2017 Nechako Juvenile White Sturgeon Sampling; 2016AFSAR-2861 (Year 2) Juvenile Recruitment Indexing

Funded via Canada's Aboriginal Funds for Species at Risk, the Carrier Sekani Tribal Council, and BC Ministry of Forests, Lands, Natural Resource Operations & Rural Development

May 2018

Prepared by the Carrier Sekani Tribal Council
2nd Floor, 1460 Sixth Ave.
Prince George, B.C.
V2L 3N2

Acknowledgements

This work was made possible through funds received from the Government of Canada's Aboriginal Funds for Species at Risk Program (AFSAR). Vivian Chow, Regional AFSAR/HSP Coordinator, provided project administrative guidance. The Carrier Sekani Tribal Council (CSTC) contributed in-kind resources and financially supported the project through its Aboriginal Fisheries Strategy Agreement with Fisheries and Oceans Canada. BC's Ministry of Forests, Lands, Natural Resource Operations & Rural Development (FLNRO-RD) also contributed funding to support the project.

Technical-field personnel included Neil Heron (Sr. Technician, CSTC), William Mole (CSTC Technician), Ashley Raphael (CSTC Technician), Aaron Raphael (CSTC Technician), Darren Raphael (CSTC), Gilbert George (CSTC), and Jeff Beardsall (contract sturgeon biologist). Cale Baby and Haley Swinden (Freshwater Fisheries Society British Columbia) lead peripheral sampling field work. Nikolaus Gartner and Ian Spendlow (FLNRO-RD) helped design and assist field activities. Jessica Courtier (Database Curator, Nechako White Sturgeon Recovery Initiative) entered the data into the Fraser River White Sturgeon Database.

Christina Ciesielski (Manager, CSTC Fisheries Program) managed this project. Jeff Beardsall (Contract Biologist) and Brian Toth (Contract Biologist) completed project reporting. Nikolaus Gartner and Ian Spendlow reviewed and provided comments on the technical report.

Table of Contents

List of Figures

List of Tables

Summary-Overview

The Nechako River juvenile white sturgeon monitoring program has been an annual data collection program since 2004. The purpose of the monitoring program has been to understand and monitor juvenile sturgeon survival, migration, and habitat use in Nechako River. In 2017 objectives included continued intensive sampling of the index zone (rkms 110-135), increasing the spatial range of sampling within the Nechako and Fraser rivers, introduction of larger hooks to target 90-150cm fork length individuals, and using radio and acoustic tags to monitor and compare post-release migration of hatchery individuals.

A total of 212 setlines (75,713 hook hours) were deployed within the index zone (rkm110-135) between August 15 and October 5 2017. Two hundred and forty-five (245) unique juveniles were captured (232 hatchery-origin and 13 wild-experimental-origin[1]); 25 hatchery origin juveniles were captured twice within the index zone (270 capture events in total within index zone; 0.357 juv/100 hook hours). To expand the spatial range of sampling 121 setlines (55,880 hook hours) were deployed outside of the index zone (peripheral zones) between September 5 and October 20 2017. Fourteen (14) unique juveniles were captured (11 hatchery-origin and 3 wild-experimental-origin; 0.025 juv/100 hook hours) in peripheral zones. One (1) wild-experimental origin fish was held for one day, tagged and released; it did not survive capture and handling stressors but is the only confirmed 2017 capture mortality. Overall, 258 juveniles (283 capture events) resulted from 131,593 hook hours of effort (0.215 CPUE) in 2017. Effort within the index zone was approximately double recent years.

Juveniles were encountered in nearly all river kilometres in the index zone however several habitat units demonstrated higher juvenile densities (rkm134, rkm125, rkm115-rkm117, rkm111-112). Rkm111-112 had unusually high CPUE values, perhaps because of conspecific competition in typical high-use juvenile habitat (e.g. rkm115-117). CPUE in peripheral zone rkm100-110 was low but comparable to habitats producing low CPUE within the index zone; CPUE was very low in other peripheral zones. However, several captures between rkm90-95 and rkm25-30 indicate hatchery juveniles do migrate downstream of the index zone habitats.

In an effort to expand the size range of fish selected by the juvenile setlines, a 5/0 hook size was fished in the index zone and 4/0, 5/0, 6/0, and 8/0 hook sizes were fished in peripheral zones. One wild-experimental origin fish measuring greater than 100cm fork length (FL) and several juveniles between 80cm and 100cm FL were captured on 5/0's. Results indicate the 5/0 hook size may be the most effective at capturing 80cm up to ~140cm FL sturgeon. Results also

[1] The term "wild-experimental" is used to reflect sturgeon that are not identifiable as being of hatchery origin, which could include fish of wild origin, and fish surviving from larval and fertilized-egg release experiments that were previously conducted.

suggest larger juvenile and subadult sturgeon (i.e. 80-140cm FL) are not abundant in the index zone or peripheral areas sampled.

Capture trends over the last three years (since the initiation of 1-yearold hatchery juvenile releases in 2015) provides a preliminary understanding of hatchery juvenile survival and wild-experimental juvenile recruitment patterns discernable within that period.

Juveniles released in 2015 have been part of the annual capture sample since their release; more 2015-releases were captured in 2017 compared to 2015 and 2016 indicating the size distribution of the cohort continues to "grow into" the sizes most susceptible to capture on the juvenile sampling gear. Results confirm hatchery juveniles are surviving and growing within the index zone.

Hatchery juveniles released in 2016 have been sampled for two seasons. A significant increase in the number of 2016-releases captured in 2017 (relative to 2016) confirms the pattern observed for the 2015 cohort; indicating the size distribution of the cohort is increasing towards the sizes most susceptible to the sampling gear.

Results suggest that a hatchery cohort will take at least 3 years until the size distribution of surviving individuals grows to the sizes most susceptible to capture on the juvenile sampling gear. This trend is dependent on the size distribution of the cohort at the time of its release and the cohort's rate of growth, and size-dependent survival factors within the cohort. These factors will influence year-to-year capture trends.

Captures of wild-experimental origin juveniles indicate a small number of individuals are surviving to subadult life stage. A small number of fish originating from spawning events since 1990 are present in the 2017 capture sample.

Between October 10-20, 2017 45 setlines (16,206 hook hours) and 8 angling events (7.16 hook hours) were deployed in the confluence of the Nechako and Fraser rivers, and in the Fraser River downstream of the Nechako confluence. Sampling sites were chosen based on expert local knowledge. No sturgeon were encountered. The intent of this sampling was to understand the potential downstream extent of hatchery origin juveniles being released into the Nechako.

Findings and recommendations are summarized below.

Findings

1. Larger sized hooks (5/0, 6/0, 8/0) were added to the standardized array in 2017 in both the index zone and peripheral areas to broaden the target size range to >100cm FL; a single fish >100cm was captured in the index zone on 5/0 hook suggesting increasing hook size to 5/0 does improve capture sample size range to include individuals up to 130cm FL. However, the low numbers of subadults captured suggests a lack of survival from late juvenile to subadult stage (Chapter 2).

2. Captures of hatchery-origin juveniles released in 2015 suggest a cohort doesn't achieve the size distribution most susceptible to capture on the juvenile sampling gear until age 3+ (at least); this would be dependent on the size distribution at the time of release, growth rate, etc. (Chapters 2 & 6).
3. Wild-experimental origin juveniles are catchable on the juvenile gear at age 3+ (~40cm fork length), and become most susceptible at ages 5 -12 (~50-70 cm fork length; Chapter 6).
4. The observation of small numbers of wild origin juveniles (since the initiation of juvenile focussed sampling) and very limited observations of late-juveniles and sub-adults suggests some degree of natural spawning success and survival to early or late juvenile life stage, and ongoing failure to survive to subadult life stage (continued recruitment failure) (Chapter 6).
5. Wild-experimental origin juvenile capture frequency declines after fish reach the size-range most susceptible to capture gear (50-70cm fork length); captures of wild-origin juveniles greater than 80cm fork length are rare in Nechako River despite efforts to target large juveniles and subadults (Chapter 6).
6. The continued ability to document similar numbers of wild-experimental origin juveniles within the sample (pre and post 2015) following substantially increased hatchery-origin juvenile density suggests sampling gear has not been subjected to saturation effects.
7. Peripheral sampling confirmed the presence of hatchery and wild-experimental-origin juvenile sturgeon outside of the index zone (0.025 $\pm$ 0.04 CPUE), although in small numbers relative to the index zone (0.252 $\pm$ 0.48 CPUE; Chapter 3). One exception is habitat between rkm105 and rkm110. Habitat within this segment is contiguous with the index zone and capture numbers suggest juvenile density is similar to some index zone habitats.
8. Similar distributions of juveniles from three tagging groups within the index zone and their similar overall detection rates within the index zone suggests the visual cue provided by a radio tag antenna is not a factor influencing predation rate, and there's no differential in susceptibility to predation between a fish emitting a radio or acoustic signal (Chapter 4).
9. Acoustic and radio telemetry monitoring results suggest very high rates of mortality on tagged individuals within months of release (Chapter 4).
10. Acoustic and radio telemetry results suggest few hatchery-origin fish migrated outside of the index zone within their first months following release, although those results are confounded by the mortality issue identified above (Chapter 4).
11. Sampling for juvenile sturgeon within the Fraser River did not produce juvenile sturgeon captures.

Recommendations

1. Continue annual monitoring of the index zone, ensuring sampling coverage in each river kilometre within the index zone while avoiding seasonal confounds in data (e.g. systematic site selection with random block design). Include 5/0 hook sizes on separate lines in an attempt to expand the target size range of the sampling – to late juvenile and subadult sturgeon (~80-130cm), which will help identify survival characteristics to those size ranges.
2. Consider including habitat between rkm105 and rkm110 into index zone sampling.
3. The index monitoring program should maintain similarly high effort going forward to develop survival estimates for hatchery cohorts in a timely manner.
4. Continue sampling peripheral zones going forward, including expanded-exploratory sampling to locate new high-use habitats in peripheral zones. Include 5/0 hook sizes on separate lines in an attempt to expand the target size range of the sampling.
5. Continue sampling Fraser River mainstem using standardized setline gear. Sampling should occur in summer water temperatures after Fraser River freshet within high potential juvenile habitats between the Nechako River confluence and mid-Fraser White Sturgeon range boundary. Include 5/0 hook sizes on separate lines to capture late juvenile and subadult sturgeon.
6. Conduct sampling utilizing standardized juvenile setlines (incorporating the larger hook sizes) within known high use juvenile habitat within the upper Fraser stock's (Sub-DU) range; with the intent to document catch characteristics when sampling within a functioning juvenile-subadult population.
7. Continue radio or acoustic telemetry to better understand movement and migration behaviours and habitat use as fish grow from early juvenile, to late juvenile and subadult size ranges. Adding additional gates at new sites and/or array coverage at sites of low migration success may improve knowledge of acoustic tag fate.
8. Develop a mark-recapture model for estimating hatchery cohort and wild-experimental cohort survival rates.

Chapter 1

Introduction

Following the conclusion of assessment activities in 1999, BC's Ministry of Water, Land and Air Protection (MoWLAP) initiated a recovery planning process for the Nechako River white sturgeon stock. This *Nechako White Sturgeon Recovery Initiative* (NWSRI) parallels recovery planning processes implemented on the Columbia and Kootenay rivers, where sturgeon populations have also experienced recruitment failures (Golder 2003). This involved the creation of a Recovery Team in 2000 (now termed the Technical Working Group – TWG), comprised of government and non-government technical personnel assembled to recommend technical directions for recovery actions. The Nechako White Sturgeon TWG, through the development of a Recovery Plan, indicated that a focused juvenile sampling program should be carried out on the Nechako River (Golder 2003). The intent of the juvenile sampling program is to monitor juvenile presence, recruitment and survival, to allow for an assessment of factors controlling recruitment and survival, provide an assessment of the effects of habitat restoration activities and monitor the growth and survival of hatchery-reared juvenile white sturgeon. These data have been collected annually since 2004, and in an index-style standardized approach since 2009.

Pilot hatchery operations were conducted between 2006 and 2009. Four thousand one hundred and thirty-three (4,133) 6-month old juveniles were released in 2006, 4,473 6-month old juveniles were released in 2007, and 5,633 6-month old juveniles were released in 2008. An additional 59 1-year old juveniles were released in 2009 for a total of 14,298 juvenile sturgeon released between 2006 and 2009. Pilot operations ceased for 6-years until the construction of the hatchery facility. Since the first fully operational hatchery release in 2015, more than 20,000 additional hatchery individuals were released and have changed the density of juvenile sturgeon in Nechako River. It is presently unknown how increased juvenile density has influenced juvenile migration behaviours.

Nechako River stocking efforts must be accompanied by a monitoring plan designed to monitor growth of early juveniles (defined as 40 days to 2 years age, DFO 2014) into the late juvenile and adult life stage (defined as 2 years or greater age, DFO 2014). A subadult life stage could also be included, characterized by a body size large enough to essentially mitigate all predation pressure but not yet sexually mature (15 years old to sexual maturity for example). Early juveniles are characterized by having greater predation pressures, different diets, and different habitat use compared to late juveniles and older life stages (DFO 2014). Late juveniles are characterized by having less predation pressure than early juveniles; they have similar diets and habitat use compared to subadult and adult life stages. Subadults could be characterized by having no predation pressure and similar habitat use and diets compared to adults but not yet achieving sexual maturity. Late juveniles and subadults may also start displaying larger migrations related to feeding, over-wintering, or spawning. An understanding of growth of hatchery and wild-experimental individuals through their life stages in Nechako River will be an outcome of the juvenile monitoring program, and is critical for managing the stocking program.

The initiation of long-term conservation-based hatchery operations on the Nechako in 2015 has supported releases of 1yr old juveniles in 2015 (~1,850), 2016 (~9,200) and 2017 (~12,000). Juvenile sampling data collected since 2015 is developing an understanding of the survival and spatial distribution of recently released hatchery juvenile sturgeon. Monitoring is necessary for adaptively managing the hatchery facility's rearing and release strategies.

Development of mark-recapture models will be a primary objective for the next several years of juvenile monitoring. Accurately modelling hatchery juvenile survival requires an understanding of sampling gear selectivity, juvenile growth and migration or emigration rates. The standardized juvenile sampling program (2010-2016) had focussed on an "index zone" between river kilometre 135 and 110. The index zone contains the known high-use habitat units in Nechako River, informed by prior sampling. In response to the introduction of hatchery juveniles since 2015, the program in 2017 extended its coverage outside of the index zone to better understand the range, migration, and emigration rates of juvenile sturgeon as their density within the river increases (due to conspecific competition or other factors).

Juvenile monitoring activities in 2017 were comprised of three components; the index zone sampling, the peripheral zones sampling, and lower Nechako River/Fraser River sampling (Figure 1). In addition, a biotelemetry monitoring program was operated during spring, summer and fall 2017. There is value to interpreting results from each independent component, and more broadly considering their combined contribution to answering key questions about juveniles. This technical report is structured in that manner.

Purpose

The primary purposes of 2017 sampling included continued monitoring of hatchery-origin juvenile survival and growth rates, monitoring the presence of wild-spawned juvenile sturgeon, as well as refining our understanding of juvenile sturgeon habitat in Nechako River.

Additional methods in 2017 included placing juvenile sampling effort within "peripheral" sites that haven't been sampled for juveniles since 2009. Sampling in habitats outside of the index zone (i.e. peripheral zones) is intended to monitor for presence and detect migration behaviours outside of the index zone.

Juvenile sampling in 2017 also included setting a variety of larger hook sizes (5/0, 6/0, 8/0) within the index zone and the peripheral zones. Larger hooks are intended to better detect subadult sized fish and better understand the survival of fish less than 1-meter to larger sizes.

Objectives

The technical objectives of this project were stated as follows:

1. Conduct sampling using methods similar to previous years.
2. Collect detailed biological and morphological information from any sturgeon captured.
3. Apply identifying tags (PIT) and marks (scute markings) to unmarked (previously uncaptured/unsampled) juvenile sturgeon.

Methodology

Index Sampling

A crew of 4-6 people completed sampling within the index area (rkms110-135; Figure 1). Sampling effort included only juvenile setlines. Setline effort was randomized relative to which 5-km river segment was sampled to ensure downstream segments were sampled at similar times to upstream segments of the river. Setline effort was also systematically applied to each river kilometre within the index zone resulting in a relatively even distribution of soak hours within and between river kilometres relative to previous years. Some river kilometres were visited twice within the sampling period (e.g. rkm110-112, 116-117, 128-129, 132). Areas that were visited twice were generally habitats that yielded the greatest number of juvenile captures earlier in the sampling period. Habitats that did not yield any captures were not revisited.

In previous years captured juveniles were classified as “Hatchery” or “Wild” based on the presence/absence of marks/tags. A new “Wild-Experimental” classification of origin was suggested to replace the “Wild” classification in 2017. The “Wild-Experimental” classification includes “Wild” individuals and reflects that some hatchery-origin fertilized eggs have been experimentally placed in the spawning reach during the spawning period. Additionally, some experimental releases of hatchery-origin larvae have taken place in some years. Juveniles surviving from these experimental releases would be visually undiscernible from “Wild” fish.

Untagged individuals captured without PIT or scute marks are now referred to as “Wild-Experimental” origin. The parentage of “Wild-Experimental” fish can be assessed and the individual can be reclassified as “Experimental” when parentage analysis suggests a match with hatchery family stock.

Peripheral Sampling

A crew of 2-4 people completed peripheral (outside of the index zone) sampling. The peripheral zones were identified as high priority sample sites with consideration to previously reported data, traditional and/or local knowledge and access logistics. Sample sites were randomized but some sites were selected based on the presence of sturgeon habitat characteristics. Sampling effort included only juvenile setlines. In the latter half of peripheral sampling water levels restricted access to sampling sites. Figure 1 depicts the entire 2017 study system including index and peripheral sampling zones.

Fraser River Sampling

A crew of 3 people completed Fraser River sampling using setline and angling methods. Sampling zones were chosen based on previous white sturgeon distribution data from Fraser River (RL&L 2001, DFO 2014, Lheidli T'enneh 2017) and local expert knowledge (Lheidli T'enneh technicians, C. Williamson). Site selection in Fraser River was guided by Lheidli Tenneh technicians and a field biologist with expert knowledge of juvenile sturgeon habitat.

Sites were sampled using setline gear identical to that used in Index and Peripheral sampling programs. Angling was used in addition to setline gear (details described below). Rods were 11ft heavy-action rods equipped with Shimano Talica overhead reels. The mainline was 200lb-breaking strength nylon braid. Leader material was 200lb-breaking strength cotton braided line. All rods were equipped with 5/0 circle hooks (Gamakatsu Circle Octopus Hooks – NS Black).

Not all desired sites were accessible in 2017 due to low water. In some cases, site access was cut off due to shallow bars preventing boat access, and in other cases the sites were accessible but too shallow to safely deploy setlines.

Setline Rigging

Setlines 40m to 60m long were rigged with standard sizes (4, 2, 1, 1/0) or large size (4/0, 5/0, 6/0, 8/0) circle hooks (Gamakatsu Circle Octopus Hooks - NS Black) on 8-12" leaders of 80lb braided line. Standard and large-hook setlines were deployed with 20 hooks per line. Five of each hook size were clipped systematically mixed along the setline (~2.5m spacing). Sockeye flesh from the Stellako stock was used for bait when available, otherwise store-bought wild sockeye flesh was used. Setlines were set, soaked overnight and retrieved the following day. In general, 10 setlines were deployed each sampling day.

