Columbia River Project Water Use Plan

Lower Columbia River

Reference: CLBMON #28 (Year 7)

Lower Columbia River Adult White Sturgeon Monitoring Program: 2014 Investigations Data Report

Study Period: January 2014 - December 2014

BC Hydro and Power Authority

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BC Hydro
Water License Requirements
Castlegar, BC

July 2015

Recommended Citation: BC Hydro. 2015. Lower Columbia River Adult White Sturgeon Monitoring Program (CLBMON-28). Year 7 Data Report. Report by BC Hydro, Castlegar, 53 pp.

EXECUTIVE SUMMARY

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 was identified as a priority during the Water Use Planning (WUP) process because it is undergoing recruitment failure and considerable uncertainties exist related to recovery. However, given the high value of power generation mandated under the Columbia River Treaty, significant flow alterations on the system were not deemed feasible and, as such, the system was designated as a working river. As a result of this designation, management responses targeted on White Sturgeon were focused on the collection of biological information that could determine the possible mechanisms resulting in recruitment failure and address issues related to recovery along with non-operational habitat improvements designed to increase spawning and rearing success. The general objectives of the early years of this program were to 1) collect mature adult White Sturgeon to serve as broodstock for the annual Conservation Aquaculture Program, 2) determine White Sturgeon spawning locations, habitat use, and movements using both direct (capture) and indirect (telemetry) methods, and 3) determine the timing and frequency of spawning events.

In 2014, conservation aquaculture broodstock targets were met with 5 females and 5 males being captured and successfully spawned at the Kootenay Sturgeon Hatchery (KSH). Similar to the past several years of the program, 8.3% of the 241 White Sturgeon collected during the broodstock programs were first time. In 2013, a five-year population assessment was initiated to estimate survival rate and abundance of the LCR White Sturgeon population. Additionally, data from this program will be used to determine growth rates across females, males, and immature fish (<150 cm fork length), fish condition, age class structuring, and density dependent responses. Movement data collected indicated that adult sturgeon activity generally occurred during the summer months for the assumed purposes of foraging or spawning. Adult White Sturgeon in the LCR are selecting deeper habitats of low flow, which do not appear to be limited under the current operational regime.

In 2014, spawning was estimated to have occurred from mid-June into late-July. The timing and duration of spawning activity was similar to past years, with the majority of spawning days occurring on the descending limb of the hydrograph at water temperatures above 14ºC. Based on developmental stages of collected eggs, it was estimated that 5 and 3 spawning days occurred in 2014 at Waneta and Kinnaird, respectively.

A 2012-2013 genetic study determined the number of adults spawning in the LCR was more than 10-fold the number used in the Conservation Aquaculture Program. In efforts to increase genetic diversity among stocked juvenile White Sturgeon, a Streamside Incubation Facility (SIF) was developed and constructed near the Waneta spawning location for the purpose of incubating naturally produced eggs collected in the LCR. Hatched larvae were transported to the KSH and reared for release in the following spring. While implemented in 2014 concurrently with the broodstock program, this program was initiated to increase number of adults contributing to stocked offspring, increase effective breeding number, and maintain genetic diversity within the population.

The state of knowledge pertaining to the various 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 most recent abundance estimate for adult White Sturgeon remains at 1,100 in the Canadian section of the lower Columbia River as estimated by Irvine et al. (2007). A systematic stock assessment was initiated in 2013 and encompasses the entire Transboundary Reach of the lower Columbia River in Canada and the US. The goals of the stock assessment are to develop population and survival estimates that can be used to track recovery targets for this population. At the conclusion of 2014, four sessions have been completed and data analyses to develop preliminary estimates will begin in 2015. - Generally, the wild population remains dominated by adult age classes, with limited wild juveniles captured during sampling programs (<1%). 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 and are just reaching a size where they will start entering the adult population. - Mature adults are abundant enough on an annual basis that individuals have not been reused for the broodstock program. A pilot aquaculture program that centers on using wild collected eggs and larvae has been developed and is based on results from previous years genetic analyses.
How much spawning occurs annually at known spawning locations, and are there other spawning locations unidentified in the lower Columbia River?	- Wild spawning has been detected annually, and while confidence around the estimates of the number of spawning days is unknown, it is estimated that multiple spawning days occur annually with eggs surviving to hatch. - Using genetic methods, it was found that 121.5 ± 34.7 adults (mean ± SD) were spawning within the Canadian section of the lower Columbia River within each of two years (2011 and 2012). - Spawning occurs annually at the Waneta area, with the number of estimating

Management Question	Status
	spawning days varying by year. - Spawning has been identified through egg and larval captures downstream of Hugh Keenleyside Dam and Arrow Lakes Generating Station (ALH). ALH represents the second known location of egg deposition in the Canadian section of the lower Columbia River and has been incorporated into annual monitoring programs to further describe spawning frequency and duration. - An additional spawning location is used annually (2007-2014) in the vicinity of Kinnaird but the exact location(s) of egg deposition remains unknown. - Additional spawning sites are used annually south of the international border (e.g., Northport WA).
What is the degree of interaction among sub-populations of White Sturgeon in the lower Columbia River?	- Though fidelity to specific habitats or locations has been identified as high, individuals have been identified to move throughout the river during the spring and summer months based on subsequent captures or telemetry tracking. Further, we know through direct capture and telemetry methods that fish move between Canada and the United States. However, though movements have been identified, 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 activity?	- Adults select deep, slow moving sections of the river, which are currently not limited by the existing operating regime of the river. Site fidelity is extremely high to very specific habitats and individuals spend >60% of their time at a single location. When movements do occur, they tend to occur during periods of warmer water and increasing flows assumed to be for either feeding or spawning. - Spawning related movements have been identified for a number of mature males and females. Individuals tend to move to spawning locations within the reach of river where they spend the majority of their time. Additional data are required to increase our confidence regarding the use of telemetry to address spawning related movements.

ACKNOWLEDGEMENTS

The 2014 study year of the lower Columbia River Adult White Sturgeon Monitoring Program (CLBMON-28) were funded by BC Hydro Water Licence Requirements White Sturgeon Management Program in Castlegar, B.C. BC Hydro would like to thank the following individuals for their contributions to the program:

BC Hydro

James Baxter
James Crossman
Dean Den Biesen
Gary Birch

Golder Associates Ltd. (Golder)

Dustin Ford
Larry Hildebrand

Freshwater Fisheries Society of BC

Ron Ek
Chad Fritz
Mike Keehn
Ken Scheer
Aaron Wolff

Terraquatic Resource Management

Marco Marrello

Jay Environmental

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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 is undergoing recruitment failure (Hildebrand and Parsley 2013) and the current level of natural recruitment is considered to be insufficient for maintaining a self-sustaining population. The exact mechanisms resulting in recruitment failure are unknown and as a result White Sturgeon were identified during the Water Use Planning (WUP) process as a priority species for conservation in the Columbia River. As such, a monitoring program was developed to address recovery of the population. It was recognized that in order to make progress towards recovery, baseline data were lacking on the population such as spawning locations, spawning activity (i.e., timing and frequency), and population level metrics like habitat use, movements, growth, and age class distribution.

Identification of spawning activity is an important component of recovery as it locates critical spawning habitat allowing for protection or enhancement of these areas as recovery moves forward. Prior to 2007, studies have identified White Sturgeon spawning sites at two primary locations in the mainstem LCR, including the confluence with the Pend d'Oreille River (Waneta, river kilometer (rkm) 56.0; UCWSRI 2012) and in the vicinity of Northport, Washington (Howell and McLellan 2006). From additional work, other sites have been located in the Canadian portion of the LCR based on egg and larval captures and adult movements. Spawning has been identified at the area immediately downstream of Hugh Keenleyside Dam (HLK) and the Arrow Lakes Generating Station (ALH, rkm 0.1; BC Hydro 2013; BC Hydro 2015a) and is known to occur in the vicinity of Kinnaird (rkm 13.0 to 19.0; Golder 2009a, 2009b; BC Hydro 2013; BC Hydro 2015a), though the exact location(s) of egg deposition remains unknown. These results demonstrate that undocumented spawning locations remain in the LCR, and emphasize the importance of continued monitoring to describe adult reproductive ecology, determine mechanisms influencing spawning site selection, and understand underlying mechanisms resulting in recruitment failure.

Outside of annual monitoring programs, the sole conservation strategy implemented to date has been restoration through releases of hatchery-reared juveniles. The objective of this strategy was to initiate a conservation aquaculture program to supplement the population until adequate levels of natural recruitment could be restored (UCSWRI 2012). 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). Additionally, the annual broodstock collection has served as the sole method of providing information on the biology of the population (e.g., length frequency, growth rates, population estimates). The program has been successful in providing 175 individual adults (78 females and 97 males) that have contributed to juveniles released into the LCR. Individuals have never been used more than once in the duration of the program. The Conservation Aquaculture Program has been successful in releasing 136,942 hatchery reared juvenile sturgeon into the LCR, 103,362 of which were released into the Canadian section (as of spring 2014).

For conservation aquaculture programs that rely on wild caught broodstock, factors such as number of spawning adults, limited access to spawning adults, and life history characteristics (i.e., intermittent spawning, delayed maturity, skewed sex ratios) can lead to management practices that reduce offspring levels of genetic diversity relative to levels represented in the natural spawning population (Allendorf and Phelps 1980; Ryman 1991; Crossman et al. 2011). Based on research conducted on White Sturgeon and other species, offspring of naturally produced eggs and larvae are less related and produce greater effective breeding numbers compared to offspring produced from direct gamete collection from adults (Crossman et al. 2011), as practiced in the LCR Conservation Aquaculture Program. Jay et al. (2014) estimated 121.5 ± 34.7 adults contributing to offspring annually within the LCR. Based on these results, it was advised by the Upper Columbia White Sturgeon Recovery Initiative Technical Working Group (UCWSRI TWG) to design a Streamside Incubation Facility (SIF) to incorporate wild offspring into the stocking practices increasing representation of LCR spawning adults and levels of genetic diversity among stocked juvenile White Sturgeon. Developing this facility in Canada also aligns with the US portion of the LCR White Sturgeon population, as collections of wild origin larvae serve as the basis for hatchery releases.

The ploidy of White Sturgeon has been previously determined to be 8N (Hedrick et al. 1991). However, spontaneous autopolyploid (12N) females that successfully mated with normal (8N) males producing viable offspring of intermediate ploidy (putative 10N; Drauch Schreier et al. 2011) using artificial spawning techniques has recently been detected in the wild brood within the Kootenai River White Sturgeon Conservation Aquaculture Program (Schreier et al. 2013). This has raised concerns within the LCR White Sturgeon Conservation Aquaculture Program, as the offspring reproductive success and effects on the wild population is unknown. Due to these recent discoveries, blood samples were recommended to be collected from all captured fish in this monitoring program going forward, to determine the incidence of 12N fish in the wild as well as hatchery-reared fish stocked in earlier years when ploidy levels were unknown.

In 2013, a systematic population assessment program was initiated to improve confidence in the abundance and survival rate estimates of the transboundary White Sturgeon population both in Canada and the US. While estimates have been made independently for both segments of the LCR population, it was deemed critical that confidence in the number of wild and hatchery origin at large was needed both to track progress towards recovery and to determining long-term population targets. This stock assessment program was developed to incorporate all habitats in Canada and the US and is being implemented concurrently by recovery initiative partners on both sides of the border. Data from this five-year program will not only provide confidence in the number of wild adults remaining, but will be used to determine growth rates across mature adults and immature fish (<150 cm fork length), assess fish condition, age class structuring, and identify density dependent responses due to an increasing hatchery origin population.

Given that the collection of life history data is an important component of addressing the mechanisms resulting in recruitment failure and overall recovery of White Sturgeon, the general objectives of this program were to:

1. Collect mature adult White Sturgeon, up to 10 females and 10 males, to contribute to the annual Conservation Aquaculture Program.
2. Determine White Sturgeon habitat use, movements and identify spawning locations through acoustic telemetry.
3. Describe White Sturgeon spawning locations, timing, and frequency through the deployment of egg mats and drift nets.
4. Implement the Canadian portion of the transboundary stock assessment to develop survival and abundance estimates for wild and hatchery origin White Sturgeon in the LCR population.

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 White Sturgeon recruitment in the LCR, 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 the 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 Columbia River Treaty.

This monitoring program was designed to provide long term information on adult White 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 LCR adult White Sturgeon population may provide key information to help resolve a number of the following outstanding issues identified by the WUP Fisheries Technical Committee (FTC).

1) As the annual average number of spawning days 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 LCR.

3) Baseline information acquired through this monitoring program may verify that the abundance of adult White Sturgeon in the LCR will not be adversely affected by management response measures.

4) Of equal importance to the maintenance of the remaining White Sturgeon population; are there sufficient adults to continue the Conservation Aquaculture 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 program's management questions.

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 LCR, 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, if deemed necessary, and assist with adjustments to stocking targets related to the Conservation Aquaculture Program.

The objectives for this program will have been met when:

1) Adult White Sturgeon life history characteristics including size, growth, age structure, and condition, and population characteristics including abundance and trajectory, survival rates, genetic status, and reproductive potential are quantified with sufficient consistency to describe annual trends.

2) Biological characteristics including spawn monitoring to assess annual 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 monitoring program are summarized as follows.

1.2.1 *Broodstock Acquisition*

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

4. Collect blood samples from all fish captured to assess ploidy levels and determine proportion of the wild adult population experiencing spontaneous autopolyploidy (12N).

1.2.2 *Spawn Monitoring*

1. Identify the timing and frequency of annual spawning days at the Waneta, ALH, and Kinnaird sites using egg mats and drift nets to collect White Sturgeon eggs and larvae.
2. Provide information on trends in the number of discrete spawning days as a measure of population demographics and reproductive potential.
3. Develop baseline data to assess the effectiveness of future management strategies.
4. Collect naturally produced eggs and larvae for streamside incubation and KSH rearing for stocking purposes.

1.2.3 *Population Monitoring, Abundance, and Characteristics*

Biological, mark-recapture, and related age structure data accumulated through bi-annual stock assessment program will be used to:

1. Assess population size and age structure, abundance, annual survival rates, and population trajectories.
2. Provide relative abundance and periodic updates to population estimates of the LCR White Sturgeon population.
3. Periodically compare new length frequency data to archived fin ray age analyses to correct for possible aging underestimates.
4. Collect blood samples from all captured wild fish to assess ploidy levels and determine proportion of population experiencing spontaneous autopolyploidy (12N).

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 population.

1.2.4 *Acoustic Tagging and Telemetry*

Monitor movements of acoustically tagged adult White Sturgeon using a passive remote receiver array established throughout the LCR to:

1. Assist with directing broodstock acquisition efforts by following movements of fish of known sex or maturity.
2. Provide new information on suspected staging areas, and other suspected spawning sites throughout the LCR that may be used during varying ranges of flows.
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 the 2014 monitoring program consisted of a 57 km stretch of the LCR between HLK and the Canada/U.S. Border (downstream of the Pend d'Oreille River confluence; Figure 1). The study area also included a small section (~2.5 km) of the Kootenay River below Brilliant Dam extending to its confluence with the LCR. To identify distribution of White Sturgeon for certain components (e.g., broodstock acquisition, population assessment), the LCR study area was stratified into 5 equal zones (11.2 km in length; consecutively numbered 1 though 5 from HLK to Canada/Us Border). Specific areas of the LCR sampled under the various components of the program are described below.

