2021 Nechako/Upper-Mid Fraser
Juvenile White Sturgeon Monitoring Summary Report

Contributing Partners:

Carrier Sekani Tribal Council, Lheidli T'enneh First Nation, Freshwater Fisheries Society of British Columbia, and British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development

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Table of Contents

List of Figures

List of Tables

Summary

The Nechako River juvenile white sturgeon monitoring program, a component of the Nechako White Sturgeon Recovery Initiative activities, has collected data annually since 2004. The purpose of annual monitoring has been to understand juvenile sturgeon survival, movement, and habitat use in the Nechako River, and more recently, within adjacent areas of Nechako watershed and Fraser River. The design of the 2021 monitoring program was informed by prior year's results, emerging information, and known data gaps.

Nechako White Sturgeon have suffered a "recruitment collapse" which infers that younger fish are not being produced and/or surviving in adequate numbers to replace the remnant adult population. This condition is believed to be related to alterations to the Nechako River following the impoundment of the river and diversion of the reservoir in the early 1950s. It is recognized that the recruitment collapse was a delayed effect beginning in the late 1960s or early 1970s, 15 to 20 years after Kenney Dam was constructed. The population was added to Schedule 1 of Canada's Species at Risk Act in 2006, and recovery efforts have been led by recovery plans/strategies completed in 2004 and 2014. Core elements of those strategies include implementing conservation-based fish culture and annually monitoring juveniles.

Hatchery augmentation is identified as one of two fundamental components necessary for achieving the recovery of Nechako White Sturgeon, along with the restoration of natural recruitment. The objectives of the Nechako White Sturgeon Conservation Centre are to create a "stop-gap" cohort that reflects the genetic diversity of the remnant adult population and provide gametes, larvae, and juveniles for habitat restoration research. Given the aging demographic of the remnant population, achieving the conservation-based fish culture objectives is considered an urgent priority.

Emerging capture data trends suggest the hatchery stop-gap efforts from 2006 to present may not contribute enough sub-adult sturgeon to achieve the initial recovery target of 1,000 adult sturgeon in the Nechako River. Juvenile sturgeon monitoring data have demonstrated low survival rates for hatchery juvenile sturgeon cohorts in the Nechako River in relation to all rearing and release strategies attempted and evaluated to date (CSTC 2021). Passive integrated transponder (PIT) tag recovery programs and radio tag recoveries have indicated predation by river otter *Lontra canadensis* and other predators could be a significant factor influencing survival rates in the Nechako River (Babey 2022). The multi-year dataset indicates that survival is lower than anticipated for hatchery and wild juvenile sturgeon ranging from less than 30 cm fork length (FL) upwards to 80 cm FL.

In 2021 juvenile monitoring objectives included continued sampling of the Nechako's Core reach (rkm 105 to rkm 135), applying effort to new sampling sites in Fraser Lake, and continuing to monitor the Fraser River. The 2021 monitoring program also continued coordinated radio telemetry efforts to intensively monitor hatchery juveniles that were implanted with radio tags prior to their release into the Nechako River in 2018, 2019, 2020, and 2021.

A total of 122 setlines (51,136 hook hours) were deployed within the Core reach between August 04 and October 05, 2021. Sixty-one unique juveniles were captured (55 hatchery juveniles and six wild-experimental juveniles[1]); Two hatchery juveniles were captured twice during 2021 sampling for a total of 63 capture events in the Core reach, resulting in catch per unit effort (CPUE) of 0.123 juveniles/100 hook hours.

Sampling within peripheral areas of the Nechako watershed included 100 setlines (51,524 hook hours) deployed in the Nechako River and Fraser Lake between July 12 and October 28, 2021. 93% of the effort was applied to Fraser Lake. Three juveniles were captured (two hatchery origin and one wild-experimental origin) in Fraser Lake. CPUE for Peripheral regions was 0.006 juveniles/100 hook hours.

Sampling in Fraser River Region 5 included 10 overnight setline deployments and 65 day set setline deployments (10,752 hook hours) between July 13 and September 23, 2021. Sampling occurred between Fraser River rkm 477 and rkm 690. Seventy-one sturgeon were captured (17 hatchery origin, 54 wild origin). Two hatchery origin and four wild origin juveniles were captured twice within 2021 for a total of 77 capture events resulting in a CPUE of 0.716 juveniles/100 hook hours.

Sampling in Fraser River Region 7 included 35 setlines plus an additional 21 setlines in Longworth canyon (14,837 and 8,603 hook hours, respectively). Sampling dates ranged between August 03 and September 19, 2021 for Region 7 sampling including Longworth (September 3 – 6, 2021). Thirty-three juveniles (14 hatchery-origin, 17 wild-origin plus two wild origin fish were captured twice) were captured in the lower portions of the Fraser River in Region 7. Fifty-seven wild juveniles (56 unique juveniles and one juvenile was captured twice) were captured in Longworth. Fraser River Region 7 (excluding Longworth) CPUE was 0.222 juveniles/100 hook hours, and Longworth CPUE was 0.650 juveniles/100 hook hours.

Hatchery juveniles released in 2015 were part of the annual capture sample since the year of their release. However, zero 2015 releases were captured in 2021 juvenile monitoring. The trend in the 2015 release cohort reflects trends observed in earlier pilot hatchery cohorts. Capture data suggest very few 2015 released individuals occupy Nechako River or Fraser River, but surviving individuals may occupy either one of the rivers.

Captures of 2016 hatchery releases in the Nechako watershed from 2018 through 2020 monitoring have demonstrated a decrease in total capture number and CPUE, and a high recapture rate (60% for 2016 and 2017 release cohorts in 2021). Data continues to indicate the 2016 release cohort is likely experiencing a lower than anticipated survival rate in the Nechako River. The 2016 release cohort is the most captured hatchery cohort in the Fraser River, and 2016 releases have demonstrated the largest movements in the Fraser River upstream and

[1] The term “wild-experimental” is used to reflect sturgeon captured in the Nechako River 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.

downstream from the Nechako River confluence. Additional sampling, including in peripheral areas and the Fraser River, will help clarify how movements influence apparent survival trends in the Nechako River.

Hatchery juveniles released in 2017 have been sampled within the Core reach for five seasons. They also demonstrate declining capture numbers and CPUE along with increasing recapture rate. This cohort was the largest in terms of numbers of fish that were released, and the monitoring trends to date are concerning for this cohort. Fish from this cohort have been captured in Nechako watershed peripheral areas and the Fraser River. Additional sampling, including in peripheral areas and the Fraser River, will help clarify the apparent survival trend in the Nechako River.

The 2018 cohort has been sampled for four years and capture numbers are following similar concerning trends in terms of catch and CPUE.

Fewer individuals were released in 2019 and 2020 (500 and 199, respectively) relative to previous release cohorts, but the individuals were grown to larger sizes. CPUE for 2019 release cohort is trending similar to previous release cohorts. Capture sample size for the 2020 release cohort stayed the same relative to 2020 and recapture rate increased from 20% in 2020 to 33% in 2021. Fish from the 2021 release cohort were the most frequently captured cohort in from the Core reach in 2021, similar to results observed for 2020 release cohort in 2020 sampling. Additional sampling and telemetry will clarify the apparent survival trend and movements of the 2020 and 2021 cohorts.

