Columbia River Project Water Use Plan

Columbia White Sturgeon Management Plan

White Sturgeon Conservation Aquaculture – 2021 Annual Report

CLBWORKS-25: Mid-Columbia River White Sturgeon Conservation Aquaculture
CLBWORKS-34: Lower Columbia River White Sturgeon Conservation Aquaculture

WUP Works Period: May 2021 – May 2022
Program Period: 2001-2022

BC Hydro and Power Authority

Prepared by: Freshwater Fisheries Society of British Columbia

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June 2022

Mid and Lower Columbia River White Sturgeon Conservation Aquaculture Report: 2021

Prepared for: BC Hydro

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1. Background

The population of White Sturgeon in the Canadian portion of the Columbia River has been undergoing recruitment failure for several decades (Hildebrand and Parsley 2014). This was recognized as a critical issue for this population in the early 1990's and resulted in the establishment of the Upper Columbia White Sturgeon Recovery Initiative (UCWSRI; http://uppercolumbiasturgeon.org) in 2000 and the population being listed as endangered under the Species at Risk Act (SARA) in 2006. Original estimates, based on annual levels of natural recruitment being insufficient for maintaining a self-sustaining population, suggested that the population would become functionally extinct by 2044 (UCWSRI 2002; Hildebrand and Parsley 2014). Accordingly, intervention and monitoring were deemed essential to preclude extinction. An integral part of the original recovery plan was the initiation of a conservation aquaculture program designed to support the population until such time as stock abundance/age structure and habitat conditions can support a self-sustaining population.

The white sturgeon conservation aquaculture program was initiated in 2001 with a focus on the lower Columbia River, which encompasses 57.0 km of the Columbia River from Hugh L. Keenleyside (HLK) Dam near Castlegar British Columbia to the international border. A parallel program was initiated in the US in 2003, to produce juvenile sturgeon for release into Lake Roosevelt. Finally, in 2007, the program was extended to the Middle Columbia River Canada, which is a 235 km section of the Columbia from HLK to Revelstoke Dam and includes the Arrow Lakes Reservoir. Annual releases of sub-yearlings have occurred into all locations since their inception. The key overarching objectives of the aquaculture program were originally to prevent extirpation and retain the genetic diversity of the wild population. In order to achieve these objectives, the program followed an adaptive management approach that continually incorporated new methods and key results into the decision-making process. The adaptive management of the program was conducted in partnership with UCWSRI partners from both Canada and the US that included agencies, First Nations, industry, and other stakeholders. A

major transition in the program occurred in 2014, when the use of adult broodstock as an egg source was replaced with capture of wild eggs and larvae in order to maximize genetic diversity.

The main objective of this report is to provide a summary of the Canadian conservation aquaculture activities for the 2021 brood year. Further details about the longer-term methods and results can be found within annual and comprehensive reports (details in FFSBC 2008-2020 available at https://www.bchydro.com/toolbar/about/sustainability/conservation/water_use_planning/southern_interior/columbia_river/columbia-sturgeon.html).

2. Methods

Background of Wild Origin Approach

The conservation sturgeon aquaculture program successfully reared and released 164,423 sturgeon originating form captured broodstock between 2002 and 2015 (brood years 2001 to 2014). However, survival of hatchery-origin juveniles in the upper Columbia River population has been higher than originally predicted, with more than 20,000 individuals estimated to be at large in the population (BC Hydro 2018). Within the hatchery population, certain year classes that benefited from high survival due to large release size are now estimated to be in higher abundance than the existing wild population (~3,000 mature individuals). Of further uncertainty was whether within year class genetic diversity has been reduced relative to the expected diversity released from the hatchery due to disproportionate survival among maternal family groups post stocking. To ensure methods for progeny collection were as genetically robust as possible, a largescale adaptive management change was made to cease use of broodstock gametes and rely completely on capture of wild progeny. This had been developed for lake sturgeon conservation aquaculture (Crossman et al. 2011) to improve genetic diversity, and field work in the Columbia demonstrated it was feasible to capture large

numbers of wild larvae and eggs downstream of known spawning locations (primarily Waneta). Work by Jay et al. (2014) demonstrated an improvement in genetic diversity and, given the objectives of the overall program to rebuild abundance and maintain genetic diversity, the use of wild progeny was deemed as the optimal source for conservation aquaculture program going forward. Therefore, in 2014 a mobile streamside rearing facility was piloted as an incubation method for wild eggs in conjunction with the traditional broodstock capture. Following 2014 the broodstock program was discontinued and the wild-origin approach has continued to date.

Spatial orientation

The Canadian portion of the Columbia River is described spatially at several different levels. Most broadly, the river is divided into two sections above and below Hugh Keenleyside (HLK) dam which controls the water level of Arrow Lakes. Directly adjacent on river left to the HLK facility is the Arrow Lakes Hydro generating station (ALH), which is more proximate to the juvenile capture location. Sturgeon populations above and below HLK are treated as separate populations and have independent recovery and aquaculture release targets (see below). Specific sites within the Canadian portion of the Columbia River are further described by a linear river kilometer relative to HLK dam. The 56km of river below HLK is also categorized into 5 equal zones (11.2 km each). Lastly, there are numerous site descriptions and nicknames for specific capture and release locations. The capture and release site names and zones are all shown in Figure 1.