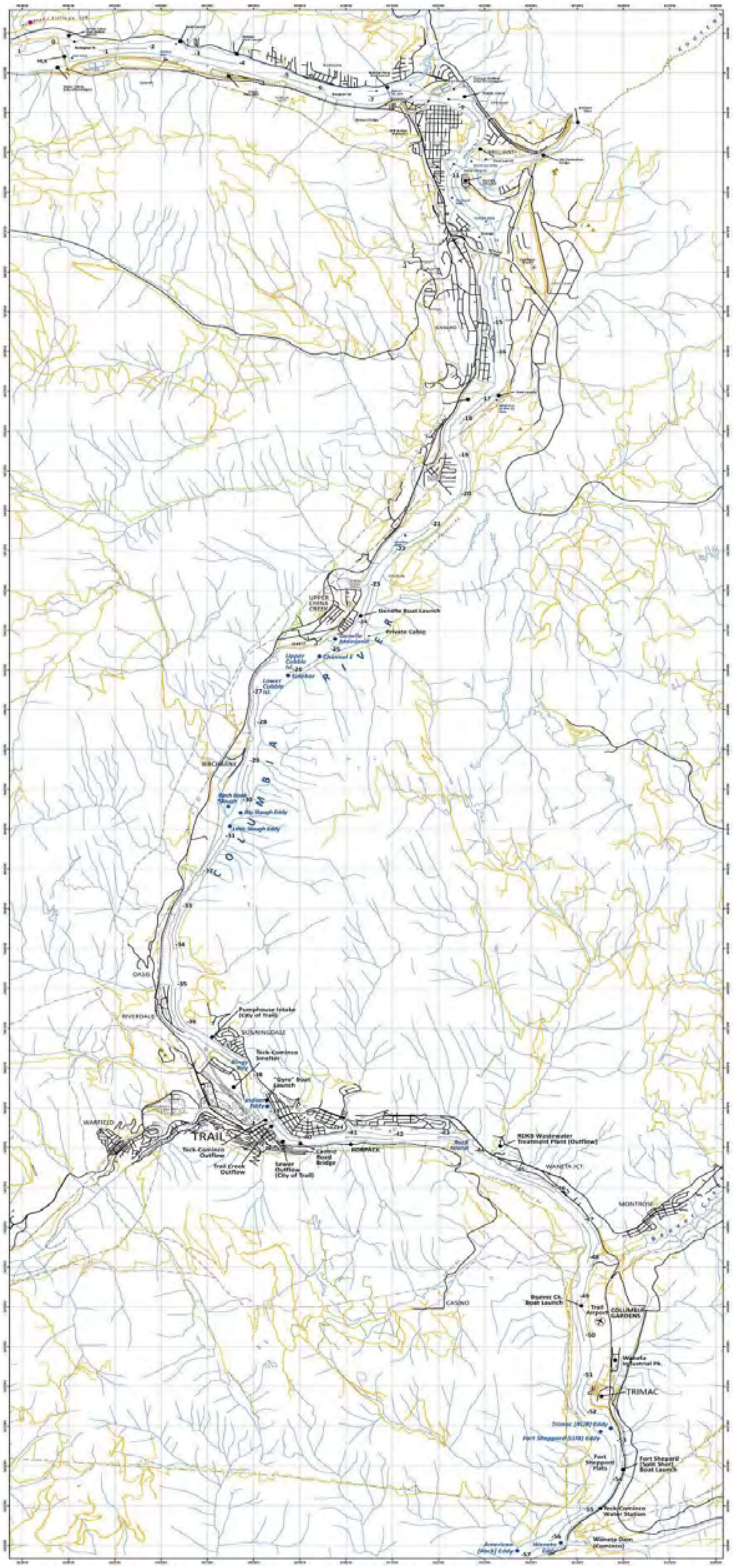

Figure 1. Overview of the study area between HLK (rkm 0.1) and the Canada/US border (rkm 57.0).

2.0 METHODOLGY

The monitoring study design follows the recommendations 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 LCR adult monitoring program (UCWSRI 2006) during the development of the Columbia WUP. Further, it incorporates the guidance of the WUP Fisheries Technical Committee (FTC). The program is divided into data collection during broodstock acquisition, spawn monitoring, stock assessment, movement studies, and a suite of population characteristics including age structure and population size and survival estimation. These are described separately below.

2.1 Physical Parameters

2.1.1 *Discharge*

In 2014, discharge records for the LCR at Arrow Reservoir (combined HLK and ALH discharges from Arrow Lakes Reservoir; rkm 0.1), the Kootenay River (combined discharge from Brilliant Dam and the Brilliant Expansion facility; rkm 10.5), the LCR at Birchbank (combine discharge from Arrow Lakes Reservoir and Kootenay River; rkm 29), and the LCR at the Canada/United States border (combined discharge from Birchbank and the Pend d'Oreille River; rkm 57.0) were obtained from BC Hydro power records. Discharge data were recorded at one-minute intervals and averaged hourly in cubic meters per second (cms) and cubic feet per second (cfs) 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, water planners and biologists readily use the non-metric discharge measurement (cfs) to discuss flows from hydroelectric facilities. As such, both units of measure (cms and cfs) are presented and referenced within the results section of this study report.

2.1.2 *Water Temperature*

For the 2014 study period, water temperatures were collected at several locations on the LCR including HLK (rkm 0.1), Kootenay River (rkm 10.5), Kinnaird (rkm 13.4), Genelle (rkm 26.0), and Waneta (rkm 56.0). Water temperatures were recorded hourly at each location using thermographs (Vemco Minilogs, accurate to ±0.1°C).

2.2 Broodstock Acquisition

2.2.1 *Study Design*

Prior to 2008, adult White Sturgeon sampling efforts in the LCR for broodstock collection (BC Hydro 2007, 2008), mark recapture, 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. As this Water Licence Requirements (WLR) study is closely linked to the other two LCR 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 sampling years to maintain consistency with related programs. Furthermore, it has been demonstrated that White Sturgeon in the LCR exhibit high site fidelity (BC Hydro 2011a; Hildebrand et al. 1999; van Poorten and McAdam 2010). Site fidelity further indicates the importance of ensuring that sampling strategies encompass the entire spatial distribution of habitats occurring throughout the entire LCR. 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.

In 2009 and 2010, sampling effort was randomly distributed with equal probability throughout the entire river (BC Hydro 2011a). In 2011 through 2014, sampling effort was not randomly distributed, but was spatially balanced throughout the study area based on previous results. To achieve this we sampled lower, middle, and upper river locations that were known as potential staging areas for adults in order to efficiently maximize the collection of mature adult White Sturgeon for conservation aquaculture broodstock.

2.2.2 *Adult Capture*

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 (UCSWRI 2012). 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 2014, the broodstock acquisition program used set lines as the method of capture. This method has been shown to provide higher White Sturgeon catch-rates, be 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 LCR 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 Washington Department of Fish and Wildlife (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 10 to 12 circle halibut hooks attached at 6.0 m intervals. 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 size used was 20/0 to limit the capture of smaller juveniles on the set lines. The barbs on all hooks were removed 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).

Set lines were deployed from a boat at both random and preselected sampling locations and set configuration was based on the physical parameters (i.e., 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 2 m. Set lines were deployed and remained in overnight at each selected site.

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 removed from the set line were tethered between two anchor points to the port or starboard side of the boat. While tethered, the entire body of the fish was 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 processing (described in Section 2.2.3).

Catch per unit effort (CPUE) was calculated as the total number of fish captured per set line hour. 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 and the number of hooks per set line was equalized relative to past studies.

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

Captured White Sturgeon were individually guided into a 2.5 m by 1.0 m 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 White 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.

Once on the boat, White Sturgeon were immediately checked for tags indicating if they had been previously captured. 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 from the removal of a section of the first pectoral fin ray for ageing purposes); 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 between the ventral edge of the dorsal fin and the right mid-dorsal line. A PIT tag was administered to any previously captured fish with no PIT tag present at time of capture. Prior to insertion, both the tag and 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. The 2nd left lateral scute was removed from new captures (or recaptured White Sturgeon if present) using a sterilized scalpel in a manner consistent with the marking strategy employed by WDFW and ODFW.

White Sturgeon were measured for fork length to the nearest 0.5 cm. Weight was determined by suspending the fish in the stretcher 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.

Blood samples were collected from all fish captured via the caudal vein. Fish were held ventral side up in the stretcher and a blood sample was taken midline just posterior of anal fin. A hypodermic needle (25 gauge) was inserted into the musculature perpendicular to the ventral surface until the spine was reached or blood entered the syringe. Blood was extracted until a sufficient amount was collected (approximately 2 ml) and a blood smear was made immediately after extraction. For each blood smear, a drop of blood was placed on an untreated slide and smeared by placing the end of another slide at an angle and dragging the blood toward the end of the sample slide. Slides were labeled with the fish ID number, air dried, and stored for later analyses by the FFSBC Fish Health Lab.

The majority of adult White Sturgeon (>150 cm fork length) were surgically examined to assess sexual maturity. This included fish that were new captures, or mature candidates for the Conservation Aquaculture Program. A 1.5 to 2.0 cm 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 using an otoscope and classified based on qualitative histology (Bruch et al. 2001; Golder 2006a; see UCWSRI for details). Female sexual maturity stage codes included: F0: females based on previous sex determination of unknown maturity (no surgical examination); F1: early developing white eggs; F2: early developing yellow eggs; F3: late developing yellow eggs; F4: black eggs of spawning maturity considered suitable candidates for broodstock; and F5: post spawn/spent. Male sexual maturity stage codes included: M0: males based on previous sex determination of unknown maturity (no surgical examination); M1: early reproductive; M2: late reproductive or ripe/flowing. Female developmental stages are usually more easily determined since ovary size, egg colour, and average egg diameter 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 (PDS). 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. White Sturgeon were returned to the water following processing and remained in the stretcher until they swam away under their own volition.

In 2014, Freshwater Fisheries Society of BC (FFSBC) staff conducted all fish transportation efforts from the LCR to the Kootenay Sturgeon Hatchery (KSH) in Wardner, B.C. White Sturgeon identified as being suitable for fish culture purposes were transferred from the 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 (e.g., hook wounds, surficial rope abrasions) sustained during capture.

All of the adult White Sturgeon transported to the 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 LCR. Salt treatments (5-10 ppt) 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. Egg biopsies were preformed regularly for each female to determine ripeness and predict when to induce spawn using standard fish culture hormone injections. Details regarding hatchery spawning of adults are provided in the FFSBC's annual reports (FFSBC 2015).

Adults were held at the KSH for a short recovery (days) and observational period before transportation back to the LCR for release near the capture location. No fish were implanted with acoustic transmitters in 2014 due to the LCR having large numbers of sturgeon (>150) and other species with active transmitters.

2.2.4 *Data Analysis*

Adult and juvenile White Sturgeon biological data analyzed in this report include sex ratios, fork length frequencies, mean weight, and mean relative weight (W_r). Relative weight (W_r) is a measure of fish plumpness allowing comparison between fish of different lengths, inherent changes in body forms, and populations (Wege and Anderson 1978). W_r is calculated with the following formula:

$$W_r = (W/W_S) * 100$$

where W is the actual fish weight (kg), and W_S is a standard weight for fish of the same length (Wege and Anderson 1978). We determined W_r for captured adults of known sex during broodstock acquisition for the years 2009 through 2014 according to the White Sturgeon standard weight-length equation developed by Beamesderfer (1993):

$$W_S = 2.735E^{-6} * L^{3.232}$$

where W_S is a standardize weight and L is fork length (FL; cm).

2.2.5 *Adult Genetics*

Though no genetic analyses using adult samples were planned in 2014, tissue samples were collected for future genetic analysis from all captured adult White Sturgeon. A small piece of tissue (approximately 1.5 cm by 1.5 cm) from the tip of the dorsal fin was removed using surgical scissors, split into two sub samples, and archived in labelled scale envelopes.

2.3 Spawn Monitoring

2.3.1 *Study Design*

Monitoring of White Sturgeon spawning was carried out at several sites for this program based on previous data collection where White Sturgeon have been confirmed to have spawned, or have been suspected to spawn. LCR White Sturgeon cannot be observed congregating to spawn due to water depth and relatively high flow volume therefore spawning was documented through the collection of progeny.

Monitoring of spawning activity occurred at Waneta (rkm 56.0), which is located at the Pend d'Oreille River confluence immediately upstream of the Canada/US border (Figure 2). This site has been monitored for spawning activity since 1993 and is the main area of White Sturgeon spawning within the LCR in Canada (Hildebrand et al. 1999; Irvine et al. 2007; Golder 2009a). Secondary sites for spawn monitoring were also located in upstream sections of the LCR at ALH (rkm 0.1) and Kinnaird (rkm 14.5 to rkm 18.2). Spawning has been documented immediately downstream of ALH with geographical boundaries previously described by Terraquatic Resource Management (2011) (Figure 2). Six sites downstream of Kinnaird were also monitored (Figure 2). These spawn-monitoring sites were selected based on past spawn monitoring surveys and White Sturgeon movement studies (BC Hydro 2013, 2015a).

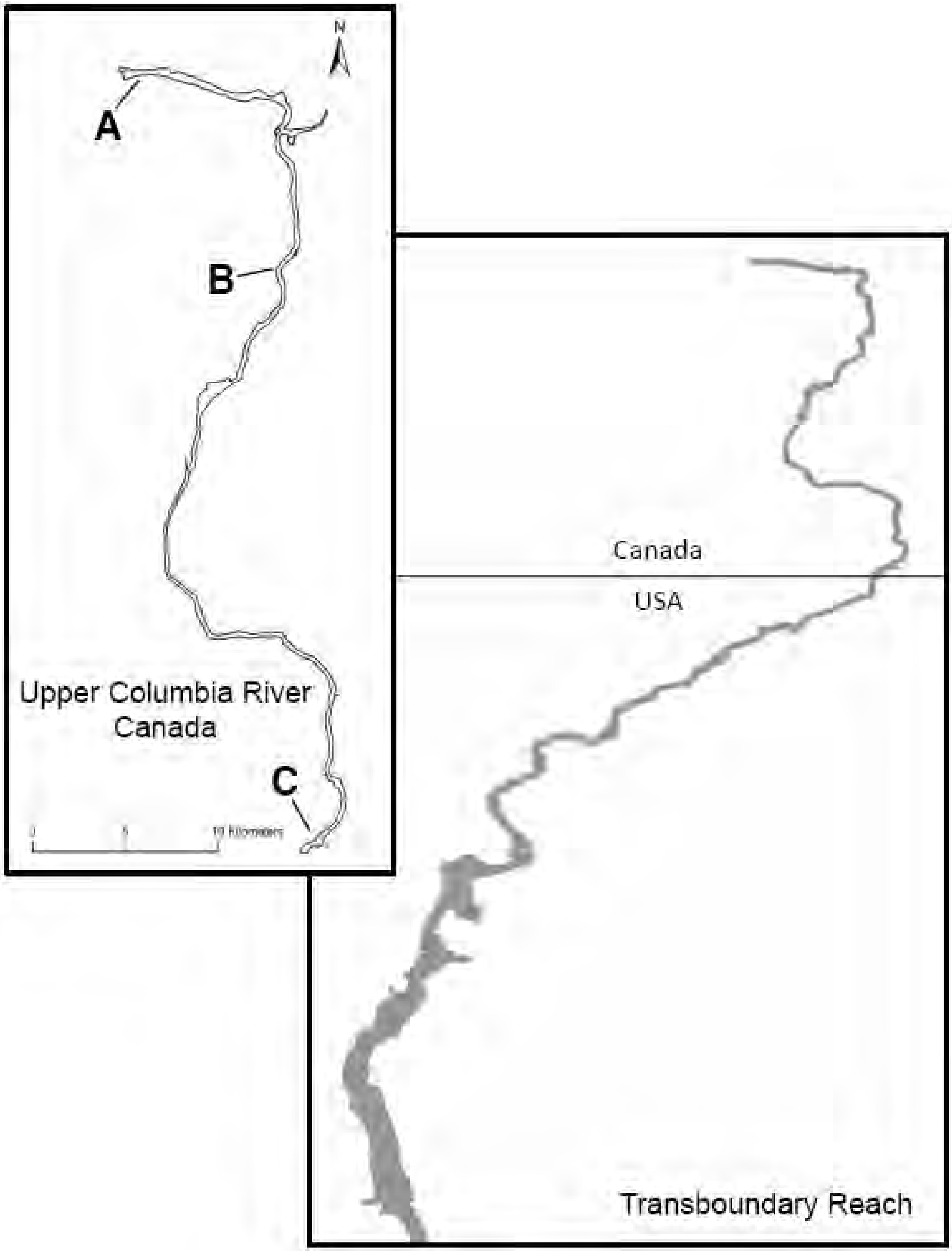

Figure 2. Egg mat and drift net deployment sites of ALH (rkm 0.1; A), Kinnaird (rkm 14.5, rkm 18.2; B), and Waneta (rkm 56.0; C) in the LCR in 2014.

