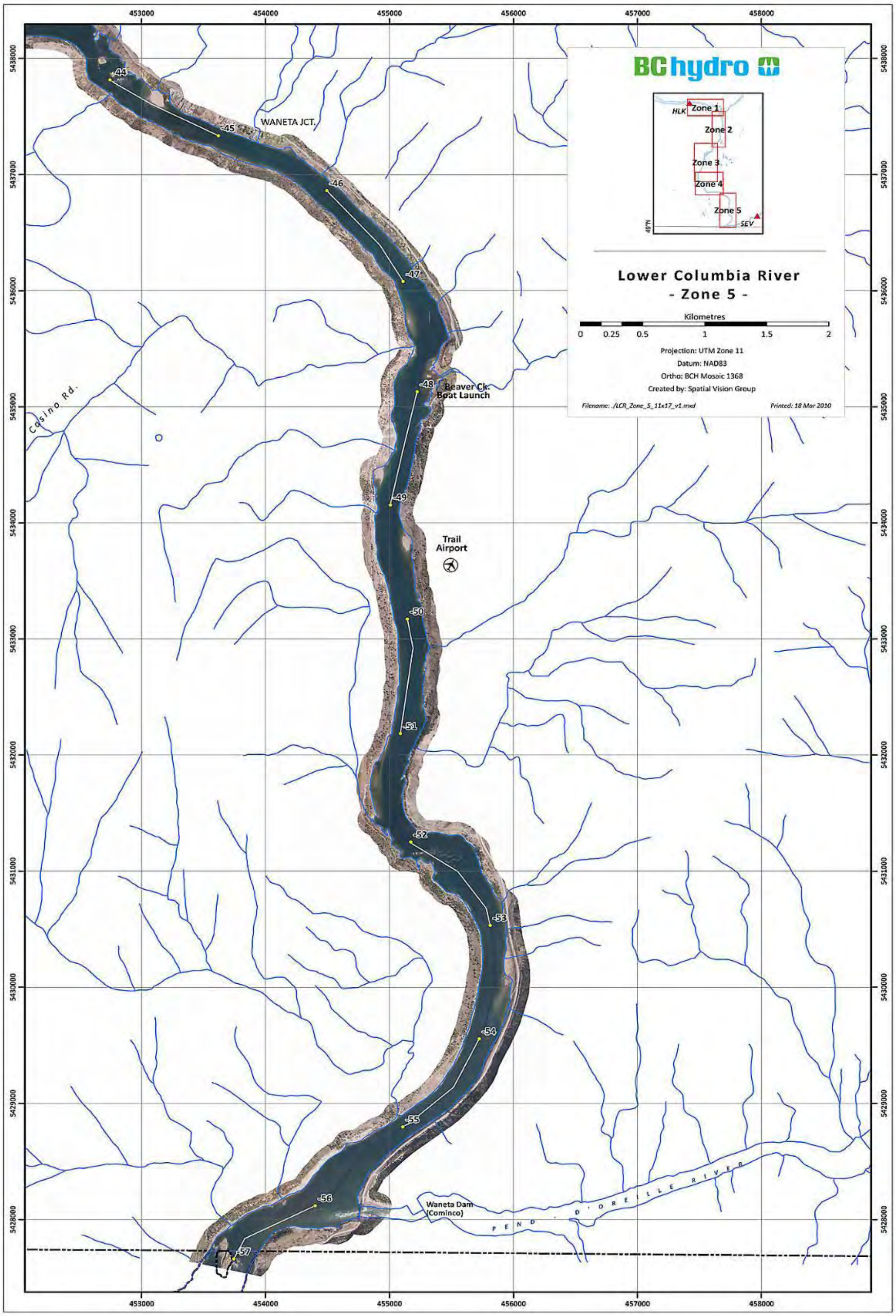

**Figure 2e.** Stratified sampling zone 5 for adult White Sturgeon capture efforts on the lower Columbia River.

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For all components of this study where whole river sampling was required, generated sites are sampled in sequential order until the objectives of the program (e.g., broodstock target) have been met or the required effort has been expended (e.g., adult acoustic tagging numbers). If a proportion of the randomly generated sites within each river zone could not be sampled, the site was omitted (due to an inability to sample for physical, biological, or safety reasons), and the next site occurring on the list was sampled. We selected the sampling order for the five river zones using a random number generator.

The random stratified approach to sampling will provide a consistent approach to determining relative abundance and to accurately update the lower Columbia River White Sturgeon population estimate in future years.

### 2.2.2 *Broodstock Acquisition and Population Characteristics*

The requirement for a consistent, well documented approach to adult White Sturgeon collection activities is a necessary component of the Upper Columbia River White Sturgeon Recovery Plan. The document, entitled “Upper Columbia River Adult White Sturgeon Capture, Transportation and Handling Manual” provides a very detailed and standardized methodology for the capture, transport, and handling of adult White Sturgeon broodstock (Golder 2006a). In 2009 and 2010, the acoustic telemetry component and the broodstock acquisition program employed two capture methods. The primary method of capture used to target adult White Sturgeon was set lines (a combination of both long lines and medium lines). Angling was used as a supplemental capture method when scheduling permitted.

**Set Lines -** Set lines were the primary method used to capture adult White Sturgeon. This method has been shown to provide higher White Sturgeon catch-rates, is less size selective compared to other sampling gear, and rarely captures non-target species (Elliot and Beamesderfer 1990). Set lines have been successfully used in the lower Columbia River to capture adult White Sturgeon for the past few decades (Irvine et al. 2007). A medium line configuration was the standard used for set lines, similar to that used by the Oregon Department of Fish and Wildlife (ODFW) and the WDFW to capture White Sturgeon in the United States portion of the Columbia River (Nigro et al. 1988). Medium lines measured 54.0 m in length and consisted of a 0.95 cm diameter nylon mainline with 8 to 10 circle halibut hooks attached at 6.0 m intervals. Modified long line configurations for broodstock capture were also used in 2009 and 2010. Long lines measured 182 m in length and consisted of a 0.95 cm diameter nylon mainline with 30 circle halibut hooks attached at 5.6 m intervals. In 2010, long line configurations were occasionally used in large eddies, and typically only 15 hooks were used and were attached at every second 5.6 m interval. This allowed researchers to access deeper portions of an eddy without having to use an overabundance of shore line. Hooks were attached to the mainline using a 0.95 cm swivel snap and a 0.7 m long ganglion line tied between the swivel and the hook. Halibut hook sizes used were either 16/0 or 20/0 or a combination of both. In 2009 4 hooks of each size were attached in random order on each medium line. In 2010, the only halibut hook size used was 20/0 to reduce the capture of younger juveniles on the setlines. The barbs on all hooks were either removed or crimped flat to reduce the severity of hook-related injuries and to facilitate fish recovery and release. All set line hooks were baited with kokanee (*Oncorhynchus nerka*) obtained from the Meadow Creek Hatchery (Meadow Creek, BC). On occasion kokanee marinated in garlic salt were used when catch rates declined over time in an effort to increase the scent of the bait and serve as an attractant. Set lines were deployed from a boat at both random and preselected sampling locations and set configuration was based on the physical parameters (depths and water flow) of the site. Set line configuration consisted of either deploying the line parallel to the shore in faster flowing water or perpendicular to the shore in slower moving water. This was conducted to ensure that fish were able to orientate themselves into the current and rest on the bottom of the river, minimizing stress. Prior to each set, water depth (m) was measured by an echo sounder, and this information was used to select a float line of appropriate length. Anchors were attached to each end of the mainline and a float line was attached to the back anchor of the mainline. The set line was secured to shore with a shore line of suitable length to ensure that the set line was deployed in water depths greater than 2m. Most set lines were deployed and remained in overnight at each selected site; however, to increase the total amount of sampling effort over the capture window, set lines were also deployed and fished during the day in addition to the overnight sets.

The set line retrieval procedure involved lifting the back anchor using the float line, until the mainline was retrieved. The boat was then propelled along the mainline and each hook line was removed. If a fish was captured on a hook, the boat was stopped while the fish was removed. White Sturgeon that were removed from the set line were tethered to the side of the boat. The 0.95 diameter tether line from the hook was attached between two anchor points along either the port or starboard side of the boat and allowed the entire body of the fish to remain submerged. Once all fish were removed from the set line, the boat was idled into shore or anchored within a nearby back eddy and White Sturgeon were individually brought aboard for biological assessment (described in section 2.2.3) and processing. All sturgeon were guided into a 2.5 m long by 1.0 m wide stretcher that was raised into the boat using a winch and davit assembly. The stretcher was secured on the boat and fresh river water was continuously pumped over the gills during the processing period. A hood on one end of the stretcher protected the head of the sturgeon from exposure to direct sunlight and also retained a sufficient amount of water allowing the fish to respire during processing. Wet towels were placed over the body of the fish to keep the skin cool and moist. White Sturgeon were returned to the water following processing and remained in the stretcher until they swam away under their own volition.

Catch per unit effort (CPUE) was used to compare numbers of sturgeon caught between sampling zones. CPUE is an expression commonly used to summarize set-line effort and is presented as the total number of fish captured per set line hour. When overall catch rates are considered too be very low, CPUE is calculated the same way; however, it may be expressed by the mean or total number of fish captured by 100 hook hours of effort. The CPUE value expressed by set line hour is more relative for this study as sampling to date occurred in a more spatially balanced design relative to past studies and the number of hooks per set line was equalized. However, since previous estimates of CPUE for the lower Columbia River are presented by both hook hour and 100 hook hours of effort it is important to offer comparable results.

**Angling -** Angling was considered a supplemental and secondary capture method to set lines and was conducted from a boat (anchored to maintain position) in areas known to support White Sturgeon. Angling equipment consisted of a stiff action rod suitable for sturgeon, a level wind reel spooled with 45 to 58 kg test braided nylon line, a single-shanked barbless stainless steel hook (size 8/0), and a lead weight (510-680 grams) with sufficient mass to hold the baited hook on the bottom of the river. Baits used for angling included kokanee, kokanee marinated in garlic, kokanee marinated in anise, brook trout (marinated in garlic), and eulachon. Angling effort was calculated using hook-hours that were based on one baited hook fished for one hour. If a fish was hooked, all other participating anglers retrieved their lines and the boat either maintained position where anchored or was released from the in-stream anchor system to give chase (in the event that the sturgeon traveled considerable distance from where the fish was originally hooked). White Sturgeon that were successfully landed at the boat had the hook removed once successfully tethered to the side of the boat. Once the boat was securely anchored on shore or within a nearby back eddy, the White Sturgeon was brought aboard (described in section 2.2.3) and was biologically processed. Identical to the release methods following a set line capture, White Sturgeon were returned to the river following processing and remained in the stretcher until they swam away under their own volition.

### 2.2.3 *Fish Handling, Transport, Hatchery Spawning and Release*

Once on the boat, White Sturgeon were immediately checked for tags indicating if they had been previously captured and tagged. Recaptured White Sturgeon were identified by either: 1) the presence of a Passive Integrated Transponder (PIT) tag from Biosonics Inc. (400 kHz PIT tags or 134.2 kHz ISO PIT tag), 2) a missing section from the first ray on the left or right pectoral fin (a noticeable mark on White Sturgeon results from the removal of a section of the first pectoral fin ray for ageing purposes; the removal of the fin ray section results in an identifiable mark that persists for several years and can easily be identified by experienced samplers); or 3) the absence of lateral scutes. Unmarked fish were considered to be new captures (i.e., not previously handled by researchers) and had PIT tags injected subdermally in the tissue layer somewhere between the ventral edge of the dorsal fin and the mid-dorsal line, generally on the fishes right side. Prior to insertion, both the tag and the tagging syringe were immersed in an antiseptic solution (Germaphene). Care was taken to angle the syringe needle so the tag was deposited in the subcutaneous layer and not the muscle tissue. Pectoral fin ray section removal has been used on the Columbia River system since 1990 for ageing purposes. Unmarked fish received Oxytetracyline (OTC) injections which are used as a marker on bony structures (i.e., fin rays) for future age-validation studies. OTC was administered at a dosage of 0.2 mL Liquamycin-LP per kilogram of body weight and was injected either through a surgical incision (Apperson and Anders 1991; R.L. & L. 1996); or administered intramuscularly posterior to the dorsal fin if surgery was not performed on the fish.

White Sturgeon were measured for fork length to the nearest 0.5 cm. Weight was determined by suspending the fish in the stretch from the winch and davit assembly using a 250 kg capacity spring scale accurate to ±2.2 kg. External examinations were conducted on each White Sturgeon to identify features such as colouration, deformities (either genetic or mechanical injury related), lesions, cysts, external parasites, and body form anomalies. All life history data were recorded in the field on standardized data forms and later entered into an electronic database.

White Sturgeon considered to be new captures, candidates for acoustic tagging, or mature candidates for the aquaculture program were surgically examined to assess sexual maturity. A 1.5 to 2.0 cm long incision was made through the ventral body wall just off the mid-line using a sterile scalpel. Maturity stages for both males and females were assessed according using an otoscope and classified based on qualitative histology (Bruch et al. 2001; Golder 2006a). Female developmental stages are usually more easily determined since ovary size, colour, average egg diameter, and egg colour can be used as indicators of maturity stage. Immature gonads or those in early stages of maturation are smaller and more difficult to find (especially in males). Following examination, the incision was closed using a half circle CP-2 reverse cutting-edge needle wedged to a 2-0 Polydioxanone violet monofilament suture. Sutures were spaced approximately 1 cm apart and sufficient slack (approximately 2.0 to 4.0 mm) was provided in the sutures to prevent tissue damage caused by swelling during the healing process.

For acoustic telemetry candidates, we used acoustic tags (Vemco, model V16) with a delay time of 60 to 180 seconds (120 sec. nominal delay). The life of these tags is estimated to be up to 10 years which will allow movements to be monitored across all years of the study period.

Finally, lateral scutes were removed using a sterilized scalpel in a manner consistent with the marking strategy employed by WDFW and ODFW. The 2nd right lateral scute was removed from new or recaptured sturgeon that received OTC injections. The 2nd left lateral scute was removed from new or recaptured sturgeon that did not receive OTC injections.

In 2009 and 2010, all fish transportation efforts from the lower Columbia River to the Kootenay Sturgeon Hatchery in Wardner, B.C. were conducted by Freshwater Fisheries Society of BC (FFSBC) staff. White Sturgeon identified as being suitable for fish culture purposes were transferred from the capture boat directly into a 1.5 m deep aluminum holding tank (mounted on a 4.8 m flat deck trailer) filled with ambient river water. The transport trailer was equipped with oxygen tanks and diffusers to maintain appropriate levels of oxygenation (90-100%; Golder 2002). Rock salt was added to the water prior to and during transport in an effort to prevent osmotic stress (FFSBC 2010), to sterilize and aid with any bacterial and/or fungal infections, and to treat any minor injuries (i.e., hook wounds and surficial rope abrasions) sustained during capture.

All of the adult sturgeon (n=19 in 2009, males=9, females=10; n=20 in 2010, males=10, females=10) transported to the Kootenay Sturgeon Hatchery (KSH) were held in large (3.7 m in diameter) circular holding ponds with water temperatures regulated as close as possible to matching that of the Columbia River. Salt treatments (5-10ppt) were applied to aid in the stress and minor injury healing process. Fluid samples (ovarian fluid and milt) were extracted from all contributing adults and were screened for virus and standard fish health culture purposes. Females were checked regularly (egg biopsies) to determine ripeness and to predict when they would be ready to be induced to spawn using standard fish culture hormone injections. Details regarding hatchery spawning of adults is provided in the FFSBC's annual reports (FFSBC 2009, 2010).

Once spawned, each adult was implanted with an acoustic transmitter (Vemco, model V16) and held at the Kootenay Sturgeon Hatchery for a short recovery and observational period. Adults were then transported back to the Columbia River for release near their capture location.