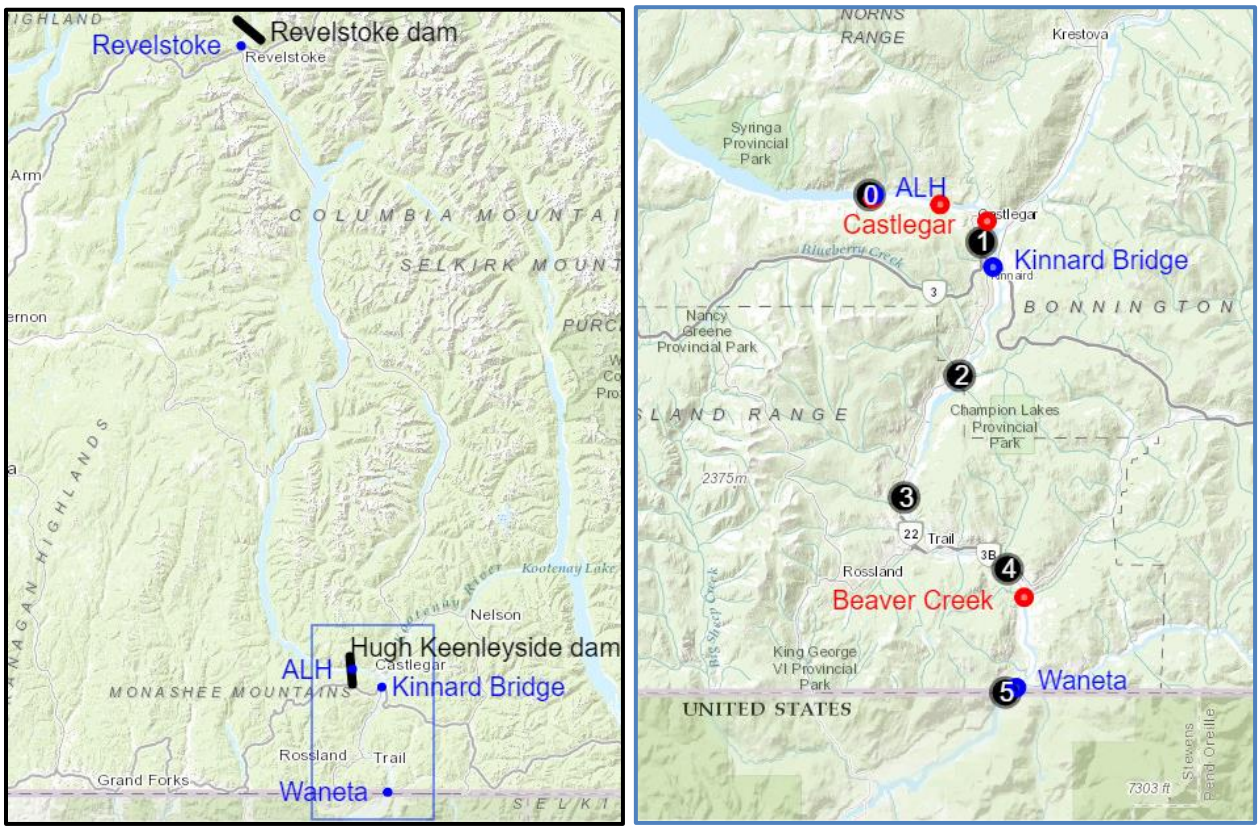

Figure 1. Left panel: Map of the full extent of Columbia River White Sturgeon in Canada, and all known spawning locations used for juvenile capture (blue). Blue rectangle refers to the extent of the right panel. Right panel: Map of the White Sturgeon spawning/juvenile capture sites (blue), juvenile release sites (red), and 5 river zones (black, numbered at downstream limit) for the Columbia river below HLK dam. Note, that fish released to "Castlegar" are spread among three proximal sites (ALH, Robson boat ramp and Millennium park).

2.1 Early life stage methods

Capture of wild origin sturgeon

Sturgeon are broadcast spawners which allows for gametes to be sampled with passive sampling gear (Egg mats and Drift nets). The captured contents of egg mats were obtained by carefully inspecting the matt surface and picking off embryos and larvae. Drift net mesh and capsule contents were rinsed into a white bucket, and then transferred in small, diluted

aliquots to several white plastic inspection trays. The trays allowed for contrast and dispersion of debris when searching for the tiny (often sediment covered) embryos.

Spawning locations

Monitoring of spawning activity occurs at all known locations in the Canadian portion of the Columbia River including at Waneta, Kinnaird near Castlegar, downstream of Arrow Lakes Hydro (ALH) and Hugh L. Keenleyside (HLK) Dams, and near Revelstoke (**Error! Reference source not found.**). Progeny collected from all spawning locations are brought to the hatchery for rearing. For the 3 sites in the lower Columbia (Waneta, Kinnaird, ALH/HLK), eggs and larvae are incubated in a streamside trailer (details in the following section) prior to transfer to the hatchery. For progeny collected near Revelstoke, they are transferred directly to the hatchery from the river given logistical challenges related to the cooler water temperatures in that part of the Columbia and the geographical proximity of the spawning grounds relative to the streamside trailer and the hatchery.

Progeny are grouped by their spawning site of origin and by the date of capture, so that each individual spawning event/aggregation can be kept separate through the entire rearing process. Furthermore, groups within each spawning site that represent distinct spawning aggregations are also kept separately to ensure supplemental progeny are representative of the entire distribution of spawning that occurs. Given small numbers of juvenile sturgeon required for release, a maximum of 500 eggs/larvae are kept from each spawning event, with excess progeny returned to the river.

Streamside incubation trailer

A streamside rearing trailer was created from a 14' by 8' cargo trailer to allow eggs and embryos to incubate at natural stream temperatures. The cargo trailer was set up with an electrical and plumbing system to enable pumping of river water through a series of MacDonald (upweller) jars, that spilled into a single trough with dividers to capture and segregate progeny from separate spawning events (Figure 2).

Figure 2. Streamside Incubation Facility (outfitted cargo trailer) used for rearing wild origin White Sturgeon progeny on the Columbia River.

The captured live embryos and larvae were immediately transferred to the streamside incubation facility. Embryos were placed into hatching jars whereas larvae were placed directly into the trough. In both cases they would be segregated based on their estimated spawning event group created from developmental stage (**Error! Reference source not found.**) and c apture location.

Five incubation jars (MacDonald Type; J30, Dynamic Aqua-Supply Ltd., Surrey, BC) were available to group embryos by their unique spawning date and location. Water was flow through pumped from the Columbia River and maintained at approximately 5 L/min to ensure adequate embryo separation and oxygenation. Upon hatch, yolk-sac larvae were flushed from the hatching jars directly into a segregated section of the rearing trough associated with each hatching jar (larvae would be placed directly into a section of the trough for their spawning event group). The troughs were supplied with artificial substrate (1" diameter sinking Bio-Spheres; Dynamic Aqua-Supply Ltd. Surrey, BC) which allowed 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 Kootenay Sturgeon Hatchery within 7 days of hatch in bags of ambient river water filled with oxygen. Temperature loggers inside the facility recorded air, river water, and facility tank water temperatures.

Transport of Larvae

Larvae need to be in the hatchery for rearing before 10 days post hatch to ensure success for first feeding. FFSBC staff made regular trips to the facility to retrieve larvae and transport them back to KTH to meet the 10 day deadline.

The larvae transport process was as follows: (1) Place two plastic bags (heavy duty clear) in a 10L pail and fill with 4-6 liters of ambient river water; (2) Carefully count and move a single spawn event group of larvae from their trough compartment into the bag; (3) Expel residual air from inner bag, then insert tygon hose from oxygen tank to fill the inner bag with oxygen, then twist and seal with electrical tape, then pull up the outer bag, twist and seal as the inner bag; (4) Places the larvae bag inside a chest cooler containing at least four bubble wrap covered ice packs, close the cooler lid, and place in the truck; (5) Transport to Kootenay hatchery with extra bags and oxygen on hand; (6) Once arriving at the hatchery, float each larvae bag within the destined container (specific to that group) to allow the water temperature in the bag to slowly equilibrate with the container water, then finally cut open the bag and release the fish into their container. As in the streamside incubation facility, each spawning group was placed into a separate container.

2.2 Juvenile rearing

One of the most important aspects of the juvenile rearing process is that each spawn event group (defined by unique location and/or date) must remain segregated throughout the entire rearing process at least until fish can be individually marked (below). Capture of progeny is not equal among spawning events, and some groups are very small (can even be 1 individual), but must still use a separate tank. This is a very different from typical production aquaculture where high densities of fish are reared.

Larval transition to feeding

The sturgeon larvae remain largely sedentary over the first 10-15 days post hatch while they consume their yok reserves and continue to develop body parts and organs. The transition to first feeding is a critical life stage for many fish species in both aquaculture and natural settings that can largely determine the relative success of a cohort. White Sturgeon require special attention at this stage.