2.3.2 *Egg Collection Mats and Drift Net Sampling Methods*

White Sturgeon are broadcast spawners allowing for the collection of eggs and larvae using passive techniques such as egg collection mats and drift nets. Egg collection mats are a proven method of collecting White Sturgeon eggs (McCabe and Beckman 1990; McCabe and Tracey 1993) and have been effective in the LCR since 1993 (Golder 2002, 2010). Drift net sampling has been used successfully to capture both fertilized eggs and passively dispersing yolk-sac larvae for many sturgeon species including White Sturgeon (Golder 2009a), Lake Sturgeon (*Acipenser fulvescens*; Auer and Baker 2002), and Shortnose Sturgeon (*Acipenser brevirostrum*; Moser et al. 2000). Drift net sampling has been added as a component to the adult spawn monitoring program in recent years and has proven successful at documenting spawning activity through the collection of and eggs and larvae (BC Hydro 2013).

Spawn-monitoring remained consistent with previously established locations of egg mat and drift net sampling (see Golder 2009b, 2010, 2012, 2013, 2014, and Terraquatic Resource Management 2011 for details). Egg mats were deployed at Waneta (n=7) and ALH (n= 6). Drift nets were deployed at Waneta (n=2), ALH (n=4), rkm 14.5 (n=2), rkm 15.0 (n=2), rkm 15.6 (n=2), rkm 16.9 (n=1), rkm 17.3 (n=1), and rkm 18.2 (n=4).

Egg Collection Mats – Equipment and procedures for deployment and retrieval were replicated from previous monitoring protocols (Golder 2009a; Terraquatic Resource Management 2011). Egg mats consisted of latex coated animal hair filter material fastened to a 0.76 m by 0.91 m steel frame. Two lead steel claw river anchors (30kg) attached by approximately 6 m of 3/8 galvanized chain were used to anchor each egg mat. Two 30 m sections of 0.95 cm diameter braided rope were attached to the downstream anchor. One rope was attached to a buoy at the surface of the river providing a means to remove the entire anchoring system. The second rope was attached directly to the front of the egg mat. A third 0.95 cm diameter braided rope was attached from the back of the egg mat to a surface buoy to facilitate deployment and retrieval without dislodging the anchor system. In areas of low flow, egg mats were deployed with a single 10 kg lead anchor fastened to a leading bridal. A rope from the back of the egg mat to a surface buoy was used to facilitate deployment and retrieval of the entire system.

Egg mats were deployed for 24 to 48 hour periods. Egg mats rested flat on the river substrate and entrapped drifting or deposited eggs in the filter material. Upon retrieval, egg mats were brought to the surface by means of the egg mat buoy line. Once at the surface, egg mats were detached from the anchor system and brought into the boat for inspection. Both sides of the egg mats were inspected thoroughly by a minimum of 2 crewmembers before being redeployed. Eggs were enumerated by egg mat for each sampling location and occasion. Deployment and retrieval times, water temperatures (°C), and depths (m) at each sampling location were recorded.

Drift Net – Deployment and anchor system specifications were consistent between sampling locations in the LCR. Drift nets used during the sampling period were of standard and altered designs. Standard drift nets consisted of a

1.3 cm rolled stainless steel frame (D shape) with a 0.6 m x 0.8 m opening trailed by a 4 m tapered plankton net (0.16 cm delta mesh size) ending with a collection cup device. Altered drift nets included 1.3 cm rolled stainless steel bars welded vertically across the standard drift net frame at 15 cm intervals to prohibit adult and juvenile White Sturgeon from entering the drift net. Standard drift nets were deployed for 2 to 4 hours periods (short-set). Altered drift nets were deployed for 24-hour periods (long-set).

Two lead steel claw river anchors (30 kg) attached by approximately 6 m of 3/8 galvanized chain were used to anchor each drift net. Two 30 m sections of 0.95 cm diameter braided rope were attached to the downstream anchor. One rope was attached to a buoy at the surface of the river providing a means to remove the entire anchoring system. The second rope was attached directly to the front of the drift net. A third 0.95 cm diameter braided rope was attached from the top of the drift net frame to a surface buoy for deployment and retrieval without dislodging the anchor system.

Drift nets were deployed to stand perpendicular to the river bottom and collect drifting eggs and larvae in the tapered plankton net. Upon retrieval, drift nets were brought to the surface by means of the drift net buoy line. Once at the surface, drift nets were detached from the anchor system and brought into the boat for sample collection. Collection cups were removed from the plankton net, and contents were rinsed into a 19L bucket containing river water. Contents remaining in the drift nets were also rinsed into the same collection bucket. Collection cups were reattached and drift nets were redeployed. Collection contents were diluted with river water and small aliquots were transferred into white plastic inspection trays to improve contrast when searching for White Sturgeon eggs or larvae. Eggs and larvae were enumerated by net for each sampling location and occasion. Deployment and retrieval times, water temperatures (°C), and depths (m) at each sampling location were recorded.

2.3.3 *Egg and Larval Sampling*

All live eggs and larvae were transported to the SIF (Section 2.3.5). No live samples were sacrificed and preserved as practiced in previous years (BC Hydro 2013, 2015a). Dead larval samples collected at the upstream locations (ALH, rkm 0.1; Kinnaird, rkm 14.5 – 18.2) were preserved for possible future genetic analyses.

2.3.4 *Developmental Staging and Estimation of Fertilization Date*

Prior to transportation to the SIF, live eggs were examined in the field using a handheld magnifying glass and assigned a developmental stage. Enumeration of stages corresponded to the classification by Dettlaff et al. (1993) for embryonic stages 1 (fertilization) through 35 (pre-hatch). Yolk-sac larvae collected at upstream locations (ALH and Kinnaird) were assigned a developmental stage 36 through 45 (hatch to exogenous feeding; Detlaff et al. 1993). No collected samples were developed beyond stage 45.

Fertilization date for collected eggs and larvae was estimated by back-calculation from the recorded date and time of preservation based on developmental stage and mean incubation water temperature. The estimated age (hours; eggs, Parsley, U.S. Geological Survey, unpublished; yolk-sac larvae, Jay 2014) was subtracted from the preservation date and time to determine the estimated date and time of fertilization (i.e. spawning date). Calculated fertilization dates provided an estimation of spawning duration for each spawning site. However, the accuracy of egg developmental staging as a method to delineate spawning days 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).

2.3.5 *Streamside Incubation Facility*

Design of the LCR SIF was based on the culture techniques used in the hatchery program (FFSBC 2015). The facility was placed near the Waneta spawning location on the banks of the LCR, as this is the primary spawning location where it was envisioned most of the eggs would originate from. Eggs collected from the LCR were transferred to the SIF for incubation in hatching jars (MacDonald Type; J30, Dynamic Aqua-Supply Ltd., Surrey, BC). Five jars were available for each collection location (i.e., upstream, downstream) and eggs of similar developmental stages were grouped together. Water was flow through from the LCR and flows were maintained to ensure adequate egg separation and oxygenation (~5 L/min). Upon hatch, yolk-sac larvae were flushed from the hatching jars directly into rearing troughs associated with each hatching jar and supplied with artificial substrate (1” diameter sinking Bio-Spheres; Dynamic Aqua-Supply Ltd. Surrey, BC) allowing yolk-sac larvae to burrow into interstitial spaces mimicking behaviour documented in the wild (McAdam 2011). All yolk-sac larvae were transported to the KSH within 7 days of hatch in tanks of ambient river water provided with an oxygen source. Juveniles were reared at the KSH until date of release into the LCR (see FFSBC 2015 for details). Temperature loggers were stationed to record outside air, inside facility air, LCR water, and facility tank water temperatures.

2.4 Population Monitoring, Abundance, and Characteristics

White Sturgeon life history information, population characteristics, and mark-recapture related information have been accumulated through the annual broodstock collection program since it was initiated in 2001 and through adult sampling conducted under CLBMON 28 (BC Hydro 2013). Starting in 2013, a systematic stock assessment program to address uncertainties in the current adult abundance and survival estimates was developed between Canadian and US recovery partners. This study represents the first systematic population estimate for the entire transboundary reach. The design of the stock assessment includes two annual surveys, one in the spring and one in the fall, and will continue for five years, ending in 2017.

2.4.1 *Study Area and Design*

The study area for the stock assessment program started at HLK, Canada, and extended downstream to Gifford, Washington, USA (Figure 3). Set lines were the only method used to capture adult White Sturgeon during the stock assessment. All methods for fish capture and data analysis are consistent with those described for White Sturgeon caught during Broodstock Acquisition sampling (Sections 2.2.2 and 2.2.4, respectively). During the stock assessment, four different hook sizes were used to select for different size classes of White Sturgeon. Hook sizes included 14/0, 16/0, 18/0, and 20/0 that are known to select for both adult and juvenile White Sturgeon. Hooks were systematically attached to the mainline in 3 sets of each hook size in descending order of size. The barbs on all hooks were removed to reduce the severity of hook-related injuries and to facilitate fish recovery and release. Set line effort was consistent at 1.6 hooks per hectare of river throughout the entire study area and setline sample sites were distributed randomly and spatially balanced using the Generalized Random-Tessellation Stratified Design (GRTS). All set line hooks were baited with pickled squid obtained from Gilmore Fish Smokehouse, Dallesport, WA USA.

Data collected during the stock assessment surveys included: PIT tag number, fork length (cm), and weight (kg). Blood and tissue samples were taken from every wild fish handled. All life history data were recorded in the field on standardized data forms and later entered into an electronic database. Biological data collected in 2014 are analyzed in this report for fork length frequencies, mean weight, and mean relative weight (W_r). After the completion of the stock assessment study, mark-recapture data will be used to estimate population abundance, age class structure, growth rates, density dependent responses, and survival rates of both wild adults and hatchery released juveniles. Catch records are analyzed across all years of broodstock collection and stock assessment in an effort to provide recommendations to annual conservation aquaculture breeding plans and to maximize the genetic diversity available for culture practices.

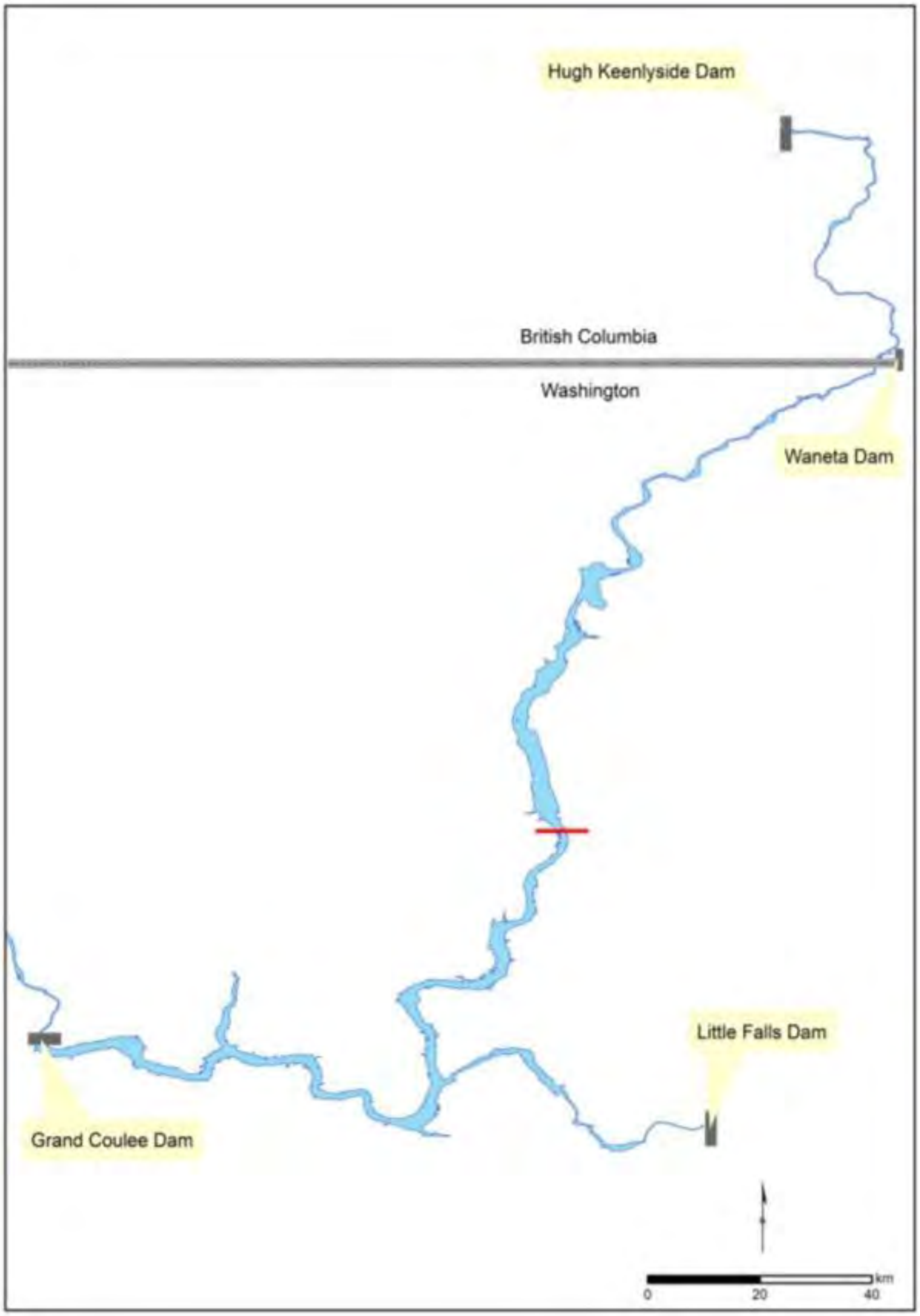

Figure 3. Study area for White Sturgeon stock assessment survey occurring from 2013-2017 in the transboundary reach of the Columbia River. Upstream extent of the study area is Hugh Keenleyside Dam in Canada, and the downstream extent of the study area ends at Gifford, Washington, USA (indicated by the horizontal red line

2.5 Acoustic Tagging and Telemetry

Acoustically tagging White Sturgeon within the LCR is required to monitor movement trends such as seasonal habitat use, and spawning site selection, timing, and duration. Additionally, unknown spawning habitat locations within the LCR have been identified through spawn related movements (BC Hydro 2013). Spawn related movements are defined as rapid movements from one area of long-term residency to an area of short-term residency during the spawning season (July/August), and returned movements to the original area of long-term residency. In 2014, movements of multiple fish were examined to provide additional support when identifying a possible spawning location.

Vemco model V16 acoustic tags (operational life of 10 years) were allocated to adult White Sturgeon predicted to spawn within the following 1-3 years (based on sex maturity examinations) in 2009, 2011, and 2013 (BC Hydro 2011a, 2013). In 2007 through 2012, all adults collected for broodstock were implanted with an acoustic tag prior to their post spawning release (BC Hydro 2013; Section 3.2.2.). In 2013, only one female that did not successfully spawn was implanted with an acoustic tag prior to release in order to monitor post release movements related to spawning. No fish were acoustically tagged in 2014. Total number of White Sturgeon acoustically tagged is provided in Table 1.

Table 1. Acoustic tags implanted by year for female and male adult White Sturgeon in the LCR.

Year	Wild		Broodstock		Total
	Female	Male	Female	Male	
2007	0	0	5	6	11
2008	0	0	8	7	15
2009	11	8	10	12	41
2010	0	0	9	10	19
2011	4	1	9	11	25
2012	0	0	8	10	18
2013	0	2	1	0	3
2014	0	0	0	0	0
Total	15	11	50	56	132

2.5.1 *Acoustic Receiver Array*

We used an array of fixed station remote receivers (Vemco, model VR2 and VR2W) already deployed within the LCR to detect spatial and temporal movements of acoustically tagged White Sturgeon. Since being initially deployed in 2003, the spatial extent of the array encompassing the LCR from HLK (rkm 0.1) southward to the Canada/U.S. International Border (rkm 57.0) 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.

Each station consisted of a weighted mainline of either 0.95 cm diameter nylon rope or 0.64 cm stainless steel cable extended between a large pyramid reinforced concrete anchor (55-80 kg) and a highly buoyant low drag float (Model LD-2 or LD-3). Materials used for each station was dependent on location and water flow. A receiver was secured with cable ties approximately 3 m below the water surface on the weighted mainline with the hydrophone orientated towards the river bottom. Data downloading and equipment maintenance (e.g., replace or repair cable ties, rope, float, mainline, and batteries) for all stations was conducted quarter annually. Raw data were downloaded using Vemco User Environment (VUE) software (version 2.1.3) and all raw data were exported at the end of each calendar year into a Microsoft Access database.