Sampling within peripheral areas of the Nechako watershed and in the Fraser River has been undertaken since 2017. Hatchery fish from all cohorts released since 2015 have been captured in relatively small numbers within the Nechako watershed outside of the Core reach. One individual from the 2006 release cohort was captured in the Core reach during adult sampling efforts in September 2020. This individual was released at rkm 116.8 on October 27 2006, measuring 18.0 cm FL. It was captured once in 2010 and once in 2012 within one kilometre of its release site. In 2020 this individual was captured 400 m downstream of its original release site and measured 116.2 cm FL.

Hatchery fish from 2016, 2017, 2018, and 2020 release cohorts were captured in the Fraser River in 2021. Hatchery fish captured in the Fraser River were smaller than individuals from the same cohorts captured in the Nechako watershed. Sampling in 2021 demonstrated CPUE for hatchery fish within Region 5 of the Fraser River was similar to CPUE for hatchery fish in the Core reach, however setline effort in Region 5 was applied in a non-standard way which creates difficulty making CPUE comparisons to other regions and previous years. The potential implications of hatchery juveniles moving downstream to the Fraser River are discussed within the report.

A trend in hatchery fish distribution and abundance in the Fraser River is becoming clearer. Sampling effort was applied as far downstream as rkm 477 in 2021 and the most downstream hatchery capture occurred at rkm 524 in 2018 and 2021. One hatchery fish was observed in

Longworth canyon (rkm 954) in 2020 which is the upstream range of hatchery fish in the Fraser River.

Monitoring trends in the Nechako watershed indicate that few of the 2006 to 2008 pilot hatchery releases (released at five to six months of age) survived to catchability on the juvenile setline gear, and even fewer are present now (one juvenile fish captured in 2017 and one adult fish captured in 2020). Trends continue to indicate one-year old hatchery cohorts (2009, 2015-2018) also experience ongoing low survival post release.

The risks of threats posed by Nechako-origin hatchery white sturgeon in the Fraser mainstem (inter-stock competition and loss of genetic integrity of wild sturgeon populations) are not understood, but the number of hatchery juveniles that have moved downstream to the Fraser River create the potential for adverse effects associated with competition to manifest rapidly.

Monitoring to date suggests achieving the stop-gap demographic and genetic objectives of hatchery augmentation may be challenged within the Nechako River's current state and additional actions may be required.

Based on findings discussed within the report, recommendations are provided in Section 6.

Key observations from sampling in 2021 include:

1. Small capture samples with less than 10 individuals continued for 2015 to 2019 hatchery release cohorts within the Core reach. Core reach CPUE increased in 2021 due to a reduction in effort applied, while recapture rate remained relatively stable compared to 2020 results (Section 2 – Nechako River Core Reach and Appendix A, Table 9).
2. Hatchery fish released in 2021 (N = 200) were similar size to the 2020 release cohort. They were released at three locations in the Nechako River and two locations in Fraser Lake, and were the most captured cohort in the Nechako watershed in 2021 (16 individuals captured). This result is similar to the 2020 release cohort and 2020 capture sample and is likely mediated by larger individuals' susceptibility to capture gear at release. The result also confirmed the setline methodology effectively targets size-classes released by the hatchery program. The monitoring data being generated is reflective of the juvenile population greater than 50 cm FL available for capture (Section 2 – Nechako River Core Reach).
3. The 2016 hatchery release cohort demonstrated reduced capture sample size in the Nechako watershed compared to previous years, however it is still the most captured hatchery cohort in the Fraser River. Recapture rates for the 2016 release cohort remain relatively high (60% in 2021) in the Nechako River Core Reach. (Section 2 – Nechako River Core Reach, Section 4 – Fraser River Regions).
4. Extensive sampling effort applied to Fraser Lake revealed juvenile sturgeon CPUE is very low in Fraser Lake except for one habitat area on the eastern end of the lake. It is unclear why the capture sample was small (N = 3) in 2021 despite similarities with 2020 sampling at the east end of Fraser Lake.

5. Sampling within the Fraser River Region 7 captured 14 hatchery juveniles from 2016 – 2019 release cohorts in 2021. Hatchery recapture rates are relatively low in Fraser River Region 7; 100% of hatchery juveniles in the Fraser River were captured downstream of the Nechako confluence in 2021.
6. Sampling within the Fraser River Region 5 captured 19 hatchery juveniles from 2016, 2017, 2018, and 2020 release cohorts in 2021. Hatchery recapture rate was higher in Region 5 (32%) compared to Region 7 (21%).
7. Hatchery fish within the Fraser River continue to demonstrate slower growth rates compared to cohort counterparts in the Nechako River (Section 4 – Fraser River Regions).

Key observations from the NWSRI multi-year, multi-program dataset include:

a. Pilot hatchery releases (2006 to 2009) capture numbers in the annual catch declined after 2014 and have not been represented in the Nechako or Fraser juvenile sampling since 2017 (one fish) despite increasing effort. Although data proves one individual from the 2006 release cohort has recruited to sub-adult life stage, the pilot hatchery releases are presumed to have had very low survival success.
b. The trend of declining capture numbers for hatchery and wild cohorts in the Nechako River Core reach has continued. (Appendix A Table 9)
c. Catch and CPUE for wild-experimental juveniles in the Nechako River Core reach increased in 2021 relative to 2020. This CPUE value continues to vary between 0.00 and 0.339 since the adoption of the new sampling standard in 2017, suggesting conditions in some years do allow for wild sturgeon recruitment in the Nechako River. Movements of juvenile sturgeon from neighbouring Upper and Middle Fraser populations may also contribute to apparent wild recruitment in the Nechako River.
d. CPUE for wild-experimental fish has been highly variable since 2009, and has generally declined since 2009. (Appendix A Table 11).
e. Individuals from each release cohort since 2016 continue to occupy and grow in Nechako Core reach and in Peripheral habitats, however no individuals were captured from the oldest 2015 1-year old release cohort. The trend in 2015 release cohort capture sample size reflects the trend observed in pilot hatchery release cohorts.
f. Hatchery juvenile recapture rates have been increasing or consistently high in the Nechako Core reach since 2018. Although hatchery juvenile recapture rate in 2021 did decrease relative to 2020, this is likely the result of several factors including a) decreasing numbers of 2015 – 2019 release cohort individuals available for capture, and b) increasing proportion of larger individuals (i.e. fully susceptible to setline gear) from 2020 and 2021 cohorts available for capture.
g. Annual growth among release cohorts observed in the Nechako Core reach suggests resources are not limited, however growth statistics have not been recently documented. The addition of a hatchery population, and an improved dataset of wild sturgeon captures

warrant a new investigation into growth rates in the Nechako River and upper Fraser River.