The troughed larvae start to change behaviour at about day 18 (260 ATUs) where they begin to congregate into discrete groups within the available area of the trough (as opposed to an evenly distributed spread of individuals). Food can be introduced soon after this behaviour is observed and typically occurs on day 20 (290 ATU). The initial feeding was done by hand with the following process: drain level of pond/trough slightly to expose a damp side, place food onto the wet area on side of trough, allow water level to rise back to previous level so that fish can feed off sides of the trough. In addition to the hand feedings a 24-hour belt feeder was operated to continually dispense a target amount of food as close to the edge of the circular as possible. Each time the pond was drained down for hand feeding (placing feed on the pond walls), the old feed was gently swept out of the pond drain. The type of food used for Sturgeon rearing has varied over the years for a variety of reasons, however, the current mix is presented in Table **1**.

Table 1. Diet mixes used to feed different stages of Sturgeon in Kootenay Trout Hatchery from 2013 to present.

Fish weight (g)			Biodiet (pellet size mm)	Krill	Golden Pear
0.2	to	1.0	27% (0.3)	53%	20%
1.0	to	1.7	30% (0.3), 20% (0.5)	40%	10%
1.7	to	6.6	20% (0.3), 70% (0.5)	10%	0%
6.7	to	20.0	40% (0.5), 40% (0.7), 20% (1.0)	0	0
20.0	to	50.0	19% (0.5), 38% (0.7), 38% (1.0), 5% (1.2)	0	0
50.0	to	greater	40% (0.7), 40% (1.0), 20% (1.2)	0	0

Feeding rates were to excess (50% of body weight per day) for first two weeks, and continuous cleaning of the trough was necessary. After the first two weeks, the feed amount was based on temperature and body weight as per Table **2**, and the feed sizes also increased to match fish size (starting at 0.3mm and up to 1.2 mm by about day 45). The relationship between body weight and feed rate in Table 6 is a simple power function with a slope of -0.355, and a temperature dependent intercept that corresponds to the row for 1g mean body weight. The early larvae were reared in troughs for about 45 days, and then moved to self-cleaning circular tanks.

Table 2. White Sturgeon feeding rate guidelines as a function of average size and ambient temperature (units are percent of body mass per day).

Mean Body Weight (g)	Temperature (°C)				
	9	11	13	15	17
0.05	21.6	2.7	5.9	4.6	5.2
0.10	16.9	2.9	5.7	4.7	5.2
0.15	14.6	3.1	5.6	4.7	5.1
0.20	13.2	3.2	5.5	4.7	5.1
0.25	12.2	3.3	5.4	4.7	5.1
0.50	9.5	3.6	5.3	4.8	5.1
0.75	8.2	3.8	5.2	4.8	5.1
1.0	7.4	3.9	5.1	4.8	5.1
2.5	5.4	4.4	4.9	4.9	5.1
5.0	4.2	4.8	4.8	5.0	5.0
7.5	3.6	5.0	4.7	5.0	5.0
10.0	3.3	5.2	4.6	5.0	5.0
25.0	2.4	5.9	4.4	5.1	5.0
50.0	1.9	6.4	4.3	5.1	5.0
75.0	1.6	6.7	4.2	5.2	5.0
100.0	1.5	7.0	4.2	5.2	5.0
250.0	1.0	7.8	4.0	5.3	4.9
500	0.8	8.5	3.9	5.3	4.9

Sturgeon larvae develop and grow at rapid rates, which makes first feeding a concentrated and sensitive time period. The fish were minimally handled at this stage, and data on growth and survival rates were not compiled. However, studies presented in a more comprehensive report, BC Hydro 2019 (CLBWORKS 24, 25, 34), show sturgeon exhibit an exponential gain in weight over the first 50 days and a non-linear mortality function. Mortality patterns show substantial

mortality occurs in in the first 21 days (highest mortality rate was between 11 and 21 days), and then stabilizes at a much lower rate after that point.

Juvenile rearing

Once mortality rates appear to have stabilized and increasing tank biomass begins to reach capacity (individuals were approximately 0.2g in size), the fish will be graded by size in order to improve overall growth and survival. The grading of individuals by size into separate tanks reduces overall population densities and ensures smaller individuals can compete for a fair ration of available food. This allows the smaller fish to achieve increased growth rates, so that they catch up to the larger individuals, and the overall group can more uniformly achieve the target release size. The size targets for 2021 brood year production were 200g for fish to be released below Arrow Lakes reservoir, and 300g for releases into Arrow Lakes (Targets section below).

Regardless of size grade, all families or spawn groups were maintained separate, until after the fish were individually marked (see marking and releases below). Juveniles were sampled to estimate overall abundance and biomass, as well as assessed individually for size, disease or deformities. Data is recorded in a group data spreadsheet for all stages prior to pit tagging, and then in an individual data spreadsheet once pit tags (see below) have been applied.

2.3 Juvenile sampling, marking and polyploid testing

The conservation and research basis of the sturgeon conservation aquaculture program requires that the fish be uniquely identifiable when recaptured in the wild. Therefore, prior to release (once the fish reached a size of approximately 50g) each juvenile sturgeon underwent two marking procedures: (1) Each individual was implanted with a PIT tag into the dorsal musculature at the midpoint between the dorsal and lateral scute line inferior to the anterior

margin of the dorsal fin. Upon recapture in the wild, PIT tags allow individual level tracking back to the release records which include data for: brood year, group (defined by egg/larvae capture location and date) , release date, release location, release length and weight. (2) All hatchery fish also have a set number/location of scutes removed so that they are quickly visually identifiable in the field. The side of the body from which scutes were removed was changed to match the source/stage that were first reared in the hatchery from broodstock spawn events (left side) to wild origin larvae (right side). All mark locations are depicted in Figure 3. DNA and blood smears were also taken during the marking process (see Polyploidy testing section below).

