Kootenay White Sturgeon in British Columbia: 2018 and 2019 Summary Report.

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1.0 Executive Summary

Kootenay White Sturgeon (*Acipenser transmontanus*) are federally listed as endangered in both the US and Canadian portions of their range (USFWS 1999; SARA, DFO 2014) and Provincially S1 Red listed (CDC 2018). For over 30 years the population has been intensively monitored and is understood to be comprised of an aging wild adult population and a juvenile population that is mostly comprised of hatchery fish. In order to monitor the ongoing hatchery program and the remnant wild population, annual Kootenay White Sturgeon sampling in British Columbia (BC) includes a gill netting program targeting juveniles in the summer months (July-September) and adult set lining and angling sampling in the spring (April-May) and fall (September-October) months. This report summarizes these annual efforts from 2018 and 2019 in the BC portion of Kootenay River and Kootenay Lake.

Gill nets continue to be an effective sampling technique for younger hatchery White Sturgeon in Kootenay River and delta lake sites. Gill nets are size selective targeting the smaller juveniles, but in this study period brood years as old as 1992 were encountered. In 2018, there were 629 captures for a mean catch per unit effort (CPUE) of 2.9 sturgeon per net-hour; 626 were hatchery fish, three wild origin fish, all of which were classified as juvenile by sizes. The mean fork length of all captures in 2018 was 56.8 cm (SE=0.8); the mean age of all hatchery origin fish was 9.7 years (SE=0.2). In 2019, there were 568 captures for a mean CPUE of 2.0 sturgeon per net-hour; 560 were hatchery fish, and eight were wild origin fish. Of all the captures in 2019, three were adult size hatchery sturgeon. The mean fork length of all gill net captures in 2019 was 59.9 cm (SE=0.9), the mean age of all hatchery origin fish was 10.3 years (SE=0.2).

BC gill net sampling includes both lake and river habitat and the lake sampling is where we see the highest catch rates and the larger White Sturgeon. Fish younger than 12 years old were significantly smaller in the river. The relative weight of older (>70cm fork length; mean age 16 (range 6 to 27) years old) hatchery fish was comparable across habitat types, but highest in the lake (91%). Catch rates of gill nets were highly variable on the Creston Delta, but most effective when water temperatures warmed to 20°C.

In the angling and set line sampling, hatchery fish made up a large portion of the captures; 64% (83/130) and 68% (80/117) were of hatchery origin in 2018 and 2019, respectively. Of the wild adults captured, 18% and 19% were new encounters for the program, in 2018 and 2019. The average fork length for all fish captured during the adult sampling was 129.9 cm (SE=3.7) in 2018 and 132.3 cm (SE=4.0) in 2019.

The acoustic telemetry work completed during this study period in BC included summarizing a three-year juvenile depth study (2015-2018) and an overview of new sonic tags put out in 2018 and 2019. The three-year acoustic depth tag study was the first study to look at juvenile depth use patterns within Kootenay Lake; ten hatchery juveniles were tagged with depth sensor Vemco tags in Kootenay Lake in 2015 (brood years 1999 to 2012). Most detections were within Kootenay Lake and primarily at the Creston Delta receiver. Depth use was deeper than expected and 17% of detections exceeding the sensor limit of 68m. Overall, there was high levels of variability across individuals, but evidence of diel movements in the fall, winter and spring months and the deepest detections were primarily in the winter months. The new sonic tags implanted in 2018 and 2019 in BC were in 36 hatchery White Sturgeon and six pre-spawning wild females to augment the telemetry dataset for future analysis and population modeling exercises.

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1.0 Introduction

White Sturgeon (*Acipenser transmontanus*) occur along the Pacific coast of North America from central California to the Aleutian Islands. In south-eastern British Columbia, the range of this species extends into Kootenay Lake and the Kootenay River (spelled Kootenai in the U.S.), located within the upper Columbia River basin. The Kootenay population is distinct from other Columbia River sturgeon (Anders *et al.* 2000), having been isolated by Bonnington Falls since the last glaciation (Northcote 1973). The range of this population is now further restricted by several dams, which have also altered river and lake environments. The Kootenay population is presently distributed from Kootenai Falls, Montana, downstream through Kootenay Lake to Corra Linn Dam on the lower West Arm of Kootenay Lake and up Duncan River to the Duncan Dam at the north end of Kootenay Lake, British Columbia (Figure 1).

The Kootenay River White Sturgeon population began to experience recruitment failure during the 1950's to mid-1960's, from diking along the Kootenay River and over harvesting (Partridge 1983, Paragamian *et al*. 2005). Furthermore, Libby Dam, located on the Kootenai River system upstream of Kootenai Falls in Montana, began operations in 1972 and has been recently linked to extensive recruitment problems (USFWS 1999). Concern for Kootenay River White Sturgeon initiated the detailed studies in both Idaho and British Columbia of the remnant wild population and the monitoring and evaluation of the sturgeon aquaculture program. Co-operative investigations by the Idaho Department of Fish and Game (IDFG), the Kootenai Tribe of Idaho (KTOI), Montana Fish Wildlife and Parks, and the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD), began in 1994 with funding from the Bonneville Power Administration (Columbia Basin Fish and Wildlife Authority).

The population is listed as endangered in the U.S. under the Endangered Species Act (USFWS 1999) and in Canada under the Species at Risk Act (SARA; DFO 2014). A recovery plan has been implemented in the U.S., providing direction for; ongoing studies, modifications to Libby Dam operations and conservation aquaculture operations (USFWS 1999). In BC, the Recovery Strategy for White Sturgeon in Canada was completed in 2014 for all White Sturgeon species (DFO 2014); presently, the US recovery plan is the guiding document and Kootenai River White Sturgeon Recovery Team is the working group, of which BC FLNRORD is a member, for the work on Kootenay White Sturgeon in BC, Idaho and Montana.

Once listed as endangered, hatchery measures were identified in the species Recovery Plan (USFWS 1999) as a necessary stopgap measure until natural recruitment could be restored. Initiated in 1988, the Kootenay White Sturgeon aquaculture program was first developed as an experimental program, with the first hatchery releases occurring in 1992 (Ireland *et al*. 2002). There are two facilities that rear Kootenay White Sturgeon from wild brood stock, the primary facility is the Twin Rivers Kootenai White Sturgeon and Burbot Hatchery and the backup facility is the original Kootenai Tribal Sturgeon Hatchery; both hatcheries are located in Bonners Ferry, Idaho, and are operated by the Kootenai Tribe of Idaho. From 2000 until 2015, Kootenay White

Sturgeon were also reared at the Kootenay Trout Hatchery & Visitor Centre located in Fort Steele, British Columbia, and operated by the Freshwater Fishery Society of British Columbia (this hatchery production was replaced with the new Twin Rivers facility in 2015). Production objectives and methods have changed over time and production numbers of juveniles have varied from ~100 in the early 1990s to over 30,000 individuals from 2004-2006 brood years and less than 10,000 in more recent years. As of 2019, 313,660 hatchery reared juvenile Kootenay White Sturgeon were released into Kootenay River and Kootenay Lake; additional experimental egg releases occurred in 2005 and 2006 and experimental larval releases in 2000-2002 as well as 2008-2012; with no ability to identify wild versus hatchery on unmarked fish, no survival of the experimental egg and larval releases has been documented. Modelled annual survival rates of juvenile hatchery releases resulted in the most recent abundance estimated between 14,000 and 16,000 hatchery origin Kootenay White Sturgeon at large in the Kootenay River and Lake (Hardy *et al.* 2020, Dinsmore 2015).

Sampling for juvenile White Sturgeon in the Kootenay system is completed primarily with gill nets and adult sampling with set lines and angling; although all sampling methods encounter both life stages. The primary focus of the juvenile sampling program is to evaluate the hatchery fish at large, but also to document any wild juveniles. In BC, gill net sampling has been completed annually since 1998 in the Kootenay River between the Canada – U.S. border and the Creston Delta at the south end of Kootenay Lake. Sites and sampling methods were jointly standardized in BC and Idaho in 2003 (Paragamian *et al.* 1999; Neufeld and Spence 2004a). One data gap identified in the hatchery monitoring program in recent years was the extent of mixing rates between sturgeon in the lake and river habitats (Hardy *et al.* 2020, Stephenson and Evans 2018). Current hatchery population evaluations pool all juveniles from the river and lake sampling together, but sampling is more intensive in the river and most is in the Idaho reach of the river, e.g., in 2018 17% of the effort was in the lake, 24% in the BC portion of the river and 59% of the effort was in the Idaho reach (Hardy *et al.* 2020). The BC annual reports provide an overview of hatchery evaluations within the lower reach and lake portion of the habitat.

Adult sampling in BC is primarily focussed in Kootenay Lake and co-managers in Idaho (KTOI and IDFG) complete river sampling upstream of the US border (Hardy *et al.* 2020). Sampling of the adult population is focussed on survival and abundance estimates, as well as the growth and condition of the remnant wild population. The current estimate of the wild adult population is 1744 individuals (Hardy *et al.* 2020), up from previous estimate of 990 individuals (Beamesderfer *et al.* 2014). In addition to mark recapture, every year up to six pre-spawning wild females are sonic tagged in BC to contribute lower river and lake caught females to telemetry spawn monitoring. Telemetry data are used to track shifts in spawn migrations and spawn habitat use relative to Libby Dam operations, Kootenay River habitat projects in the spawning reach and sturgeon population structure changes with aging hatchery origin fish (KTOI 2013; Ross *et al.* 2018, Hardy *et al.* 2020).

Passive Vemco acoustic telemetry technology continues to be an important tool within the Kootenay White Sturgeon evaluations. In this report we summarize the depth data from the ten juveniles tagged in 2015 (tags expired in 2018), to improve our understanding of how juveniles utilize the lake habitat and if there are seasonal or diel patterns. Additionally, in 2018-2019 we put out 36 sonic tags to increase the sample size of hatchery fish caught in the lake and lower river in BC for the evaluations of habitat mixing between and within the lake and river. Modelling of hatchery fish habitat use is planned for 2020 or 2021.

Specific goals of the monitoring program within the Canadian reach, completed in 2018 and 2019 were:

- describe population trends related to age, body condition, size, and distribution of hatchery White Sturgeon;
  - compare lake and river sampling within BC;
  - identify recapture events of recent hatchery releases put in the lake;
- describe capture efficiency of wild adults and body condition of wild adults;
- index natural recruitment events in the Kootenay system through any wild juveniles caught; and,
- using acoustic Vemco technology, tag hatchery White Sturgeon across the range of available brood years in Kootenay Lake and the lower river.