h. Five years of sampling within Nechako peripheral habitats has occurred in what are believed to be the highest use areas in the Nechako River outside of the Core reach, and in Fraser Lake. Capture numbers within Peripheral regions remain significantly smaller than capture numbers within the Core reach (Appendix A Table 9).
i. Radio tagged hatchery release groups from 2019 and 2020 were grown to larger sizes but have demonstrated lower than anticipated survival rates and appear to be susceptible to predation at relatively large, late juvenile size range. 2021 telemetry data have not been analyzed yet; results are expected in an upcoming FLNRORD report.
j. Hatchery fish have been documented within the Fraser River over four years of sampling and appear to be present in similar numbers to wild juvenile sturgeon in certain Fraser River habitat downstream of the Nechako River confluence (Section 4 – Fraser River Regions).
k. Captures of hatchery juveniles in the Fraser River are more numerous in habitats closer to and downstream of the Nechako River confluence (Section 4 – Fraser River Regions).
l. Recapture rates on hatchery fish within the Fraser remain relatively low after four years of sampling.
m. Sampling effort in Region 5 was applied as far downstream as rkm 477. The downstream extent of hatchery juvenile captures in the Fraser River was rkm 524 in 2021.
n. This report incorporates standardized juvenile-focused sampling undertaken in 2021 in the middle and upper Fraser, and the Nechako. Additional juvenile sturgeon sampling effort (outside the scope of this report) was applied downstream of Region 5 in 2021, including juvenile sturgeon sampling projects conducted in Regions 2 and 3 (T. Nelson, pers comm, 2023).
o. Sampling in Region 2 in 2021 resulted in the recapture of a juvenile white sturgeon that originated from the Nechako White Sturgeon Conservation Centre. This fish was recaptured on June 6, 2021 at Fraser rkm 177, about 5 kms downstream of Yale (T. Rhodes, pers comm 2022). This is the first documented recapture of a hatchery-origin sturgeon in the Fraser River watershed downstream of Fraser rkm 524. The fish was recaptured over 730 kms downstream of its initial release location in the Nechako River. The fish was 35.6 cm FL when initially released on May 3, 2016 at Nechako rkm 116.9, and 55.5 cm FL when recaptured 5 years later in the lower Fraser River (T. Nelson, pers comm, 2023).

The following are recommendations to help predict threats related to hatchery sturgeon in the Fraser River, and other considerations relative to the multi-year dataset and recovery objectives:

I. Completion of a thorough risk assessment is recommended in relation to the threats Nechako-origin hatchery fish pose to other Fraser white sturgeon stock groups. That assessment would identify a multi-year strategy to address data and information gaps,

and manage risk as understanding and knowledge is developed. The recommendations below are anticipated to compliment that strategy.

II. Continued sampling in the middle Fraser River is required to monitor hatchery and wild juveniles and provide samples. Near-term priorities should include identifying the downstream extent of hatchery fish in the Fraser River and identifying "nursery areas" with the smallest age-classes of wild juveniles.

   a. Ensure standardization of sampling equipment and methodologies with Nechako and Fraser River sampling (hook models and hook size arrays, etc.), as well as data collected (morphological anomalies, weights, tissue samples, finray samples, etc.).

III. Develop and implement an interim plan for removing hatchery juveniles captured in the Fraser River. That plan would consider existing and emerging data related to downstream risk in the context of options related to removal, spatial boundaries, triggers/thresholds, costs, and implementation, etc.

   a. Piloting removal/repatriation in 2021 would be important for gaining experience, overcoming challenges, and understanding the scale and scope of risk mitigation that may be possible.

IV. Collecting additional data from hatchery and wild juveniles captured in the Fraser River, including weight and girth will be critical to understanding growth and resource competition between hatchery and wild juveniles.

V. Collecting tissue and finray samples from wild juveniles captured in the Fraser River (mixing area – particularly Region 5) is necessary to provide data to understand genetic stock group markers, annual growth, size-at-age, and microchemistry analyses.

   a. Confirming the stock composition of juvenile sturgeon in the middle Fraser River is required to understand the threat hatchery juvenile presence may pose.

VI. Refining the understanding of genetic relatedness between Nechako and mid and upper Fraser stock groups will inform both threats identified.

VII. Refining the understanding of juvenile sturgeon growth and condition in Nechako and Fraser rivers. This would include analyzing capture and tag recovery data from upper Fraser, middle Fraser, and Nechako datasets.

VIII. Applying radio tags to hatchery and wild juveniles captured in the Fraser River may expedite the understanding of downstream movements and emigration risks.

IX. Sampling within the Nechako's Core reach and upper Fraser should continue as in 2021, informed by prior recommendations related to gear/methodology, timing and effort distribution, sample collection, etc..

a. Continue to improve sampling schedule in relation to water temperature and Nechako River discharge conditions (e.g. access to Peripheral regions during STMP period vs. post-STMP period)

b. Ensure the morphological anomalies (fins etc.) protocol is standardized and followed by all sampling crews.

c. Recommended 90,000 hook hours applied to the Core reach, 90,000 – 100,000 hook hours applied to peripheral areas in Nechako watershed including newly identified Fraser Lake site, and a minimum of 30,000 hook hours applied to Fraser River Region 7 including Longworth canyon and new sampling sites in McGregor and Bowron reaches in the upper Fraser River.

d. Ensure habitat between Stone Creek and Cottonwood River confluence in the Fraser River are thoroughly sampled.

X. Sampling within the Nechako watershed's peripheral habitats should continue and be expanded. Fully understanding the distribution of hatchery fish is important to refining survival estimates. This must include greater understanding of their movement patterns and distribution in the larger lakes within the Nechako watershed.

XI. Investigating the habitat limitations that are resulting in recruitment-limiting survival constraints on wild and hatchery origin juveniles and sub-adults should be undertaken.

a. Summarizing the two decades of work (and related findings) that have been completed in the context of NWS recovery should be completed (juvenile monitoring, hatchery introductions, adult sampling, telemetry, substrate experiments and spawn monitoring) to inform the current state of knowledge regarding habitat, and prioritize and guide ongoing actions.

b. Develop and implement a plan to refine an understanding of survival constraints for various life history stages (<3-years) of white sturgeon (linked to the capacities provided by the CFC).

XII. It is not advisable to increase annual juvenile stocking rates given potential downstream risks and emerging data and trends within the Nechako. Any additional juvenile stocking creates increased downstream risk. These downstream risks must be balanced with recovery objectives. At present the information required to fully assess and balance risks is incomplete.

XIII. Additional releases of cultured juveniles should be grown to the largest target-size practical, and a large proportion should be radio tagged and intensively monitored to understand movements, migration, and survival/predation.

a. Culturing fish for longer periods will increase hatchery effects and may influence post release behavior.

XIV. If releases of cultured juveniles are not going to continue, the recovery approach, strategy and actions should be reconsidered (see Recommendations XIV and XV below).

If trends continue and hatchery release strategies are unable to produce cohorts that can survive beyond "a late juvenile survival bottleneck" then hatchery augmentation of the Nechako River may not achieve stop-gap objectives without increasing risks to Fraser River wild sturgeon populations. Preparing for this potential situation is urgent because adapting could take considerable time and effort.