### 2.2.4 *Adult Genetics*

Tissue samples were collected for genetic analysis from all adult White Sturgeon sampled in 2009 and 2010. A small piece of tissue (approximately 1.5 cm x 1.5 cm) from the tip of the dorsal fin was removed using surgical scissors, and archived in labelled scale envelopes. The individual DNA samples were then split into two sub samples and preserved in 95% denatured ethanol.

## 2.3 Spawn Monitoring

### 2.3.1 *Study Design*

Monitoring of sturgeon spawning was carried out at several sites for this program, and was based on previous data collection where sturgeon have been confirmed to have spawned, and on suspected spawning locations from telemetry data and tracking.

Monitoring of spawning activity occurred at Waneta, which is located where the Pend d'Orielle enters the Columbia River near the US border. This site has been monitored for spawning activity since 1993 and is the main area of sturgeon spawning within the lower Columbia River in Canada (Hildebrand et al. 1999; Irvine et al. 2007; Golder 2009a). The Waneta spawning area was sampled in both 2009 and 2010 and both egg mat and drift net sites remained consistent with previously established locations. These sampling sites have been described in detail in other reports (Golder 2009a)

Secondary sites for spawn monitoring were also located in the upper river in 2009 and 2010. In 2009, sampling occurred only using drift nets in an attempt to determine downstream dispersal of larvae from suspected spawning areas to help inform egg mat deployments in 2010. Drift nets were deployed in 2009 downstream from HLK/ALH (rkm 5.1) and downstream of Kinnaird (rkm 18.2). In 2010, egg mats were dispersed throughout the upper river (Figure 3) from HLK/ALH (rkm 0.1) as far downstream as Kinnaird eddy (rkm 13.0). More egg mat effort was expended at suspected spawning locations, specifically near the HLK/ALH outflow and just above Kinnaird eddy (Figure 3). Further in 2010, drift nets were deployed downstream of HLK/ALH and consistent with 2009 at rkm 18.2.

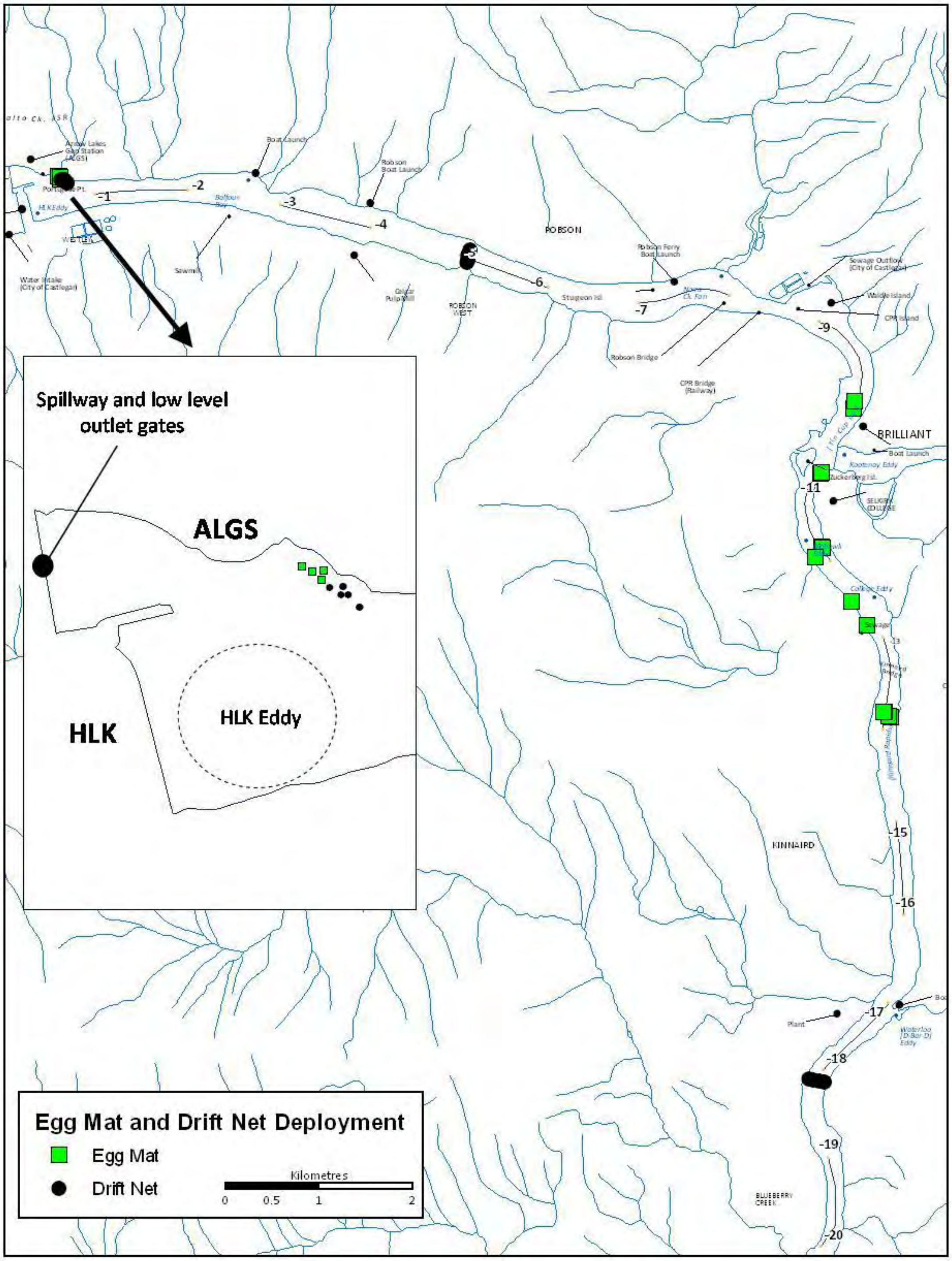

**Figure 3.** Egg mat and drift net deployment sites in the lower Columbia River in 2009 and 2010.

### 2.3.2 *Egg Collection Mats and Drift Net Sampling*

**Egg Collection Mats -** White Sturgeon are broadcast spawners which allows for the collection of eggs using passive sampling techniques. Egg collection mats are a proven method of collecting White Sturgeon eggs (McCabe and Beckman 1990; McCabe and Tracey 1993). Studies conducted in the Waneta area of the Columbia River since 1993 have proven that egg collection mats are effective at collecting White Sturgeon eggs (Golder 2002, 2010).

Egg collection mats consisted of a 0.76 by 0.91 m steel frame with latex coated animal hair filter material fastened to frame. Egg mats were deployed on the river substrate and collect drifting or deposited eggs that became entrapped in the filter material.

The type of equipment deployed and the procedure for deployment and retrieval in the Waneta area mimicked past monitoring protocols (i.e., paired egg collection mats retrieved from the river bottom and inspected in metal trays filled with river water; Golder 2009a). The type of equipment used to deploy egg mats in other locations of the lower Columbia River deviated from the proven methods used in the Waneta area and were very similar to the methods used for deployment and retrieval of drift nets (as described in section 2.3.2). A lead steel claw river anchor (30 kgs) was used to hold the entire system to the river floor. Approximately 6 m of 3/8 galvanized chain is attached to the main anchor and is followed by a secondary steel anchor (also 30 kg) to ensure the anchor remained flat on the river bottom. Two 30 m sections of 0.95 cm diameter braided rope were attached to the second anchor. The first rope was attached to a buoy at the surface of the river which provided a means to remove the entire anchoring system. The second rope was attached directly to the front of the egg mat. We attached an additional rope from the back of the egg mat to a surface buoy to facilitate deployment and retrieval. Alternatively, a single egg mat (containing a 10 kg lead anchor fastened to a leading bridal) with a rope from the back of the egg mat to a surface buoy to facilitate deployment and retrieval was deployed in areas of the river where flows allowed. When retrieving the egg mat, the buoy attached directly to the back of the egg mat would be picked up from the boat and the mat would be brought to the surface. Once at the surface, the egg mat would be detached from the anchor system and brought into the boat for inspection and analysis. Both sides of the egg mats were inspected thoroughly by a minimum of 2 crew members before being reattached to the anchor system and redeployed. The buoy attached directly to the back of the egg mat allowed the retrieval of the net without dislodging the anchoring setup and ensured that sampling sites were consistent across the sampling program.

Upon detection of a spawning event through the collection of either eggs, a proportion (20%) of the samples collected were preserved so that the timing of individual spawning events could be estimated (based on egg developmental stage estimated in the field) and the predicted timing of hatch could be calculated (see section 2.3.4 for detailed procedure).

**Drift Net Sampling -** Drift net sampling has been used successfully to capture both fertilized eggs and passively dispersing free embryos for many sturgeon species including White Sturgeon in the lower Columbia River (Golder 2009a), lake sturgeon (*Acipenser fulvescens*; Auer and Baker 2002), and shortnose sturgeon (*Acipenser brevirostrum*; Moser et al. 2000). Drift nets are deployed on the bottom of the river and are designed to passively capture sturgeon larvae (a primary objective of the CLBMON 29 Lower Columbia River Juvenile White Sturgeon Detection Program) dispersing downstream from spawning areas. Drift net sampling has been added as a supplemental component to the adult spawn monitoring program in recent years and has proven successful at documenting spawning events and egg dispersal patterns through the collection of eggs and larvae.

Drift nets used in this program consisted of a 1.3 cm rolled stainless steel frame (D shape) with a 0.6 m x 0.8 m opening that is trailed by a 4 m tapered plankton net (0.16 cm delta mesh size) with a collection cup device. Deployment and anchor system specifications were consistent between sampling locations in the lower Columbia River are described as follows. A lead steel claw river anchor (30 kg) was used to hold the entire system to the river bottom. Approximately 6 m of 3/8 galvanized chain was attached to the main anchor and was followed by a secondary steel anchor (14 -30 kg depending on site river velocities) to ensure the anchor remained flat on the river bottom. Two 30 m sections of 0.95 cm diameter braided rope were attached to the second anchor. The first rope was attached to a buoy at the surface of the river which provided a means to remove the entire anchoring system. The second rope was attached directly to the front of the drift net. We attached an additional rope from the top of the frame on the drift net to a surface buoy for both deployment and retrieval of the net. When retrieving the drift net, the buoy attached directly to the net would be picked up from the boat and the net brought to the surface. Typically, drift nets were deployed and retrieved from the bow of the boat using an electronic winch. Once at the surface, the net would be detached from the anchor system and brought into the boat for collection cup removal. Drift nets were rinsed thoroughly with river water before being reattached to the anchor system and redeployed. The buoy attached directly to the drift net allowed the retrieval of the net without dislodging the anchoring setup and ensured that sampling sites were consistent across the sampling program. Following removal of the collection cup, the contents were rinsed into a white bucket (19 L) and diluted with river water. The contents were then transferred in small aliquots into several white plastic inspection trays. The white trays provided improved contrast when searching for White Sturgeon eggs or larvae. Numbers of sturgeon eggs and larvae were enumerated by net for each sampling occasion. A proportion (20%) of the larvae collected were preserved so that estimates could be developed for the time of hatch and the time egg fertilization occurred (see section 2.3.4). We also recorded deployment and retrieval times, water temperatures and depths at each net location.

### 2.3.3 *Egg Preservation and Staging*

As part of the Waneta Spawn Monitoring Program completed by in 2009 and 2010, a random sample (1 in 5) of the total number of eggs and larvae captured were preserved in a Prefer solution (a buffered glyoxal/ethanol preservative) for developmental staging. At all sites sampled in the upper river in 2009 and 2010, all eggs and larvae captured were preserved in a Prefer solution for developmental staging.

Following field collection activities, all preserved eggs and larvae were then inspected using a stereo microscope (Nikon, model: SMZ745T) to assess egg developmental stages and aid in the back calculation process that allows one to predict the time and number of potentially different spawning events based on published rates of White Sturgeon egg development (Beer 1981; Wang et al. 1985).

Once a spawning event was estimated, a range of time in which each spawning event likely occurred was assigned based on the developmental stages of the eggs associated with timing of that specific event. The accuracy of egg developmental staging as a method to delineate spawning events and estimate time of spawning can be affected by individual White Sturgeon spawning behaviour, egg maturation rates, and more importantly the fluctuation in daily thermal regimes (Parsley et al. 2010).

## 2.4 *In Situ* Egg Incubation

In 2009 and 2010, White Sturgeon eggs captured on egg mats from the Waneta spawning area were incubated *in situ* in egg incubation trays to obtain tissue for future genetic analysis (as a means to determine parental contributions to the eggs captured) but also to provide a general assessment of egg incubation success at Waneta.

Based on previous study results in the Waneta area, incubation trays have been effective in incubating eggs to hatch (Golder 2010). The incubation trays consisted of an 18 cm long by 9 cm wide piece of 6 mm thick plexiglass middle sheet with 50 perforations (6 mm wide) distributed in a rectangular grid pattern. Two 3 mm thick sheets of similarly sized and perforated plexiglass, with 1 mm plastic screen glued to one side, were placed on either side of the middle sheet to seal the eggs within the incubator. Only collected eggs that were assessed to be developing were placed in incubation trays. To load the incubation trays with eggs, the bottom and middle plates of the incubator were placed in a shallow tray of fresh river water and a single White Sturgeon egg was placed in each of the 50 perforations. The top sheet was then placed over the other two sheets and the entire unit was sealed by bolting all three sheets together. The incubation trays were returned to the river near the capture site and incubated *in situ* until hatch.

The incubation trays were generally deployed in incubation groups consisting of one or two crab bait cages (one incubator per cage) attached to a weighted 25 m length of mainline (the incubation array) and originally set at 3.6 m depth. Concrete anchors at each end of the mainline were used to maintain position on the river bottom. The upstream end of the array was tethered to shore. A buoy attached to the downstream anchor served as a backup method of retrieval in case the shoreline tether failed. To reduce sediment accumulation within the incubators, they were suspended in the water column by attaching the bait cages (containing the incubators) to a loop on a 0.5 m tether equipped with a small float. For additional ballast and stabilization, the end of the tether was attached to metal weight which was in turn attached to the mainline with a carabineer. The incubation groups on the array were left undisturbed until a sufficient amount of time had elapsed for the eggs to hatch. Incubation tray retrieval timing was determined based on the approximate developmental stage of the eggs at capture and the rates of embryonic development provided in the literature (Beer 1981; Wang et al. 1985) and water temperatures at the spawning area. The larvae from eggs that successfully hatched were preserved in 99% anhydrous ethanol and were archived for future genetic analysis.

## 2.5 Egg Incubation Experiments

In 2009 and 2010, we conducted egg incubation experiments at four different locations in the lower Columbia River to provide a general assessment of egg incubation success, but to also to test if egg incubation success varied by location and associated physical conditions (e.g., water temperature). Known factors that contribute to incubation success are water temperature and family (maternal) effects.