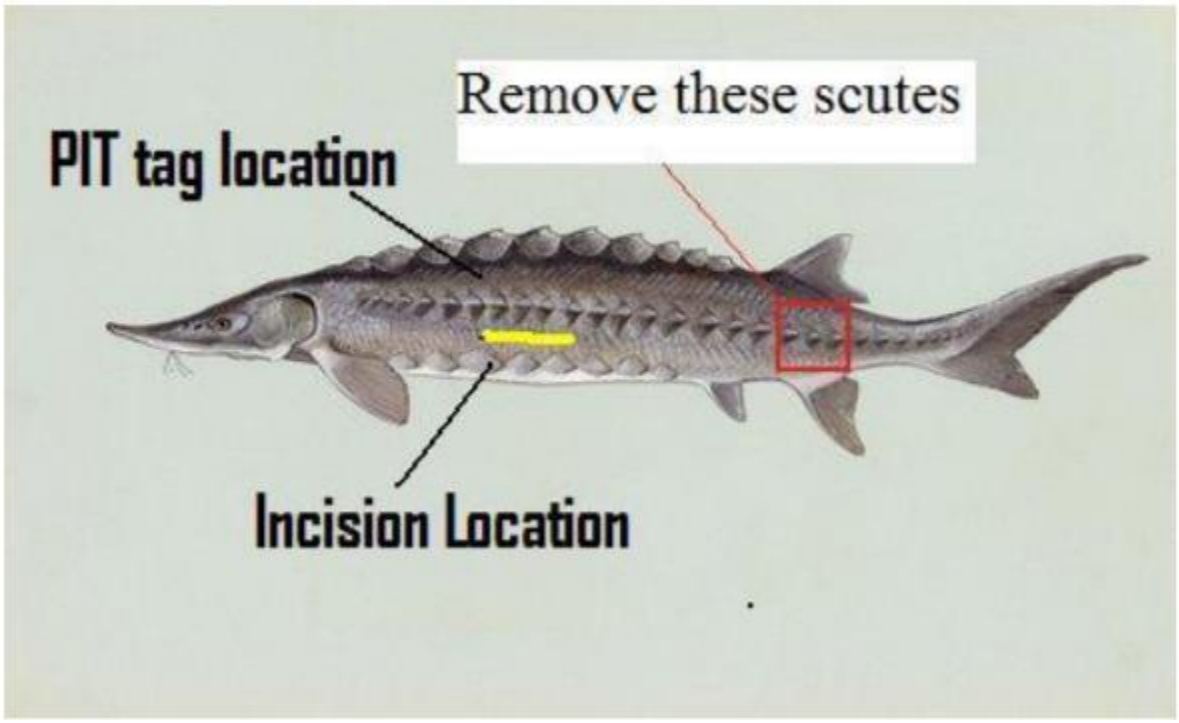

Figure 3. Diagram of physical locations of marks applied to hatchery reared juvenile sturgeon. Incision location refers to the location of acoustic tag insertion in years where acoustic tags were released (image extracted from BC Hydro CLB WORKS-34 2013 report).

Immediately prior to release (within 1 week) all fish were measured for length and weight in order to accurately reflect their size-at-release. A sub-sample of fish were run through an

additional disease screening. The juveniles were transported to the release site using FFSBC transport vehicles according to UCWSRI TWG transport protocols. Sturgeon were strategically released at locations as directed by the technical working group (See releases).

Autopolyploidy

The ploidy (number of sets of chromosomes) of White Sturgeon is typically 8N in Columbia and Kootenay River populations (Schreier et al. 2011, Schreier et al. 2013, Gille et al. 2015). However, 12N White Sturgeon were found to occur (at a rate of up to 50%) at the Kootenay Tribe of Idaho's (KTOI) Sturgeon Hatchery in family groups that were derived from their wild broodstock program. The mechanism of this ploidy shift is unknown, but it is hypothesized to occur at the fertilization stage. Given the findings in the Kootenay River White Sturgeon, the Columbia River Technical Working Group directed the assessment of ploidy for all Columbia River White Sturgeon families reared at the Kootenay Sturgeon Hatchery. The standard protocol set be the Technical Working Group is that individuals found to be 12N will not be released in to the wild (i.e., must be culled).

During the marking and tagging process, fish were sampled live using a diabetic syringe and collecting blood via the caudal vein. Collected blood samples were then dispensed into labelled heparinized vacutainer tubes, the tubes were organized into Styrofoam trays, bagged and then shipped on ice pack overnight via Air Canada cargo to the FFSBC fish health lab in Duncan, BC.

Once at the lab, blood samples were acclimated to room temperature on the lab bench for 2 hours. Capillary tubes were used to extract blood sample from the vacutainer and drop sample into previously prepped Coulter counter vial. Each Coulter counter vial is pre-prepped with 8mls Isotoner solution to 2 drops Zapglobulin. Each sample is then individually measured using the Coulter counter. The Coulter counter (Beckman Coulter Z2) has been used at FFSBC fish health lab since 2018 and is a much more efficient and accurate method to assessing poloidy compared to the historical blood smear method. Coulter counters operate on the same basic premise of blood smears using the size of cell nuclei to assign ploidy, but the counter allows

20,000+ cells from each sample to be measured. The equipment manual provides all technical details for operation, but the key setting of note is that the upper size Tu be set at 9 microns and the lower size Ti be set at 3 microns. The Coulter counter will measure 20,000+ cells from each sample. All sample results are analyzed using a computer program.

2.4 Release Targets

The conservation aquaculture program has evolved substantially over the two decades since inception. Analysis of survival from previous stocking events has shown that juvenile survival improves with size-at-release and is expected to be approximately 86% in the Canadian portion of the Columbia River below HLK dam if a release size of 200g is achieved. Since the incorporation of wild-origin progeny, there has been a concerted effort to attain a minimum release size of 200g for fish released in the Columbia River below HLK and 300g for fish released above HLK into Arrow Lakes (Mid Columbia River) in order to maximize survival of these more genetically diverse groups. Further, wild-origin progeny from the Revelstoke spawning site are reared to even larger sizes (~700 g) in an attempt to further promote survival as progeny from wild adults residing in Arrow Reservoir have only recently been incorporated into the aquaculture program. The increased size target for Arrow Lakes is due to apparently low survival as very few hatchery-origin fish have been recovered to date, despite intensive sampling effort. Numbers of fish released into Arrow Lakes were higher earlier in the program when broodstock progeny were available in large numbers but the targets are now reliant on wild-origin collections which leads to annual variation and lower average release numbers. Conversely the target number of fish to be released in Canada below HLK dam has decreased over time (with knowledge of high survival rates) and is currently set at a maximum of 200. For the full retrospective time series on stocking targets, see Table 15 in: Mid and Lower Columbia River White Sturgeon Conservation Aquaculture Comprehensive Report: Study Period 2001 to 2019 (BC Hydro 2019).

While the specific release number and size-at-release targets are largely driven by objectives to recover the Columbia White Sturgeon population to specified adult spawner abundance levels;

there are also broad recovery objectives in regard to maintenance of genetic diversity. This objective is considered in how the specific wild origin spawn groups are segregated and released to specific locations. Release locations are selected with the goal of releasing progeny back to an accessible site as close as possible to the spawning site of their original capture. The mix of fish released to a location is set with the objective of including the full diversity of spawning groups from that source location and then using surplus to augment numbers at locations where sufficient embryos were not captured to fulfill the spawning target numbers. To date, Waneta has produced far more fish for release than other sites and is the only location where enough progeny are captured to satisfy the target for the lower Columbia. Therefore, generally all fish form sites other than Waneta are released back to their source location, and Waneta fish are used to make up the balance of the target number. All surplus are released into Arrow Lakes, following annual discussions with agencies and the technical working group.

3. Results

3.1 Captured embryos and larvae

Wild embryos and larvae have been captured annually since 1993 and incorporated into the hatchery program in 2014, however, capture rates across years can be variable. Waneta has been the most consistent capture location, and this was the case for the 2021 brood year (all larvae were from Waneta), but almost 700 eggs were also captured at Revelstoke. The number of eggs and larvae from each spawn group brought to Kootenay Sturgeon hatchery in 2021 is summarized in Table 3 (for map of collection sites refer to Figure 1). In total 722 larvae and 685 eggs were transferred to the hatchery in 2021. When eggs or larvae are collected, they are assigned a group alphanumeric code that follows the sequence: spawning event number across all locations, first letter of spawn location, spawning event number with in location (e.g. 1W1 is the first spawn event overall and first event at Waneta).