XV. Management of the primary predator (river otter) identified as the major contributor to mortality and low survival of late juvenile and sub-adult life stages may be a means of facilitating better survival of hatchery cohorts and successfully achieving stop-gap objectives in the short term. This approach will bring with it multiple challenges and uncertainties including:

a. Potential for unintended ecosystem consequences (e.g. worsening early life history survival challenges linked to recruitment failure, increasing downstream movements to the Fraser River, etc.);

b. Failure to address the persistent conditions that have set up to allow predator-prey imbalance;

c. Socio-political and socio-cultural ramifications; and

d. Unknown costs and unknown potential for success.

XVI. The TWG should reconsider the complexities and timelines inherent in pursuing recruitment restoration through the single-species adaptive management approach (i.e. conservation fish culture), given the emerging understanding the Nechako's recruitment collapse.

a. Key questions may include how can the single-species adaptive management approach (including hatchery augmentation) be broadened and/or combined with an ecosystem-based approach?

XVII. An updated assessment of the Nechako's adult population size and demographics should be undertaken to inform consideration of the timelines of various recovery actions and the associated ramifications of success or failure (incorporating updated inter-NSP movement data (Williamson et al 2021), population data, capture data, mortality assumptions, spawning periodicity data, etc.).

Section 1 – Introduction and Objectives, Methods, and River Conditions

Introduction

Hatchery augmentation of the Nechako White Sturgeon (NWS) population was initiated in 2006 and continues to present through the Nechako White Sturgeon Conservation Centre (NWSCC). The hatchery release strategy has shifted from pilot annual releases of thousands of "early juveniles" sized 15 to 30 cm FL to an approach that annually released several thousand juveniles sized 30 cm to 70 cm FL, and now to an approach that releases several hundred "late juveniles" sized 70 cm to 80 cm FL annually. The shift in strategy was expected to facilitate improved hatchery sturgeon survival within the Nechako River and reduce the number of hatchery fish movements into the Fraser River. To date 45,145 juvenile sturgeon and 800,000 sturgeon embryos have been released. Hatchery releases from 2006 to 2021 are outlined in Table 8 found in Appendix A.

A number of recovery objectives and associated timelines have been identified in relation to NWS:

- Korman and Walters (2001) modelled a "pre-recruitment failure population" of 5,000 "vulnerable individuals" present in 1950
- Basin-specific recovery plan (NWSRI 2004) refers to:
    - a desired adult population size of 2,500 based on COSEWIC criteria (noting that goal can change depending on emerging data on carrying capacity)
    - ensuring the persistence and viability of a naturally reproducing population and restoring opportunities for beneficial use
- National recovery strategy (DFO 2014) establishes a recovery goal to ensure that:
    - Each of the populations are sustainable throughout their natural range, are self-sustaining through natural reproduction, and to increase or restore opportunities for beneficial use;
    - Preventing extirpation by maintaining a minimum viable population;
    - A minimum viable population target for these populations is to reach or exceed 1,000 mature individuals; 1:1 sex ratio at maturity (defined as 1.6 metres fork length or 18-20 years of age).

The federal recovery strategy (DFO 2014) prioritizes conservation fish culture to prevent the extirpation of NWS. Creating a stop-gap hatchery cohort is considered an urgent priority recognizing the long-term chronic nature of NWS recruitment collapse, the growing demographic gap and aging remnant population, and anticipated challenges to restoring natural recruitment. The objectives above reflect the priority of achieving stop-gap population objectives through conservation fish culture while concurrently working to address the underlying causation of juvenile and sub-adult recruitment failure.

Juvenile monitoring work in the Nechako watershed as well as the upper and middle Fraser River is essential to generating data to inform an understanding of:

1. The trajectory of the hatchery stocking towards achieving the stop-gap objectives;
2. Adaptive management of hatchery rearing and release strategies; and,
3. The risks that hatchery augmentation of the Nechako population may be creating for other populations.

This report presents data from 2021 monitoring activities, but considers the longer-term dataset.

Monitoring juvenile white sturgeon within the Nechako River has been an annual activity since 2004. The design of annual sampling has been adaptively managed in response to recovery activities, emerging data, and information, and known data gaps (CSTC 2021). Recent monitoring has identified several factors that have been incorporated into the design of annual sampling activities including:

- Hatchery-origin juveniles have moved downstream to the Fraser River and are occupying habitats that may not have been normally used by juveniles originating from the Nechako.
- Following large-scale releases of 1-year old hatchery origin fish, sampling is occurring more broadly within the Nechako watershed to understand distribution and survival.
- Trends indicate declining capture numbers, declining catch per unit effort (CPUE), and increasing recapture rates for hatchery cohorts in the Nechako River. These trends persist for fish achieving sizes greater than 50cm fork length (FL).
- Monitoring late-juvenile/sub-adult size fish in the interest of understanding the unanticipated survival challenges observed in these size categories, adapting gear accordingly.

Juvenile monitoring data, including capture monitoring and telemetry data, have identified unexpectedly high juvenile mortality rates on hatchery cohorts released from 2006 to 2017 within the Nechako River mainstem (CSTC 2021). Monitoring in 2020 (and prior years) indicated that larger sized hatchery cohorts may still be experiencing high mortality at least 12 months post release, but more time was needed to collect data on the most recent release cohorts. The data collected over the next several years will be critical to forming an understanding of the success or shortfalls of the current hatchery release strategy, and related stopgap objectives.

Priorities for juvenile monitoring in 2021 included continuing to collect data for monitoring survival and distribution trends in the target areas to inform mark-recapture modelling, and monitoring other population health metrics. Efforts were also undertaken to monitor a large portion of 2021 hatchery releases with radio tags to assess the fate of larger-sized releases. The primary objectives of 2021 juvenile monitoring were as follows:

1. Collect data to monitor survival and distribution trends and inform mark-recapture modelling from the Nechako core-index reach, peripheral areas within the Nechako watershed, and the Fraser River mainstem.
2. Collect morphometric data and tissue/bone samples (soft tissue for DNA and finray for age and microchemistry profiles) from wild-experimental and hatchery juveniles.
3. Sample "peripheral habitats" in the Nechako River and major tributaries and the Fraser River mainstem to understand and support the monitoring of hatchery-origin and wild juvenile white sturgeon distribution within these areas.

Unfortunately, a number of factors challenged the juvenile monitoring program in 2021 including qualified crew shortages and equipment/vessel mechanical issues. Therefore sampling within the Nechako watershed was not as thorough as intended. Sampling in the Core area of the Nechako River (river kilometer – rkm – 105 to rkm 135) was prioritized during September when sampling tends to be most effective, as well as non-depth limited areas such as Fraser Lake. Sampling within other peripheral areas of the Nechako watershed was minimal.

