Columbia River Project Water Use Plan

Lower Columbia River

Reference: CLBMON #29 (Year 8)

Lower Columbia River Juvenile Sturgeon Detection Program: 2015 Investigations Data Report

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EXECUTIVE SUMMARY

The population of White Sturgeon (*Acipenser transmontanus*) in the lower Columbia River (LCR) Canada was listed as one of four endangered populations under the Species at Risk Act (SARA) in 2006. Despite evidence of limited natural recruitment in the LCR, the level of annual recruitment is considered insufficient to maintain a self-sustaining population. Accordingly, the population was forecast to become functionally extinct by 2044 in the absence of effective recovery measures. Recovery was directly initiated in 2001 through the release of hatchery-reared juveniles as a stopgap measure until recruitment failure could be addressed. It was identified during the development of the Columba Water Use Plan (WUP) that direct management responses for White Sturgeon were limited to non-operational habitat improvements designed to improve spawning success and juvenile survival. However, life history data (e.g., abundance, growth, survival) were lacking, and habitat suitability and availability across larval and juvenile life stages were unknown. Accordingly, larval and juvenile monitoring in the LCR over a longer period was deemed critical to addressing management questions related to recruitment and success of the Conservation Aquaculture Program.

For early life stage monitoring, passive sampling was conducted using drift nets in order to determine the distribution of White Sturgeon yolk-sac larvae in the LCR and assist in identifying spawning locations and identify areas of habitat use. In 2015, drift net sampling was conducted at monitoring sites downstream of Arrow Lakes Generating Station (ALH; rkm 0.1), Kinnaird (rkm 13.4 – 19.2) and downstream of the Pend d'Oreille confluence (Waneta; rkm 56.0). Based on development stages of captured yolk-sac larvae, spawning was estimated to have occurred over a short period between June 13 and June 20 at Waneta and July 2 and July 9 Kinnaird and between. We were unable to assign a developmental stage to the one yolk-sac larvae collected at ALH due to the sample's poor condition. The majority of yolk-sac larvae samples captured in 2015 were at an early developmental stage. However, of the developmentally staged samples, 16% were further developed and transitioning to exogenous feeding suggesting some suitable habitat exists for yolk-sac larvae to hide in until they reach developmental stages where drift would naturally occur.

A 2011-2012 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 in 2014 for the purpose of incubating naturally produced eggs collected in the LCR in order to increase number of adults contributing to stocked offspring to increase effective breeding numbers and maintain genetic diversity within the population. Hatched larvae collected as embryos and incubated in the SIF were transported to the Kootenay Trout Hatchery in 2015 and were reared for release as juveniles the following spring.

An annual juvenile White Sturgeon program was initiated in 2008 to describe important parameters related to growth, survival, and distribution in the Canadian portion of the LCR. Monitoring is focused on hatchery origin juveniles as wild juvenile age classes are lacking. Releases of hatchery origin juveniles have

occurred from 2002-2015 with 144,881 individuals stocked into the lower Columbia River and into Lake Roosevelt in the United States. In 2013, juvenile monitoring was established as part of a five-year population assessment initiated to estimate survival rate and abundance of the White Sturgeon population within the transboundary reach of the LCR. Additionally, data from this program will be used to determine juvenile growth rates, fish condition, age class structuring, and density dependent responses. This program is standardized throughout the Transboundary section of the Columbia River, incorporating all habitats within Canada and the US. While wild juvenile sturgeon are encountered, captures from 2013-2015 have been predominantly hatchery-released fish with wild juveniles representing <1% of the total catch. Survival analyses of juvenile capture data have indicated that survival has been higher than originally predicted, and is significantly associated with size at release, with fish released at the largest body size (>300 g) having the highest survival. These survival rates have resulted in an abundance estimate for hatchery origin White Sturgeon of over 30,000 individuals. Additional refinements to survival estimates and discussions around stocking numbers going forward are occurring as part of the larger recovery initiative.

Results from this long- term monitoring program will contribute to knowledge regarding larval and juvenile stages to better understand potential causes of recruitment failure and help inform recovery measures moving forward. The state of knowledge pertaining to the various management questions associated with this monitoring project are summarized in Table ES1.

Table ES1. CLBMON #29 Status of Lower Columbia River Juvenile White Sturgeon Monitoring Program Management Questions.

Management Question	Status
What are the relative abundance, survival rates, and distribution locations of larvae and juvenile White Sturgeon in the lower Columbia River under current operating parameters?	- Larval Stage: Relative abundance and survival of larval sturgeon will be difficult to address given limitations sampling this life stage. However, data pertaining to timing, locations, and frequency of spawning in the lower Columbia River (LCR) has been collected. Larvae have been collected near the HLK/ALH spawning area, downstream of Kinnaird, and from the Waneta spawning site downstream into the US portion of the LCR. Larval catch has predominantly consisted of young (1-3 days post hatch) individuals; however older feeding larvae are collected in large numbers on the US side of the Columbia River suggesting that hiding habitat exists from the Canadian/US border downstream to North Port, Washington. - Juvenile Stage: Survival of hatchery origin juveniles has been higher than originally predicted. This has resulted in a large hatchery population estimated at more than 30,000 individuals. With continued sampling in the coming years, abundance and survival rates will be able to be revised. Distribution of juveniles has been assessed throughout the LCR, and is restricted primarily to slower moving habitats like eddy's and deeper runs. While these habitats are available primarily in the upper (Robson to Genelle) or lower (Beaver Creek to Waneta) sections of the river, juveniles of hatchery origin are captured throughout the entire LCR.
What are the physical and hydraulic properties of this habitat that define its suitability as juvenile sturgeon habitat?	- Juveniles are selecting deeper (>10 m), slow moving (< 1.0 m/s), habitats with smaller substrates (e.g., sand, small gravel). These habitats are widely distributed through the upper reaches (e.g., Robson) and are restricted to eddy habitats downstream of the Kootenay River confluence to the US border.
How do normal river operations affect larval habitat conditions in the lower Columbia River?	- At the present time more data are required to address this question. Spawning has been identified at several locations but the quantity and quality of spawning habitat is currently unknown. Based on the capture of

Management Question	Status
	primarily yolk-sac larvae within a few days of hatch, the spawning habitat throughout the LCR was presumed to be poor for hiding after hatching from the egg. However, increased drift net effort in 2015 compared to all previous sampling years downstream of the Waneta spawning site indicated that a percentage of larvae hide until feeding age before initiating dispersal downstream. Additionally, older feeding larvae are collected in large numbers on the US side of the Columbia River suggesting that hiding habitat exists from the Canadian/US border downstream to North Port, Washington. Additional years of data collection will help further clarify habitat conditions.
How do normal river operations affect juvenile habitat conditions in the lower Columbia River during dispersal and on a seasonal basis?	- The distribution of juvenile White Sturgeon in the LCR is restricted to deeper, slower moving, habitats. These habitats are currently not limited by the operational regime of the river, irrespective of the time of year. Additional data will help to further address this question over a longer time period that includes more operational scenarios and reflects the increasing densities of juvenile sturgeon in the lower Columbia River.

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1 INTRODUCTION

The population of White Sturgeon (*Acipenser transmontanus*) in the lower Columbia River (LCR) Canada was listed as one of four endangered populations under the Species at Risk Act (SARA) in 2006. In Canada, the LCR is defined as the 57.0 km reach of the Columbia River downstream of Hugh L. Keenleyside Dam (HLK) to the United States border. An estimated 1,157 adult White Sturgeon (95% C.I. 414-1899; Irvine et al. 2007) reside within the Canadian reach, with an additional 2,003 individuals (95% C.I. 1093-3223) in the United States between the border and Grand Coulee Dam, WA (Howell and McLellan 2007). This transboundary population is suffering from recruitment failure similar to other populations of White Sturgeon residing in the Kootenay (Anders et al. 2002), Nechako (McAdam et al. 2005), and Snake (Jager et al. 2002) rivers. Despite some evidence of limited natural recruitment in the LCR, the level of recruitment annually is considered insufficient to maintain a self-sustaining population, and the population was forecast by the Upper Columbia White Sturgeon Recovery Initiative (UCWSRI) to become functionally extinct by 2044 in the absence of effective recovery measures (UCWSRI 2002).

The Columbia River Water Use Plan (WUP) Consultative Committee (CC; 2005) recommended giving priority to conservation and recovery of White Sturgeon. However, in recognition of its high value power generation, the Columbia River was designated to remain a working river. It was identified that direct management responses for White Sturgeon were limited to non-operational habitat improvements designed to improve spawning success and juvenile survival. In order to meet this goal, data are required to assess habitat use, suitability, and availability for all life stages of White Sturgeon residing in the LCR. These data include life history measures that are indicative of habitat quality including abundance, growth, development, condition, evidence of food availability, and survival rates. Furthermore, providing estimates of successful reproduction (e.g., egg and larval captures) at both known and suspected spawning locations in the LCR is critical to addressing management questions related to recruitment.

The WUP CC outlined a juvenile sturgeon program that would provide annual monitoring of the relative abundance and distribution of juvenile White Sturgeon in the LCR (CC 2005). The supporting rationale indicated monitoring was to provide information on the patterns of habitat use to better understand potential causes of recruitment failure and opportunities for feasible mitigative actions (CC 2005). The rationale assumed that, the probable bottleneck affecting juvenile survival could be determined with the release of hatchery-reared juvenile White Sturgeon into the system to help identify non-operational changes required for a positive effect on levels of natural recruitment of age 1+ sturgeon. As such, the B.C. Comptroller of Water Rights (CWR) issued a Water License Order directing operations of BC Hydro’s projects on the Columbia River (Mattison 2007). The Order (Schedule F(1)(h)) specifies that the Juvenile Sturgeon Detection Program shall monitor the abundance, distribution, and patterns of habitat use in the LCR in relationship to discharges from HLK.

Identification of critical rearing habitat within the LCR is an important component of recovery to allow for protection or enhancement as recovery moves forward.

Monitoring White Sturgeon spawning activity determines the location of yolk-sac larvae rearing sites. Past studies have documented White Sturgeon spawning behavior immediately downstream of Arrow Lakes Generating Station (ALH, river kilometer (rkm) 0.1; BC Hydro 2013b), downstream of Kinnaird (rkm 13.0 to 19.0; Golder 2009a; BC Hydro 2013b), Pend d'Oreille River confluence (Waneta, rkm 56.0; UCWSRI 2012) and in the vicinity of Northport, WA (Howell and McLellan 2006). At the upstream locations of ALH and Kinnaird, exact locations of egg deposition remains unknown therefore continued monitoring is important to identify location of spawning and yolk-sac larvae rearing habitats.

Outside of annual monitoring programs used to collect information to guide recovery, the sole conservation strategy implemented to date for this population has been restoration through a Conservation Aquaculture Program. The objective of this strategy is to supplement the population with hatchery reared juveniles until adequate levels of natural recruitment can be restored (UCSWRI 2012). Since 2001, an annual broodstock acquisition program has been conducted, with wild mature adults spawned in the hatchery to contribute progeny for stocking in the LCR (BC Hydro 2009). The Conservation Aquaculture Program has been successful in releasing 144,881 hatchery reared juvenile sturgeon into the transboundary section of the Columbia River; 107,256 of which were released in the lower Columbia River in Canada (as of the spring of 2015).

In 2014, it was advised by the Upper Columbia White Sturgeon Recovery Initiative Technical Work 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 (Jay et al. 2014). This has been successful for other sturgeon species (e.g. Lake Sturgeon *Acipenser fulvescens*, Crossman et al. 2011). Developing this facility in Canada also aligned with the US portion of the population, as collections of wild origin yolk-sac larvae serve as the source for the aquaculture program in the US. Results of this program were successful in 2014, with 1,095 wild origin juvenile White Sturgeon were successfully reared to release in the spring of 2015. It was determined that the wild collection program would continue for the next several years.

Hatchery-reared juveniles released as part of the Conservation Aquaculture Program serve as an important learning tool as juvenile age classes are absent in many populations. Determining factors influencing growth and survival of these fish will not only contribute to refining the Conservation Aquaculture Program, but will provide critical insight into the ecology of this species which can be used to guide recovery efforts.

Work that has occurred over the past decade has identified that hatchery-reared juveniles have been successful in surviving after release from the hatchery (Golder 2009b). The survival of hatchery released age-0 juveniles combined with high survival at the older life stages (Golder 2009b; Irvine et al. 2007) suggests that the recruitment bottleneck is likely the result of poor survival during earlier life stages (Gregory and Long 2008; Golder 2009b), which is similar to other systems (Ireland et al. 2002; Gross et al. 2002). As a result, recent monitoring has focused on the potential causes of mortality at the yolk-sac larvae and young-of-year life stages, and to understand underlying mechanisms resulting in recruitment failure.

This report describes the eighth (2015) year of ongoing monitoring in the LCR as a component of the WUP under the project: CLBMON-29 Lower Columbia River Juvenile Sturgeon Detection. Specific components of the study are to:

1. Monitor distribution of both larvae and juveniles.

2. Estimate growth and survival of both wild and hatchery origin juvenile White Sturgeon.

3. Juvenile sex and stage of maturity

1.1 Management Questions

Key management uncertainties encountered during development of the WUP related to how operations of HLK may adversely affect habitat suitability and availability for juvenile sturgeon and thus potentially contribute to recruitment failure of White Sturgeon in the LCR (Columbia River WUP CC 2005). Fundamental management questions to be addressed through the Juvenile Sturgeon Detection Program include:

1. What are the relative abundance, survival rates, and distribution locations of larval and juvenile White Sturgeon in the LCR under current operating parameters?

2. What are the physical and hydraulic properties of this habitat that define its suitability as juvenile sturgeon habitat?

3. How do normal river operations affect larval habitat conditions in the LCR?

4. How do normal river operations affect juvenile habitat conditions in the LCR during dispersal and on a seasonal basis?

1.2 Management Hypothesis

While impoundments and water management at HLK and other dams in the Columbia watershed may be correlated with declines in White Sturgeon recruitment in the LCR, the precise mechanisms remain unclear. Early life stages appear to be most adversely affected and spawning site selection and timing may impact mortality rates experienced by these early life stages. The Juvenile Sturgeon Detection Program is designed to provide baseline information that may be used to evaluate recruitment failure hypotheses and can be used in design of future operational or physical mitigative approaches. Additionally, where feasible, the program is experimentally testing of research hypotheses to get at underlying mechanisms behind recruitment failure. This is the established process outlined at the Upper Columbia White Sturgeon Recovery Initiative Technical Working Group, and described in the groups operational plan which available at www.uppercolumbiasturgeon.org.

The following management hypotheses were used to guide the Juvenile Sturgeon Detection Program studies:

H_0: The operations of the Columbia River dams and reservoirs are not contributing to changes in survival among juvenile sturgeon in the lower Columbia reach.

H_1: Columbia River operations (HLK alone or the cumulative operations of dams affecting the LCR reach hydrograph) are affecting larval behaviour, development, growth, and habitat selection, which result in reduced survival of early life stages.

H_2: Columbia River operations (HLK alone or the cumulative operations of dams affecting the lower Columbia reach hydrograph) are affecting juvenile movements, growth, and selection of suitable rearing habitat, which result in reduced survival of juvenile life stages.

H_3: Columbia River operations (HLK alone or the cumulative operations of dams affecting the lower Columbia reach hydrograph) are affecting the suitability and availability of habitat parameters resulting in reduced survival of early life and juvenile stages of White Sturgeon.

1.3 Objectives and Scope

The LCR Juvenile Sturgeon Detection Program in 2015 was designed to describe life history aspects of juvenile White Sturgeon, as well as provide input to the ongoing consideration of recruitment failure hypotheses, the evaluation of the effects of future management responses, and information to guide conservation culture stocking targets.

As stated in the terms of reference for the work, the objectives of this program will have been met when:

1. The development, condition, drift and movement behaviours, growth, and survival of yolk-sac larvae and juvenile sturgeon are assessed with sufficient consistency to describe annual trends.

2. Early life stage distributions over time, including location and parameters of yolk-sac larvae and juvenile rearing habitats, are adequately defined.

3. Relationships between yolk-sac larvae and juvenile habitat quality and variations in discharge from upstream dams and water levels of Lake Roosevelt reservoir are quantified.

4. Assessment of the effects of current operations and determine feasibility of

management responses are completed.

The scope of the juvenile program focuses on data collection to define yolk-sac larvae and juvenile habitat conditions, determine the effect of existing hydraulic conditions, and identify and assess the most suitable of several management responses to be considered in lieu of operational changes. The specific objectives related to the various components of this Juvenile Sturgeon Detection Program are summarized as follows:

1.3.1 Conservation Aquaculture Program

1. Wild Progeny: Collect naturally produced eggs and larvae for streamside incubation and Kootenay Sturgeon Hatchery (KSH) rearing for stocking purposes.

1.3.2 Larval Stage

1.3.2.1 Yolk-sac Larval Assessment

1. Identify timing and frequency of annual spawning days at Waneta, ALH, and Kinnaird sites using drift nets to collect White Sturgeon yolk-sac larvae.

2. Identify specific locations of unknown spawning grounds and describe yolk-sac larvae rearing habitat.

3. Assess yolk-sac larvae development, condition, behaviour, and survival.

4. Determine effects of current operations on yolk-sac larvae survival and rearing habitats.

1.3.3 Juvenile Stage

1.3.3.1 Juvenile Population Assessment

1. Assess juvenile population abundance, growth, age structure, annual survival rates, and population trajectories.

2. Provide relative abundance and periodic updates to population estimates of the LCR juvenile White Sturgeon populations.

3. Periodically compare new data describing length/weight relationships to monitor growth and conditions of all age classes.

1.3.3.2 Juvenile Sex and Stage of Maturity

1. Identify the sex of hatchery origin White Sturgeon in the Upper Columbia River using non-lethal methods

2. Develop methods and a program to describe annual changes to the reproductive structure of the hatchery origin White Sturgeon. Reproductive

structure can be defined as the proportion of females and males in the adult population that are capable of spawning in any given year.

1.3.4 Habitat Mapping

1. Assess availability and suitability of juvenile White Sturgeon habitat.

2. Quantify physical habitat that can be tied to early life stages and juvenile data collected as part of the Detection Program.

3. Describe and classify physical habitat in the LCR downstream of HLK to the Canada/US border.

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.

1.4 Study Area and Study Period

The study area for the 2015 monitoring program encompassed the 57 km stretch of the LCR from HLK to the Canada/US Border (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. Specific areas of the LCR sampled under the various components of the program are described below.

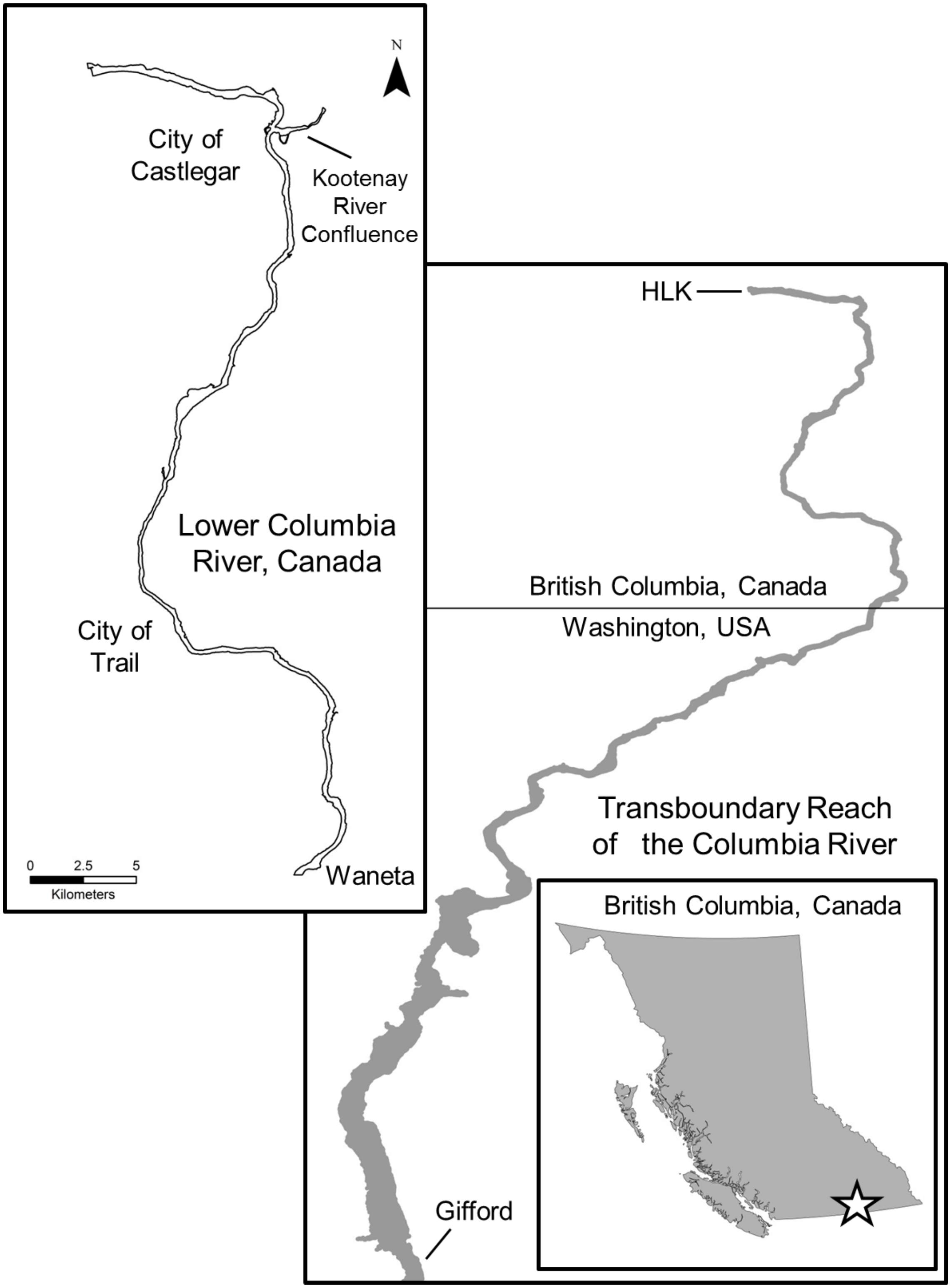

Figure 1. Overview of the study area in the lower Columbia River between Hugh L. Keenleyside Dam (HLk, rkm 0.1) and the Canada/US border (rkm 57.0).

2 METHODOLGY

The monitoring study design follows the recommendations of the UCWSRI Technical Working Group (TWG) who provided an outline for what they viewed as the components of a LCR juvenile 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 spawn monitoring, yolk-sac larvae and juvenile assessments, and a suite of population characteristics including diet composition, and population size estimation. These are described separately below.

2.1 Physical Parameters

2.1.1 Discharge

In 2015, discharge records for the LCR at Arrow Reservoir (combined HLK and ALH discharges from Arrow Lakes Reservoir), the Kootenay River (combined discharge from Brilliant Dam and the Brilliant Expansion facility), 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), cubic feet per second (cfs), and in thousands of cubic feet per second (kcfs) of passage flow.

Typically, the metric discharge measurement (cms) is used to discuss and present results of volumetric flow rates in technical reports and scientific publications. However, 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 and discussion sections of this study report.

2.1.2 Water Temperature

For the 2015 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), Rivervale (rkm 35.8), and Waneta (rkm 56.0). Water temperatures were recorded hourly at each location using thermographs (Vemco Minilogs, accurate to +0.1°C).

2.2 Larval Stage

2.2.1 Yolk Sac Larval Assessment

2.2.1.1 Study Design

Sampling was conducted at several sites to determine the relative abundance and distribution of White Sturgeon yolk-sac larvae in the LCR. Sites were selected based on previous monitoring program data collection where White Sturgeon have been confirmed to have spawned, or have been suspected to spawn.

Within the Canadian portion of the LCR, White Sturgeon reproduction occurs from mid-June through August (BC Hydro 2013a, 2013b) at two known spawning sites of Waneta (rkm 56.0) and ALH (rkm 0.1) (Figure 2). Waneta sampling is located downstream of the Pend d'Oreille River confluence immediately upstream of the Canada/US border. This site has been monitored for spawning activity since 1993 and is the main area of White Sturgeon spawning activity within the LCR, Canada (Hildebrand et al. 1999; Irvine et al. 2007; Golder 2009a). In addition, sampling occurred immediately downstream of ALH tailraces as described by Terraquatic Resource Management (2011). Sampling was also conducted downstream of Kinnaird (rkm 13.4 to rkm 19.2; Figure 2) based on previous studies (BC Hydro 2015a, 2015b), however location of exact egg deposition remains unknown.