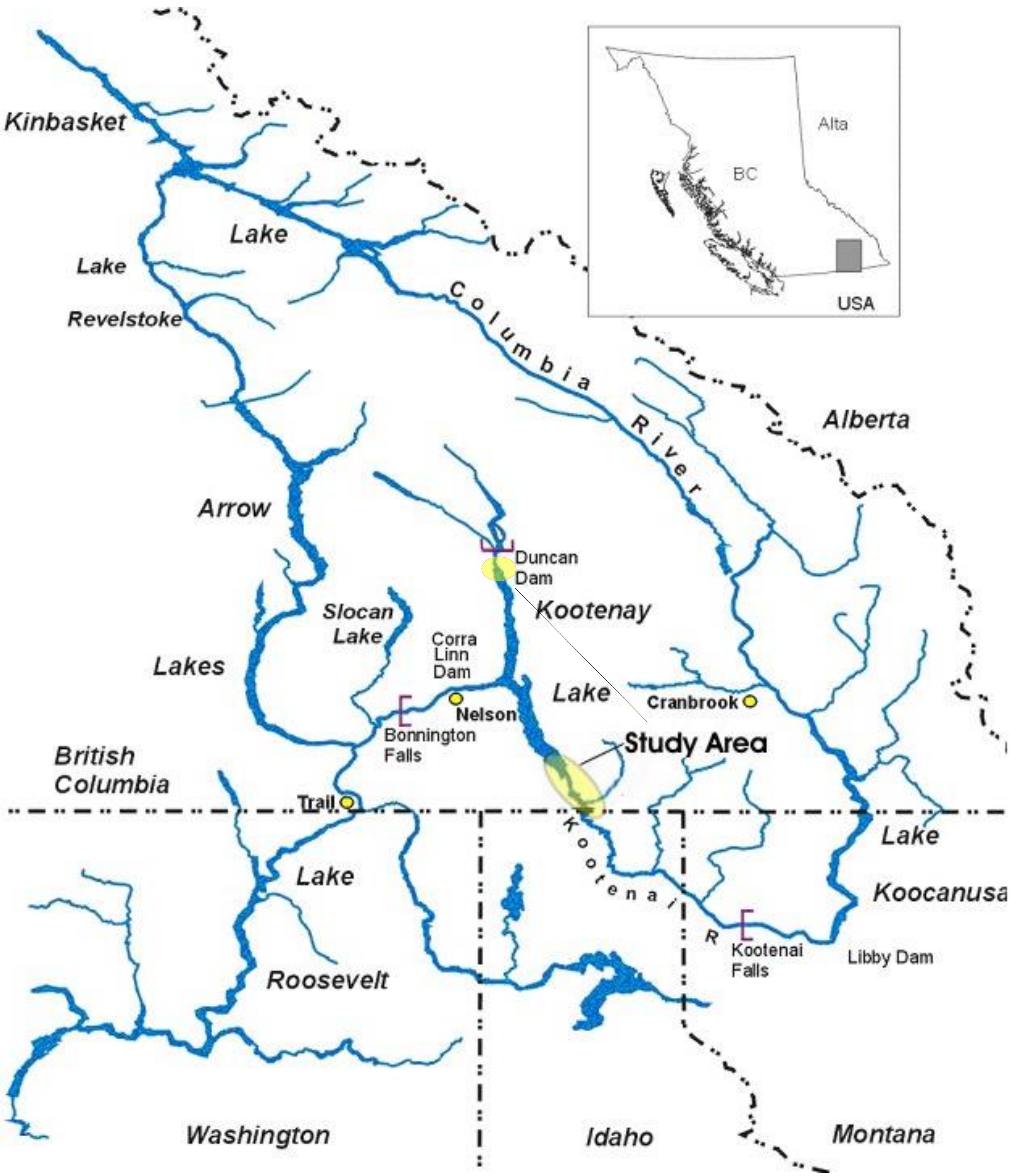

Figure 1. Overview of study area, with the main BC juvenile and adult sampling areas highlighted.

2.0 Study area overview

The Canadian portion of the Kootenay White Sturgeon range is in south-eastern British Columbia, immediately north of the State of Idaho (Figure 1). The present study includes approximately 50 river kilometers (kilometers as measured tracing the thalweg; RKMs) of Kootenay River from the Canada/ U.S. border, downstream to Kootenay Lake. Excluding the West Arm outflow, the Kootenay Lake has an area of 389 km^2, or approximately 105 linear RKMs (Daley *et al.* 1981). The Kootenay River enters Kootenay Lake at its southern tip. After Kootenay River, the next largest tributary to Kootenay Lake is the Duncan River at the north end, where the town of Lardeau gives the name of the “Lardeau Delta”. The West Arm outlet of Kootenay Lake flows from the lake’s mid-point for 47 km in a westerly direction to Corra Linn Dam, the first in a series of dams before converging with the Columbia River near Castlegar, BC. The Duncan Dam, Corra Linn Dam and Kootenai Falls currently restrict distribution of White Sturgeon in the Kootenay system. A more detailed description of Kootenay Lake can be found in Daley *et al.* (1981).

As in previous years, sampling on the lake was focused to three sites (Figure 1 and 2); two sites where the Kootenay River enters Kootenay Lake (referred to locally as the Creston Delta) as well as one site, established in 2012, at the north end of Kootenay Lake on the Lardeau Delta. RKM 16 to RKM 122 are in lake habitat, RKM 123 is classified as a lake-river transition site and everything upstream of RKM 123 is river habitat.

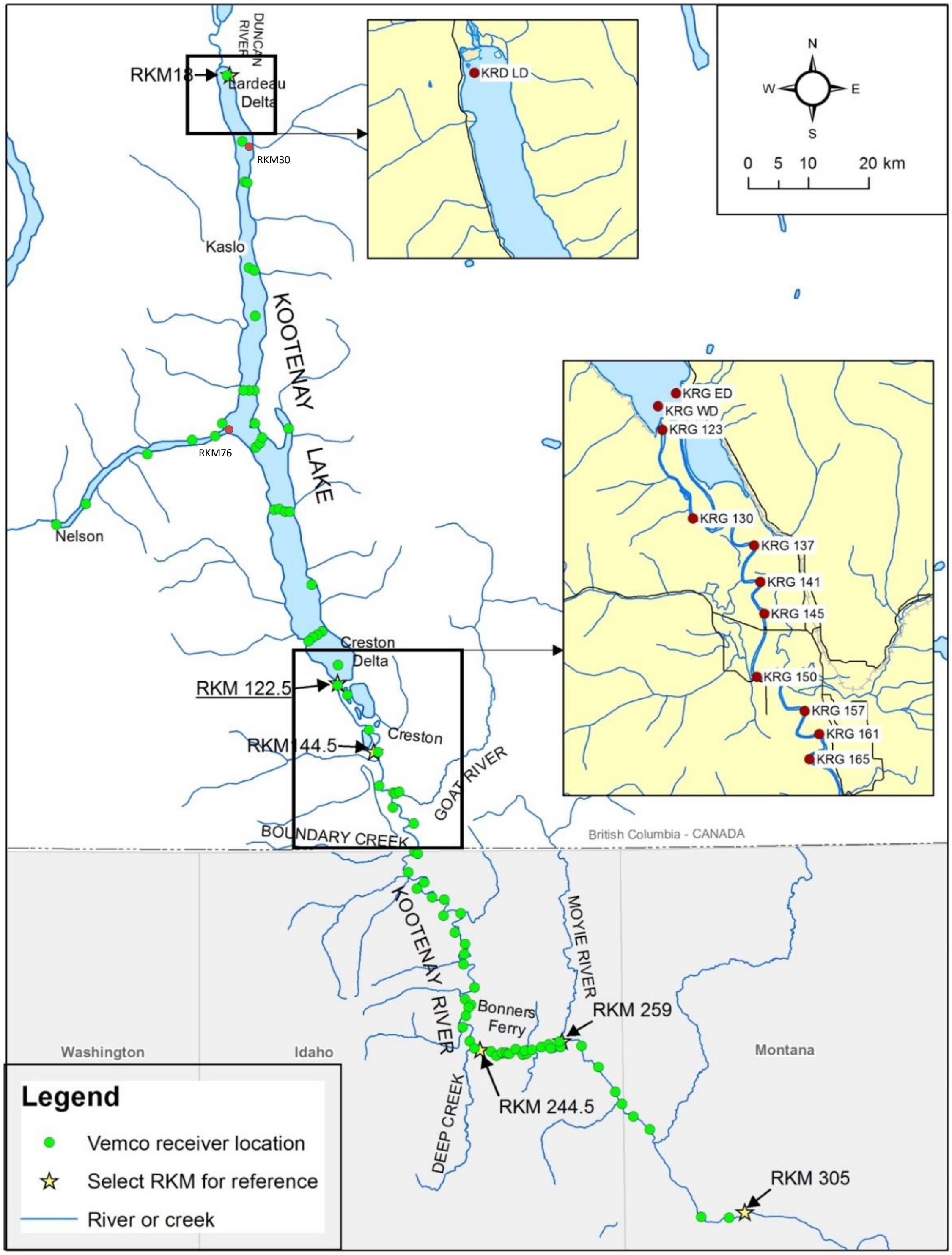

Figure 2. Overview of study area with all mainstem river and lake VR2W Vemco receiver locations in Kootenay River and Lake in 2018. The inset maps identify the BC juvenile White Sturgeon gill net sampling site locations.

3.0 Methods

All captured White Sturgeon were brought into the boat for sampling and processed according to techniques developed to minimize handling stress on individuals (details found in previous reports, e.g., Neufeld and Spence 2004b; Stephenson *et al.* 2014). Fork and total length (cm), weight (kg), missing lateral scutes, body deformities, and presence or absence of tags were assessed on all White Sturgeon at capture. A second scute removed on the left side indicates a wild fish; a sturgeon without scutes removed and without a PIT tag were considered a new wild fish. Hatchery fish were identified by lateral scute removal patterns and, when possible, PIT tags connecting to release information; there are 25 brood years available for capture during this study (Figure 3). White Sturgeon were considered "unknown" (i.e., can not be confidently linked to wild or hatchery) if there was no PIT tag on capture and some lateral scutes removed, but not removed in a clear pattern or in areas not used by the hatchery. A fish was considered an untraceable recapture if they had scute marks to link them to hatchery or wild but no PIT tag on capture or if the PIT tag on capture was not previously recorded in the database. A pectoral fin ray section for aging and genetic sample for future genetic evaluations was taken from any newly captured juvenile wild White Sturgeon.

All incidental captures of non target fish species had fork length measurements taken at capture and were summarized by species.

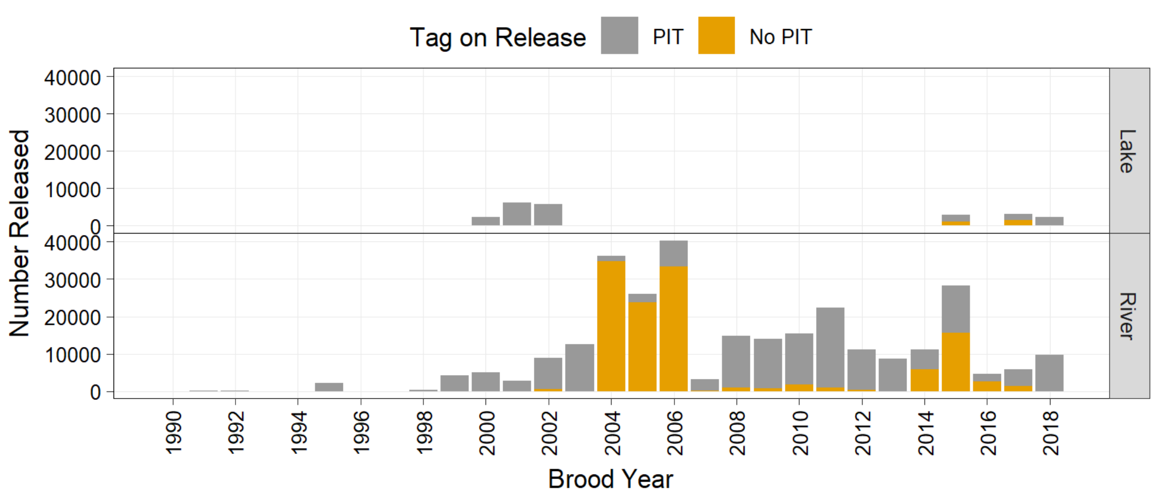

Figure 3. All juvenile hatchery releases in the Kootenay system by brood year and habitat release location (lake releases between RKM 76 and 101, river releases above RKM 144). Releases from all hatcheries, season of release and size at release pooled together; all fish >30g at release received a PIT tag prior to release.