Methodology

Nechako Watershed and Fraser River Region 7 Juvenile Setlines

Setlines were 40m to 60m long and rigged with standard hook arrays of small-gauge circle hooks (4, 2, 1, 1/0 hook sizes; Gamakatsu Circle Octopus Hooks). The standard hook array is designed to target juvenile sturgeon and avoid capture of larger subadult and adult sturgeon. Large sized hook arrays (4/0, 5/0, 6/0, 8/0 hook sizes; Gamakatsu Circle Octopus Hooks) were deployed on approximately 20% of the setline deployments in Nechako watershed and Fraser River Region 7. Setlines were deployed with 20 or 24 hooks, however some hooks become fouled, bent, broken (i.e. damaged), or bait-less during deployment. Hooks that were retrieved damaged or baitless are excluded from hook hour calculations.

Setlines in the Nechako River Core reach were systematically applied to Nechako River between rkm 135 and rkm 105. The 30 km Core reach was divided into six, five kilometre "blocks" of river. Setlines were applied every 200 m within each block. Not all blocks were sampled in 2021, and additional setlines were applied to sites that were expected to have high catch per unit effort. Rkm 117 was avoided due to a high number of broken hooks documented for that habitat unit. Although juveniles are known to occupy that habitat unit, the effectiveness of setline sampling is greatly reduced due to the low number of hooks effectively fishing.

A systematic approach to setline sampling Fraser Lake was used in 2021. The lake was divided into four North-South running zones arranged side by side East-West. Ten thousand hook hours were applied to each zone using randomized sample site placements up to 15m depth.

Setlines in the Fraser River (Region 7) were applied at index sites that have previously produced juvenile captures. Setlines were also applied to new sites that were suspected juvenile habitat based on historical adult sturgeon capture records.

All captured sturgeon were inspected for missing scutes and scanned for PIT tags. Morphometric information was collected from all fish, and finrays and/or DNA samples were collected from a select number of fish.

Telemetry

Telemetry effort included monthly aerial surveys of the Nechako River and opportunistic boat surveys throughout Nechako, Stuart, and Fraser rivers. Radio telemetry ground stations also monitored for juvenile radio tags throughout Nechako watershed and upper Fraser River.

Four agencies coordinated telemetry surveys in 2021: Carrier Sekani Tribal Council (CSTC), Lheidli T'enneh First Nation (Lheidli), Freshwater Fisheries Society of British Columbia (FFSBC or NWSCC), and British Columbia's Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD).

Ground stations were deployed at shore sites on the Fraser River, Nechako River, Stuart River, and Nautley River. All ground stations consisted of an Orion receiver unit and hydra antenna switch, two directional antennas, and batteries for back-up power. Stations were powered by either electricity from grid service or solar-generated electricity. Grid-powered stations consisted of two lead-acid batteries connected in parallel, with a 0.75 Ampere direct current (DC) charger plugged into the electricity source, plus the appropriate wiring. Solar-powered stations consisted of three batteries in parallel, 200 W photovoltaic cell array (i.e. solar panel(s), and one pulse width modulation (PWM) charge controller plus the appropriate wiring. Solar panels were mounted on aluminum masts to maximize time in direct sun and to shade the station equipment box.

Aerial surveys were conducted using a Bell 206 Jet Ranger helicopter equipped with one R2-AHS 2-element directional antenna (Telonics Inc. USA) externally mounted. Tag detections were decoded using SRX600 mobile receiver (Lotek, Canada). Flights were conducted following the Nechako River at approximately 75 m above ground elevation and approximately 100 km/h speed over ground. Boat surveys were conducted using a three-element directional antenna mounted near the bow of the boat. Boat surveys were conducted moving in upstream or downstream directions at speed over ground between 5 km/h and 30 km/h.

Analyses

Data collected in 2021 were provided by four organizations (CSTC, LTN, FFSBC, FLNRORD) and compiled in the NWSRI Access database. Data from the Access database were directly imported into R version 4.0.3 (R core team 2020) using RStudio version 1.2.5 (RStudio 2019). The data were summarized using R in tandem with the following packages: "lubridate", "plyr", "dplyr", "ggplot2", "sp", "ggmap", "ggrepel", "FSA", and their dependency packages.

Nechako River and Fraser River Conditions

Juvenile setline capture efforts are most effective when water temperatures are moderate (defined here as between 10°C and 18°C) and river discharge conditions are moderate to low relative to peak discharge levels observed earlier in the summer. Juvenile monitoring efforts are applied during mid to late summer and early fall seasons when river conditions are most likely to be favorable.

Water temperature and river discharge data were accessed through Water Survey Canada's online real time database (https://wateroffice.ec.gc.ca/). Data were extracted for two hydrometric stations continuously recording river discharge and water temperature. One station (08JC001) was located on Nechako River in Vanderhoof BC. The other station was located on the Fraser River near Shelley (08KB001). Daily mean and standard deviation (SD) for discharge and water temperature data are presented in Figure 1 and Figure 2, respectively. Daily mean and SD for water temperatures recorded at sampling sites are presented in red in Figure 2.

Figure 1 shows discharge conditions for Nechako River and Fraser River starting on May 1 until October 31 2021; a data window that covers peak discharge conditions for both rivers in 2021. Nechako River reached peak discharge of 417.18 $m^3/s \pm 0.83$ m^3/s on June 05 2021. Discharge conditions ranged between peak discharge and 200 m^3/s (approximately 50% of peak discharge) from prior to May 01 to August 29, 2021.

Peak discharge for Fraser River near Shelley was 3933.53 $m^3/s \pm 17.50$ m^3/s also on June 05 2021. Discharge conditions greater than 2000 m^3/s started near Shelley around May 17 and persisted until July 05 2021. Fraser River near Shelley maintained discharge conditions between 1000 m^3/s and 2000 m^3/s for a short period from around July 05 to July 26, 2021, and conditions were relatively low (i.e. less than 1000 m^3/s) for 2021 after July 26.

Figure 2 shows water temperature conditions for Nechako River and Fraser River starting on July 05 and ending October 12 2021; a data window that covers the 2021 sampling period and peak water temperature conditions for both rivers. Nechako River near Vanderhoof reached peak temperature of 21.40 °C ± 0.65 °C on June 30 2021 (08JC001). Peak temperature recorded at a sampling site was 20.72 °C ± 0.14 °C on August 05 2021. Two sampling days had recorded mean temperatures greater than 18.00 °C, both in occurring in early August.

Peak water temperature for Fraser River near Shelley was 17.60 °C ± 0.47 °C on July 31 2021. Fraser River near Shelley was consistently warmer than 10.00 °C starting prior to July 05 and lasting until September 17 2021. Peak temperature recorded at a Fraser River sampling site was 18.62 °C ± 0.10 °C on August 03. The minimum recorded site temperature in Fraser River was 8.72 °C on September 27 2020 at a site upstream of Shelley.