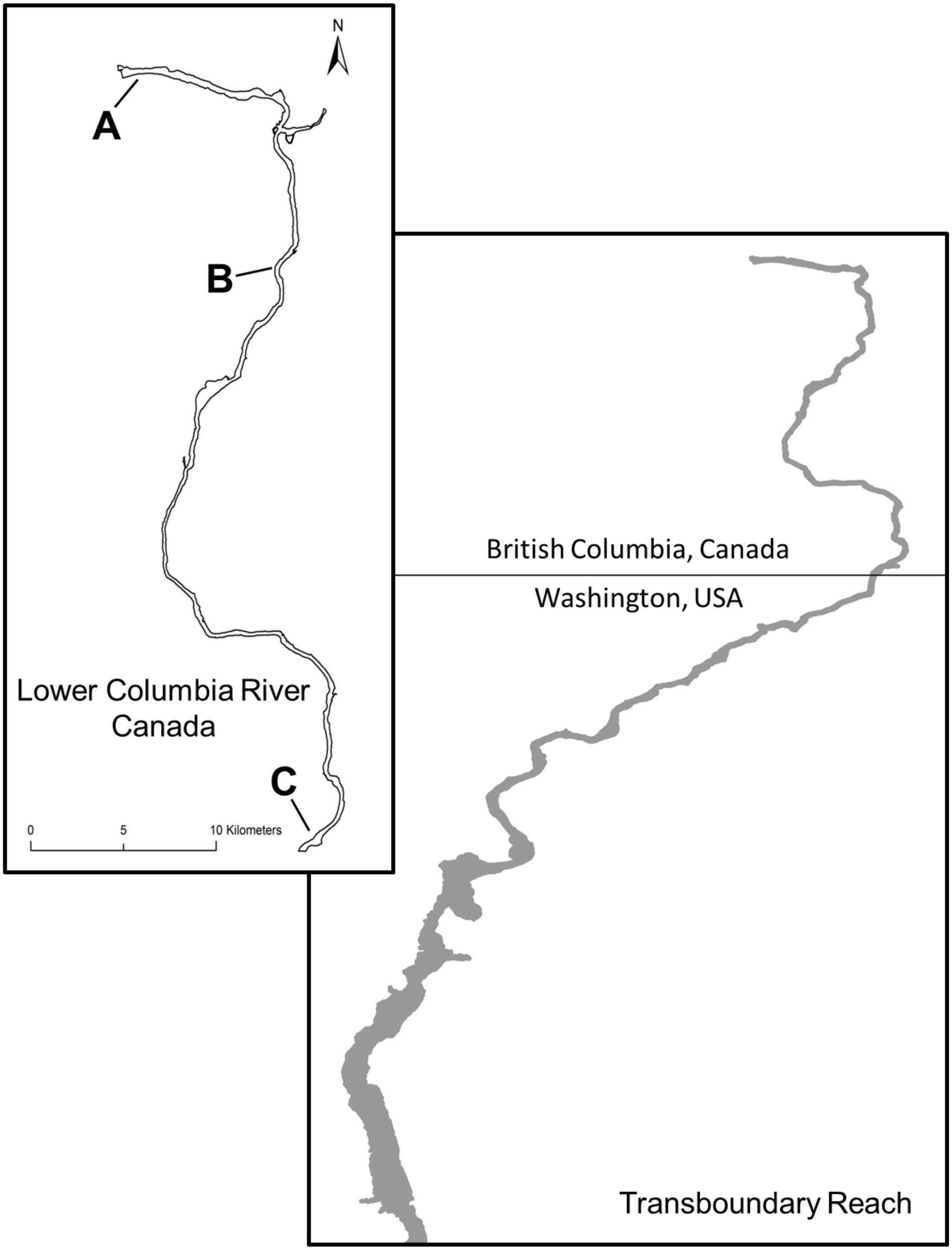

Figure 2. Drift net deployment sites in the lower Columbia River including: A) Arrow Lakes Generating Station (rkm 0.1), B) downstream of Kinnaird (rkm 13.4 to rkm 19.2), and C) Waneta (rkm 56.0).

2.2.1.2 Sampling Methods

Drift net sampling has been used successfully to capture passively dispersing yolk-sac larvae for many sturgeon species including White Sturgeon in the LCR (BC Hydro 2015a), Lake Sturgeon (*A. fulvescens*; Auer and Baker 2002), and Shortnose Sturgeon (*A. brevirostrum*, Moser et al. 2000). Drift net sampling has been added to the spawn monitoring program in recent years and has proven to be successful at documenting spawning days and larval dispersal patterns (BC Hydro 2013b).

Spawn monitoring remained consistent with previously established locations of drift net sampling (see Golder 2009a, 2010, 2012, 2013, 2014, and Terraquatic Resource Management 2011 for details). Drift nets were deployed at ALH (n=3), rkm 13.4 (n=4), rkm 16.9 (n=1), rkm 17.3 (n=1), rkm 18.2 (n=4), rkm 19.2 (n=1), and Waneta (n=7). Catch per unit effort (CPUE) was calculated for each site across years. The Waneta effort was elevated compared to previous years in an attempt to provide embryos and larvae for the SIF and to further describe the timing and frequency of spawning at that location.

Drift net deployment and anchor system specifications were consistent among sampling locations and between sampling years in the LCR. Drift nets used during the sampling period were of standard design 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 only deployed for short-sets (2 to 4 hour periods). Altered drift nets were deployed for long- (24-hour periods) and short sets.

Drift net anchor systems were comprised of two lead steel claw river anchor (30 kg) attached by approximately 6 m of 3/8 galvanized chain. One 30 m section of 0.95 cm diameter braided rope was extended between the upstream anchor and a buoy at the surface of the river providing a means to remove the entire anchor system. A second rope was attached between the downstream anchor and the front of the drift net. A third 0.95 cm braided rope was attached to the top of the drift net frame to a surface buoy for deployment and retrieval purposes without dislodging the anchor system.

Drift nets were deployed to stand perpendicular to the river bottom and collect drifting 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 19 L buckets 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 trays to improve contrast when searching for White Sturgeon larvae. White Sturgeon larvae were enumerated by net for each sampling location and session. Deployment and retrieval times, water temperatures (°C), and water depths (m) for each sampling location were recorded.

2.2.1.3 Larval Sampling

All live yolk-sac larvae were transported to the SIF (see BC Hydro 2015b). No live samples were sacrificed for preservation as practiced in previous years (BC Hydro 2015a). Dead larval samples collected at all locations were preserved for possible future genetic analyses.

2.2.1.4 Developmental Staging and Estimation of Fertilization Date

Preserved yolk-sac larvae were randomly examined with respect to date, stage, and site (to reduce observer bias) using a digital compound microscope (Nikon SMZ-745t Stereo Microscope with 10X eyepiece) and assigned a developmental stage. Enumeration of stages corresponded to the yolk-sac larvae classification by Dettlaff et al. (1993), including stages 36 (hatch) through 45 (exogenous feeding). No preserved samples had developed beyond stage 45.

Fertilization dates for collected yolk-sac larvae were estimated by back-calculation from the recorded date and time of preservation based on developmental stage and mean incubation water temperature (BC hydro 2016b). The estimated age 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 developmental staging as a method to delineate spawning days and estimate time of spawning can be affected by individual White Sturgeon spawning behaviour, yolk-sac larvae maturation rates, and more importantly, the fluctuation in daily thermal regimes (Parsley et al. 2010).

2.3 Juvenile Stage

2.3.1 Conservation Aquaculture Program

Design of the LCR Streamside Incubation Facility (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). To reduce sediment in the incubation jars and tanks, water was filtered (254 micron; Spin-Down Separator, Denton, TX) and tanks were cleaned twice a week by purging to remove sediment and waste. All yolk-sac larvae were transported to the KSH within 7 days of hatch in bags of ambient river water fill with oxygen. Juveniles were reared at the KSH until date of release into the LCR (see FFSBC 2016 for details). Temperature loggers inside the facility recorded air, LCR water, and facility tank water temperatures.

2.3.2 Juvenile Population Monitoring, Abundance, and Characteristics

Starting in 2013, a systematic stock assessment program to address uncertainties in the current population 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 (TBR). 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. Results presented here include data collected in the Canadian and US portions of the LCR.

2.3.2.1 Study Design

The study area for the stock assessment program started at HLK, Canada, and extended downstream to Gifford, Washington, USA (Figure 3). Identifying the distribution of juvenile White Sturgeon was an important component to the CLBMON-29 program as previous sampling efforts were limited to specific spatial areas of the LCR (Golder 2006a). Therefore, the LCR study area was stratified into 5 equal zones (11.2 rkm in length), and sampling effort was consistent at 1.6 hooks per hectare of river throughout the entire study area. We used a generalized random-tessellation stratified (GRTS) design developed by Stevens and Olsen (2004) to randomly assign sampling locations spatially balanced within each river zone. This was conducted with the statistical package R (Program R, version 2.9.0) using the library packages spsurvey and sp, provided by the United States Environmental Protection Agency (US EPA). The library package spsurvey allows a user to input data/criteria needed for a GRTS sampling design. We developed shapefiles (i.e. geo-referenced maps) for each river zone using ArcMap (version 10.0, Environmental Systems Research Institute, Inc. (ESRI)). Each river zone shapefile was imported into spsurvey and sampling sites were randomly generated. The locations of each sampling site were output as coordinates in Universal Transverse Mercator (UTM) format for visual display on maps and for importing into handheld global positioning system (GPS) devices used for field application. Sites were sampled in ascending order until the required effort had been expended (further detail provided below).

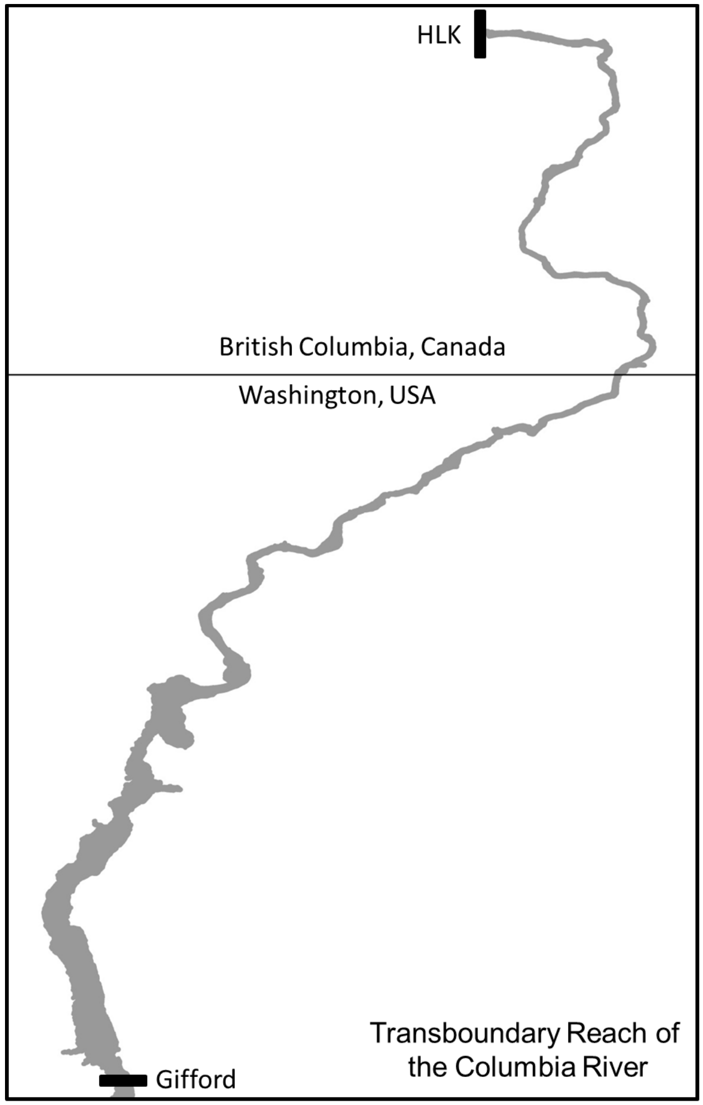

Figure 3. Study area for White Sturgeon stock assessment survey occurring from 2013-2017 in the Transboundary Reach of the Columbia River. Upstream extent of the study area is Hugh L. Keenleyside Dam in Canada, and the downstream extent of the study area ends at Gifford, Washington, USA.

2.3.2.2 Juvenile Capture

The requirement for a consistent, well-documented approach to 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 and handling of White Sturgeon (Golder 2006b). Set lines were the only method used to capture White Sturgeon during the stock assessment and have been successfully used in the LCR 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 84.0 m in length and consisted of a 0.95 cm diameter nylon mainline with 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. Four different Halibut 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 a 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. All set line hooks were baited with pickled squid obtained from Gilmore Fish Smokehouse, Dallesport, WA USA.

Set lines were deployed from a boat at 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 2.3.3). Catch per unit effort (CPUE) was calculated as the total number of fish captured per set line hour.

2.3.2.3 Fish Handling, Biological Processing, 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.

All individuals were assessed for external markings (removed scutes; see FFSBC 2013, 2014, 2015, 2016 for juvenile marking details) and the presence of a PIT tag (400 kHz PIT tags or 134.2 kHz ISO PIT tag; Biosonics Inc.) indicating previous capture. We followed the assumption that juvenile White Sturgeon captured without external markings were of wild origin. Untagged 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. 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 (± 0.5 cm) and weight (± 2.2 kg). All life history data were recorded in the field on standardized data forms and later entered into an electronic database.

Tissues samples were taken from every wild fish captured for future genetic analysis. 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. Blood samples were collected from all fish captured via the caudal vein to determine ploidy levels (see BC Hydro 2015b for details). 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. For autopolyploidy assessment see FFSBC (2014, 2015, 2016).

Once all biological data was collected, White Sturgeon were returned to the water following processing and remained in the stretcher until they swam away under their own volition.

2.3.2.4 Data Analysis

Catch per unit effort (CPUE) was calculated as total White Sturgeon captures per effort hour. Proportion of total capture was calculated by means of brood year class and sampling zone. Spatial distribution of juvenile White Sturgeon in the LCR was assessed qualitatively by visual examination of capture locations and quantitatively by comparison of CPUE among sampling zones within each year.

Biological data collected and analyzed in this report included fork length (FL; cm), weight (kg), and relative weight (W_r). Relative weight is a measure of fish plumpness allowing comparison between fish of different lengths, inherent changes in body forms, and populations (Wege and Anderson 1978). Relative weight was 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 juveniles in 2011 and 2012, as well as previous years including 2009 and 2010 (BC Hydro 2013a), 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 standardized weight and L is fork length (FL; cm).

Statistical analyses were performed using JMP (Version 12.0.1; SAS Institute Inc. 2015). The relationship between year class (including wild fish as a factor) and data on FL, weight, and W_r were each examined. The influence of sampling zone on each of FL, weight, and W_r was also examined. Where normal distributions were present, an Analysis of Variance (ANOVA) and Tukey-Kramer HSD tests were used to determine differences. When nonnormal distributions were identified, data transformations were conducted followed by an ANOVA and Tuky-Kramer HSD test. If transformations resulted in a poor goodness of fit (Shapriro-Wilk test for normality), a Wilcoxon's rank-sum test was used to test for differences.

Total and annual growth was calculated for each age class. We used an allometric growth model ($W = \alpha L^{\beta}$) to predict juvenile sturgeon weight from length and to develop a relationship for use in further sampling efforts. Prior to fitting the model, the equation was log-transformed on both sides to achieve a linear relationship:

$$\ln W_i = \ln(\alpha) + \beta * \ln(L_i)$$

where W_i is the predicted weight and L_i is the fork length of the individual juvenile sturgeon used to predict W_i. We fit the model by minimizing the residual sum of squares using the solver tool in excel. After fitting the model the estimates were back transformed using the equation:

$$W_i = EXP(\alpha)*EXP(L_i)^{\beta}$$

A von Bertalanffy growth model (Equation 9.9, Ricker 1975) was used to predict juvenile White Sturgeon length-at- age from age using the solver tool in excel to predict model parameters. The equation used was:

$$l_t = L_\infty\left(1 - e^{(-K(t-t_0))}\right)$$

where l is length at age t, L_∞ is the length that a fish would achieve if it continued to live and grow indefinitely, K is a constant determining the rate of increase or decrease in length, and t_0 is the age at which the fish would have been zero length if it grew according to the manner described in the equation (Ricker 1975).

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 hatchery released juveniles. Catch records will be analyzed across all years of stock assessment in an effort to provide recommendations to annual conservation aquaculture breeding plans and maximize the genetic diversity available for culture practices.

2.3.3 Juvenile Survival and Abundance Analyses

A key component of the Upper Columbia White Sturgeon Recovery Initiative (UCWSRI) Recovery Plan is the supplementation of the existing White Sturgeon population through broodstock collections, hatchery rearing, and stocking of juvenile White Sturgeon. The 136, 914 hatchery-reared juvenile White Sturgeon released in the TBR from 2002 to 2014 have been monitored annually by Canadian and US organizations providing data regarding distribution, abundance, growth, and condition; however, data and analyses of survival is limited. This component of the monitoring program utilizes the entire combined dataset (2002-2014) from Canadian and US capture efforts to provide a preliminary analysis of survival for hatchery-reared juvenile White Sturgeon in the Upper Columbia River and estimate population abundance of hatchery origin sturgeon.

2.3.3.1 Data Sources and Manipulation

Recapture data of hatchery-reared juveniles stocked in the Columbia River were compiled in both Canada and the US from sampling years 2002 through 2014. Prior to stocking, all juveniles were measured for weight-at-release, administered a PIT tag, and marked externally by the removal of lateral scutes (see FFSBC 2016 for details). Individuals of hatchery origin that did not bear a PIT tag at time of recapture were tagged with a PIT tag prior to re-release after study processing and the new tag number was treated as the original tag administered prior to stocking. Analyses focused on annual survival therefore all within-year recaptures and season of fish stocking data were discarded. All fish reported as sampling mortalities or sacrificed for laboratory analyses were removed from the dataset.

Stocking release locations were grouped into three sections: (1) Upper: Canadian locations including HLK, Robson, Kootenay River; (2) Lower: Canadian locations including Waneta Eddy, Beaver Creek, Genelle; and (3) US: locations in the USA including Kettle Falls, Nancy Creek/Marcus Flat, North Gorge, Northport, Barnaby Island, China Bend boat ramp, Lincoln boat ramp, Porcupine Bay, Spring Canyon boat Ramp, Hunters boat ramp, and Sherman Creek. At time of release, all fish were coded as age-0.

Due to differences in sampling methods across years, data were separated into two blocks for separated analyses. Data Block 1 included the 2002-2007 release data and 2002-2007 recapture data. Data Block 2 included the 2002-2008 release data and the 2008-2014 recapture data. All recaptures of fish less than 6 years of age were removed to account for sampling methods targeting larger juvenile fish.

2.3.3.2 Statistical Methods for Juvenile Survival Estimates

Cormack-Jolly-Seber (CJS) models were used to estimate annual apparent survival rates (φ) and recapture probabilities (p) of hatchery-reared juvenile White Sturgeon at large. The analyses were implemented using the statistical program R, v. 3.1.0 (R Development Core Team, 2014), interfaced with Program MARK (White and Burnham 1999) through the package RMARK (Laake 2013).

The statistical models grouped the data by release section (Upper, Lower, and US). The models also grouped Data Block 2 by the dichotomous variable of whether the fish were released in 2002 or in a different year. The encounter history for all fish was coded into individual recapture events for each release group (Table 1). This accounted for differences between rates of recapture of fish released in the different sections.

In both data blocks, recapture was modeled as a constant [P(.)], as year-specific [p(t)], as release section-specific, and as specific to each recapture event grouping (Table 1). Survival was modeled using two age classes. For data Block 1, the first age class represented survival from period of release (e.g., spring, age-0) to the modeled first recapture (e.g., the fall of the year after release, 1.5 year intervals). This interval was different than survival between all subsequent recapture intervals (1 year intervals). For data Block 2, survival between release and first recapture event represented 6 years at large (first age class), whereas all subsequent periods between recaptures represented 1-year intervals (all subsequent ages). The models were specified by pairing all possible combinations of chosen survival and recapture parameters (Table 2).

Data Block 1 was also analyzed using 3 and 4 age bins, since mortality may change between the first years of life. In contrast, since data Block 2 represented fish of age-6+, there was no biological reason to assign different survival to fish older than 6 years. A survival specification used only for data Block 2 reflected the high presence of 2002-released fish in 2008-2014 recapture data. The survival specification was a dichotomous variable, identifying whether a fish was released in 2002 or in a different year.

Since the first modeled age class represented 1.5 years in the analysis of data Block 1 and 6 years in data Block 2, survival estimates had to be adjusted to reflect annual survival. Annual survival of the first age class was estimated as $x^{2/3}$ and $x^{1/6}$ of the predicted survival in analysis of data Block 1 and 2, respectively.

The variance inflation factor ($\hat{c}$) was estimated using program RELEASE. To account for the heterogeneity due to weight at release, and since RELEASE does not account for individual covariates, the continuous weight at release variable was divided into 5 weight bins, based on the quintiles of release weight distribution (bin cutoffs were 34.0, 43.0, 55.0, 82.3, and 672 g, respectively). Goodness-of-fit was tested using the TEST2 and TEST3 procedures in

RELEASE, where TEST2 examines whether recapture probability of recapture at event (*i*+1) is a function of recapture at the previous event, and TEST3 examines the distribution of recaptures of all animals captured at event *i*. Together, the tests examine whether recapture probability is even for all animals in the study. The estimated ĉ value was used to estimate the corrected quasi-Akaike Information Criterion (QAICc) values and to adjust the 95% confidence intervals (CI) on predicted survival values.

Model selection was performed using the QAICc, which adjusted AIC by a variance inflation factor (ĉ) to account for over dispersion (Burnham and Anderson 2002):

$$QAICc = \frac{-2\ln(L)}{\hat{c}} + 2K + \frac{2K(K+1)}{n-K-1}$$

where *L* is the maximized value of the likelihood function for the model, *K* is the number of model parameters, *n* is the number of data cases, and ĉ is the measure of the lack of fit between the general and saturated models. Analyses focused on results from the QAICc-selected best-fitting model.

Table 1. Coding of recapture events, specified by data block.

Data Block	Group	Recapture Event Year	Recapture Event Code
Block 1	Upper	2003, 2004	e
		2005	f
		2006	g
		2007	h
	Lower	2003, 2004	a
		2005	b
		2006	c
		2007	d
	US	2003, 2004	*
		2005, 2006	i
		2007	j
Block 2	Upper	2008	a
		2011-2013	b
		2009, 2010, 2014	c
	Lower	2008	a
		2009-2013	b
		2014	c
	US	2008-2009	*
		2010-2012	d
		2013-2014	e

*no releases in 2002-2003; fixed zero recapture

Table 2. Description of Cormack-Jolly-Seber models used to examine annual apparent survival rates and recapture probabilities of stocked hatchery juvenile White Sturgeon. The candidate models were constructed by matching each survival structure with each recapture structure.

Data Block	Survival	Recapture
	ϕ(ages2, c/c), age-specific; two age bins (bin 1 = ages 0-1.5 for block 1, ages 0-6 for block 2, bin 2 = age-1.5+ for block 1, age-6+ for block 2), both bins constant (c) across years	p(.), constant
	ϕ(ages2, weight at release / weight at release), age-specific survival as a function of release weight (g); two age bins (bin 1 = ages 0-1.5 for block 1, ages 0-6 for block 2, bin 2 = age-1.5+ for block 1, age-6+ for block 2	p(t), year-specific (t)
Block 1	ϕ(ages2, release weight/c), where survival of the first age bin (ages 0-1.5 for block 1, ages 0-5 for block 2) depends on release weight (g), and survival of all other ages is constant	p(release section), specific to release sections
	ϕ(ages3, c/c/c), age-specific; 3 age bins (ages 0-1.5, 1.5-2.5, & 2.5+), all bins constant (c) across years	p(event), specific to recapture event grouping
	ϕ(ages4, c/c/c/c), age-specific; 4 age bins (ages 0-1.5, 1.5-2.5, 2.5-3.5, & 3.5+), all bins constant (c) across years	
	ϕ(release year = 2002), a dichotomous variable, to account for the higher proportion of 2008-2014 catches from fish released in 2002.	p(.), constant
	ϕ(release year = 2002 + ages2, release weight/c), an additive function of whether the fish were released in 2002 and weight-dependent survival for the first age class (ages 0-1.5 for block 1, ages 0-5 for block 2) and constant survival for all subsequent ages.	p(t), year-specific (t)
Block 2	ϕ(release year = 2002 * ages2, release weight/c), a multiplicative function of whether the fish were released in 2002 and weight-dependent survival for the first age class (ages 0-1.5 for block 1, ages 0-5 for block 2) and constant survival for all subsequent ages.	p(release section), specific to release sections
	ϕ(ages2, c/c), age-specific; two age bins (bin 1 = ages 0-1.5 for block 1, ages 0-6 for block 2, bin 2 = age-1.5+ for block 1, age-6+ for block 2), both bins constant (c) across years	p(event), specific to recapture event grouping
	ϕ(ages2, weight at release / weight at release), age-specific survival as a function of release weight (g); two age bins (bin 1 = ages 0-1.5 for block 1, ages 0-6 for block 2, bin 2 = age-1.5+ for block 1, age-6+ for block 2)	
	ϕ(ages2, release weight/c), where survival of the first age bin (ages 0-1.5 for block 1, ages 0-5 for block 2) depends on release weight (g), and survival of all other ages is constant	

2.3.3.3 Juvenile Abundance Estimates

The sum of estimated number of surviving juveniles in a given year and the number of hatchery-reared fish released that same year yielded mean abundance values (CI 95%).