In 2009, surplus White Sturgeon eggs spawned from broodstock at the KSH were incubated in the river in egg incubation cells. The incubation cells consisted of a 15 cm long by 9 cm diameter perforated poly cylinder (1mm perforation size openings) that was permanently capped at one end and had a removal cap at the other end to facilitate loading of eggs. Eggs from three different females were each crossed with milt from 3 individual males to create 9 half sib families. 3 ml of neurolated eggs (approximately 35-40 eggs/mL) from each of the 9 families were loaded into individual incubation cells. This was replicated across three different incubation sites, downstream of HLK/ALH (rkm 1.0), in the Kootenay River (rkm 0.1), and at Kinnaird (rkm 13.0). Following the loading procedure, incubator cells containing eggs were placed in a cooler of ambient hatchery water (approximately 15 °C) and were transported to the three predetermined incubation locations. The incubation cells were deployed in incubation groups consisting of nine incubation cells (one for each of the 9 families) randomly assigned in a top to bottom order on a weighted 20 m length of mainline. A 14 kg concrete anchor was fastened at one end of the mainline and a buoy was attached to the opposite end. To reduce sediment accumulation within the incubators and to ensure that sufficient and equal flow was received by all incubation cells within the group, they were suspended in the water column by attaching the incubator cells to a loop at 1 meter intervals (starting 2 m from the anchor). The incubation groups on each of the three incubation locations were checked occasionally to document egg development and effects of water quality factors (i.e., sedimentation). Once a sufficient amount of time had elapsed for the eggs to hatch (based on the rates of embryonic development in relation to water temperature provided in the literature; Beer 1981; Wang et al. 1985), the incubation cells were retrieved and the total number of eggs and total number free embryos from eggs that successfully hatched were enumerated. Water temperatures were recorded hourly at each location using thermographs (Vemco Minilogs, accurate to +0.1°C). For egg incubation data in 2009, we calculated the proportion of eggs surviving to hatch at each location.

In 2010, surplus White Sturgeon eggs spawned from broodstock at the KSH were incubated in the river in egg incubation units at 4 different river locations.

Sites chosen were downstream of HLK/ALH (rkm 0.5), Kootenay (rkm 0.1), Kinnaird (rkm 13.0), and at Waneta (rkm 56.0). Based on results from the 2009 egg incubation experiment and results in the Waneta area (Golder 2010), incubation cells used in 2009 were abandoned in 2010 and new incubation plates were manufactured for future incubation experiments. These incubation plates consisted of an 18 cm long by 20 cm wide piece of 6 mm thick plexiglass middle sheet with 100 perforations (6 mm wide) distributed in a square grid pattern. Two 3 mm thick sheets of similarly sized and perforated plexiglass, with 1 mm nylon mesh screen secured to one side, were placed on either side of the middle sheet to seal the eggs within the incubator. To load the incubation plates with eggs, the bottom and middle plates of the incubator were placed in a shallow tray of KSH water and a single neurolated White Sturgeon egg was placed in each of the 100 perforations.

The top sheet was then placed over the other two sheets and the entire unit was sealed by bolting all three sheets together. Eggs from three different females were each crossed with milt from 6 individual males to create 6 family groups. 100 eggs from each of the 6 families were loaded into 6 different incubation plates and were randomly placed on evenly spaced rods and fastened together to form an incubation cell. This configuration was replicated three more times meaning that a total of four incubation sites were used in the 2010 experiment. Following the egg loading procedure, incubation units containing 6 individual incubator plates with eggs were placed in a large poly tank of ambient hatchery water (approximately 15 °C) and were transported by truck to a boat waiting on the lower Columbia River, where they were then transported to four predetermined incubation locations.

The incubation units were deployed in a similar fashion to the incubation groups in 2009; a 30 kg anchor was fastened at one end of the mainline and a buoy was attached to the opposite end. The incubation units were suspended 3m from the river substrate between 2 small polyform floats to provide sufficient buoyancy to keep the incubation units from being subjected to sedimentation or damage from impact on the rivers substrate, and to ensure that sufficient and equal flow was received by all incubation plates within the group. Once a sufficient amount of time had elapsed for the eggs to hatch (based on the rates of embryonic development in relation to water temperature provided in the literature; Beer 1981; Wang et al. 1985), the incubation cells were retrieved and the total number of eggs and total number free embryos from eggs that successfully hatched were enumerated. Again water temperatures were recorded hourly during transportation from the hatchery to the river, and at each of the respective incubation location for the duration of the experiment using thermographs (Vemco Minilogs, accurate to +/- 0.1°C).

For egg incubation data collected in 2010 we measured egg incubation success as the percentage of surviving eggs to hatch. We tested the effects of location and maternal family group on incubation success using a 2 factor analysis of variance (ANOVA). *A posteriori* comparisons were completed by a least squared means test using Tukey's correction.

## 2.6 Population Monitoring and Abundance

White Sturgeon life history information, population characteristics and mark-recapture related information were accumulated primarily through the annual broodstock collection program of each year and through adult sampling conducted under CLBMON 30 (BC Hydro 2011a).

Biological data collected from adult sturgeon sampled in 2009 and 2010 are analyzed in this report for characteristics such as length frequency, length-weight relationship, sex ratio, and seasonal timing of spawning. In future years, mark-recapture data will be used to estimate population abundance and mortality rate. Catch records are analyzed across all years of broodstock collection in an effort to provide recommendations to annual conservation aquaculture breeding plans and to maximize the genetic diversity available for culture practices.

## 2.7 Acoustic Tagging and Telemetry

As biological characteristics of the White Sturgeon population in the lower Columbia River including spawn timing and trends, and movements to seasonal habitat use and spawning site selection are poorly understood under the current range of operating conditions, the tagging and tracking of fish is required.
As per section 2.2.4, acoustic transmitters (Vemco model V16, operational life of 10 years) were allocated to adult White Sturgeon predicted to spawn within the next 2-3 years (based on sex maturity examinations). Total of 25 acoustic transmitters were allocated to be surgically implanted in adult sturgeon in 2009, with an additional 25 transmitters implanted within the life of the study. Higher percentage of males (60%) than females (40%), were targeted for acoustic transmitter implantation, as males are more likely to spawn more frequently over the course of the transmitter's operational life than females. Information from these tagged adults will be important to addressing the objectives of this study. Finally, since 2007, all broodstock transported to the KSH have received an acoustic transmitter prior to their post spawning release to their original capture location in the lower Columbia River.

### 2.7.1 *Acoustic Receiver Array*

We used an array of fixed station remote receivers (Vemco, model VR2 and VR2W) already deployed within the lower Columbia River as the primary method of detecting spatial and temporal movements of tagged White Sturgeon
The spatial extent of the array encompassed the lower Columbia River from HLK Dam Lake southward to the Canada/U.S. International Border has not changed since being initially deployed in 2003 and remained constant until 2009. In early May of 2010, the array was repositioned to 3 km intervals starting at HLK and moving downstream to the international border. This was done to improve spatial coverage throughout the study range (as indicated through increased detectability of individual fish exhibiting site fidelity). We also increased the spatial coverage of the array by adding receivers in areas that were previously not covered, improving our ability to detect movements on a finer spatial scale.

The receivers were deployed approximately 3 m below the water surface on a weighted length of mainline consisting of either 0.95 cm diameter nylon or 0.64

cm stainless steel cable. A large pyramid shaped concrete reinforced anchor (55-80 kg; varied depending on receiver station location within the river channel) was attached at one end of the mainline and highly buoyant low drag float (Model LD-2 or LD-3) was attached to the opposite end to the anchor. The receiver was fastened to the mainline (using cable ties) with the hydrophone orientated towards the river bottom. Stations were checked for wear and tear (cable ties, rope, float, sufficient extra float line to accommodate fluctuating water levels, remaining battery life) during each download and repair/replacement was conducted as necessary.

Raw data from the receivers were downloaded using the latest versions of Vemco User Environment (VUE) software (version 1.8) which was installed on a weather resistant laptop computer. Due to the volume of data collected, telemetry station downloads were split into separate VUE databases for each year of the study and the data was then exported into a separate database (Microsoft Access) for further analyses (see section 2.7.3).

### 2.7.2 *Acoustic Receiver Range Testing*

Range tests were conducted on select receiver stations in both the Robson Reach and Waneta area in 2009. The range test was conducted by attaching a test tag (pinging at 1 m intervals) to an anchored float line approximately 1-2 m off the bottom and leaving the tag at fixed distances from select receivers for a minimum duration of time (>12 hours). The receiver was then subsequently downloaded and based on the time the tag was pinging, and the number of detections recorded during the test period, an approximate detection range was determined. In addition to range testing, detections by month, and at the individual level, were analyzed to determine if receiver placement and orientation (coupled with inherent limitations of acoustic detection created by acoustic signal deflection) is the primary reason why the fish were not detected.

### 2.7.3 *Telemetry Data Analysis*

Raw detection data recorded on receivers were uploaded frequently (>4 times/year) into a telemetry database and software (Vemco, VUE) for management and long term storage. Although the acoustic array was originally intended to track the movements of White Sturgeon, multiple research projects involving other fish species are ongoing in the lower Columbia River, and as such, user agreements with other agencies and researchers have been developed for the utilized of this telemetry array. For White Sturgeon projects and all other projects combined we often recorded more than 4 million detections annually. Over a period of the last several years, this has resulted in a larger amount of data thananticipated and has resulted in issues regarding tag collisions which have increased the total number of “false” detections occurring in the database. False detections were detections in the database that were not linked to an active transmitter, or that were the same ID as an active transmitter but does not align with movement data for that fish. They can be generated by echoing due to the system (bathymetric profile, lots of rock, narrow river) or due to tag collisions when multiple tags ping at once. Finally, our ability to upload, store, and analyze raw data collected from the multitude of acoustic receivers has become more labour intensive with the large numbers of active acoustic transmitters at large (>400) in the Columbia River between HLK Dam in Canada and Grand Coulee Dam in the US.

We developed a telemetry database using a Client-Server model in Microsoft Access to help address data requirements related to examining White Sturgeon movements, to assist with identifying “false” detections, and to filter out unwanted/unnecessary tag data (e.g., non sturgeon species). The database was designed as a filtering tool that allows the organization and summary of data in an manner that results in outputs suitable for analyses. Queries were generated for each individual sturgeon tag that automatically generated a spreadsheet file containing the total number of times each tag was detected, each day, at a particular station or river kilometer. Data were binned in 24 hour periods as site fidelity is known to be high in this system and hourly observations of movement proved to be to fine scale for this species. The detection record was examined for each individual and in cases where there were false detections, these detections were removed.

A main objective of this program is to identify spawning related movements to help identify alternate spawning locations used in the system. We defined spawning movements in this study as rapid movements from one area during the spawning window, a residence period in an area for a short period of time, and then a migration to another location where residency time is long. In past years, fish appearing to make spawning related movements tended to return to their original location following time spent on the presumed spawning area. Further, other fish movements (timing and locations) that aligned with that individual were examined to provide additional support when identifying a possible spawning area.

Once the data were screened and all false detections removed, we summarized the 2008 through 2010 detection data and evaluated general movement patterns throughout each year and across years both by individuals and by sex. Proportional habitat use throughout the river was examined for all adults and then at the level of sex. We determined movements (spawning related and otherwise) on an individual basis and examined habitat use based on the proportion of detections of tagged White Sturgeon at each receiver location. Movements (distance travelled, km) between receiver stations were calculated by taking the difference in river kilometers between successive detections. The amount of distance travelled by month was calculated separately by sex, to help determine if either sex made movements to staging areas prior to spawning. We calculated the proportion of time an individual spent at a single location by dividing the number of detections per station by the total number of detections for that individual. This was conducted by monthly and by year for both sexes. Residence time, or site fidelity, was expressed by sex as the maximum amount of time spent at a single location over the study period.

# 3.0 MONITORING RESULTS

It is intended that the long term results of the adult monitoring program will be used to characterize movements and redistribution patterns, spawning behavior and frequency, relative abundance, habitat preferences, growth rates, survival, provide information on potential new hypotheses and physical works options, and provide baseline information necessary to evaluate physical works experiments and effects of opportunistic flows.

## 3.1 Physical Parameters

### 3.1.1 *Discharge*

Mean daily discharge measured from Arrow Reservoir (combined flows from HLK and ALH facility), the Kootenay River (combined discharge from Brilliant Dam (BRD) and the Brilliant Expansion (BRX) facility), at the Columbia River at Birchbank (combined Arrow Reservoir and Kootenay River discharge at rkm 29), and at the Columbia River at the Canada/U.S. International Border (combined discharge from Birchbank and the Pend'Oreille River) for the 2009 and 2010 study period is presented in Figure 4 and Figure 5, respectively.

The White Sturgeon spawning period is generally estimated to occur between May 01 - July 31, annually, and is based on a number of factors including egg and larval collections, historical river temperatures, and the timing peak freshet flows. For 2009 and 2010, mean daily discharge measured from Arrow Reservoir, the Kootenay River, at Birchbank, and at the Canada/U.S. International Border on the Columbia River during the predicted spawning period is summarized in Table 1. Peak freshet flows were reached on June 02 in 2009 and on June 21 in 2010. During both years, considerable variation in hourly mean discharge occurred within the predicted spawning period.

**Table 1.** Mean and maximum flow (in cubic meters per second; cms) at four locations on the Columbia River during the projected White Sturgeon spawning period in 2009 and 2010.

| Location (Year) | Mean Minimum Flow | Mean Maximum Flow |
|---|---|---|
| Arrow Reservoir (2009) | 527.9 cms (18642.2 cfs) | 1519.7 cms (53668.0 cfs), |
| Arrow Reservoir (2010) | 550.4 cms (19437.0 cfs) | 1482.2 cms (52343.4 cfs) |
| Kootenay River (2009) | 526.6 cms (18595.6 cfs) | 1960.2 cms (69222.6 cfs) |
| Kootenay River (2010) | 520.8 cms (18392.1 cfs) | 2112.4 cms (74599.1 cfs) |
| Birchbank (2009) | 1176.9 cms (41562.2 cfs) | 2727.9 cms (96334.6 cfs) |
| Birchbank (2010) | 1227.5 cms (43349.6 cfs) | 2360.7 cms (97493.6 cfs) |
| Border (2009) | 1969.2 cms (69542.2 cfs) | 4925.7 cms (173947.9 cfs), |
| Border (2010) | 1287.7 cms (45473.9 cfs) | 5132.3 cms (181244.8 cfs) |

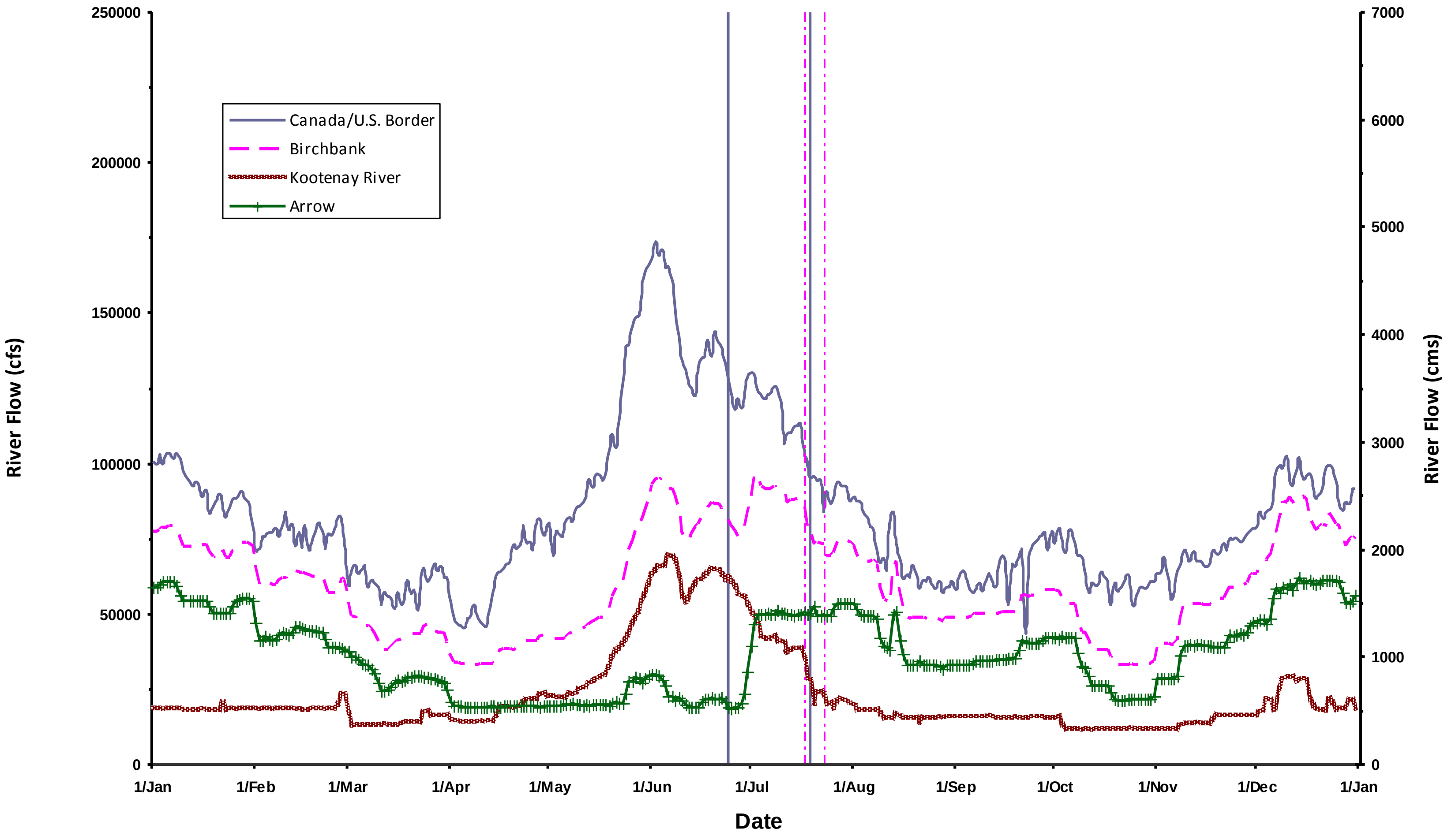

**Figure 4.** Mean daily discharge measured from Arrow Reservoir, the Kootenay River, at Birchbank, and at the Canada/U.S. International Border on the Columbia River from January 01, 2009 – December 31, 2009. The solid vertical bars represent the first and last estimated spawning dates at Waneta Eddy in 2009, either based on the collection of fertilized eggs or larvae. Vertical dashed bars represent the first and last estimated spawning date in the upper portion of the Columbia River (at or above rkm 18.2). Note that this spawning event estimate is based on the collection of larvae captured on two separate dates at rkm 18.2.