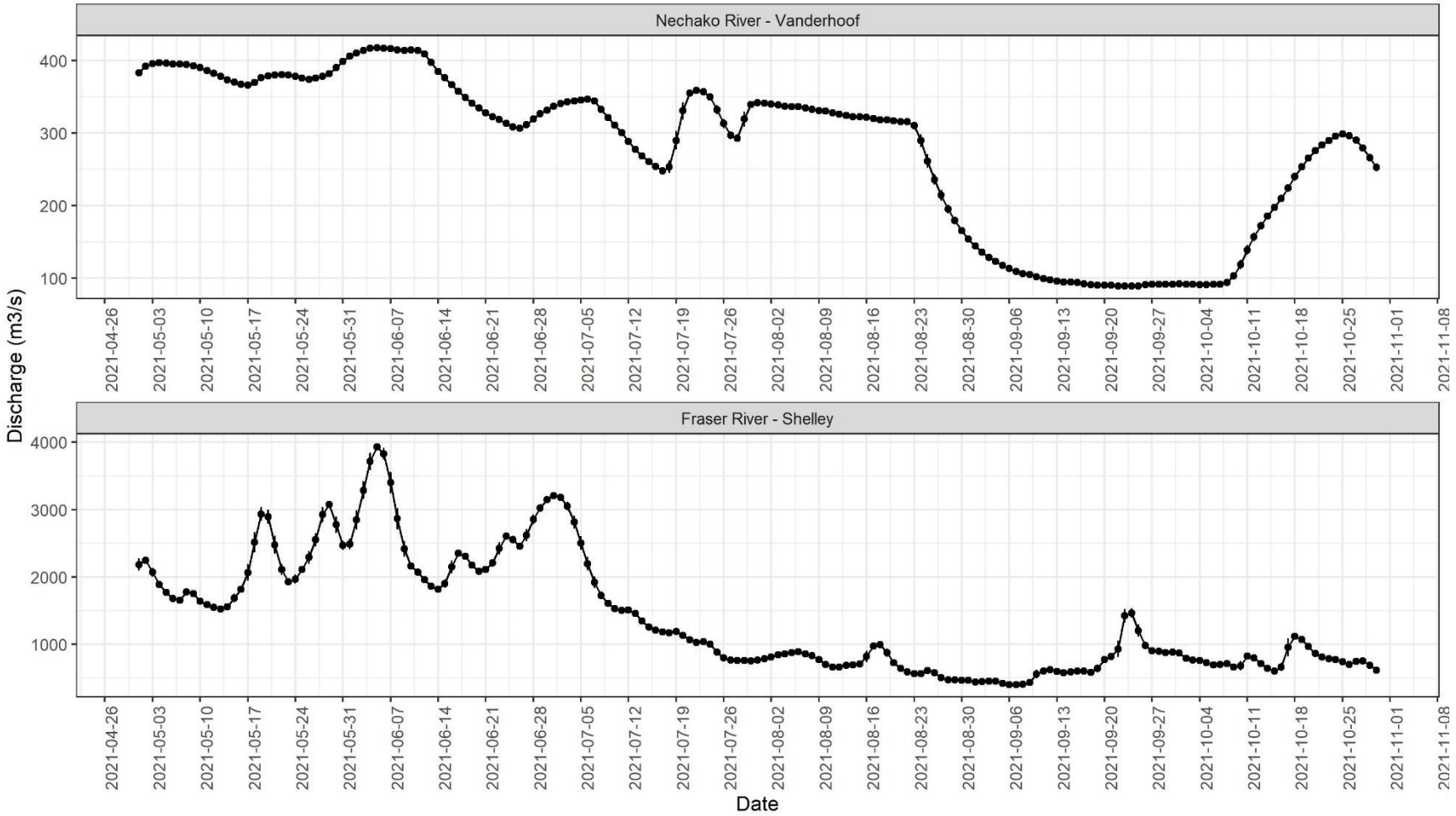


Figure 1. Daily mean river discharge conditions ± one SD in the Nechako River and the Fraser River recorded by Water Survey of Canada hydrometric stations in Vanderhoof (08JC001) and Shelley (08KB001).

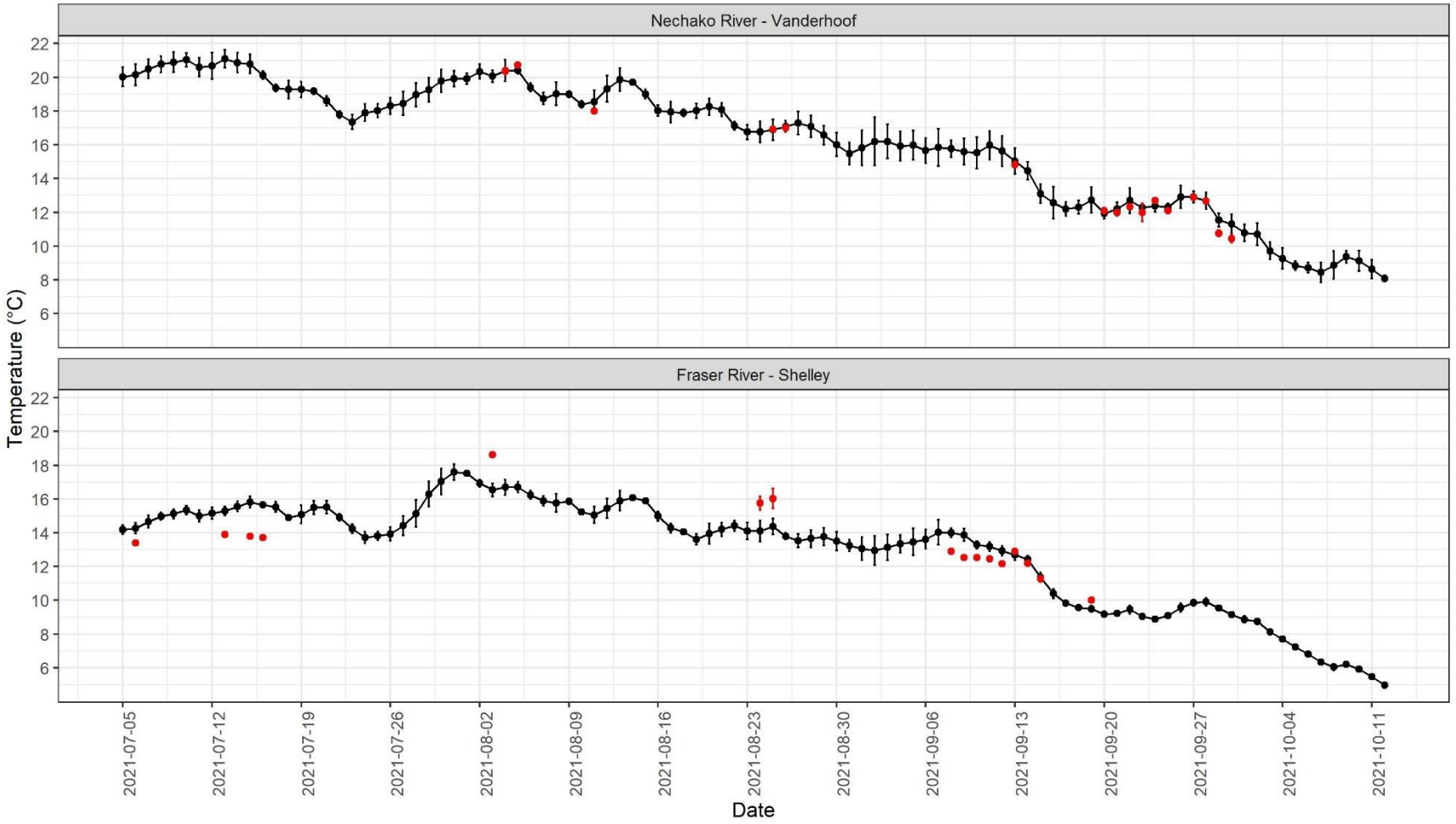


Figure 2. Daily mean river temperature conditions ± one SD in Nechako River and Fraser River recorded by Water Survey of Canada hydrometric stations located in Vanderhoof (08JC001) and Shelley (08KB001). Water temperatures recorded at sampling sites ± one SD are presented in red.