2.5.2 *Telemetry Data Analysis*

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 LCR and, as such, user agreements with other agencies and researchers have been developed for the utilization of the telemetry array. For all 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 than anticipated and has resulted in issues regarding tag collisions, which have increased the total number of "false" detections occurring in the database. False detections are echoes generated by the system's environment (e.g., bathymetric profile, substrate, narrow river) or pings of multiple tags colliding resulting in detections that were not linked to an active transmitter, or does not align with movement data for an active transmitter. 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 LCR between HLK in Canada and Grand Coulee Dam in WA.

We developed a telemetry database using a Client-Server model in Microsoft Access to help address data requirements related to examining White Sturgeon movements, assist with identifying "false" detections, and 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 a manner that results in outputs suitable for analyses. Queries were generated for each individual tag containing the total number of times each tag was detected by 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 too fine scale for this species. The detection record was examined for each individual, and observed false detections were removed.

Detection data from 2014 were summarized and proportional habitat use throughout the LCR was examined as a function of individual fish and sex. We calculated the proportional spawning site use as a function of individual fish and sex based on suspected spawn related movements (defined in Section 2.5).

Additionally, we examined migration trends from site of residency to suspected spawning site including total distance travelled (rkm), travel time (days) and time spent at a spawning location (days).

3.0 MONITORING RESULTS

It is intended that the long term results of all White Sturgeon monitoring programs will be used to characterize movements and redistribution patterns, spawning behavior and frequency, relative abundance, habitat preferences, growth rates, and survival. Additionally, results will 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 (cms; cfs) measured from Arrow Reservoir, Kootenay River, Birchbank, and Canada/U.S. International Border for the 2014 study period is presented in Figure 4. Minimum and maximum discharge (cms; cfs) for each location and year is given in Table 2.

White Sturgeon spawning in the LCR typically occurs when water temperatures exceed 14.0°C and flows are on a descending pattern (Hildebrand et al. 1999; BC Hydro 2013). The timing and duration of White Sturgeon spawning period is annually estimated to occur between June 1 and August 15 based on egg and larval collections (see Section 2.3.5). At the US border, peak freshet flows of 6,258 (cms) were reached on 28-May-2014, ahead of with the estimated initial spawning date (Figure 4; Section 3.3). Considerable variation in hourly mean discharge occurred within the predicted spawning period.

Table 2. Minimum and maximum discharge (cubic meters per second, cms; cubic feet per second, cfs) at four locations on the LCR in 2014.

Location	Minimum Discharge	Maximum Discharge
Arrow Reservoir	500 cms (17,680 cfs)	2,265 cms (79,982 cfs)
Kootenay River	396 cms (13,995 cfs)	2,532 cms (89,433 cfs)
Birchbank	1,020 cms (36,009 cfs)	3,740 cms (132,080 cfs)
Border	1,212 cms (42,800 cfs)	6,258 cms (221,000 cfs)

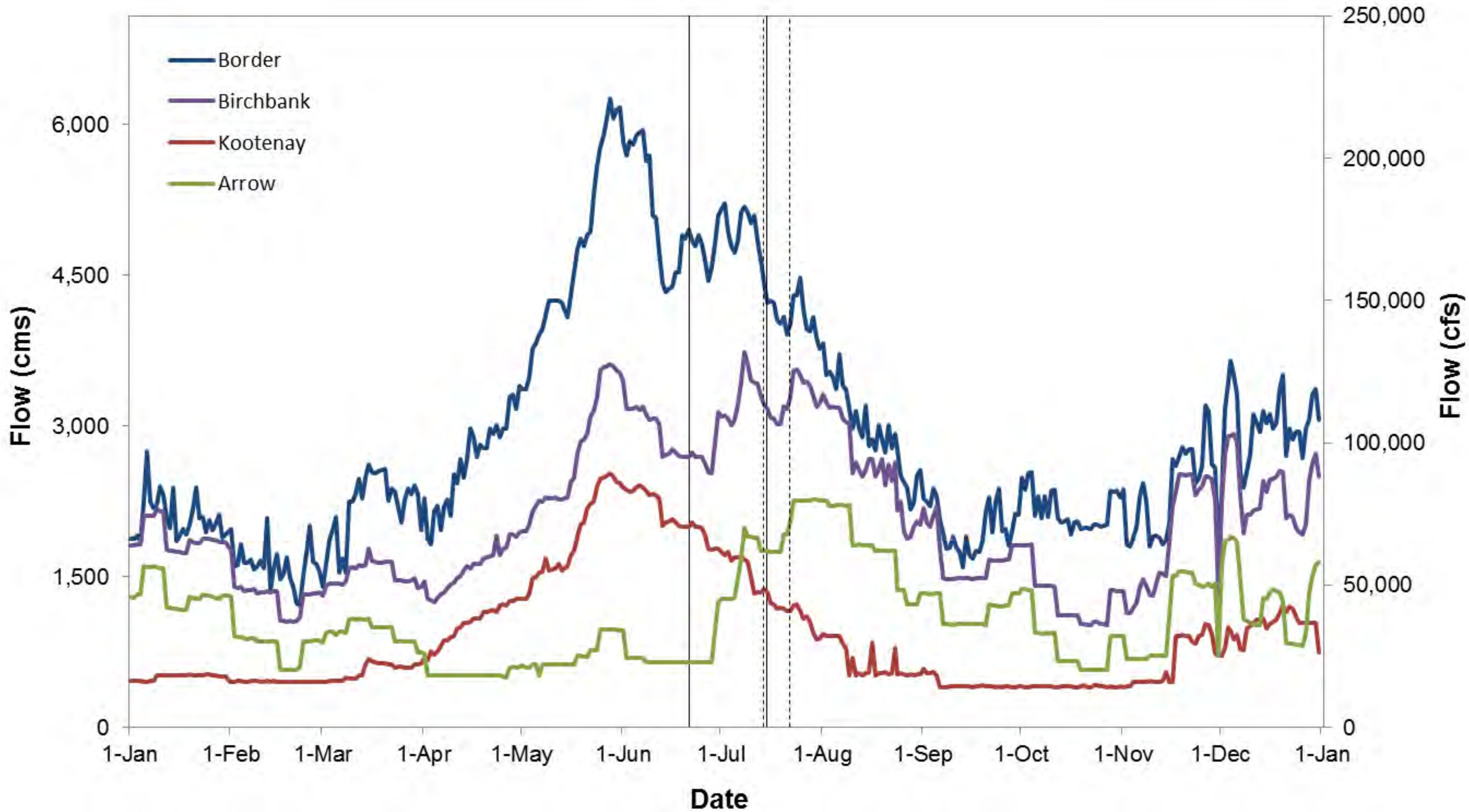

Figure 4. Mean daily discharge measured from Arrow Reservoir, Kootenay River, Birchbank, and the Canada/U.S. International Border on the LCR from January 01, 2014 – December 31, 2014. The solid and dashed vertical bars represent the first and last estimated spawning dates at Waneta and Kinnaird, respectively. Estimated spawning dates are based on the developmental stage of collected eggs and/or larvae. Despite sampling effort, estimated spawning dates were not calculated for ALH.

3.1.2 *Water Temperature*

LCR mean daily water temperatures (°C) during 2014 are illustrated in Figure 5. Annual mean (± SD), minimum, and maximum water temperatures (°C) at locations HLK (rkm 0.1), Kootenay Eddy (rkm 10.5), Kinnaird (rkm 13.4), Genelle Eddy (rkm 26.0), and Waneta Eddy (rkm 56.0) are summarized in Table 3. The date of occurrence of spawning temperature threshold (14°C) at each location is provided in Table 3. 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), and other cold-water tributary influences.

Table 3. Daily mean (± SD), minimum, and maximum water temperatures (^{o}C) recorded within the LCR during 2014. Data was recorded at locations of HLK (rkm 0.1), Kootenay Eddy (rkm 10.5), Kinnaird (rkm 13.4), Genelle Eddy (rkm 26.0), and Waneta Eddy (rkm 56.0).

		Temperature			Date of Suspected
Location	RKM	Mean ± SD*	Minimum	Maximum*	Spawning Threshold (14°C)
HLK	0.1	N/A	2.49	18.0	July 1
Kootenay	10.5	9.8 ± 5.7	1.6	20.2	July 6
Kinnaird	13.4	9.5 ± 5.3	2.0	19.0	July 6
Genelle	26.0	9.5 ± 5.3	1.9	18.8	July 3
Waneta	56.0	9.7 ± 5.9	1.3	21.1	July 1

*****N/A: data unavailable due to lost or damaged temperature loggers

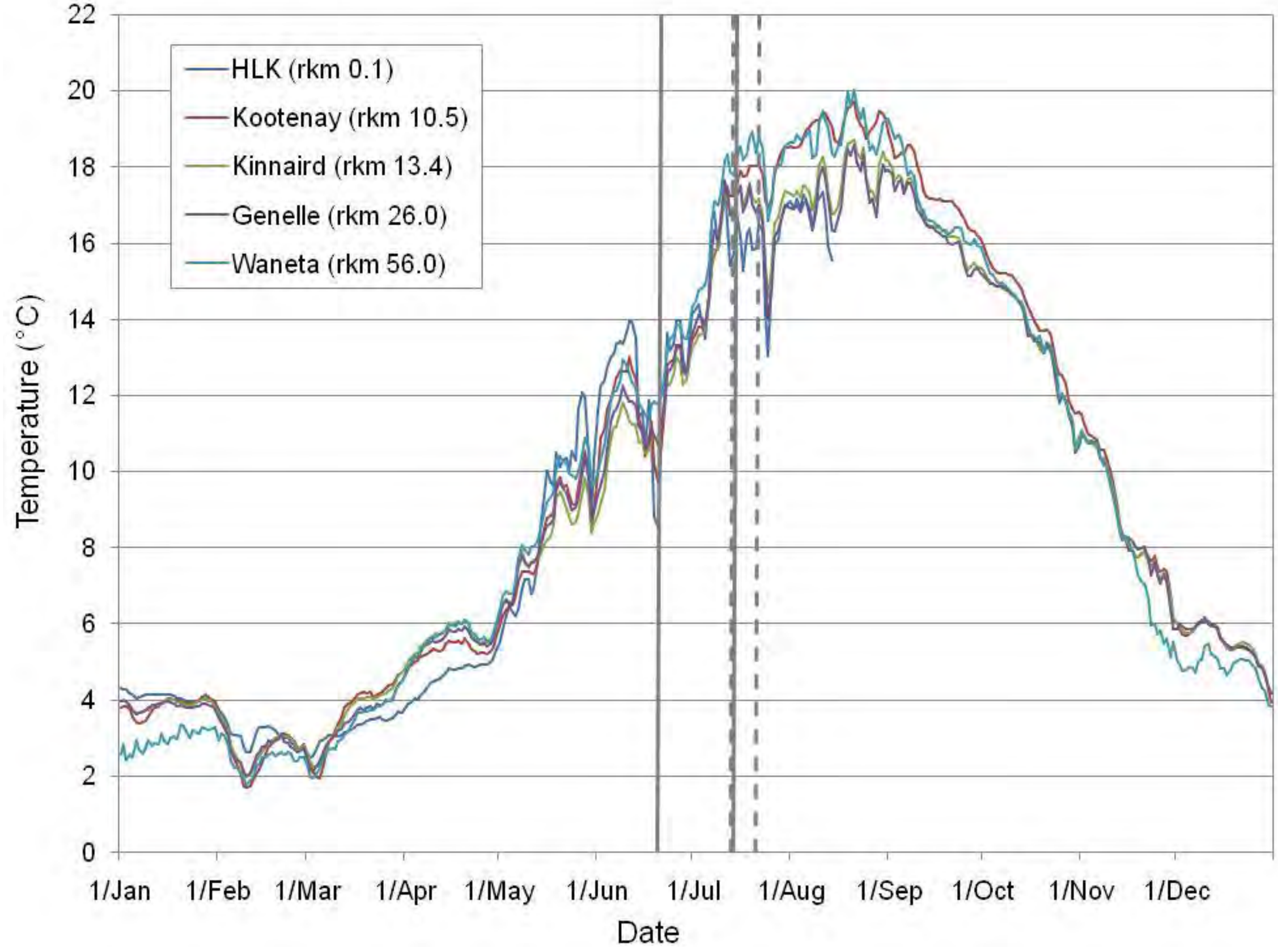

Figure 5. Mean daily water temperature (°C) of the LCR in 2014. Data was recorded at locations of HLK (rkm 0.1), Kootenay Eddy (rkm 10.5), Kinnaird (rkm 13.4), Genelle (rkm 26.0), and Waneta (rkm 56.0). Missing data is due to lost or damaged temperature loggers. Vertical solid and dashed lines represent first and last estimated spawning dates at Waneta and Kinnaird, respectively. Estimated spawning duration is based on the developmental stage of collected of fertilized eggs or larvae. Despite sampling effort, spawning dates were not estimated for ALH.

3.2 Broodstock Acquisition

3.2.1 *Adult Capture*

In 2014, 241 White Sturgeon were captured over 4,298 hours of effort extended over 24 days (June 9 – July 3) at a mean water temperature of 12.3°C (Table 4). CPUE was 0.06 captures/set line hour (Table 4). A total of 110 adults and 131 juveniles were captured with 2 adults recaptured over the sampling effort period. A total of 20 fish (0.08 of total capture) were first time captures (hatchery released juveniles were considered recaptures; Table 4). The majority of fish were captured in zones 1 (0.51) and 5 (0.27) (Table 4).

Table 4. Total number and proportion of White Sturgeon capture within each sampling zone of the LCR. New fish were first time captures (excluding hatchery released juveniles).

Zone	Fish	Prop.[1]	New Fish	Prop.[1]	Effort (hours)	Prop.[2]	CPUE
LCR	241	1.00	20	0.08	4,298	1.00	0.06
1	122	0.51	9	0.04	976	0.23	0.13
2	30	0.12	5	0.02	363	0.08	0.08
3	23	0.10	2	0.01	546	0.13	0.04
4	1	0.00	0	0.00	23	0.01	0.04
5	65	0.27	4	0.02	2,388	0.56	0.03

[1]*Proportion of total capture (n=241)*

[2]Proportion of total effort (4,298 hours)

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

Of the 241 White Sturgeon captured, 11 fish (5 females, 6 males) were of spawning condition and transported to the KSH to be used as broodstock. The remaining 230 White Sturgeon were assessed and released alive at their capture locations. Of the 20 first time capture (new) fish, 2 (0 female, 2 males) were considered to be sexually mature and transported to the KSH. All broodstock fish, excluding one male, were spawned successfully and family crosses were determined based on a full factorial mating design. The unspawned male was used previously in 2006 for the Conservation Aquaculture Program and was transported to KSH only to be used as an alternative male if another could not be spawned. After the induced spawning event, all White Sturgeon were released into the LCR.

From 2001 to 2014, the majority proportion of adults used as broodstock for conservation aquaculture have been captured in the downstream section (0.68; Trail (rkm 36.0) to Waneta (rkm 56.0)) while the upstream sections have had a lower proportion of broodstock representation (Table 5).

Table 5. The proportion of adult White Sturgeon broodstock selected from different sections of the LCR for use in the Conservation Aquaculture Program from 2001-2014.

Reach	Proportion
HLK (rkm 0.1) to Norn's Creek (rkm 8.0)	0.16
Kootenay Eddy (rkm 10.5)	0.13
Kinnaird (rkm 13.4) to Trail (rkm 36.0)	0.03
Trail (rkm 36.0) to Border (rkm 57.0)	0.68

3.2.3 *Sex and Maturity*

During broodstock acquisition, sex of White Sturgeon was determined from previous capture records or through surgical examination (Section 2.2.3; see UCWSRI 2006 for sex determination details). Sex was determined for 67 captured fish consisting of 28 males and 39 females (male:female sex ratio of 0.7:1) (Table 6). Male captures consisted of 12 M0 (0.43; proportion of total male capture), 9 M1 (0.32), and 7 M2 (0.25). Female captures included 17 F0 (0.44), 11 F1 (0.28), 5 F2 (0.13), 1 F3 (0.03), 5 F4 (0.13), and 0 F5 (0.00). Table 6 outlines the sex ratios observed for most years between 1992 and 2014.