3.1 Gill net sampling

White sturgeon juvenile targeted gill netting took place from July through September of 2018 and 2019 at standardized sampling locations (Figure 2); nine sites in the river, one site at the transition to the lake at the Creston Delta (KRG 123), and three areas on Kootenay Lake (KRG wd, ed and ld). All sites were visited in both 2018 and 2019. In 2018, exploratory gill netting effort also occurred at the alluvial fans near Fry Creek (RKM 30) and Davis Creek (RKM 20). All nets were multifilament single panel nets, 45 m long by 1.8 m deep, of three different mesh sizes, 5.1cm (2”), 10.2cm (4”) and 15.2cm (6”) stretch measurement. Each site was set with four gill nets; two nets with the 2” stretch mesh size (to target the smallest juveniles) and one net of each of the other two larger mesh sizes. Sets were replicated approximately twice (eight gill nets set in a day) and set duration was no longer than 120 minutes, to minimize any impact on sturgeon. Detailed gill net sampling methods can be found in previous reports (e.g., Neufeld and Spence 2004a; Neufeld 2006; Stephenson *et al.* 2014).

3.2 Angling and set line sampling

Adult sampling for Kootenay White Sturgeon focused primarily on Kootenay Lake, at river kilometer (RKM) 18 and 118 through 122, but also included two lower river sites at RKM 130 and 123 (500m up from the lake-river gill net transition site). Sampling took place in April-May and September-October of both years. Outside of standard sites, short exploratory set line sets were completed in the fall 2019 north of Fry Creek (RKM 25.5 and 27) and at the mouth of Kootenay Lake West Arm (RKM 76). Set lines consisted of eight hook lines using size 16/0 halibut hooks; angling was with size 4/0 and 6/0 barbless Octopus hooks, all hooks were baited with Kokanee spawner carcasses (sourced from Whatshan Lake, IHN disease free, or from within Kootenay Lake).

3.3 Data summary and analyses

Life history was collected into a Kootenay White Sturgeon Master Microsoft Access Database shared with all Kootenay White Sturgeon co-managers. Ages of hatchery fish were determined by matching PIT tags with available release records in the Microsoft Access database. Scute removal patterns applied at the hatchery prior to release were used to age the hatchery fish that did not receive a PIT tag on release, or those juveniles who lost their PIT tag. Unique scute removal patterns are 87% accurate on fish larger than 30 cm fork length (Stephenson *et al.* 2016). We used scute pattern for brood year assignment on juveniles when there was no traceable release record (see Supplementary Appendix A for the list of scute mark patterns).

Length frequencies, age structure, recapture frequency, size at age and body condition was summarized. Body deformities were recorded when more than 20% of a fin was affected. Adults were defined as those with a fork length ≥ 120 cm. Size at age was used, not annual growth rates, due to the length of time between encounters, sometimes exceeding 15 years (Stephenson and

Evans 2016). The standard weight equation developed by Beamesderfer (1993) was calculated for fish with a fork length over 70 cm, to account for changing body shape and measurement error on the smaller fish ($Ws=2.735E\text{-}6*(FLcm^{3.232})$; relative weight (Wr) = W/Ws*100).

Data summaries and figure generation were done in program R (R Core Team 2020).

3.4 Telemetry

3.4.1 Juvenile depth tags

In September 2015, 10 juvenile hatchery White Sturgeon caught in Kootenay Lake were surgically implanted with Vemco V13 depth sensor tags. Tag specifications were; 2.89 year battery life, 180 second nominal delay and a depth sensor range of 68 m (accuracy of +/- 3.4m), surgical procedures and tagging details can be found in Stephenson and Evans 2016. A depth sensor of 68 m was chosen as a trade off for accuracy, the next depth range was 136m with an accuracy of +/- 6.8m.

Most of the tags went out at the Creston Delta (n=7) and the other three went into hatchery juveniles caught at the Lardeau Delta (Figure 2). Brood years of juveniles ranged from 1999 to 2012. The size range was 36 cm to 91 cm (mean = 58.9 cm); the tag burden ranged from 0.2% to 4% (mean =1.6%). Movements of the depth tags were included in the telemetry summary from all 50 juveniles sonic tagged in Kootenay Lake over two years, 2014 and 2015 (Stephenson and Evans 2018).

Detection data was all from the permanent fixed array of VR2W receivers located throughout Kootenay Lake and River (Figure 2). For depth analysis in the lake we used the Lardeau Delta (RKM 18), Creston Delta (RKM 118), Crawford Bay (RKM 81) and then RKM 20-75 was grouped as the “North Arm”, all receivers in the West Arm were grouped as such, RKM 79-117 was considered the “South Arm” and river receivers above RKM 122 were all grouped together. Receivers are set up as a gate system, ensuring detection as a fish passes that location, but not set up as a fine scale habitat array. There are likely many instances of missing data from fish as they are non-detectable due to bathymetry changes, most likely in the shallower habitats. However, this dataset will provide insight into habitat use and how sampling could be modified to set gear across depths used by juveniles.

Depth data was summarized by tag, by locations within Kootenay Lake, diel movements and seasonal depth use. Season separation was set for all years as spring = March 19 - June 20, summer = June 21 - Sept 21, fall = Sept 22 - Dec 20, winter = Dec 21 - March 18. Data analyses and figure generation were done in program R (R Core Team 2020).

3.4.2 In-season tagging summary

In 2018 and 2019 there were 36 sonic tags (22 V13s and 14 V16s) to implant in hatchery juveniles in Kootenay Lake and River to expand our evaluations of habitat use and shifting habitat use between, and within, the lake and river. Additionally, we had six V16 tags for pre-spawning females caught in BC. Pre-spawning females are targeted in the year before, or year of spawning, to track the movements of that spawn year and up to three more events (spawn periodicity ranges from 3-5 years for female Kootenay White Sturgeon).

4.0 Results

4.1 Gill net effort

Sturgeon were captured in all index sites in 2018 and 2019. Catch rates were variable by sampling location although higher catches were observed on the two Creston delta sites and the lake-river transition site at RKM 123 (Figure 4; Supplementary Appendix B). In both years the three sets with highest CPUE occurred when water temperatures were greater than 18ºC (range of all set temperatures for both years was 11.6-21.8ºC). Water depths of all sets ranged from 1.8m to 38m; the three sets with the highest CPUE in the lake ranged in depth from 4m to 22m.

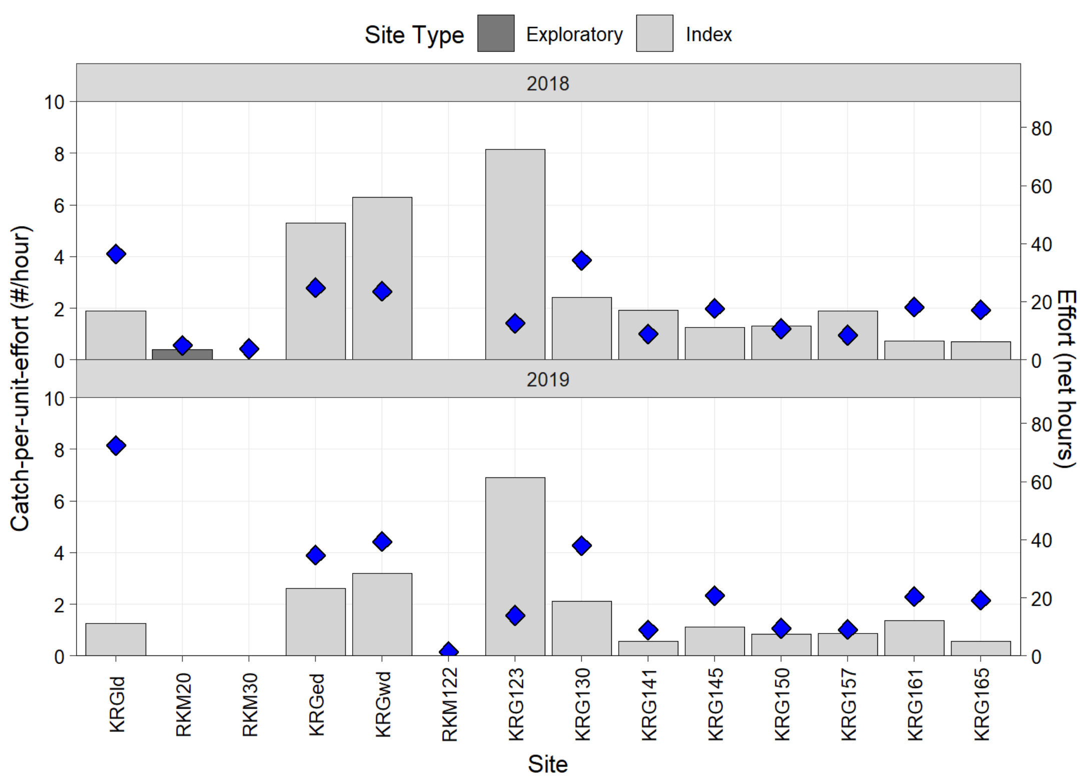

Figure 4. Total catch per unit effort (CPUE; effort = 1 net hour) and effort (blue diamond) by site for gill net sampling in 2018 and 2019 (see Figure 2 for sample site locations).

In 2018, gill nets were set 207 times between July 16 and September 26. A total of 221 net-hours of effort resulted in 629 sturgeon captures and a catch per unit effort (CPUE) of 2.9 sturgeon per net-hour (Supplementary Appendix C). There were 17 intra-year recaptures, one of which was caught three times. All sturgeon in 2018 gill netting were juveniles, fork lengths < 120 cm.

In 2019, gill nets were set 243 times between July 15 and September 23. A total of 287.3 net-hours of effort resulted in 568 sturgeon captures and a CPUE of 2.0 sturgeon per net hour (Supplementary Appendix C). Two of the captures were wild adults, with a fork length ≥120 cm. In 2019 there were 12 intra-year recaptures.

4.2 Gill net catch summary

4.2.1 Wild fish

During the gill net sampling, 11 wild fish were caught, three in 2018 and eight in 2019 (Appendix 1). In 2018, all wild fish were recaptures, one untraceable recapture and two recaptures; in 2019, one was an untraceable recapture and seven were new fish.

4.2.2 Hatchery fish

Gill net sampling is the most effective sampling method in the Kootenay system for capturing more and smaller hatchery fish than set lines and angling (Figure 5, Table 1). All brood years of hatchery released juveniles were encountered in the gill net sampling (Figure 6). Some brood years had higher representation in our catch, such as 2012, which was not a large release cohort, but also 2005, 2007 and 2015, which were larger release years. Brood year assignments were made from direct hatchery records when possible, 61% (n=721) with hatchery release records, 27% (n=319) by scute removal patterns, and 12% (n=146) could not be assigned to a brood year (Figure 5). Most hatchery fish were caught for the first time since their release from the hatchery. In 2018, 68% of the hatchery juveniles caught in BC were caught for the first time since release, 64% of the hatchery fish in 2019 were first time encounters; in total, over both years of sampling, 784 hatchery fish were handled for the first time.

Table 1. Summary of captures from all sampling in 2018 and 2019, separated based on sturgeon origin (hatchery, wild or unknown). All measurements are in centimeters.