Section 2 – Nechako River Core Reach

Preface

The Core reach in the Nechako River includes all habitat between rkm 105 and rkm 135. The Core reach contains the downstream end of the spawning reach and several known Critical Habitat sites for rearing and overwintering sturgeon.

The objective for 2021 Core reach sampling was to maintain sampling methods standardized from 2017 onwards (random-systematic sampling of "blocks" and including larger hook sizes within the array).

Results

Core Reach Effort

One hundred and twenty-two setlines were applied to the Core reach between August 4 and October 5 2021. The sum of setline soak hours was 2967.4 hours. The mean soak time for a setline deployment was 24.3 ± 6.6 hours. The mean number of hooks fishing per setline was approximately 17 (17.3 ± 3.7 hooks), and the median number of hooks was 18. A total of 51,136.5 hook-hours of effort were applied to the Core reach in 2021.

Rkm 125 was the only rkm to receive close to 5000 hours (i.e. a high amount, actual hook hours was 4992.5) of hook effort (Figure 3). Between 3000 and 5000 hours (i.e. a moderate amount) of hook effort was applied to rkms 111, 112, 124, and 126. Between 1500 and 3000 hours (i.e. basal amount) of hook effort was applied to rkms 108 – 110, 113 – 115, 118, 119, 127, and 133. Less than 1500 hours of hook effort was applied to rkms 107, 116, 120 – 123, 130 – 132, and 134 – 135. No effort was applied to rkms 105, 106, 117, 128, and 129.

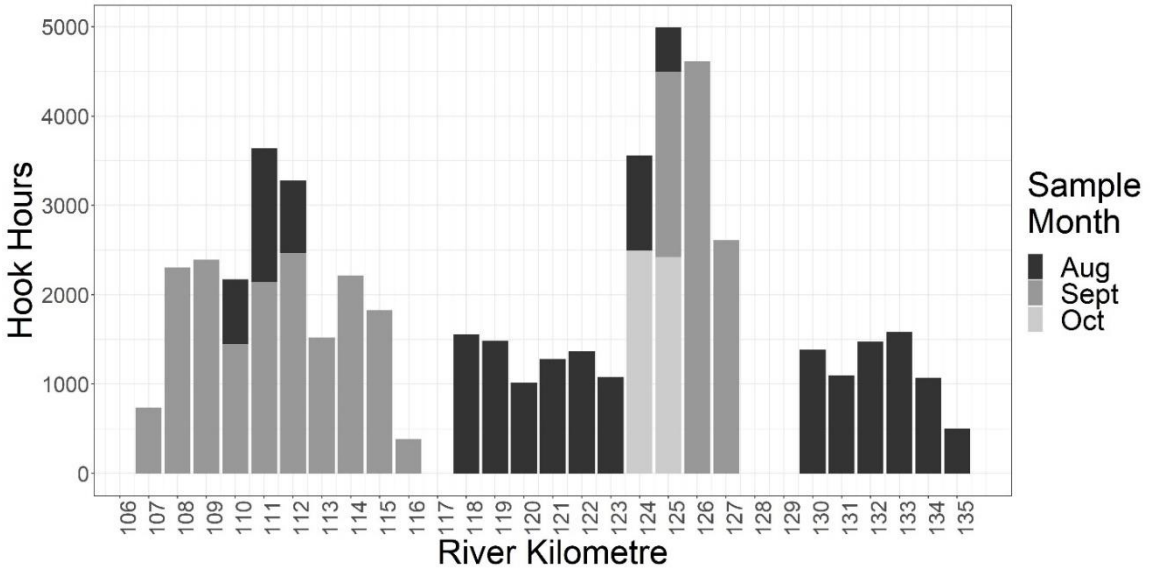


Figure 3. Spatial and temporal distribution of sampling effort applied to the Core reach in 2021.

Core Reach Capture Sample

Sixty-one unique juvenile sturgeon were captured in the Core reach. Two hatchery juveniles released in 2020 were captured twice for a total of 63 juvenile capture events in the Core reach in 2021. Fifty-five juveniles were hatchery origin, and six were wild-experimental origin. Three of the 55 hatchery juveniles were wild-spawned eggs reared in the hatchery and released in 2019.

The Core reach capture sample had the following release year cohort structure: Ten captures were 2016 releases, five captures were 2017 releases, seven captures were 2018 releases, four captures were 2019 releases, 15 captures were 2020 releases (including the two individuals with two captures in 2021), and 16 captures were 2021 releases. Table 1 below provides the number of first-time captures, recaptures, number of individuals captured more than once within 2021, and mean ± one standard deviation (SD) fork length (FL) for each release cohort in the 2021 Core reach capture sample. Recapture rate was highest for 2016 (60%) and 2017 (60%) release cohorts.

Table 1. Capture statistics from hatchery and wild-experimental juveniles in 2021 Core reach capture sample. First-time captures + Recaptures = Total Captures including multiple captures.

Cohort	First-time Captures	Recaptures	Multiple Captures (within 2021)	Mean ± SD Fork Length (cm)	Number of Juveniles Released
2015 release	0	0	0	NA	1247
2016 release	4	6	0	67.5 ± 5.2	9162
2017 release	2	3	0	58.9 ± 5.6	11518
2018 release	4	3	0	55.1 ± 5.3	7924
2019 release	2	2	0	68.3 ± 16.5	606
2020 release	10	5	2	70.5 ± 4.2	199
2021 release	16	0	0	71.3 ± 7.3	200
Wild-Experimental	4	2	0	64.9 ± 11.7	NA

Sample sizes of 2016 – 2019 release cohorts are small and are not considered suitable for overall cohort size estimates, but mean FL values in Table 1 show individuals have increased in length relative to previous years (CSTC 2021). Captures from the 2016 release cohort demonstrate a relatively normal distribution between 55 cm and 80 cm FL with a modal size class frequency between 65 cm and 70 cm FL. Captures from the 2017 and 2018 release cohorts demonstrate similar size distributions between 45 cm and 70 cm FL. Both cohorts have a weak modal size class between 50 cm and 60 cm FL. Captures from the 2019 release cohort have the widest size range between 45 cm and 90 cm FL. Captures from the 2020 and 2021 release cohorts demonstrate similar size class distributions; each cohort's modal size class is between 65 and 70 cm, and both cohort size distributions are slightly positively skewed. The size distributions for 2016, 2020, and 2021 release cohorts are all similar.