Physical Conditions

Water temperatures were obtained at the start of every set (when the setline was placed in the water) using either a digital thermometer or the sampling vessel's fish finder. Water depth at the site of gear deployment was measured utilizing the vessel's fish finder, which was tested for accuracy using a known length of rope with weight attached. Water clarity was estimated utilizing a standard size Secchi Disc deployed and interpreted in a standardized manner. Nechako River temperature and discharge information collected at the Vanderhoof Hydrometric station was retrieved from Environment Canada's Water Survey of Canada website for the duration of sampling activities.

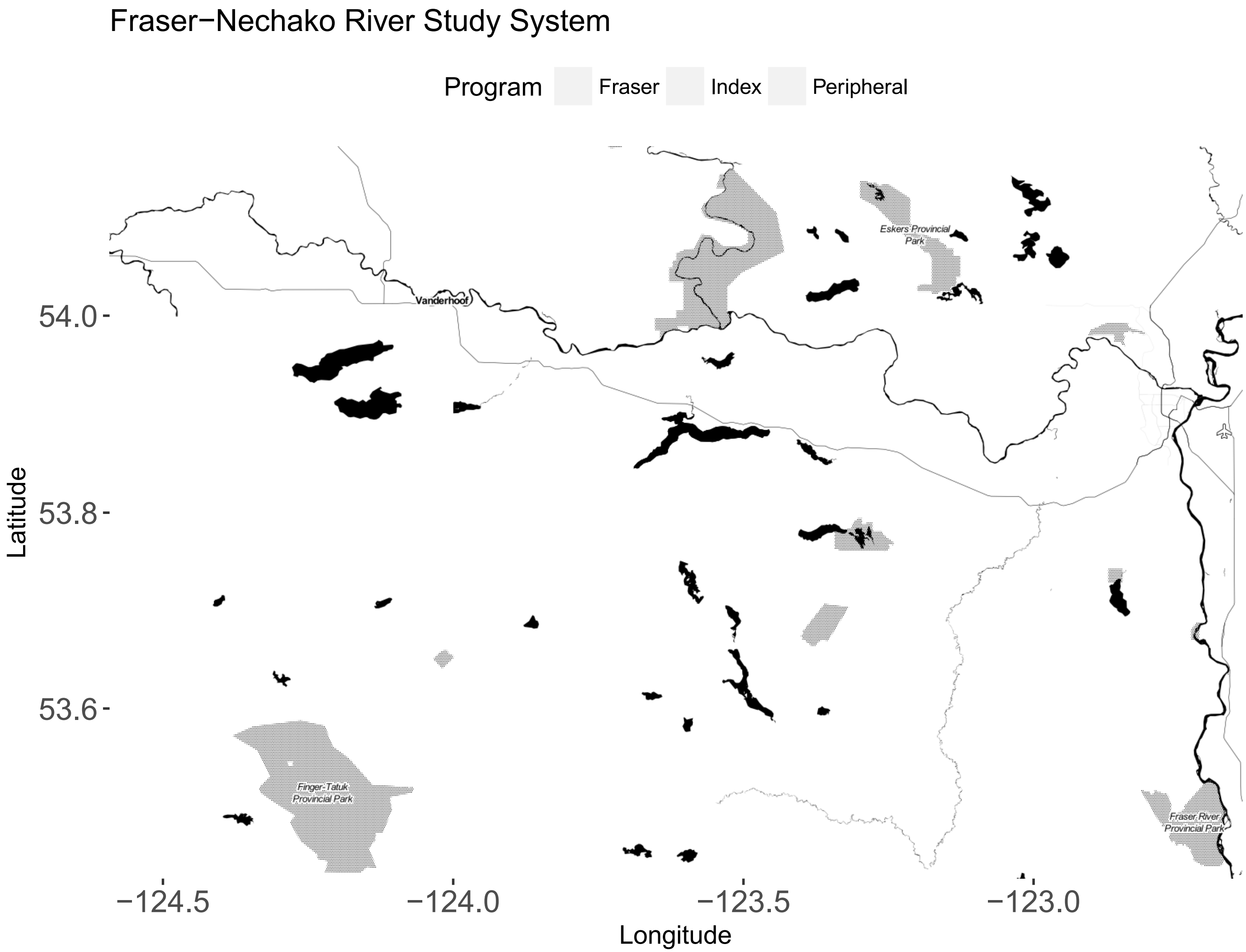

Figure 1. Map of Nechako River and Fraser River sampling sites for 2017 juvenile monitoring program. Sampled sections of each river are color coded based on monitoring program.

Age Structure Analysis

When fish were captured for which an age estimation was desired (typically previously uncaptured wild-experimental origin individuals), a ~1.5 cm section of leading finray was surgically removed from the right pectoral fin approximately 0.5cm from the “knuckle” and sent to Coastal Ecology Lab at Acadia University, Nova Scotia, Canada for aging analysis. Finray samples were sectioned (~1.0mm) at least three times using an isomet saw with a diamond cutting edge. Each section was cleared in 95% EtOH for approximately 30 seconds depending on section thickness. Cleared sections were placed on a dissecting scope and annular growth rings were counted. The processed finray samples were returned to the CSTC.

Physical Conditions of the Nechako River at time of Sampling

River discharge and water temperature were continuously measured at Burrard Bridge (rkm137.7) by Water Survey Canada during the 2017 sampling period (Figures 2 and 3 respectively). River discharge was greater than 200 m^3/s at the start of the index sampling period and declined to approximately 50 m^3/s by the end of the sampling period. Discharge decreased relatively rapidly between mid-August and September 1, and then the rate of decrease became slow near the second week of September. Slight increases in discharge were recorded on September 18, October 1, and October 17 (Figure 2**Error! Reference source not found.**).

Water temperature was approximately 15.0°C at the beginning of the sampling period and declined to approximately 10.0°C at the end of the sampling period. Water temperature decline was gradual with small temperature increases between Sept. 05 – 07, Sept. 13 – 15, and Sept. 19 – 20. The measurements recorded at Burrard Bridge by the Environment Canada hydrometric station closely matched average daily temperatures recorded at setline locations (Figure 3).

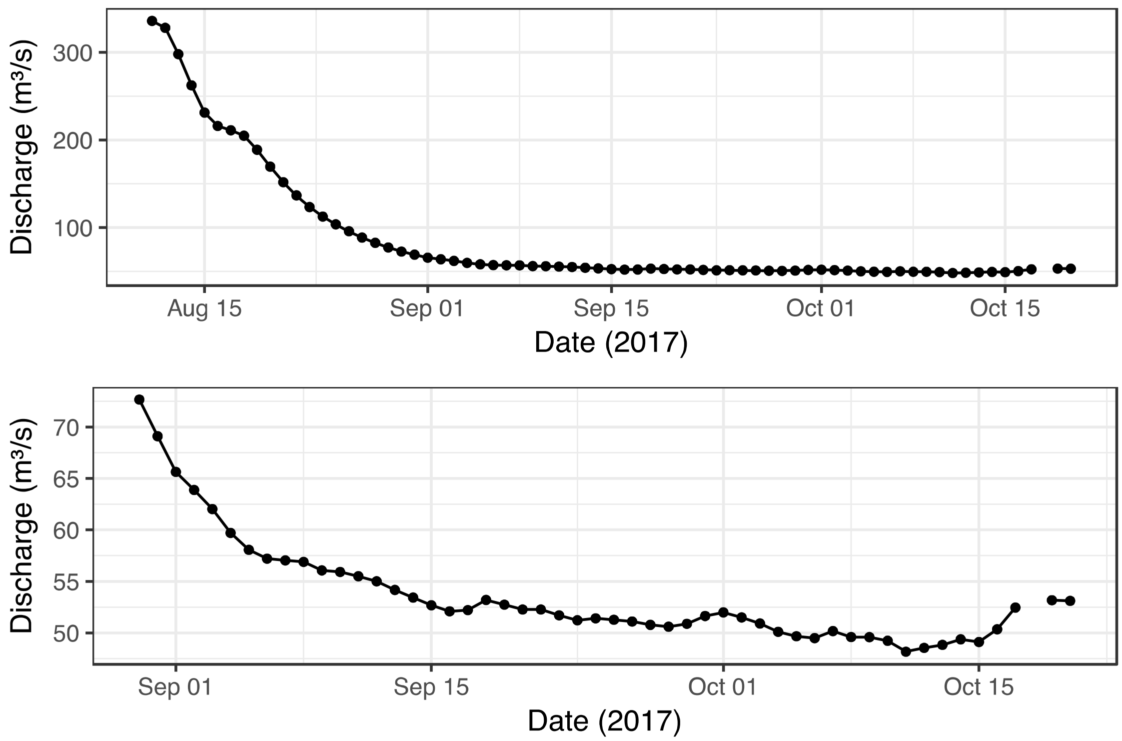

Figure 2. Daily average discharge (m^3/s) for the Nechako River at Vanderhoof Environment Canada hydrometric station 08JC001 from August 14 to October 20 2017 (top panel), and August 30 to October 20 2017 (bottom panel) for detailed y-scale

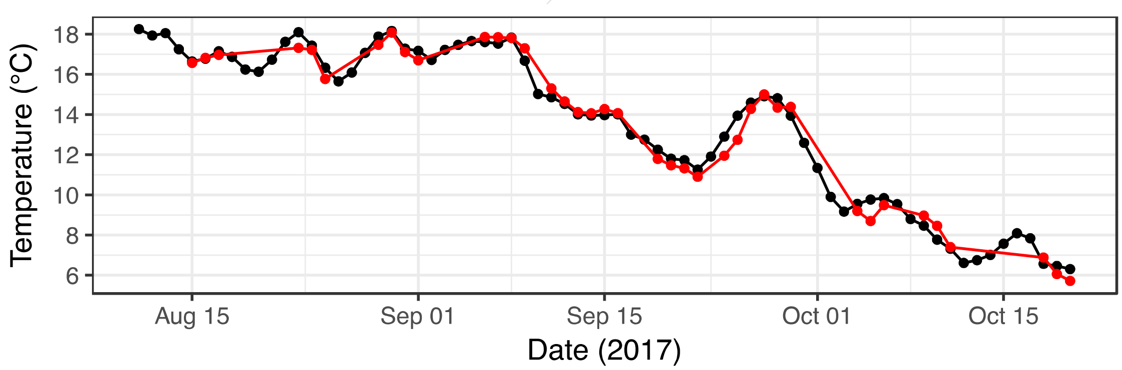

Figure 3. Daily average water temperature (Celsius) for Nechako River at Vanderhoof Environment Canada hydrometric station 08JC001 from August 29 to October 15, 2017 in black. Daily average water temperature for Nechako River at setline locations measured using the boat temperature sensor in red.

Water clarity was measured once at the beginning of the day. All days were estimated (via Secchi disc measurements) to be 2m throughout the duration of the sampling program.

Chapter 2 Index Sampling

Sampling Effort Results

Two hundred and twelve (212) setlines were deployed within the index zone (rkm110-135) between August 15 and October 5 2017. These deployments resulted in a total of four thousand six hundred and thirty-one (4,631.08) setline soak hours; the mean soak time for a deployment was twenty-one hours and forty-eight minutes (21.84 hours $\pm$ 2.24 hours' standard deviation). Setlines were typically deployed with twenty (20) or twenty-four (24) hooks, however some hooks become fouled, bent, broken, or bait-less during deployment. Excluding hooks that were retrieved as "damaged/baitless", the mean number of hooks fishing per setline was approximately 17 (exactly 16.58 $\pm$ 4.91 SD). The minimum number of hooks fishing upon setline retrieval was 0, and the maximum was 20. Only hooks that were fishing for the entire deployment were counted towards total hook-hours. A total of 75,713.33 hook-hours of effort were applied to the index zone in 2017. A summary of 2017 sampling effort is provided in the table below.

Table 1. Summary of setline effort and capture statistics for 2017 index monitoring.

Juv. WSG Captures	Setline Deployments	Effort (Hook-Hours)	CPUE (# WSG/100 hook-hours effort)	Distribution of Sampling
270	212	75,713.33	0.357	All river kilometres between 110-135; systematic 200m spacing within river kilometre.

Figure 4 shows the randomized block sampling relative to soak hours. The figure shows downstream sites (black bars) and upstream sites (lightest grey) were fished early and later in the sampling period. The randomized block sampling mitigates seasonal confounds on capture data. Figure 5 demonstrates effort was systematically applied to each river kilometre within the index zone.

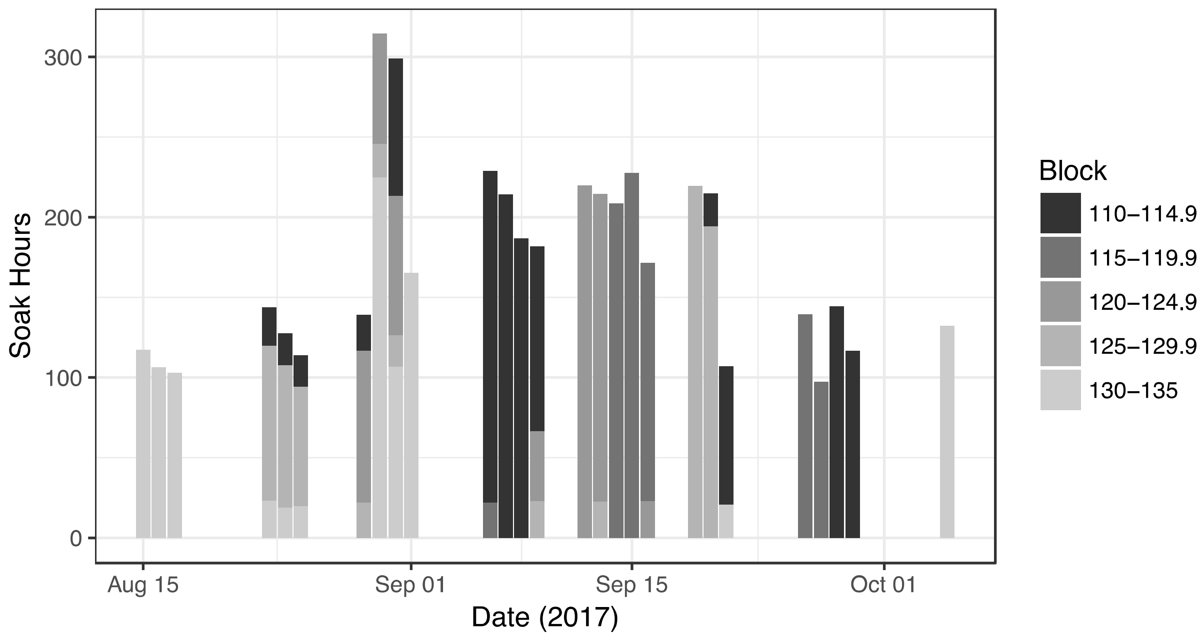

Figure 4. Stacked bar plot of setline soak hours by date. Shade of bar represents 5-km blocks of Nechako River sampled at least twice at random over the sampling period.

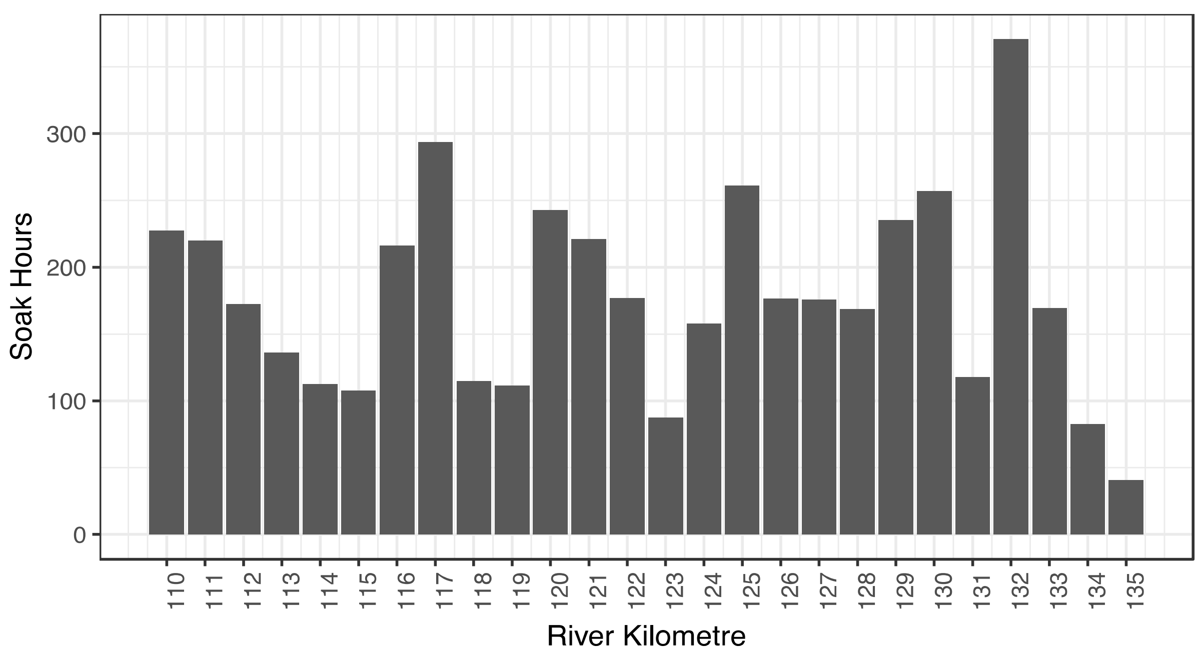

Figure 5. Bar plot of setline soak hours by river kilometre within the index zone.

Juvenile Sturgeon Capture Results

Two hundred and forty-five (245) unique juvenile sturgeon were captured within the index zone in 2017. Twenty-five of those individuals were caught twice in 2017 resulting in a total of 270 captures between August 17 and September 29. Catch-per-unit-effort (CPUE) was less than 0.5 captures per 100 hook hours on most sampling dates, except for September 7 (1.20 CPUE), 8 (1.23 CPUE), 26 (1.26 CPUE), 27 (1.10 CPUE), and 29 (1.94 CPUE) (Figure 6).