Method	**Year of sampling**	**Total: number caught**	**Total: mean fork length (SE)**	**Hatchery: number caught**	**Hatchery: mean fork length (SE)**	**Unknown: number caught**	**Unknown mean fork length (SE)**	**Wild: number caught (% new fish)**	**Wild: mean fork length (SE)**
Gill net	2018	629	56.8 (0.8)	626	56.7 (0.8)	0	NA	3 (0%)	74.8 (18.9)
	2019	568	59.9 (0.9)	560	59.5 (0.9)	0	NA	8 (88%)	89.3 (13.7)
Set line and angling	2018	130	129.9 (3.7)	83	103.3 (2.1)	2	135.5 (36.5)	45 (18%)	178.7 (3.4)
	2019	117	132.3 (4.0)	80	107.7 (2.7)	0	NA	37 (19%)	186.9 (3.6)

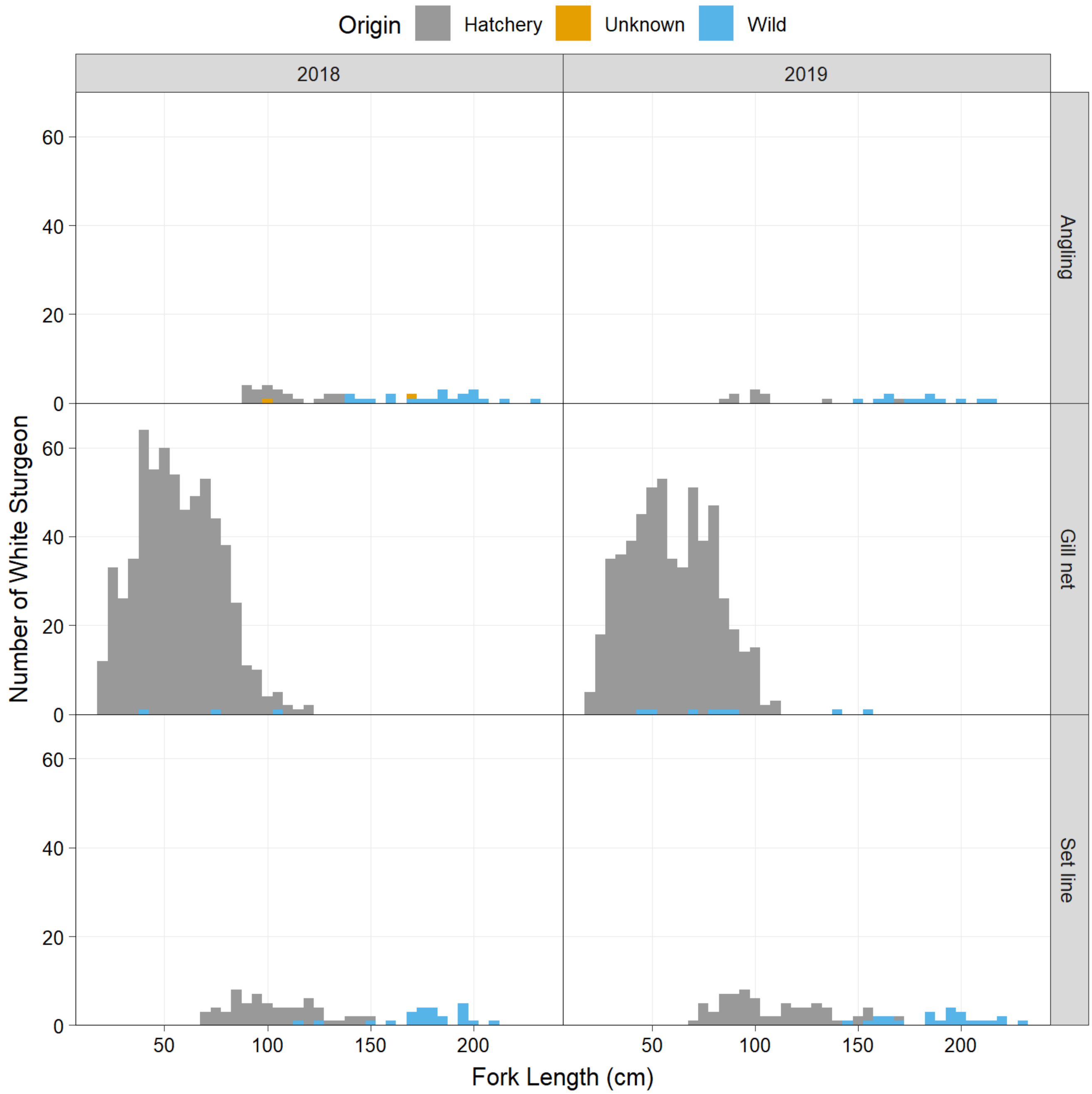

Figure 5. The length histogram (5 cm bins) of White Sturgeon caught in the three sampling methods, set line, gill net and angling in 2018 and 2019, separated based on origin (hatchery, wild or unknown).

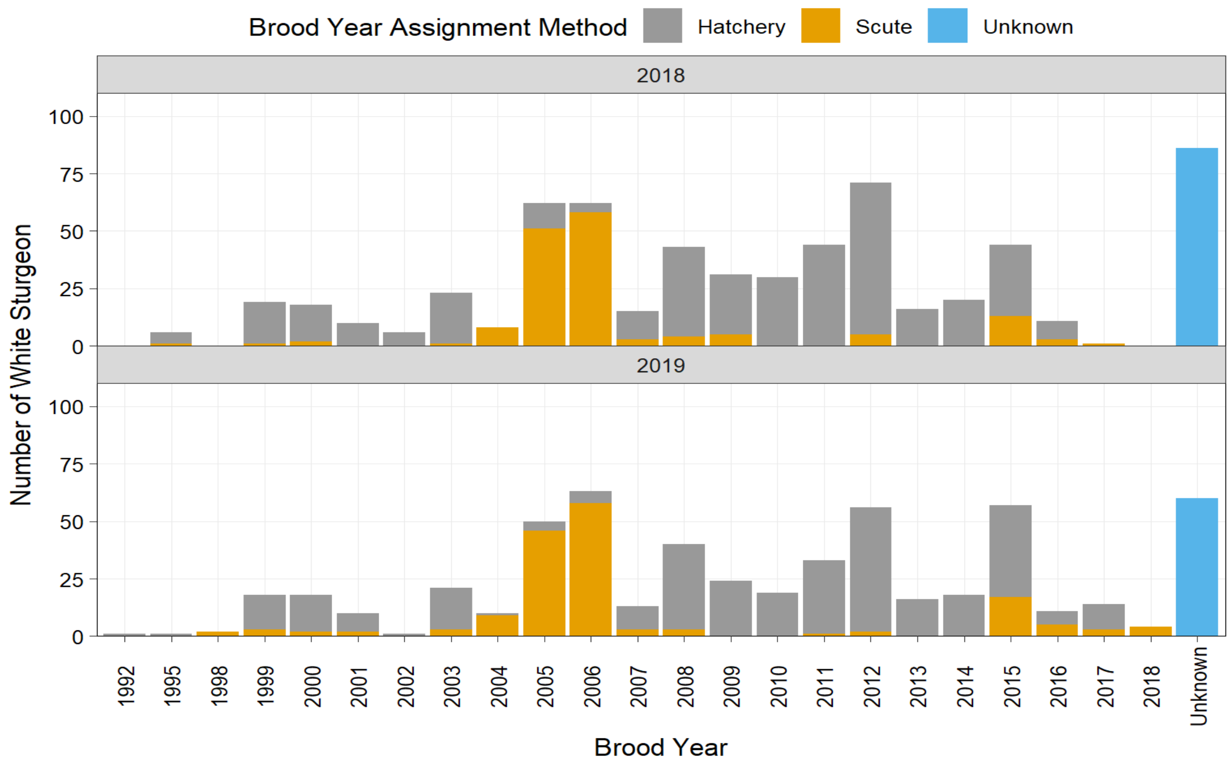

Figure 6. Hatchery White Sturgeon captures from gill net sampling in BC in 2018 and 2019 based on brood year and how brood year was assigned (hatchery release records when available from a PIT tag and otherwise scute removal patterns when possible).

In the 2018 and 2019 gill netting, 9% of hatchery fish (n=102) had body deformities recorded. The majority of deformities were pectoral fin deformities; either one or both fins missing parts, or curled (80/102; 78%). Other deformities included curled caudal fin deformities, shortened snouts and anal fin wave.

Hatchery release location was available for 720/1152 hatchery origin fish and 96% of those were released in the river, primarily at RKM 144.5 and 170 (75% of those with records were released at RKM 144.5 and 170). There were 28 encounters of hatchery fish released into the lake (lake releases were at several release sites between RKM 76 at Kootenay Bay ferry landing and RKM 101 at Boswell boat launch); two from the 2000 brood year, 11 from the 2001 brood year, seven from the 2002 brood year, eight from the 2015 brood year. All recaptured lake released hatchery fish were captured in the gill nets in the lake or at RKM 123, with none in the river sampling.

The 2015 brood year was a large year class released in 2016, and recapture data suggests wide range dispersal of this year class. There were over 12,000 PIT tagged juveniles released into the river from RKM 150 to 300 and 1900 juveniles into the lake at Crawford Bay (RKM 81). Of this year class, eight juveniles released in Kootenay Lake were recaptured in the 2019 BC sampling and a total of 63 of the river releases were encountered starting in 2018. All lake releases were encountered during lake or lake-river transition sampling in 2019, five at the Lardeau sampling site and three at the Creston Delta area. The river releases were encountered in our river and Creston Delta sampling starting in 2018; an example of the large downstream movement from release site is from recaptures of juveniles released at RKM 300 caught at the Creston Delta as early as July 2018.

Over the past 28 years, most hatchery releases occurred in the river portion of the habitat and recapture records suggest variable river use prior to emigration to the lake with limited movement back into the river. A third of hatchery fish caught in the gill nets in 2018 and 2019 had a previous recapture at large (n=351, 31% of total catch). Of these fish with a previous recapture record and caught in the lake in 2018 and 2019, 43% (101/234) had a previous encounter in river sampling, but only 12% (14/117) of hatchery fish caught in the river this session were previously encountered in the lake.

Data from 2018 and 2019 gill net sampling was pooled to evaluate differences in size and age by location for hatchery Kootenay White Sturgeon in BC. Ages of hatchery sturgeon ranged from one year to 27 years old, and the mean age of captures was highest in the lake sampling. Mean age of captures was 12.1 (SE=0.2), 10.6 (SE=0.4), 9.2 (SE=0.3) years, for the lake, lake-river transition (RKM 123) and river sampling, respectively. Size at age also differed across habitat types; there were significant differences in size at age for juveniles <12 years old between river and both lake-river transition and lake habitats (Figure 7). The relative weight of the >70cm fork length hatchery fish corresponded to a mean age of 16 years old and represented fish from 1992 through 2012 brood years. Wr did not greatly differ across habitat types; the mean Wr was 91.2 (SE=0.6), 87.0 (SE=1.8), 88.0 (SE=1.6) for the lake, lake-river transition and river sampling, respectively. Regardless of brood year, Wr was most variable for the smaller fish, across all habitat types (Figure 8).

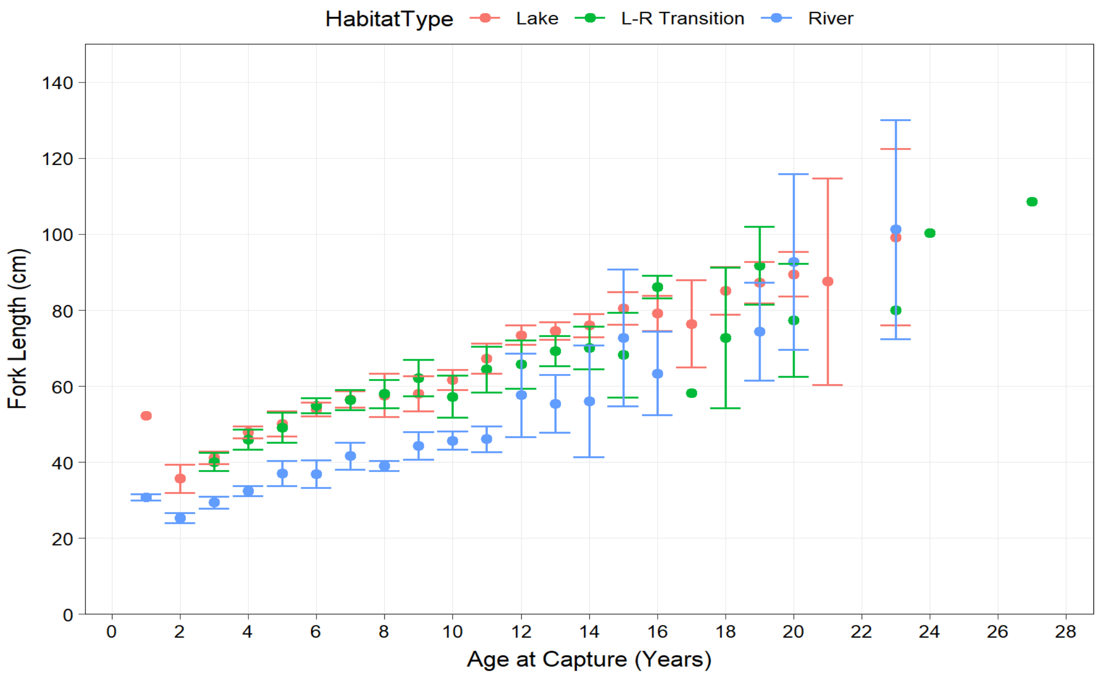

Figure 7. Mean fork length with 95% CI at all ages of hatchery juveniles caught in BC gill net sampling pooled for 2018 and 2019; mean lengths separated by habitat types (lake, lake-river transition and river habitats).