Table 6. Sex ratios for White Sturgeon captured from 1992-1998 and 2001-2014 in the LCR.

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
2011	45	64	0.7:1
2012	49	69	0.7:1
2013	71	93	0.8:1
2014	28	39	0.7:1
Total	681	739	0.9:1

3.2.4 *Fork Length (FL) Frequency and Weight*

FL (cm; mean ± SD) of all fish captured during the 2014 broodstock acquisition was 138.6 ± 46.3 cm (Figure 6). FL of captured adults and juveniles was 184.8 ± 22.5 cm and 99.7 ± 32.4 cm, respectively (Figure 6). The length frequency distribution of all sexually mature adult White Sturgeon used for the Conservation Aquaculture Program from 2001-2014 shows that females (FL, 198.8 ± 18.0 cm) were on average larger than males (FL, 179.3 ± 16.3 cm; Figure 7).

Weight (kg; mean ± SD) of all fish captured was 28.3 ± 27.3 kg. Weight of captured adults and juveniles was 53.6 ± 21.0 kg and 7.1 ± 2.9 kg, respectively. Weight of captured females and males was 71.5 ± 21.4 kg and 49.2 ± 12.9 kg, respectively (Table 7). Weight for specific maturation stages (Section 2.2.3; see UCWSRI 2006 for details) are given in Table 7.

W_r (mean ± SD) of all fish captured was 88.7 ± 13.1. W_r of captured adults and juveniles was 88.9 ± 10.7 and 88.6 ± 14.3, respectively. W_r of captured females and males was 88.5 ± 7.6 and 90.3 ± 12.2, respectively (Table 8). W_r was highest for individuals in spawning condition (F4, 97.0 ±5.4; M2, 101.6 ± 11.7). Small variation was observed in W_r between females and males in 2014, as well as previous years data (2009 – 2013; Table 8). W_r for White Sturgeon in the LCR, Canada, is less than reported in Columbia River populations downstream of Grand Coulee Dam, USA (Devore et al. 2000; Howell and McLellan 2007).

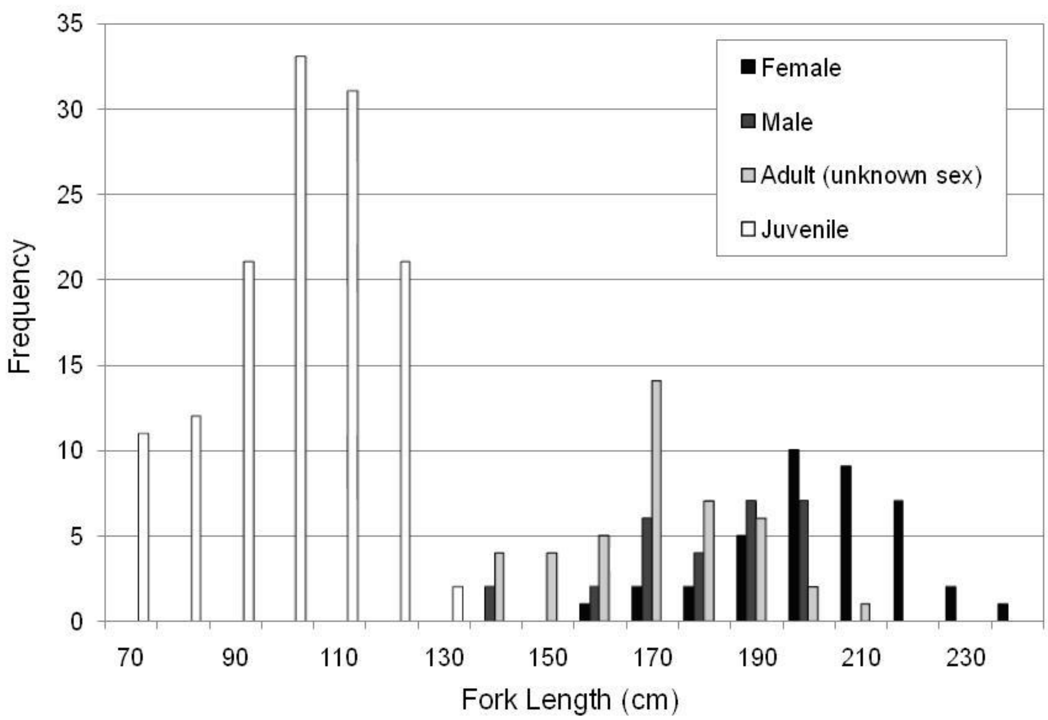

Figure 6. Fork length (cm) frequency of White Sturgeon including known females, known males, adults of unknown sex, and juveniles captured during broodstock acquisition conducted on the LCR in 2014.

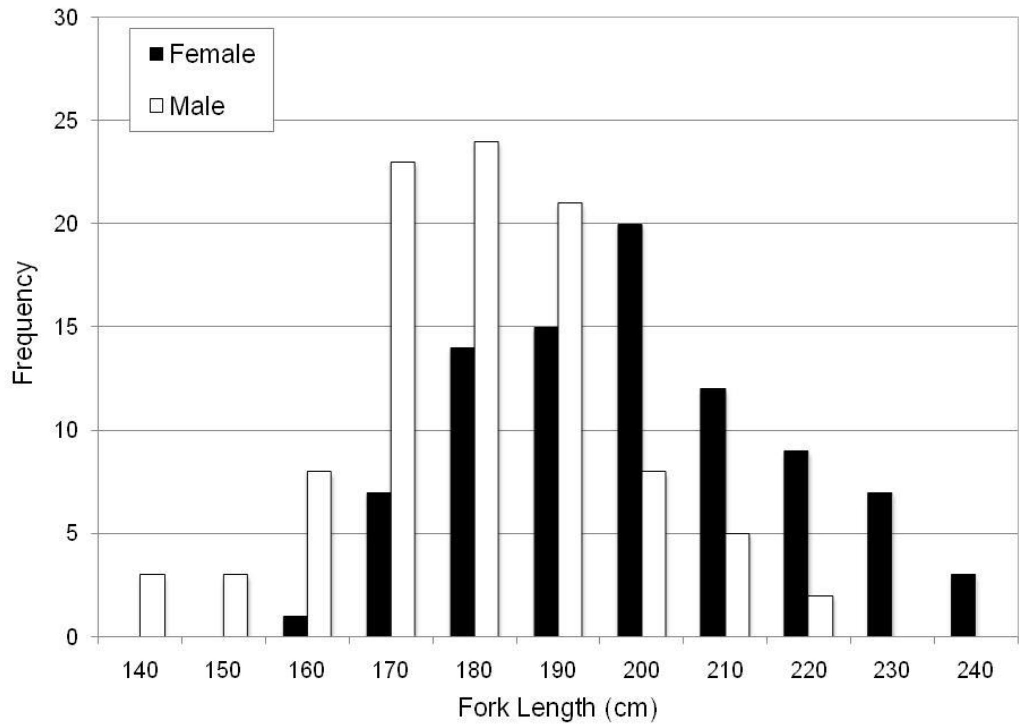

Figure 7. Fork length (cm) frequency of sexually mature female and male White Sturgeon captured and used as broodstock in the LCR Conservation Aquaculture Program during the years 2001 through 2014.

Table 7. Weight (kg; mean ± SD) for female and male adult White Sturgeon collected during broodstock acquisition on the LCR in 2012 through 2014. Weights are provided for specific maturation stages as described in Section 2.2.3 and UCWSRI (2006).

Sex	2012	2013	2014
Female	55.9 ± 13.9	57.7 ± 16.9	71.5 ± 21.4
F4	68.0 ± 17.7	69.3 ± 21.4	95.8 ± 31.9
F3	65.1 ± 13.2	56.0 ± 0.0	59.0
F2	69.5 ± 14.1	55.7 ± 9.1	76.6 ± 22.6
F1	50.6 ± 9.1	59.3 ± 15.7	66.1 ± 19.0
F0	51.8 ± 11.7	54.7 ± 16.5	67.2 ± 15.3
Male	43.3 ± 12.5	47.9 ± 11.1	49.2 ± 12.9
M2	54.4 ± 14.7	48.2 ± 12.6	51.1 19.2
M1	40.3 ± 10.2	48.4 ± 11.8	50.8 ± 9.8
M0	40.8 ± 10.8	45.6 ± 8.7	46.9 ± 11.1

Table 8. Relative weights (W_r ; mean ± SD) for female and male adult White Sturgeon collected during broodstock acqusition on the LCR in 2009 through 2014. Relative weights are provided for specific maturation stages as described in Section 2.2.3 and UCWSRI (2006).

Sex	2009	2010	2011	2012	2013	2014
Female	90.4 ± 20.1	85.9 ± 9.0	86.0 ± 13.2	86.0 ± 8.8	84.4 ± 9.3	88.5 ± 7.6
F4	105.5 ±11.3	95.3 ± 7.7	90.7 ± 8.5	95.4 ± 4.6	90.8 ± 12.1	97.0 ± 5.4
F3	90.1 ± 8.4	89.6 ± 8.7	89.6 ± 6.2	91.4 ± 11.9	88.4	82.8
F2	84.9 ± 7.4	84.3 ± 6.1	86.4 ± 8.5	94.1 ± 11.9	89.3 ± 7.3	87.2 ± 4.0
F1	85.5 ± 6.6	82.9 ± 8.5	86.6 ± 17.1	83.5 ± 7.0	83.4 ± 10.1	88.0 ± 9.8
F0	83.0 ± 8.8	81.3 ± 7.4	79.6 ± 8.7	82.2 ± 7.3	83.0 ± 8.3	87.0 ± 6.3
Male	90.3 ± 22.8	83.3 ± 7.5	83.1 ± 8.5	83.5 ± 9.5	85.1 ± 8.6	90.3 ± 12.2
M2	-	-	-	90.7 ± 6.0	86.1 ± 10.4	101.6 ± 11.7
M1	-	-	-	81.2 ± 9.5	86.1 ± 9.1	91.3 ± 11.0
M0	-	-	-	82.3 ± 9.6	83.0 ± 7.0	83.0 ± 7.8

3.2.5 *Adult Genetics*

The collection of tissue samples, in the form of dried fin clips, of all captured adults and wild juveniles was continued and archived during broodstock acquisition as well as the population stock assessment survey. Future genetic analysis of all samples will provide insight into population genetic diversity, adult breeding dynamics including number of breeding adults, variation in reproductive success through parentage and pedigree analysis, and spatial genetic structuring among spawning sub-populations. Future results will be applied to recovery planning and aquaculture programs for LCR White Sturgeon.

FFSBC Fish Health Lab is currently analyzing blood samples collected from all adults and wild juveniles captured during the broodstock and population stock assessment surveys. Results of population ploidy levels will be provided once completed.

3.3 Spawn Monitoring

3.3.1 *Egg and Larval Sampling: Sampling Effort and Collection*

Downstream Location – Waneta (rkm 56.0)

Egg mats (n=7) and drift nets (n=2) were deployed on June 2 and sampling continued until July 30. Water temperatures ranged from 14.5 to 18.9°C (Figure 5) and water depth (mean ± SD) was 5.1 ± 2.1 m for egg mats (depth not recorded for drift nets). Total sampling effort for egg mats and drift nets were 19,362.3 hours and 42.9 hours, respectively, for a cumulative effort of 19,405.2 hours (Table 9). Single set effort was 115.3 ± 28.0 hours and 2.2 ± 0.7 hours for egg mats and drift nets, respectively.

A total of 5,762 eggs (egg mat, n=5,729; drift net, n=33) and 67 larvae (egg mat, n=5; drift net, n=62) were captured at Waneta between the dates of June 23 and

July 23 (Table 9). The largest daily egg mat sample was 2,532 (eggs, n=2,532; larvae, n=0) collected on July 4 representing 0.44 of total egg mat sample collection. The largest daily drift net sample was 39 (eggs, n=2; larvae, n=37) collected on July 9 representing 0.41 of total drift net sample collection. Of the total capture, 5,176 eggs and 17 larvae were staged and transported to the SIF. Hatched larvae were transported to KSH.

Upstream Location – Kinnaird (rkm 14.5 to rkm 18.2)

Drifts were deployed at rkm 14.5 (n=2; long-set), rkm 15.0 (n=2; short-set), rkm 15.6 (n=2; short-set), rkm 16.9 (n=1; short-set), rkm 17.3 (n=1; short-set and long-set), rkm 18.2 (n=4; long-set) on July 14 and sampling continued until August 8. Water temperatures ranged from 14.6 to 17.6°C (Figure 5) and sampling water depth was 5.39 ± 1.4 m. Total sampling effort for drift nets were 2,537.5 hours (rkm 14.5, 699.7 hours; rkm 15.0, 106.2 hours; rkm 15.6, 76.9 hours; rkm 16.9, 43.0 hours; rkm 17.3, 128.1 hours; rkm 18.2, 1,513.7 hours; Table 9). Single set effort for long- and short-sets was 23.6 ± 1.5 hours and 3.1 ± 0.5 hours, respectively.

A total of 6 eggs (rkm 14.5, n=1; rkm 18.2, n=5; Table 9) were collected between July 14 and July 25. A total of 13 larvae (rkm 14.5, n=2; rkm 16.9, n=2; rkm 17.3, n=1; rkm 18.2, n=8; Table 9) were collected between July 16 and July 31. All live eggs (n=3) were staged prior to transportation to the streamside incubation facility and successfully hatched larvae (n=2) were transported to KSH. All larvae collected in the drift nets were dead upon capture and preserved for developmental staging.

Upstream Location – ALH (rkm 0.1)

Egg mats (n=6) and drift nets (n=4) were deployed on July 10 and sampling continued until August 8 with water temperatures ranging from 13.0 to 17.6°C (Figure 5). Total sampling effort for egg mats and drift nets were 1,808.0 hours and 857.3 hours, respectively, for a cumulative effort of 2,665.4 hours (Table 9). Single set effort was 51.7 ± 18.9 hours and 25.2 ± 4.7 hours, and sampling water depth was 9.1 ± 2.8 m and 6.6 ± 1.6 m for egg mats and drift nets, respectively. No eggs or larvae were captured at ALH (Table 9).

Table 9. White Sturgeon egg and larval collection and sampling effort for monitoring locations in the LCR including Waneta (rkm 56.0), downstream of Kinnaird (rkm 14.5, rkm 15.0, rkm 15.6, rkm 16.9, rkm 17.3, rkm 18.2), Kootenay (rkm 10.5), downstream ALH (rkm 6.0), ALH (rkm 0.1) and HLK (rkm 0.1) for years 2008 through 2014.

Year	Location	Egg Mats			Drift Nets		
		Eggs	Larvae	Effort (hrs)	Eggs	Larvae	Effort (hrs)
2008	Waneta	3,456	7	19,428	494	220	72
	rkm 18.2	0	0	16,493	0	1	164
2009	Waneta	1,715	2	21,964	77	39	90
	rkm 18.2	-	-	-	0	5	976
	rkm 6.0	-	-	-	0	0	3,091
2010	Waneta	4,003	16	18,204	888	89	113
	rkm 18.2	0	0	10,600	1	8	2,104
	ALH	12	0	3,608	30	115	2,084
2011	Waneta	2,318	9	19,882	234	16	50
	rkm 18.2	-	-	-	2	32	1,400
	rkm 14.5	-	-	-	0	0	154
	rkm 10.5	-	-	-	0	0	993
	HLK	-	-	-	0	0	461
	ALH	2	0	3,614	183	308	2,538
2012	Waneta	226	2	16,627	134	15	48
	rkm 18.2	-	-	-	0	0	197
	ALH	-	-	-	6	0	2,929
2013	Waneta	410	0	14,739	-	-	-
	rkm 18.2	-	-	-	0	4	363
	rkm 14.5	-	-	-	0	1	154
	ALH	-	-	-	0	0	680
2014	Waneta	5,729	5	19,362	33	62	43
	rkm 18.2	-	-	-	5	8	1,514
	rkm 17.3	-	-	-	0	1	128
	rkm 16.9	-	-	-	0	2	43
	rkm 15.6	-	-	-	0	0	77
	rkm 15.0	-	-	-	0	0	106
	rkm 14.5	-	-	-	1	2	670
	ALH	0	0	1,808	0	0	857

3.3.2 *Developmental Staging and Estimated Spawning Dates*

Eggs and larvae were assigned a developmental stage based on Dettlaff et al. (1993) to calculate an estimated date of fertilization. Stages were generalized compared to previous sampling years (BC Hydro 2015a) to reduce handling of collected eggs and larvae. Samples ranged from newly fertilized eggs to yolk-sac larvae (Table 10).