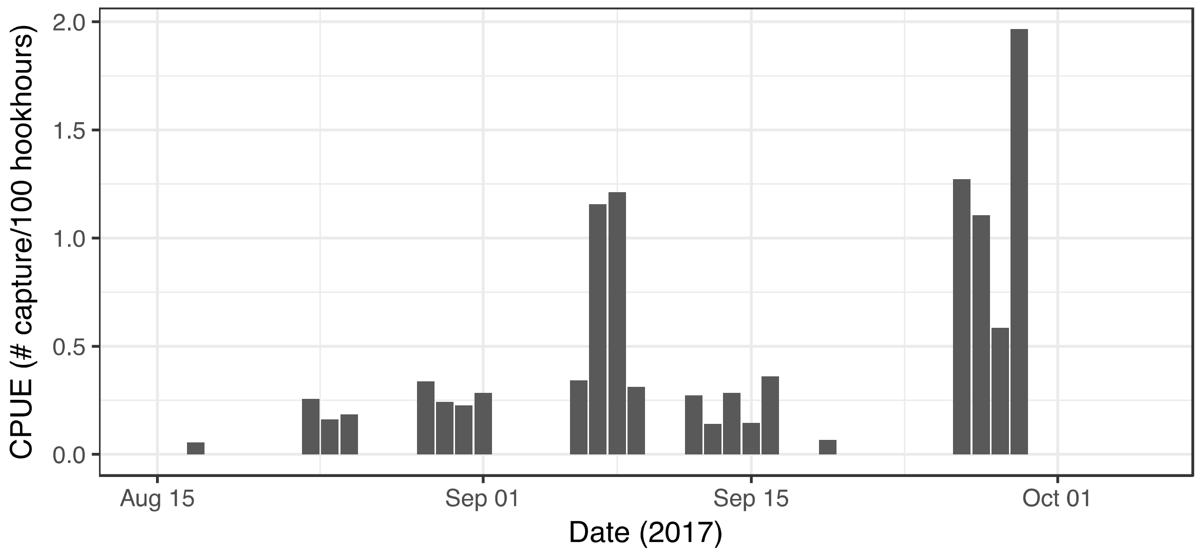

Figure 6. Summary of juvenile CPUE (# juveniles captured / 100 hook hours) by capture date during index zone sampling.

Sampling on dates when CPUE was greater than 1.0 was focused on Block 110-114.9 (black bars in Figure 4) and Block 115-119.9 (dark grey bars in Figure 4). Specifically, river kilometre 111 produced significantly higher juvenile sturgeon capture counts than any other river kilometre within the index zone (Figure 7). River kilometres 110, 112, 117, 120 and 125 produced 10 or more juvenile captures. Interestingly, a high proportion (88%) of river kilometres within the index zone produced at least one juvenile capture.

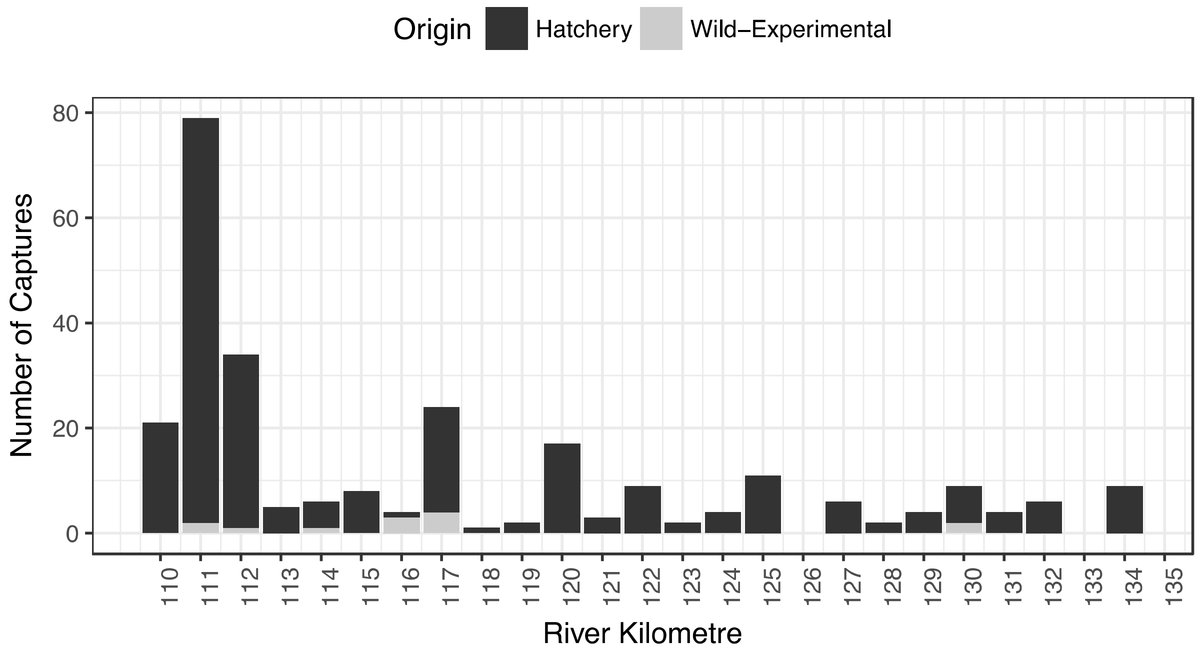

Figure 7. Capture counts of juvenile white sturgeon by Nechako River kilometre within the index zone. Shade of bars represent origin of juvenile captured.

Overall catch per unit effort within the index zone sampling was 0.357 juveniles per 100 hook hours but there are substantial differences in catch-per-unit-effort based on river kilometre (Figure 8). River kilometre 111 had the highest CPUE at 2.0 juveniles / 100 hook hours, followed by rkm112 with ~1.25 juveniles/100 hook-hours, and then rkm 117 with ~1.0 juvenile/100 hook hours. As expected due to hatchery releases, CPUE within the index zone in 2017 was higher than previous years. CPUE in previously documented low-use habitats was below average as expected.

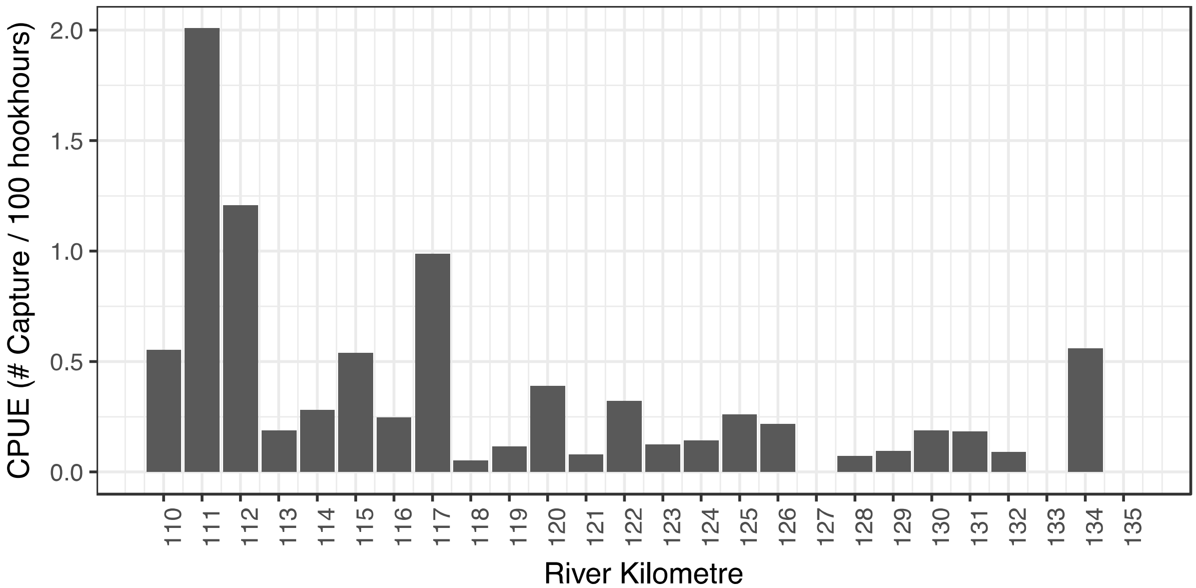

Figure 8. Catch-per-unit-effort for each river kilometer within the index zone

A total of 231 hatchery-origin and 14 non-hatchery-origin individuals were captured in the index zone during 2017; 21 individuals were released in 2015, 165 individuals were released in 2016, and 45 individuals were released in 2017. All individuals captured twice within the 2017 sampling period were hatchery-origin. Note that one capture of a 2017-release did not have a hatchery ID recorded, but given scute markings and small size at capture (red in Figure 9) it was counted as a 2017-release. Fourteen juveniles were wild-experimental origin. A histogram of hatchery juvenile fork lengths shows the smallest juveniles were released in 2017 ranging from 30cm to 40cm fork length. Fish captured from the 2016-release cohort ranged from 30cm to 55cm fork length, and the 2015-release cohort ranged from 40cm to 65cm fork length. One individual released in 2008 (as a 6-month old) measured within the 75cm to 80cm fork length category.

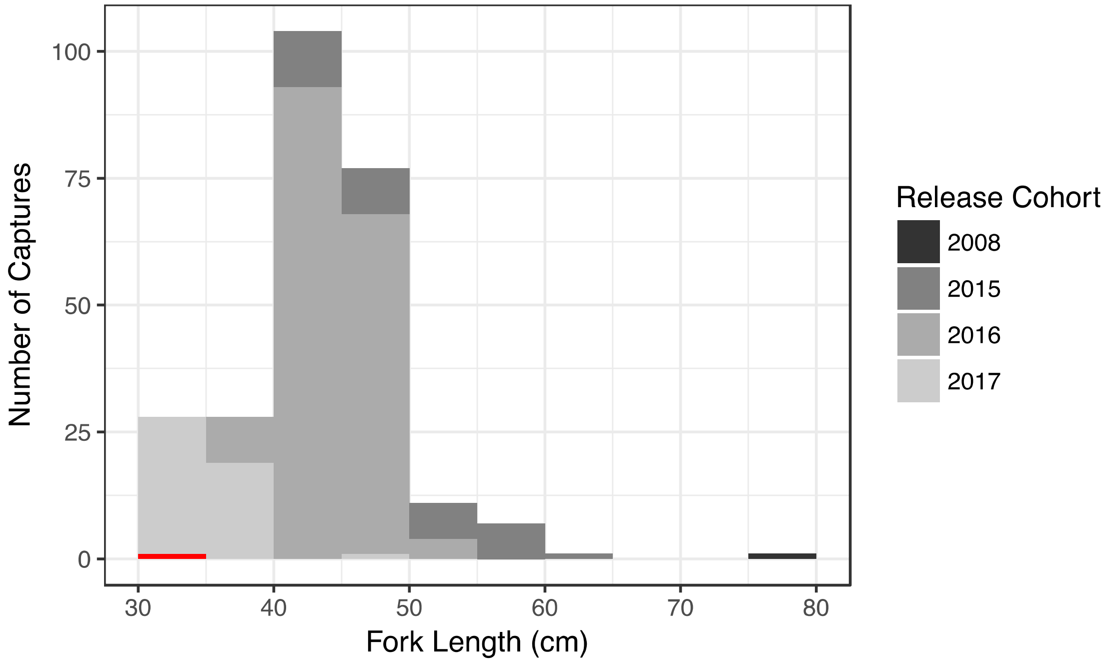

Figure 9. Stacked frequency distribution of hatchery-origin juvenile fork lengths. Shade of stacked bar represents hatchery release cohort. Red represents one capture with unconfirmed release cohort, but assumed to be 2017-release.

Wild-Experimental Origin Age Analysis

Age analysis of wild-experimental-origin juveniles will help monitor survival from early-juvenile to subadult life stages. Nine of the 14 wild-experimental-origin juveniles captured during index sampling were first time captures thus had age structures removed. One wild-experimental origin juvenile initially captured during peripheral sampling was later captured during index sampling; this individual is counted in the 14 wild-experimental-origin captures during index sampling. Ages and sizes of an additional two wild-experimental-origin juveniles captured during peripheral sampling are included in this section also. One age structure has not been analyzed. Five of the juveniles had previous capture records therefore age/year of origin was already available.

Spawn years of 16 Wild-Experimental individuals captured in 2017 are provided in Figure 10. Interrater reliability has not been assessed thus ages should be interpreted as estimates until accuracy can be validated through more readings. Age estimates show 11 individuals spawned between 2010 and 2012 with 2011 representing the modal spawn year. Previous juvenile monitoring reports have indicated juveniles spawned in 2011, and perhaps 2007, have been better represented in catches relative to juveniles originating from other years. In Chapter 6 “Wild-Experimental Origin Juvenile Status” a more comprehensive discussion of wild-experimental cohorts is provided.

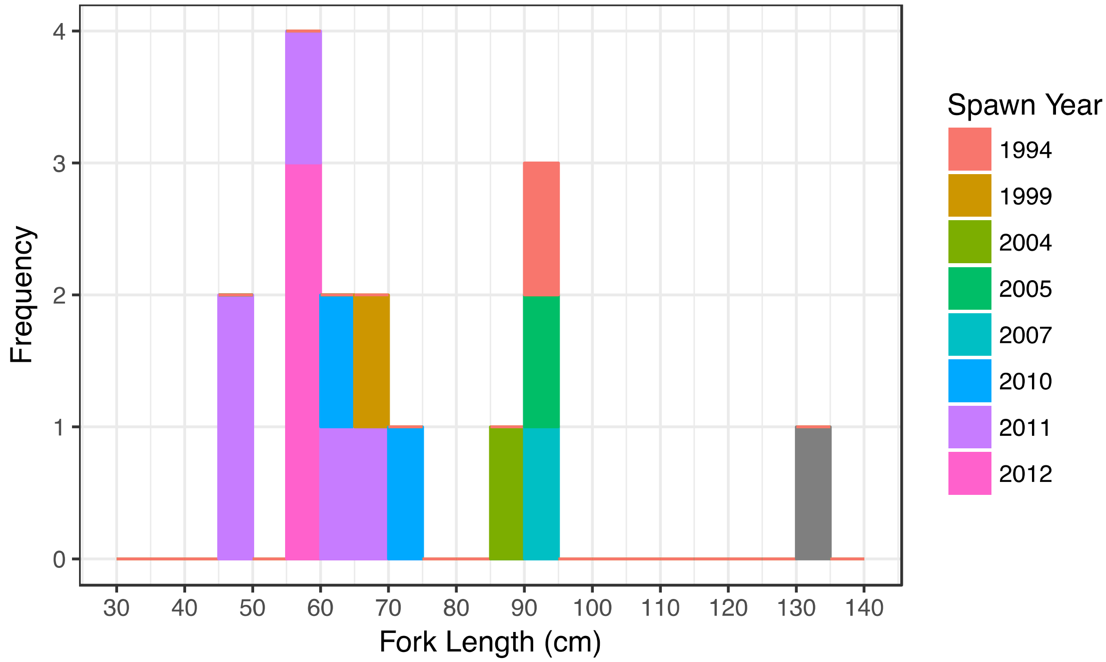

Figure 10. Fork length histogram where color of bar represents spawn year of the contributing individual (grey bar is unaged individual).

Hatchery-origin juveniles were distributed throughout the whole index region and wild-experimental-origin juveniles had patchy distribution around specific habitat units. Figure 11 is a map of the Nechako River index zone with juvenile sturgeon capture sites marked. The color of the point depends on the origin of the juvenile captured.

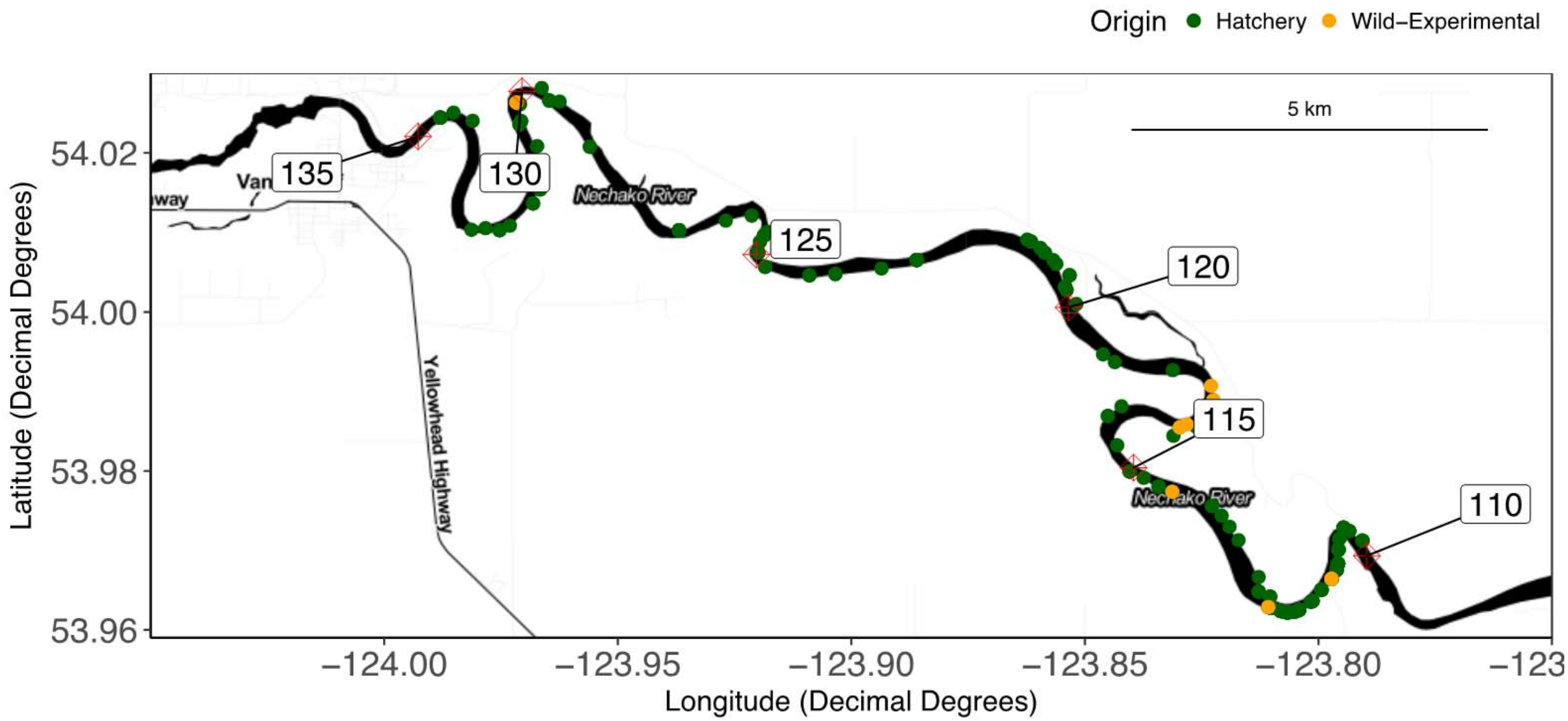

Figure 11. Map of Nechako River study area depicting distribution of juvenile WSG captured in 2017 (dark green dots – hatchery origin fish; orange dots – wild and experimental-origin fish). River kilometres are labeled and marked with a red X.

Hook Sizes

Large hook sizes (4/0, 5/0, 6/0, 8/0) were added to the array of standard hook sizes (4, 2, 1, 1/0) that had previously been used on the juvenile setlines. The larger hook sizes were intended to target subadult sized sturgeon (>100cm FL). This was intended to better understand if subadult sized sturgeon were present in the index zone. Boxplots reveal that hook size did not strongly influence the mean fork length (FL) of juveniles captured (Figure 12), however 5/0 and 8/0 hook sizes did capture the largest individuals within the catch. The 5/0 hook size was most successful at capturing individuals greater than 70cm FL (6/7 from index sample). Only one fish greater than 100cm FL was captured (on a 5/0 hook), that fish measured 131 cm FL.

Few white sturgeon in the 100-130cm FL range have been captured with the juvenile hook array used in previous years of sampling. The low catch rate of individuals measuring longer than 100cm FL in 2017 (and previous years) suggests subadult sized fish are not abundant within the index zone. Effort for each hook size is displayed in Table 2.