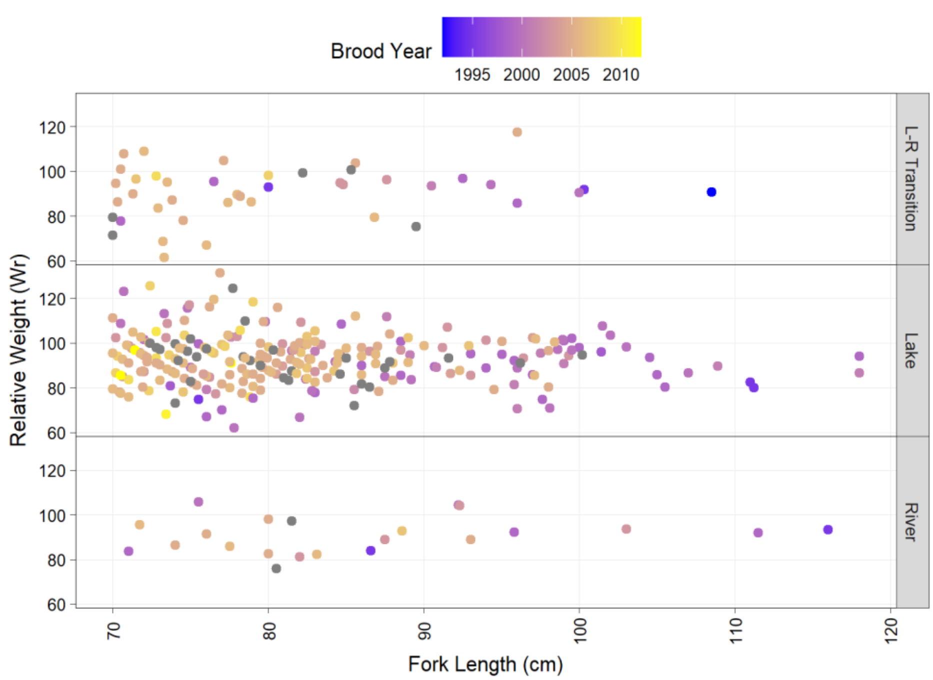

Figure 8. Relative weight for hatchery juveniles >70cm fork length caught gill netting in 2018 and 2019, separated by habitat capture location. Brood years range from 2012 to 1992, unknown brood years= grey dots.

4.2.3 Gill net bycatch

A total of 211 fish were collected incidentally (non-target species) during 2018 (n=146) and 2019 (n=65) gill netting (Figure 9). The bycatch capture rate was 0.66 fish per net-hour in 2018 and 0.22 fish per net hour in 2019. In pooled data from 2018 and 2019, bycatch sampling included 58 sucker spp (pooling longnose sucker (*Catostomus catostomus*) and largescale sucker (*C. macrocheilus*)), 36 northern pikeminnow (*Ptychocheilus oregonensis*), 66 peamouth chub (*Mylocheilus caurinus*), 34 mountain whitefish (*Prosopium williamsoni*), 8 yellow perch (*Perca flavescens*), four bull trout (*Salvelinus confluentus*), one rainbow trout (*Oncorhynchus mykiss*), two crayfish (*Pacifastacus leniusculus*), one cutthroat trout (*Oncorhynchus clarkii)* and one unknown species of fresh water clam (Supplementary Appendix D). Most years, bycatch is highest in the lake, but in 2019 the bycatch in the lake was lower (Figure 9).

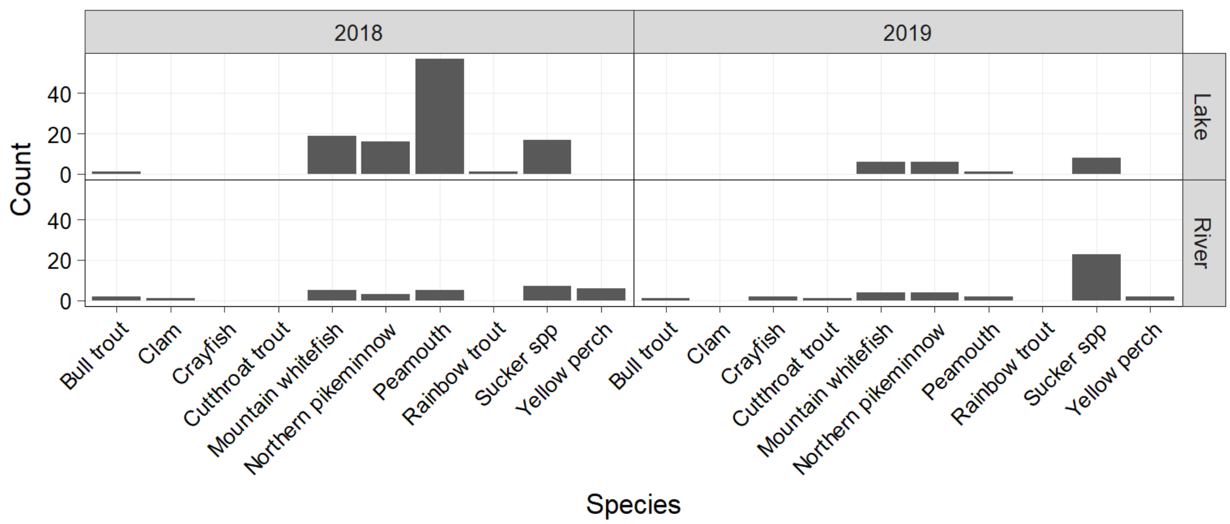

Figure 9. Count of incidental captures, by species, from the river and lake in 2018 and 2019 Kootenay White Sturgeon gill net sampling in BC.

4.3 **Angling and set line sampling**

4.3.1 Catch and effort

The highest catch rates were observed in the fall for both 2018 and 2019 (Table 2). As with previous years, angling was the primary sampling method at the Lardeau Delta (due to underwater wood debris right at the delta), but elsewhere set lines were the main sampling method. High catch rates (six sturgeon or more on an eight-hook line), occurred on many of our set line sets at the Creston Delta, as well at RKM 130 (Supplementary Appendix E); the average depths of these sets ranged from 15 to 28m.

Table 2. Angling and set line effort in the BC lower Kootenay River and Kootenay Lake in 2018 and 2019.

Year	Method	Season	Dates	RKM	Water Temp (°C)	Total Hours	Total # WSG	CPUE (#/hour)
2018	Angling	Spring	April 18, 19, May 2, 3	121-122.5	5.4-6.5	4.6	0	0.00
		Fall	Sep 10-13, 18, 19, 25-27	18, 121-123, 130	11-15.1	13.8*	44	0.65*
	Set line	Spring	April 18, 19, May 2, 3	121-130	4.6-6.5	255.9**	18	0.07**
		Fall	Sep 10, 17-19, 25-27, Oct 9-11	18, 121-130	10.3-15.3	408.0**	68	0.11**
2019	Angling	Spring	Apr 10, 11, 16-18, 23, 24	121-123	5.8-6.8	10.2	1	0.10
		Fall	Sep 10-12, 19, 24	18, 121-122	13-17	9.4*	21	0.64*
	Set line	Spring	Apr 10-12, 16-18, 23-25, May 28	76, 121-130	4.8-10.4	410.6**	37	0.07**
		Fall	Sep 18-20, 23-25, Oct 9-11	121-130	8.6-16.5	426.3**	58	0.13**

*Angling effort only calculated from boats where it was recorded, fish counts from all boats included
**Set line effort only calculated on overnight sets, fish counts included from both short and overnight sets

4.3.2 Angling and set line catch

In the adult sampling, hatchery fish now make up most captures; 64% (83/130) and 68% (80/117) in 2018 and 2019, respectively (Table 1 and Figure 4). In both years of sampling, the brood years of hatchery fish caught angling and on set lines ranged from 1991 to 2007 (Figure 10). The hatchery release location was known for 121 fish; 112 were river releases (brood years 1991- 2007) and 9 were from lake releases from 2001 and 2002 brood years. Of the wild adults captured, 18% and 19% were new encounters for the program, in 2018 and 2019 respectively. The mean Wr of sturgeon caught in set line and angling sampling was similar to the Wr from the gill net sampling, 88.9 (SE=0.84) for hatchery and 86.6 (SE=1.2) for wild.

The mean fork length for all fish captured during the adult sampling was 129.9 cm (SE=3.7) in 2018 and 132.3 cm (SE=4.0) in 2019 (Table 1). The catch composition was nearly half juveniles within angling and set line sampling; 52% (67/130) and 49% (57/117) juveniles (<120 cm FL) in 2018 and 2019, respectively. Mean size of hatchery origin fish was smaller than wild encounters (Figure 11). The size range of hatchery origin fish was 67.6 cm to 171 cm (mean=105.4 cm, SE=1.7), wild fish ranged from 115 cm to 231cm (mean=182.4 cm. SE=3.6).

Bycatch during set line and angling included seven northern pikeminnow, three suckers and one peamouth (Supplemental Appendix D).

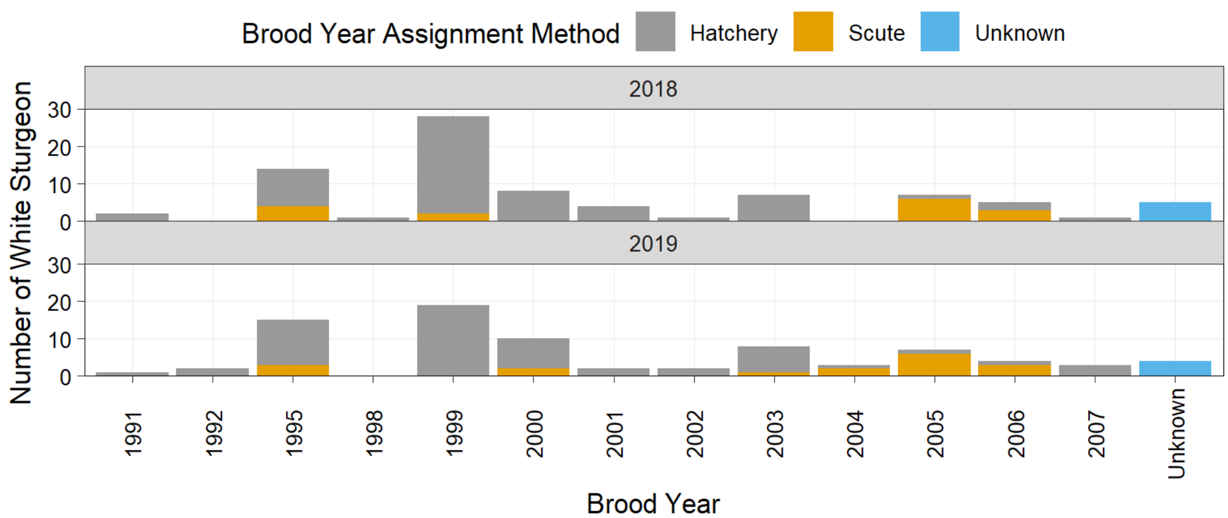

Figure 10. Hatchery catch composition from angling and set line sampling in BC lower Kootenay River and Kootenay Lake, 2018 and 2019.