It was noted that all the eggs received at the hatchery from Revelstoke in 2021 were in poor condition due to significant amounts of didymo (*Didymosphenia geminata*) and other debris adhered to the eggs. The extreme fragility of eggs prevents any possibility of cleaning the debris

in the hatchery, however, the fibrous covering does have a negative impact on water and oxygen circulation around the eggs, and can lead to suffocation. Many of the eggs did not survive (see below). Since the number of eggs were greatly reduced, and arrival groups were from mixed spawning events, these groups eggs were later combined and labelled as a single Revelstoke group (10R1) once the hatched.

Table 3. Wild captured eggs and larvae transferred to the Kootenay Sturgeon hatchery in 2021.

Brood Year	Check-In Date	Group	Larvae	Eggs	Collection Site
2021	21/06/2021	1W1	401		Waneta
2021	28/06/2021	2W2	14		Waneta
2021	28/06/2021	1W1	2		Waneta
2021	02/07/2021	3W3	90		Waneta
2021	02/07/2021	4W4	105		Waneta
2021	02/07/2021	5W5	72		Waneta
2021	02/07/2021	6W6	29		Waneta
2021	09/07/2021	4W4	2		Waneta
2021	09/07/2021	5W5	2		Waneta
2021	09/07/2021	3W3	1		Waneta
2021	14/07/2021	6W6	1		Waneta
2021	14/07/2021	8W8	2		Waneta
2021	14/07/2021	9W9	1		Waneta
2021	05/08/2021	10R1		20	Revelstoke
2021	05/08/2021	11R2		65	Revelstoke
2021	11/08/2021	11R2		10	Revelstoke
2021	11/08/2021	12R3		35	Revelstoke
2021	25/08/2021	13R4		485	Revelstoke
2021	25/08/2021	14R5		70	Revelstoke

3.2 Juvenile growth, survival

In-hatchery growth trends were documented at several points through the rearing year after the fish are received during summer. For the 2021 brood year fish, three sample occasions Aug.

3, Sept. 7-9 and Oct. 12 were recorded in the database for fish prior to individual tagging information. Individual level data was recorded starting on November 23, then Dec. 10, Jan. 19, Mar. 1, Mar. 30 and then a final pre-release sampling on May 4-5.

The complete growth trajectory of each group from fall through to spring of the next year prior to release is documented in Figure 4. The size distribution of fish as measured during the pre-release sort showed the modal weight of fish to be near the 200g release target for lower Columbia. However, the distribution was right-hand skewed with significant variation in size, so that most fish were well in excess of the release target. Incredibly, one fish reached a size of 818g in less than a years time of being received in the hatchery (from group 3W3).

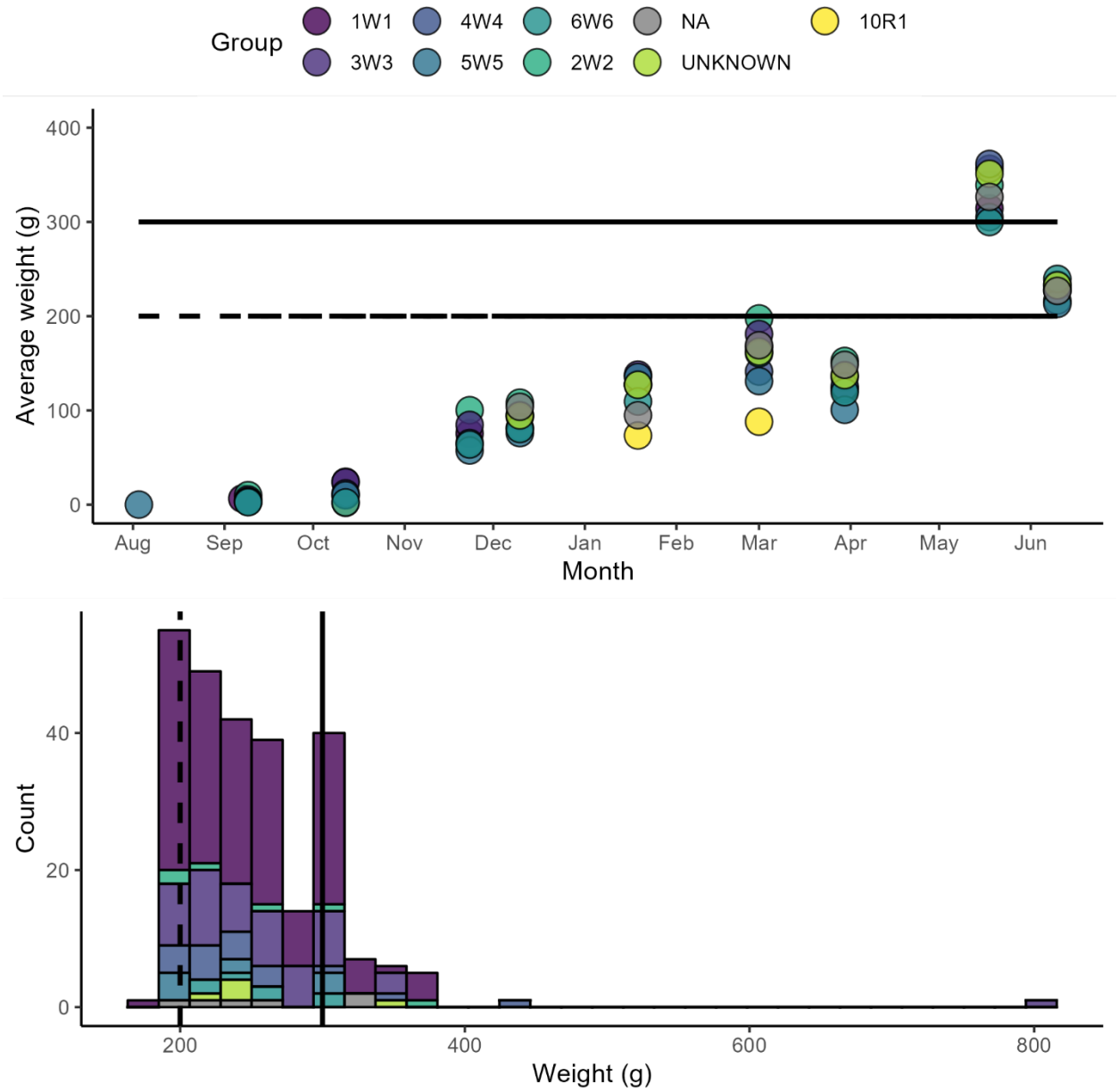

Figure 4. Growth trajectory over time (upper) and size distribution in May pre-release (lower) of all wild juvenile white sturgeon groups from 2021 brood year reared in Kootenay hatchery. Reference lines refer to minimum size-at-release targets for Columbia River (dashed) and Arrow Lakes reservoir (solid). Colour scheme in both panels match legend)

In the more recent years of wild origin progeny collection there has not been intentional culling of fish, and so it is possible to observe the overall survival and growth rates from received

larvae to yearlings (or older) released. Table 4 documents numbers of each brood year class from larvae to release. The survival rate has varied around about 50%, and survival for the 2021 brood year age-class was 58% to the spring of 2022. 260 of the Waneta origin groups were released in 2022, whereas 160 individuals from those groups were smaller than the 300 gram target release size and held over for a 2023 release.