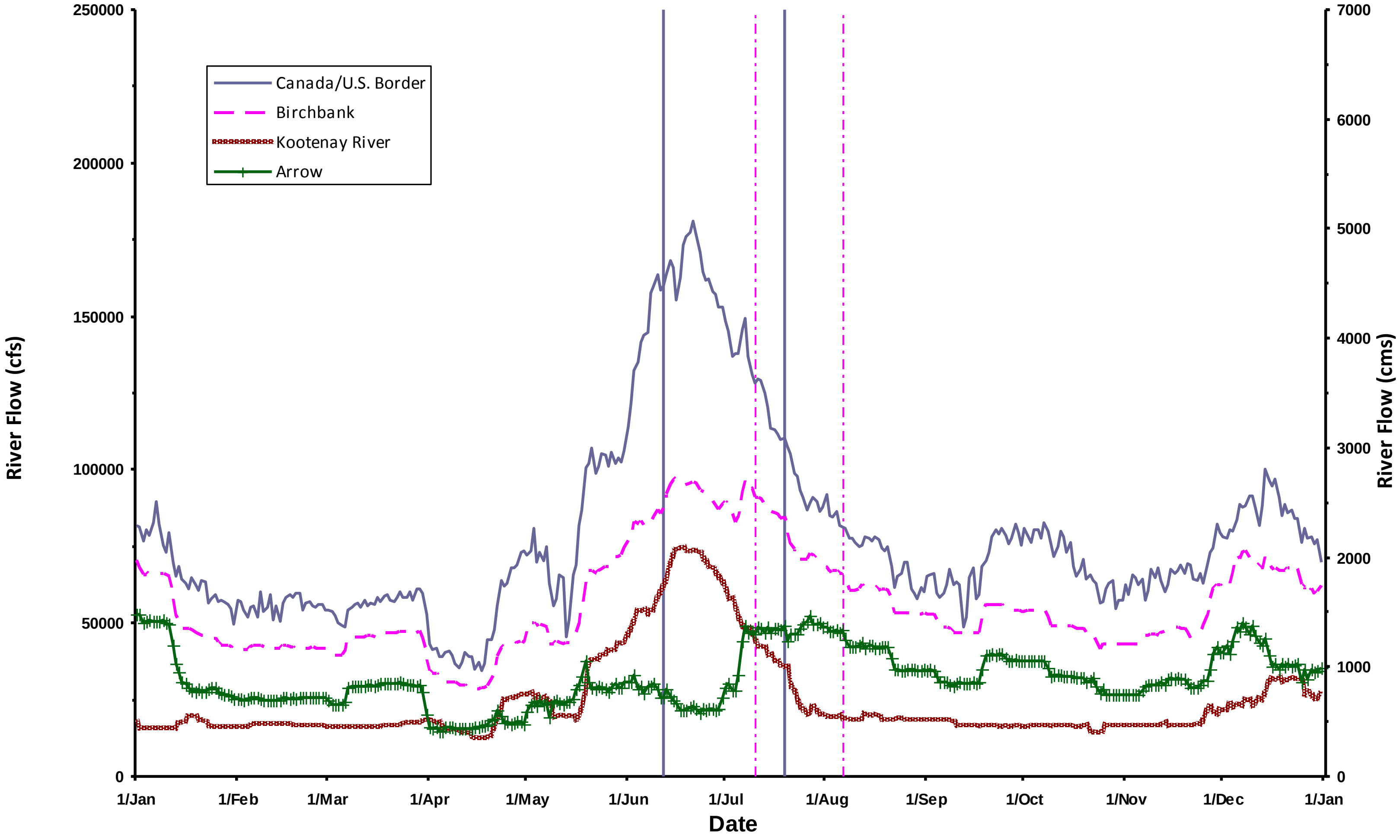

**Figure 5.** Mean daily discharge measured from Arrow Reservoir, the Kootenay River, at Birchbank, and at the Canada/U.S. International Border on the Columbia River from January 01, 2010 – December 31, 2010. The solid vertical bars represent the first and last estimated spawning dates at Waneta Eddy in 2010, either based on the collection of fertilized eggs or staged larvae. Vertical dashed bars represent the first and last estimated spawning dates in the upper portion of the Columbia River (at or above rkm 18.2). Note that these spawning events are estimated based on the collection of both eggs and larvae immediately downstream of ALH, and the collection of both a single egg and several larvae at rkm 18.2.

### 3.1.2 *Water Temperature*

During the predicted White Sturgeon spawning period in 2009, daily average water temperature at the Robson Bridge, Kinnaird Eddy, Waneta Eddy, and the Kootenay River ranged from 5.6°C to 13.8°C, 7.4°C to 16.5°C, 13.9°C to 18.2°C, and 7.9°C to 19.9°C, respectively (Figure 6). Spawning generally begins in the lower Columbia River when water temperatures reach 14°C (Hildebrand et al. 1999). River temperatures reached 14°C at Waneta Eddy on June 28, 2009 and the remainder of the sampling locations on June 30. Columbia River water temperatures were variable during the predicted spawning period but trends did not vary between monitoring locations (Figure 6).

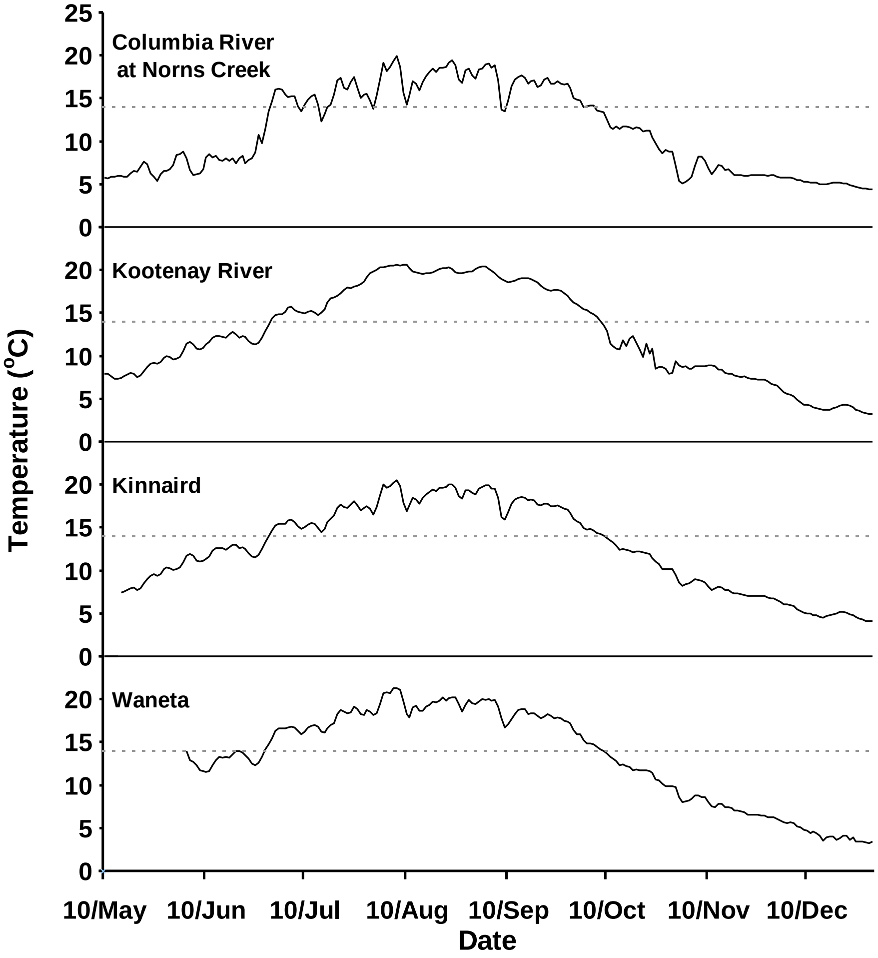

**Figure 6.** Mean daily water temperature recorded at four different locations within the lower Columbia River from May 10th until December 31st 2009. Locations are presented from most upstream (Columbia River at Norns Creek) to most downstream (Waneta). 14°C has been documented as the lower threshold for White Sturgeon spawning in the lower Columbia River (Hildebrand et al. 1999).

In 2010, daily average water temperature at the Robson Bridge, Kinnaird Eddy, Waneta Eddy, and the Kootenay River ranged from 4.9°C to 17.6°C, 7.4°C to 18.3°C, 7.4°C to 22.3°C, and 7.3°C to 19.3°C, respectively (Figure 7). River temperatures reached 14°C at Waneta Eddy on June 22, 2010 and the remainder of the sampling locations by July 03. Very similar to 2009, Columbia River water temperatures in 2010 were variable during the predicted spawning period but trends did not vary between monitoring locations (Figure 7). For both years, variations in water temperatures experienced during the study period can be attributed to warm/cold water influences caused in the Arrow Reservoir system (i.e., combined HLK and ALH discharges from Arrow Lakes Reservoir).

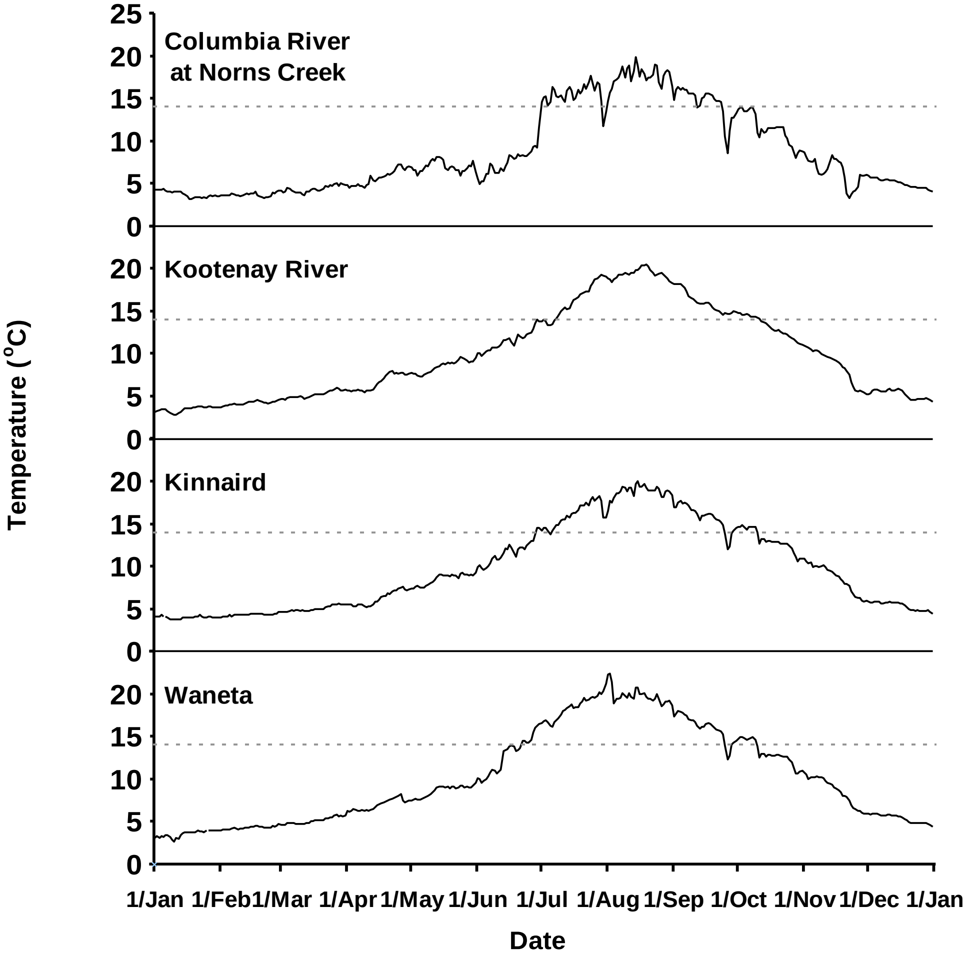

**Figure 7.** Mean daily water temperature ($^{o}$C) recorded at four different locations within the lower Columbia River from January 01 until December 31, 2010. Locations are presented from most upstream (Columbia River at Norns Creek) to most downstream (Waneta). 14$^{o}$C has been documented as the lower threshold for White Sturgeon spawning in the lower Columbia River (Hildebrand et al. 1999).

## 3.2 Adult Capture and Broodstock Acquisition

### 3.2.1 *Broodstock Acquisition and Population Characteristics*

**Set Lines -** A total of 124 White Sturgeon were captured in 1017.4 hours of set line effort expended over 12 field days during the 2009 broodstock acquisition program. Mean CPUE, as expressed as the number of fish captured per set line hour and incorporated all sampling zones, was 0.12. When compared to capture efforts from 2008 (38 White Sturgeon in 1277.3 hours of setline effort; 0.030 fish/set line hour) a mean CPUE of 0.12 was considerably higher as less effort was expended to capture 3 times as many fish. Effort to sample and select broodstock from a larger proportion of the river was instituted in 2009 and the resulting high CPUE values may be attributed to expanding sampling effort into new locations. The highest CPUE rates were from zone 5, zone 3, and zone 1. Mean CPUE expressed by the number of fish captured by 100 hook hours of effort was calculated to be 1.52 fish/100 hook hours. Of these 124 fish, 41% (n=51) were captured in zone 5 (primarily Fort Shepherd Eddy, Waneta Eddy, and American Eddy portion of the study area), 14% (n=17) were captured in zone 3 (primarily Genelle Eddy and Big Slough Eddy). An additional 45% (n=56) were captured in zone 1 (Robson Reach and Kootenay Eddy).