Table 2. Summary of hook hours applied to index zone by hook size.

Hook Size	4	2	1	1/0	4/0	5/0	6/0	8/0
Hook Hours	15036	15226	14259	14724	2687	9700	2560	2662

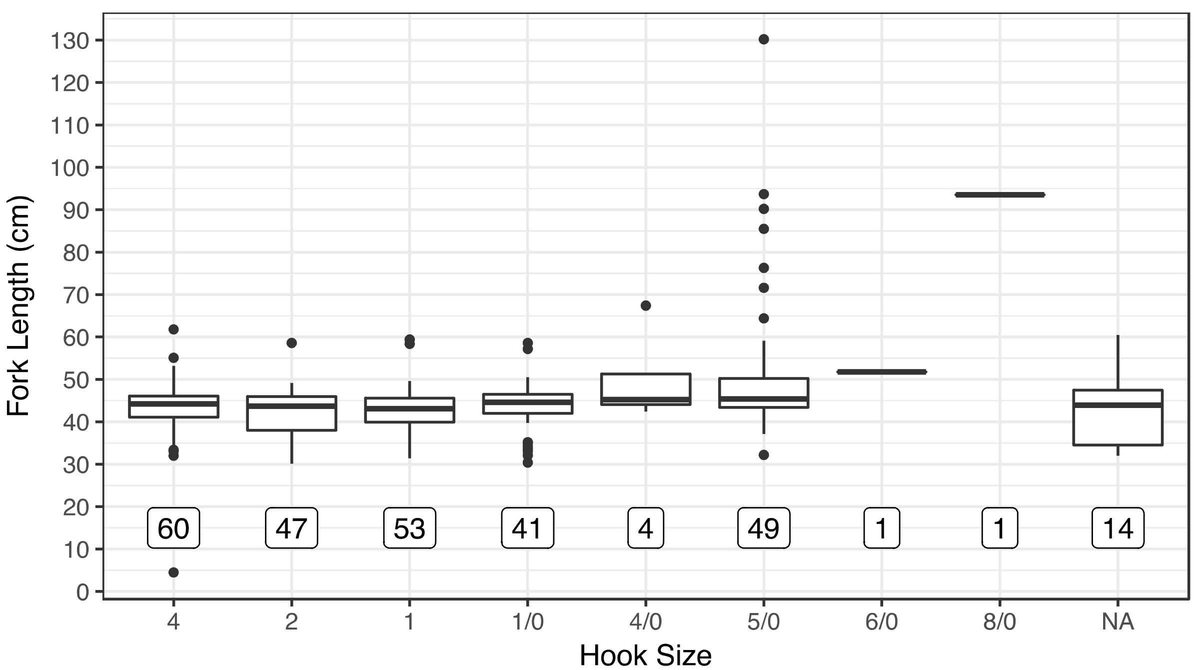

Figure 12. Boxplots of fork length per hook size. Boxes contain 50% of data, whiskers contain inter-quantile range, and median value shown using heavy black line within boxes. Outlier values indicated using black points, and sample sizes are labeled under each box.

Index Sampling Discussion

CPUE and Habitat Use

As anticipated, in 2017 there was a substantial increase in total number of juveniles captured. Interestingly, overall CPUE within the index zone remained similar from 2015 – 2017, however CPUE for some habitat units was slightly different compared to previous years. Notable is the high number of captures and CPUE within rkm111 in 2017 (relative to 2015 and 2016), while other high-use habitat units around rkm116 and rkm125 did not show a similar trend in 2017. One possible explanation might be high rates of conspecific competition in traditional high-use areas upstream has forced a large number of juveniles (mostly hatchery) to other habitats. Another possible explanation might relate to annual variation in predator presence at certain habitat, forcing and condensing juvenile sturgeon to other habitats. Future monitoring within the index zone and in peripheral upstream and downstream habitats will be crucial to monitoring the dispersion of hatchery juveniles.

Status of Juvenile Recruitment

The capture sample in 2017 was comprised of individuals from all three of the recent hatchery release cohorts. The presence of 2015-release cohort and their general growth to sizes ranging 40-65cm FL is an encouraging sign of survival of individuals from this cohort. Implementing the use of large hook sizes (5/0, 6/0, 8/0) did not return a high number of subadult sized sturgeon in Nechako River. Recent hatchery cohorts have likely not yet grown >65cm FL. The presence of very few subadult sized pilot-hatchery and/or wild-experimental fish suggests there may be significant early and late juvenile survival barriers (confirming ongoing recruitment failure).

One Wild-Experimental-origin sturgeon measured 130.2cm FL was captured at rkm116.8, which is the habitat unit considered as an overwintering site for adult and juvenile sturgeon. Three out of 4 sturgeon greater than 90cm FL were captured at that specific site, and all four fish longer than 90cm FL were Wild-Experimental-origin. The small number of 90+cm FL Wild-Experimental juveniles suggests a small degree of survival from late juvenile to subadult life stages in Wild-Experimental cohorts. In addition, the consistent presence of a small number of Wild-Experimental-origin juveniles in the index capture sample, with a wide range of spawn cohorts suggests natural spawning sporadically results in individuals that survive to the early juvenile life stage.

Considerations

The index sampling program in 2017 was like previous years in methodology except for four differences:

1) Hook hour effort within the index zone increased 208% in 2017 compared with 2016

2) Effort was applied in a way that minimizes potentially confounding environmental factors
3) Effort was applied such that each river kilometre within the index region was sampled nearly equally, and,
4) Some river kilometres which were strategically sampled a second time.

Ensuring effort was applied within each river kilometre ensures that juveniles in patchy but suitable habitat are targeted for capture. This methodology improves the likelihood of capturing juvenile sturgeon in “low-use” habitats. Ensuring effort placed into sampling blocks was randomized in time reduced potential influence from seasonal movement bias on distribution. Maintaining a 2017-level effort will help collect more capture data for building a mark-recapture dataset in a timely manner.

Chapter 3 – Peripheral Sampling

Sampling Effort Results

One hundred and twenty-one (121) setlines were deployed in several different zones peripheral to the index zone between September 5 and October 20 2017. These deployments provided a total of 2531.61 setline soak hours; the mean soak time for a setline deployment was twenty hours and fifty-five minutes (20.92 $\pm$ 5.66 hours). Setlines were typically deployed with twenty-four (24) hooks, however some hooks become fouled, bent, broken, or bait-less during deployment. Excluding damaged/baitless hooks the mean number of hooks fishing per setline was approximately 21 (exactly 20.68 $\pm$ 6.25 hooks). The minimum number of hooks fishing upon setline retrieval was 1, and the maximum was 24. Only hooks that were fishing for the entire deployment were counted towards total hook-hours. A total of 55,879.65 hook-hours of effort were applied to the peripheral zones in 2017. Effort was relatively evenly spread out across sampling dates (Figure 13).

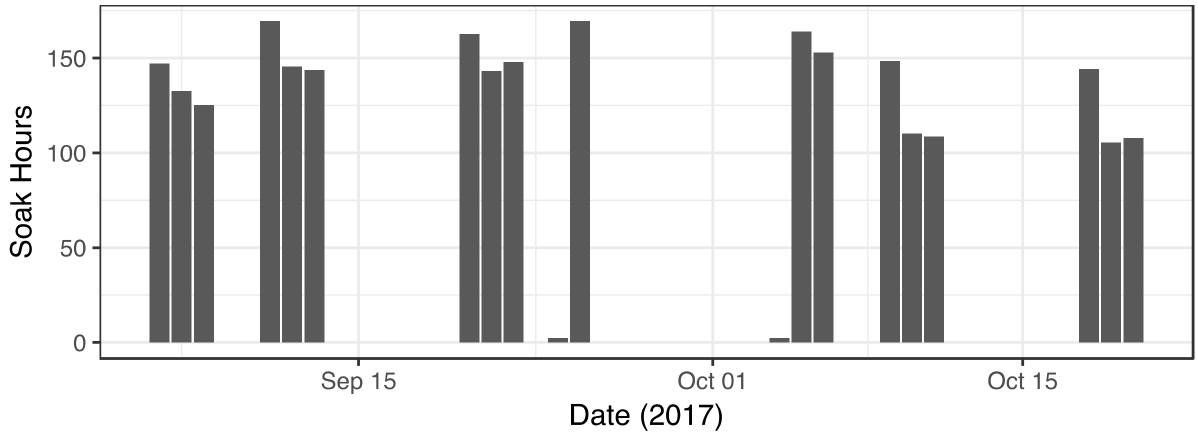

Figure 13. Summary bar plot of setline soak hours by sampling date in peripheral zones during 2017.

Peripheral sampling occurred in several 5-km or 10-km zones. The zones were spread between the lower Nechako River (rkm25-30), mid Nechako River and Stuart River confluence (rkm88 – 99, rkm100-109), and upper Nechako River and Nautley River confluence (rkm159-162). These areas were selected based on expert opinion (Figure 1).

Setline placement within these zones was initially guided using a random placement method, however once the zones had been surveyed setline sites were chosen based on habitat characteristics suiting juvenile sturgeon (e.g. relatively deep habitat, deposition area, side-channel eddy). Each peripheral zone tended to have one or several river kilometres that were sampled more heavily (e.g. more than 100 soak hours) and several river kilometres that were sampled less heavily, related to the presence of suitable habitat within those kilometres.

Juvenile Sturgeon Capture Results

Fourteen (14) unique juvenile sturgeon were captured in the peripheral zones between September 05 and October 20. The captures occurred across the range of sampling dates but there was a higher number of captures during early September (Figure 14).

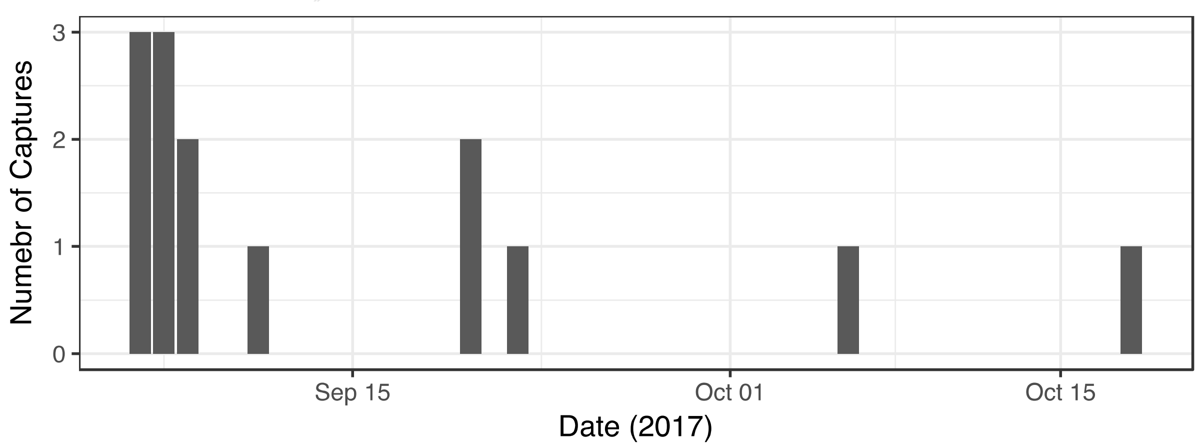

Figure 14. Frequency plot of juvenile sturgeon captures in the peripheral zones by sampling date

Nine juvenile sturgeon captures occurred between river kilometres 100 and 109 immediately downstream of the index zone, four captures occurred near Stuart River confluence between rkm93 and 95, and one capture occurred in the lower Nechako River near the Miworth area at rkm29 (Figure 15). The sampling downstream of the index zone offer new information regarding the distribution of hatchery-origin juveniles in present environmental and demographic conditions.

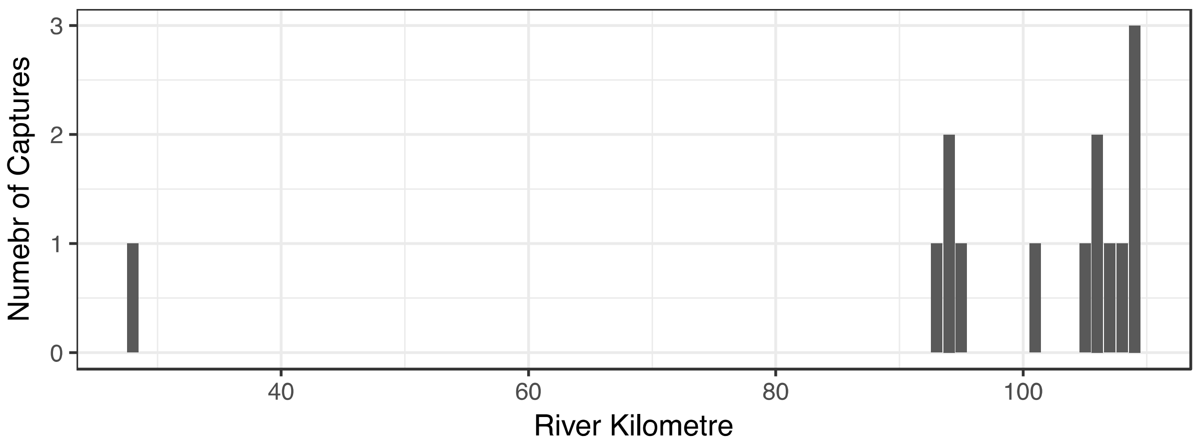

Figure 15. Frequency plot of juvenile sturgeon captures by river kilometre in peripheral sampling zones of the Nechako River.

Although there were captures of juvenile sturgeon in peripheral habitat downstream of what is considered the high-use habitats within the Nechako River Index Zone, the catch-per-unit-effort in the peripheral zones was substantially lower than high-use habitat units within the index zone (Figure 16).

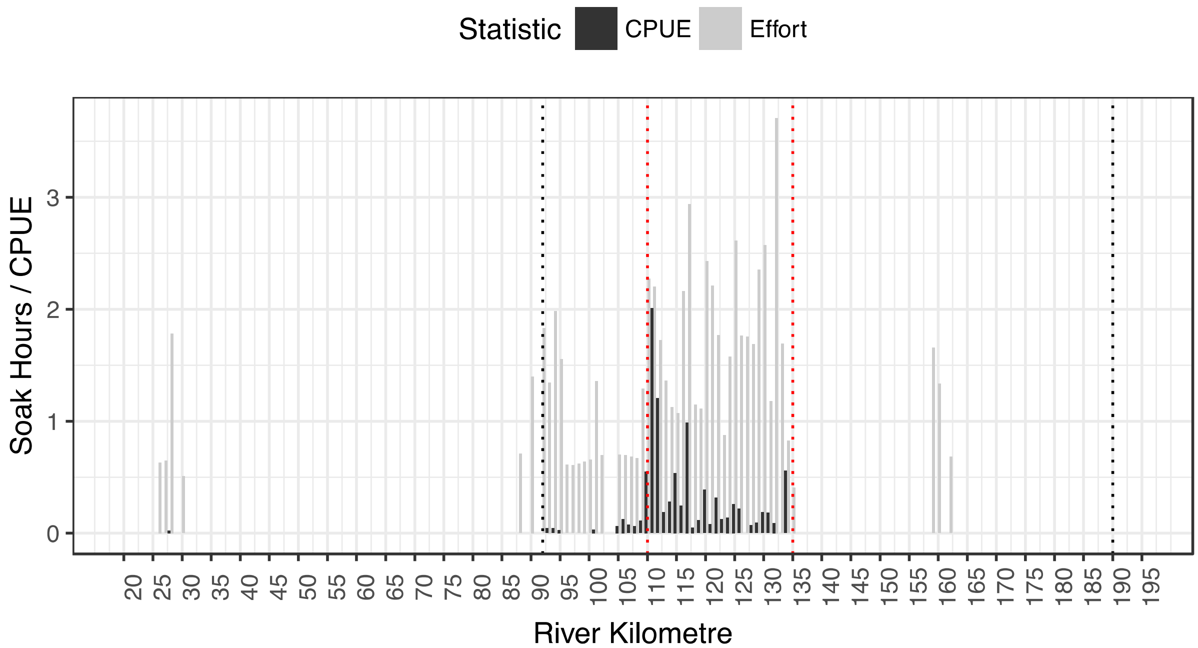

Figure 16. Bar plot of soak hours (light grey bars, y-value x 100) and CPUE (black bars, # juveniles / 100 hook hours) to show distribution of sampling effort and juvenile captures in Nechako River. Dotted black lines mark confluences of Stuart River (rkm92) and Nautley River (~rkm190). Dotted red lines mark the current index zone boundaries.

Capture results from peripheral sampling indicate there are juvenile sturgeon occupying habitats outside of the index zone, albeit much less commonly than within the index zone, except for rkms105 – 110 which show sturgeon densities similar to the index zone. Results in 2017 suggest rkm105-110 have similar juvenile density to low-use habitat units within the index zone, and the two other peripheral habitat units may have even lower juvenile density. However, this is the first year of results from peripheral zones. Repeat/ongoing sampling in the peripheral habitats will provide more certainty in juvenile density interpretations from CPUE data.

Eleven of the fourteen individuals captured during the peripheral sampling were hatchery-origin fish, and three were Wild-Experimental origin. Seven of the 11 hatchery juveniles captured in the peripheral zones were released in 2016, three were released in 2017, and one was released in 2015. No individuals from other hatchery release-years were captured in peripheral sampling zones.

One of the wild-experimental origin juveniles was kept and radio-tagged at the hatchery facility then released; that juvenile was spotted several days later near rkm117 as a mortality. This is the only post-release mortality suspected in 2017. Another wild-experimental-origin juvenile was first captured and tagged during peripheral sampling and then subsequently captured during index sampling; this individual's age and size are addressed in Chapter 2 "Wild-

Experimental-Experimental Origin Age Analysis" section. The third Wild-Experimental-origin juvenile was captured and tagged in peripheral sampling and its age and size are also addressed in Chapter 2.

Hook Sizes

The same array of standard and larger sized hooks that were used in the index zone in 2017 were also used in the peripheral sampling program (excluding 5/0). Figure 17 indicates there is no clear relationship between increasing hook size and the fork length of captured fish (likely due to the small sample size), however the 6/0 hook size (2^{nd} largest) did capture the largest fish (69.9cm FL) sampled from the peripheral zones. Effort for each hook size are presented in Table 3.

Table 3. Summary of hook hours applied to peripheral zones by hook size.