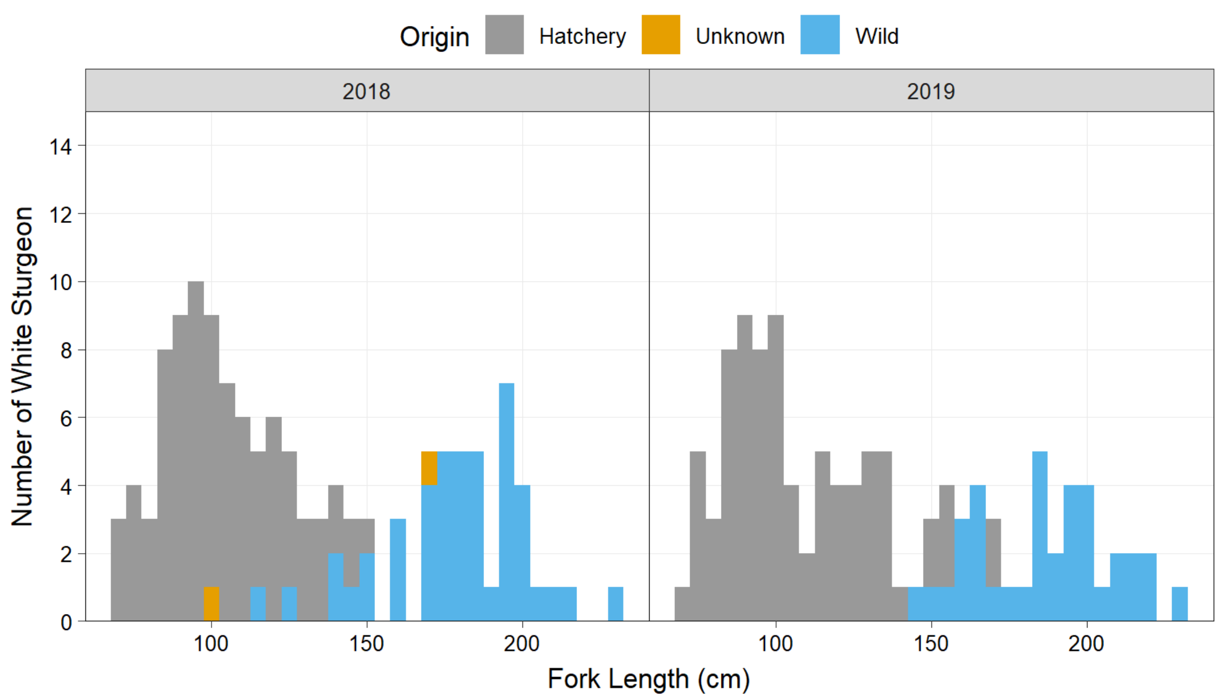

Figure 11. Length histogram of hatchery, wild and unknown origin Kootenay White Sturgeon from angling and set line sampling in BC in 2018 and 2019. The histogram is count by 5 cm bins.

4.4 **Telemetry**

4.4.1 Juvenile depth tags

The mean age of depth tagged juveniles was 8 years old and ranged from three to 16 years old (Appendix 2); all ten depth tags were detected for a minimum of 1.5 years post tagging. The majority of tagged juveniles stayed within Kootenay Lake, except a couple brief forays into Kootenay River by four of the ten fish (Appendix 3). Most of the fish had high fidelity to their tagging location, as such, most detections over the three years were at the Creston Delta. None of the 10 juveniles tagged were detected within the West Arm of Kootenay Lake.

The depth use varied by individual and there was more use of deep habitat than expected. In total, 17.5% of all detections were over the 68 m sensor tag limit; the sensor appears to continue to function after going over 68 m but would not read past 76 m (Appendix 4). There was evidence of seasonal depth differences; most individuals showed increased depth use through fall and deeper, and stable depths in the winter, moving shallower through the spring into the summer. Individual depth use was variable and although the sample size was small, there was no evidence of age effects; at the Creston Delta the median daily depth during the summer ranged from 6.2 m (tag 118, BY 2011) to 74.1 m (tag 121, BY 2001; Appendix 5).

Diel depth use differences were evident in fall, winter and spring, but no clear diel patterns for the summer (Figure 12). At the Creston Delta, the extent of vertical migrations in a 24-hour period on average was variable between individuals, but on average between 10-15m for all three seasons, moving shallower in the night hours. Although individual variability was evident, at the Creston Delta site there was the highest density of detections between 25 and 50m across the fall, winter and spring months (Figure 13). The other area with evidence of diel depth patterns was within the South Arm, which had less detections to use than the Creston Delta location, but evidence of moving to shallower water in the night (40-50m) and deeper in the day (>65m). There were no clear diel migrations in the summer months at any area of the lake.

Figure 12. Median depth with 95% confidence bounds for all tags and detections pooled by time of day; figures separated by area of detections and season.

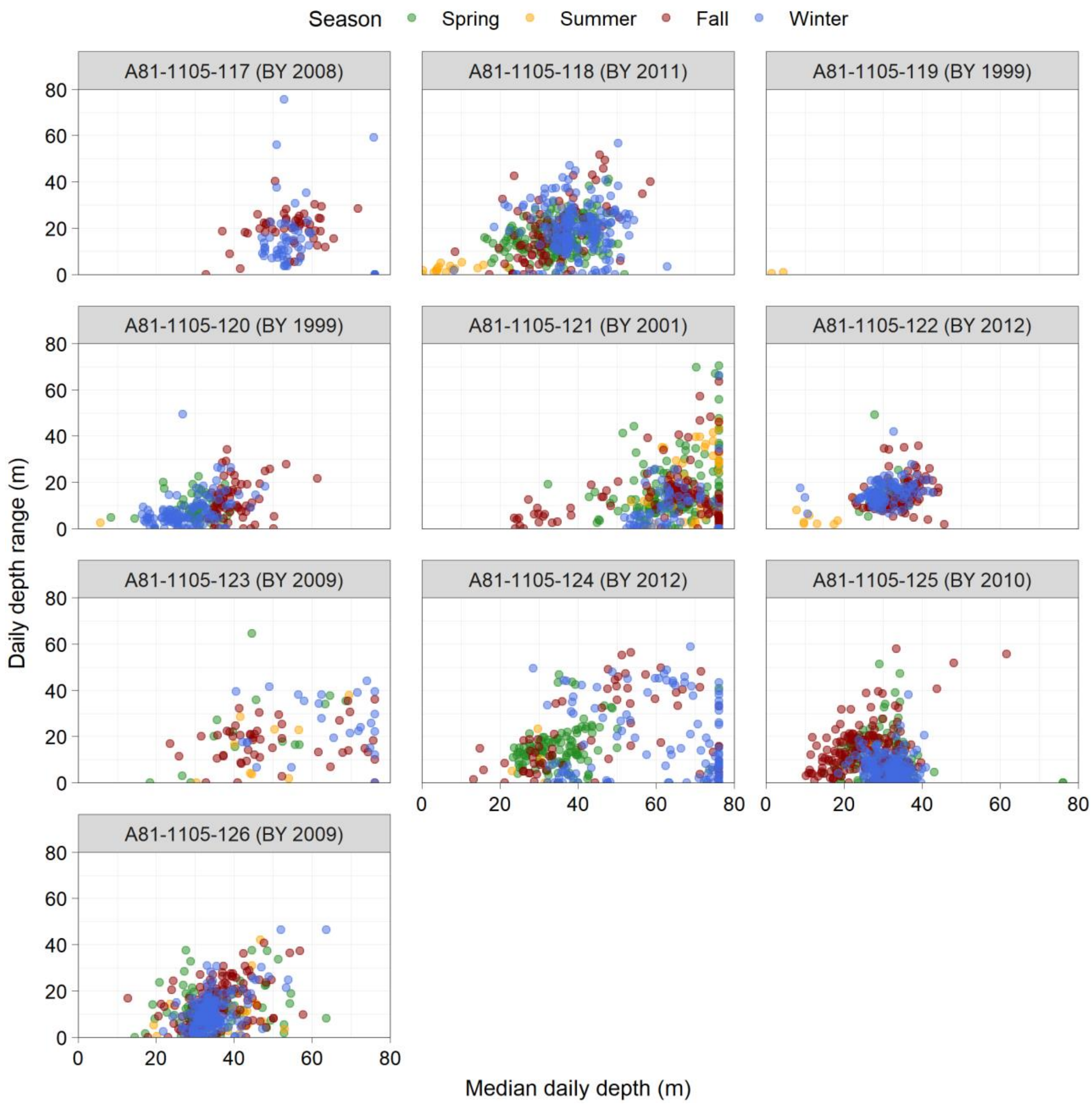

Figure 13. Diel migrations by individual fish at the Creston Delta receiver, by season; the extent of vertical migration (y axis) plotted against the median daily depth where the fish was detected.

4.4.2 In-season tagging summary

There were 42 Vemco 81kHz sonic tags implanted into Kootenay White Sturgeon in BC during the 2018 and 2019 sampling sessions; 36 into hatchery fish and 6 into pre-spawning females (Appendix 6). Twenty-two of the hatchery fish were tagged with V13 (three year battery life) tags and the remaining fish received 10 year battery life V16s. Brood years of the hatchery fish ranged from 1991 to 2015; most fish (35/42) were caught and tagged in Kootenay Lake, and 7/42 were tagged in the river at RKM 130. Fifteen of the hatchery tagged fish were >120 cm fork length; sex was determined for three of them to be female with no egg development. A summary of hatchery fish movement will be updated in the next reporting period.

One hatchery fish sonic tagged fall 2018 was recovered as a mortality at Corra Linn Dam in July 2019 (Tag A81-1206-1110; 1999 brood year). The cause of mortality is unknown, the last detection was at the closest receiver at the Grohman Narrows in the West Arm on June 18th, 2019 and it was recovered on July 5th, 2019 at the dam; movements of this fish are included in Appendix 7.

5.0 Discussion

Hatchery evaluations

Overall, the Kootenay White Sturgeon conservation aquaculture program has been very successful; all year classes are represented throughout BC and body condition was good. Body condition of the hatchery fish >70cm in both the river and lake habitat in BC was comparable to the overall average reported for all White Sturgeon populations (90%, Beamesderfer 1993). The relative weight was higher than the lowest estimate for the Kootenay system (77%), but still substantially lower than the more productive and warmer systems in both impounded and un-impounded White Sturgeon populations in the lower Columbia River (97%-112%, Beamesderfer *et al.* 1995). The smaller size of juveniles in the river highlights the productivity differences between the lake and river, but also these differences may also be related to density impacts recently identified in the river (Hardy *et al.* 2020).

With evidence of differences of movement and growth between the lake and river, evaluating population parameters by habitat types would improve population estimates and inform hatchery operations. Current hatchery survival estimates and population modelling pool all sampling and releases sites (Dinsmore *et al.* 2015; Hardy *et al.* 2020). Although this study is limited to a two-year summary, of the lake releases caught in the 2018 or 2019 BC sampling, all were encountered within the lake, none in the river. Furthermore, the most recent lake releases caught in BC were from the 2015 brood year and recapture data suggests wide range dispersal from river sites to the lake and throughout the lake for lake releases, but not into the river from the lake. In the past, only a small portion of the hatchery releases have gone directly into Kootenay Lake (7% of total over all years of releases) but more lake releases are planned in the future.

In order to evaluate release location differences, PIT tags are needed prior to release from the hatchery. In this study 39% of the hatchery fish did not have a PIT tag to connect it to release information. Without a PIT tag, brood year information was deduced from lateral scute removal patterns applied at the hatchery. However, due to unreliable scute readings, inconsistent scute pattern recordings across years, or scute patterns used for multiple years 12% of the hatchery fish were not assign a brood year in this study. Scute marks do aid in assigning brood year when possible, but PIT tags are the most reliable and provide the link to release information (e.g., size at release and release location).