Table 4. Numbers of wild larvae received at Kootenay Sturgeon Hatchery for each brood years and the resulting number of juveniles (yearlings or older) released.

Brood Year	Starting larvae	Released	Survival rate
2014	1,951	1,095	56%
2015	174	76	44%
2016	2,245	1,224	55%
2017	1,452	607	42%
2018	1,940	1,036	53%
2019	424	298	70%
2020	1241	538	43%
2021	722	420*	58%

*260 released in spring 2022 and 160 undersized hold-overs to be released in 2023.

In 2021, 685 eggs were collected from the Revelstoke site and reared in addition to the larvae. As would be expected survival of eggs to pre-release inventory in May is lower than the larvae, and the large amount of debris adhesion to eggs prior to hatchery arrival (see above) can lower expectations further. For the 2021 brood year eggs collected in the Revelstoke area 11 % (75) of the eggs survived to the spring inventory in May. This survival rate was below the multi-year average of 20%.

Figure 5 shows all of the 2021 brood year groups reared at Kootenay hatchery and the proportion surviving from check-in to May 2022 inventory. Some released fish had unknown original group due to tag shedding as documented in Table 6, but original source location was known for all fish.

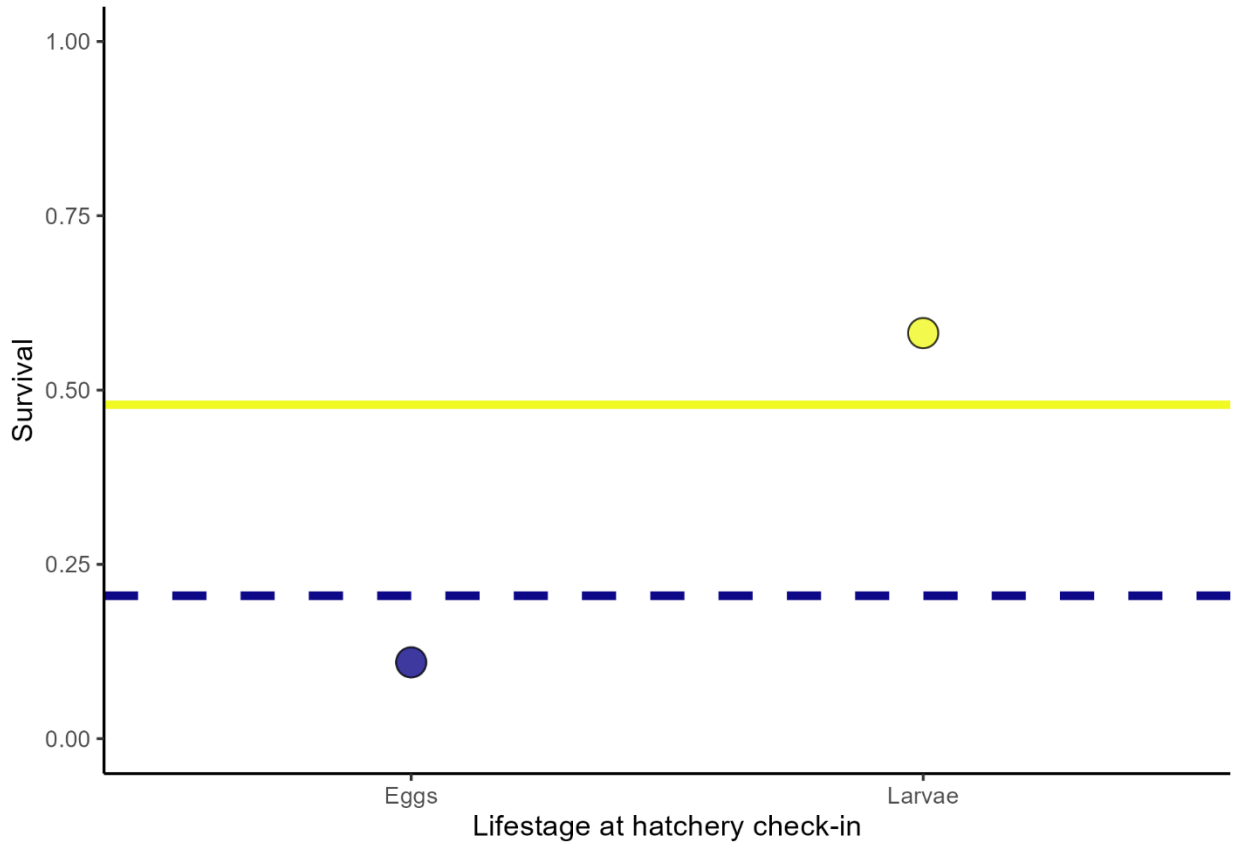

Figure 5. Survival rates from hatchery check-in (see Table 3) to pre-release inventory approximately 1 year later. All groups captured for a lifestage are combined, and compared against all-year average survival rates for eggs (dashed line) and larvae (solid line). In 2021 all eggs were captured at Revelstoke and all larvae were from Waneta.

3.3 Juvenile sampling, marking and testing

Fish were initially pit tagged on November 23, 2021, thus individual level sampling information is available for most fish from November 2021 to May 2022 in the database. However, 19 fish from the Waneta origin larvae were slow growers and were too small to be pit tagged with the rest of the fish. These fish are scheduled to receive pit tags on July 1st and will be mixed together in a single tank with other Waneta (tagged) hold-back fish (141) to a total of 160 that will be released in 2023. The group origins of the 19 Waneta slow growers were as follows: 1W1 = 6, 2W2 = 2, 3W3 = 4, 4W4 = 2, 5W5 = 4, 6W6 = 1.

All of the Revelstoke origin fish will be held back (as is standard) for an additional year to reach the larger size targets for that system. There are currently 75 fish remaining as a single mixed Revelstoke group (10R1) for release next year.

Autopolyploidy

Results from screening of hatchery reared fish (since brood year 2013) have demonstrated the 12N occurrence to be very low (Table 5), but fish originating from broodstock have significantly higher rates of occurrence than fish originating from wild captured embryos (BC Hydro 2019 CLBWORKS 24,25,34). In 2022 sampling , 6 of the 519 fish (1.2%) sampled in March by the FFSBC fish health lab in Duncan, BC were 12N. These fish have been removed from the groups to be released.

Table 5. The proportion of hatchery reared fish testing positive for 12N ploidy.