In 2010, a total of 135 White Sturgeon were captured in 1322.0 hours of set line effort expended over 15 field days during the broodstock acquisition program. Mean CPUE, as expressed as the number of fish captured per set line hour and incorporated all sampling zones, was 0.10. When compared to capture efforts from 2009, a mean CPUE of 0.10 in 2010 was considered to be consistent. Effort to sample and select broodstock from a larger proportion of the river was instituted again in 2010 and the relatively high CPUE values (when compared to years prior to 2009; BC Hydro 2009) may be attributed to expanding sampling effort into new locations. For 2010 the highest CPUE rates were from zone 1, zone 3, and zone 5, respectively. When compared to 2009 CPUE rates, the highest catch rates by zone are the exact opposite even though the similar effort was expanded across all three zones. Mean CPUE expressed by the number of fish captured by 100 hook hours of effort was calculated to be 1.28 fish/100 hook hours. Of these 135 fish, 69% (n=93) were captured in zone 1 (Robson Reach and Kootenay Eddy), 12% (n=16) were captured in zone 3 (primarily Genelle Eddy); and, 19% (n=26) were captured in zone 5 (primarily Fort Shepherd Eddy, Waneta Eddy, and American Eddy portion of the study area).

**Angling -** In 2009, a total of 35.18 hook-hours of angling effort were expended over the 12 day broodstock sampling period; resulting in the capture of 48 White Sturgeon (1.36 fish/hook-hour). Of these, 88% (n=42) of the fish were captured in the Fort Shepherd Eddy (zone 5; rkm 52.3), 2% (n=1) were captured at Kinnaird (zone 2; rkm 13.4), 6% (n=3) were captured in Big Slough Eddy (zone 3; rkm 30.4)and 4% (n=2) were captured in Waneta Eddy (zone 5; rkm 56.0). Angling resulted in relatively low rates of capture for mature fish (n=15; 31%) in 2009 when compared to setline captures of mature fish (n=111; 90%). Only 1 of the 48 fish captured angling were chosen as suitable hatchery candidates.

In 2010, a total of 24.75 hook-hours of angling effort were expended over the 15 day broodstock sampling period; resulting in the capture of 25 White Sturgeon (1.01 fish/hook-hour). Of these, 72% (n=18) of the fish were captured in Fort Shepherd Eddy (zone 5; rkm 52.3) and the remaining 28% (n=7) were captured in Big Slough Eddy (zone 3; rkm 30.4). Angling resulted in relatively low rates of capture for mature fish (n=4; 16%) in 2010; with the majority of the catch being represented by hatchery released juveniles from 2001-2004 brood years. None of the 4 adult fish captured during the angling component of this program were suitable hatchery candidates.

### 3.2.2 *Fish Handling, Transport, Hatchery Spawning and Release*

During the 2009 White Sturgeon broodstock acquisition program, 172 White Sturgeon were captured and assessed for marks that would indicate previous capture (presence of a tag, evidence of removal of a lateral scute, or removal of a section of a pectoral fin ray). Of the 172 White Sturgeon captured, 18 (males n=8; females n=10) were transported to the Kootenay Trout Hatchery (for possible contribution to the aquaculture program) and the remaining 154 were assessed for maturity, had biological information recorded, and were released at their capture locations. All White Sturgeon captured in this program were released alive. Of these fish, a total of 46 fish (26.7%) were first time captures (hatchery released juveniles are considered recaptures). Of the 46 first time captured fish, 41 were processed and released and 5 were determined to be sexually mature adults suitable for potential contribution to the conservation aquaculture program (4 males and 1 female), and were transported to the Kootenay Trout Hatchery.

In 2010, 135 White Sturgeon were captured and assessed for marks that would indicate previous capture (presence of a tag, evidence of removal of a lateral scute, or removal of a section of a pectoral fin ray). Of the 135 White Sturgeon captured, 20 (males n=10; females n=10) were transported to the Kootenay Trout Hatchery (for possible contribution to the aquaculture program) and the remaining 115 were assessed for maturity, had biological information recorded, and were released at their capture locations. All White Sturgeon captured in this program were released alive. Of these fish, a total of 54 fish (40%) were first time captures (hatchery released juveniles are considered recaptures). Of the 54 first time captured fish, 40 were processed and released and 14 were determined to be sexually mature adults suitable for potential contribution to the conservation aquaculture program (9 males and 5 female), and were transported to the Kootenay Trout Hatchery.

In 2009, 18 White Sturgeon (8 males, 10 females) were transported to Kootenay Trout Hatchery in Ft. Steele, B.C. for use as potential broodstock in the White Sturgeon conservation aquaculture program (FFSBC 2010), while in 2010, this number was 20 (10 males, 10 females) (FFSBC 2011).

All of the males and females that were spawned successfully contributed to six or more families in 2009 and 2010 (FFSBC 2010, 2011) and were released into the Columbia River during the spring of 2010 and 2011, respectively.

The mating design used was a complete factorial design where a portion of each female’s eggs were fertilized by each individual male. This design maximizes effective population size compared to monogamous or partial mating design, where the eggs from each female are mated with a single male (Fiumera et al. 2004). Fertilizations were conducted separately for each female/male combination to eliminate sperm competition which can result in the overrepresentation of a few males (Campton 2004).

### 3.2.3 *Adult Genetics*

During the early years of the program, tissue samples are being preserved for genetic analyses in later years. This includes fin clips from adults and juveniles as well as subsamples of eggs (incubated to hatch) and larvae collected each year. Using a these genetic samples to provide insight into adult breeding dynamics of the population, including estimates of variance in reproductive success, which can be used to guide aquaculture programs. Genetic data obtained from fertilized naturally produced eggs or dispersing larvae may be used to estimate genetic relationships among adults spawning at different locations to determine whether evidence exists for spatial genetic structure among sub-populations that spawn in different locations. Evidence for reproductive isolation among adults spawning in different locations would indicate spawning site fidelity at a fine spatial scale and could indicate that management of different sub-populations which occupy different areas of the river is warranted. No results exist to date as the tissue samples for both years have been archived.

## 3.3 Spawn Monitoring

### 3.3.1 *Egg Collection Mats and Drift Net Sampling*

**Waneta Area -** A total of eight index egg collection mat stations (two mats/station; seven tied to shore and one mid-channel) were repeated in the Waneta spawning area in 2009 and 2010 to facilitate comparisons with previous studies. These index stations have been consistently sampled since 2000 (R.L. & L. 2001; Golder 2002, 2003, 2004, 2005, 2006c, 2007, 2009a), and general monitoring has occurred in this area since 1993 (Tables 2 and 3).

In 2009 sampling occurred over a period of 24 field days between June 08 and August 07. In total, 1,715 eggs and 2 free embryos were captured during 21,964 hours of egg collection mat sampling; and an additional 77 eggs and 39 free embryos were captured during 90.1 hours of drift net sampling (Table 3). Similar to previous years, spawning occurred during the descending limb of the Pend d'Oreille River hydrograph and commenced after mean daily water temperatures in that system exceeded 14°C.

Sampling in 2010 occurred over a period of 22 field days commencing on June 09 and ending on July 30. In total, 4,003 eggs and 16 free embryos were captured during 18,204 mat-hours of egg collection mat sampling using egg collection mat sampling methods; and an additional 888 eggs and 89 larvae were captured during 113.4 hours of drift net sampling (Table 3). The total number of eggs captured (n=4,891) in 2010 also represent the largest number of eggs collected in a single spawning season when compared across all years that data have been collected (Tables 2 and 3).

**Table 2.** White Sturgeon egg and larvae catch at Waneta on the lower Columbia River,1993-2007.

| Year | Eggs | Larvae |
|---|---|---|
| 1993 (Low effort) | 61 | 4 |
| 1994 (Low Effort) | 33 | 0 |
| 1995 | 762 | 4 |
| 1996 | 1680 | 13 |
| 1998 | 1621 | 2 |
| 2000 | 474 | 1 |
| 2001 | 620 | 1 |
| 2002 | 2058 | 15 |
| 2003 | 3829 | 1 |
| 2004 | 2038 | 0 |
| 2005 | 4815 | 5 |
| 2007 | 1528 | 2 |

**Table 3.** White Sturgeon egg and larvae catch (and effort) on the lower Columbia River by year, site, and capture method, 2008-2010.

| | | Egg Mats | | | Drift Nets | | |
|---|---|---|---|---|---|---|---|
| Year | Location | Eggs | Larvae | Effort (Hrs) | Eggs | Larvae | Effort (Hrs) |
| 2008 | Waneta | 3,456 | 7 | 19,428 | 494 | 220 | 72 |
| | Kinnaird | 0 | 0 | 16,493 | 0 | 1 | 164 |
| 2009 | Waneta | 1,715 | 2 | 21,964 | 77 | 39 | 90.1 |
| | Kinnaird | 0 | 0 | 0 | 0 | 5 | 976.1 |
| | Robson | 0 | 0 | 0 | 0 | 0 | 3091.3 |
| 2010 | Waneta | 4,003 | 16 | 18,204 | 888 | 89 | 113.4 |
| | Kinnaird | 0 | 0 | 10,600 | 1 | 8 | 2,104 |
| | ALH | 12 | 0 | 3,608 | 30 | 115 | 2,084 |

In the majority of sampling years, spawning has occurred during the descending limb of the Pend d'Oreille River hydrograph and commenced after mean daily water temperatures in that system exceeded 14°C. Interestingly, in 2010, 37% (n=10) of the minimum estimated number of spawning events (n=27) occurred prior to the peak freshet date on 21 June and almost a week prior to the mean daily water temperatures in the Columbia river system reaching 14°C. While it is not considered uncommon for the species to spawn on both the ascending and descending limb of the hydrograph, it is considered rare in the lower Columbia River and in particular at the Waneta spawning site, as this has only occurred one other time in the past decade Table 4.

**Table 4.** Estimated number of annual spawning events at the Waneta spawning area from 2001-2010. Total numbers of White Sturgeon eggs and the estimated number of spawning events (based on staged embryos) is also presented as a comparison by year. The percentage of spawning events occurring on the descending limb of the hydrograph is also presented as a comparison by year.

| Year | Peak Discharge (cfs) | Peak Freshet Date | Total Number Eggs Sampled | Estimated Minimum Number of Spawning Events | % of Spawning Events Occurring on Descending Limb of Freshet Hydrograph |
|---|---|---|---|---|---|
| 1993 | 62154[a] | 17-May | 61 | 5 | 100 |
| 1994 | 52266[a] | 05-Jun | 33 | 4 | 100 |
| 1995 | 67804[a] | 10-Jun | 762 | 9 | 100 |
| 1996 | 98457[a] | 14-Jun | 1680 | 12 | 100 |
| 1998 | 71971[a] | 02-Jun | 1621 | 5 | 100 |
| 2000 | 60388[a] | 03-Jun | 474 | 5 | 100 |
| 2001 | 114651[b] | 26-May | 620 | 7 | 100 |
| 2002 | 230412[b] | 30-Jun | 2058 | 9 | 56 |
| 2003 | 150526[b] | 05-Jun | 3829 | 9 | 100 |
| 2004 | 135089[b] | 14-Jun | 2038 | 9 | 100 |
| 2005 | 166521[b] | 10-Jun | 4815 | 12 | 100 |
| 2007 | 185984[b] | 09-Jun | 1528 | 10 | 100 |
| 2008 | 216651[b] | 04-Jun | 3456 | 17 | 100 |
| 2009 | 173948[b] | 02-Jun | 1715 | 15 | 100 |
| 2010 | 181245[b] | 21-Jun | 4891 | 27 | 63 |

[a] discharge records from 1993 to 2000 only measured discharge from the Pend d'Oreille River at Waneta Dam

[b] discharge records from 2010 to 2010 indicate combined discharge from the Pend d'Oreille River at Waneta Dam and the Columbia River at the Canada/U.S. International Border

**Other Locations -** In addition to the egg mats and drift nets used for sampling at Waneta in 2009, additional nets were deployed at other locations previously noted that were suspected White Sturgeon spawning locations. While this sampling method was intended to collect early life stage larvae as part of the Early Life Stage and Juvenile Monitoring Program (CLB MON-29), drift nets have proven very effective at capturing eggs in the Waneta area in recent years. A total of 6 nets were fished in the Robson Reach area at river kilometre 5.1 (downstream of a suspected spawning location) in 2009 and sampled continuously for 24hours/day for the sampling period (July-early August). No eggs or larvae were captured at this location (Table 3). A total of 5 nets were deployed across the river channel near Blueberry at river kilometre 18.2; downstream of another suspected spawning location. Two drift nets were located near the right downstream bank, two were located near the left bank, and a fifth drift net was placed near the center of the river. Nets were sampled 5-6 hours/day during the study period (July-early August). Nets were deployed and retrieved daily, cleaned, samples collected, and then nets removed until the following days sampling. No eggs were collected in 2009; however, spawning was detected through the capture of several larvae at this site (Table 3; BC Hydro 2011b).

In 2010, both egg mat sampling and drift nets were strategically placed in other areas of the lower Columbia River in an effort to potentially locate alternate spawning locations. Egg mat sampling occurred over a period of 42 field days between June 14 and July 26 and drift net sampling occurred over a period of 26 field days between July 16 and August 11. In total, 14,208 mat-hours of egg collection mat sampling; and 4,188 hours of drift net sampling resulted in the capture of 43 eggs (Table 3). 42 were captured by both egg mats and drift nets in the Arrow Lakes Generating Station (ALH) tailrace site and a single egg was captured in a drift net at river kilometre 18.2 (Table 3). In 2010, drift nets sampled a total of 123 larvae, with the majority (n=115) sampled at the ALH site (Table 3).

### 3.3.2 *Egg Preservation and Staging*

**Waneta Area -** In 2009, the developmental stage of approximately 22% (n=379) of the total eggs captured at Waneta during egg collection mat and drift net sampling was determined. Based on the time of egg capture, developmental differences among eggs captured, and the presence of recently spawned eggs, it is estimated that 15 spawning events occurred in the Waneta spawning area in 2009. This was the second largest number of spawning events recorded since spawning studies were initiated in 1993. Based on the total number of eggs collected and the developmental stage of the proportion of eggs that were preserved, 59% (n=1,014) of the total eggs captured (n=1,715) and 5 of the 15 identified spawning events (33%) occurred in June (between June 21-30), with the remainder occurring between July 01-20.

In 2010, the developmental stage of approximately 15% (n = 718) of the total eggs captured at Waneta during egg collection mat and drift net sampling was determined. Based on the time of egg capture, developmental differences among eggs captured, and the presence of recently spawned eggs, it is estimated that a minimum of 27 spawning events occurred in 2010 at the Waneta spawning site. This is the largest number of spawning events estimated since spawning studies were initiated in 1993. Based on the total number of eggs collected and the developmental stage of the proportion of eggs that were preserved, 19% (n=936) of the total eggs captured and 12 of the 27 identified spawning events (44%) occurred in June (between June 11-30), with the remainder occurring between July 01-21.

**Other Locations** - In 2010, the developmental stage of 100% (n=43) of the total eggs captured at ALH and river kilometre 18.2 during egg collection mat and drift net sampling was determined. Based on the time of egg capture, developmental differences among eggs captured, and the presence of recently spawned eggs, it is estimated that only 2 spawning events occurred at the ALH spawning site and 1 event occurred upstream of rkm 18.2. Based on the total number of eggs captured and the developmental stage of the eggs that were preserved, the two events (n=42 eggs) at ALH occurred between July 10-16 and the single event upstream of rkm 18.2, occurred in August.

## 3.4 *In Situ* Egg Incubation

In 2009, White Sturgeon spawn monitoring was conducted in the Columbia and Pend d'Oreille confluence area (the Waneta area). 400 eggs were incubated in stream using an *in situ* approach, of which 65.3% successfully hatched (Table 5). Again in 2010, White Sturgeon spawn monitoring was conducted in the Waneta area. 1000 eggs were incubated in stream using an *in situ* approach, of which 49% successfully hatched (Table 6).