2.3.4 Juvenile Sex and Stage of Maturity

A program to determine the sex and stage of maturity for juvenile White Sturgeon was initiated in fall 2015 to address uncertainties related to the proportion of hatchery origin juvenile White Sturgeon that could initiate spawning with the existing wild adults. In addition to determining sex through the use of an otoscope, endoscopy techniques were used to build a catalogue of images to track stage of maturity over time at the individual level and to help identify the sex of individuals that can't be conclusively determined in the field. Biopsy samples of the gonad were also collected for histology work to further increase confidence when assigning sex in the field. Knowledge of when hatchery-released fish reach reproductive maturity is particularly important for recovery planning and confidence in assigning sex of White Sturgeon is critical for many of the LCR research projects including telemetry and population assessments.

2.3.4.1 Study Design

As a pilot study, sampling effort was distributed between upstream and downstream sections of the LCR to efficiently maximize the collection of hatchery released juvenile White Sturgeon. Based on capture results of previous stock assessment studies (BC Hydro 2016b), sampling was conducted within two river zones: zone 1, rkm 0.1 – 11.2, and zone 5, rkm 45.8 – 57.0 (Figure 4).

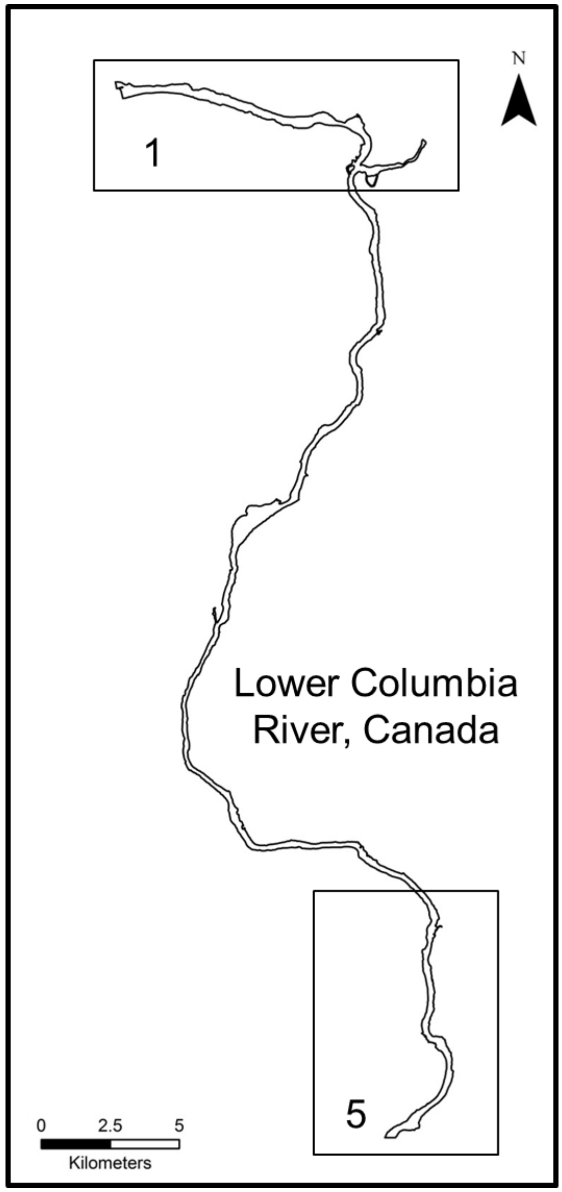

Figure 4. Lower Columbia River showing the two zones (1 and 5) of the river where juvenile White Sturgeon were sampled in 2015 for sex and stage of maturity work.

2.3.4.2 Juvenile Capture

This program used two capture methods including set lines (as described in Section 2.3.2.2) and angling. Angling has been a proven method of capture in the LCR during previous studies (BC Hydro 2015a, 2015c). Hook sizes for setlines (14/0 and 16/0) and angling (8/0) were used to target juvenile White Sturgeon.

Angling equipment consisted of a stiff action rod suitable for White Sturgeon, level wind reel spooled with 45 to 58 kg test braided nylon line, barbless hook baited with earth worms, and lead weight (510-680 g) to hold the hook on the river bottom.

At each sampling site, angling rods were deployed from an anchored boat and sampling continued until no fish were captured within 30 minutes of sampling effort. If multiple fish were captured at a time, fish were placed in a holding tank of ambient river water until processing and release. All individuals were assessed for external markings (removed scutes, see FFSBC 2013, 2014, 2015 for juvenile marking details), presence of a PIT tag, fork length (± 0.5 cm) and weight (± 2.2 kg). Untagged fish were administered a PIT tag as described in Section 2.3.2.3. Fish handling, biological processing, and release were completed as described in Section 2.3.2.3.

2.3.4.3 Sex Determination, Stage of Maturity, and Biopsy Sampling

All individuals from year classes older than 2007 were selected for sex determination and biopsy sampling. Year class was determined by external markings from the removal of lateral scutes (FFSBC 2016) and verified by PIT tag. A 1.5 cm long incision was made through the ventral body wall just off the midline using a sterile scalpel. An otoscope was inserted into the incision and sex was assigned based on qualitative histology (Webb and Van Eenennaam 2015). Females were classified by the presence of ovarian tissue; bright white, yellow, or orange in colour with grainy ovigerous folds. Males were classified bythe presence of testicular tissue; smooth, turgid, and whitish in colour. Stage of maturity for females and males are provided in Table 3 and Table 4, respectively.

A biopsy tool (Miltex Cup Jaw Biopsy Tool) was inserted into the body cavity via the otoscope to collect a small (2 mm^3) sample of the gonad. Each sample was preserved in formalin for histological analyses. The otoscope and biopsy tool was removed and a handheld USB digital endoscope (Vividia 2.0MP) was inserted into the body cavity to capture an image of the gonads. The image was projected onto a computer screen and the endoscope was manipulated in the body cavity to ensure a clear image was obtained. Images were saved directly on the computer and further edited to improve contrast and clarity. Images were catalogued by individual fish and sex. Following endoscopy, the incision was closed using a half circle CP-2 reverse cutting-edge needle wedged to a 2-0 monofilament Polydioxanone suture. Sutures were spaced approximately 0.75 cm apart and sufficient slack was provided in the sutures to prevent tissue damage caused by swelling during the healing process.

Table 3. Stage of female gonad development identified through visual examination.

Developmental Stage		Description
1	Differentiation	Ovarian groove starts to develop into small, very thing ovigerous ribbon containing clusters of oogonia
2	Pre-vitellogenic	Obvious ovigerous folds with small translucent oocytes
3	Early vitellogenic	Ovigerous folds contain small white oocytes
4	Mid-vitellogenic	Eggs in the ovary are seen as larger spheres, white to cream to yellowish in colour
5	Late vitellogenic	Grey to black ovarian follicles are visible
6	Post vitellogenic	Fully grown, black ovarian follicles
7	Oocyte Maturation/ Ovulation	Eggs are freely flowing from vent
8	Post-ovulatory	Ovaries contain postovulatory follicles and the next generation of oocytes are present (stage 2 or 3)
9	Atretic	Oocytes are soft, crush easily, and have a marbled appearance

Table 4. Stage of male gonad development identified through visual examination.

Developmental Stage		Description
1	Differentiation	Testicular tissue is a thin white thread (≤ 1mm)
2	Pre-meiotic	Testicular tissue is a thicker white thread (1-4 mm)
3	Onset of meiosis	Testis have whitish colour and turgid texture ranging from 0.5-2 cm
4	Meiotic	Gonad is primarily testicular tissue (2-3 cm) with much less adipose tissue
5	Mature	Large milky-white testis (3-8 cm) with no adipose tissue
6	Spermiation	Release of milt
7	Post-spermiation	Classification requires histological methods

2.3.4.4 Data Analyses

Statistical analyses were performed using JMP (Version 12.0.1; SAS Institute Inc. 2015). A Student's T-test was used to determine differences between assigned sex and data on FL and weight. Data were tested for normality and equal variances.

2.3.4.5 Biopsy Sample Analyses

All biopsy samples will be transported to a laboratory for histological analyses of sex and stage of maturity in 2016. Additional methods will be provided at that time.

2.4 Habitat Mapping

To address questions regarding the use and availability of suitable habitat for larval or juvenile stages of White Sturgeon in the LCR, it is important to quantify physical habitat that can be tied to data collected as part of this program. It is believed that small substrate (e.g., gravel) with interstitial spacing is important for survival of YSL by providing hiding habitat that they can use to avoid predators (McAdam 2011) while age-0 and older juvenile White Sturgeon tend to prefer substrates of hard clay, mud, silt, and sand (Parsley and Beckman 1994). Uncertainties exist in the LCR as to how the quality and quantity of such habitat changes across different sections of the river. As such, physical habitat data are required to assess habitat use and suitability/availability for both wild and hatchery released juvenile sturgeon found in the LCR.

As part of this monitoring program, a habitat mapping program was developed for the LCR to describe and classify physical habitat in the LCR between HLK and the US border. Riverbed images were acquired in 2010 and 2011 with a Tritech Starfish sidescan sonar. Image editing, processing, and mapping of substrate classes were completed in 2012 (see BC Hydro 2015c for details).

3 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, survival, provide information on potential new hypotheses and physical works options, and provide baseline information necessary to evaluate physical works experiments and effects of opportunistic flows.

3.1 Physical Parameters

3.1.1 Discharge

Mean daily discharge (cms; cfs) measured from Arrow Reservoir, Kootenay River, Birchbank, and Canada/U.S. International Border for the 2015 study period is presented in Figure 5. Minimum and maximum discharge (cms; cfs) for each location is given in Table 5.

Table 5. Minimum and maximum discharge (cubic meters per second, cms; cubic feet per second, cfs) at four locations on the Lower Columbia River in 2015.

Location	Discharge			
	Minimum (cms)	Maximum (cms)	Minimum (cfs)	Maximum (cfs)
Arrow Reservoir	248.4	2,035.2	8,771.5	71,873.1
Kootenay River	181.0	1,090.8	6,391.4	38,519.6
Birchbank	1,320.9	3,468.8	46,645.5	122,498.3
Border	1,803.0	4,399.9	63,672.6	155,382.3

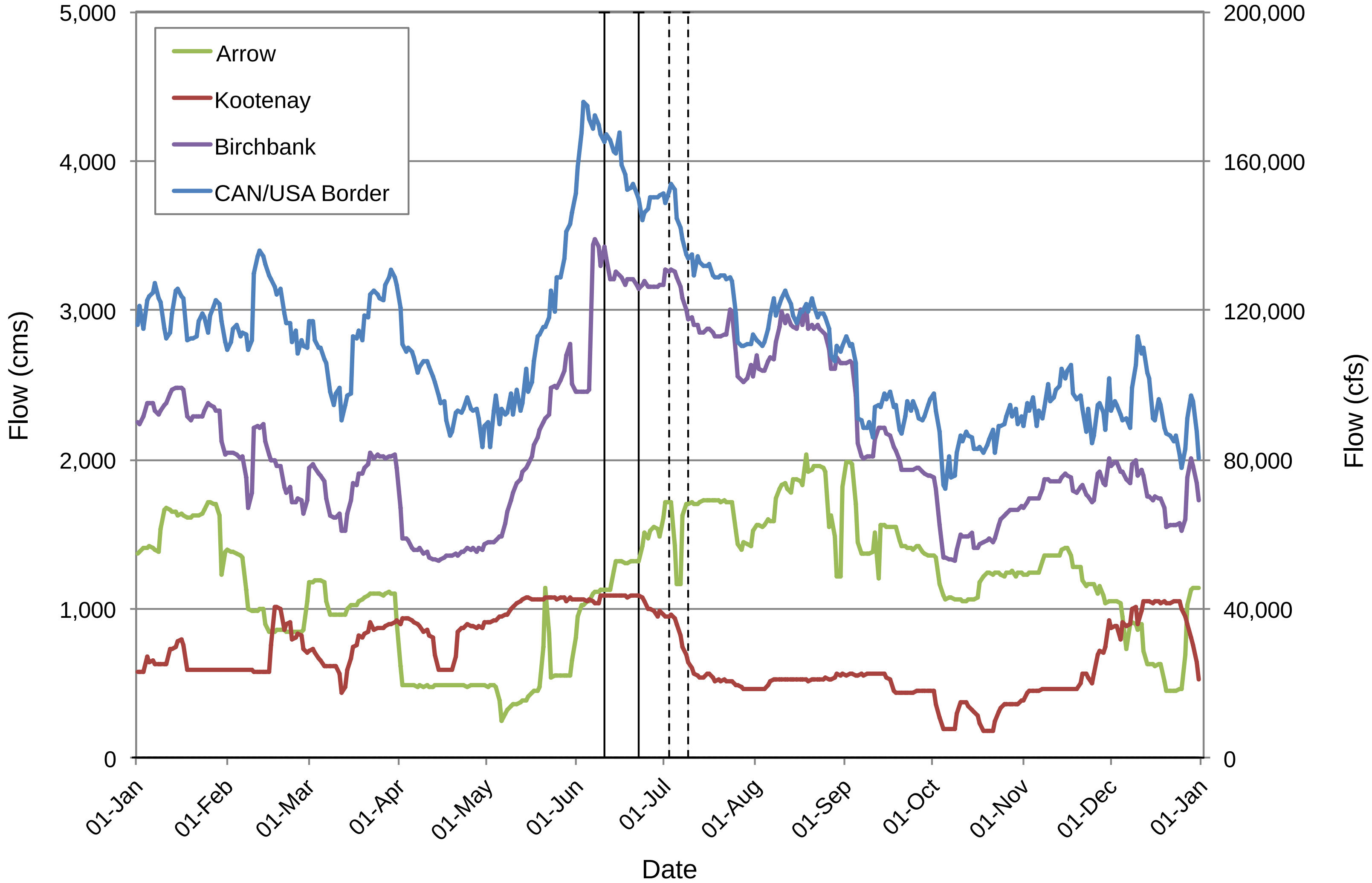

Figure 5. Mean daily discharge measured from Arrow Reservoir, Kootenay River, Birchbank, and the Canada/U.S. International Border on the Lower Columbia River from January 01, 2015 – December 31, 2015. The solid and dashed vertical bars represent the first and last estimated spawning dates at Waneta and Kinnaird, respectively. Estimated spawning dates are based on the developmental stage of collected eggs (BC Hydro 2016a) and/or larvae. Estimated spawning dates were not calculated for Arrow Lakes Generating Station due to poor conditions of samples collected.

3.1.2 Water Temperature

Mean daily river temperatures (°C) during 2015 are illustrated in Figure 6. 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), Rivervale (rkm 35.8), and Waneta Eddy (rkm 56.0) for 2015 are summarized in Table 6. 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 6. Mean (± SD) daily, minimum, and maximum water temperatures (^{o}C) recorded within the Lower Columbia River during 2015. Data was recorded at locations of Hugh L. Keenleyside (rkm 0.1), Kootenay Eddy (rkm 10.5), Kinnaird (rkm 13.4), Genelle Eddy (rkm 26.0), Rivervale (rkm 35.8) and Waneta Eddy (rkm 56.0).

Location	RKM	Temperature			Date of Suspected
		Mean ± SD	Minimum	Maximum	Spawning Threshold (14°C)
HLK	0.1	9.6 ± 4.8	3.7	18.2	06-Jun
Kootenay	10.5	10.6 ± 5.7	3.0	20.8	10-Jun
Kinnaird*	13.4	10.2 ± 4.9	3.1	20.4	10-Jun
Genelle*	26.0	10.6 ± 5.8	3.4	20.8	10-Jun
Rivervale*	34.8	9.7 ± 5.4	3.2	18.7	10-Jun
Waneta*	56.0	10.3 ± 6.3	3.7	18.2	n/a

*Data incomplete due to lost or damaged temp loggers

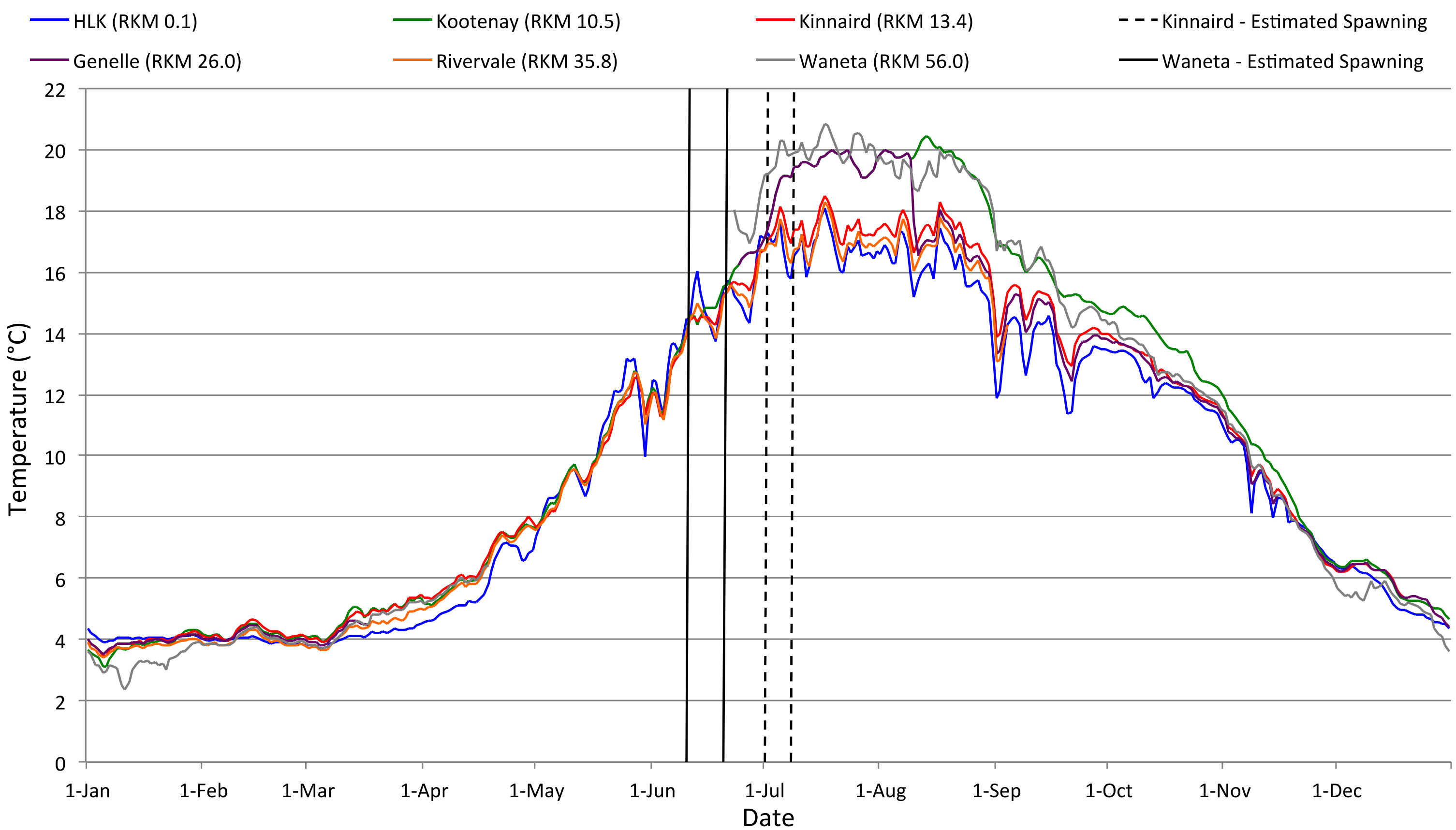

Figure 6. Mean daily water temperature (°C) of the Lower Columbia River in 2015. Data was recorded at locations of HLK (rkm 0.1), Kootenay (rkm 10.5), Kinnaird (rkm 13.4), Genelle (rkm 26.0), Rivervale (rkm 35.8) and Waneta (rkm 56.0). Missing data is due to lost or damaged temperature loggers. Vertical solid and dashed lines represent estimated first and last spawning dates at Waneta and Kinnaird, respectively. Estimated spawning duration is based on the developmental stage of collected fertilized eggs (BC Hydro 2016a) and/or larvae. Spawning dates were not estimated for Arrow Lakes Generating Station due to poor condition of samples collected.

3.2 Larval Stage

3.2.1 Yolk Sac Larval Assessment

3.2.1.1 Larval Sampling Effort and Collection

Downstream Location – Waneta (rkm 56.0)

Sampling was conducted from June 5 to July 31 at depths of 7.8 ± 2.5 m (mean ± SD) and water temperatures ranging from 16.5 to 21.6°C (Figure 6). Drift nets were deployed for 2.7 ± 0.9 hours per sampling period with a total sampling effort of 275.6 hours (Table 7).

A total of 55 yolk-sac larvae were captured at Waneta between the dates of June 10 and July 13 (Table 7), however only 5 were alive and transported to the SIF. The largest daily sample was 28 larvae collected on June 26 representing 0.44 of total drift net sample collection. All live larvae were transported to the KSH for rearing purposes. For egg collection details see BC Hydro (2016a).

Upstream location – Kinnaird (rkm 13.4 to rkm 19.2)

Drifts nets were deployed at rkm 13.4 (n=4; short- and long-set), rkm 16.9 (n=1; short- and long-set), rkm 17.3 (n=1; short- and long-set), rkm 18.2 (n=4; long-set), and rkm 19.2 (n=1; short-set) on July 7 and sampling continued until August 7. Water temperatures ranged from 16.5 to 18.8°C (Figure 6) and sampling water depth was 6.7 ± 2.0 m. Total sampling effort for drift nets were 4,410.5 hours (rkm 13.4, 805.1 h; rkm 16.9, 43.0 h; rkm 17.3, 187.2 h; rkm 18.2, 1,767.1 h; rkm 19.2, 91.3 h; Table 7). Mean daily effort for long- and short-sets was 23.2 ± 1.4 hours and 4.0 ± 1.0 hours, respectively.

A total of 8 yolk-sac larvae (rkm 14.5, n=1; rkm 16.9, n=4; rkm 17.3, n=1; rkm 18.2, n=2; Table 7; Figure 7) were collected between July 8 and July 15. All yolk-sac larvae collected in the drift nets were dead upon capture and preserved for developmental staging.

Upstream Location – ALH (rkm 0.1)

Drift nets (n=3) were deployed on July 6 and sampling continued until August 7 with water temperatures ranging from 15.3 to 18.2°C (Figure 6). Total drift net sampling effort was 1,373.4 h (Table 7). Mean daily effort was 23.9 ± 2.1 h and sampling water depth was 5.7 ± 1.4 m. One dead yolk-sac larvae was collected at ALH on July 10 and was preserved for developmental staging (Table 7).

Table 7. White Sturgeon egg and yolk-sac larvae collection and sampling effort at Lower Columbia River monitoring locations of Waneta (rkm 56.0), downstream of Kinnaird (rkm 18.2, rkm 14.5), Kootenay (rkm 10.5), downstream Arrow Lakes Generating Stationg (ALH; rkm 6.0), ALH (rkm 0.1), and HLK (rkm 0.1) for years 2008 through 2015.