Origin	Brood Year	Method	Sample	12N	Proportion 12N
Hatchery	2013	ImageJ	180	9	0.050
Hatchery	2014	ImageJ	1,693	124	0.073
Wild	2014	ImageJ	1,098	2	0.002
Wild	2015*	ImageJ	63	1	0.016
Wild	2016	ImageJ	1,209	1	0.001
Wild	2017	ImageJ	737	3	0.004
Wild	2018	Coulter	1,063	4	0.004
Wild	2018*	ImageJ	112	5	0.045
Wild	2018*	Coulter	112	7	0.063
Wild	2019	Coulter	302	0	0.000
Wild	2020	Coulter	710	10	0.014
Wild	2021	Coulter	519	6	0.012

* 2018 Paired re-sampling of same 112 individuals to compared methods.
* In 2015, an additional 2,154 wild origin sturgeon larvae captured in the USA were transferred to Kootenay Sturgeon hatchery and all 2,154 were confirmed as 8N using Image J method.

3.4 Juvenile releases

The timing of release is generally focused on the month of May but hold back to a later time does occur to ensure the size targets, health and polyploidy testing are all achieved. In the spring of 2022 sturgeon were released on May 18th or June 10th. The released fish were

primarily of 2021 brood year, but 61 individuals from the Revelstoke group belonging to the 2020 brood year were also released. Detailed information on the release location, collection site, collection group, the number released and average weight at release are all summarized in Table 6. All of this information is recoverable on recapture through pit tag identification and will allow for analyses of effects of different release strategies and collection site in the future. Occasionally, the information on original group origin of a fish is lost due to pit tag extrusion, but this usually does not prevent knowing the collection site. 10 of the 2021 brood year fish had lost their original group information at time of release, but all were known to be of Waneta origin.

In 2022 a total of 121 large (>300g) sturgeon were released above HLK into the Arrow Lakes section of the river at Revelstoke or Shelter Bay, and all of those fish were originally collected from Waneta. Exactly 200 individuals (>200g) were released below HLK, evenly split between Beaver Creek and Robson Boat launch release locations. All of the fish released below HLK were originally captured at Waneta and distributed among 6 different spawn groups.

Table 6. All White Sturgeon releases to the Columbia River in 2022.

Brood Year	Release date	Release Site	Collection Site	Group	Number Released	Average Wt (g)
2020	May 18	Shelter Bay	Waneta	Unknown	61	823.3
2020	**May 18**	**Shelter Bay Total**			**61**	**823.3**
2021	May 18	Revelstoke	Waneta	1W1	8	322.6
2021	May 18	Revelstoke	Waneta	2W2	1	378.0
2021	May 18	Revelstoke	Waneta	3W3	4	456.8
2021	May 18	Revelstoke	Waneta	4W4	1	435.0
2021	May 18	Revelstoke	Waneta	5W5	1	300.0
2021	**May 18**	**Revelstoke Total**			**15**	**368.1**
2021	May 18	Shelter Bay	Waneta	1W1	27	311.7
2021	May 18	Shelter Bay	Waneta	2W2	1	300.0
2021	May 18	Shelter Bay	Waneta	3W3	8	306.4
2021	May 18	Shelter Bay	Waneta	4W4	2	325.0
2021	May 18	Shelter Bay	Waneta	5W5	2	307.5
2021	May 18	Shelter Bay	Waneta	6W6	2	300.0
2021	May 18	Shelter Bay	Waneta	Unknown	2	334.7
2021	**May 18**	**Shelter Bay Total**			**45**	**311.9**
		TOTAL ABOVE HLK			**121**	
2021	June 10	Beaver Creek	Waneta	1W1	62	215.6
2021	June 10	Beaver Creek	Waneta	2W2	3	203.7
2021	June 10	Beaver Creek	Waneta	3W3	19	217.8
2021	June 10	Beaver Creek	Waneta	4W4	9	212.9
2021	June 10	Beaver Creek	Waneta	5W5	4	208.3
2021	June 10	Beaver Creek	Waneta	6W6	1	212.0
2021	June 10	Beaver Creek	Waneta	Unknown	2	203.7
2021	**June 10**	**Beaver Creek Total**			**100**	**215.0**
2021	June 10	Robson Launch	Waneta	1W1	58	243.0
2021	June 10	Robson Launch	Waneta	2W2	1	255.0
2021	June 10	Robson Launch	Waneta	3W3	22	247.0
2021	June 10	Robson Launch	Waneta	4W4	7	245.9
2021	June 10	Robson Launch	Waneta	5W5	2	223.0
2021	June 10	Robson Launch	Waneta	6W6	4	246.5
2021	June 10	Robson Launch	Waneta	Unknown	6	236.5
2021	**June 10**	**Robson Boat Launch Total**			**100**	**243.6**
		TOTAL BELOW HLK			**200**	**229.3**

Over 180,000 sturgeon have been released as yearlings or older since the inception of the conservation aquaculture program (Table 7). One key finding gleamed form the historical releases is that survival is size dependent (BC Hydro CLBMON-29 2016), and a trend towards larger release size is notable in the stocking records (Figure 6). The fish released in 2022 achieved an average size well in excess of the target size-at-release (Figure 6). At present, the large release size targets are seen as an important measure to ensure survival of the more genetically diverse wild origin progeny.

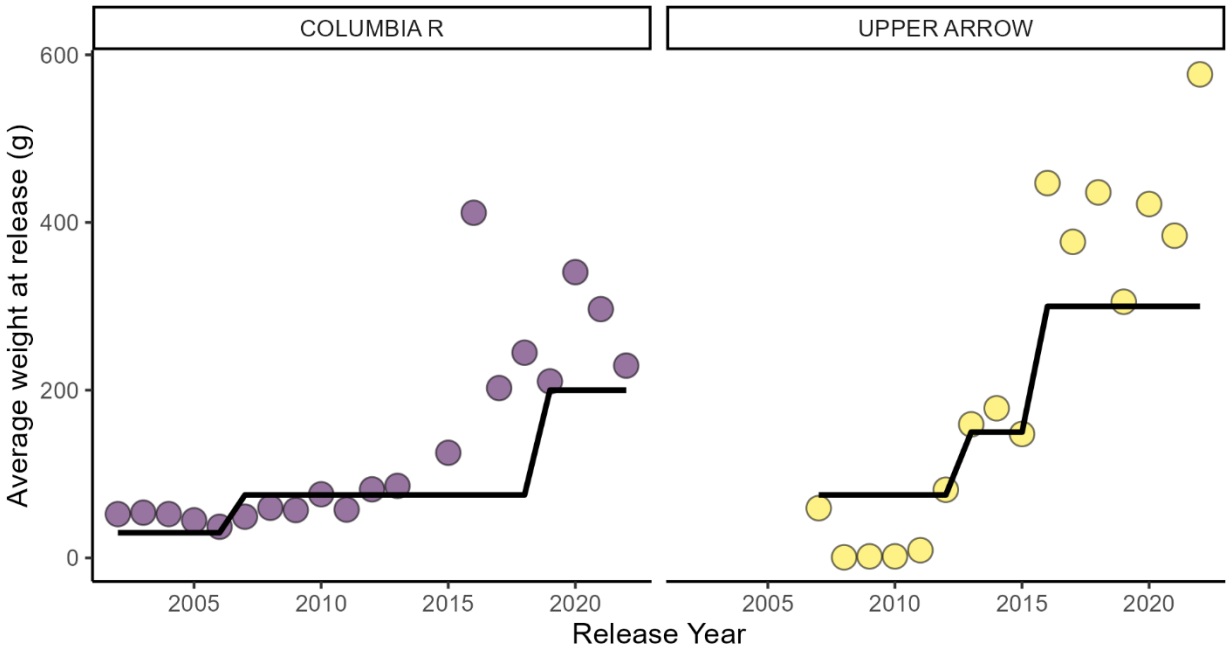

Figure 6. Trends in release size (g) over the full span of the aquaculture program to spring 2022. Each point is the average size for the release year across groups. Panels are labelled by release location: Columbia R = All release sites below HLK, and Upper Arrow = All releases size above HLK. Points appearing as 0g, were larvae experimentally released into Upper Arrow. The solid back lines depict the minimum size-at-release targets, which changed for both areas over time.