An estimated 5 discrete spawning days occurred at Waneta between the dates of June 21 and July 15 (Table 11). Spawning was estimated to have occurred between July 14 and July 22 downstream of Kinnaird with an estimate of 3 spawning dates (Table 11). Spawning dates were estimated solely based on egg samples.

Table 10. Proportion of White Sturgeon eggs and larvae collected across different developmental stages from spawn monitoring locations of Waneta and Kinnaird (rkm 14.5 and rkm 18.2) in 2014. No samples were collected at ALH in 2014. Developmental stages are based on Dettlaff et al. (1993). Due to limited handling of eggs and larvae collected for Streamside Incubation Facility, developmental stages were generalized compared to previous collection years (BC Hydro 2015a).

Development Category	Stage	Waneta		Kinnaird	
		n	*Prop.*	*n*	*Prop.*
Cleavage / Gastrulation / Yolk Plug	1 - 18	4502	0.87	2	0.13
Neurulation / Heart Formation	19 - 33	647	0.12	1	0.06
Pre-Hatch	34 - 35	26	0.01	0	0.00
Yolk-Sac Larvae	36 - 45	17	0.00	13	0.81

Table 11. Estimated spawning dates in the LCR during 2014 at locations of Waneta (rkm 56.0), and Kinnaird (rkm 14.5, rkm 18.2). Dates are determined through back calculation from date of capture based on developmental stage of each sample. No live eggs or larvae were collected at ALH.

Spawning Event	Location	Date
1	Waneta	June 21
2	Waneta	July 3
3	Waneta	July 4
4	Waneta	July 12
5	Waneta	July 15
6	rkm 14.5	July 14
7	rkm 18.2	July 21
8	rkm 18.2	July 22

3.3.3 *Streamside Incubation Facility*

Daily air and water temperatures recorded at the streamside facility are illustrated in Figure 8. Mean (± SD), minimum, and maximum air and water temperatures are provided in Table 12. Despite elevated air temperatures in the SIF, water temperatures recorded from the LCR and facility tanks were not significantly different (Student's t-Test; $P = 0.07$).

Eggs (n=5,176) and larvae (n=17) collected at Waneta (Figure 9) and eggs (n=3) collected at Kinnaird were transferred to the SIF for incubation. No live larvae were collected at Kinnaird and no samples were collected at ALH. Post hatch, yolk-sac larvae collected from Waneta (n=2,118; hatch success = 0.41) and Kinnaird (n=2; hatch success = 0.67) were transported to the KSH in three groups on July 1 (Group 1; n=153), July 9 (Group 2; n=1,810), and July 13 (Group 3; n=155). Groups were determined by field collection period and estimated fertilization dates. Daily survival for each group and total abundance is illustrated in Figure 10 and 11, respectively. In the spring of 2015, 1,095 wild progeny were released into the LCR at an average FL and weight of 29.0 cm and 172.5 g, respectively.

Table 12. Mean (± SD), minimum, and maximum air and water temperatures recorded at the location of the streamside incubation facility. Temperature loggers were stationed to record outside air, inside air, LCR water, and tank water temperatures (°C).

Source	Temperature (°C)		
	Mean ± SD	Minimum	Maximum
Air Outside	27.4 ± 17.0	6.9	72.4
Air Inside	22.5 ± 7.2	9.1	39.9
Water LCR	15.8 ± 2.3	10.2	32.4
Water Tank	16.3 ± 1.6	12.6	21

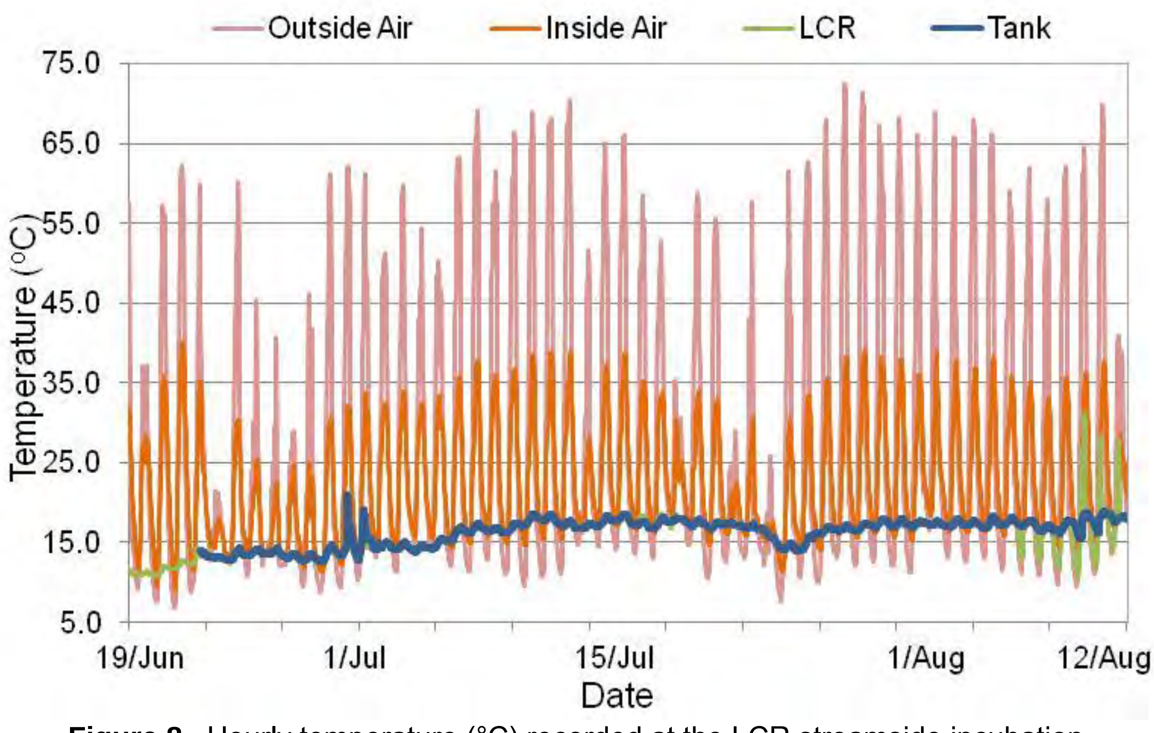

Figure 8. Hourly temperature (°C) recorded at the LCR streamside incubation facility in 2014. Data includes air temperatures outside and inside the facility, and water temperatures of the LCR and incubation tanks.

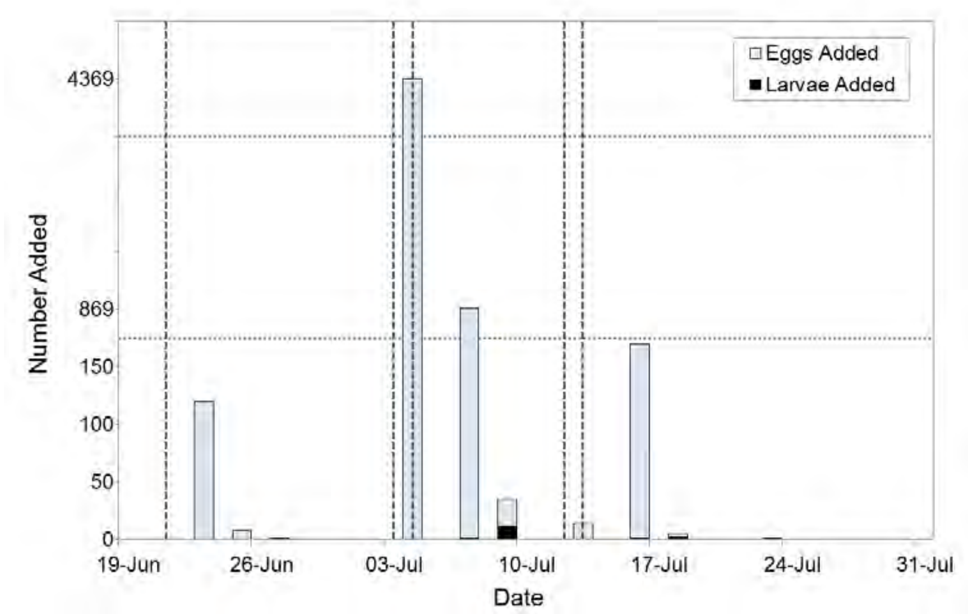

Figure 9. Eggs and larvae collected at Waneta spawn monitoring site and added to the streamside incubation facility. Naturally produced eggs and larvae were collected by egg mat and drift net sampling. Vertical bars represent each estimated spawning date based on devvelopmental stages of collected eggs and larvae at Waneta. Eggs collected at the Kinnarid spawn monitoring site (n=3) are not included.

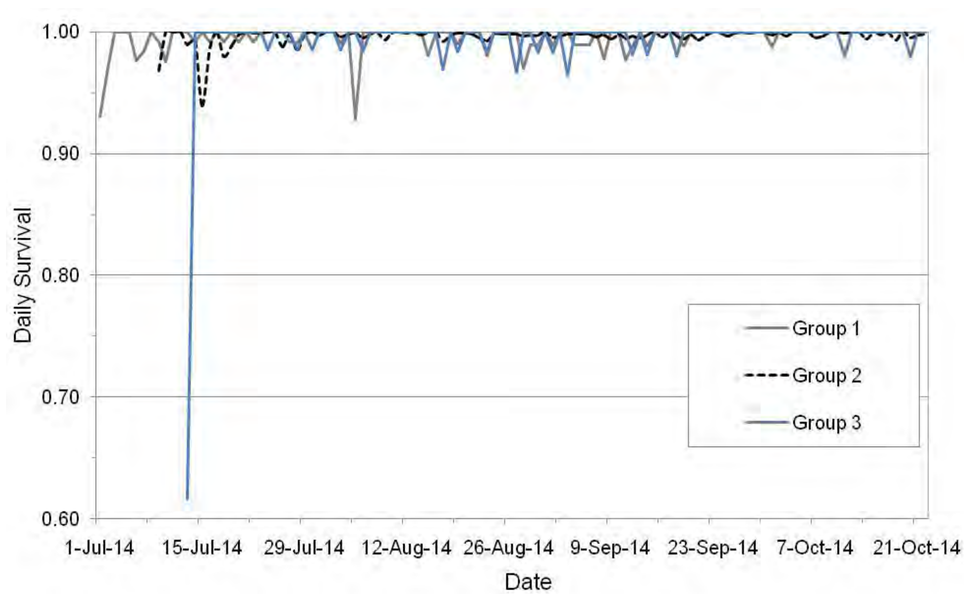

Figure 10. Daily survival of larvae at the Kootenay Sturgeon Hatchery (KSH) collected from the Waneta spawn monitoring site in 2014. Groups (1 through 3) were organized based on field collection periods and estimated fertilization dates.

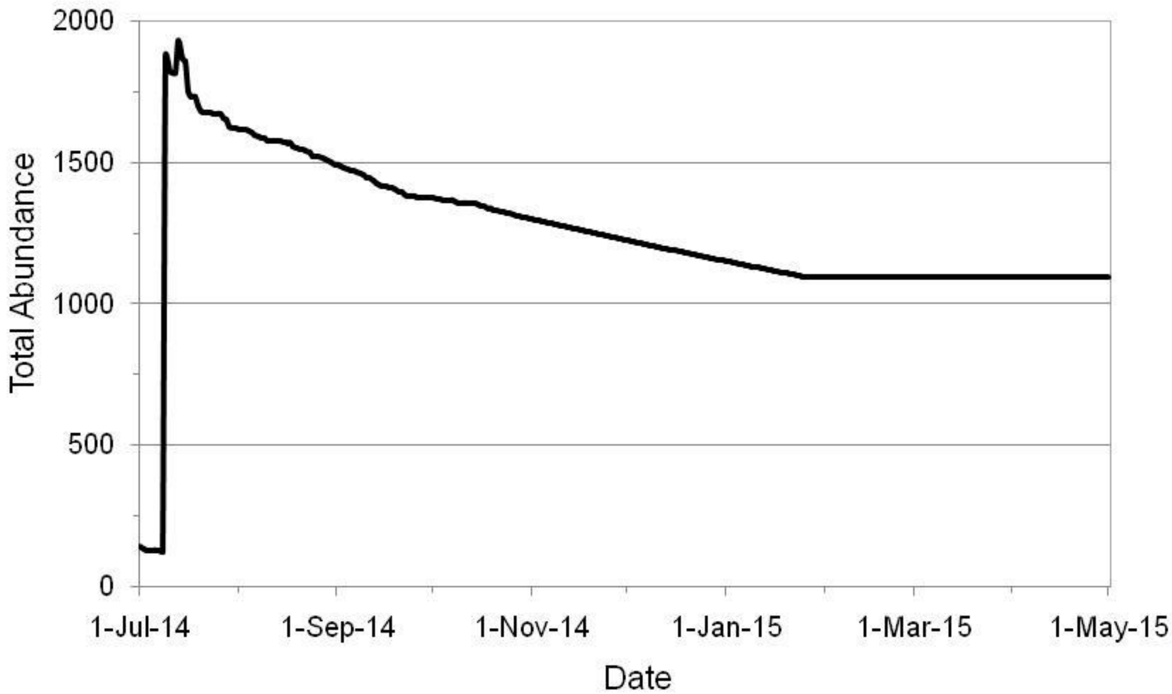

Figure 11. Total abundance of wild juveniles reared at the Kootenay Sturgeon Hatchery from date of collection (July 1, 2014) to release (May 1, 2015). Juveniles were collected as eggs and larvae at the Waneta spawn-monitoring site via egg mat and drift net in 2014. Samples collected at Kinnaird spawn-monitoring site (n=2) had zero survival. A total of 1,095 wild juveniles were released into the LCR in spring 2015.

3.4 Population Monitoring, Abundance, and Characteristics

3.4.1 *Fish Capture and Handling*

The biannual stock assessment program was initiated in Spring 2013. Sampling will continue twice a year (spring and fall), in both the Canadian and USA portions of the LCR, until Fall 2017. Results are only presented for data collected in Canada as results from USA captures were unavailable at the time this report was finalized.

Within Canada, spring and fall stock assessments were conducted between the dates of May 4 through May 15 (12 days) and September 16 through September 30 (15 days) with water temperatures (mean ± SD) of 7.5 ± 0.6°C and 15.7 ± 0.7°C, respectively. For both the spring and fall assessments, 1,440 hooks were set using 120 lines. Sampling effort for the spring and fall assessments was 2,453.2 hours and 2504.4 hours, respectively. Set line deployment during the spring and fall assessments was 20.4 ± 1.4 hours and 20.9 ± 1.5 hours at water depths of 9.8 ± 4.3 m and 15.7 ± 0.7, respectively.

Total White Sturgeon captures was 194 and 358 for a CPUE of 0.079 and 0.143 captures/effort hour during the spring and fall assessments, respectively (Table 13). Over the two completed survey years (2013 -2014), a total of 919 fish were captured proportionally represented by adults (0.38), hatchery released juveniles (0.62), new captures (not previously handled; 012), and fish recaptured over the entire survey period (0.05) (Table 14).

Table 13. Total capture and catch per unit effort (CPUE) by sampling zone for White Sturgeon captured during the 2013 and 2014 stock assessments in the LCR, Canada.

Zone	Total Capture (CPUE)			
	2013 Spring	2013 Fall	2014 Spring	2014 Fall
1	82 (0.088)	117 (0.203)	148 (0.176)	222 (0.227)
2	13 (0.023)	42 (0.090)	29 (0.058)	55 (0.138)
3	7 (0.012)	37 (0.073)	8 (0.021)	33 (0.078)
4	2 (0.004)	16 (0.048)	2 (0.006)	13 (0.050)
5	13 (0.027)	38 (0.083)	7 (0.017)	35 (0.079)
LCR	117 (0.039)	250 (0.106)	194 (0.079)	358 (0.143)

Table 14. Total White Sturgeon captures during the 2013 and 2014 stock assessments in the LCR, Canada. Unmarked fish were considered new captures (i.e., not previously handled by reserachers; does not include hatchery released juveniles). Recaptured fish were handled more than once during the sampling period.