Year	Location	Eggs	Larvae	Effort (hrs)	CPUE
2008	Waneta	494	220	72	9.92
	rkm 18.2	0	1	164	0.01
2009	Waneta	77	39	90	1.29
	rkm 18.2	0	5	976	0.01
	rkm 6.0	0	0	3,091	0.00
2010	Waneta	888	89	113	8.65
	rkm 18.2	1	8	2,104	<0.00
	ALH	30	115	2,084	0.07
2011	Waneta	234	15	50	4.98
	rkm 18.2	2	33	1,413	0.02
	rkm 14.5	0	0	154	0.00
	rkm 10.5	0	0	993	0.00
	HLK	0	0	461	0.00
	ALH	183	308	2,538	0.19
2012	Waneta	134	15	48	3.10
	rkm 18.2	0	0	197	0.00
	ALH	6	0	2,979	<0.00
2013	rkm 18.2	0	4	363	0.01
	rkm 14.5	0	1	154	0.01
	ALH	0	0	680	0.00
2014	Waneta	33	62	43	2.21
	rkm 18.2	5	8	1,514	0.01
	rkm 17.3	0	1	128	0.01
	rkm 16.9	0	2	43	0.05
	rkm 15.6	0	0	77	0.00
	rkm 15.0	0	0	106	0.00
	rkm 14.5	1	2	670	<0.00
	ALH	0	0	857	0.00
2015	Waneta	8	55	275	0.23
	rkm 13.4	0	0	805	0.00
	rkm 14.5	0	1	272	<0.00
	rkm 16.9	0	4	186	0.02
	rkm 17.3	0	1	187	0.01
	rkm 18.2	0	2	1,767	<0.00
	rkm 19.2	0	0	91	0.00
	ALH	0	1	1,373	<0.00

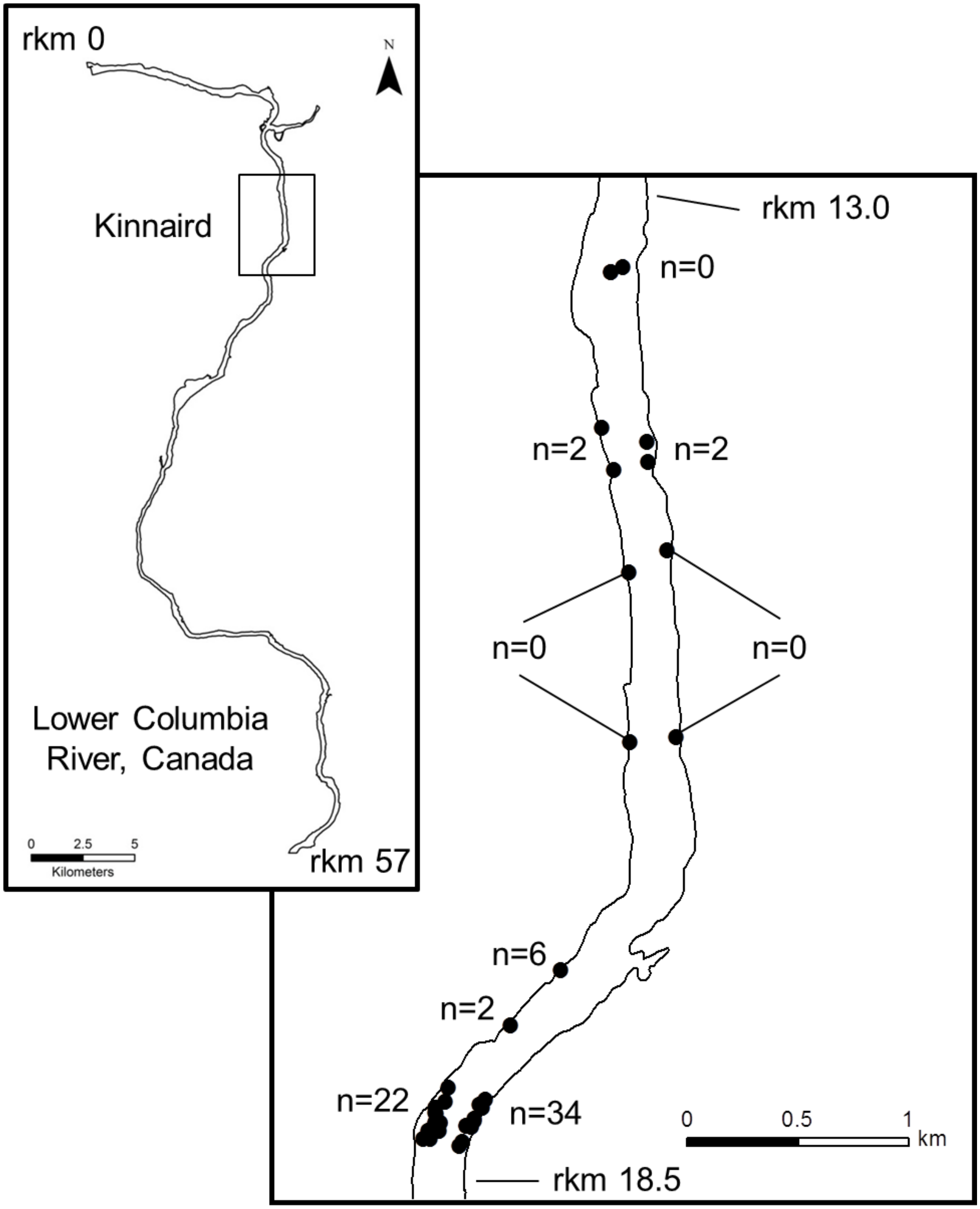

Figure 7. Drift net sampling and larvae collection downstream of Kinnaird (rkm 13.5 – 19.2) in the Lower Columbia River during 2010 through 2015 sampling seasons.

3.2.1.2 Developmental Staging and Estimated Spawning Dates

All preserved yolk-sac larvae in good condition were assigned a developmental stage based on Dettlaff et al. (1993) to calculate an estimated date of fertilization. Based on 12 developmentally staged larvae (Table 8), three spawning days was estimated to have occurred between June 13 and June 20 at Waneta. Spawning was estimated to have occurred on four days between July 2 and July 9 downstream of Kinnaird based on 5 developmentally staged larvae (Table 8). For 2015 estimated spawning days via developmental staging of egg samples see BC Hydro (2016a). Spawning dates were not estimated for ALH due to poor condition of the yolk-sac larvae collected.

Table 8. Developmental stages of White Sturgeon larvae collected at multiple locations (river kilometer, RKM) in the Lower Columbia River in 2015.

		Developmental Stage									
Location	n	36	37	38	39	40	41	42	43	44	45
RKM 14.5	1	1	0	0	0	0	0	0	0	0	0
RKM 16.9	3	3	0	0	0	0	0	0	0	0	0
RKM 17.3	1	1	0	0	0	0	0	0	0	0	0
Waneta	12	9	0	0	0	0	0	0	0	0	3

3.3 Juvenile Stage

3.3.1 Conservation Aquaculture Program

The Conservation Aquaculture Program has released a total of 144,881 juvenile White Sturgeon through 2002 to 2015 (Table 9). In 2015, 2,800 hatchery-reared juveniles (year class 2014) from five maternal families were released into the Canadian portion of the LCR at locations of Robson (rkm 4.0; n=600), Millennium Park (rkm 10.5; n=1000), Genelle (n=600), and Gyro Park (rkm 39.5; n=600) (Table 10; FFSBC 2014). A total of 1,095 wild-origin juveniles (year class 2014) were released at Beaver Creek (rkm 49.0). FL for released White Sturgeon of hatchery and wild origin was 24.4 ± 2.0 cm and 29.0 ± 3.2 cm, respectively (Figure 8 and 9). Weight for released White Sturgeon of hatchery and wild origin was 107 ± 28.6 g and 172 ± 59.9 g, respectively (Figure 10 and 11).

Table 9. Numbers of hatchery reared juvenile White Sturgeon released annually into both the Lower Columbia River, Canada, and Lake Roosevelt, USA. Release numbers are presented by release year and indicated whether they occurred in the fall or spring.

Release Year	Year Class	Canada		USA		Total
		Spring	Fall	Spring	Fall	
2002	2001	8,671				8,671
2003	2002	11,803				11,803
2004	2003	9,695		1,881		11,576
2005	2004	12,748		3,755		16,503
2005	2005		5,039			5,039
2006	2005	10,828		4,351		15,179
2006	2006		4,042			4,042
2007	2006	8,123		3,422		11,545
2007	2007		4,029			4,029
2008	2007	6,448		3,821		10,269
2009	2008	4,141		3,537		7,678
2010	2009	3,947		3,873		7,820
2010	2010				522	522
2011	2010	4,010		3,869		7,879
2011	2011				3,590	3,590
2012	2011	4,000				4,000
2012	2012				302	302
2013	2012	4,037				4,037
2014	2013	1,800			657	2,457
2015	2014	3,895		4,045		7,940
Total		94,146	13,110	32,554	5,071	144,881

Table 10. Number of reared juvenile White Sturgeon of hatchery and wild origins released in 2015 (year class 2014) . Release numbers are presented by origin, family, and release location.

Release Year	Year Class	Origin (Family)	River Kilometer				
			4.0	10.5	24.0	39.5	49.0
2015	2014	Hatchery (A)	120	200	120	120	0
2015	2014	Hatchery (B)	120	200	120	120	0
2015	2014	Hatchery (C)	120	200	120	120	0
2015	2014	Hatchery (D)	120	200	120	120	0
2015	2014	Hatchery (E)	120	200	120	120	0
2015	2014	Wild	0	0	0	0	172

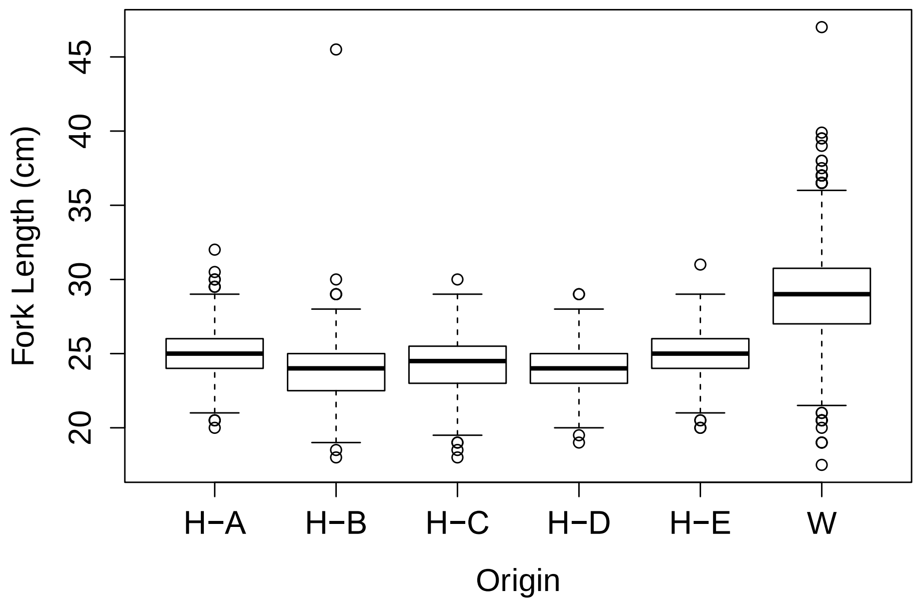

Figure 8. Fork length (cm) at release (approximately 9 months of age) of 2014 year class juvenile White Sturgeon of hatchery (H) and wild (W) origins. Letters (A-E) represent different maternal families.

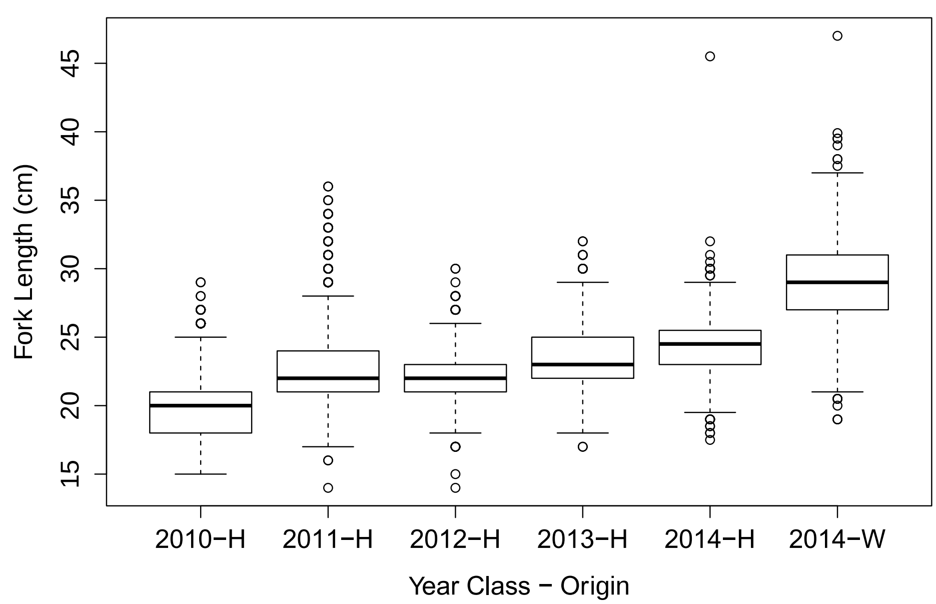

Figure 9. Fork length (cm) at release (approximately 9 months of age) of 2010 through 2014 year class juvenile White Sturgeon of hatchery (H) and wild (W) origins.

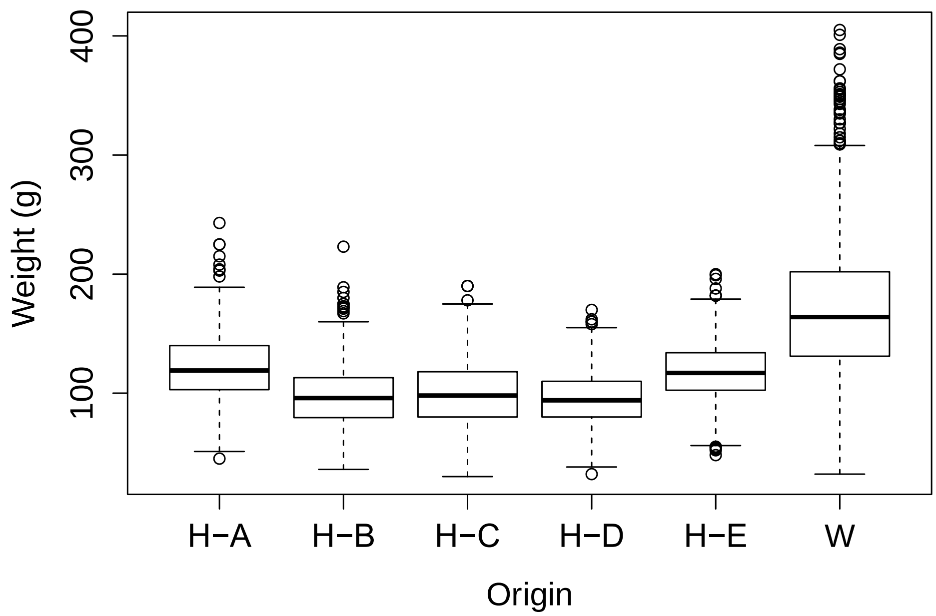

Figure 10. Weight (g) at release (approximately 9 months of age) of 2014 year class juvenile White Sturgeon of hatchery (H) and wild (W) origins. Letters (A-E) represent different maternal families.

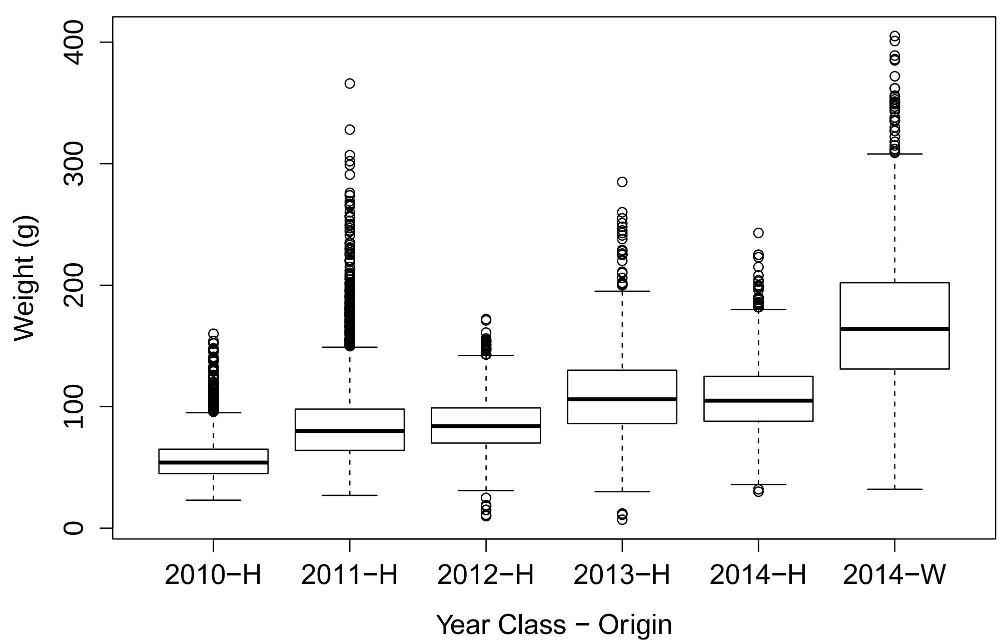

Figure 11. Weight (g) at release (approximately 9 months of age) of 2010 through 2014 year class juvenile White Sturgeon of hatchery (H) and wild (W) origins.

3.3.2 Juvenile Population Assessment

3.3.2.1 Juvenile Sampling Effort and Captures

The biannual stock assessment program was initiated in the spring of 2013. Sampling will continue twice a year (spring and fall) in the TRB extending from HLK in Castlegar British Columbia, Canada, to Gifford Washington, USA, until Fall 2017. Results are presented for data collected in the Canadian portion of the LCR as well as the TBR.

Within Canada, spring and fall stock assessments were conducted between the dates of May 4 through May 15 (12 days) and September 28 through October 9 (12 days) with water temperatures (mean ± SD) of 8.9 ± 0.5°C and 13.7 ± 0.3°C (Figure 6), respectively. During the spring assessment, 1,584 hooks were set using 132 lines. During the fall assessment, 1,440 hooks were set using 120 lines. Sampling effort for the spring and fall assessments was 2,694.8 h and 2,450.4 h, respectively. Set line deployment during the spring and fall assessments was 20.4 ± 1.9 h and 20.4 ± 1.6 h at water depths of 9.8 ± 3.8 m and 9.2 ± 4.0 m, respectively. Sampling effort within the USA portion of the TBR was not available at the time of this report.

Within Canada, total juvenile White Sturgeon captures during the 2015 spring and fall stock assessments were 217 and 286, respectively (Table 11). Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age. Over the stock assessments 3-year sampling period, 38 captured fish were identified as wild representing a 0.04 proportion of total capture across all sampling years (Table 11; Figure 12).

Table 11. Total juvenile White Sturgeon capture during the 2013, 2014, and 2015 stock assessments in the Lower Columbia River Canada. Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age.

Year	Season	Hatchery	Wild	Total
2013	Spring	31	6	37
2013	Fall	152	5	157
2014	Spring	99	2	101
2014	Fall	263	12	275
2015	Spring	209	8	217
2015	Fall	281	5	286
Total		1035	38	1073

Within Canada, total capture and proportional data by brood year class (YrC) for sampling years 2013, 2014, and 2015 is provided in Table 12 and Figure 12, respectively. The 2001 and 2002 year classes represented the largest proportion of total capture across all stock assessments (0.25 and 0.24, respectively). The YrC of highest proportion of capture in 2015 spring and fall stock assessments were 2004 (0.20) and 2002 (0.29), respectively. See BC Hydro (2016b) for 2009 through 2014 juvenile capture data.

Total capture across 2013, 2014, and 2015 stock assessments within each sampling zone included: zone 1, n=714; zone 2, n=126; zone 3, n=61; zone 4, n=21; and zone 5, n=93 (Table 13; Figure 13). The majority of wild fish were captured in zone 1 (n=22) representing 58% of all wild fish captured over the three sampling years. The highest proportions of fish captured in each zone were: zone 1, YrC 2002 (0.29) and 2001 (0.25); zone 2, YrC 2001 (0.27) and 2002 (0.14); zone 3, YrC 2001 (0.25), and equal representation of YrC 2002, 2005, and 2006 (0.13); zone 4, YrC 2001 (0.29), and equal representation of YrC 2004, 2005, and 2009 (0.14); zone 5, YrC 2005 (0.23) and 2001 (0.22). Juveniles were distributed widely throughout zone 1 (Figure 14), and were caught in specific habitat types (e.g., eddies) in zone 2 (Figure 15), zone 3 (Figure 16), zone 4 (Figure 17), and zone 5 (Figure 18).

Table 12. Total juvenile White Sturgeon captured by brood year class within the Lower Columbia River during sampling years 2013, 2014, and 2015. Year class of hatchery origin fish was determined by external mark of removed lateral scutes and PIT tag. Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age.

Year Class	2013		2014		2015		Total
	Spring	Fall	Spring	Fall	Spring	Fall	
2001	14	32	34	49	52	69	250
2002	9	35	34	53	58	51	240
2003	2	11	4	19	15	24	75
2004	4	12	10	30	23	25	104
2005	0	12	5	41	18	41	117
2006	0	30	2	28	25	27	112
2007	0	5	2	14	7	13	41
2008	0	1	0	11	3	5	20
2009	0	1	0	7	0	9	17
2010	0	0	0	0	0	3	3
2011	0	0	0	0	0	1	1
2012	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0
Wild	6	5	2	12	8	5	38
Total	35	144	93	264	209	273	1018

Table 13. Total juvenile White Sturgeon captured by brood year class within the Lower Columbia River for each sampling zone during the 2013, 2014, and 2015 stock assessments. Year class of hatchery origin fish was determined by external mark of removed lateral scutes and PIT tag. Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age. Sampling zones represent 11.2 km increments starting from Hugh L. Keenleyside Dam and moving downstream to the US Border.

Year	Zone				
Class	1	2	3	4	5
2001	175	34	15	6	20
2002	208	18	8	2	4
2003	41	13	5	0	16
2004	77	13	6	3	5
2005	69	16	8	3	21
2006	78	17	8	0	9
2007	24	3	6	2	6
2008	12	4	0	1	3
2009	6	2	2	3	4
2010	1	1	1	0	0
2011	1	0	0	0	0
2012	0	0	0	0	0
2013	0	0	0	0	0
Wild	22	5	2	1	5
Total	714	126	61	21	93

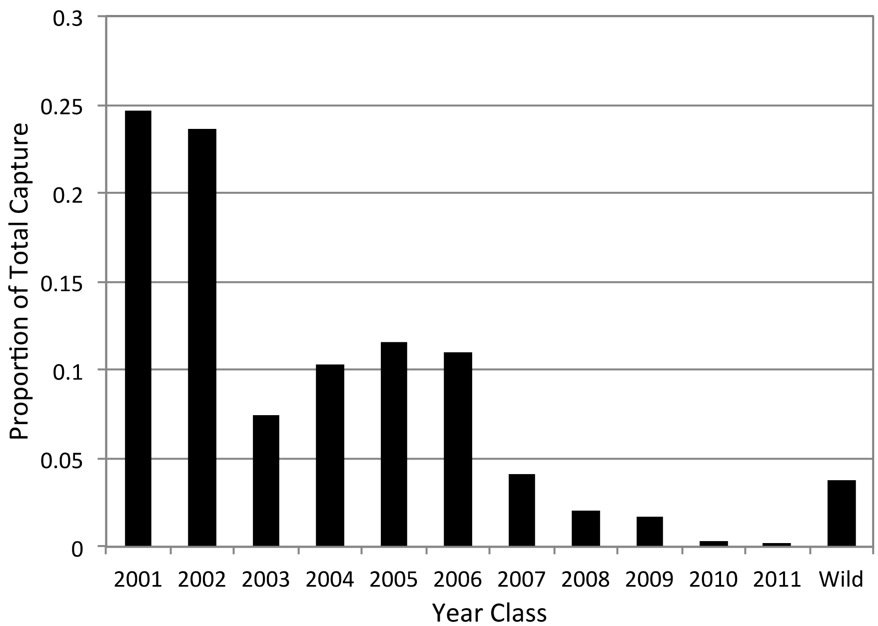

Figure 12. Proportion of total juvenile White Sturgeon captured by brood year class within the Lower Columbia River during the 2013, 2014, and 2015 stock assessments. Year class of hatchery origin fish was determined by external mark of removed lateral scutes and PIT tag. Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age.

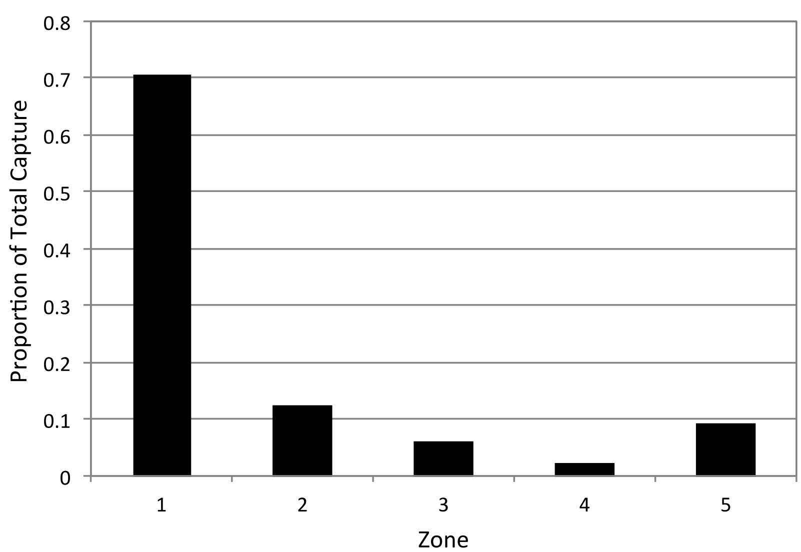

Figure 13. Proportion of total juvenile White Sturgeon captured within the Lower Columbia River for each sampling zone during the 2013, 2014, and 2015 stock assessments. Sampling zones represent 11.2 km increments starting from Hugh L. Keenleyside Dam and moving downstream to the US Border.

Stock assessment captures through the entire transboundary reach, including Canada and US capture efforts are presented in Table 14. Total juvenile captures over the 3 year period were significantly higher on the US side of the border with 4,933 captures compared to 1,073 in Canadian sampling efforts. On average, only 1% of juvenile captures were individuals of wild origin (Table 15). The 2001 and 2002 year classes were the most frequently captured in Canadian sampling efforts while the 2006 year class was captured significantly more on the US side compared to other year classes (Table 16).

Table 14. Total juvenile White Sturgeon capture during the 2013, 2014, and 2015 stock assessments in the Lower Columbia River within Canada, the US, and the entire Transboundary Reach (TBR). Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age.

Year	Season	Canada	USA	TBR
2013	Spring	37	448	485
2013	Fall	157	1,074	1,231
2014	Spring	101	258	359
2014	Fall	275	1,555	1,830
2015	Spring	217	451	668
2015	Fall	286	1,147	1,433
Total		1,073	4,933	6,006

Table 15. Number of hatchery and wild juvenile White Sturgeon capture during the 2013, 2014, and 2015 stock assessments in the entire Transboundary Reach of the Lower Columbia River. Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age.