Hook Size	4	2	1	1/0	4/0	6/0	8/0
Hook Hours	9528	9810	9625	9708	6192	6060	5773

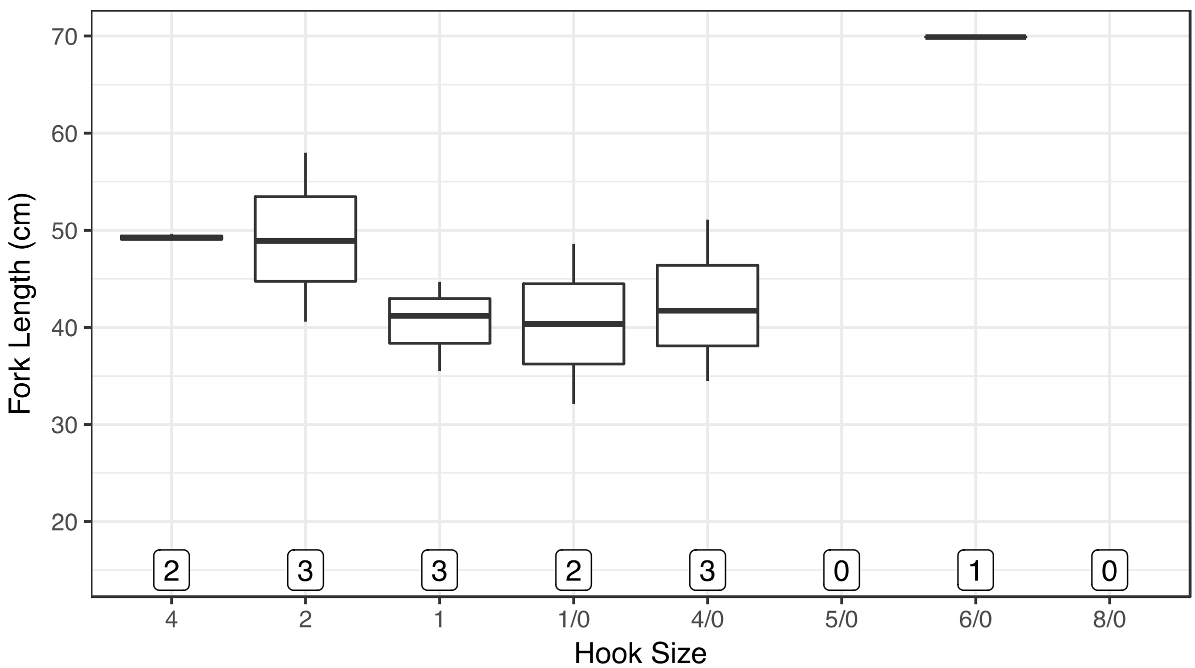

Figure 17. Boxplot of sturgeon fork length (cm) per hook size. Boxes contain 50% of data, whiskers contain inter-quantile range, and median value shown using heavy black line within boxes. Outlier values indicated using black points, and sample sizes are labeled under each box.

Peripheral Sampling Discussion

Peripheral sampling was conducted in 2017 to better understand dispersion of hatchery releases within the Nechako River and to identify juvenile presence and habitat use outside of the index zone. Fourteen captures outside of the index zone is significant and demonstrates that hatchery juveniles are migrating downstream of index zone habitats. However, CPUE in peripheral zones is below the mean CPUE for the index zone, and well below CPUE for habitat units that are considered crucial habitat for rearing juveniles (e.g. rkm110-112, rkm115-118, rkm134). Despite the relatively low CPUE there is significant reason to continue monitoring peripheral zones in the future, and likely add additional areas to the peripheral sampling. Downstream and upstream habitat use (relative to index zone) may become more common as the juvenile population grows in response to stocking efforts.

One juvenile sturgeon released in 2017 was captured at rkm28 in Nechako River and is the largest downstream migration confirmed by juvenile sampling. This lone capture suggests the downstream extent of this fish's movement was not common among either hatchery or wild-experimental-origin juveniles. This is supported by juvenile telemetry records (CSTC 2009, 2017) and the results of juvenile sampling in the Nechako River. However, it confirms the need to continue monitoring efforts at downstream sites into the future.

Continued monitoring of the peripheral zones will be critical to understanding downstream movements and habitat use by hatchery and wild-experimental-origin juveniles.

Chapter 4 – Juvenile Telemetry in Nechako River

Introduction

Acoustic and radio telemetry are reliable and efficient technologies that can help answer questions related to migration of juvenile sturgeon in Nechako and Fraser river systems. They may also provide insights on survival of juveniles in the system (e.g. areas of poor migration success related to prevalence of predators). Radio telemetry was used in 2016 to study the dispersion of newly released hatchery juveniles, however approximately 80% of radio tags were detected on-shore near wildlife middens, and in some cases physically recovered (CSTC 2017, Pers. Comm. Ian Spendlow). Survival of radio tagged individuals was low but it was unclear if low survival was a function of a tagging effect or reflective of the survival experienced by the whole population of newly-released juveniles. One possible mechanism that could introduce tagging effects is how visually salient the juveniles are to predators. Radio tags have an external antenna which may provide visual cues for predators, but acoustic tags are entirely internal and do not provide visual cues.

Two groups (15 fish in each) of acoustically tagged juveniles were used to test if external visual cues (i.e. a radio antenna) may influence juvenile migration success. One group had only an acoustic tag implanted (pure acoustic), and one group had an acoustic tag implanted with a fake radio antenna trailing external to the fish (dummy radio/acoustic). A third control group (also 15 fish) had a radio tag implanted (with external antenna) for comparison with the acoustic groups. Monitoring the movement of acoustic tagged individuals was accomplished using acoustic receiver checkpoints spread throughout the Nechako River index zone. Active tracking using a mobile acoustic receiver was also necessary to monitor for juveniles in between the checkpoints. Boat or aerial mobile tracking was the primary method for monitoring movement of radio tagged individuals.

Methodology

Tagging and Release

Juveniles were netted from hatchery rearing tanks. Once netted the juveniles were measured, tagged with PIT tag and weighed. Individuals selected from radio or acoustic tagging were then surgically implanted with either a V9-HP (VEMCO/AMIRIX Canada, NS.) acoustic tag (tag life 487 days) with or without fake antenna, or MST-930 (Lotek Inc. Canada, Ont.) radio tags. Juveniles were held for 28 to 30 days to monitor for adverse tagging effects. None were observed.

Fifteen juveniles were released in each group of the telemetry sample (acoustic, dummy radio/acoustic, and radio) for a total of 45 juvenile individuals in the telemetry sample (Appendix 1). The telemetry sample was released on May 19 2017 at rkm 136.9 (the Vanderhoof release site for all hatchery juveniles).

Acoustic Detections/Checkpoints

Thirteen (13) VR2W acoustic receivers (AMIRIX/VEMCO, Nova Scotia Canada) were deployed individually in locations identified as ideal checkpoint locations (determined using river channel morphology and spacing relative to other sites; Figure 18).). The acoustic receivers were deployed on May 3 2017. All receiver stations were checked, downloaded, and cleaned on June 6, July 6 and July 12, and finally retrieved on October 25, 2017. On July 14 two receiver stations (rkm138 and rkm137) were moved downstream to rkm97 and rkm92. Receiver stations at rkm110, rkm106, and rkm105 were downloaded on September 8 as well. Receiver station at rkm98 was pushed downstream to rkm95 by September 22, and receiver station at rkm92 went missing and was never downloaded. The receivers continuously recorded during the monitoring period from May 3 to October 25 2017.

In addition, 7 boat acoustic surveys were conducted from a drifting boat while a VR100 continuously monitored upstream and downstream directions for 30 seconds each. Three surveys occurred in June, three surveys occurred in July, and one survey in October. A directional hydrophone allowed for operators to more precisely locate the signal source.

Radio Detections

Mobile (boat) radio telemetry surveys using a SRX-800 radio receiver (Lotek Inc., Ontario Canda) and a radio receiver station installed near rkm136 (other receiver stations) provided radio telemetry effort during the 2017 monitoring season. Mobile and stationary radio receivers scanned all bandwidths with active radio tags (e.g. 148.xxx, 149.xxx, and 151.xxx MHz bandwidths).

Thirteen (13) mobile radio telemetry surveys occurred between 2017-05-04 and 2017-10-26. Mobile surveys generally covered from rkm140 to rkm120, however two surveys went as far downstream as rkm105. Two aerial radio telemetry surveys were conducted on 2017-06-23 and 2017-10-26 which covered rkm50 to rkm192. Those surveys monitored 151.420 and 151.700 MHz.

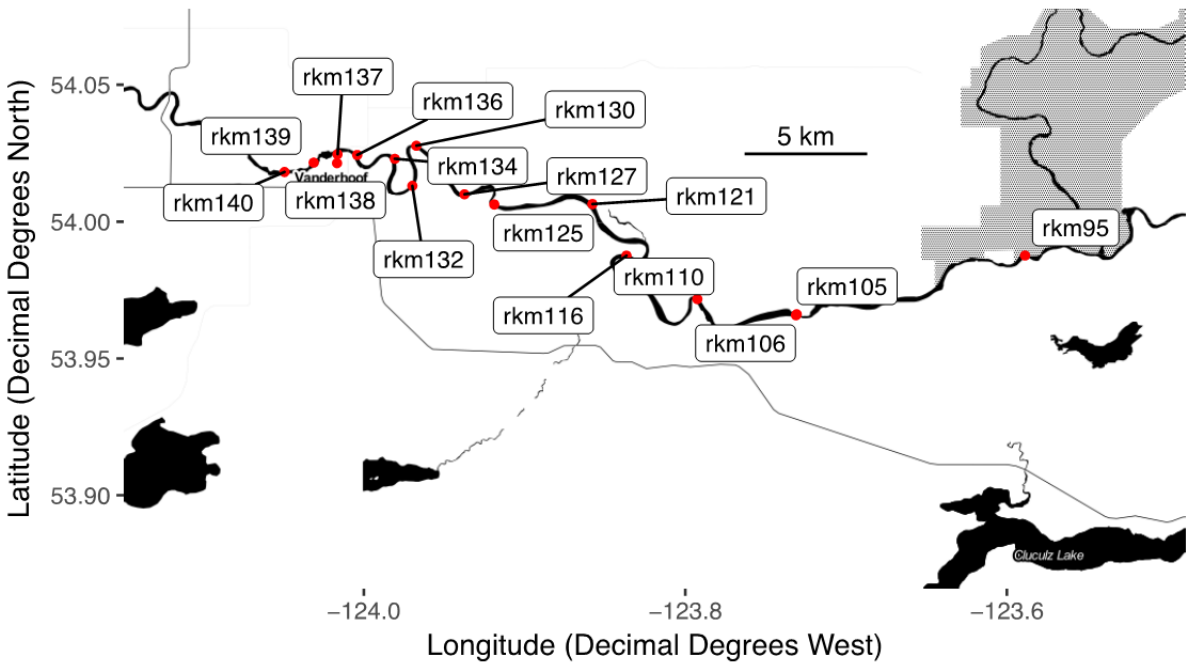

Figure 18. Map showing location of acoustic receiver checkpoints deployed in Nechako River during 2017 monitoring.

Results

All 45 tagged juveniles were detected by their respective receivers near rkm137. At the time of release the 2017 Spawn Monitoring VPS was installed between rkm137.6 and rkm136.5, this acoustic detection system provided detections of all 30 acoustic individuals (CSTC in prep.). Figure 18 shows the location of acoustic checkpoints and radio stations operating during the monitoring period. Figure 19 provides the number of individuals detected at each receiver location from each group. A radio tagged individual qualified for detection so long as it was detected at or downstream of the acoustic receiver site.

All three telemetry groups had similar numbers of individuals migrate to rkm116, but group migration success differed based on river sections between acoustic checkpoints. Acoustic telemetry group had 10 individuals migrate past rkm 134 therefore 5 individuals did not migrate downstream of rkm134. The failure of 33% of acoustic-only individuals to migrate past rkm134 may demonstrate high predation pressure between rkm137 and rkm134. However, Dummy and Radio telemetry groups had much better migration success between rkm137 and rkm134 compared to Acoustic telemetry group. Radio telemetry group demonstrated poor migration success between rkm132 and rkm127 with 6 individuals showing no further downstream migration. Dummy telemetry group demonstrated the best migration success from rkm137 to rkm127 with 9 individuals successfully migrating to rkm127. However, Dummy telemetry group was the least successful of the three telemetry groups migrating from rkm127 to rkm125 with 4 individuals showing no further downstream migration. All three telemetry groups demonstrated similar detections between rkm125 and rkm116 one individual from each group showing no further detections. Thirteen of the 45 tagged individuals were detected near rkm116; 5 individuals in acoustic group, 4 individuals in radio and dummy radio/acoustic groups each (Figure 19). The detections for all three tagging groups suggest each had similar but low migration success (20-30% of individuals from each group) to rkm116.

Individuals failing to show downstream movement (via gate detections) through the Index Zone can be interpreted several ways. Juveniles commonly move through the index as far downstream as high use habitats at rkm116, however juvenile sampling has identified high-use habitat near rkm134 and rkm125 and therefore some juveniles may only migrate to these habitat units then take up residence. Mobile acoustic surveys can detect juveniles between checkpoint-gates but can’t discern between holding behaviour or mortality. One interpretation of the combined checkpoint and mobile detections could be that if juveniles are not engaged in downstream migration and are not detected between checkpoints, those tags have been removed from the river and are likely mortalities. The fate of acoustic and radio tags are discussed in more detail below.

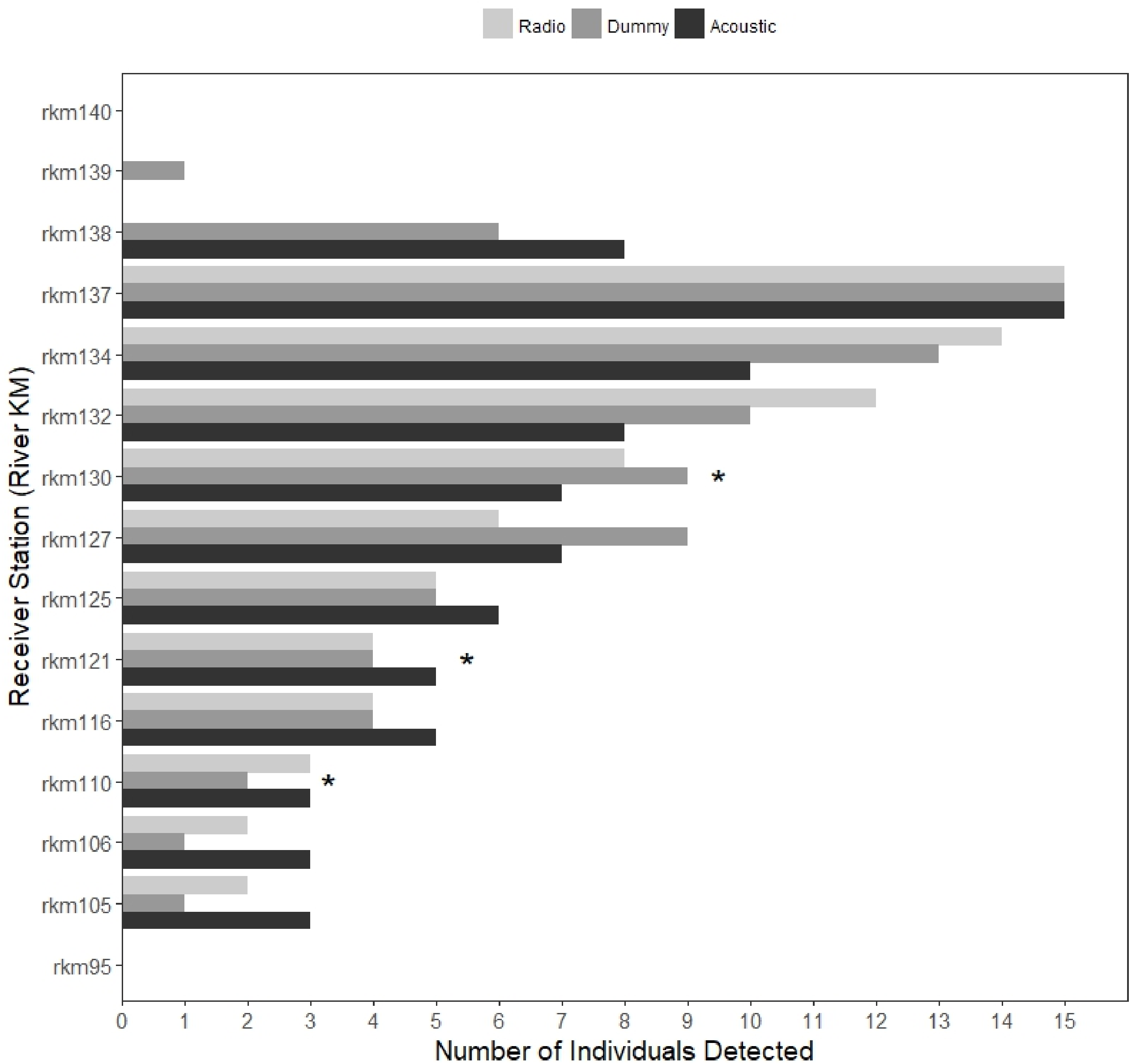

Figure 19. Bar plot showing number of individuals with acoustic (15), fake radio (acoustic w/ antenna) (15) and radio (15) tags detected at receiver checkpoints from each telemetry group from May 19 to October 26 2017. Individuals were released at rkm 136.9 on May 19. Stars flag stations that were bypassed by an acoustic individual that was detected at downstream stations.

Acoustic Telemetry

Acoustic telemetry provides relatively fine-scale spatial movement patterns because acoustic checkpoints are generally spaced much closer than radio telemetry stations. However, unlike radio telemetry, acoustic telemetry makes it difficult to discern fate of tagged animals when they disappear from detection records. Radio tags can be detected and recovered even after removed from the river but acoustic tags cannot be detected out of river.

Mobile acoustic boat surveys were conducted to provide detection coverage between the acoustic checkpoints and hopefully detect tags that otherwise would appeared to have taken up residence according to the checkpoint detection records. Five juveniles were detected in June, and three different juveniles were detected in July (last detection date was July 13). Only one juvenile was detected on October 12 near rkm113. Thirty-four adult acoustic tags were detected during the same acoustic surveys, and 13 of those were on October 12 implying the mobile receiver was functioning effectively.

Plotting detection locations over time for all acoustic tags reveals different movement profiles for different tags. Some individuals from both acoustic and dummy groups quickly migrated downstream, typically as far as rkm127 station (Figure 20). Other individuals remained near upstream detection stations, but this was much more common in the acoustic telemetry group. Three individuals in acoustic group were detected near rkm105. No more upstream detections were made for those three individuals, and their last detection dates were June 26, July 1, and July 23, 2017 (Figure 20). One individual in dummy radio/acoustic group was detected at rkm105, but later detected upstream at rkm110 (Figure 20). Significant upstream movements (i.e. full distance between two acoustic checkpoints) were uncommon in both acoustic telemetry groups. The last acoustic detection was made on July 26th 2017 at rkm110 (Figure 22). Mobile acoustic surveys conducted after July 26th did not detect any juvenile acoustic tags between receiver sites. To summarize, 26 of the 30 acoustic tags released in 2017 had detection profiles between the upper (rkm137) and lower (rkm105) receiver checkpoints but eventually could not be detected (despite mobile surveys) suggesting 26/30 acoustic tags were removed from the river. The remaining 4 acoustic tags appear to have migrated downstream of rkm105 and may still be alive.