Year	Survey	Total	Adult	Juvenile	New Fish	Recaptured Fish	Water Temp (°C)
2013	Spring	116	83	34	23	1	6.1 ± 0.8
2013	Fall	250	93	157	29	0	15.9 ± 0.6
2014	Spring	194	93	101	21	0	7.5 ± 0.7
2014	Fall	358	83	275	35	0	15.7 ± 0.7
Both	All	919	352	567	108	49	-

3.4.2 *Population Abundance*

Abundance and survival estimates will be calculated as additional recapture data become available in future years of the stock assessment program.

3.4.3 *Fork Length Frequency and Weight*

Fork length (FL; cm; mean ± SD) of all fish collected in both stock assessments of 2014 (n=552) was 124.9 ± 41.4 cm (Table 15; Figure 12). FL of juveniles captured during the spring and fall was 103.8 ± 13.0 cm and 97.1 ± 15.5 cm, respectively. FL for adults captured in the spring and fall was 179.4 ± 17.2 cm and 182.0 ± 18.3 cm, respectively. FL of fish captured by sampling zone is illustrated in Figure 13. Weight (kg) of all captures was 19.1 ± 20.4 kg (Table 16). Weight of juveniles captured during the spring and fall was 7.7 ± 3.1 kg and 6.3 ± 3.5 kg, respectively. Adult weight was 43.7 ± 13.9 kg and 47.4 ± 17.7 kg for spring and fall captures, respectively. Relative weight (W_r) for all captures was 81.1 ± 8.4 (Table 17). W_r for adults captured in the spring and fall was 80.7 ± 7.4 and 83.0 ± 12.6, respectively. Juvenile W_r was 82.2 ± 7.2 and 80.3 ± 7.4 during the spring and fall stock assessments, respectively. W_r for each hatchery released year class captured is available in Table 17.

Table 15. Fork length (FL; cm; mean ± SD) for adult and juvenile captures during the 2013 and 2014 stock assessments in the Canadian portion of the LCR.

Year	Survey	Adults	Juvenile	LCR
2013	Spring	184.3 ± 19.0	103.4 ± 15.7	160.2 ± 41.3
2013	Fall	181.1 ± 18.7	93.0 ± 15.2	126.6 ± 46.2
2014	Spring	179.4 ± 17.2	103.8 ± 13.0	140.1 ± 40.8
2014	Fall	182.0 ± 18.3	97.1 ± 15.5	116.8 ± 39.4

Table 16. Weight (kg; mean ± SD) for adult and juvenile captures during the 2013 and 2014 stock assessments in the Canadian portion of the LCR.

Year	Survey	Adults	Juvenile	LCR
2013	Spring	53.6 ± 16.2	8.5 ± 6.3	40.1 ± 25.0
2013	Fall	47.0 ± 17.7	5.9 ± 5.0	21.7 ± 23.2
2014	Spring	43.7 ± 13.9	7.7 ± 3.1	25.0 ± 20.5
2014	Fall	47.4 ± 17.7	6.3 ± 3.5	15.9 ± 19.6

Table 17. Relative weight (W_r; mean ± SD) for White Sturgeon collected during 2013 and 2014 stock assessments in the Canadian portion of the LCR. W_r is provided by year class for juveniles stocked through the Conservation Aquaculture Program.

Year Class	2013		2014	
	Spring	Fall	Spring	Fall
Juvenile	85.3 ± 15.6	81.3 ± 8.5	82.2 ± 7.2	80.3 ± 7.4
2009	-	86.6	-	81.5 ± 8.0
2008	-	80.1 ± 5.2	-	78.6 ± 4.6
2007	-	76.4 ± 7.4	93.8	78.6 ± 8.3
2006	-	84.1 ± 8.2	95.6 ± 1.8	80.9 ± 8.2
2005	-	84.1 ± 7.4	87.1 ± 2.5	77.9 ± 6.4
2004	81.4 ± 8.6	75.5 ± 7.6	79.0 ± 5.4	76.7 ± 6.4
2003	77.5 ± 3.9	79.6 ± 7.6	78.0 ± 5.1	80.1 ± 6.9
2002	82.4 ± 8.1	78.4 ± 5.7	80.0 ± 6.9	81.3 ± 6.1
2001	83.7 ± 8.5	85.9 ± 9.4	84.0 ± 7.0	83.1 ± 8.0
Adult	91.3 ± 9.6	84.1 ± 8.8	80.7 ± 7.4	83.0 ± 12.6

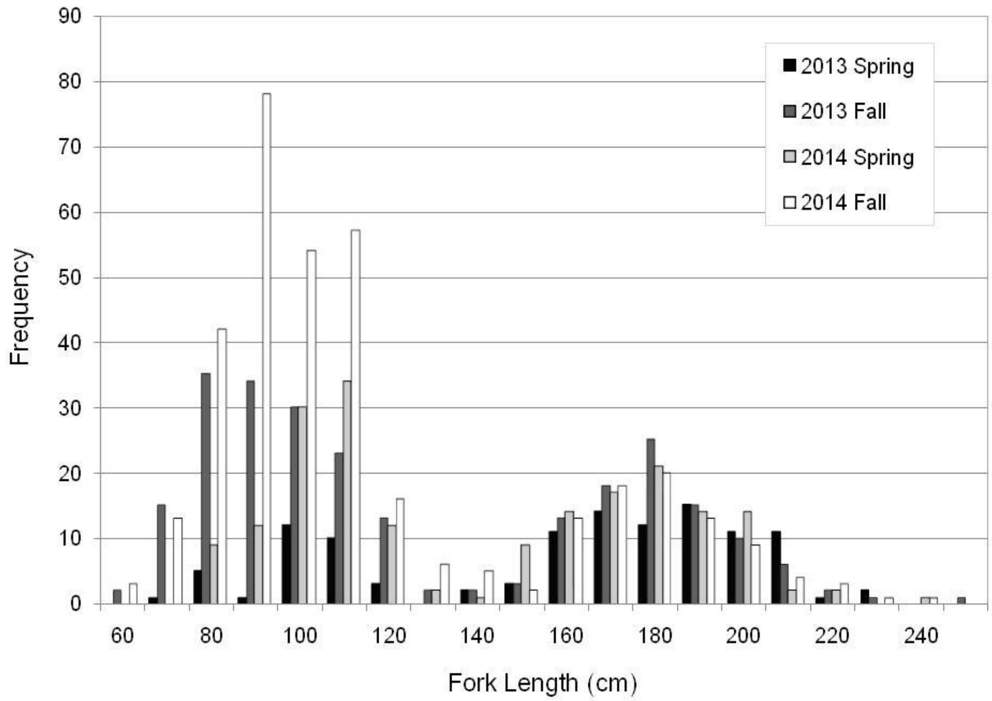

Figure 12. Fork length (cm) frequency of White Sturgeon captured during the 2013 and 2014 stock assessments in the LCR, Canada.

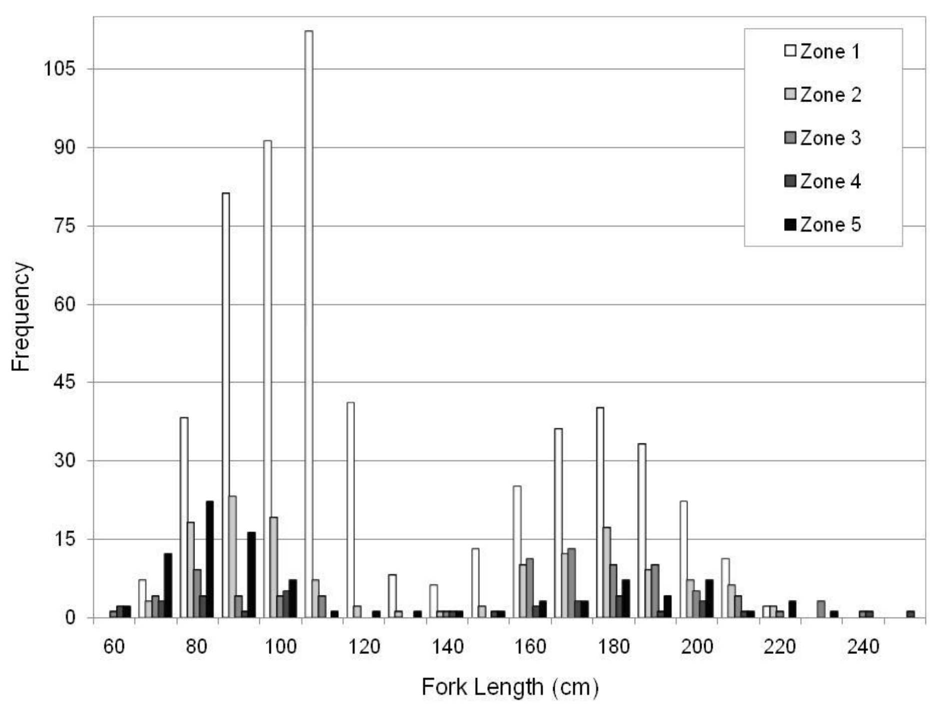

Figure 13. Fork length (cm) frequency by sampling zone of White Sturgeon captured during the 2013 and 2014 stock assessments in the LCR, Canada.

3.5 Acoustic Tagging and Telemetry

The movements of 101 adults (53 females and 48 males) tagged with acoustic transmitters were examined during 2008 through 2014. A total of 139,840 detections were recorded with a mean (± SD) of 1540.1 ± 1485.4 and 1244.1 ± 1173.6 detections for females and males, respectively. Habitat use was highest in the upper section of the river (e.g., Robson reach, rkm 0.1, 2.5, and 6.5) with marginal differences between females and males (Figure 14).

In 2014, 12 (8 males, 4 females; Figure 15) adults were identified for suspected spawn related movements, respectively. The highest proportion of adults identified at a suspected spawning location was detected at rkm 26.0 (0.33) followed by rkm 56.0 (0.25). The majority of males were detected at rkm 26.0 (0.38) and rkm 56.0 (0.25). Female detection was evenly distributed between rkm 16.9, rkm 26.0, rkm 37.5, and rkm 56.0 (0.25).

A high proportion of fish residing in the Upper section (0.80; HLK (rkm 0.1) to Kootenay River Confluence (rkm 10.5)) migrated downstream to the Middle section (downstream Kootenay River Confluence to Birchbank (rkm 29)) during suspected spawn related movements (Table 18). Individuals detected in the Middle and Lower sections (downstream Birchbank to Waneta (rkm 56.0)) tended to remain within their suspected location of residency for spawn related movements (proportion of 0.75 and 0.67, respectively; Table 18). One individual was suspected to have spawned in the Upper section and had travelled the furthest (43.4 km) from the suspected residency location (Lower section) compared to those suspected to spawn in the Middle (n=7; 10.3 ± 7.3 km) and Lower (n=4; 23.9 ± 16.7 km) sections (Table 19). Time spent on the suspected spawning grounds was greater within the Lower section (21.4 ± 5.7 days) than the Upper (14.7 days) and Middle (16.0 ± 13.8 days) sections (Table 19).

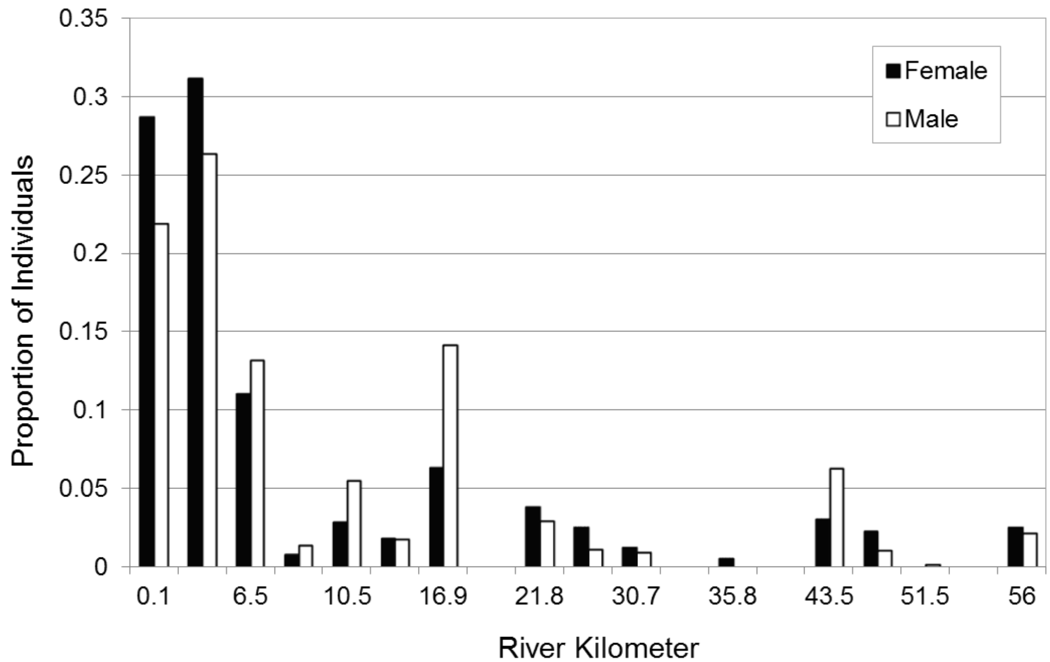

Figure 14. The proportion of detections by river kilometer of female (n = 53) and male (n = 48) adult White Sturgeon implanted with acoustic transmitters in the LCR, 2008-2014.

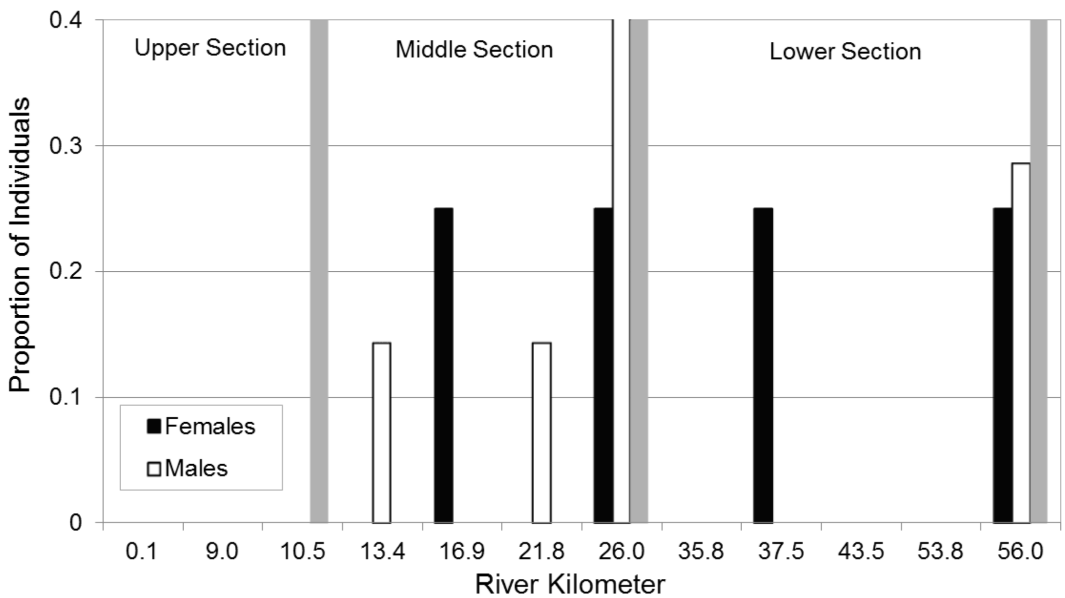

Figure 15. Proportion of detections by river kilometer of acoustically tagged female (n=4) and male (n=8) White Sturgeon identified for suspected spawn related movements in the LCR in 2014. LCR was divided into three sections including: Upper (HLK (rkm 0.1) to Kootenay River Confluence (rkm 10.5)), Middle (downstream Kootenay River Confluence to Birchbank (rkm 29)), and Lower (downstream Birchbank to Waneta (rkm 56.0)).

Table 18. The proportion, by river section, of adult White Sturgeon (n=12) implanted with acoustic transmitters identified for suspected spawn related movements in the LCR in 2014. LCR was divided into three sections including: Upper (HLK (rkm 0.1) to Kootenay River Confluence (rkm 10.5)), Middle (downstream Kootenay River Confluence to Birchbank (rkm 29)), and Lower (downstream Birchbank to Waneta (rkm 56.0)).