Year	Season	Hatchery	Wild	Unknown	Total
2013	Spring	471	14	0	485
2013	Fall	1,218	11	2	1,231
2014	Spring	352	5	2	359
2014	Fall	1,803	23	4	1,830
2015	Spring	653	8	7	668
2015	Fall	1,410	5	18	1,433
Total		5,907	66	33	6,006

Table 16. Total juvenile White Sturgeon captured by year class during the 2013, 2014, and 2015 stock assessments in the Lower Columbia River within Canada, the US, and the entire Transboundary Reach (TBR). Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age.

Year Class	Location		
	Canada	USA	TBR
2001	250	216	466
2002	240	44	284
2003	75	243	318
2004	104	336	440
2005	117	487	604
2006	112	1,442	1,554
2007	41	702	743
2008	20	631	651
2009	17	260	277
2010	3	354	357
2011	1	14	15
2012	0	6	6
2013	0	2	2
Wild	38	28	66
Unknown	55	168	223
Total	1,073	4,933	6,006

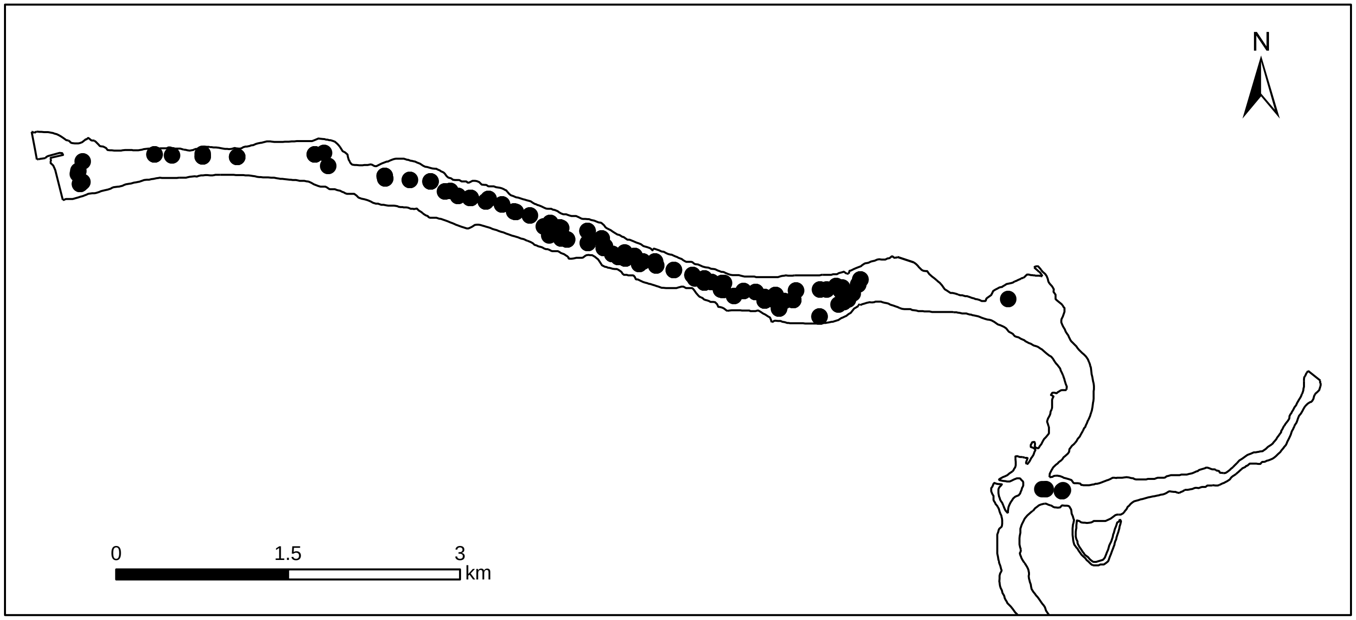

Figure 14. Juvenile White Sturgeon distribution in zone 1 of the Lower Columbia River based on locations of fish capture during 2015. Sampling zones represent 11.2 km increments starting from Hugh L. Keenleyside Dam and moving downstream to the US Border.

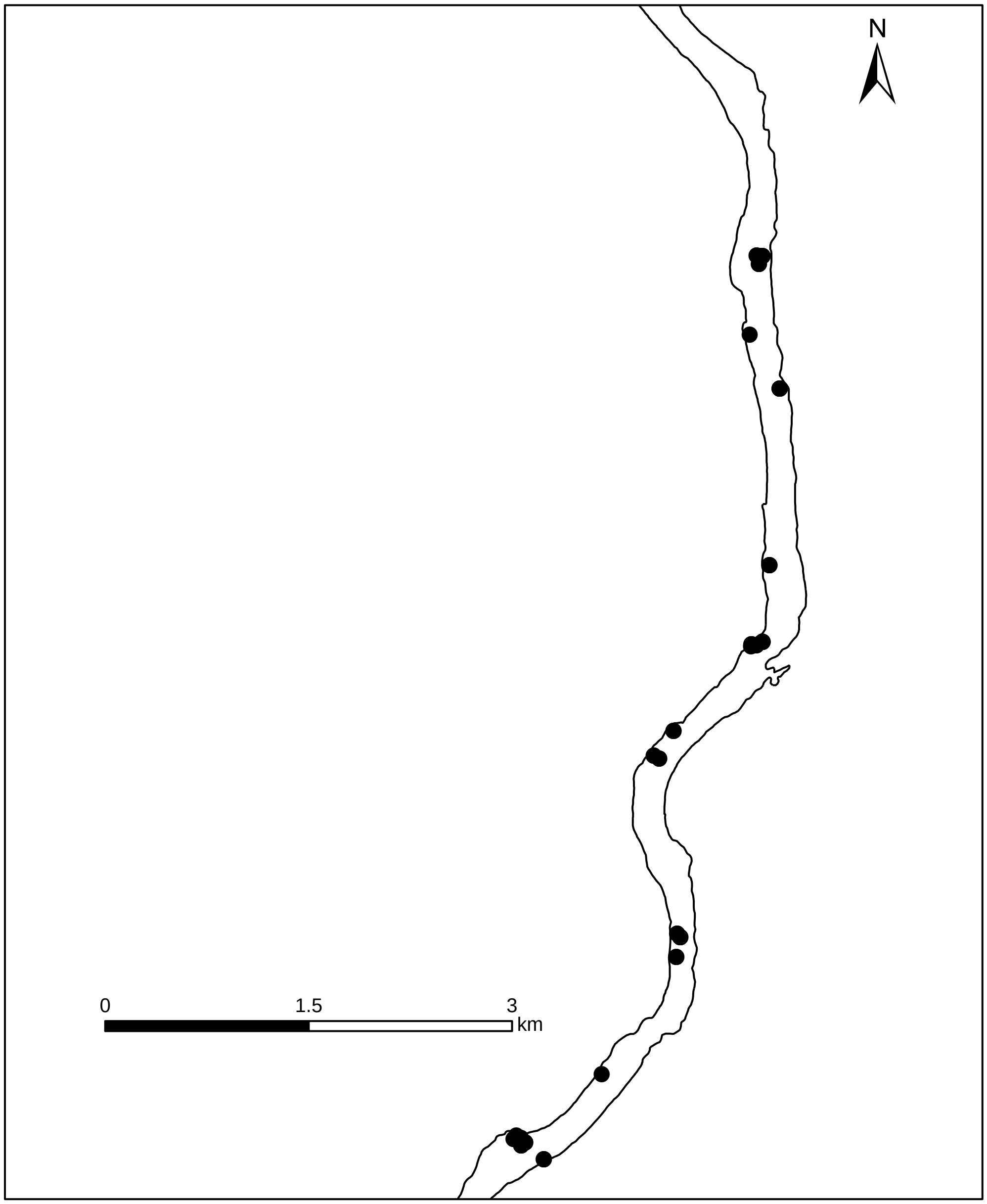

Figure 15. Juvenile White Sturgeon distribution in zone 2 of the Lower Columbia River based on locations of sampling effort and fish capture during 2013, 2014, and 2015. Sampling zones represent 11.2 km increments starting from Hugh L. Keenleyside Dam and moving downstream to the US Border.

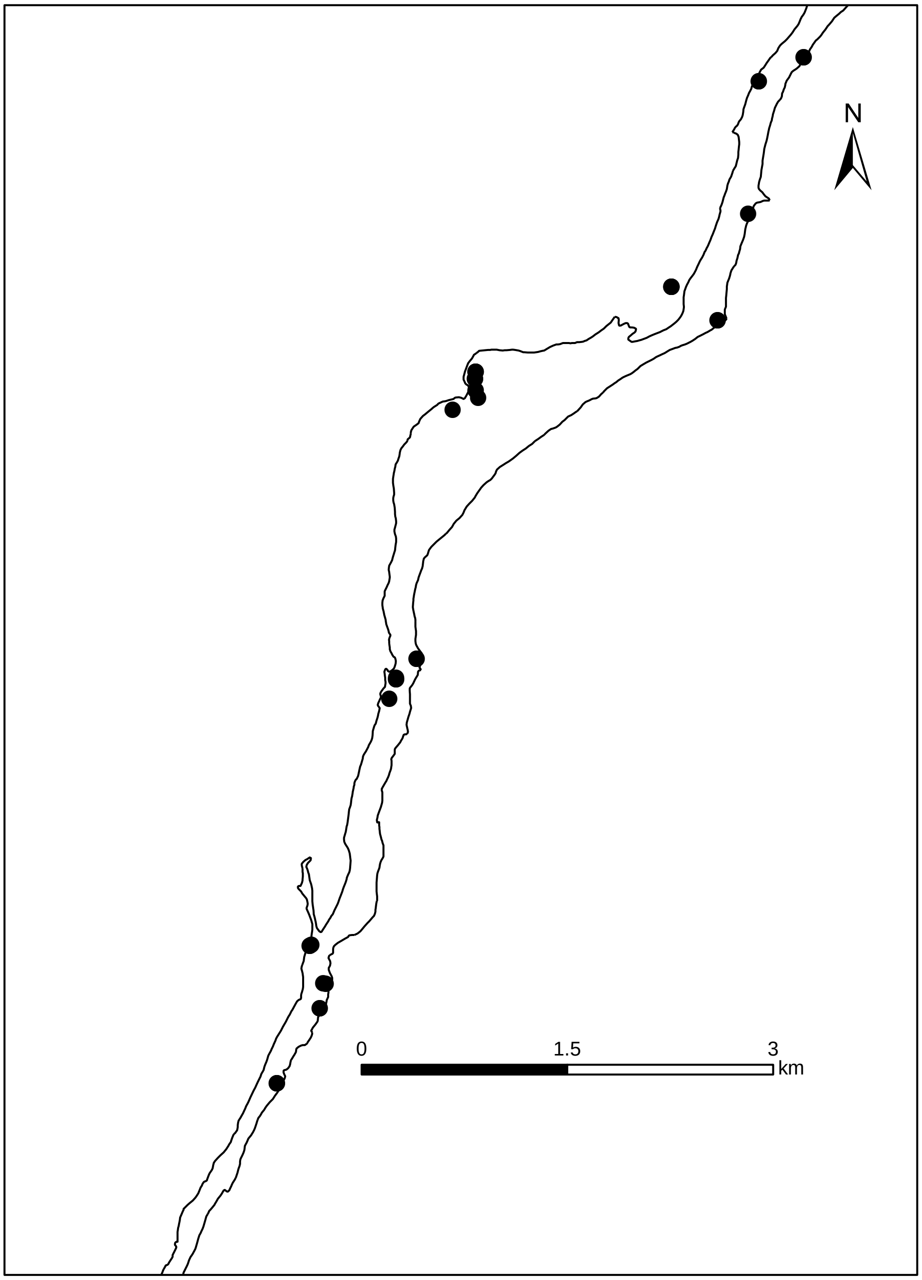

Figure 16. Juvenile White Sturgeon distribution in zone 3 of the Lower Columbia River based on locations of sampling effort and fish capture during 2013, 2014, and 2015. Sampling zones represent 11.2 km increments starting from Hugh L. Keenleyside Dam and moving downstream to the US Border.

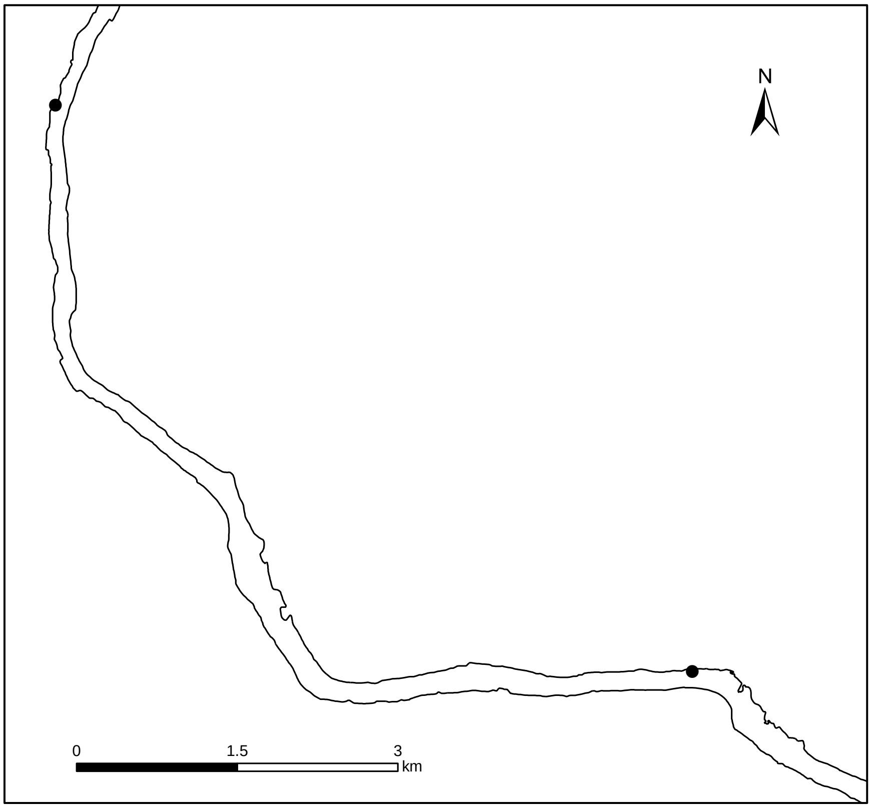

Figure 17. Juvenile White Sturgeon distribution in zone 4 of the Lower Columbia River based on locations of sampling effort and fish capture during 2013, 2014, and 2015. Sampling zones represent 11.2 km increments starting from Hugh L. Keenleyside Dam and moving downstream to the US Border.

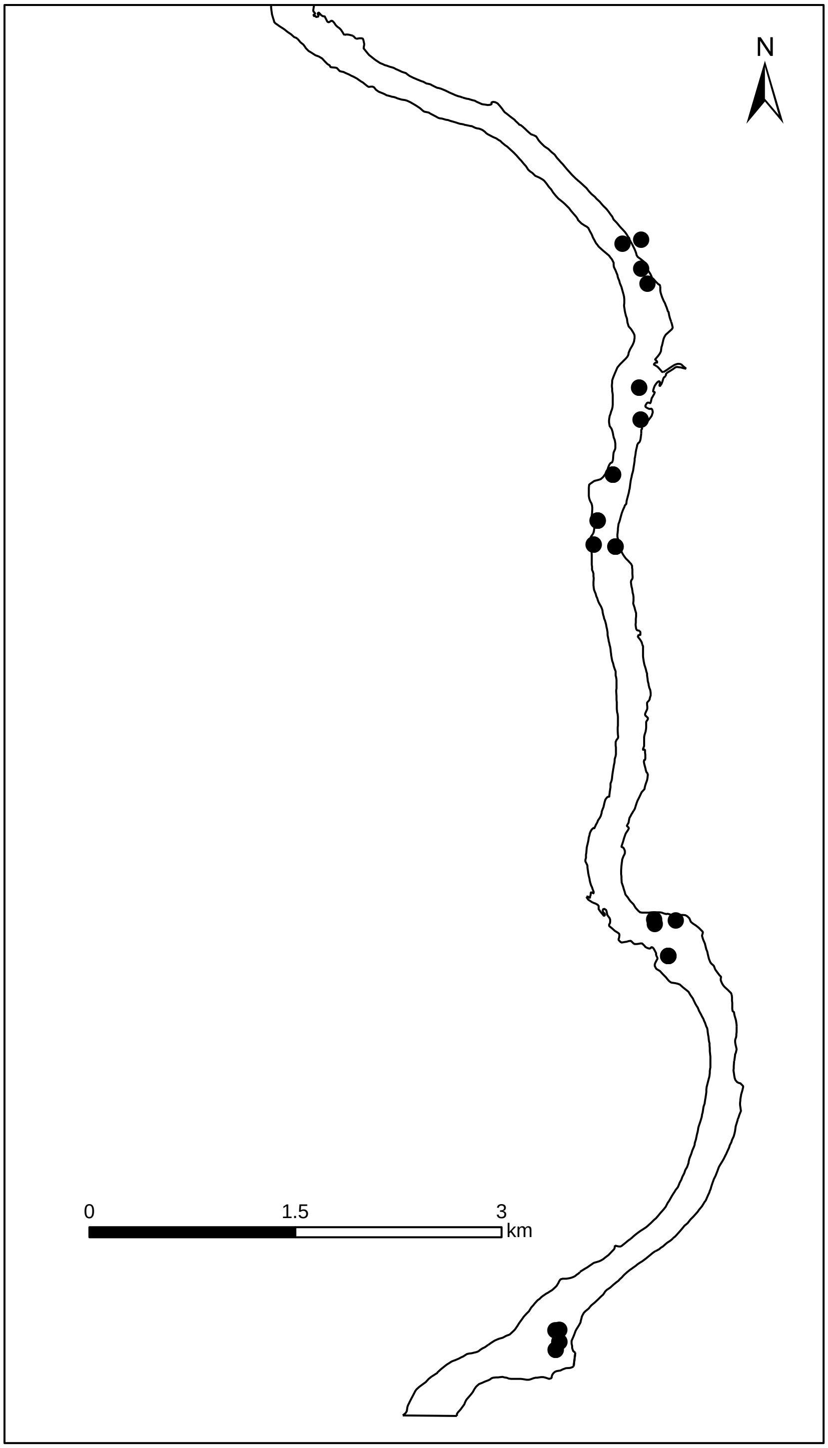

Figure 18. Juvenile White Sturgeon distribution in zone 5 of the Lower Columbia River based on locations of sampling effort and fish capture during 2013, 2014, and 2015. Sampling zones represent 11.2 km increments starting from Hugh L. Keenleyside Dam and moving downstream to the US Border.

3.3.2.2 Fork Length, Weight, Relative Weight, and Growth

3.3.2.2.1 Fork Length

Fork length (FL; cm; mean ±SD) of juveniles captured within Canada during the spring and fall 2015 stock assessments was 99.6 ± 14.5 cm and 98.2 ± 13.6 cm, respectively (Table 17). Juvenile FL as a function of year class (Table 17) and sampling zone (Table 18) is provided below. Over all stock assessments (2013-2015), FL generally decreased as a function of YrC with the exceptions of YrC 2002 (106.2 ± 8.4 cm) measuring significantly larger than YrC 2001 (103.4 ± 12.4 cm; P=0.0036; Table 17). Wild juveniles were significantly larger than all hatchery-reared fish (P<0.0001; Table 17, Figure 19). Fork length of fish captured in sampling zone 1 (101.0 ± 13.3 cm) was significantly larger than fish captured in zone 2 (95.0 ± 14.8 cm), zone 3 (95.6 ± 17.1 cm), zone 4 (88.9 ± 20.8 cm), and zone 5 (85.3 ± 15.2 cm) (P<0.0001).

Fork length of juvenile White Sturgeon captured in the TBR across all stock assessments (2013 – 2015) was 97.6 ± 19.0 (Table 19). As seen in the Canadian section, FL generally decreased as a function of YrC and juveniles of wild origin were significantly larger than all hatchery-reared fish (P<0.0001; Table 19). Juveniles captured in the USA section of the TBR were larger in fork length across all year classes, with the exception of YrC 2010, compared to juveniles captured in Canada (Table 19, Figure 19).

Table 17. Mean ± SD fork length (cm) by brood year class of juvenile White Sturgeon captured in the Lower Columbia River during the 2013, 2014, and 2015 stock assessments. Year class of hatchery origin fish was determined by external mark of removed lateral scutes and PIT tag. Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age

Year Class	2013		2014		2015		Total
	Spring	Fall	Spring	Fall	Spring	Fall	
2001	102.1 ± 11.7	98.9 ± 13.0	103.8 ± 10.0	104.4 ± 14.3	105.5 ± 10.3	103.1 ± 13.2	103.4 ± 12.4
2002	104.4 ± 10.9	105.3 ± 10.1	109.5 ± 7.5	106.0 ± 7.9	104.8 ± 9.0	106.5 ± 6.6	106.2 ± 8.4
2003	89.0 ± 15.6	91.6 ± 13.1	104.5 ± 16.9	95.2 ± 7.1	96.2 ± 8.7	101.8 ± 12.3	97.3 ± 11.4
2004	85.6 ± 12.1	90.5 ± 11.1	94.8 ± 10.6	98.6 ± 10.8	93.4 ± 8.3	101.5 ± 8.4	96.4 ± 10.5
2005	-	80.8 ± 9.6	86.8 ± 5.5	87.1 ± 7.8	88.3 ± 7.1	88.6 ± 8.1	87.1 ± 8.1
2006	-	83.1 ± 8.0	82.3 ± 3.2	90.1 ± 7.9	86.8 ± 4.5	92.6 ± 6.7	88.0 ± 7.8
2007	-	70.8 ± 4.0	80.3 ± 0.4	80.6 ± 9.3	82.3 ± 6.1	88.8 ± 8.4	82.3 ± 9.4
2008	-	-	-	80.5 ± 7.1	77.2 ± 5.5	86.8 ± 8.0	80.6 ± 8.7
2009	-	-	-	68.4 ± 7.1	-	77.3 ± 5.5	72.9 ± 7.5
2010	-	-	-	-	-	77.7 ± 2.1	77.7 ± 2.1
2011	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-
2013	-	-	-	-	-	-	-
Wild	131.0 ± 12.7	140.9 ± 5.7	145.0 ± 2.8	130.4 ± 13.4	142.7 ± 11.8	119.9 ± 34.9	134.0 ± 17.9
Total	102.3 ± 14.7	93.4 ± 16.5	103.8 ± 13.0	97.1 ± 15.5	99.6 ± 14.5	98.2 ± 13.6	98.2 ± 14.9

Table 18. Mean (±SD) fork length (FL; cm) of juvenile White Sturgeon captured in the 5 sampling zones of the Lower Columbia River during the 2013, 2014, and 2015 stock assessments. Sampling zones represent 11.2 km increments starting from Hugh L. Keenleyside Dam and moving downstream to the US Border.