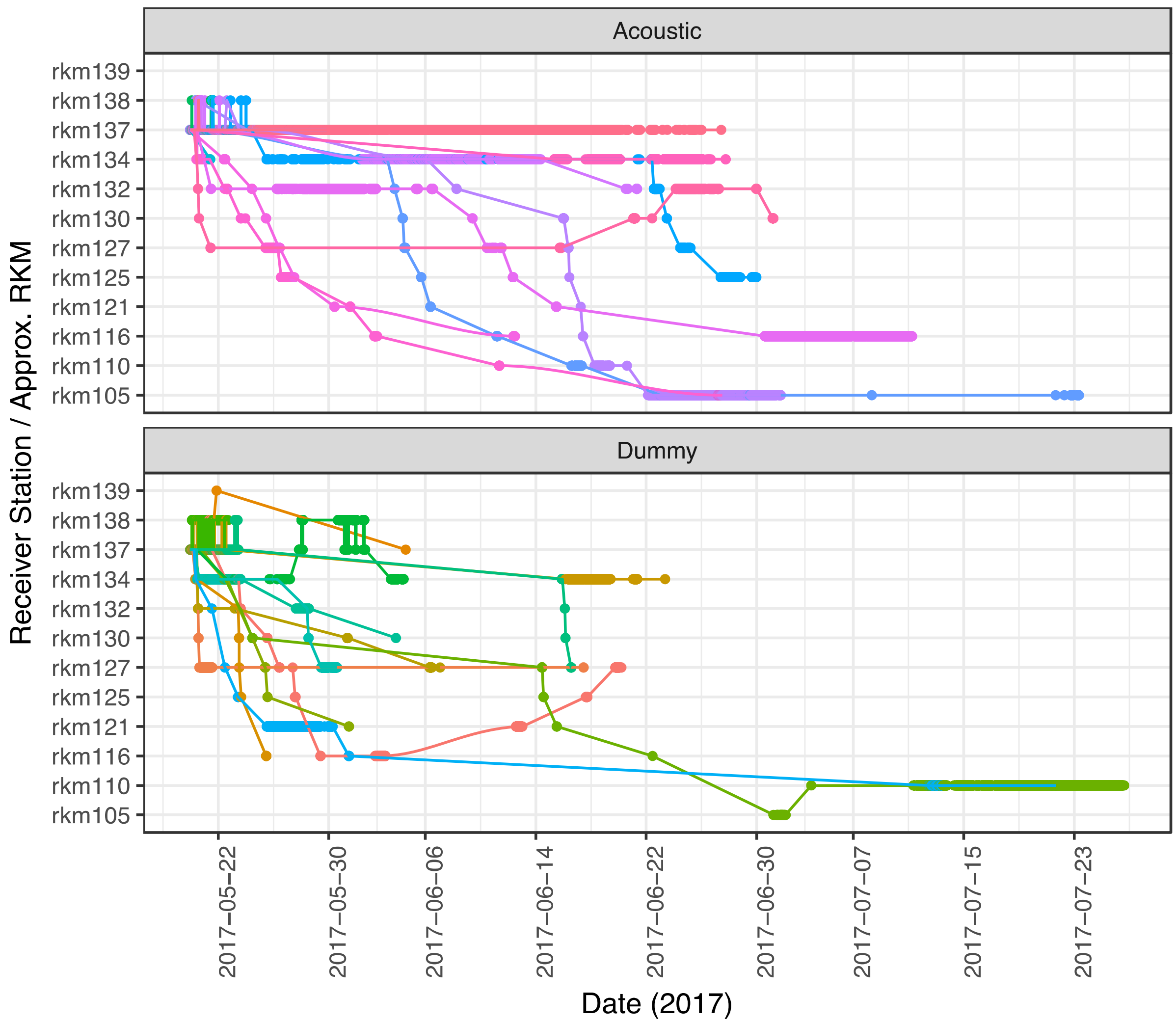

Figure 20. Movements of individuals in Acoustic and Dummy Radio/Acoustic telemetry groups using detections at acoustic receiver sites over time.

Radio Telemetry

A total of 77 unique radio tagged individuals were detected on mobile boat surveys. Thirty detections were radio tagged juveniles (e.g. 151.420 or 151.700 mHz); four detected tags were released in 2015 (a total of 15 radio tagged juveniles were released), 11 detected tags were released in 2016 (a total of 15 radio tagged juveniles were released), and 15 detected tags were released in 2017 (i.e. all 15 radio tags released in 2017 were detected). The remaining 47 tags detected in 2017 were adult radio tags. Adult telemetry results are reviewed in context of spawn monitoring in another report (CSTC 2018 in prep). The radio tags implanted in juvenile white sturgeon have an expected 444 - 723 day tag life. Tags released in 2015 are expected to stop signalling sometime between autumn 2017 and autumn 2018. Tags released in 2016 are expected to stop signalling sometime between autumn 2018 and autumn 2019.

For the 30 juvenile tags detected in 2017 survival status was classified as "Alive", "Dead", and "Undeterminable" based on inferences from their radio detection profiles (Figure 21). "Alive" tags showed consistent and movements greater than 1 kilometre. "Dead" tags did not display movement for at least three surveys. "Undeterminable" tags were either detected once, or had two detections in similar locations. In addition, some radio tags were recovered and therefore confirmed dead. Those tags are marked with "X" points in Figure 21.

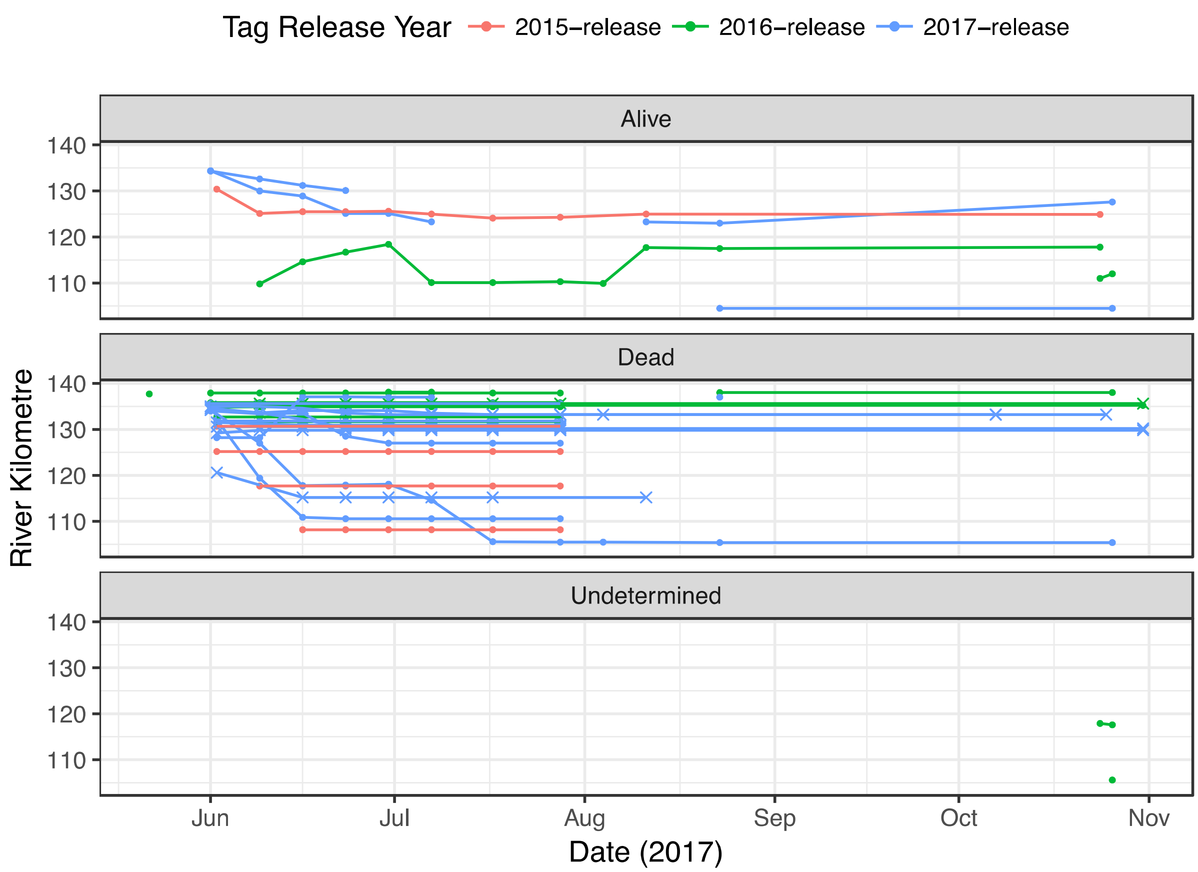

Figure 21. Radio detection profiles of thirty juvenile radio tags detected in 2017. Color shows which year tags were released. X-points are tags that have been recovered (confirmed dead).

Radio telemetry data show many radio tags do not migrate past rkm130 (Figure 21), which is corroborated by the survival model (discussed below) in which radio tags experience lowest survival between rkm132 and rkm130. "Alive" tag last detection locations range throughout the index zone near rkm125, rkm117 and rkm112 suggesting multiple juvenile over winter habitats within the index zone. Note most of the last detection locations were also high-CPUE habitat in 2017. Radio tagged individuals were detected near rkm105 via aerial survey, but not downstream of rkm105. To summarize, 4 of 15 radio tagged individuals released in 2017 were "Alive" status by October 26 2017, and the remaining 11 individuals were "Dead" status. Of the 11 "Dead" tags 3 were recovered thus confirmed mortalities. Two radio tags released in 2017 were detected near rkm105; those individuals were detected near rkm105 in mid-August and again in late October suggesting those fish are holding in that habitat and not migrating further downstream.

A Cormack-Jolly-Seber model was used to determine probability of successful migration (survival) between detection checkpoints. This analysis includes acoustic checkpoint data, as well as stationary and mobile radio detection data. Although numbers of successful migrants to rkm116 have already suggested similar migration success to rkm116 (Figure 19), the mark-resight survival analysis can be useful for identifying river reaches with low juvenile migration success. Combined across all tagging groups, the probability of migration success between the top five gates (137-134, 134-132, 132-130, and 130-127) was between 80% and 90% (Figure 22 lightest grey column). Note that the two acoustic telemetry groups (Figure 22 Dummy and Acoustic groups) had slightly lower probability of survival between rkm137 and rkm132 compared to the radio telemetry group, and substantially higher probability of survival between rkm132 and rkm127. The reach between rkm127 and rkm125 appears to be an area of lower survival relative to the other reaches within the index zone. Combined tagging group survival from rkm125 to rkm116 was greater than 85%, but drops to between 60% and 75% survival from rkm116 to rkm105.

There are interesting group trends between radio and dummy radio/acoustic groups; when radio group tends to have high probability of success the dummy group tends to have lower probability and vice versa. The pure acoustic group tended to have moderate migration success relative to radio and dummy groups. The reaches with lowest survival probabilities include rkm127-125, rkm116-110, and rkm110-105. No tagged individuals were detected near rkm95, however rkm95 was not deployed until July 14 2017, potentially allowing downstream migrants to pass undetected prior to then. The “Overall” interval is a mean probability of migration success to any checkpoint after release for each telemetry group.

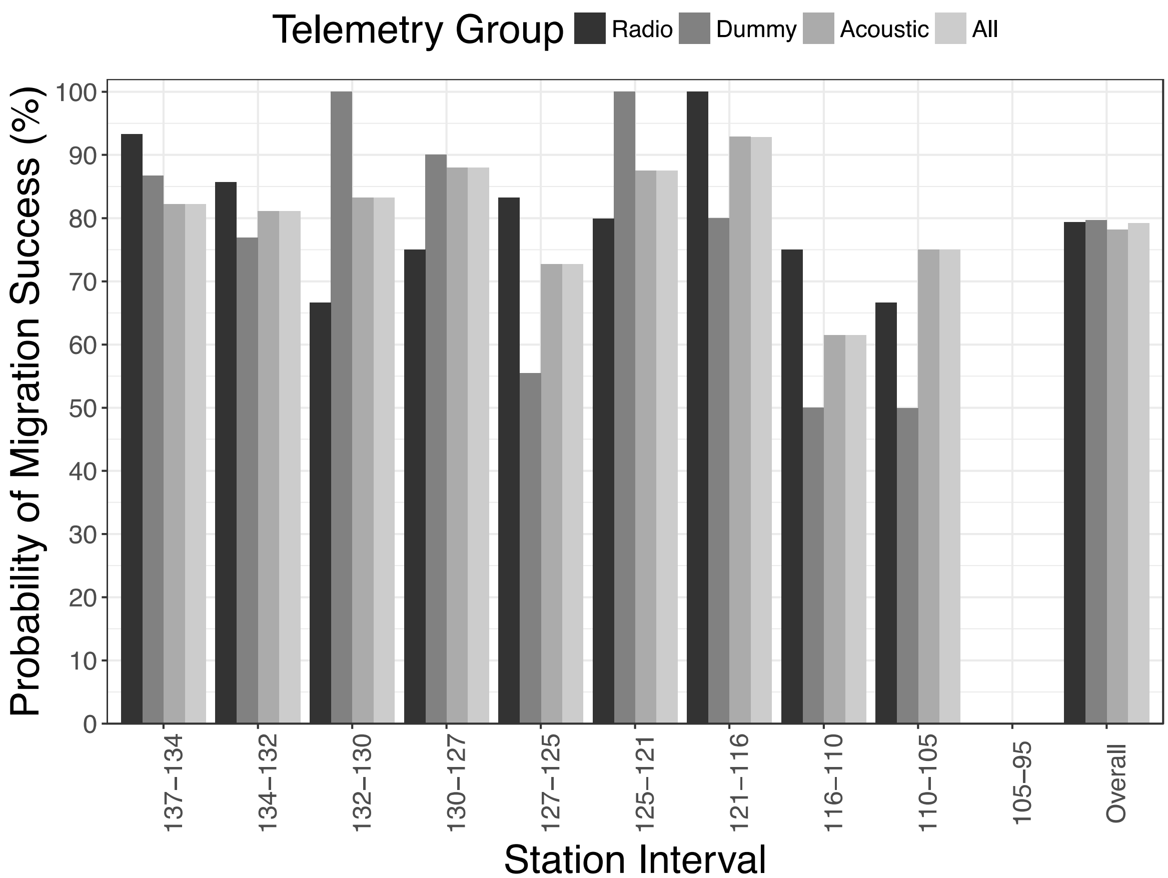

Figure 22. Probability of migration success between upper and lower checkpoint for each telemetry group and combined groups

Discussion

Each of the three experimental telemetry groups demonstrated similar detectability within the gated zones from rkm137 to rkm116. This result suggests that visual cues such as trailing radio tag antennae do not influence the ability of tagged individuals to successfully migrate within the index zone. More generally, this result could be interpreted to mean there's no differential between acoustic and radio tagging effects in terms of the high mortality rate observed, which may be applicable to the whole hatchery release cohort.

All 30 acoustic tags deployed in 2017 were not detectable after July 26 2017, except for acoustic ID 49787 which was detected October 12 near rkm113 via mobile acoustic survey. Combined acoustic monitoring results via the checkpoint receivers and mobile surveys provide a reasonable degree of certainty that it was not possible for acoustically tagged individuals to migrate outside of the gated area without detection. There is a reasonable level of certainty that the tags with last observed detections upstream of rkm116 were removed from the system via predation. There is less certainty with respect to the status of tags which were last detected at rkm105 (five acoustic tags); there is potential those tags migrated outside of the gated area, but they were not detected in mobile surveys downstream of the rkm105 gate, nor detected at the rkm95 gate (upstream of the Stuart River confluence). The last acoustic detection on October 12 suggests juveniles may overwinter between rkm110 and rkm116, thus tags last detected at rkm116 or rkm110 may have held between the two gates over winter. Future monitoring efforts need to identify suitable acoustic receiver sites downstream of rkm105 to better monitor downstream migrations.

Radio tag monitoring results found very few surviving individuals tagged in previous years, and most individuals released in 2017 did not survive. Six of the 15 radio tags released in 2017 showed no movements after June 2, suggesting 40% mortality of tagged individuals within 14 days post release. By the end of the monitoring period in 2017, 2 of the 15 tags released in 2017 were classified as "Alive". Radio receiver stations located at Stuart River confluence and Nautley River have not detected movements from any juvenile radio tags released 2015 to 2017.

Results from 2017 telemetry have indicated some sections of river may have higher mortality rates than other sections. Acoustic telemetry group demonstrated high loss of migrating individuals between rkm137 and rkm134, and radio telemetry group demonstrated high loss of migrating individuals between rkm132 and rkm127. Mobile surveys were unable to detect individuals holding in these river sections implying the individuals were removed from the river. Future telemetry efforts could monitor these river sections in more detail (e.g. acoustic array) perhaps providing better data relative to when and where tags are removed from these river sections.

Telemetry data from 2017 indicated that 3 individuals from the acoustic group, 2 from the radio group, and 1 from the dummy tagged group migrated as far downstream as rkm105. This suggests some juveniles migrate out of the index zone, which was supported by the peripheral sampling. Continuing the expanded juvenile monitoring program in areas outside of the index zone is important.

Chapter 5 – Fraser River Sampling

Introduction

Monitoring the dispersion of Nechako hatchery origin juveniles is important for the purposes of understanding juvenile habitat use, migrations, and adaptively managing hatchery production towards population rebuilding objectives. Capture patterns and telemetry studies from pre-2015 monitoring of hatchery origin juveniles in the Nechako River indicated juveniles had an initial residency within the index zone, and were not seen to migrate downstream of Hulatt rapids (rkm105; CSTC 2009). However, observations were based on few tagged individuals and over a short duration, and were conducted with a known low juvenile abundance within the river (CSTC 2015a, 2015b, 2015c). Now, after the introduction of more than 21,000 1-year old hatchery-reared juvenile sturgeon between 2015 and 2017, juvenile distribution is anticipated to change. Potential outcomes of the hatchery releases could include downstream migration into unoccupied habitats. The migration of hatchery-origin individuals into non-native habitats poses risks to other white sturgeon populations in the Fraser watershed. Risks include competition for habitat and food resources, and in the long-term, potential genetic issues. Due to these risks, the distribution and migrations of hatchery-origin sturgeon must be monitored. To address these concerns a juvenile-focussed sampling program in Fraser River habitat (e.g. Upper Fraser and Mid-Fraser habitat) was initiated in 2017.

Results

Sampling occurred between October 10 and October 21 2017. Fraser River was relatively low water (approximately 4m – WSC staff gauge) at the start of the sampling period. A large wind/precipitation (i.e. storm) event increased water levels by more than 3.5m very quickly in mid-October, followed by a second event around October 25 (Figure 23). Sampling did not occur in peak water levels due to safety concerns.

Table 4. Daily mean temperatures (°C) recorded from sampling boat's temperature sensor.

Date (MM-DD)	10-11	10-12	10-13	10-14	10-15	10-19	10-20	10-21
Temperature (Mean ± SD)	7.4 ± 0.0	6.97 ± 0.08	6.34 ± 0.05	NA	NA	6.40 ± 0.0	6.2 ± 0.0	5.63 ± 0.82

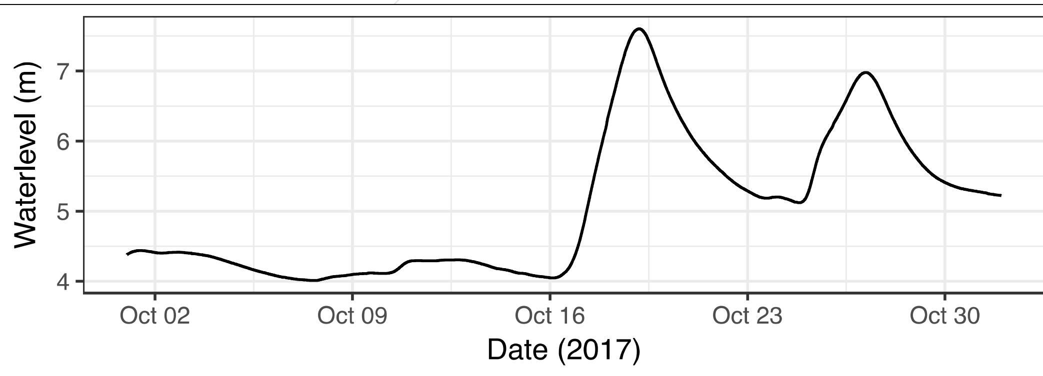

Figure 23. Water level measured at South Fort Fraser (08KE018) by Water Survey Canada station.