Gill nets continue to be the most effective sampling method for the younger hatchery fish in the Kootenay system. As in years past, the highest catch sites were at the lake delta sites or at the lake-transition site during the short window of water temperatures close to 20ºC, when the hatchery fish are likely very active in more shallow water. However, as the hatchery fish grow, each year we will see more hatchery fish in our set line and angling sampling. These past two years, hatchery fish were the majority (66%), compared to 28% of the set line and angling catch in 2014 (Stephenson and Evans 2015). Due to their lack of size selectivity and effective capture method, set lines are the most common method in most other juvenile monitoring programs in the Columbia River system (e.g. BC Hydro 2015, Robichaud 2014). Within the lake habitat, set lines may be more effective due to overnight sets and use of bait, versus the passive short gill net sets. Future sampling should include increased lake sampling and evaluating the potential shift to a stratified random design, incorporating gill nets and set lines.

Hatchery depth use

This study was the first insight into depth use of hatchery juveniles in Kootenay Lake and identified diel movements using shallower habitat in the night for fall, winter and spring. At the Creston Delta diel migrations were greatest in the fall, and deepest in the winter, but all three seasons between fish were primarily located between 30 and 50m, shallowest in the night hours. Other locations had evidence of diel migrations, but Creston Delta had the most data in this study, corresponding to where most juveniles were caught and aligning with site fidelity as seen with the larger hatchery juvenile telemetry study (Stephenson and Evans 2018). Although there is limited work on diel migrations of juvenile White Sturgeon, previous work in the lower Columbia River reported diel migrations of a smaller scale in a river system (~5m changes) in spring, summer and fall months (Parsley *et al.* 2008). The lack of diel migration detections in the summer in this study could be explained by the high variability of depth detections by individuals and by reduced detectability of tags in more shallow waters in the summer. Micro habitat changes can affect detectability of tags and if the juveniles were going closer to shore in shallower habitat, further from the receivers in the summer, likely detections were missed. This would also explain the lower number of detections in summer months. Although limited data for the summer, it was clear that this was the time when juveniles used the shallow habitat.

Depth data can inform sampling and improve our understanding of habitat use within Kootenay Lake. Although this study was limited to 10 juveniles over a three year period (2015-2018), data suggest individual variability, but use of depths deeper than first thought. Juveniles were detected over a wide range of depths in the main sampling periods (spring, summer and fall), but high use of depths >20m (and depth over the 68m tag limit). The use of deep habitat suggests that juvenile Kootenay White Sturgeon could utilize other deep areas throughout the lake, but also leads to potential challenges for effective sampling in the lake. The deeper depths may have implications on the ability to capture juveniles within the lake and based on this study we suggest including future set line and gill net sets around 35-40m to evaluate capture rates by sampling depth.

Wild population

As seen since the start of the gill net program in 1993, only a handful of wild juveniles were encountered in the current study in BC but catch rates of wild adults remains high (Hardy *et al.* 2020). Within the angling and set line sampling the percentage of new wild fish in the BC sampling appears to have stabilized in recent years, ranging from 14% in 2017 to 19% in 2019, and is comparable to what is observed in the river sampling in Idaho (Hardy *et al.* 2020). The increased sampling effort in BC, as well as increased fall sampling in Idaho has resulted in the increased wild adult abundance estimate of 1744 individuals (Hardy *et al.* 2020).

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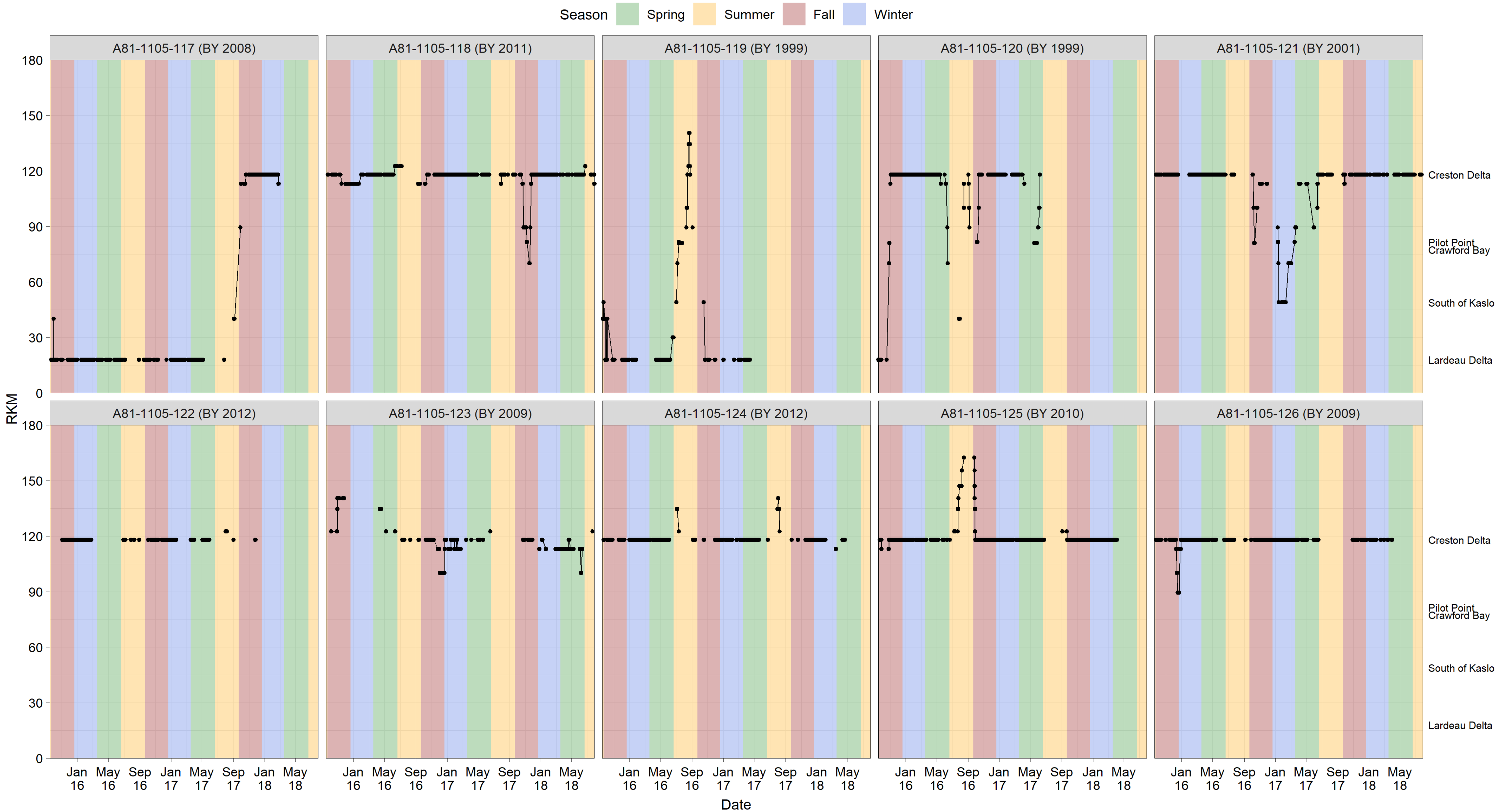
Appendix 1. Fin ray aging for wild Kootenay White Sturgeon caught by gill netting in BC in 2018 and 2019.

Date	WSGID	River km	Fork Length (cm)	Weight (kg)	Age on Capture (Years)	Brood Year	Capture Status
17-Jul-18	77657	165	107	8.6	no fin ray	NA	Recapture
09-Aug-18	269632	18	76	3.4	16	2002	Untraceable Wild
15-Aug-18	266937	121	41.4	0.42	6	2012	Recapture
02-Aug-19	276312	123	68.9	2	11	2008	New Wild
02-Aug-19	276316	123	91	5.4	15	2004	New Wild
02-Aug-19	276324	123	44.5	0.5	7	2012	New Wild
02-Aug-19	276326	123	139	20.4	adult-no fin ray	NA	Untraceable Wild
13-Aug-19	276083	18	81.2	4.03	no fin ray	NA	New Wild
13-Aug-19	276084	18	86.7	4.55	no fin ray	NA	New Wild
21-Aug-19	276371	121	153	25.8	adult-no fin ray	NA	New Wild
19-Sep-19	276400	121	50.3	0.8	12	2007	New Wild

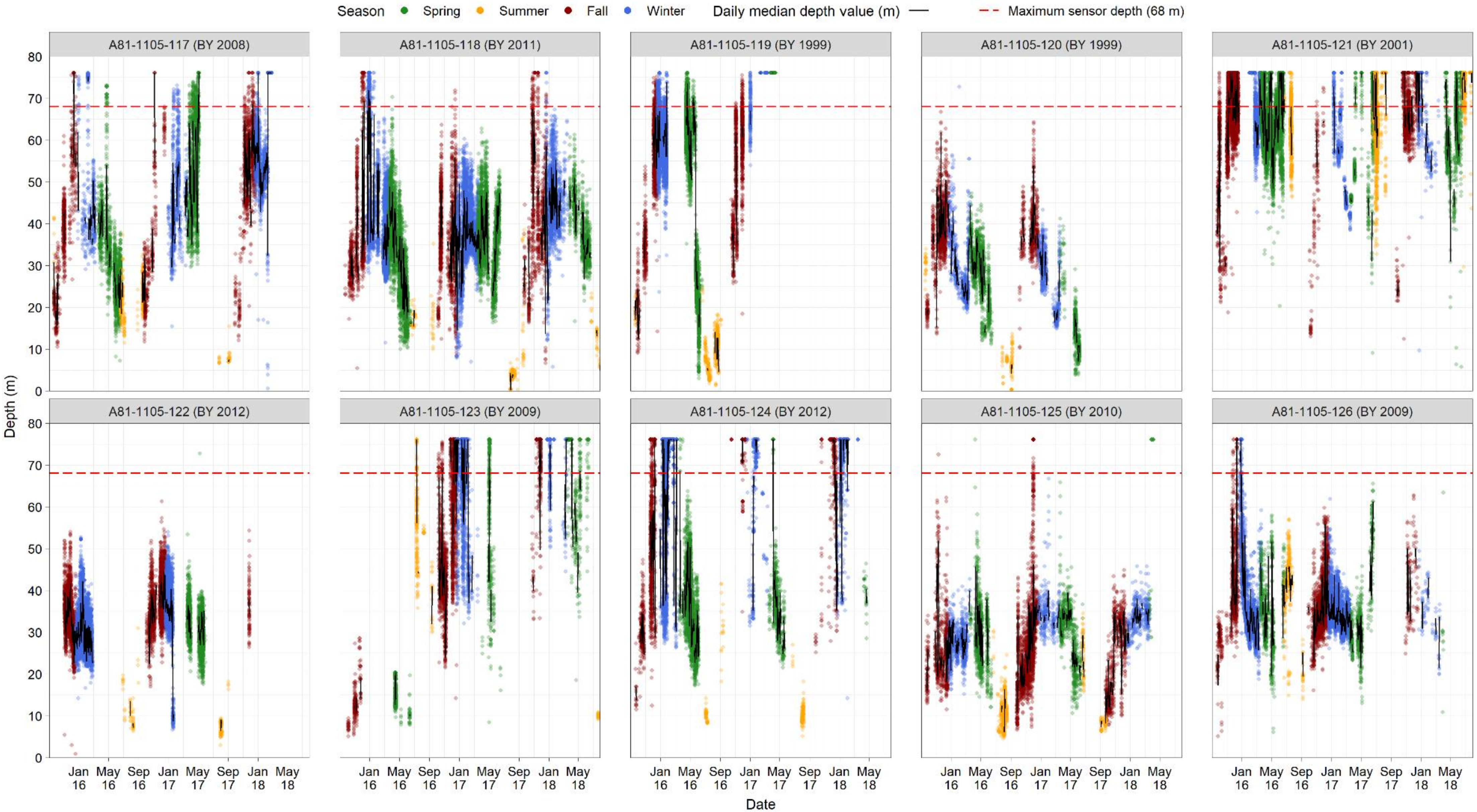
Appendix 2. Hatchery juveniles implanted with Vemco depth tags in 2015 in BC (3-year battery life). River kilometer = RKM.