Zone	2013		2014		2015		Total
	Spring	Fall	Spring	Fall	Spring	Fall	
1	107.1 ± 13.1	99.1 ± 14.5	106.7 ± 12.4	100.1 ± 13.1	99.9 ± 13.7	100.5 ± 12.1	101.0 ± 13.3
2	87.8 ± 10.6	89.3 ± 11.5	91.8 ± 7.9	97.3 ± 18.6	97.6 ± 16.7	96.1 ± 10.5	95.0 ± 14.8
3	94.5 ± 22.6	81.2 ± 13.1	-	90.5 ± 13.9	108.9 ± 28.7	99.2 ± 15.0	95.6 ± 17.1
4	95.5 ± 0.7	80.9 ± 15.3	-	88.0 ± 31.8	-	94.6 ± 21.6	88.9 ± 20.8
5	94.3 ± 18.3	85.9 ± 19.6	90.2 ± 10.4	80.1 ± 10.7	83.3 ± 1.3	87.3 ± 14.6	85.3 ± 15.2
Total	102.3 ± 14.7	93.4 ± 16.5	103.8 ± 13.0	97.1 ± 15.5	99.6 ± 14.5	98.2 ± 13.6	98.2 ± 14.9

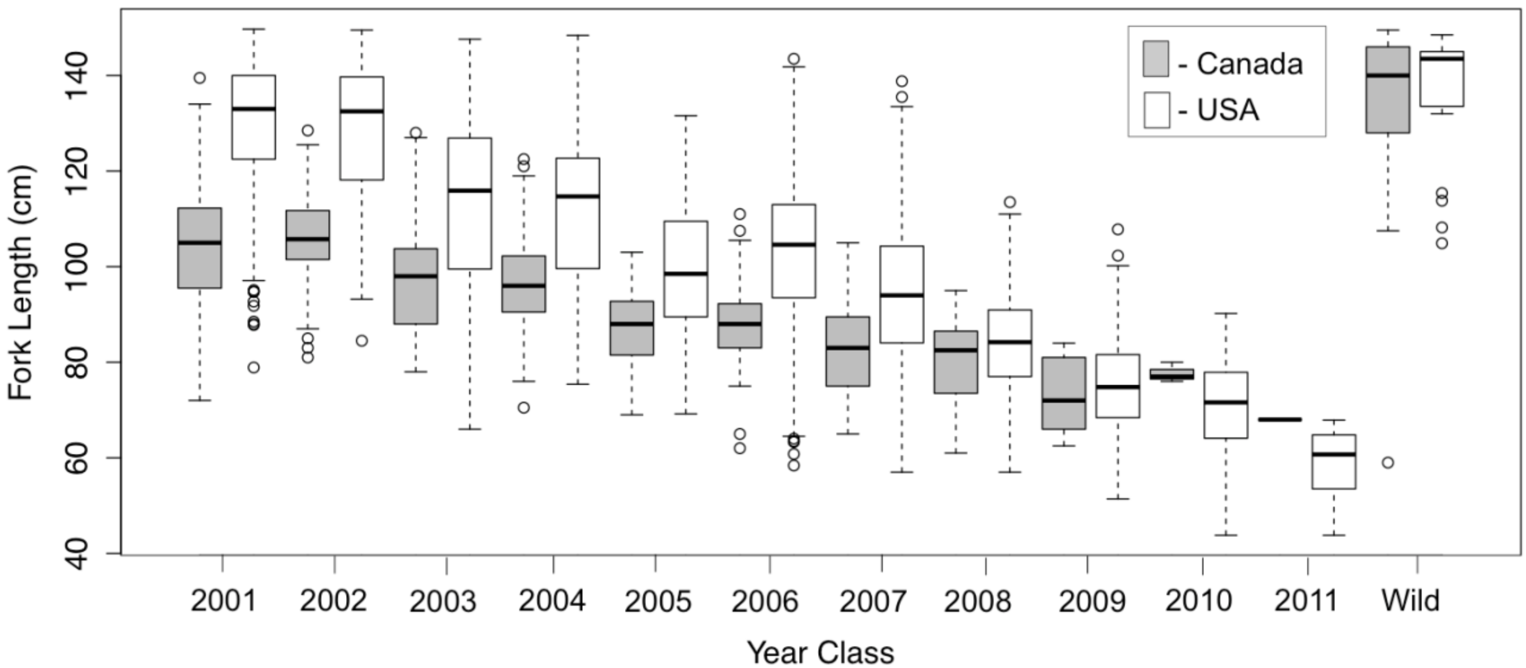

Figure 19. Fork length (cm) of juvenile White Sturgeon captured during stock assessments conducted in 2013, 2014, and 2015. Fork lengths are presented as a function of year class in the Canadian and US portions of the Lower Columbia River. Year class of hatchery origin fish was determined by external mark of removed lateral scutes and PIT tag. Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age.

Table 19. Mean (±SD) fork length (FL; cm) of juvenile White Sturgeon year classes captured in Canada, USA, and the entire Transboundary Reach (TBR) of the Lower Columbia River during the 2013, 2014, and 2015 stock assessments.

Year Class	Location		
	Canada	USA	TBR
2001	103.4 ± 12.4	129.7 ± 14.5	115.7 ± 18.8
2002	106.2 ± 8.4	128.4 ± 15.3	109.6 ± 12.6
2003	97.3 ± 11.4	113.5 ± 17.1	109.6 ± 17.3
2004	96.4 ± 10.5	112.3 ± 15.1	108.5 ± 15.7
2005	87.1 ± 8.1	99.4 ± 12.8	97.0 ± 13.0
2006	88.0 ± 7.8	103.2 ± 13.9	102.1 ± 14.1
2007	82.3 ± 9.4	93.9 ± 14.7	93.2 ± 14.7
2008	80.6 ± 8.7	83.9 ± 10.6	83.8 ± 10.6
2009	72.9 ± 7.5	75.3 ± 9.8	75.1 ± 9.7
2010	77.7 ± 2.1	70.8 ± 9.0	70.9 ± 9.0
2011	-	59.2 ± 7.2	59.9 ± 7.3
2012	-	50.4 ± 1.1	50.4 ± 1.1
2013	-	56.1 ± 5.9	56.1 ± 5.9
Wild	134.0 ± 17.9	136.7 ± 13.3	135.1 ± 16.1
Total	98.2 ± 14.9	97.5 ± 19.8	97.6 ± 19.0

3.3.2.2.2 Weight

Weight (kg) of juveniles captured within Canada during the spring and fall 2015 stock assessments was 7.0 ± 3.9 kg and 6.4 ± 2.9 kg, respectively (Table 20). Weight of juveniles as a function of year class (Table 20) and sampling zone (Table 21) is provided below. Generally, weight decreased as a function of YrC with the exception of YrC 2001 (7.7 ± 2.9) weighing less than YrC 2002 (7.9 ± 1.9; no significance, P=0.557; Table 20). Juveniles of wild origin were significantly larger than all hatchery-reared fish (P<0.0001; Table 20). Weight of fish captured in sampling zone 1 (7.0 ± 3.2 kg) was significantly larger than fish captured in zone 2 (6.0 ± 3.6 kg), zone 3 (6.5 ± 4.1 kg), zone 4 (5.4 ± 4.6 kg), and zone 5 (4.5 ± 4.0 kg; P<0.0001; Table 21). These patterns were similar to comparisons of fork length measurements.

Weight of juvenile White Sturgeon captured in the TBR across all stock assessments (2013-2015) was 8.1 ± 5.1 kg (Table 22). As seen in the Canadian section, weight generally decreased as a function of YrC. Juveniles of wild origin were significantly larger than hatchery-reared fish (P<0.0001; Table 22). Juveniles captured in the USA section of the TBR were larger in weight across all year classes compared to juveniles captured in Canada (Table 22; Figure 20).

Table 20. Mean (±SD) weight (kg) of juvenile White Sturgeon captured in the Lower Columbia River during the 2013, 2014, and 2015 stock assessments. Year class of hatchery origin fish was determined by external mark of removed lateral scutes and PIT tag. Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age.

Year Class	2013		2014		2015		Total
	Spring	Fall	Spring	Fall	Spring	Fall	
2001	7.2 ± 2.0	6.9 ± 2.4	7.7 ± 2.4	8.2 ± 3.9	8.1 ± 2.3	7.6 ± 3.0	7.7 ± 2.9
2002	7.7 ± 2.0	7.5 ± 2.1	8.6 ± 1.8	8.0 ± 1.8	7.7 ± 2.2	7.7 ± 1.5	7.9 ± 1.9
2003	4.3 ± 2.2	5.3 ± 2.3	7.9 ± 3.6	5.5 ± 1.2	5.9 ± 1.8	7.0 ± 2.6	6.1 ± 2.3
2004	4.2 ± 2.1	4.6 ± 1.9	5.5 ± 1.7	5.9 ± 2.0	5.4 ± 1.6	6.5 ± 1.9	5.7 ± 1.9
2005	-	3.4 ± 1.3	4.5 ± 1.0	4.1 ± 1.1	4.5 ± 1.3	4.5 ± 1.2	4.2 ± 1.2
2006	-	3.7 ± 1.1	3.8	4.7 ± 1.3	4.4 ± 0.8	5.1 ± 1.2	4.5 ± 1.2
2007	-	2.0 ± 0.2	3.2 ± 0.6	3.2 ± 1.1	3.6 ± 0.7	4.6 ± 1.6	3.6 ± 1.4
2008	-	-	-	3.2 ± 0.9	3.0 ± 1.0	3.9 ± 1.0	3.2 ± 1.0
2009	-	-	-	1.9 ± 0.6	-	2.8 ± 0.7	2.4 ± 0.7
2010	-	-	-	-	-	2.8 ± 0.2	2.8 ± 0.2
2011	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-
2013	-	-	-	-	-	-	-
Wild	19.2 ± 11.1	20.6 ± 6.3	20.5 ± 2.1	15.1 ± 4.8	21.5 ± 5.3	13.4 ± 7.5	17.6 ± 6.3
Total	7.7 ± 4.2	5.8 ± 3.6	7.7 ± 3.1	6.3 ± 3.5	7.0 ± 3.9	6.4 ± 2.9	6.6 ± 3.5

Table 21. Mean (±SD) weight (kg) of juvenile White Sturgeon captured in the sampling zones of the Lower Columbia River during the 2013, 2014, and 2015 stock assessments. Sampling zones represent 11.2 km increments starting from Hugh L. Keenleyside Dam and moving downstream to the US Border.

Zone	2013		2014		2015		Total
	Spring	Fall	Spring	Fall	Spring	Fall	
1	8.8 ± 4.5	6.5 ± 2.8	8.3 ± 3.1	6.8 ± 3.2	7.0 ± 3.5	6.6 ± 2.5	7.0 ± 3.2
2	4.6 ± 1.6	5.0 ± 2.1	5.5 ± 1.8	6.7 ± 4.6	6.7 ± 4.7	5.8 ± 2.0	6.0 ± 3.6
3	6.5 ± 4.0	4.0 ± 2.3	-	5.2 ± 2.6	10.6 ± 9.5	6.9 ± 3.5	6.5 ± 4.1
4	5.9 ± 0.3	3.7 ± 2.3	-	5.7 ± 6.9	-	6.7 ± 5.6	5.4 ± 4.6
5	5.3 ± 3.2	5.2 ± 6.2	4.9 ± 1.7	3.4 ± 1.6	3.5 ± 0.2	4.9 ± 3.6	4.5 ± 4.0
Total	7.7 ± 4.2	5.8 ± 3.6	7.7 ± 3.1	6.3 ± 3.5	7.0 ± 3.9	6.4 ± 2.9	6.6 ± 3.5

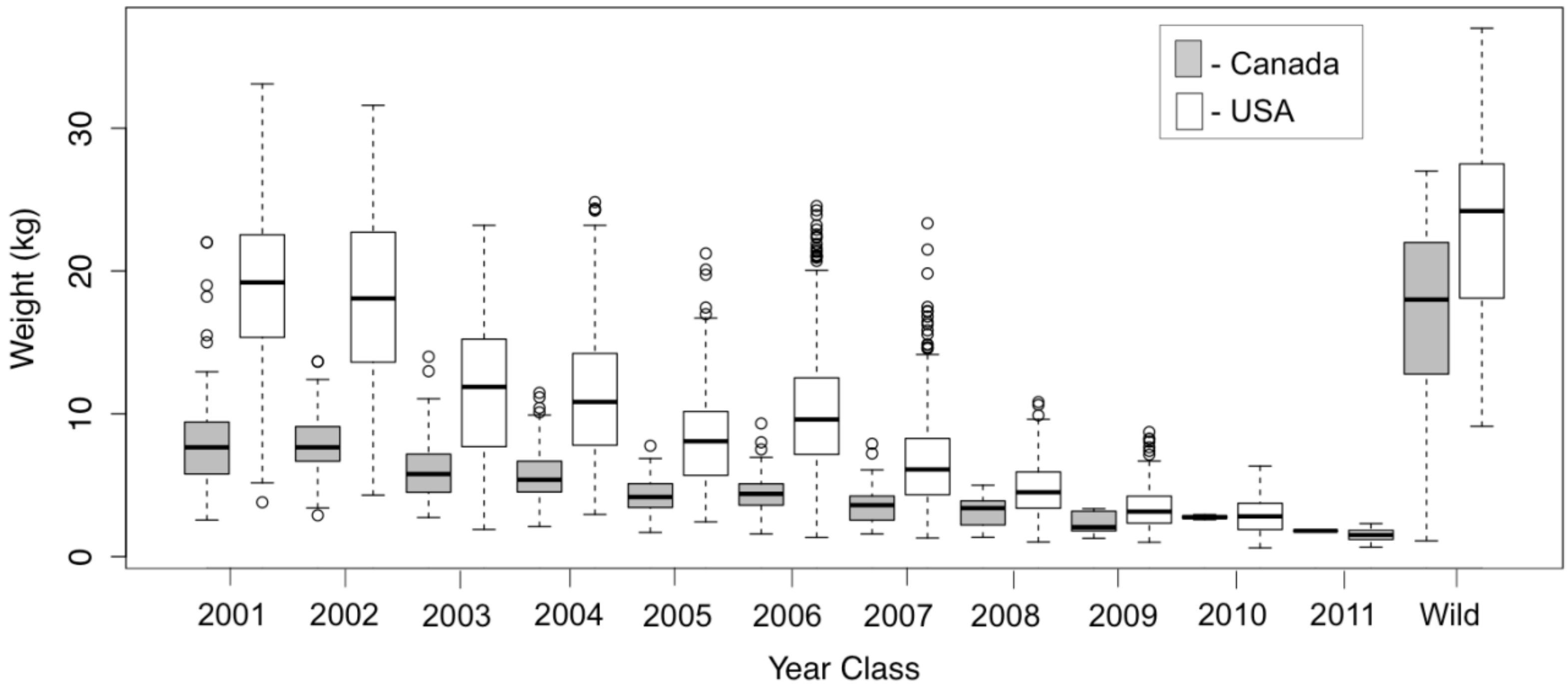

Figure 20. Weight (kg) of juvenile White Sturgeon captured during stock assessments conducted in 2013, 2014, and 2015. Weight is presented as a function of year class in the Canadian and US portions of the Lower Columbia River. Year class of hatchery origin fish was determined by external mark of removed lateral scutes and PIT tag. Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age.

Table 22. Mean (±SD) weight (kg) of juvenile White Sturgeon year classes captured in the Lower Columbia River within Canada, USA, and the entire Transboundary Reach (TBR) during the 2013, 2014, and 2015 stock assessments.

Year Class	Location		
	Canada	USA	TBR
2001	7.7 ± 2.9	18.6 ± 6.3	12.8 ± 7.0
2002	7.9 ± 1.9	18.1 ± 5.8	9.4 ± 4.8
2003	6.1 ± 2.3	11.8 ± 6.4	10.5 ± 5.0
2004	5.7 ± 1.9	11.3 ± 4.9	10.0 ± 4.8
2005	4.2 ± 1.2	8.2 ± 4.7	7.4 ± 3.3
2006	4.5 ± 1.2	10.0 ± 3.2	9.6 ± 4.2
2007	3.6 ± 1.4	6.6 ± 4.1	6.4 ± 3.2
2008	3.2 ± 1.0	4.6 ± 3.2	4.6 ± 1.8
2009	2.4 ± 0.7	3.4 ± 1.8	3.3 ± 1.5
2010	2.8 ± 0.2	2.9 ± 1.5	2.9 ± 1.1
2011	-	1.5 ± 1.1	1.5 ± 0.5
2012	-	.9 ± 0.5	.9 ± 0.1
2013	-	1.4 ± 0.1	1.4 ± 0.4
Wild	17.6 ± 6.3	22.8 ± 0.4	19.8 ± 7.2
Total	6.6 ± 3.5	8.4 ± 5.3	8.1 ± 5.1

3.3.2.2.3 Relative Weight

Relative weight (W_r) for juveniles captured within Canada during the spring and fall 2015 stock assessments was 83.0 ± 7.4 and 80.3 ± 7.4 (Table 23), respectively. Generally, W_r was similar among all year classes (Figure 21). Unlike the measurements of FL and weight, juveniles of wild origin did not have a significantly larger W_r compared to hatchery-reared fish (P>0.05). Relative weight of juveniles captured in sampling zone 1 (80.5 ± 7.3) was smaller than fish captured in zone 2 (82.4 ± 9.0; P=0.0419), zone 3 (84.4 ± 7.6; P=0.0017), zone 4 (82.6 ± 9.2; P>0.05), and zone 5 (83.1 ± 8.7; p=0.0029; Table 24). An increased mean W_r was observed in juvenile captures throughout the entire TBR (97.0 ± 14.0) due to the larger W_r of juveniles captured in the USA section (100.4 ± 12.6) compared to Canada (Figure 21; Table 25).

Table 23. Mean (±SD) relative weight (W_r) of juvenile White Sturgeon by brood year class captured in the Lower Columbia River during the 2013, 2014, and 2015 stock assessments. Year class of hatchery origin fish was determined by external mark of removed lateral scutes and PIT tag. Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age.

Year Class	2013		2014		2015		Total
	Spring	Fall	Spring	Fall	Spring	Fall	
2001	83.4 ± 8.2	84.7 ± 9.3	83.7 ± 6.7	83.9 ± 8.4	83.0 ± 5.6	83.0 ± 7.2	83.5 ± 7.4
2002	82.0 ± 8.0	77.9 ± 6.1	80.1 ± 7.3	81.6 ± 5.9	81.3 ± 7.3	78.6 ± 7.9	80.1 ± 7.1
2003	75.4 ± 1.6	84.0 ± 5.3	83.1 ± 9.0	80.2 ± 6.6	81.6 ± 7.2	79.5 ± 5.9	80.8 ± 6.5
2004	81.4 ± 8.6	76.1 ± 7.2	81.0 ± 6.2	75.5 ± 5.4	83.6 ± 8.9	75.8 ± 6.1	78.2 ± 7.5
2005	-	82.7 ± 8.3	87.1 ± 2.5	79.3 ± 6.8	83.1 ± 10.9	81.1 ± 7.3	81.2 ± 7.9
2006	-	83.6 ± 8.0	89.1 ± 11.0	81.1 ± 7.9	86.0 ± 10.0	81.3 ± 5.3	83.0 ± 8.1
2007	-	76.1 ± 8.2	81.5 ± 17.4	77.4 ± 8.0	84.7 ± 5.3	82.4 ± 11.4	80.3 ± 9.4
2008	-	-	-	77.9 ± 4.3	83.8 ± 10.9	76.4 ± 5.1	78.7 ± 5.9
2009	-	-	-	80.6 ± 7.6	-	78.0 ± 4.8	79.5 ± 6.2
2010	-	-	-	-	-	78.5 ± 4.9	78.5 ± 4.9
2011	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-
2013	-	-	-	-	-	-	-
Wild	94.7 ± 27.8	84.0 ± 16.7	77.3 ± 3.1	78.0 ± 10.0	83.9 ± 7.0	77.3 ± 8.9	81.0 ± 11.3
Total	7.7 ± 4.2	5.8 ± 3.6	7.7 ± 3.1	6.3 ± 3.5	7.0 ± 3.9	6.4 ± 2.9	6.6 ± 3.5

Table 24. Mean relative weight (W_r) of juvenile White Sturgeon by sampling zone in the Lower Columbia River captured during the 2013, 2014, and 2015 stock assessment. Sampling zones represent 11.2 km increments starting from Hugh L. Keenleyside Dam and moving downstream to the US Border.

Zone	2013		2014		2015		Total
	Spring	Fall	Spring	Fall	Spring	Fall	
1	83.5 ± 9.8	79.1 ± 6.2	81.1 ± 6.8	79.7 ± 7.0	83.3 ± 7.7	78.5 ± 6.5	80.5 ± 7.3
2	85.7 ± 11.4	84.9 ± 9.1	87.2 ± 7.8	81.2 ± 8.8	81.3 ± 9.4	80.5 ± 8.9	82.4 ± 9.0
3	91.7 ± 10.1	89.6 ± 7.7	-	83.7 ± 7.3	82.1 ± 9.3	83.1 ± 6.8	84.4 ± 7.6
4	86.0 ± 2.1	81.7 ± 9.6	-	81.2 ± 8.9	-	83.6 ± 11.6	82.6 ± 9.2
5	73.5 ± 2.4	83.8 ± 12.1	84.3 ± 5.8	81.3 ± 7.3	79.4 ± 2.0	85.4 ± 6.7	83.1 ± 8.7
Total	7.7 ± 4.2	5.8 ± 3.6	7.7 ± 3.1	6.3 ± 3.5	7.0 ± 3.9	6.4 ± 2.9	6.6 ± 3.5

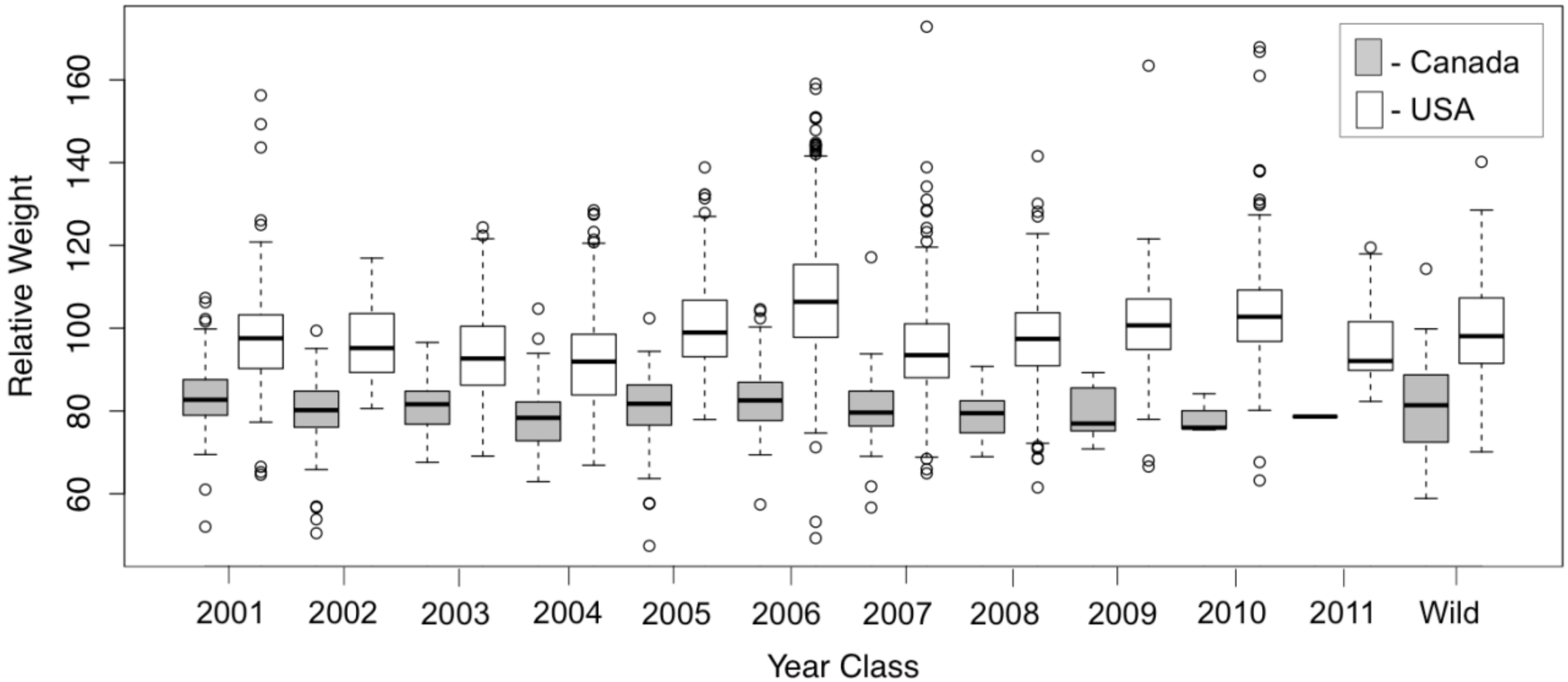

Figure 21. Relative weight (W_r) of juvenile White Sturgeon captured during stock assessments conducted in 2013, 2014, and 2015. Relative weight is presented as a function of year class in the Canadian and US portions of the Lower Columbia River. Year class of hatchery origin fish was determined by external mark of removed lateral scutes and PIT tag. Individuals with no PIT tag administered by the hatchery or lateral scutes removed were considered wild fish as a product of natural reproduction and of unknown age.

Table 25. Relative weight (W_r) of juvenile White Sturgeon year classes captured in the Lower Columbia River within Canada, USA, and the entire Transboundary Reach (TBR) during the 2013, 2014, and 2015 stock assessments.

Year Class	Location		
	Canada	USA	TBR
2001	83.5 ± 7.4	97.6 ± 12.0	90.1 ± 12.1
2002	80.1 ± 7.1	96.5 ± 9.4	82.7 ± 9.5
2003	80.8 ± 6.5	93.3 ± 9.9	90.3 ± 10.6
2004	78.2 ± 7.5	92.4 ± 11.2	89.1 ± 12.1
2005	81.2 ± 7.9	100.3 ± 9.9	96.6 ± 12.2
2006	83.0 ± 8.1	107.3 ± 13.2	105.5 ± 14.3
2007	80.3 ± 9.4	95.0 ± 10.4	94.1 ± 10.9
2008	78.7 ± 5.9	97.2 ± 10.3	96.7 ± 10.7
2009	79.5 ± 6.2	101.0 ± 9.9	99.7 ± 11.0
2010	78.5 ± 4.9	103.6 ± 11.4	103.4 ± 11.5
2011	-	97.2 ± 12.3	95.9 ± 12.9
2012	-	99.4 ± 9.6	99.4 ± 9.6
2013	-	116.8 ± 9.4	116.8 ± 9.4
Wild	81.0 ± 11.3	100.7 ± 15.9	89.1 ± 16.5
Total	81.3 ± 7.8	100.4 ± 12.6	97.0 ± 14.0

3.3.2.2.4 Growth

The relationship that best described juvenile White Sturgeon length-at-age was the von Bertalanffy growth equation (Figure 22):

$$L_t = 164.73\left(1 - e^{-0.066(t-3.11)}\right)$$

The length-weight relationship was described by the model (Figure 23):

$$W = 3.401e^{-6} \times TL^{(3.1742)}$$

As with the length-at-age relationship, this weight-length relationship predicted faster growth in fork length at younger ages (Figure 2) and faster growth in weight at later ages (Figure 25). The model results are similar to relationships present for the LCR in previous years (BC Hydro 2013a, BC Hydro 2015c) and other White Sturgeon populations (Beamesderfer 1993).