Table 7. All releases of brood and wild origin progeny reared at Kootenay Sturgeon Hatchery and released into the Columbia River. Columbia River zones refer to five 11.2 km sections between Hugh Keenleyside Dam and the USA border.

Source	Release Year	Columbia Zone of Release 1	2	3	4	5	Arrow	USA	Total Releases
Brood Spawn	2002	4,407				4,264			8,671
	2003	5,724				6,079			11,803
	2004	4,828				4,867		1,882	11,577
	2005	8,996				8,881		3,755	21,632
	2006	7,267				7,603			14,870
	2007	6,237				5,915	4,206		16,358
	2008	3,216				3,233	6,534		12,983
	2009	3,738				400	8,118		12,256
	2010	3,458	15	14	15	515	9,575		13,592
	2011	2,500		1,000		510	8,078	2,621	14,709
	2012	3,189		1,000			6,567		10,756
	2013	2,293		875		869	5,944		9,981
	2014	1,200		300		301	6,017		7,818
	2015	1,600		600		600	3,288		6,088
Wild Capture	2015					1,095			1,095
	2016					76	1,324		1,400
	2017					800	1,589		2,389
	2018	378				229	975		1,582
	2019	100				100	541		741
	2020	100				100	212		412
	2021	100				99	285		484
	2022	100				100	121		321
	Total	59,431	15	3,789	15	46,636	63,374	8,258	181,518

*Not yet released

4. Discussion

The Upper Columbia White Sturgeon Recovery Initiative has accomplished a vast amount of work towards numerous aspects of recovery of this population (e.g. see Upper Columbia White Sturgeon Recovery Initiative Operational Plan updated annually by the technical working group). The conservation aquaculture program has been a vital component of the initiative and

the successful establishment of hatchery-origin juveniles in the Columbia River has prevented extirpation of the population. The present abundance of sturgeon in the upper Columbia is estimated to be 5 to 10 times greater than without intervention for Canada and USA respectively. Moreover, one of the key recovery plan objectives of 2,500 reproductive adults in Canada has been found to be achievable with the current stocking program given current estimates of survival and maturation rates of hatchery fish.

The 2021-2022 sturgeon aquaculture program has once again been very successful. All targets for release numbers and size-at-release were met, and survival rates of wild-origin progeny were similar to the long-term average. The larvae were slightly above average at 58% and the eggs were slightly below average at 11%. The Revelstoke eggs were noted to have substantial amounts of debris, especially didymo adhered upon arrival at the hatchery and it is hypothesized that this is the main reason for the lower survival. In addition to the released fish 235 individuals (160 Waneta and 75 Revelstoke) remain in the hatchery for release next year.

The change to wild-origin progeny is assumed to have significantly increased the genetic diversity of the released juveniles since the earlier days using broodstock, which is a key objective of the program. The majority of the wild progeny continue to be captured only at Waneta, but effort to represent as many spawning locations as possible is ongoing. Further, another program is evaluating genetic diversity of the program releases since the inception of the wild-origin approach. A key objective of the genetic work will be to examine genetic diversity between groups within year classes as well as between stocking years. It is expected that results from this genetic work will greatly inform next steps of the aquaculture program and release strategies. The release strategy for individual spawn groups within the Waneta site has varied slightly over the years. All of the 2021 brood year fish were of Waneta origin, so there was no need to allocate fish to specific release groups in order to match capture location with proximity to release location. The specific Waneta fish selected for release above HLK were selected based on size to meet the 300g target. The specific fish (groups) allocated to the lower locations, was meant to generally match the relative abundance of the individual spawn groups

equivalently at each location. In future years, it may be worth considering creation of a mathematical group allocation rule that can be plugged into the hatchery database, and prescribe consistent release group-location strategies based on current understanding of the best approach for long term genetic diversity.

Autopolyploidy was a minor issue in the 2021 brood year class with 1.2% confirmed 12N. This is well within the range of historical values, despite using the more accurate Coulter counter method which has a higher detection probability than the historical blood smear methods.

5. References

BC Hydro. 2013. CLBWORKS-34 Lower Columbia Sturgeon Conservation Aquaculture Program (Year 5). Report by FFSBC, Kootenay Sturgeon Hatchery, Wardner, BC, 41 pp.

BC Hydro. 2016. Lower Columbia River Juvenile Detection Program (CLBMON-29). Year 8 Data Report. Report by BC Hydro, Castlegar, BC, 88 pp.

BC Hydro. 2018. Lower Columbia River Adult Sturgeon Population Monitoring (CLBMON-28). Year 10 Data Report. Report by BC Hydro, Castlegar, BC, 82 pp.

BC Hydro. 2018. Lower Columbia River Juvenile Detection Program (CLBMON-29). Year 10 Data Report. Report by BC Hydro, Castlegar, BC, 77 pp.

BC Hydro. 2019. White Sturgeon Conservation Aquaculture – 2018 Annual Report and Comprehensive Program Report (CLBWORKS 24, 25, 34). Report by FFSBC, Science Division. 70pp.

Crossman, J.A., K.T. Scribner, D.T. Yen, C.A. Davis, P.S. Forsythe, and E.A. Baker. 2011. Gamete and larval collection methods and hatchery rearing environments affect levels of genetic diversity in early life stages of lake sturgeon (Acipenser fulvescens). Aquaculture 310: 312-324.

Gille, D.A., T.R. Famula, B.P. May, and A.D. Schreier. 2015. Evidence for a maternal origin of spontaneous autopolyploidy in cultured white sturgeon (Acipenser transmontanus). Aquaculture 435: 467-474.

Jay, K., J.A. Crossman, J. A., & K. T. Scribner. 2014. Estimates of effective number of breeding adults and reproductive success for white sturgeon. Transactions of the American Fisheries Society, 143: 1204-1216.

McAdam, S.O., 2011. Effects of substrate condition on habitat use and survival by white sturgeon (Acipenser transmontanus) larvae and potential implications for recruitment. Canadian Journal of Fisheries and Aquatic Sciences, 68: 812-822.

Schreier, A. D., B. May, and D. A. Gille. 2013. Incidence of spontaneous autopolyploidy in cultured populations of white sturgeon, Acipenser transmontanus. Aquaculture 416: 141-145.

Schreier, D.A., D. Gille, B. Mahardja, and B. May. 2011. Neutral markers confirm the octoploid origin and reveal spontaneous autopolyploidy in white sturgeon, Acipenser transmontanus. Journal of Applied Ichthyology 27: 24-33.