## 3.5 Egg Incubation Experiments

In 2009, egg incubation experiments were conducted at three locations in the Columbia River and results are presented in Table 7. Egg survival was very low, leading to methodological changes for 2010.

In 2010, White Sturgeon egg incubation was conducted at four locations in the Columbia River using different incubators than used in 2009. The results are presented in Table 8. The percent of eggs hatched in incubation plates in 2010 was 0.64 ± 0.33. There was no significant difference in the percent of eggs surviving to hatch between sites ($F = 1.12_{3,12}$, $p = 0.38$). There was a significant difference ($F = 12_{2,12}$, $p = 0.001$) in the percent of eggs surviving to hatch between maternal family groups with one female/male paring producing mostly dead. This was a consistent trend between sites and the interaction of maternal family group and site was not significant ($F = 0.44_{6,12}$, $p = 0.84$).

**Table 5.** Survival to hatch for White Sturgeon eggs collected from wild spawning events and incubated *in situ* at the Waneta spawning area in 2009.

| Set | | Pull | | Depth (m) | Total Eggs Incubated | Total Live Eggs | Total dead Eggs | Live Larvae | Dead Larvae | Survival to hatch |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Date | Time | | | | | | | |
| 24-Jun-09 | 13:43 | 2-Jul-09 | 13:43 | 3.6 | 50 | 0 | 10 | 23 | 2 | 0.50 |
| 24-Jun-09 | 13:43 | 2-Jul-09 | 13:43 | 3.6 | 50 | 0 | 6 | 20 | 11 | 0.62 |
| 26-Jun-09 | 13:41 | 2-Jul-09 | 13:41 | 3.7 | 100 | 0 | 24 | 46 | 10 | 0.56 |
| 2-Jul-09 | 13:36 | 6-Jul-09 | 13:36 | 3.6 | 50 | 0 | 17 | 22 | 3 | 0.50 |
| 6-Jul-09 | 13:35 | 10-Jul-09 | 13:35 | 2.8 | 50 | 0 | 15 | 34 | 0 | 0.68 |
| 13-Jul-09 | 14:07 | 17-Jul-09 | 14:07 | 2.9 | 50 | 0 | 4 | 46 | 0 | 0.92 |
| 20-Jul-09 | 10:14 | 27-Jul-09 | 10:14 | 2.2 | 50 | 0 | 5 | 44 | 0 | 0.88 |
| | | | | Totals | 400 | 0 | 81 | 235 | 26 | 0.67 |

**Table 6.** Survival to hatch for White Sturgeon eggs collected from wild spawning events and incubated *in situ* at the Waneta spawning area in 2010.

| Set | | Pull | | Depth (m) | Total Eggs Incubated | Total Live Eggs | Total dead Eggs | Live Larvae | Dead Larvae | Survival to hatch |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Date | Time | | | | | | | |
| 14-Jun-10 | 16:59 | 23-Jun-10 | 14:22 | 5.5 | 100 | 10 | 58 | 32 | 0 | 0.32 |
| 16-Jun-10 | 15:02 | 23-Jun-10 | 14:22 | 4.6 | 50 | 28 | 19 | 3 | 0 | 0.06 |
| 18-Jun-10 | 16:20 | 28-Jun-10 | 14:46 | 5.1 | 300 | 0 | 146 | 164 | 0 | 0.55 |
| 21-Jun-10 | 17:45 | 30-Jun-10 | 15:55 | 5.3 | 100 | 0 | 88 | 12 | 0 | 0.12 |
| 30-Jun-10 | 15:56 | 07-Jul-10 | 15:29 | 5.9 | 50 | 4 | 16 | 30 | 0 | 0.60 |
| 02-Jul-10 | 17:04 | 07-Jul-10 | 15:29 | 6.5 | 200 | 65 | 68 | 67 | 0 | 0.34 |
| 14-Jul-10 | 13:39 | 19-Jul-10 | 14:55 | 5.6 | 100 | 0 | 42 | 58 | 0 | 0.58 |
| 14-Jul-10 | 13:38 | 19-Jul-10 | 14:55 | 4.8 | 100 | 0 | 73 | 21 | 6 | 0.27 |
| | | | | Totals | 1000 | 107 | 510 | 387 | 6 | 0.35 |

**Table 7.** White Sturgeon egg survival to hatch within incubators placed at three locations within the lower Columbia River in 2009.

| Location | Set | | Pull | | Family | Total Eggs Incubated | Total Live Eggs | Total Dead Eggs | Live Larvae | Dead Larvae | Survival to Hatch |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | Time | Date | Time | | | | | | | |
| Balfour Bay | 15-Jul-09 | 15:40 | 22-Jul-09 | 19:22 | 1 | 0* | 0* | 0* | 0* | 0* | N/A |
| Balfour Bay | 15-Jul-09 | 15:40 | 22-Jul-09 | 19:22 | 2 | 110 | 0 | 80 | 8 | 22 | 0.27 |
| Balfour Bay | 15-Jul-09 | 15:40 | 22-Jul-09 | 19:22 | 3 | 126 | 0 | 122 | 2 | 2 | 0.03 |
| Balfour Bay | 15-Jul-09 | 15:40 | 22-Jul-09 | 19:22 | 4 | 94 | 0 | 94 | 0 | 0 | 0.00 |
| Balfour Bay | 15-Jul-09 | 15:40 | 22-Jul-09 | 19:22 | 5 | 104 | 0 | 91 | 0 | 13 | 0.13 |
| Balfour Bay | 15-Jul-09 | 15:40 | 22-Jul-09 | 19:22 | 6 | 98 | 0 | 96 | 1 | 1 | 0.02 |
| Balfour Bay | 15-Jul-09 | 15:40 | 22-Jul-09 | 19:22 | 7 | 102 | 0 | 101 | 0 | 1 | 0.01 |
| Balfour Bay | 15-Jul-09 | 15:40 | 22-Jul-09 | 19:22 | 8 | 101 | 0 | 79 | 11 | 11 | 0.22 |
| Balfour Bay | 15-Jul-09 | 15:40 | 22-Jul-09 | 19:22 | 9 | 119 | 0 | 88 | 1 | 30 | 0.26 |
| | | | | | | | | | | **Mean ± 1 SD** | **0.12 ± 0.11** |
| Kootenay Eddy | 15-Jul-09 | 15:21 | 22-Jul-09 | 20:10 | 1 | 115 | 0 | 114 | 0 | 1 | 0.01 |
| Kootenay Eddy | 15-Jul-09 | 15:21 | 22-Jul-09 | 20:10 | 2 | 97 | 0 | 97 | 0 | 0 | 0.00 |
| Kootenay Eddy | 15-Jul-09 | 15:21 | 22-Jul-09 | 20:10 | 3 | 106 | 0 | 106 | 0 | 0 | 0.00 |
| Kootenay Eddy | 15-Jul-09 | 15:21 | 22-Jul-09 | 20:10 | 4 | 122 | 0 | 122 | 0 | 0 | 0.00 |
| Kootenay Eddy | 15-Jul-09 | 15:21 | 22-Jul-09 | 20:10 | 5 | 107 | 0 | 107 | 0 | 0 | 0.00 |
| Kootenay Eddy | 15-Jul-09 | 15:21 | 22-Jul-09 | 20:10 | 6 | 118 | 0 | 118 | 0 | 0 | 0.00 |
| Kootenay Eddy | 15-Jul-09 | 15:21 | 22-Jul-09 | 20:10 | 7 | 120 | 0 | 115 | 0 | 5 | 0.04 |
| Kootenay Eddy | 15-Jul-09 | 15:21 | 22-Jul-09 | 20:10 | 8 | 157 | 0 | 157 | 0 | 0 | 0.00 |
| Kootenay Eddy | 15-Jul-09 | 15:21 | 22-Jul-09 | 20:10 | 9 | 106 | 0 | 103 | 0 | 3 | 0.03 |
| | | | | | | | | | | **Mean ± 1 SD** | **0.01 ± 0.02** |
| Kinnaird | 15-Jul-09 | 15:04 | 22-Jul-09 | 20:10 | 1 | 123 | 0 | 116 | 0 | 7 | 0.06 |
| Kinnaird | 15-Jul-09 | 15:04 | 22-Jul-09 | 20:10 | 2 | 124 | 0 | 38 | 78 | 8 | 0.69 |
| Kinnaird | 15-Jul-09 | 15:04 | 22-Jul-09 | 20:10 | 3 | 100 | 0 | 77 | 17 | 6 | 0.23 |
| Kinnaird | 15-Jul-09 | 15:04 | 22-Jul-09 | 20:10 | 4 | 82 | 2 | 78 | 0 | 2 | 0.02 |
| Kinnaird | 15-Jul-09 | 15:04 | 22-Jul-09 | 20:10 | 5 | 118 | 0 | 99 | 19 | 0 | 0.16 |
| Kinnaird | 15-Jul-09 | 15:04 | 22-Jul-09 | 20:10 | 6 | 85 | 3 | 65 | 10 | 7 | 0.20 |
| Kinnaird | 15-Jul-09 | 15:04 | 22-Jul-09 | 20:10 | 7 | 108 | 0 | 108 | 0 | 0 | 0.00 |
| Kinnaird | 15-Jul-09 | 15:04 | 22-Jul-09 | 20:10 | 8 | 90 | 0 | 72 | 3 | 15 | 0.20 |
| Kinnaird | 15-Jul-09 | 15:04 | 22-Jul-09 | 20:10 | 9 | 95 | 0 | 66 | 22 | 7 | 0.31 |
| | * incubator cell missing from array | | | | | | | | | **Mean ± 1 SD** | **0.20 ± 0.21** |

**Table 8.** White Sturgeon egg survival to hatch within incubators placed at four locations within the lower Columbia River in 2010.

| Location | Set | | Pull | | Family | Total Eggs Incubated | Total dead Eggs | Hatched Larvae | Survival |
|---|---|---|---|---|---|---|---|---|---|
| | Date | Time | Date | Time | | | | | |
| Robson | 23-Jun-10 | 13:41 | 06-Jul-10 | 15:09 | 1 | 100 | 2 | 98 | 0.98 |
| Robson | 23-Jun-10 | 13:41 | 06-Jul-10 | 15:09 | 2 | 100 | 10 | 90 | 0.90 |
| Robson | 23-Jun-10 | 13:41 | 06-Jul-10 | 15:09 | 3 | 100 | 7 | 93 | 0.93 |
| Robson | 23-Jun-10 | 13:41 | 06-Jul-10 | 15:09 | 4 | 100 | 8 | 92 | 0.92 |
| Robson | 23-Jun-10 | 13:41 | 06-Jul-10 | 15:09 | 5 | 100 | 100 | 0 | 0.00 |
| Robson | 23-Jun-10 | 13:41 | 06-Jul-10 | 15:09 | 6 | 100 | 19 | 81 | 0.81 |
| | | | | | | | | **Mean ± 1 SD** | **0.76 ± 0.37** |
| Kootenay | 23-Jun-10 | 12:55 | 06-Jul-10 | 13:20 | 1 | 100 | 12 | 88 | 0.88 |
| Kootenay | 23-Jun-10 | 12:55 | 06-Jul-10 | 13:20 | 2 | 100 | 15 | 85 | 0.85 |
| Kootenay | 23-Jun-10 | 12:55 | 06-Jul-10 | 13:20 | 3 | 100 | 14 | 86 | 0.86 |
| Kootenay | 23-Jun-10 | 12:55 | 06-Jul-10 | 13:20 | 4 | 100 | 15 | 85 | 0.85 |
| Kootenay | 23-Jun-10 | 12:55 | 06-Jul-10 | 13:20 | 5 | 100 | 100 | 0 | 0.00 |
| Kootenay | 23-Jun-10 | 12:55 | 06-Jul-10 | 13:20 | 6 | 100 | 22 | 78 | 0.78 |
| | | | | | | | | **Mean ± 1 SD** | **0.70 ± 0.35** |
| Kinnaird | 23-Jun-10 | 13:11 | 06-Jul-10 | 12:20 | 1 | 100 | 12 | 88 | 0.88 |
| Kinnaird | 23-Jun-10 | 13:11 | 06-Jul-10 | 12:20 | 2 | 100 | 20 | 80 | 0.80 |
| Kinnaird | 23-Jun-10 | 13:11 | 06-Jul-10 | 12:20 | 3 | 100 | 11 | 89 | 0.89 |
| Kinnaird | 23-Jun-10 | 13:11 | 06-Jul-10 | 12:20 | 4 | 100 | 36 | 64 | 0.64 |
| Kinnaird | 23-Jun-10 | 13:11 | 06-Jul-10 | 12:20 | 5 | 100 | 100 | 0 | 0.00 |
| Kinnaird | 23-Jun-10 | 13:11 | 06-Jul-10 | 12:20 | 6 | 100 | 96 | 4 | 0.04 |
| | | | | | | | | **Mean ± 1 SD** | **0.54 ± 0.41** |
| Waneta | 23-Jun-10 | 11:19 | 06-Jul-10 | 9:42 | 1 | 100 | 36 | 64 | 0.64 |
| Waneta | 23-Jun-10 | 11:19 | 06-Jul-10 | 9:42 | 2 | 100 | 22 | 78 | 0.78 |
| Waneta | 23-Jun-10 | 11:19 | 06-Jul-10 | 9:42 | 3 | 100 | 35 | 65 | 0.65 |
| Waneta | 23-Jun-10 | 11:19 | 06-Jul-10 | 9:42 | 4 | 100 | 37 | 63 | 0.63 |
| Waneta | 23-Jun-10 | 11:19 | 06-Jul-10 | 9:42 | 5 | 100 | 25 | 75 | 0.75 |
| Waneta | 23-Jun-10 | 11:19 | 06-Jul-10 | 9:42 | 6 | 100 | 46 | 54 | 0.54 |
| | | | | | | | | **Mean ± 1 SD** | **0.67 ± 0.09** |

## 3.6 Population Monitoring and Abundance

### 3.6.1 *Length Frequency Distribution*

The average fork length of all fish collected in 2009 (n=172) (Figure 8; black bars) was 148.3 ± 48.9 cm (± 1 Standard Deviation; SD). The average fork length of males (confirmed through maturation staging during surgical examinations or from previous capture history records of recaptured fish) captured in 2009 (n=38) was 176.8 ± 14.2 cm. The average fork length of females (confirmed through maturation staging during surgical examinations or from previous capture history records of recaptured fish) captured in 2009 (n=51) was 188.9 ± 19.8 cm. The average weight of all fish (n=172) was 35.9 ± 29.1 kg (± 1 SD). The average weight of known males in 2009 (n=38) was 46.1 ± 14.8 kg. The average weight of known females captured in 2009 (n=51) was 58.2 ± 22.0 kg.

The average length of fish sampled in 2009 is consistent with data collected across recent broodstock capture programs in the lower Columbia River (BC Hydro 2009). A large proportion of captures in 2009 (n=83) were not sexed. This is attributed in part by the fact that we tend to capture large numbers of hatchery released juveniles through both angling and set lines during the sampling period, and unless sex products are flowing from a fish upon capture the only method of determining sex is by surgical examination. This is only conducted if the adult appears to be a possible broodstock candidate (based on appearance or previous capture history). A total of 78 fish were examined using surgical methods, meaning that the remaining 94 were either sexed through previous capture history records of recaptured fish or were not sexed based on size and appearance.

The average fork length of all fish (n=135) collected in 2010 (Figure 8; white bars) was 177.9 ± 28.2 cm (± 1 SD). The average fork length of males (confirmed through maturation staging during surgical examinations or from previous capture history records of recaptured fish) captured in 2010 (n=41) was 180.9 ± 13.5 cm. The average fork length of females (confirmed through maturation staging during surgical examinations or from previous capture history records of recaptured fish) captured in 2010 (n=63) was 192.3 ± 18.7 cm. The average weight of all fish (n=135) was 47.4 ± 20.9 kg (± 1 SD). The average weight of known males in 2009 (n=41) was 45.7 ± 9.6 kg. The average weight of known females captured in 2009 (n=51) was 59.1 ± 19.4 kg.