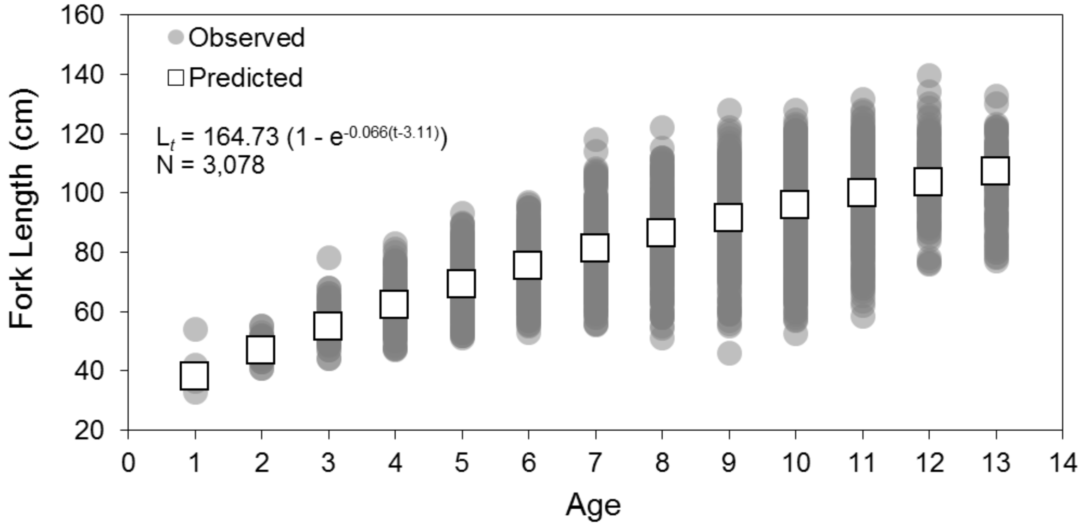

Figure 22. Length-at-age relationship and von Bertalanffy growth equation for juvenile White Sturgeon captured in the Lower Columbia River during 2009 and 2015.

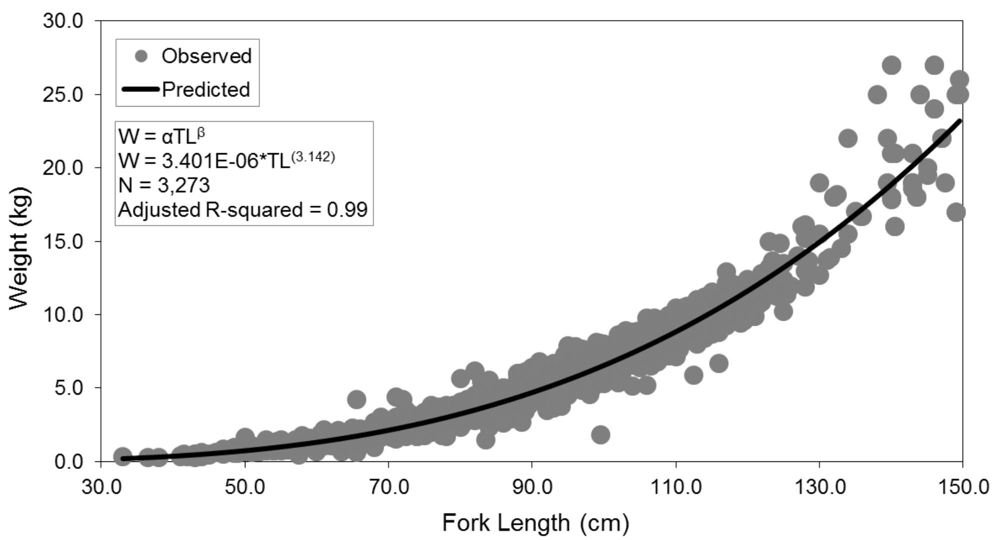

Figure 23. Observed and predicted length-weight relationship and equation for juvenile White Sturgeon captured in the Lower Columbia River in 2009 through 2015.

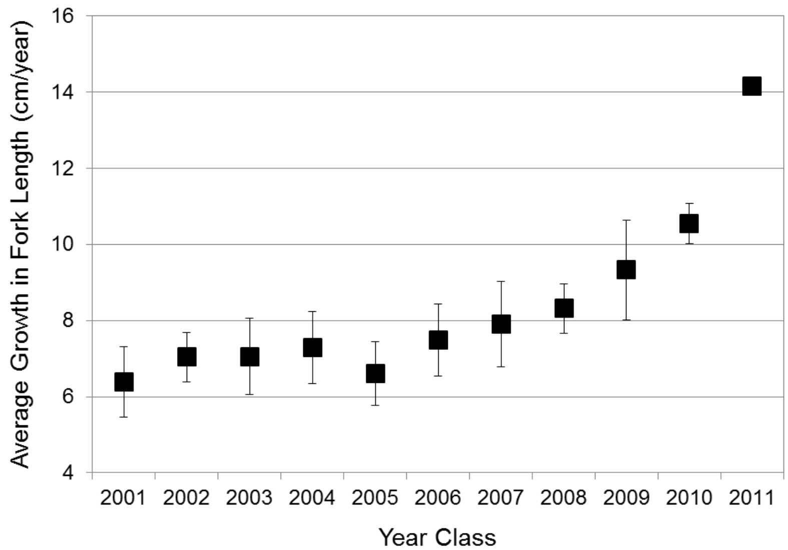

Figure 24. Fork length growth (cm/year) since release by brood year class for juvenile White Sturgeon captured in the Lower Columbia River in 2015. Year class of hatchery origin fish was determined by external mark of removed lateral scute and PIT tag.

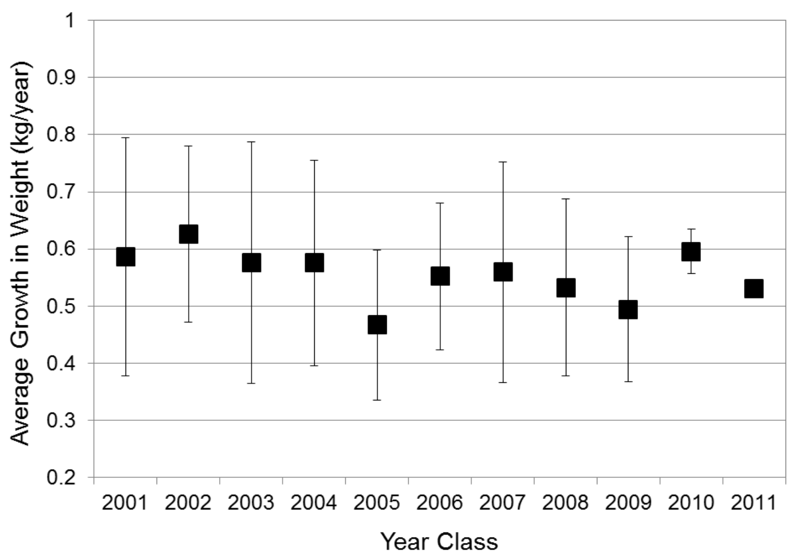

Figure 25. Growth (kg/year) in weight since release by brood year class for juvenile White Sturgeon captured in the Lower Columbia River in 2015. Year class of hatchery origin fish was determined by external mark of removed lateral scute and PIT tag.

3.3.3 Juvenile Survival and Abundance Estimates

3.3.3.1 Data Management

After cleaning the data for sampling mortalities, individuals with missing information (i.e., weight, year class, release location) and within-year recaptures, the final dataset consisted of 7,320 records (Table 26). Juveniles of year classes 2001, 2003, and 2006 had the highest percent recaptured of respective number of year class individuals released (16.2%, 5.9%, and 9.1%, respectively; Table 27). Juveniles of year classes 2001, 2004, and 2006 were of the highest percent recaptured of total recaptures across all sampling years (19.2%, 13.0%, and 19.3%, respectively; Table 27). Juveniles of year classes 2011, 2012, and 2013 had the lowest percent recaptured of respective number of year class individuals released (0.3%, 0.15, and 0.0%, respectively; Table 27). Juveniles released in the US section of the LCR were considerably larger than those released in the Upper and Lower sections within Canada (Figure 26).

Table 26. Number of juvenile White sturgeon released and recaptured by year of release in the Transboundary Reach of the Columbia River in 2002 to 2014.

Release		Recapture													
Year	N	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
2002	8,668	33	55	62	154	89	10	8	91	100	278	203	216	104	1,403
2003	11,789	0	34	50	85	72	6	1	27	44	106	95	108	49	677
2004	11,571	0	0	61	89	99	16	2	47	33	108	58	109	61	683
2005	21,603	0	0	0	72	211	67	1	64	52	139	85	147	110	948
2006	19,205	0	0	0	0	94	49	1	65	57	142	81	190	132	811
2007	15,559	0	0	0	0	0	79	3	106	40	123	83	528	450	1,412
2008	10,259	0	0	0	0	0	0	1	29	29	80	28	191	222	580
2009	7,673	0	0	0	0	0	0	0	12	19	28	19	148	194	420
2010	8,404	0	0	0	0	0	0	0	0	12	15	19	65	79	190
2011	11,458	0	0	0	0	0	0	0	0	0	3	15	64	97	179
2012	4,189	0	0	0	0	0	0	0	0	0	0	4	3	7	14
2013	4,081	0	0	0	0	0	0	0	0	0	0	0	2	1	3
2014	2,455	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	136,914	33	89	173	400	565	227	17	441	386	1,022	690	1,771	1,506	7,320

Table 27. Total juvenile White Sturgeon released and total number of individuals recaptured by year class in the Transboundary Reach of the Columbia River in 2002 – 2014. Highest proportion of captures are bolded for comparison.

Release Year	YRC	Number Released	Recapture		
			Total	% of YRC Released	% of Total Recaptures
2002	2001	8,668	1,403	**16.2**	**19.2**
2003	2002	11,789	677	5.7	9.2
2004	2003	11,571	683	**5.9**	9.3
2005	2004	21,603	948	4.4	**13.0**
2006	2005	19,205	811	4.2	11.1
2007	2006	15,559	1,412	**9.1**	**19.3**
2008	2007	10,259	580	5.7	7.9
2009	2008	7,673	420	5.5	5.7
2010	2009	8,404	190	2.3	2.6
2011	2010	11,458	179	1.6	2.4
2012	2011	4,189	14	0.3	0.2
2013	2012	4,081	3	0.1	0.0
2014	2013	2,455	0	0.0	0.0
Total		136,914	7,320		

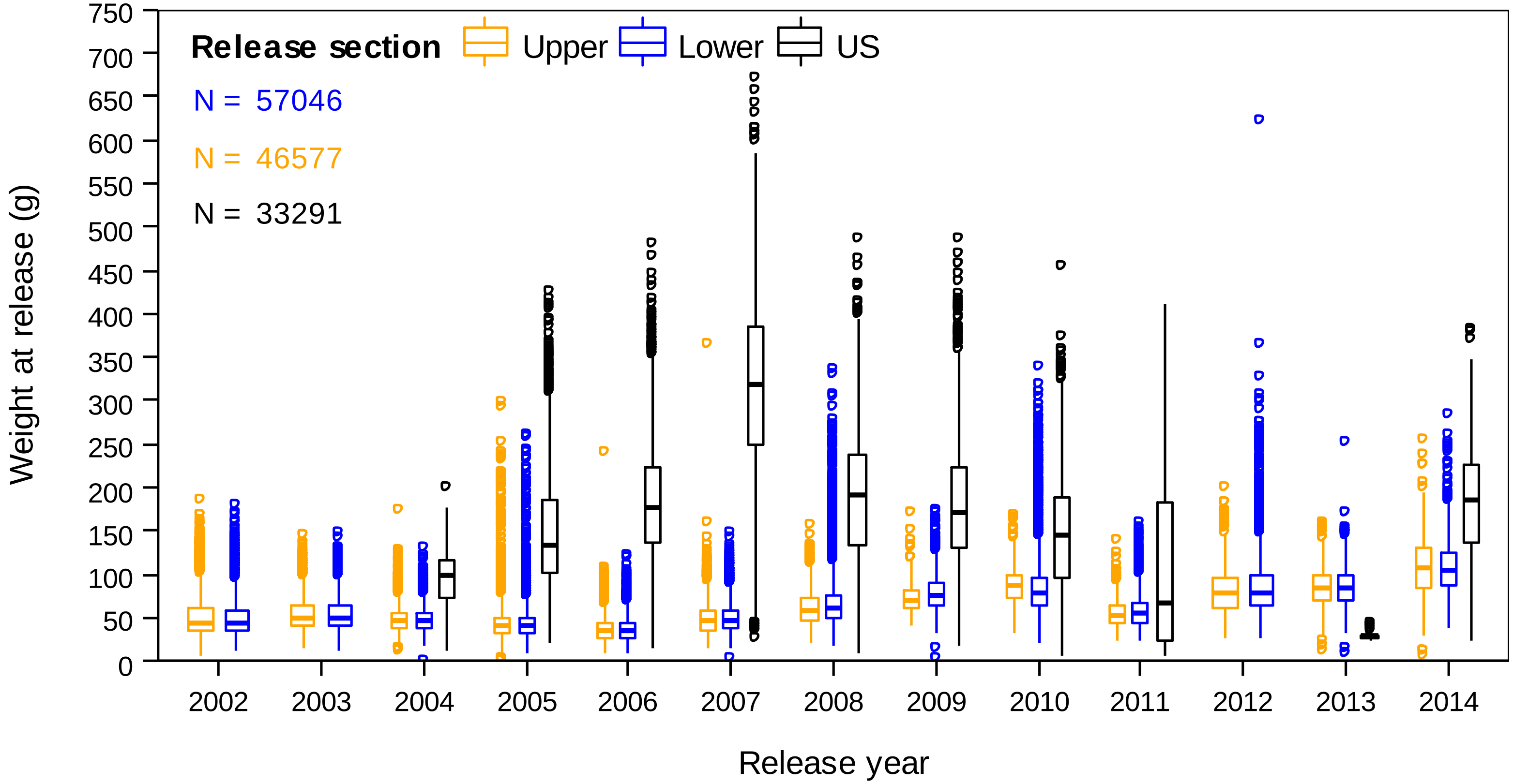

Figure 26. Hatchery-reared juvenile White Sturgeon weight-at-release (g) as a function of release location and year.

3.3.3.2 Model Selection

Goodness-of-fit statistics for data Block 1 and Block 2 indicated no lack of fit related to the equal catchability among fish (Block 1 TEST2: χ^2 = 41.9, df = 38, p = 0.304; Block 2 TEST2: χ^2 = 1.09.9, df = 132, p = 0.919), but suggested that the chance of survival between recapture events was not equal (Block 1 TEST3: χ^2 = 108.5, df = 54, p < 0.001; Block 2 TEST3: χ^2 = 423.1, df = 87, p < 0.001). The resulting value of the variance inflation factor used to calculate QAICc, ĉ, was 1.6 and 2.4 for data Block 1 and Block 2, respectively.

3.3.3.3 Juvenile Survival Estimates

The four best-fitting models for data Block 1 included recapture probability as a function of event, and survival as a specification of 2,3, or 4 age classes with constant survival values in models 2 to 4 and an interaction between age class and release weight in model 1 (Table 28). With Model 1, survival estimates for older age classes were predicted to decline with release weight, and models 2 to 4 predicted survival of age classes older than age-0 was predicted to be exactly 1, indicating potential estimation problems. As the next best model, Model 5 included survival as a function of release weight for the first age class, a constant survival for all ages past the first age class, and recapture as a function of year. Therefore, Model 5 was selected for further analysis of data Block 1 as it predicted a plausible constant survival for age-1+ fish.

For data Block 1, annual survival of the first age class increased with release weight, from 0.476 (95% CI: 0.382-0.574) at 100 g, to 0.863 (95% CI: 0.744-0.933) at 200 g, and 0.981 (95% CI: 0.938-0.994) at 300 g (Figure 27). The 20th, 50th, 75th, and 90th, percentiles of all release weights (2002-2014) were 35, 55, 93, and 181 g, respectively, which corresponded to annual survival estimates of 0.238, 0.293, 0.444, and 0.811, respectively. All annual survival estimates were higher than those reported in the analysis of 2002-2006 releases (Golder 2009c). Survival of the second age class (fish older than 1.5 years) was estimated as a constant, with mean of 0.979 (95% CI: 0.476-0.999). This value was in the higher range of age-2 survival reported for White Sturgeon in the Kootenay River (Justice et al. 2009).

Table 28. Comparisons of the Cormack-Jolly-Seber models developed for data Block 1 of hatchery-reared juvenile White Sturgeon released in the Transboundary Reach of the Columbia River between 2002 and 2007. The specification of survival and recapture rates, number of model parameters (npar), and QAICs statistics are indicated for each model. ΔQAICc and QAICc weights were only estimated for models that converged.

Model	Phi	p	npar	QAICc	ΔQAICc	QAICc weight
1	ϕ(ages2, weight at release / weight at release)	p(event)	14	7212.4	0	0.989
2	ϕ(ages2, c/c)	p(event)	12	7222.2	9.8	0.007
3	ϕ(ages3, c/c/c)	p(event)	13	7224.2	11.8	0.003
4	ϕ(ages4, c/c/c/c)	p(event)	14	7226.2	13.8	0.001
5	ϕ(ages2, release weight/c)	p(t)	8	7300	87.7	0
6	ϕ(ages2, weight at release / weight at release)	p(t)	9	7301	88.6	0
7	ϕ(ages2, weight at release / weight at release)	p(release section)	7	7457	244.7	0
8	ϕ(ages2, release weight/c)	p(release section)	6	7462.5	250.1	0
9	ϕ(ages2, c/c)	p(release section)	5	7475	262.6	0
10	ϕ(ages2, c/c)	p(t)	7	7491.1	278.8	0
11	ϕ(ages4, c/c/c/c)	p(t)	9	7491.1	278.8	0
12	ϕ(ages3, c/c/c)	p(t)	8	7491.7	279.4	0
13	ϕ(ages2, weight at release / weight at release),	p(.)	5	7509.4	297.1	0
14	ϕ(ages2, release weight/c)	p(.)	4	7516.2	303.8	0
15	ϕ(ages4, c/c/c/c)	p(.)	5	7658.3	445.9	0
16	ϕ(ages3, c/c/c)	p(.)	4	7672.5	460.2	0
17	ϕ(ages2, c/c)	p(.)	3	7673.6	461.2	0
18*	ϕ(ages2, release weight/c)	p(event)	13	7210.6		

*Model did not converge

The best-fitting model for data Block 2 described survival as a function of whether the fish were released in 2002, a function of release weight (ages 0-6), a constant survival at age-6+, and recapture probability as a function of event (Table 29). This model was selected for further analysis of data Block 2 as it predicted a plausible survival estimates for both modeled age classes of fish.

For data Block 2, 2002 releases were predicted to have higher annual survival (i.e., survival adjusted to a 1-year period) than 2003-2008 releases (Figure 27). At 100, 200, and 300 g, 2002-released fish had predicted annual survival of 0.907, 0.956, and 0.981, whereas fish released in 2003-2008 had predicted annual survival of 0.734, 0.827, and 0.904, respectively. At the 20th, 50th, 75th, and 90th percentiles of all release weights (35, 55, 93, and 181 g respectively), annual survival of 2002-released fish was 0.863, 0.876, 0.902, and 0.949, respectively. Survival of 2003-2008 released fish at these weight percentiles was 0.674, 0.690, 0.727, and 0.811, respectively. These values were considerably higher than those reported in the analysis of 2002-2006 releases (Golder 2009c). Survival of the second age class (fish older than 6 years) was estimated as two constants including 2002-released fish and all other fish with means of 0.995 (95% CI: 0.978-0.999) and 0.965 (95% CI: 0.873-0.991), respectively. These values were comparable to higher range of age-2 survival reported for White Sturgeon in the Kootenay River (Justice et al. 2009).

Table 29. Comparisons of the Cormack-Jolly-Seber models developed for data Block 2 of hatchery-reared juvenile White Sturgeon released in the Transboundary Reach of the Columbia River between 2002 and 2007. The specification of survival and recapture rates, number of model parameters (npar), and QAICs statistics are indicated for each model. ΔQAICc and QAICc weights were only estimated for models that converged.

Model	Phi	p	npar	QAICc	ΔQAICc	QAICc weight
1	ϕ(Is.2002 + ages2, release weight/c)	p(event)	9	15322.9	0	1
2	ϕ(Is.2002 x ages2, release weight/c)	p(t)	12	15454.6	131.7	0
3	ϕ(Is.2002 + ages2, release weight/c)	p(t)	11	15490	167.1	0
4	ϕ(Is.2002)	p(event)	7	15812.7	489.8	0
5	ϕ(ages2, c/c)	p(event)	7	16186	863.1	0
6	ϕ(Is.2002)	p(release section)	5	16195.8	872.9	0
7	ϕ(ages2, c/c)	p(release section)	5	16419.2	1096.3	0
8	ϕ(ages2, release weight/c)	p(t)	10	16640.1	1317.2	0
9	ϕ(ages2, release weight/c)	p(.)	4	17041.3	1718.4	0
10	ϕ(Is.2002)	p(t)	9	17057	1734.1	0
11	ϕ(ages2, c/c)	p(t)	9	17497.5	2174.6	0
12	ϕ(Is.2002)	p(.)	3	17530.3	2207.4	0
13	ϕ(ages2, c/c)	p(.)	3	17753.2	2430.3	0
14*	ϕ(Is.2002 + ages2, release weight/c)	p(.)	5	15753.4		
15*	ϕ(Is.2002 + ages2, release weight/c)	p(release section)	7	15534.3		
16*	ϕ(Is.2002 x ages2, release weight/c)	p(.)	6	15755.4		
17*	ϕ(Is.2002 x ages2, release weight/c)	p(event)	10	15323.5		
18*	ϕ(Is.2002 x ages2, release weight/c)	p(release section)	8	15536.3		
19*	ϕ(ages2, release weight/c)	p(event)	8	16079.9		
20*	ϕ(ages2, release weight/c)	p(release section)	6	16278.6		
21*	ϕ(ages2, weight at release / weight at release),	p(.)	4	17058.5		
22*	ϕ(ages2, weight at release / weight at release),	p(event)	8	16079.9		
23*	ϕ(ages2, weight at release / weight at release),	p(release section)	6	16278.4		
24*	ϕ(ages2, weight at release / weight at release),	p(t)	10	16783.9		

* Model did not converge

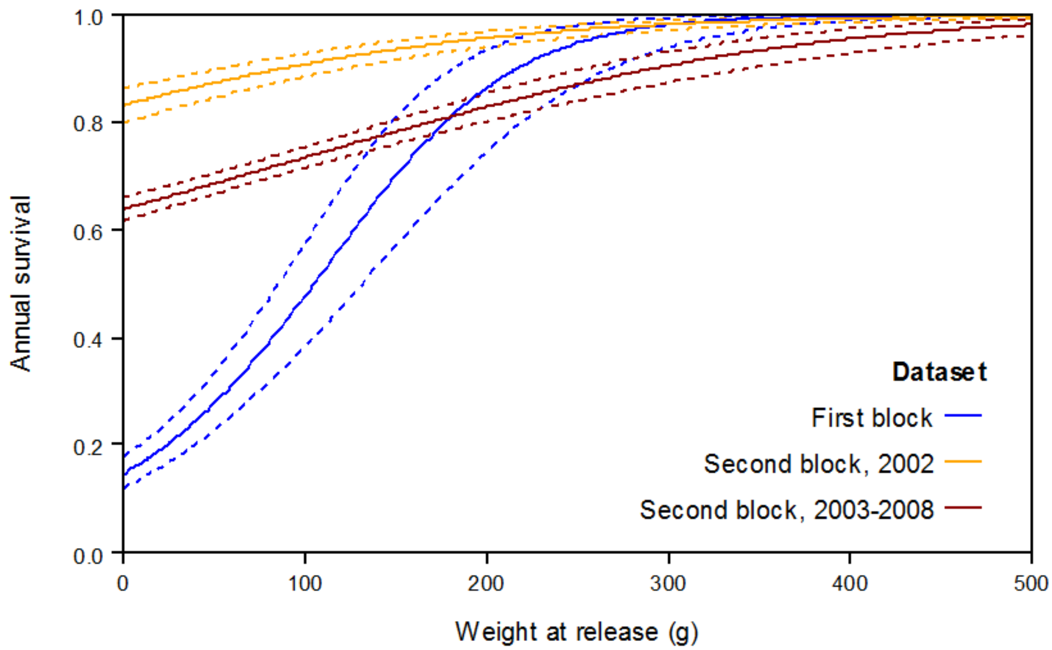

Figure 27. Estimated annual survival (mean ± 95% CI) of age-0 fish as a function of release weight (g), plotted by data block and year of release (all years for Block 1, 2007 or 2008 and on for Block 2).