Forty-five (45) setlines (968.42 soak hours) and 8 angling events (7.16 hours) were applied to three sections of the river between Fraser River rkm745 and rkm798 (Figure 25). Several sites within the Nechako River approximately 1 kilometre upstream from the Fraser confluence were also sampled (light grey bars; Figure 25). The mean soak time for setlines was 21 hours and 31 minutes (21.52 ± 1.32 hours). Excluding bent, broken, baitless, or fouled hooks the minimum number of fishing hooks was 0 and the maximum was 20 fishing hooks per line. The mean number of fishing hooks per line was approximately 14 (exactly 14.36 ± 6.06 hooks). Total effort in the Fraser River (and Fraser- Nechako confluence) was 16,206 hook hours. No juvenile sturgeon or adult sturgeon were encountered during this sampling, therefore sturgeon catch-per-unit effort was 0. Bycatch species were encountered throughout the range of river kilometres sampled.

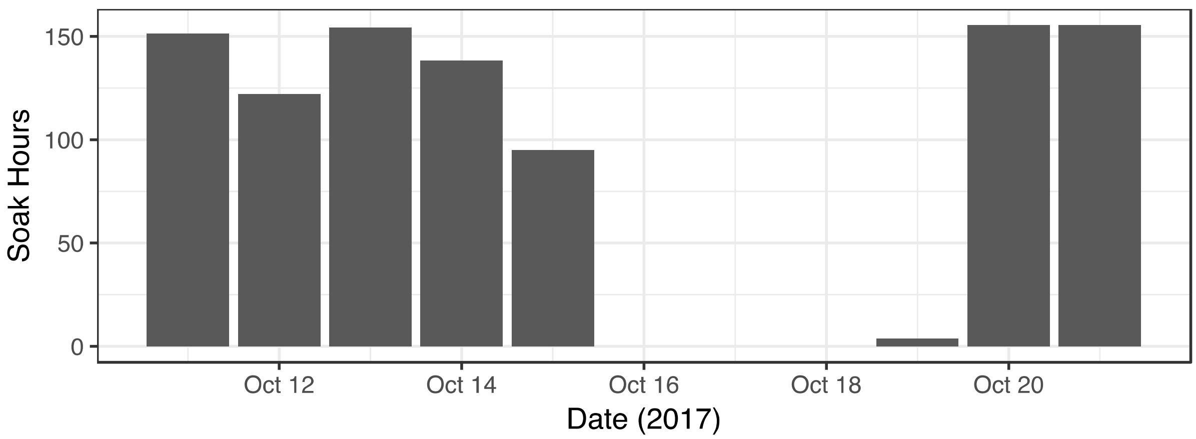

Figure 24. Barplot of soak hours by sampling date. No sampling occurred October 16 – 18 due to unsafe river conditions.

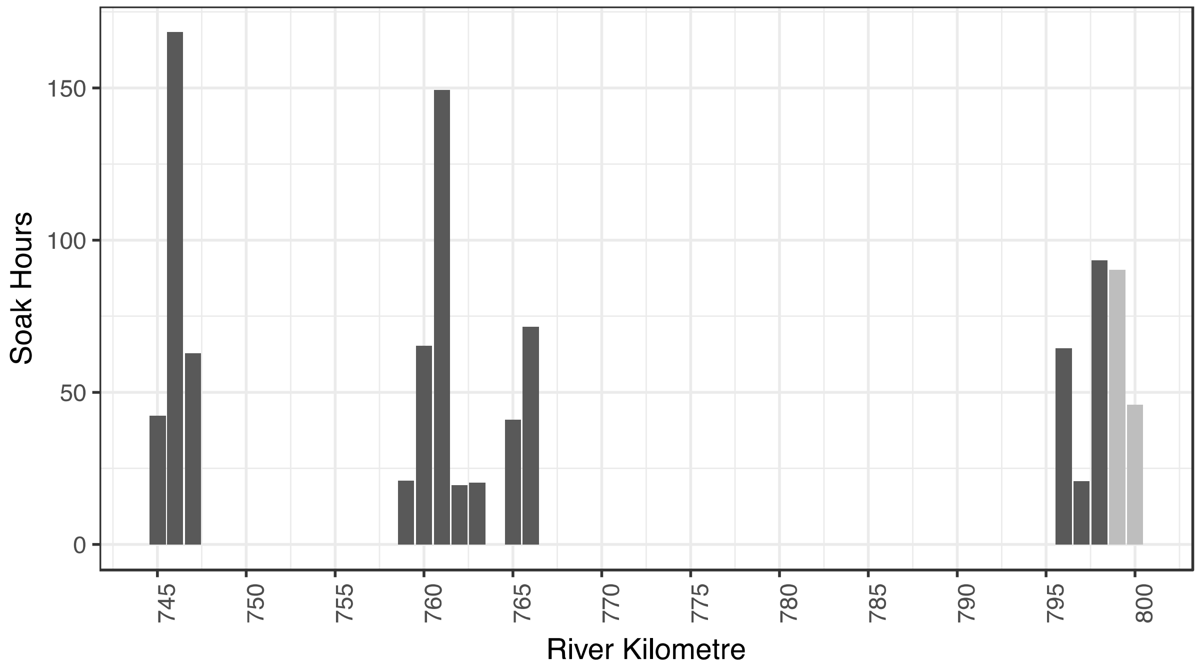

Figure 25. Barplot of effort (soak hours) by river kilometre. Grey-filled bars indicate soak hours applied to Nechako River near the Fraser-Nechako confluence.

Bycatch

Seven non-target (bycatch) species were captured during Fraser River juvenile sturgeon sampling (Table 5.). The most abundant bycatch was northern pikeminnow *Ptychocheilus oregonensis* (172), followed by bull trout *Salvelinus confluentus* (25) and peamouth chub (10). Other species included burbot *Lota lota*, rainbow trout *Oncorhynchus mykiss,* sculpin Cottidae sp., and white sucker *Catostomus commersonii*. Bycatch CPUE was highest for juvenile bull trout and rainbow trout within the Nechako River. Northern pikeminnow were captured through the whole range sampled in Fraser River, with some Fraser River sites providing bull trout and burbot captures.

Table 5. Summary of bycatch in 2017 Fraser juvenile monitoring program.

Northern pikeminnow	Bull trout	Peamouth chub	Burbot	Rainbow trout	Sculpin	White sucker
172	25	10	5	3	3	2

Discussion

CPUE and Habitat Use

No sturgeon were encountered during 2017 juvenile focussed sampling in the Fraser River. The absence of captures could suggest low juvenile density at the sample sites during mid-fall, however water temperatures were below the ideal range for capturing juvenile sturgeon using setline sampling method (Table 4). It is likely sampling in summer (after Fraser River freshet) will provide more reliable results, as well as allowing a better selection of sampling sites.

Considerations

Seasonal timing of sampling was potentially a factor influencing the lack of juvenile sturgeon captures from Fraser River. Fraser River sampling occurred during a period of low water and relatively low water temperatures less than 10.0°C. Experience from juvenile sampling in Nechako River suggests juvenile catchability decreases below 10.0°C. White sturgeon presence downstream of Prince George to the Blackwater River confluence has been documented to be generally low density and highly associated with habitat units within the reach. Monitoring the Fraser mainstem for juveniles within this area will provide a means of understanding risk associated with hatchery-origin juveniles potentially taking up residence outside of the Nechako River. Future efforts should target sampling key sites in warmer water temperatures and greater river discharge to allow better access to sample sites.

Chapter 6 – Combined Results and Discussion

Sampling Methods

The sampling methods used in 2017 are a combination of standardized techniques that have been used in Nechako juvenile monitoring since 2009 and new techniques that have been incorporated. Mixed block sampling and systematic site selection within river kilometre were new techniques aimed to remove potential confounding factors in sampling data. Larger hook sizes were incorporated on separate setlines to target larger late-juvenile and subadult sturgeon. The majority (6/8) of large juveniles (> 70cm FL) were captured on 5/0 hook size. One sturgeon measuring 131cm fork length was captured on a 5/0 hook, suggesting the 5/0 hook size is most efficient at targeting late-juvenile and subadult sturgeon and should be incorporated into the standard juvenile sampling methods.

Timing of sampling is well established for Index monitoring program and future index zone sampling should continue during the same time period. The monitoring within the peripheral Nechako and Fraser River areas do not have well established timeframes and future sampling in these programs should be balanced between suitable water levels, water temperatures above 10°C, and availability of sampling crew and resources resources.

The expanded spatial range of the monitoring is required to respond to increasing juvenile density. Hatchery operations have recently stocked the Nechako River index zone with 1-3yr old hatchery releases and the expectation is increased conspecific competition will result in juvenile displacement/migration into habitats previously documented as low-use areas.

Fraser River sampling was conducted using setline gear identical to gear used in Nechako River sampling despite differences in river size. Using the same gear was considered a necessity to maintain similar catchability of juveniles and therefore allow comparisons between data. Despite poor capture success in 2017 setlines should be used in future Fraser River sampling.

Capture Sample

The 2017 index capture sample was twice as large as 2016; a large sample size was expected due to increased effort in the index zone and due to stocking activities from 2015 to 2017, including the largest number of releases in 2017.

Trends in the capture sample are becoming apparent. After sampling the 2015-release cohort for three years it appears a hatchery-cohort will take at least two years post release (3 sampling seasons) to be fully vulnerable to capture by setline. This result implies at least three years of sampling a cohort post-release is required to accurately model survival of that cohort, depending on the cohort's size at release and growth rate, among other factors.

The fork length distribution of the 2010-2016 capture sample highlights a trend of declining capture frequencies of wild-experimental origin fish 80cm+ fork length (Figure 26). One possible explanation for lack of 80cm+ wild-experimental fish in the capture sample is the standard suite of hook sizes (4,2,1,1/0) are ineffective at capturing 80+cm fish. The addition of the larger hook array in 2017 showed a slight trend of increased selection for larger sized fish, but few larger fish were caught (as in previous years).

Hatchery fish released since 2015 show low capture frequencies of fish 70+cm FL, however recently released hatchery fish may not have had sufficient time to grow that large. Earlier hatchery cohorts were present in the capture sample in 2013 at sizes ranging from 60cm to 90cm FL (Figure 26), however those individuals have not been captured since 2013. One would expect to find those earlier hatchery cohorts present in index capture samples as late-juveniles and subadults but their absence suggests; 1) as with the trend observable among wild-experimental-origin juveniles, the standard hook array may be potentially ineffective at capturing 80+cm fish, 2) they are alive but not available for capture in the index zone, or 3) they are not alive.

Testing larger-gauge hook sizes in 2017 was intended to broaden-increase the size of fish susceptible to capture by the juvenile setlining methodology, in order to better understand the extremely low occurrence of fish 80cm+FL within past catches. Within the index zone in 2017 five individuals measuring longer than 80 cm fork length were captured, including one subadult sturgeon (>100cm FL). No fish ≥80cm FL were captured within the peripheral sampling.

Results suggest the addition of larger hooks can increase the catch of larger individuals, and confirms a low density of late juveniles and subadults throughout the areas sampled. Understanding the growth and survival of wild-experimental and hatchery-origin juveniles into the subadult life stage is critical to understanding recruitment failure and managing hatchery operations to meet subadult and adult population rebuilding objectives. That will require understanding the life history of subadult sized fish within the Nechako watershed, including increased effort (e.g. telemetry) to identify movements, migrations and habitat use.

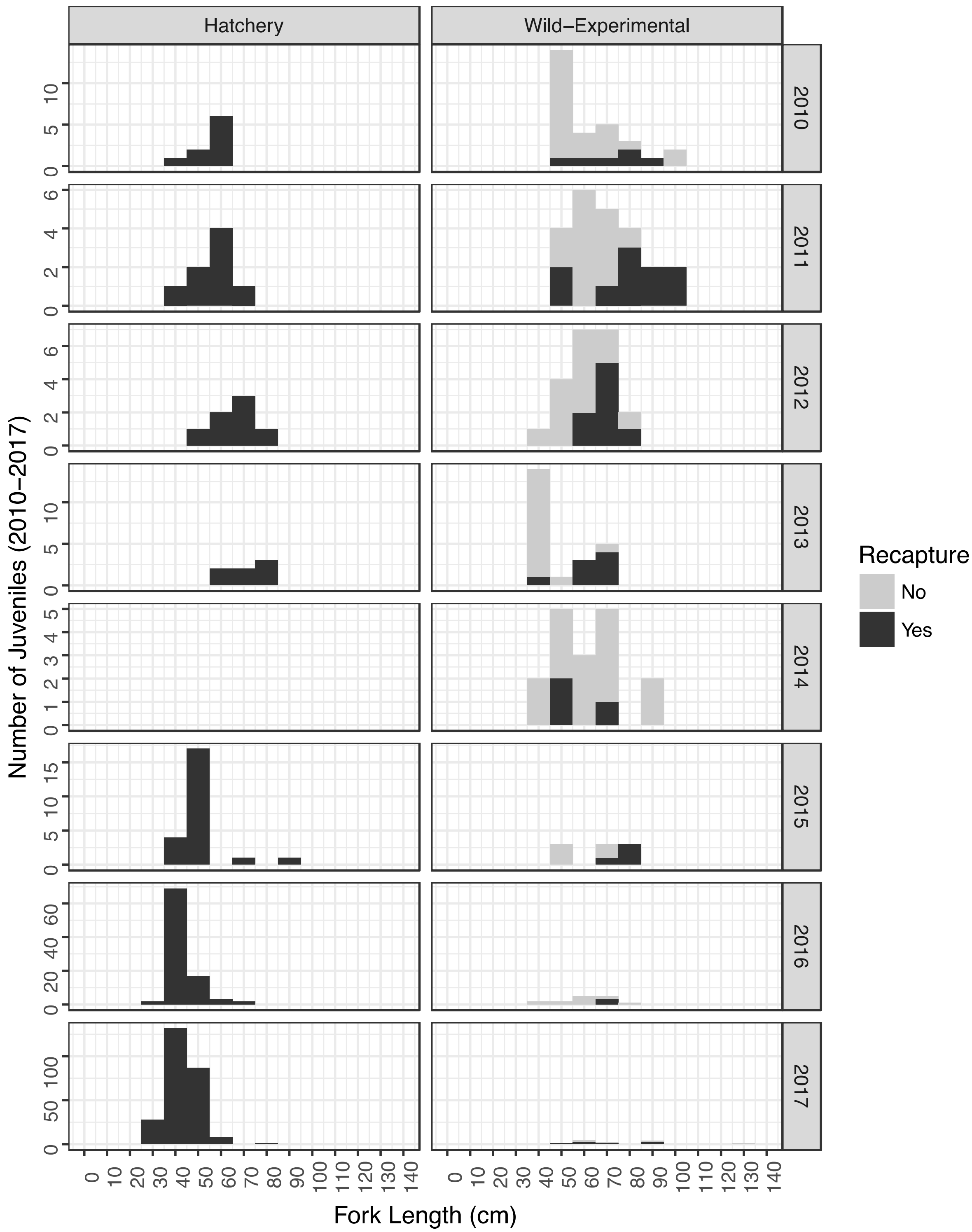

Figure 26. Fork length distributions of hatchery and wild origin capture samples collected 2010-2017. Note y-scale changes between years.

Habitat Use, Distribution and Migration

Index reach CPUE increased slightly from ~0.30/100 hook hours in 2016 to ~0.35/100 hook-hours in 2017. The highest CPUE per river kilometre occurred at rkm111 and rkm112; this is not normally the "hot spot" although it is considered a high-occupancy habitat. In previous years, sites near rkm116, rkm117, and rkm125 were most productive. Reasons for the spatial change in juvenile density may include the presence of predators in typical high-use habitat and/or conspecific competition with other juvenile sturgeon. CPUE for combined index and peripheral sampling was slightly lower at 0.215 juveniles/100 hook hours due to low CPUE in the peripheral zones.

Wild-experimental origin fish presented a clustered spatial distribution, centered around rkm116. If rkm116 is the ideal overwintering habitat then it would make sense that larger/older wild-experimental individuals would occupy this habitat unit. As previously discussed, the high CPUE experienced near rkm111 and rkm112 was unusual and suggests conspecific competition may be a factor.

Hatchery juveniles were captured in habitats downstream of index zone, including a single individual in habitat only 30rkms upstream of Fraser River. The presence of this individual within relatively close proximity to Fraser River necessitates continued monitoring in those habitats.

Juvenile Telemetry

Three experimental telemetry groups (15 juveniles each) were released in 2017. One group was tagged with radio tags, one group was dummy radio tagged with an acoustic tag and fake radio tag antenna, and the last group received regular acoustic tags. All three groups performed similarly in terms of distribution and detection within the index zone suggesting a trailing antenna has little effect on migration or survival within the index reach.

The last detection of an individual from the acoustic group was July 26 2017, despite acoustic gates continuously monitoring until October. Excluding the 4 acoustic tags that were last detected at rkm105, detections within the index zone implies 26/30 juveniles that received acoustic tags in 2017 were mortalities shortly after release. This is a worrisome result suggesting very low survival of tagged juveniles. Furthermore, telemetry group comparisons suggest tag type does not influence survival, and these low survival rates may be generally applicable. Survival status of acoustic tags is more difficult to interpret than radio tags, which are detectable on shore, and recoverable. Acoustic tags cannot be detected out of water thus mortalities typically cannot be confirmed. However, the detection efficiency within the index zone was highly reliable and in combination with mobile survey results, should give reasonable certainty that undetected tagged fish were likely removed from the river by predators.

Using telemetry to monitor hatchery individuals as they grow into late juvenile and subadult size classes, in order to understand their potential migrations may prove extremely useful in upcoming years, in combination with expanded setline sampling. Tagging large hatchery juveniles (70cm+ FL) within the index zone would provide survival data for larger individuals, and within several years the individuals will have grown enough to potentially show behaviours of subadult sized fish (migratory or not).

Hatchery-Origin Juvenile Status

Pilot Hatchery Releases

Monitoring the number of juveniles from each release cohort captured each sample year provides trends of relative cohort abundance. Pilot hatchery operations resulted in the release of nearly 15,000 6-month old sturgeon into Nechako River between 2006 and 2008; 4133 released in 2006, 4473 released in 2007, 5633 released in 2008. An additional 59 1-year old sturgeon were released in 2009. **Error! Reference source not found.** below shows the earliest hatchery cohorts are extremely rare within the recent capture samples suggesting that after their initial regular detection within the sampling program, these juveniles experienced very poor survival or migrated outside of the sampled areas. Only one year of peripheral sampling has been conducted and more is required to demonstrate with certainty that those early cohorts are no longer present in Nechako River.