A small proportion of captures in 2010 (n=31), when compared to 2009, were not sexed and many of the fish capture in 2010 appeared to be possible broodstock candidates (based on appearance or previous capture history), warranting further biological sampling by surgical examination. A total of 88 fish were examined using surgical methods, meaning that the remaining 47 were either sexed through previous capture history records of recaptured fish or were not sexed based on size and appearance.

Similar to previous broodstock capture programs, differences in size selectivity were observed in both 2009 and 2010 between the two capture methods. Set line sampling resulted in catching larger fish when compared to angling (Figure 9). In both 2009 and 2010, angling resulted in low rates of capture of mature fish; cumulatively for both years, only 13 of 74 fish captured angling were adults and only 1 of the 13 was selected as a suitable hatchery candidates. Cumulatively, set lines accounted for 37 of the 38 mature fish (n=17 in 2009; n=20 in 2010) captured and chosen as suitable hatchery candidates in 2009 and 2010.

The overall length-frequency distribution of White Sturgeon sampled in 2009 and 2010 is presented in Figure 8. Most of the large sturgeon captured were sampled by set line compared to angling (Figure 9), and the length frequency distribution of males and females was similar (Figure 10). Fish in the 40-110 cm range represent juvenile White Sturgeon released through the conservation aquaculture program since 2001. To reduce probability of capture of juvenile sturgeon on the setlines, hook used were only larger 2/0 size. This resulted in significantly larger sized fish (fork length; t = 1.97, df = 258, p = 0.001) captured in 2010 (mean fork length = 177.5 cm) compared to 2009 (mean fork length = 164.5 cm) following changes to larger hook sizes.

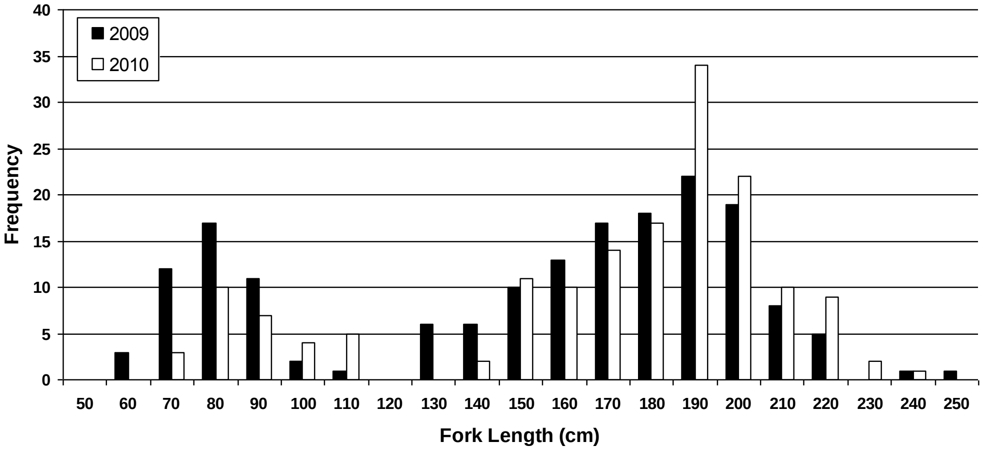

**Figure 8.** Length frequency of White Sturgeon captured during assessments in the lower Columbia River during 2009 and 2010.

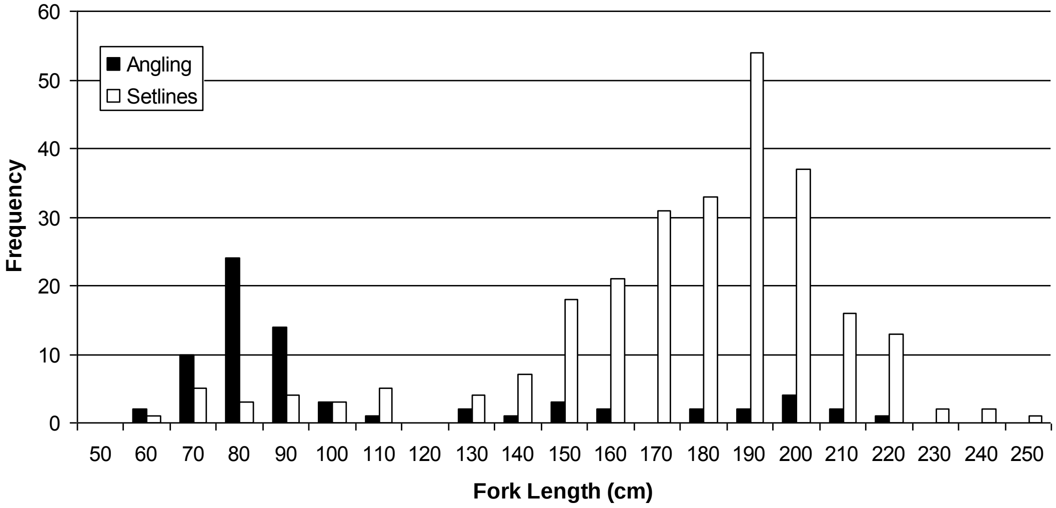

**Figure 9.** Length frequency of White Sturgeon captured using two gear types, angling and setlines, during assessments conducted during 2009 and 2010 in the lower Columbia River.

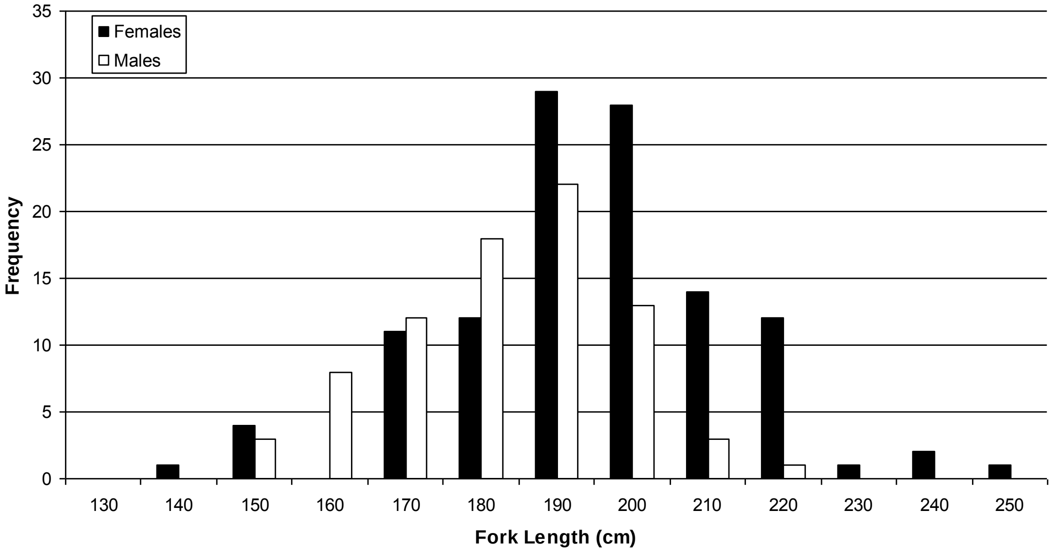

**Figure 10.** Length frequency of adult White Sturgeon of known sex (Female and Male) captured during assessments in the lower Columbia River during 2009 and 2010.

### 3.6.2 *Sex and Maturity*

In 2009, for the 89 White Sturgeon whose gender was known (through records from past captures) or determined through surgical examination, 38 were males and 51 were females (male:female sex ratio of 0.7:1). In 2010, for the 104 White Sturgeon whose gender was known (through records from past captures) or determined through surgical examination, 41 were males and 63 were females (male:female sex ratio of 0.7:1).

These ratios are not considered to be abnormal when comparing records from 2001 (since the start of the conservation aquaculture program; BC Hydro 2009) but slightly lower than all the life history data collected from research efforts in the 1990's (Hildebrand et al. 1999). Table 9 outlines the sex ratios observed for most years in the 1990's and since the conservation aquaculture program was initiated in 2001.

Of the 38 male White Sturgeon captured in 2009, 4 (11%) were of unknown maturity, 25 (66%) were early reproductive, and 9 (23%) were late reproductive or ripe (flowing). Of the 51 female White Sturgeon captured in 2009, 5 (10%) were of unknown maturity, 20 (39%) were early developing "whitish eggs", 4 (8%) were early developing "yellow egg", 12 (24%) were late "yellow egg", 10 (19%) were black eggs of spawning maturity and considered to be suitable candidates for the conservation aquaculture program, and 0 (0%) were post spawning/spent.

Of the 41 male White Sturgeon captured in 2010, 4 (10%) were of unknown maturity, 26 (63%) were early reproductive, and 11 (27%) were late reproductive or ripe (flowing). Of the 63 female White Sturgeon captured in 2009, 10 (16%) were of unknown maturity, 24 (38%) were early developing "whitish eggs", 12 (19%) were early developing "yellow egg", 7 (11%) were late "yellow egg", 10 (16%) were black eggs of spawning maturity and considered to be suitable candidates for the conservation aquaculture program, and 0 (0%) were post spawning/spent.

**Table 9.** Sex ratios for White Sturgeon captured from 1992-1998 and from 2001-2010 upper Columbia White Sturgeon broodstock acquisition program.

| Year | Number of Males | Number of Females | Sex Ratio (Males:Females) |
|---|---|---|---|
| 1992 | 45 | 28 | 1.6:1 |
| 1993 | 42 | 18 | 2.3:1 |
| 1994 | 23 | 22 | 1.1:1 |
| 1995 | 12 | 4 | 3.5:1 |
| 1996 | 25 | 8 | 3.1:1 |
| 1997 | 3 | 3 | 1.0:1 |
| 1998 | 7 | 6 | 1.2:1 |
| 2001 | 58 | 46 | 1.3:1 |
| 2002 | 21 | 31 | 0.7:1 |
| 2003 | 25 | 36 | 0.7:1 |
| 2004 | 39 | 50 | 0.8:1 |
| 2005 | 33 | 41 | 0.8:1 |
| 2006 | 26 | 17 | 1.5:1 |
| 2007 | 35 | 32 | 1.1:1 |
| 2008 | 15 | 18 | 0.8:1 |
| 2009 | 38 | 51 | 0.7:1 |
| 2010 | 41 | 63 | 0.7:1 |
| **Total** | **488** | **474** | **Mean 1.0:1** |

## 3.7 Acoustic Tagging and Telemetry

The total number of adult White Sturgeon that were implanted with an acoustic tag for this study was 62 with 54 used for telemetry data analysis.

Range testing conducted in the Robson and Waneta area resulted in higher detection range in the Robson area (up to 1 km) in the deeper lower flows compared to shorter detection ranges in the lower section of the river (~350 m). Other differences between the sites include less bedrock in the Robson area which is known to increase signal echoing and reduce detection range. More detailed range testing will be conducted in the coming years to describe detection probabilities throughout the system.

Movement data were compiled for adult White Sturgeon (n = 54) detected using the acoustic array in the lower Columbia River between January 2008 and November 2010. A final cleaned database totalling 3,573,260 detections were used to describe movements and habitat use across the different receiver locations in the river. An average of 83,099 and 65,114 detections were recorded per acoustic receiver station and per individual fish, respectively. Differences in distance travelled were observed prior to April 2009, with lower distances travelled during that period. In May of 2009, the array was reconfigured at 3 km intervals from HLK to the Canadian/US border and this resulted in the detection of small scale movements that were not originally detected under the original array design (Figure 11). Generally, peak movements occurred during the summer months (June-August) across all years (Figure 11). The largest distances travelled were observed in July of 2009 for both males (mean ± SE; 26.1 ± 9.2 km) and females (37.4 ± 10.5 km). Interestingly, a peak of movement was observed for females (n=10) in the month of January in both 2009 and 2010 which is typically a month of low movements compared to results from the previous array design (Golder 2009b).

Adult White Sturgeon have been suggested to exhibit high site fidelity in the lower Columbia River (Irvine et al. 2007; van Poorten and McAdam 2010). We found that the mean time an individual spent at a single location was 0.62 ± 0.21 (mean ± 1 SD) for individual White Sturgeon used in our analysis (Figure 12). Though not significantly different (t = 1.24, df = 52, p = 0.22), females had marginally higher site fidelity (0.65 ± 0.20) at single location compared to males (0.58 ± 0.21; Figure 13). The Robson reach was the highest used section of river by White Sturgeon irrespective of the time of year (Figure 12), though habitat use varied marginally between females and males (Figure 13). Generally, the number of sites used by White Sturgeon was higher during summer and fall months compared to the spring and winter months when water temperatures are lower. Waneta Eddy (56.0 rkm) is a high use site in the lower Columbia River for White Sturgeon. Adult White Sturgeon examined in this study spent time there throughout the year with the exception of the winter months. The sections of river immediately downstream of HLK (0.7 rkm) and at Fort Sheppard Eddy (52.5 rkm) were the primary sites for overwintering for the individuals we examined.

Fish implanted with acoustic transmitters that were of known sex and maturity were examined on an individual level to determine if spawning related movements occurred in either year. In 2009 during the predicted spawning period (June-August), two mature males predicted to spawn that year exhibited possible spawning related movements to the HLK Eddy and ALH area in late June. It is unknown whether these two fish spawned but these movements triggered an investigation of that specific area as a spawning location, and in July 2010, focused spawn monitoring efforts in this area confirmed spawning through both egg and larvae captures in the tailrace of ALH. Other spawning related movements in 2009 were made to the middle section of the Columbia between river kilometer 13 and 19 and the Waneta area.

Though descriptive in nature, identifying movement patterns of individuals during the spawning period helps to identify possible spawning areas that were previously unknown by helping to direct efforts for other parts of the program (e.g., egg mats and drift nets). Examination of White Sturgeon movements during the 2010 spawning period, indicate that two female White Sturgeon exhibited spawning related movements to Waneta. Both of these fish were present in the Waneta area for a small duration of time in early July of 2010. The movement pattern of these fish indicated a rapid migration from the upper section of the lower Columbia River downstream to the Waneta area, after which they returned to their original locations. Three males also exhibited spawning related movements during the 2010 spawning period. One male (considered to be a potential spawner between 2009-2011) exhibited a rapid upstream movement from the lower River to the HLK/ALH area during late June before falling back to lower sections of the river in late July. Another individual male made a rapid downstream movement from rkm 30.7 to the Waneta area in late June, and then returned back to its origin in late July. Finally, a male that was predicted to spawn in 2010 or 2011 based on sexual maturation at time of capture resided in Kootenay Eddy (following acoustic tag insertion) for almost 9 months before making a movement in July and August to an area downstream (between rkm 13.4 and rkm 19.8) and then returning to its previous location of origin. Further investigation of alternate or potential spawn sites in this stretch of river is warranted again in 2011. Based on the remaining White Sturgeon implanted with acoustic transmitters in 2009, 5 males and 3 females are likely to spawn in 2011.