Predicted recapture estimates ranged from 0.01 (95% CI: 0.008-0.014) in 2007 to 0.053 (95% CI: 0.039-0.072) in 2005 for data Block 1 (Table 30). In the data Block 2 model, recapture probabilities were more varied (Table 30), ranging from 0.002 (95% CI: 0.001-0.006) in recapture event “a” (2008 recapture effort in Lower and Upper Canadian release sections) to 0.167 (95% CI: 0.140-0.198) in event “e” (2013-2014 effort in the US), likely due to the high rate of hatchery-reared fish released in the US in 2007 (Table 26).

Table 30. Capture probabilities estimated, lower confidence interval (LCI), and upper confidence interval (UCI) in data Blocks 1 and 2. Recapture event specification of is provided in Table 1.

Data block	Year/recapture event	Estimate	LCI	UCI
1	2003	0.037	0.024	0.056
	2004	0.029	0.02	0.042
	2005	0.053	0.039	0.072
	2006	0.047	0.035	0.061
	2007	0.01	0.008	0.014
2	a	0.002	0.001	0.006
	b	0.049	0.042	0.059
	c	0.024	0.019	0.03
	d	0.064	0.050	0.082
	e	0.167	0.140	0.198
	US, 2008-2009	Fixed at 0.0		

3.3.3.4 Abundance Estimates

Abundance estimates differed by model, both in mean and variability (Figure 28; Table 31). While the data Block 1 model had wide CIs (up to 121% of the mean value in 2014), the data Block 2 model had much tighter CIs (up to 33% of the mean value in 2014). Although the predicted 95% CIs of abundance based on the two data blocks did not overlap during 2003-2009, estimates of the two analyses began converging in 2010 with almost identical mean estimates were in 2013-2014. The tighter CIs of data Block 2 abundance estimates were likely the result of 1) smoothing of survival estimates across the first 6 years at large, and 2) an expectedly high survival of age-6+ fish (in comparison to age-1.5+ fish modeled in data Block 1).

The data Block 1 model estimated the hatchery-reared juvenile White Sturgeon population in the Columbia River to have increased from 8,668 fish released in 2002 to 28,372 (95% CI: 25,794 – 30,209) in 2005, plateaued in population size from 2006 through 2009, and increased in 2011 estimating a size of 40,632 (95% CI: 19,107 - 48,951). After 2011, population estimates slowly declined reaching 32,857 (95% CI: 4,064 - 44,107) in 2014.

The data Block 2 model estimated the hatchery-reared juvenile White Sturgeon population in the Columbia River to have increased from 8,668 fish released in 2002 to 47,437 (95% CI: 45,656 - 49,301) in 2007 and remained relatively constant until 2011 when a slow decline occurred estimating the population size to be 32,358 (95% CI: 26,603 - 37,332) in 2014.

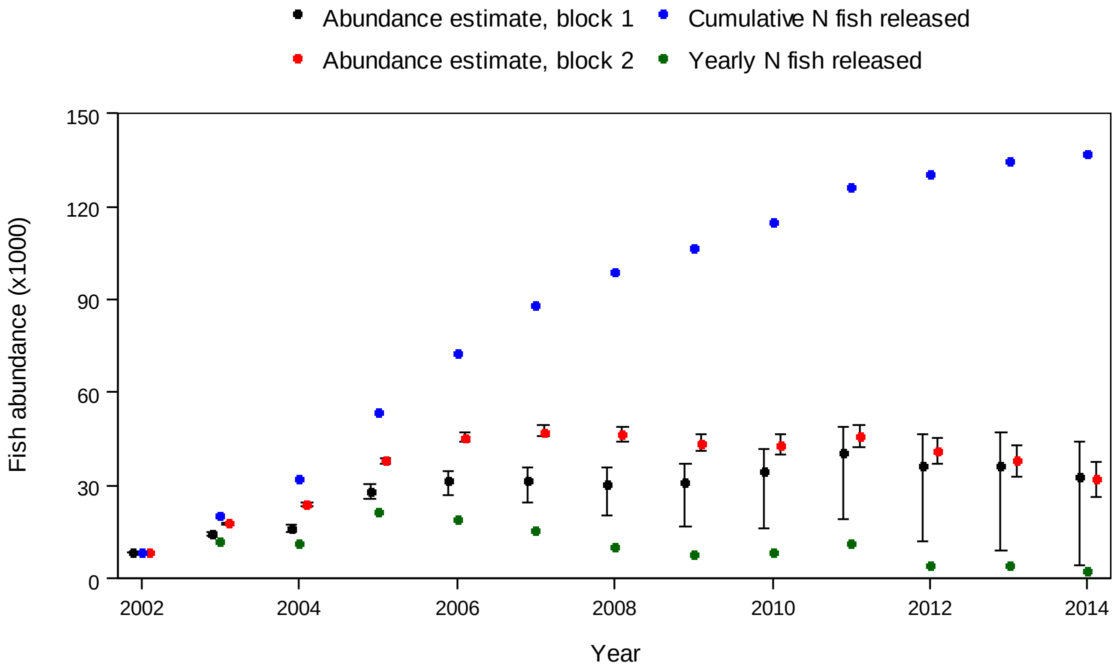

Figure 28. Number of hatchery-reared juvenile White Sturgeon released and estimated abundance in the Transboundary Reach of the Columbia River in 2002-2014. Abundance estimates are plotted separately for models of best fit for data Block 1 and 2. Error bars are 95% confidence intervals.

Table 31. Yearly and cumulative totals of hatchery-reared juvenile White Sturgeon released and estimated abundance (mean [lower and upper 95% confidence intervals]) in the Transboundary Reach of the Columbia River in 2002 to 2014 by data block model.

Year	Number Released		Abundance Estimate	
	Yearly	Cumulative	Block 1	Block 2
2002	8668	8668	8668	8668
2003	11789	20457	14,314 (13,857 – 14,825)	17,748 (17,579 – 17,919)
2004	11571	32028	16,434 (15,131 – 17,607)	23,797 (23,340 – 24,263)
2005	21603	53631	28,372 (25,794 – 30,209)	38,027 (37,261 – 38,822)
2006	19205	72836	31,422 (26,708 – 34,516)	45,594 (44,327 – 46,913)
2007	15559	88395	31,815 (24,425 – 35,997)	47,437 (45,656 – 49,301)
2008	10259	98654	30,677 (20,078 – 35,800)	46,588 (44,351 – 48,904)
2009	7673	106327	31,112 (16,779 – 37,166)	43,863 (41,157 – 46,610)
2010	8404	114731	34,502 (16,414 – 41,603)	43,177 (39,997 – 46,327)
2011	11458	126189	40,632 (19,107 – 48,951)	46,134 (42,432 – 49,709)
2012	4189	130378	36,712 (12,028 – 46,353)	41,404 (36,940 – 45,563)
2013	4081	134459	36,479 (9,238 – 47,082)	38,250 (33,036 – 42,930)
2014	2455	136914	32,857 (4,064 – 44,107)	32,358 (26,603 – 37,332)

3.3.4 Juvenile Sex and Stage of Maturity

3.3.4.1 Fish Capture and Biopsy Sampling

Sampling by angling and setlines was conducted between October 26 and 29 and on November 12, respectively. Total angling and setline sampling effort was 18.6 hours and 143.4 hours at depths of 20.4 ± 11.3 m (mean ± SD) and14.8 ± 1.9 m, respectively (Table 32). A total of 104 juveniles of hatchery origin were captured during the sampling period (Table 32). The majority of the sampling effort was conducted in Zone 1 (157.1 hours) versus Zone 5 (4.9 hours), and as a result, the majority of individuals were captured in Zone 1 (n=82; Table 32).

Table 32. Sampling effort (hrs), depth (m), and total juvenile White Sturgeon capture for each sampling method (i.e., angling, setlines) and sampling zone (i.e., zone 1, zone 5) during the 2015 sex determination study in the Lower Columbia River. Year class of hatchery origin fish was determined by external mark of removed lateral scutes and PIT tag. No fish of wild origins was captured. Sampling zones represent upstream (zone 1, rkm 0.1 to 11.2) and downstream (zone 5, rkm 45.8 to 57.0) river sections.

Sampling Method/Zone	Effort (hrs)	Depth		Total Capture
		Mean	SD	
Angling	18.6	20.4	11.3	75
Setline	143.4	14.8	1.9	29
Zone 1	157.1	14.6	1.8	82
Zone 5	4.9	30.0	14.1	22

Biopsy sampling was completed for 34 individuals of year classes 2001 (n=20), 2002 (n=10), and 2006 (n=4; Table 33). Sex was assigned to all biopsied individuals resulting in 12 females and 21 males based on visual examination (Table 33; Figure 29 and 30).

Table 33. Biopsy sampling and sex determination for juvenile White Sturgeon captured within each sampling zone (i.e., zone 1 and zone 5) during the 2015 sex determination study in the Lower Columbia River. Year class of hatchery origin fish was determined by external mark of removed lateral scutes and PIT tag. No fish of wild origins was captured. Sampling zones represent upstream (zone 1, rkm 0.1 to 11.2) and downstream (zone 5, rkm 45.8 to 57.0) river sections.

Year Class	Total	Biopsy Sample		Assigned Sex	
		Zone 1	Zone 5	Female	Male
2001	20	16	4	9	11
2002	10	8	2	3	7
2006	4	4	0	1	3
Total	34	28	6	13	21

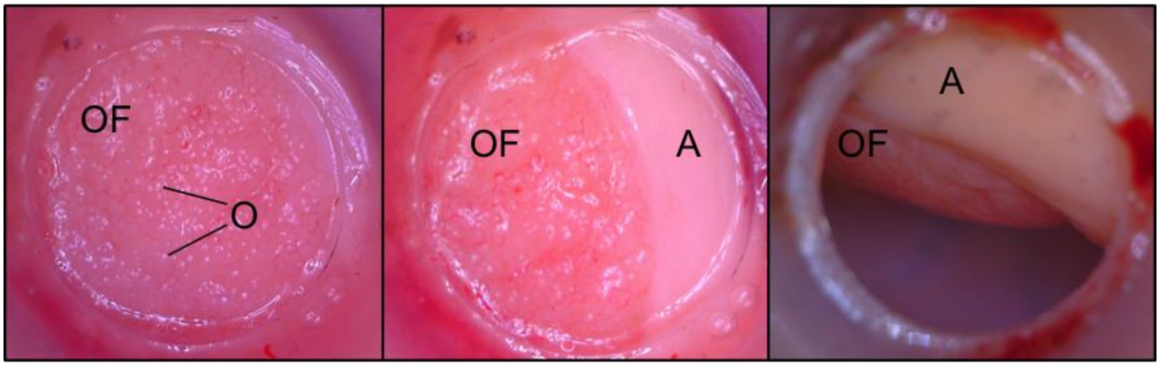

Figure 29. Endoscopic images of adipose tissue (A), ovigerous folds (OF) and small translucent oocytes (O) in pre-vitellogenic female juvenile White Sturgeons.

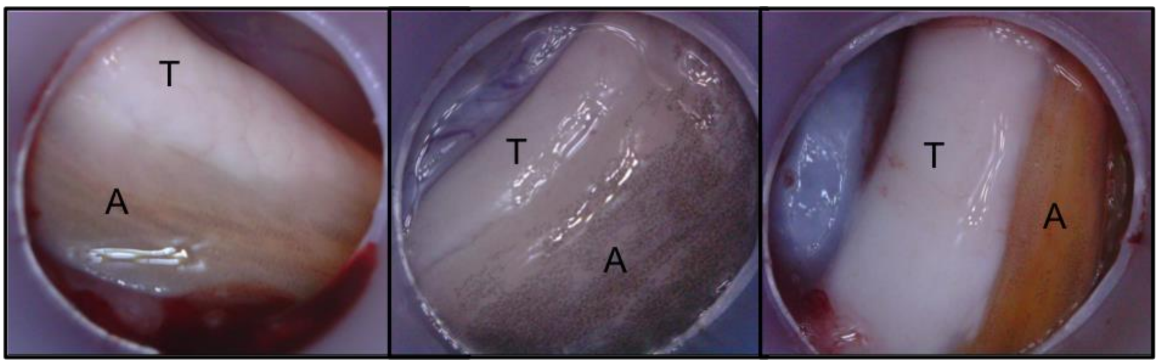

Figure 30. Endoscopic images of testicular tissue (T) and adipose tissue (A) in male juvenile White Sturgeon. Stage of maturity cannot be determined through visual examination.

Fork length (FL) and weight (W) for all individuals captured is provided in Table 34. Fork length and weight for biopsied individuals was 101.3 ± 17.5 cm and 6.7 ± 4.5 kg, respectively. Individuals assigned as females were slightly larger (FL: 103.5 ± 6.9 cm; W: 7.1 ± 1.5 kg) than assigned males (FL: 99.9 ± 13.0 cm; W: 6.6 ± 2.1 kg); however, this difference was not significant (FL: P=0.4061; W: P=0.5113)

Table 34. Fork length (cm) and weight (kg) of total juvenile White Sturgeon captured, biopsied individuals, and individuals assigned a sex during the 2015 sex determination study in the Lower Columbia River. Year class of hatchery origin fish was determined by external mark of removed lateral scutes and PIT tag. No fish of wild origins was captured.

Year Class	Total Capture	Fork Length		Weight	
		Mean	SD	Mean	SD
All Captured Individuals					
2001	21	100.5	12.8	6.7	2.1
2002	11	103.9	9.3	7.3	1.6
2003	3	95.3	12.4	5.7	1.9
2004	10	93.6	12.3	5.1	1.9
2005	11	94.9	7.4	5.6	1.5
2006	19	90.7	6.0	4.7	1.0
2007	8	89.1	10.2	4.4	1.8
2008	5	82.1	7.6	3.2	0.9
2009	7	72.9	12.0	2.6	1.4
2010	2	70.8	6.0	2.3	0.6
2011	3	62.5	2.6	1.4	0.2
2012	3	54.2	6.8	1.0	0.4
Biopsied Individuals					
2001	20	101.3	12.6	6.8	2.1
2002	10	103.6	9.8	7.1	1.6
2006	4	95.8	3.9	5.6	0.7
Assigned Sex					
Female	13	103.5	6.9	7.1	1.5
Male	21	99.9	13.0	6.6	2.1

3.3.4.2 Biopsy Sample Analysis

All biopsy samples will be transported to a laboratory for histological analyses in 2016. Stage of maturity will be determined at this time.

3.4 Habitat Mapping

Recorded images have been edited and processed identifying ten acoustic substrate classes. Detailed results of analyses are provided in Appendix 1 of BC Hydro 2015c. Image processing identified ten acoustic substrate classes. Ground truthing will be required to identify specific riverbed sediment types (e.g., cobble, gravel, sand) represented by each acoustic class.

4 DISCUSSION

While this report is primarily a data report, general discussion points are provided for each of the main areas of this monitoring program. Results are discussed in the context of the monitoring program objectives, however they should be interpreted with caution as they represent only the early years of this program. While this monitoring program has contributed significant knowledge pertaining to larval and juvenile White Sturgeon ecology and the overall success of the Conservation Aquaculture Program, additional years of data are required to assess trends and answer the management questions of this program.

4.1 Yolk Sac Larval Assessment

For White Sturgeon throughout their range, it has generally been observed that the spawning period is protracted and occurs in the late spring and early summer months (May through early August) with specific timing dependent on environmental cues (e.g., temperature, flows; Parsley and Beckman 1994). Based on developmental stages of collected yolk-sac larvae, spawning was estimated to have occurred in late June downstream of Waneta and mid-July downstream of Kinnaird in 2015. The number of days between when spawning started and ended was small in 2015 compared to previous sampling years, with spawning events only detected for a week at Waneta. While 2015 was the 3rd driest year on record since regulation of the Columbia (BC Hydro Generation Resource Management, personal communication) began, all of the estimated spawning days still occurred after freshet flows had peaked. The majority of spawning events estimated to occur since 1993 in the LCR have been on the descending limb of the hydrograph and at water temperatures above 14ºC.

In 2015, larvae were again collected within the vicinity of Kinnaird, which has now had spawning documented annually since 2007 and is an area that requires additional monitoring to further describe where spawning may be occurring (Fisheries and Oceans 2014). Despite annual monitoring since 2007, the exact location of the spawning area (egg deposition and larval hiding habitat) remains unknown and is the focus of this component of the program. In 2013, 2014 (BC Hydro 2016a; BC Hydro 2016b), and 2015 (this study), extensive sampling with drift nets has been conducted in an attempt to narrow down the location where larvae are dispersing from (Figure 7). Despite a significant amount of effort, larvae have been collected throughout the 8 km stretch of river. While egg mats can be used once the main areas of egg deposition have been identified, drift nets will remain the primarily method of collection when attempting to assign a general location where spawning may be occurring. Once geographical boundaries of the spawning location can be described, a monitoring program that includes the use of egg mats should be developed consistent with work being done at other spawning locations (e.g., Waneta, Golder 2013; or Revelstoke, AMEC 2014).

Reduced quality of early life stage habitat used for egg incubation and early rearing of larvae is one of several recruitment failure hypotheses for this population. Larvae that are young in developmental stage (Primarily 1-3 days post hatch) have dominated the collections to date across all spawning locations in Canada, suggesting the substrates at the spawning locations are not adequate for hiding until they reach feeding age. However, increased larval monitoring efforts with drift nets at the Waneta spawning site has resulted in the capture of a percentage (16%) of later stage larvae close to feeding age. This additional monitoring was in response to the SIF that was developed and the need for more sampling to increase captures. Sampling at Waneta has been primarily been egg mats since 1993 with short set drift nets. In addition, refinements to drift net methods have resulted in the capture of tens of thousands of feeding age larvae downstream of North Port WA (Jason McLellan, Colville Confederated Tribes, unpublished data). This suggests that while eggs and larvae in early developmental stages are dispersed downstream of the immediate spawning area at Waneta, there is suitable hiding habitat between the Canada/US border and the North Port spawning site. Describing spawning and early life stage habitat at known (e.g., Waneta, ALH) and suspected (e.g., Kinnaird) spawning locations is important to determine habitat suitability for yolk-sac larvae hiding behaviour and young-of-year rearing conditions and the potential effects of habitat on recruitment. Further, it will be important to incorporate results from larval monitoring programs in the US section of the TRA, as captures of larvae at feeding stages occur annually (Hildebrand and Parsley 2013). These results suggest that hiding habitat is present between the Waneta spawning location and the capture location downstream of Northport WA. Genetic analyses in addition to those already completed (Jay et al. 2014) could determine the proportion of larvae that originated from the Waneta location and should be considered if data are available in future years.

4.2 Juvenile Population Assessment

For approximately the last 40 years, recruitment of White Sturgeon in the Transboundary Recovery Area (TRA) of the Columbia River (Hugh L. Keenleyside Dam (HLK) to Grand Coulee Dam (GCD) in WA, USA) has not occurred at a rate sufficient to maintain the population. In response to this, the Upper Columbia White Sturgeon Recovery Initiative (UCWSRI) was formed in 2000, and developed a Recovery Plan, a key component of which is the supplementation of the existing White Sturgeon population through broodstock collections, hatchery rearing, and stocking of juvenile White Sturgeon (UCWSRI 2002).

In total, 144,881 hatchery-reared juvenile White Sturgeon have been released into the TRA from 2002 to 2015 (yearly releases ranging from 4,302 in 2012 to 21,603 in 2005). These juveniles are being monitored annually by various agencies (i.e., Golder, BC Hydro, Washington Department of Fish and Wildlife (WDFW)). Results from analyses conducted indicate that hatchery-reared juveniles are growing and surviving beyond original expectations of the recovery plan. Abundance estimates based on the long-term capture data set analyzed in this report (Section 3.3.3.3) put the hatchery component of the Upper Columbia White Sturgeon Population in excess of 30,000 individuals. Survival has been significantly associated with size at release, with certain year classes that were released at a large body size having high survival and associated abundance. For example, the 2006 year class progeny released in the US portion of the TRA were >300 g in weight and survival was estimated to be >90%. This translates to an abundance of that single year class that is greater than the wild adult population. This is cause for concern as relatively few adults contributed to progeny released in certain year classes. Discussions around numbers of hatchery origin fish at large and the numbers to be released in future years are being held at the recovery initiative table. Results from survival analyses conducted under this monitoring program serve as tools that can be used to guide decisions around the supplementation of juveniles going forward.

Hatchery origin juveniles in the LCR represent a significant learning opportunity as juvenile age classes are lacking in many sturgeon populations throughout the world. Significant learnings about habitat use, growth, diet (details in Crossman et al. 2016), and survival have been made that not only inform recovery activities for White Sturgeon, but other species in North America. While this program serves as a means of detecting wild juveniles, they remain rarely encountered and represent < 1% of the total catch in the stock assessment program to date. One of the management questions of this work is to evaluate how normal river operations affect juvenile habitat conditions in the LCR. In the first 8 years of this program, we have used a spatially balanced and randomly assigned sampling design and documented habitat use throughout the entire LCR. Results suggest that habitat is characterized primarily by deep slow moving water and smaller substrates (e.g., sand, gravel, cobbles). These habitats are available throughout the upper section of the river and become more isolated further downstream (e.g., Kootenay River confluence to the US Border). These deeper slow moving habitats are not limited by the current operational regime of the LCR. Importantly, juvenile habitat distribution is similar to, and overlaps with, adult habitat use (described in BC Hydro, 2013b, 2015a, and 2015b).

4.3 Juvenile Sexing

This is a new component of the monitoring program and is in response to the increasing abundance of hatchery origin juveniles in the TRA. As discussed in section 4.2, there are certain year classes in large abundance in the TRA due to disproportional survival. Certain year classes are from relatively few adults and there are concerns around these fish spawning with wild adults as interrelatedness is high, which could result in genetic swamping of the existing wild stock. However, the point when hatchery origin juvenile White Sturgeon might start reproducing with the wild adults is unknown. We were able to determine the sex of all individuals captured. Both females and males were at early developmental stages and no fish are expected to spawn in the coming year. However, this will be confirmed with histology of collected gonadal tissue. Importantly, the ability to noninvasively determine sex of hatchery origin juveniles will be an important monitoring component going forward to track when they enter the breeding population. Additional results will be available in 2017.

4.4 Habitat Mapping

The lower Columbia River (LCR) was surveyed with a sidescan sonar, primarily to map riverbed character to assist in delineating habitat. Raw acoustic data were used to generate maps of riverbed character by segmenting the survey area into regions of homogeneous acoustic character that are acoustically distinct from other regions (e.g. sand, rock, and silt). Important next steps will be to ground truth the maps produced to produce a final habitat map for the LCR that can be used to identify important areas for White Sturgeon early life stages.

5 RECCOMENDATIONS

The following recommendations are based on sampling results from the first five years of project implementation. Specific recommendations are provided for larval, juvenile, and habitat sampling.

5.1 Larval Sampling

- Larval sampling should continue to occur annually at the HLK/ALH spawning area to determine spawning timing and frequency at this area and if habitat allows for larvae to develop to later developmental stages prior to dispersing downstream.
    - Sampling should start in early July and continue through the middle of August, as the timing of spawning in the upper parts of the LCR is still uncertain.
- Drift nets have been shown to maximize catch per unit effort of eggs and larvae from spawning locations upstream of the sampling equipment and should be used as the primary collection method in areas where the exact geographical boundary of the spawning location remains unknown.
    - Additional drift net stations should be deployed downstream of Kinnaird to determine where larvae may be originating from.
    - If hydrology permits, drift net sampling should be attempted in the lower Kootenay River to determine if larval captures near Kinnaird could be originating from this location.
- Tissue samples should be collected from as many larval captures as possible to determine how many adults are contributing using molecular methods. If possible, genetic analyses should address if larval captures near Kinnaird are genetically similar to upstream spawning locations (e.g., HLK/ALH spawning area).

5.2 Juvenile Sampling

- Continue to approach juvenile sampling programs in a spatially balanced random design, to acknowledge variability in growth between habitat types (e.g., upstream versus downstream) and age classes.

- Survival estimates should be revised as additional data is collected going forward. Results from survival estimates should be used to continually update abundance estimates for White Sturgeon of hatchery origin in the LCR. This information can be used to revise the Conservation Aquaculture Program and help guide long-term population targets.

- Sampling effort should continue to be focused using setlines as they minimize harm to the individual and can be fished for longer time periods throughout all areas that juveniles have been identified to use in the LCR.

- Continue to describe the diet of juvenile White Sturgeon in the LCR using gastric lavage.

- Determine sex and stage of maturity for as many juvenile captures as possible.

- Use known age hatchery-reared juveniles to develop ageing methodology to improve confidence in the ages of wild origin juveniles.

- Continue to monitor habitat use and distribution of juveniles under varying operational scenarios over the life of the monitoring program.

5.3 Habitat Mapping

- Continue to develop a habitat map for the entire LCR. Validate side scan sonar data collected in years 2 and 3 of this study using videography or physical substrate collection (e.g., ponar grabs).

- Describe the spawning and early life stage habitat at key spawning locations (e.g., HLK/ALH and Kinnaird locations). Focus should be given to determining the suitability of the immediate larval hiding habitat and downstream rearing habitat.

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