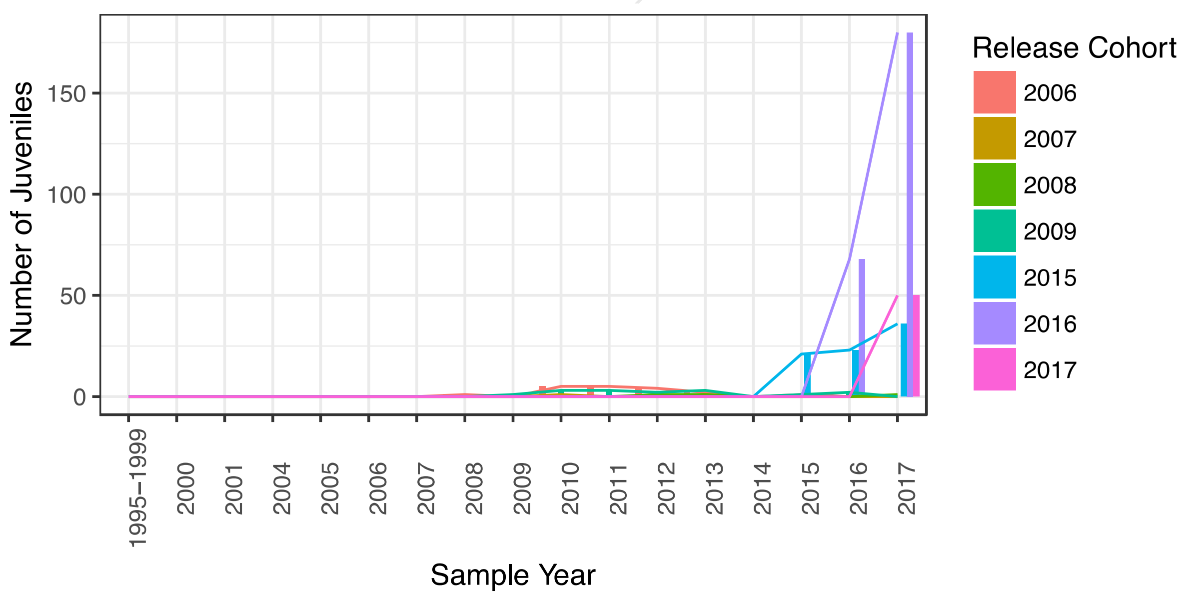

Figure 27. Trends in capture numbers of hatchery cohorts.

2015 Hatchery Releases

The 2015 release cohort (1861 individuals released) shows a positive trend in terms of the number of juveniles caught each year from 2015 to 2017, indicating the cohort's size distribution is growing into sizes most susceptible to capture on the juvenile sampling gear. Twenty-one (21) individuals from the 2015 cohort were captured in 2015 (1.1% of the number released). A total of 21 (plus 2 recaptures within year) and 29 (plus 6 recaptures within year) individuals from 2015-release cohort were captured in 2016 and 2017 respectively.

2016 Hatchery Releases

Sixty-eight (68) individuals from 2016 cohort (8548 individuals released) were captured in 2016 (0.8% of the number released). The 2016 cohort shows a vigorous positive trend in juvenile captures from 2016 to 2017, indicating 2nd year growth (into gear-vulnerable size-range) for this cohort. The 2015 cohort did not show the same substantial increase in capture numbers in their 2nd year, but the overall numbers released were much larger for the 2016 cohort.

2017 Hatchery Releases

Interestingly the 2017 cohort release was 11518 individuals and only 50 individuals were captured in 2017 (0.4% capture/release rate), which is the lowest capture/release rate since 2015. Several factors may be affecting within-year capture/release rate including size differences among the cohorts at the time of release, and gear saturation from cohorts more vulnerable to capture.

The present dataset makes it difficult to speculate on the rate of survival of early hatchery cohorts into the subadult life history stage. The lack of captures of these individuals within the index zone suggests the early pilot hatchery cohorts did not survive to the subadult size ranges, but factors such as migration out of the index zone cannot be ruled out until more extensive peripheral sampling is conducted. Ensuring all hatchery individuals have an equal chance of capture in the monitoring program is an essential assumption to CJS mark-recapture survival models.

Wild-Experimental Origin Juvenile Status

Wild-experimental origin juveniles have been consistently present in the capture samples since the start of annual sampling in 2004. Figure 28 shows the frequency of wild-experimental individuals in each sample year separated based on their spawning cohorts (5-year aggregations). The data demonstrates that:

1. The size distribution of wild cohorts reach the size of maximum catchability by the juvenile gear after approximately 5 years post spawning.

2. The numbers of any particular cohort captured generally increase up to year 5-6 years post spawn then generally decline thereafter.
3. The rate of decline in capture frequency following maximum representation in capture sample suggests their declining presence within the sampled area (i.e. migration out of the sampled area or mortality), rather than outgrowing juvenile sampling gear catchability.
4. Wild-experimental origin juveniles are being produced regularly and small numbers are surviving to the age of capture and beyond, and,
5. Individuals originating from spawning events in 1990-94 continue to be present in small numbers (2) in 2017 (and in 2013 and 2014), indicating some level of survival to subadult life stage.

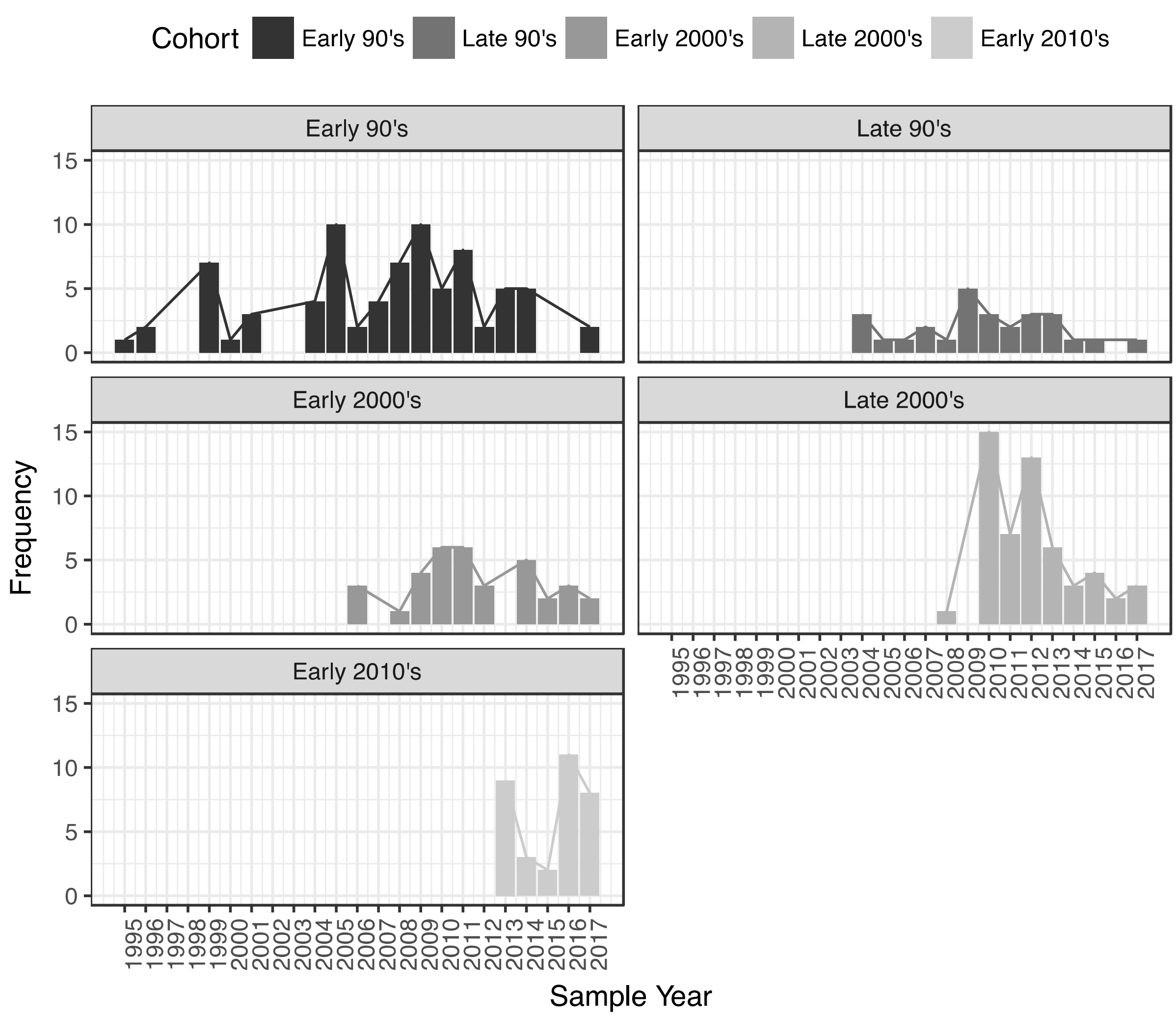

Figure 28. Trends in annual capture numbers of wild-origin juveniles-subadults within 5yr-cohorts.

Based on these results it is reasonable to conclude that the Nechako River within its current state is capable of supporting very small numbers of wild-experimental origin sturgeon through to the late-juvenile and subadult stage. But the small numbers documented to survive to the late juvenile and subadult stage are well below numbers required to survive to become adults and effectively rebuild the population. Further, as discussed above (Fig. 26), there is some question about the potential ability of fish to survive beyond 80cm FL.

Findings

1. Larger sized hooks (5/0, 6/0, 8/0) were added to the standardized array in 2017 in both the index zone and peripheral areas to broaden the target size range to >100cm FL; a single fish >100cm was captured in the index zone on 5/0 hook suggesting increasing hook size to 5/0 does improve capture sample size range to include individuals up to 130cm FL. However, the low numbers of subadults captured suggests a lack of survival from late juvenile to subadult stage (Chapter 2).
2. Captures of hatchery-origin juveniles released in 2015 suggest a cohort doesn't achieve the size distribution most susceptible to capture on the juvenile sampling gear until age 3+ (at least); this would be dependent on the size distribution at the time of release (Chapters 2 & 6).
3. Wild-experimental origin juveniles are catchable on the juvenile gear at age 3+ (~40cm fork length), and become most susceptible at ages 5 -12 (~50-70 cm fork length; Chapter 6).
4. The observation of small numbers of wild origin juveniles (since the initiation of juvenile focussed sampling) and observation of very few late-juveniles and subadults suggests some level of natural spawning success and survival to early or late juvenile life stage, but ongoing failure to survive to subadult life stage (continued recruitment failure) (Chapter 6).
5. Wild-experimental origin juvenile capture frequency declines after fish reach the size-range most susceptible to capture gear (50-70cm fork length); captures of wild-origin juveniles greater than 80cm fork length are rare in Nechako River despite efforts to target large juveniles and subadults (Chapter 6).
6. The continued ability to document similar numbers of wild-experimental origin juveniles within the sample (pre and post 2015) following substantially increased hatchery-origin juvenile density suggests sampling gear has not been subjected to saturation effects.
7. Peripheral sampling confirmed the presence of hatchery and wild-experimental-origin juvenile sturgeon outside of the index zone (0.025 $\pm$ 0.04 CPUE), although in small numbers relative to the index zone (0.252 $\pm$ 0.48 CPUE; Chapter 3). One exception is

habitat between rkm105 and rkm110. The habitat is contiguous with the index zone and capture numbers suggest juvenile density is similar to index zone habitat

8. Similar overall detection rates for individuals from the three telemetry tagging groups within the index zone suggests the visual cue provided by an external radio tag antenna is not a factor influencing predation rate, and there's no differential in susceptibility to predation between a fish emitting a radio or acoustic signal (Chapter 4).
9. Acoustic and radio telemetry monitoring results suggest very high rates of mortality on tagged individuals within months of release (Chapter 4).
10. Acoustic and radio telemetry results demonstrated some hatchery-origin fish migrated outside of the index zone within their first months following release (Chapter 4).
11. Sampling for juvenile sturgeon within the Fraser River did not produce juvenile sturgeon captures.

Recommendations

1. Continue annual monitoring of the index zone, ensuring sampling coverage in each river kilometre within the index zone while avoiding seasonal confounds in data (e.g. systematic site selection with random block design). Include 5/0 hook sizes on separate lines in an attempt to expand the target size range of the sampling – to late juvenile and subadult sturgeon (~80-130cm), which will help identify survival characteristics to those size ranges.
2. Consider including rkm105 to rkm110 into index zone sampling.
3. The index monitoring program should maintain similarly high effort going forward to develop survival estimates for hatchery cohorts in a timely manner.
4. Continue sampling peripheral zones going forward, including expanded-exploratory sampling to locate new high-use habitats in peripheral zones (i.e. Stuart River). Include that standard array of juvenile hook sizes, and also 5/0 hook sizes on separate lines in an attempt to expand the target size range of the sampling.
5. Continue sampling the Fraser River mainstem using standardized setline gear. Sampling should occur in summer water temperatures after Fraser River freshet within high potential juvenile habitats between the Nechako River confluence and mid-Fraser White Sturgeon range boundary. Include 5/0 hook sizes on separate lines in an attempt to expand the target size range of the sampling.
6. Conduct sampling utilizing standardized juvenile setlines (incorporating the larger hook sizes) within known high use juvenile habitat within the upper Fraser stock's (sub-DUs)

range; with the intent to document catch characteristics when sampling within a functioning juvenile-subadult population.

7. Continue radio or acoustic telemetry to better understand movement and migration behaviours and habitat use as fish grow from early juvenile, to late juvenile and subadult size ranges. Adding additional gates at new sites and/or array coverage at sites of low migration success may improve knowledge of acoustic tag fate.
8. Develop a mark-recapture model for estimating hatchery cohort and Wild-Experimental cohort survival rates.

References Cited

CSTC. 2009. Nechako White Sturgeon; Assessing Habitat Use/Preference and Monitoring Survival and Distribution. Prepared by the Carrier Sekani Tribal Council.

CSTC, 2009. 2008 Assessment of Juvenile White Sturgeon (Acipenser transmontanus) Abundance and Distribution in the Nechako River; Development of an Index of Juvenile Recruitment. Prepared by the Carrier Sekani Tribal Council.

CSTC, 2015a. 2012 Nechako Juvenile White Sturgeon Sampling; 2012AFSAR-2437 Juvenile Recruitment Indexing. Prepared by the Carrier Sekani Tribal Council. Not Available Online.

CSTC, 2015b. 2013 Nechako Juvenile White Sturgeon Sampling; 2013AFSAR-1799 Juvenile Monitoring and Habitat Use Study. Prepared by the Carrier Sekani Tribal Council. Not Available Online.

CSTC, 2015c. 2014 Nechako Juvenile White Sturgeon Sampling; 2014AFSAR-2437 Juvenile Recruitment Indexing. Prepared by the Carrier Sekani Tribal Council. Not Available Online.

CSTC 2016. 2015 Nechako Juvenile White Sturgeon Sampling; 2014AFSAR-2437 (Year 2)
Juvenile Recruitment Indexing. Prepared by the Carrier Sekani Tribal Council. Not Available Online.

CSTC 2017. 2016 Nechako River Juvenile White Sturgeon Recruitment Monitoring; 2016AFSAR-2861 (Year 1). Prepared by the Carrier Sekani Tribal Council. Available Online.

Fisheries and Oceans Canada. 2014. Recovery strategy for White Sturgeon (*Acipenser transmontanus*) in Canada [Final]. In Species at Risk Act Recovery Strategy Series. Ottawa: Fisheries and Oceans Canada. 252 pp

Golder Associates Ltd. 2003. Recovery Plan for Nechako White Sturgeon. Prepared for Nechako White Sturgeon Recovery Team, 73 pp.

Lheidli Tenneh Band. 2017. 2016 Upper Fraser White Sturgeon; Refining Important Habitats. File 2016HSP7743 Final Project Report (2016) Prepared for the Habitat Stewardship Program. Not Available Online.

RL&L Environmental Services Ltd. 2000. Fraser River White Sturgeon Monitoring Program – Comprehensive Report (1995 to 1999). Final Report Prepared for BC Fisheries. RL&L Report No. 815F: 92 p. + app.

Appendix 1 - Biophysical data for tagged juvenile white sturgeon released in 2017.

PIT	Fork Length (cm)	Weight (kg)	Family	Radio Frequency	ID Code
0A181D643E	36.8	0.322	7	151.42	55
0A181C2D18	33	0.226	2	151.42	56
0A181D6566	30.9	0.176	7	151.42	57
0A181C2D46	31	0.196	2	151.42	58
0A181D263A	33.2	0.201	8	151.42	59
0A181D621D	32	0.218	7	151.42	60
0A181D2640	35	0.281	8	151.42	61
0A181D6A75	32.6	0.218	8	151.42	62
0A181D4D58	34.5	0.24	7	151.42	63
0A181D2735	34.1	0.264	8	151.42	64
0A181D4B6C	31.3	0.191	7	151.42	65
0A181D5E3E	31.6	0.203	2	151.42	66
0A181C2C3E	32.5	0.228	2	151.42	67
0A181D2738	33.5	0.23	8	151.42	68
0A181C2D0B	31.1	0.182	2	151.42	69
0A181D5231	32.3	0.23	2	N/A	49795
0A181C3A43	33.7	0.25	2	N/A	49799
0A181D267D	34.2	0.256	8	N/A	49800
0A181D156C	33.9	0.24	8	N/A	49801
0A181D507D	31.1	0.211	2	N/A	49803
0A181D672B	32.1	0.199	7	N/A	49804
0A181D1515	32.9	0.209	8	N/A	49805
0A181D4A57	33.1	0.218	7	N/A	49806
0A181D2C53	33.9	0.23	2	N/A	49807
0A181D4A22	32.4	0.222	7	N/A	49808
0A181D273F	33.8	0.259	8	N/A	49809
0A181D1909	32.4	0.218	8	N/A	49810
0A181D6737	31.5	0.182	7	N/A	49811
0A181D5D74	32	0.208	2	N/A	49812
0A181D6702	30.5	0.174	7	N/A	49813
0A181D2648	35	0.275	8	w/ antenna	49784
0A181D5E34	33.6	0.247	2	w/ antenna	49785
0A181D177C	33.5	0.235	8	w/ antenna	49786
0A181D712A	31	0.186	2	w/ antenna	49787
0A181D2C57	33.9	0.231	2	w/ antenna	49788

0A181C3B69	31.8	0.189	2	w/ antenna	49789
0A181D4D04	33	0.216	7	w/ antenna	49790
0A181C2E06	31.2	0.196	2	w/ antenna	49791
0A181D267B	33.8	0.239	8	w/ antenna	49792
0A181D1647	36.3	0.308	8	w/ antenna	49793
0A181D260E	33.4	0.241	8	w/ antenna	49794
0A181D655C	31.5	0.181	7	w/ antenna	49796
0A181D4F71	31.4	0.249	7	w/ antenna	49797
0A181D662D	32.2	0.207	7	w/ antenna	49798
0A181D4F57	31.5	0.202	7	w/ antenna	49802