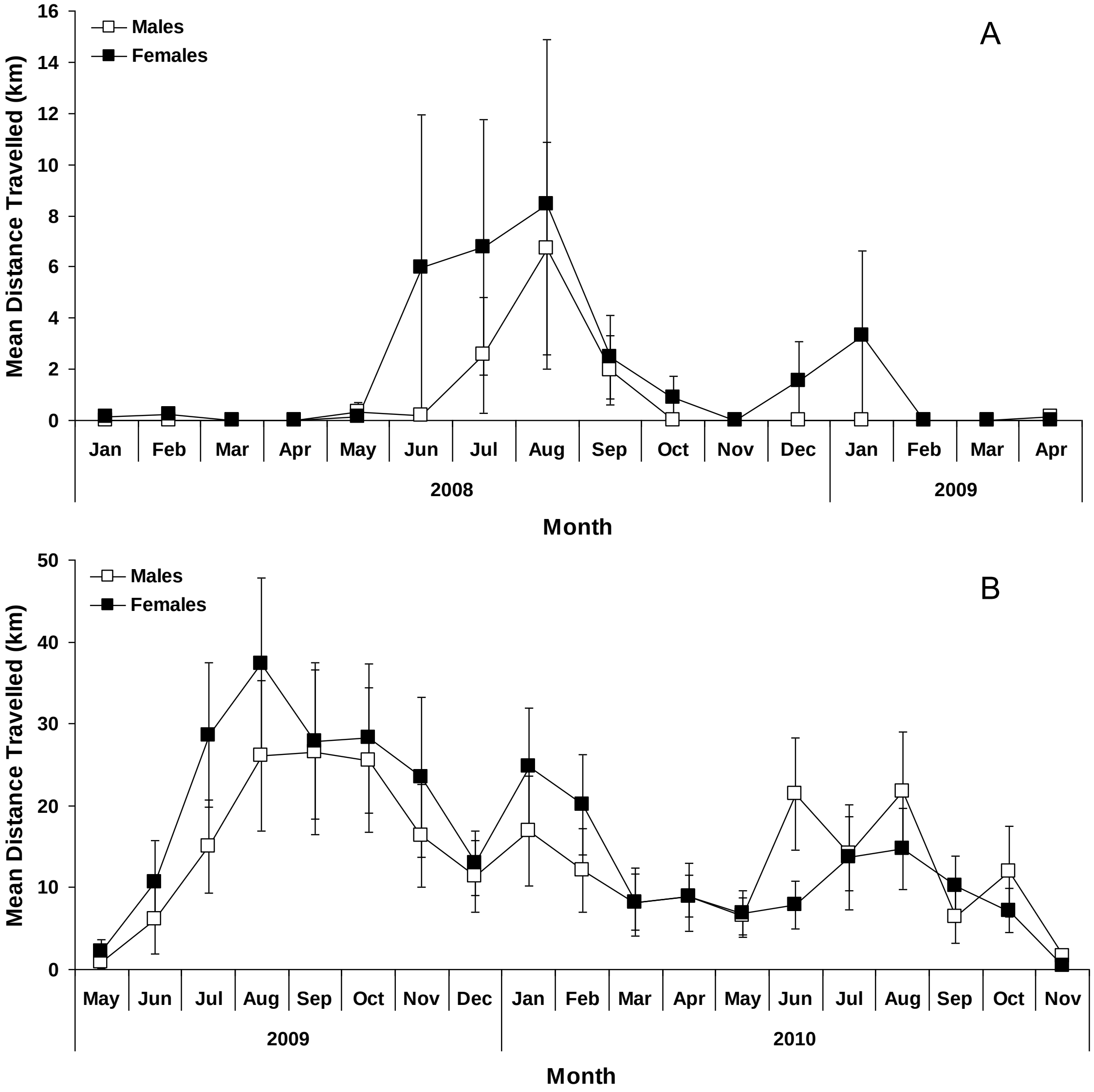

**Figure 11.** Panel A: Mean (± 1 SD) distance travelled for adult White Sturgeon in the lower Columbia River recorded in 2008 and early 2009 under the existing acoustic array configuration. Panel B: Mean (± 1 SD) distance travelled for adult White Sturgeon in the lower Columbia River following a change in the acoustic array configuration in 2009 through 2010.

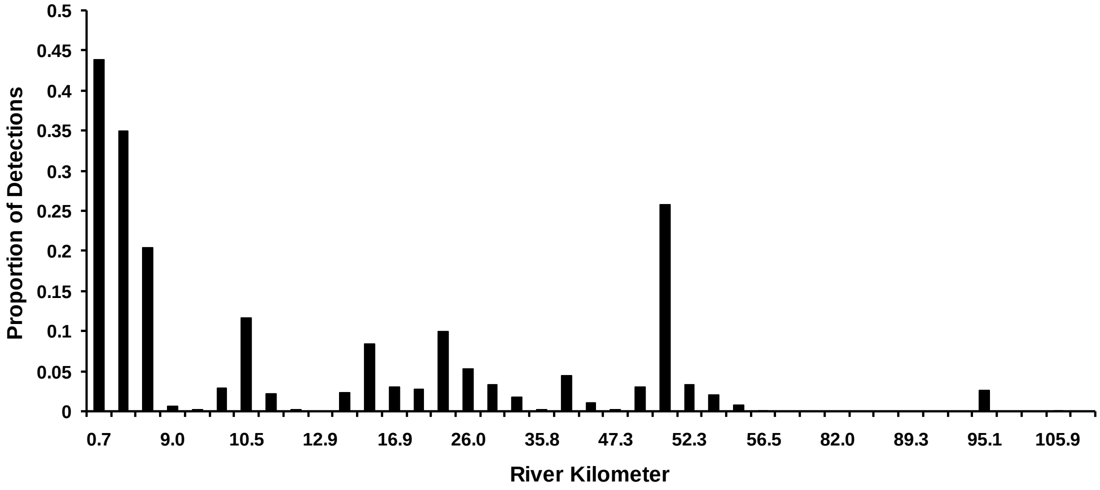

**Figure 12**. The maximum amount of time spent at a single location (site fidelity) for adult White Sturgeon (n=54) detected using acoustic telemetry in the lower Columbia River between 2008 and 2010.

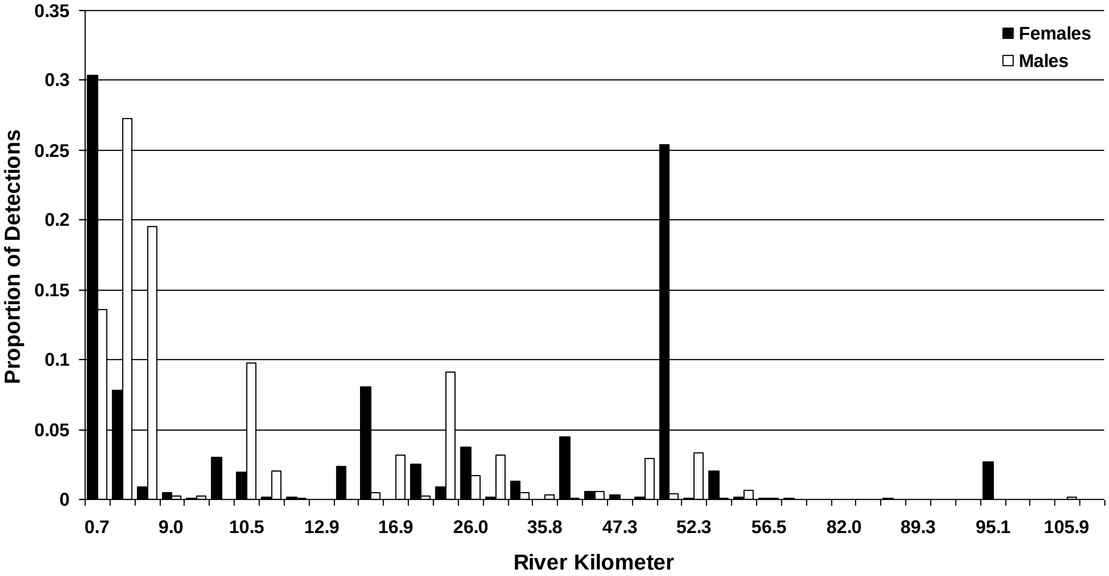

**Figure 13**. The maximum amount of time spent at a single location (site fidelity) for female (n=29) and male (n=25) adult White Sturgeon detected using acoustic telemetry in the lower Columbia River between 2008 and 2010.

## 4.0 DISCUSSION

One of the main objectives of this long term study is to improve our knowledge pertaining to White Sturgeon spawning timing, frequency, and, where possible, determine if there are other locations that are utilized for spawning in the study area. Throughout the species range, the spawning period is protracted and is generally estimated to occur in late spring through the summer months (May 01 - July 31; Parsley and Beckman 1994), with specific timing dependent on environmental cues (e.g., temperature, flows). In the lower Columbia River, in 2009 and 2010, spawning occurred from June into August, with slightly later timing in the upper portion of the study area above rkm 18.2 (Late July and August). This timing was estimated based on the developmental stages of eggs and larvae at the time of capture, and spawning may have occurred later into August than previously thought given the capture of a single egg at rkm 18.2 on the final day of sampling (Table 3). Spawning generally occurred on the descending limb of freshet (BC Hydro 2011a) and when water temperatures increased to above 14°C which is consistent with data collected across all years at this spawning location. This is similar to other studies in the Columbia (Hildebrand et al. 1999), Kootenai (Paragamian et al. 2001; Paragamian et al. 2002) and Fraser (Perrin et al. 2003) Rivers.

Another key finding of this study is that there are multiple locations in the study area where White Sturgeon spawning occurs outside of the Waneta area. Through the adult acoustic telemetry component of this study we were able to focus in on more specific areas in the upper river. By deploying both egg mats and drift nets at these sites, another spawning area was located at the ALH tailrace, and there is another site in the vicinity of Kinnaird. Numbers of adults spawning at these locations is unknown and it is unclear if they are used on an annual basis. Based on larval captures since 2007, the area near Kinnaird supports some level of annual reproduction. More work will be conducted in the coming years to determine specific egg deposition and larval hiding areas, which are important for recovery actions. Results in 2009 and 2010 suggest that the use of egg mats is appropriate at the Waneta area as there are larger numbers of spawning events compared to estimates at upstream locations and it is a method that has been consistently used for the past two decades. In other areas where exact spawning locations are poorly described, the use of drift nets accounted for the majority of eggs and larvae sampled (e.g., ALH; Table 3), so this method may be more applicable in trying to identify areas where a minor amount of spawning may occur. Another benefit of sampling with drift nets throughout the river is that they encounter various life stages of other species. These data are especially important for listed species such as Columbia sculpin (*Cottus hubbsi*) and Umatilla dace (*Rhinichthys umatilla*) and help inform work in other WUP programs (e.g., CLBMON 43; AMEC 2011).

The annual broodstock program provides an opportunity to assess several population parameters including length frequency, spawning periodicity, juvenile recruitment, etc. that otherwise may not be assessed on an annual basis in absence of a conservation culture program. The primary focus of the program is to provide adults that can contribute to the culture program. To date, the target of 10 females and 10 males has proved challenging to meet, with the number of adults successfully spawned each year not reaching those numbers several times in the decade the program has been underway. This is influenced annually by adult capture efficiency as exceeding 3-4 weeks of sampling effort is logistically challenging given other program objectives (e.g., spawn monitoring). Additionally, adults sexed to be in spawning condition on the river do not necessarily reproduce successfully in the hatchery (FFSBC 2011). To date, adults have not been reused in the program other than a single female who contributed eggs for production (2001) the first time and for experimental purposes (2010) the second time. Given the number of adults captured annually that have not been used in the hatchery program remains high, the goal remains to not reuse adults to contribute to production across multiple years.

Of the total fish captured, 0.52 and 0.77 percent of captured fish were mature and we were able to assign a sex and maturity stage to them in 2009 and 2010, respectively. Adding these data to previous years, the sex ratio in the population continues to be an average of 1 male per 1 female. Other studies have demonstrated slightly skewed sex ratios towards more males (Devore et al. 1995; Paragamian et al. 2005), which is not surprising given that males tend to mature early at smaller sizes. Since 2009, the sex of more than 100 adults has been assessed annually and an average (± 1 SD) of 19.0 (± 0.03) percent of females collected have been in spawning condition (F4 or F5). The assumption is that this is representative of the available spawning population as the broodstock program sampling is selective towards adults (hook and bait size) and has been spatially balanced throughout the Canadian section of the river. We acknowledge that adults residing in Lake Roosevelt are unaccounted for in this estimate as sampling is conducted prior to spawning, and adults move up to the lower Columbia from that area to spawn. However, based on several years worth of data, if we assume that the sex ratio is representative of the adult population at large (1,157; Irvine et al. 2007), that would indicate that 110 of 578 females may be in spawning condition on an annual basis. Genetic work planned in the coming years will help to confirm this.

We adjusted the setline gear in 2010 to only include large (size 20/0) hooks for the sampling program in an attempt to reduce by-catch of juvenile sturgeon. This resulted in a significant increase in the mean total length of fish captured while only a marginal increase in total fish capture was observed with 124 fish in 2009 and 136 in 2010. Direct comparison of total catch is not possible due to differing levels of setline effort across the two years (2009 = 3200; 2010 = 1500 hrs) though CPUE was lower in 2009 as more effort was deployed throughout the system in order to tag mature adults that were going to spawn within the coming years. A change to larger hooks resulted in a marginal decrease in juvenile captures from 23% in 2009 to 17.2% in 2010. Given high annual growth rates for juveniles in the lower Columbia (e.g., >10 cm/year; BC Hydro 2011b) it is unlikely that further changes can be made to prevent immature fish from being collected in proportionally higher abundances in the coming years.

Egg incubation, conducted *in situ*, has been completed over the past decade to improve survival to the larval stage and to provide tissue for future genetic analyses. This has traditionally been done at the Waneta area to incubate wild caught eggs and larvae (Golder 2009b, 2010) with survival exceeding 60% in most years. We conducted egg incubation at several locations in the river to evaluate survival to hatch. Results indicate that egg survival is high and this technique can be reliably used throughout the system. This is important when new spawning areas, like the one at HLK/ALH, are identified.

Finally, a specific objective for the early stages of this program was to deploy acoustic transmitters in adult male and female White Sturgeon that were predicted to spawn within 1-3 years of tagging. These data are important to identifying alternate spawning habitats, habitat use, and movements. Examination of individual fish movements during the 2009 spawning window led to an assessment of a possible alternate spawning location in the HLK and ALH area. Spawning was confirmed at this location in 2010 through the captures of both eggs and larvae and represents the second spawning area in the lower Columbia. It is not fully understood if this site is a spawning location that is used on an annual basis. Further monitoring of spawning activity for the life of this program will be important, especially as it relates to recovery goals and objectives. Movement data indicated movements generally occurred during the summer months for foraging or spawning with high site fidelity (> 60%) to specific river locations. Nelson and McAdam (2012) estimated site fidelity at greater than 90% but included much larger geographic zones in their estimates compared to the finer scale used in this study. Ultimately, high site fidelity suggests that maintaining spatial balance when sampling for adults is important for sampling efforts moving forward. This is especially critical when revising population estimates in the coming years as previous estimates were generated using capture data from a more restricted spatial scale.

# 5.0 RECOMMENDATIONS

1. Egg mats and drift nets should be utilized for collecting White Sturgeon eggs and larvae at the Waneta spawning site, but only drift nets should be used in areas where the spawning locations are unknown as they better represent samples from upstream locations. Egg mats should be deployed once the geographical boundaries are defined.
2. As additional years of data become available, utilize the adult capture data from the broodstock program to describe growth, length frequencies, and determine weight/length relationships.
3. Range testing should be conducted throughout the system to describe detection probabilities for unique receiver stations to inform movement results from adults.
4. A more concerted effort for acoustic telemetry downloads and mobile tracking in the White Sturgeon pre-spawning period would allow drift net effort to be deployed in suspected spawning locations.
5. Results demonstrate that majority of effort for broodstock collection should be through setlines and that large, size 20/0, hooks should be used exclusively to limit juvenile bycatch.
6. Now that a second spawning area has been defined in the lower Columbia River, undertake genetic work to determine the number of adults contributing to offspring collected at different spawning areas (e.g., Waneta and ALH) and at different life stages (e.g., eggs and larvae).

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