Transmitter TagID	Capture and Tag Date	Capture and Tagging RKM	Fork Length (cm)	Weight (kg)	Brood Year	WSGID	Original Release Date	Hatchery Release RKM
A81-1105-117	15-Sep-15	18	68.9	2.2	2008	77552	20-Apr-09	144.5
A81-1105-118	11-Sep-15	120	36	0.28	2011	102306	01-May-12	199.5
A81-1105-119	15-Sep-15	18	79.7	3.2	1999	7564	28-Sep-00	170
A81-1105-120	16-Sep-15	18	70.7	2.35	1999	7347	28-Sep-00	170
A81-1105-121	10-Sep-15	120	91	4.8	2001	21823	16-Apr-03	101
A81-1105-122	11-Sep-15	120	42.5	0.4	2012	133368	08-May-13	144.5
A81-1105-123	22-Sep-15	121	56	1	2009	86819	20-Apr-10	144.5
A81-1105-124	22-Sep-15	120	40.5	0.415	2012	134923	08-May-13	144.5
A81-1105-125	10-Sep-15	120	49.6	0.75	2010	100369	27-Sep-11	258.6
A81-1105-126	10-Sep-15	120	54.5	1	2009	88635	21-Apr-10	144.5

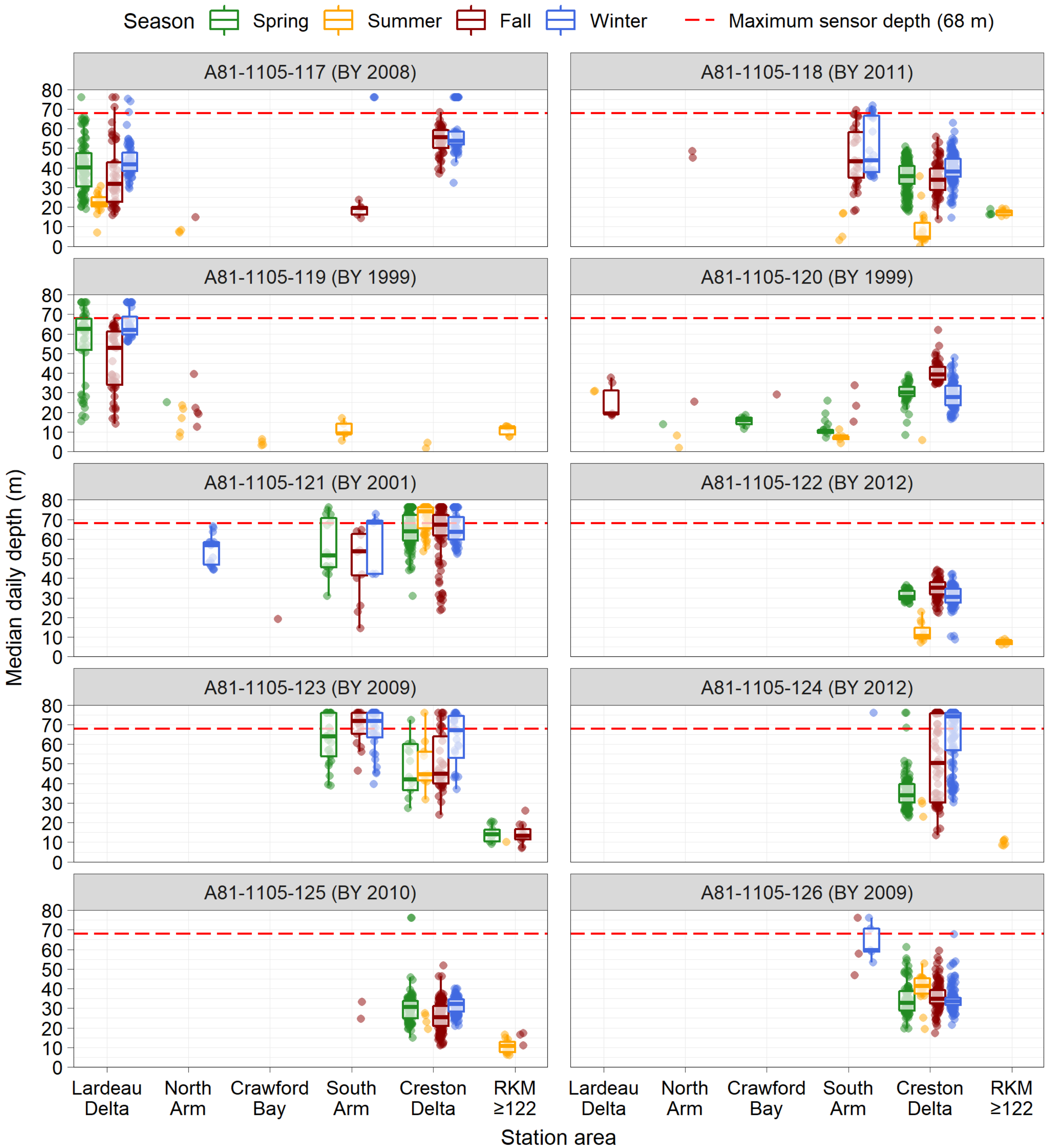
Appendix 3. Kootenay Lake and River tracking of individual juvenile White Sturgeon by average river kilometer per day detected, from September 2015 until September 2018. Each subplot labelled with tag ID and brood year (BY); River kilometer (RKM) > 122 is river habitat. All Vemco tags deployed in 2015 and expired in 2018.



Appendix 4. Seasonal depth use of Vemco tagged juvenile White Sturgeon in Kootenay Lake and River, all detections plotted overlaid with median daily depth. Date range plotted = September 2015 until September 2018. Each subplot labelled with tag ID and brood year (BY).



Appendix 5. Seasonally pooled depth use of Vemco tagged juvenile White Sturgeon in Kootenay Lake and River (date range plotted = September 2015 until September 2018). Each subplot labelled with tag ID and brood year (BY).



Appendix 6. Summary of all Vemco tagged Kootenay White Sturgeon in 2018 and 2019 in BC.

Transmitter tag ID	Tagging date	Projected expiry	Tag RKM	FL (cm)	Wt (kg)	Brood year	Sex	WSGID	Original release date	Original release RKM
A81-1206-1125	19-Apr-18	05-May-22	121	85	3.6	2000	Unk	25793	25-Oct-02	177
A81-1105-1126	03-May-18	19-May-22	121	71	3	2006	Unk	58008	04-May-07	151
A81-1105-1124	03-May-18	19-May-22	121	124.5	15.8	2000	Unk	25816	25-Oct-05	177
A81-1105-1121	04-May-18	20-May-22	121	80	3.2	1995	Unk	4089	07-Oct-97	244.6
A81-1206-1122	10-Sep-18	26-Sep-22	18	68.6	2.4	2011	Unk	108703	18-Apr-12	144.5
A81-1206-1109	10-Sep-18	12-Sep-28	18	132	13.6	1995	F	4649	29-Apr-97	244.6
A81-1206-1111	10-Sep-18	12-Sep-28	18	160	43		F	244932		
A81-1206-1112	10-Sep-18	12-Sep-28	18	198	67	1971	F	2344		
A81-1206-1110	11-Sep-18	Mort Jul 2019	18	134	26	1999	Unk	7865	28-Sep-00	170
A81-1206-1123	17-Sep-18	03-Oct-22	130	40.6	0.43	2010	Unk	98259	19-Apr-11	144.5
A81-1206-1128	17-Sep-18	03-Oct-22	121	61.9	1.6	2011	Unk	105770	18-Apr-12	144.5
A81-1206-1107	19-Sep-18	21-Sep-28	123	139	20.2	1991	Unk	3122	01-Aug-92	243
A81-1206-1136	25-Sep-18	11-Oct-22	121	120	12.8	1999	Unk	8412	19-Apr-01	200
A81-1206-1108	25-Sep-18	27-Sep-28	121	195	70.2		F	289		
A81-1206-1113	25-Sep-18	27-Sep-28	121	152	23.8	1991	Unk	3120	01-Aug-92	204
A81-1206-1127	26-Sep-18	12-Oct-22	130	39.3	0.38	2010	Unk	100830	19-Apr-11	144.5
A81-1206-1139	26-Sep-18	23-Sep-28	121	135	16.2	1995	F	4266	30-Apr-97	244.6
A81-1206-1106	26-Sep-18	28-Sep-28	121	120	11.4	1995	Unk	5174	29-Apr-97	244.6
A81-1206-1142	11-Oct-18	08-Oct-28	130	83.5	3.8	1999	Unk	8569	19-Apr-01	200
A81-1206-1145	10-Apr-19	07-Apr-29	121	201	63.4		F	276262		
A81-1206-1153	11-Apr-19	08-Apr-29	121	153.5	25.8	1995	Unk	2371		
A81-1206-1156	12-Apr-19	21-Jun-22	121	77.5	3.2	2005	Unk	81932		
A81-1206-1157	17-Apr-19	26-Jun-22	121	72.5	3	2005	Unk	250257		
A81-1206-1158	17-Apr-19	26-Jun-22	121	84	4	2003	Unk	44749	20-May-04	151
A81-1206-1159	17-Apr-19	26-Jun-22	121	114	8.4	2000	Unk	11039	03-Oct-01	170
A81-1206-1160	18-Apr-19	27-Jun-22	121	100.5	8.8	1999	Unk	9149	19-Apr-01	170
A81-1206-1161	20-Aug-19	29-Oct-22	130	60.5	1.2	2014	Unk	245472	06-May-15	144.5
A81-1206-1162	20-Aug-19	29-Oct-22	130	41.7	0.4	2014	Unk	249253	06-May-15	144.5
A81-1206-1163	21-Aug-19	30-Oct-22	121	49.9	0.6	2015	Unk	264837	17-May-16	81
A81-1206-1164	22-Aug-19	31-Oct-22	120	53.5	1	2013	Unk	236788	06-May-14	144.5
A81-1206-1165	22-Aug-19	31-Oct-22	120	48.3	0.6	2015	Unk	251790	17-May-16	150
A81-1206-1166	22-Aug-19	31-Oct-22	120	77	3.4	2007	Unk	63120	28-Apr-08	199.5
A81-1206-1150	10-Sep-19	07-Sep-29	18	168	39	1995	Unk	4509	29-Apr-97	244.6
A81-1206-1167	11-Sep-19	20-Nov-22	18	55.9	1	2015	Unk	250560	27-May-16	150
A81-1206-1148	11-Sep-19	08-Sep-29	18	180	42		F	138101		
A81-1206-1149	11-Sep-19	08-Sep-29	18	134	20	1999	Unk	7200	27-Sep-00	200
A81-1206-1172	19-Sep-19	28-Nov-22	121	49.8	0.6	2015	Unk	259374	11-May-16	199.5
A81-1206-1173	19-Sep-19	28-Nov-22	121	57.4	1.2	2014	Unk	246113	06-May-15	144.5
A81-1206-1151	19-Sep-19	16-Sep-29	121	119.5	12.4	1999	Unk	8835	19-Apr-01	200
A81-1206-1186	20-Sep-19	17-Sep-29	123	199	60		F	1447		
A81-1206-1154	25-Sep-19	22-Sep-29	130	127	14	1999	Unk	8666	19-Apr-01	170
A81-1206-1185	25-Sep-19	22-Sep-29	130	126	14.6	1999	Unk	8464	19-Apr-01	200

Appendix 7. Movements of A81-1206-1110, a 1999 brood year fish sonic tagged September 2018 at RKM 18 and discovered as a mortality on July 5, 2019 at Corra Linn Dam. The last month of detections are in the West Arm (RKM 76).