Suspected Residency	Suspected Spawning Area		
	Upper	Middle	Lower
Upper	0.00	**0.80**	0.20
Middle	0.00	**0.75**	0.25
Lower	0.33	0.00	**0.67**

Table 19. Mean (± SD) distance travelled (km), travel time (days), and total time on site (days) for suspected spawn related movements for adult White Sturgeon implanted with acoustic tags in the LCR in 2014. LCR was divided into three sections including: Upper (HLK (rkm 0.1) to Kootenay River Confluence (rkm 10.5)), Middle (downstream Kootenay River Confluence to Birchbank (rkm 29)), and Lower (downstream Birchbank to Waneta (rkm 56.0)).

River Section	n	Distance Travelled (km)	Travel Time (Days)	Time Spent on Site (Days)
Upper	1	43.4	12.0	14.7
Middle	7	10.3 ± 7.3	2.7 ± 3.5	16.0 ± 13.8
Lower	4	23.9 ± 16.7	6.1 ± 6.2	21.4 ± 5.7
Overall	12	17.6 ± 14.6	4.6 ± 5.0	17.7 ± 10.6

4.0 DISCUSSION

The primary objectives of this monitoring program were to describe adult White Sturgeon life history, biological, and population characteristics. Through the seventh year of this work, we have been successful in quantifying fish condition, estimating timing and duration of spawning, identifying environmental spawning cues, and describing spawning-related movements and habitat use of adult White Sturgeon in the LCR. Further, this program was responsible for the collection of sexually mature White Sturgeon to use as broodstock and rearing naturally produced offspring collected from the wild for the Conservation Aquaculture Program. Data collection will continue in the following years to provide an estimate of population abundance, growth rates, age class structure, and survival rates, all of which will be used in recovery planning going forward. Outstanding issues identified by the WUP Fisheries Technical Committee (FTC) during the creation of the Columbia Water Use Plan, as provided in the ToR for this program, are described and addressed in Table 20.

Table 20. Outstanding issues identified by the WUP Fisheries Technical Committee (FTC) in the Terms of Reference for this monitoring program.

FTC Outstanding Issue	Current Status
As the annual average number of spawning days at Waneta Eddy appears small relative to the adult population size and the approximate female reproductive cycle, this adult monitoring program may identify additional spawning sites.	Year 7 Update: After collecting early life history data for the first several years of the program, spawning days are not viewed as a reliable indicator of the adult breeding population, given uncertainties in how efficient the methodology is when comparing among years. This inefficiency is driven by annual changes in hydrology and uncertainties regarding the exact geographical locations where spawning (i.e., release of eggs) occurs. This is true even for spawning sites where large amounts of data have been collected (Waneta). Genetic analyses has identified >100 adults spawning annually in the Canadian portion of the Columbia River, with additional adults spawning at two locations downstream. There are now 5 known spawning sites in the transboundary section of the Columbia River.
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 LCR.	Additional spawning sites have been identified through analysis of adult movements (e.g., ALH spawning area in 2010) and through the collection of larvae downstream from suspected locations (e.g., Kinnaird 2007-current). Currently, known spawning sites in Canada are being monitored annually and spawning related movements are evaluated in order to identify any further locations.
Baseline information acquired through this monitoring program may verify that the abundance of adult White Sturgeon in the LCR will not be adversely affected by management response measures.	Revised abundance estimates for wild adult White Sturgeon are being conducted through the entire transboundary reach under a new stock assessment program, with a revised population estimate expected by 2017. This estimate will be used as a baseline for recovery planning moving forward.
Of equal importance to the maintenance of the remaining White Sturgeon population; are there sufficient adults to continue the Conservation Aquaculture Program?	As of 2014, 157 individual adults (97 males and 88 females) have contributed to the Conservation Aquaculture Program. Based on capture records and genetic studies completed to date, there are enough mature wild adults at large to maintain the Conservation Aquaculture Program if needed. However, it is important to note that the success of the Conservation Aquaculture Program has resulted in a strong presence of juvenile age classes, many of which are captured during assessments for

FTC Outstanding Issue	Current Status
	broodstock. This has reduced efficiency of the broodstock program and as a result, significant sampling effort is required to meet broodstock goals (10 males and 10 females). A Streamside Incubation Facility is now being piloted in addition to the broodstock program with the goal of improving genetic diversity in supplemental progeny.

4.1 Broodstock Acquisition

The primary focus of the White Sturgeon broodstock program is to provide mature adults to contribute progeny for stocking through the Conservation Aquaculture Program. The target of 10 mature females and 10 mature males was revised for 2014 due to the pilot Streamside Incubation Facility (SIF) being operational. . It was assumed for the SIF to be properly evaluated that less pressure should be placed on removing mature females from the LCR. As a result, ten White Sturgeon (5 females and 5 males) were transported to the KSH and successfully spawned. To date, adults have not been reused in the program other than a single female that contributed eggs for production in 2001 and reused strictly for experimental purposes in 2010. Given the high number of adults captured annually that have not been used in the Conservation Aquaculture Program, the goal remains to not reuse adults to contribute to production across multiple years. The majority of the adults taken to the hatchery since the program began have been from downstream areas (e.g., Waneta 68%; Table 4) reinforcing the importance of spatially balanced sampling due to high site fidelity. Of importance is the high incidence of juvenile by-catch on the adult sampling gear (Figure 16). This has increased the effort (Figure 17) required to capture sufficient numbers of adults for the aquaculture program. Given the high growth rates of hatchery origin juveniles in this population the issue is expected to worsen over time. The number of hatchery fish at large, as determined through CLBMON29 (BC Hydro 2015b) along with the broodstock program and SIF should be evaluated on an annual basis to determine the most efficient means of meeting recovery targets for this population.

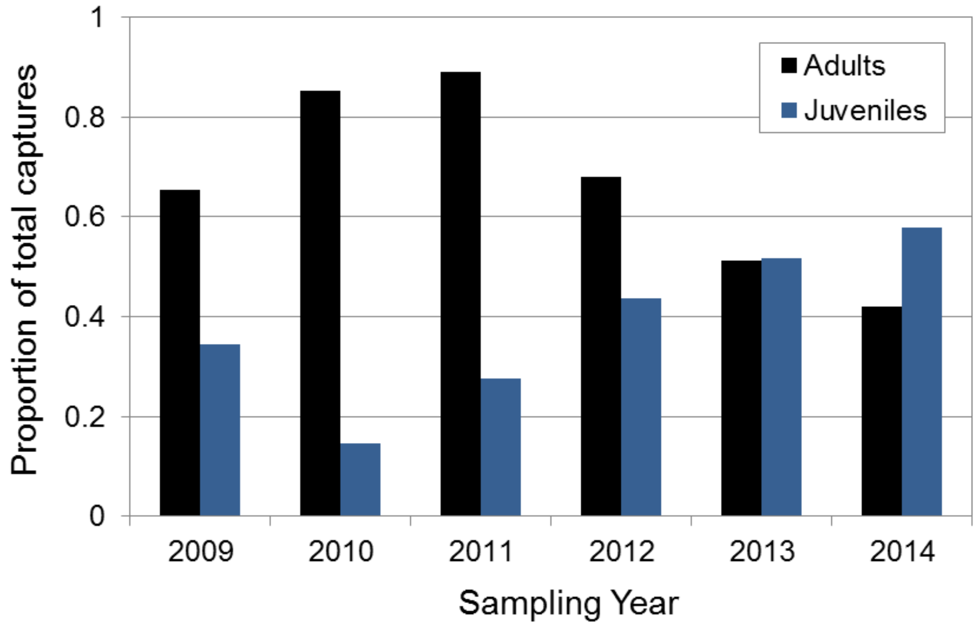

Figure 16. The proportion of wild adult White Sturgeon and hatchery origin juvenile White Sturgeon capture during annual broodstock collection efforts 2009-2014.

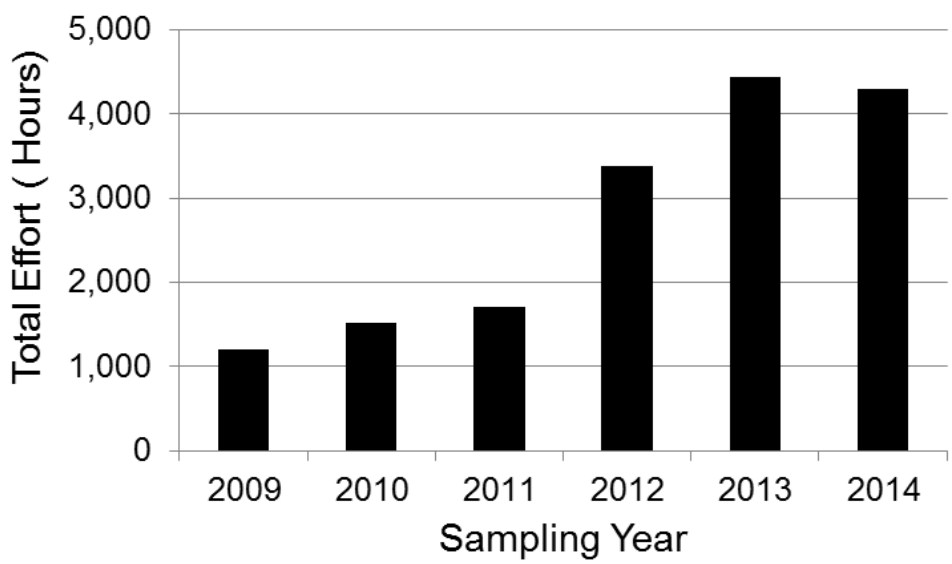

Figure 17. The total amount of effort expended during annual White Sturgeon broodstock collection efforts 2009-2014.

4.2 Streamside Incubation Facility

A key component of the recovery program for LCR White Sturgeon has been the supplementation of the existing wild population through the release of hatchery produced and reared juvenile White Sturgeon (Hildebrand and Parsley 2013). The program was initiated in 2001 through the annual capture of broodstock and the original goals of the conservation aquaculture program were to:

I. Prevent extirpation of the LCR White Sturgeon.

II. Retain genetic diversity of the existing wild adults.

Since the Conservation Aquaculture Program was initiated, 136,914 hatchery-reared juvenile White Sturgeon have been released into the TRA from 2002 to 2014 (yearly releases ranging from 2,455 in 2014 to 21,603 in 2005). These juveniles are known to be in high abundance and objective 1 is considered by the UCWSRI to have largely to be met. As a result, the pilot streamside incubation facility was developed by the UCWSRI TWG to focus on retaining the genetic diversity of the existing wild adults while suitable numbers are still spawning. This was based on the results of genetic work by Jay et al. (2014). The main goals of the facility were ranked by TWG members to be:

1. Maximize genetic diversity [increase effective population size (N_e) and decrease relatedness (rxy)] of supplemental progeny compared to current aquaculture program by representing a larger proportion of wild spawning adults.

2. Rear supplemental progeny in a more natural rearing environment to reduce hatchery effects and provide for imprinting to a specific river location.

Results from the 2014 pilot year for the SIF were successful, with over 1,000 wild origin juveniles released into the LCR. The SIF is planned to be trialed again in 2015, pending outcomes of UCWSRI discussions.

4.3 Spawn Monitoring

For White Sturgeon throughout their range, it is generally thought that the spawning period is protracted and occurs in the late spring and early summer months (May to July) with specific timing dependent on environmental cues (e.g., temperature, flows; Parsley and Beckman 1994). In 2014, spawning was estimated to have occurred from late June into late July at the downstream site of Waneta and in late July at the upstream site of Kinnaird (Table 11). Dispersing larvae were collected within the vicinity of Kinnaird; however, exact location of the spawning area remains unknown. The timing and duration of spawning activity for both years is similar to past years, with the majority of estimated spawning days occurring on the descending limb of the hydrograph and at water temperatures above 14ºC (Golder 2012).

Determining capture efficiency of both egg and larval samples between gear types is important when identifying exact spawning locations of unknown areas.

Egg mats have been consistently used at Waneta for the collection of White Sturgeon eggs since the spawning location was first described in 1993 (Hildebrand and Parsley 2013). At the upstream locations (ALH, rkm 14.5, and rkm 18.2), the use of drift nets has been more effective in collecting eggs or larvae (Table 8). For spawning areas where the exact geographical location is uncertain, drift nets are more effective as they can represent all areas upstream of the sampling location. Though egg mats are effective when the main areas of egg deposition have been identified, drift nets should be used primarily when attempting to assign a general location where spawning may be occurring. To address the objectives of this program as it relates to describing new spawning areas, it is recommended that use of egg mats be restricted to Waneta, and that drift nets are the primary technique used in areas where spawning locations are uncertain (e.g., Kinnaird).

4.4 Population Monitoring, Abundance, and Characteristics

Prior to 2013, the broodstock program served as the sole method of providing information on the biology of the population (e.g., length frequency, growth rates, population estimates). The systematic stock assessment program was initiated to address uncertainties in abundance and survival rate estimates of the LCR White Sturgeon population. Using life history and biological data collected using capture-mark-recapture methods, we will also be able to estimate growth rates across females, males, and immature fish (<150 cm fork length), fish condition, age class structuring, and density dependent responses. This information is required to inform management of LCR White Sturgeon population dynamics and assess trends within the population. It is expected that preliminary population estimates can be generated for the transboundary area starting in late 2015 once data from Canada and US sampling efforts are combined.

4.5 Acoustic Tagging and Telemetry

White Sturgeon in the LCR tend to select deep, slow moving sections of the river which do not appear to be limited under the current operating regime. Adult movements have been similar across all years evaluated with activity generally occurring during the summer months for assumed foraging or spawning. In 2014, White Sturgeon residing in the Middle (Kinnaird to Genelle) and Lower sections (Trail to Waneta) were observed migrating within the respective section of residency for suspected spawning related movements (Table 17). This behavior is similar to observations made previous to 2012 (BC Hydro 2013). As seen in 2012 and 2013, suspected spawning related movements revealed that resident adults within the Upper river section tend to migrate to adjacent downstream spawning areas (Middle section) (Table 17). A small portion of adults monitored in this study exhibited putative spawning migrations to adjoining river areas indicating mixing of adults throughout the river (Table 17). A more fine scale acoustic array (< 1km intervals) will be trialed in 2015 to further describe movements to the Kinnaird area during the spawning period.

Though current results from the telemetry monitoring program reveal patterns of habitat use and possible spawning related movements, caution is advised when interpreting results, as the long-term movement patterns of White Sturgeon are poorly understood. Additional data through the duration of this program (10 years) are needed to address how the operation of the river may influence White Sturgeon habitat use or movements. At the present time, there are sufficient numbers of adults with active acoustic transmitters so additional telemetry tagging is not planned in the coming years. Data will continue to be collected in a systematic fashion using the longitudinal array of receivers in the LCR. An in-depth analysis incorporating a decade of movement data is planned for 2016-2017 to address this management question.

5.0 RECCOMENDATIONS

1. Drift nets maximize catch per unit effort of eggs and larvae from locations upstream of the sampling equipment and should continue to be used as the primary collection method in areas where the exact geographical boundary of the spawning location remains unknown (e.g., in the vicinity of Kinnaird).

    a. Egg mats should continue to be used at Waneta and HLK/ALH in the same consistent fashion as previous years sampling.

    b. Consider deploying additional drift net stations downstream of Kinnaird to help determine where larvae may be originating from.

2. Continue to collect tissue samples from offspring (larvae) at the different spawning areas and from wild juveniles and adults for future genetic analyses.

3. Evaluate a fine scale (< 1km intervals) acoustic array near Kinnaird to describe adult movements in this area during the spawning window. If possible, tag mature females (e.g., F4) with short-term tags (~6 month battery life).

    a. Additional range testing should be conducted throughout the LCR to describe detection probabilities for each unique receiver station.

4. Continue coordinated stock assessment program with US agencies to improve our confidence in the abundance of White Sturgeon in the transboundary reach.

    a. Developed models to estimate survival and abundance that can be updated annually as additional survey data are collected.

5. Development of a database that could store all life history data and telemetry data among researchers and industries.

6. Evaluate and discuss the streamside incubation facility with UCWSRI partners to determine an approach going forward.

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