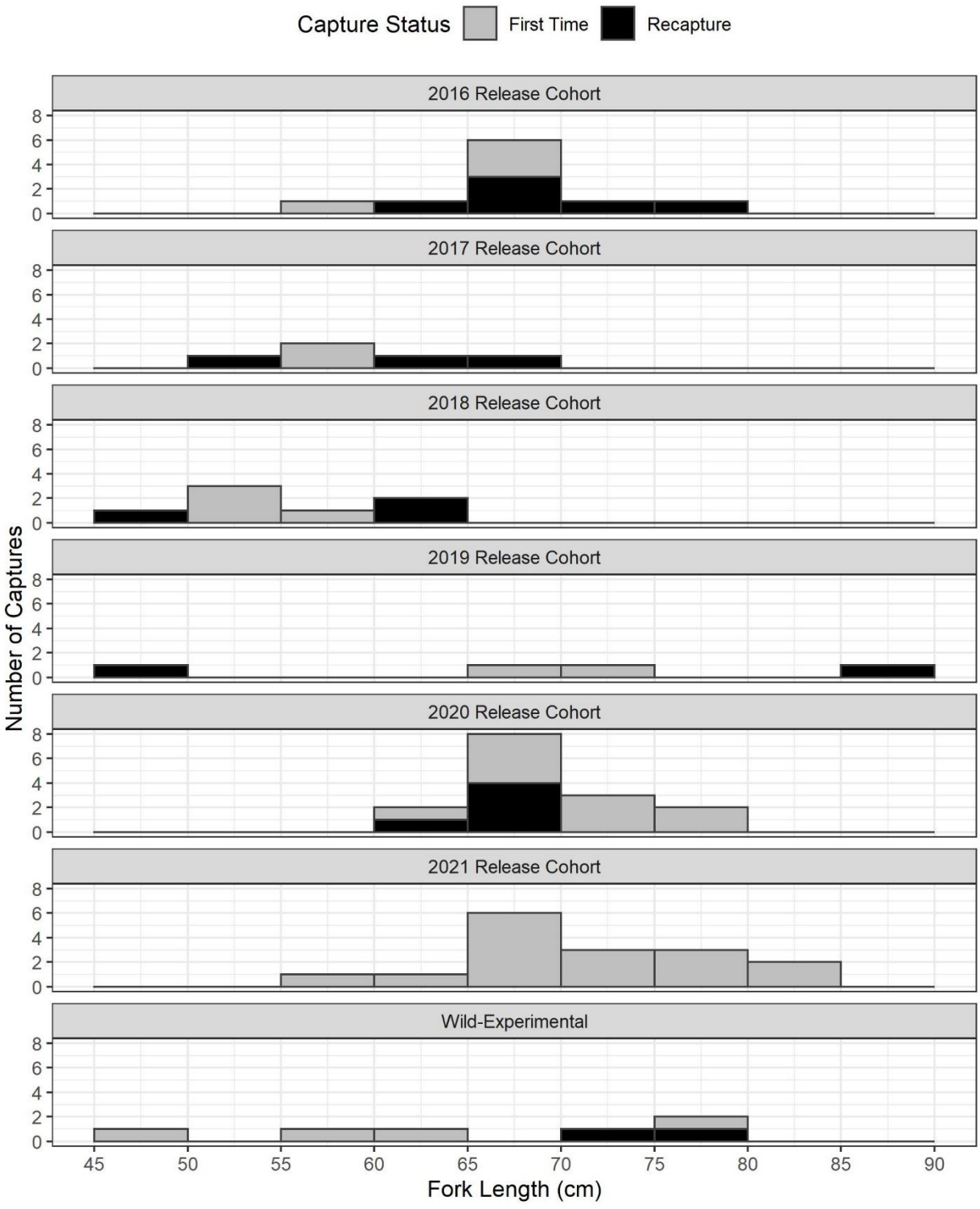


Figure 4. Fork length distributions for hatchery release cohorts and wild-experimental origin fish captured in 2021 Core reach sample.

Hook sizes were recorded for 56 capture events in 2021. All hook sizes used in Core reach monitoring captured a similar size distribution of captured juvenile sturgeon (Figure 5).

Table 2. Summary of hook hours for hook sizes applied to Core reach in 2021 monitoring.

Hook Size	4	2	1	1/0	4/0	5/0	6/0	8/0
Hook Hours	10589.7	10306.2	10377.1	10389.0	2428.9	1330.2	2363.5	2509.1

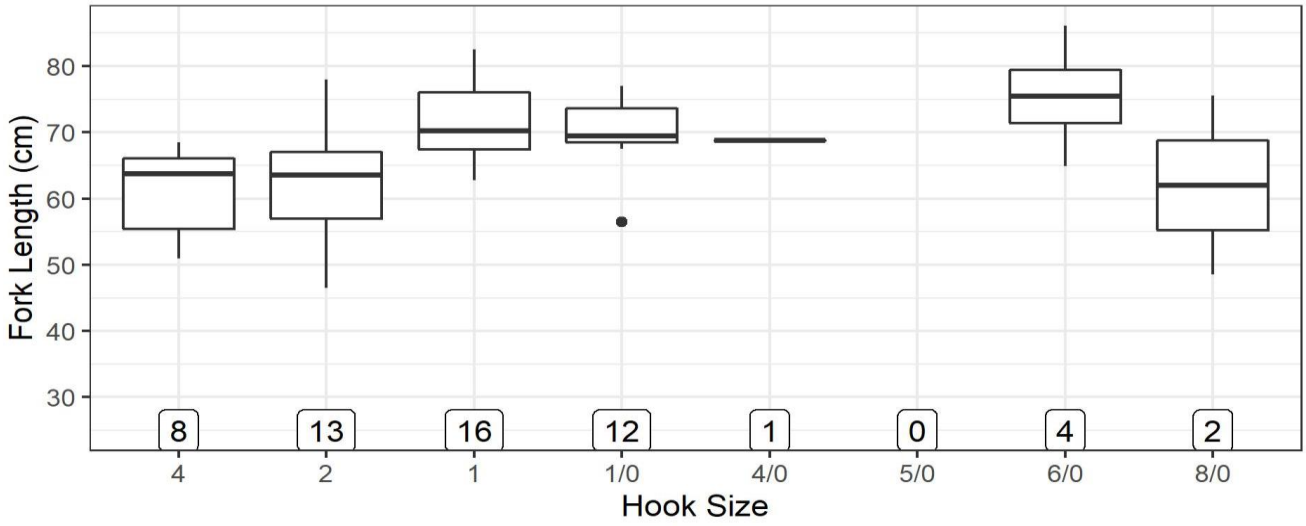


Figure 5. Boxplots showing size distribution of captured juvenile sturgeon for each hook size used in Core reach monitoring. Number of captures are displayed under each boxplot.

The spatial distribution of juvenile captures in 2021 is shown in Figure 6. Rkms 110-114 produced 35% of the Core reach capture sample in 2021, and rkm 115 produced 16% of the capture sample, the most of any single rkm (Figure 6). Rkm 125 produced 13% of the capture sample, and the remaining 38% of the capture sample was spread throughout the Core reach.

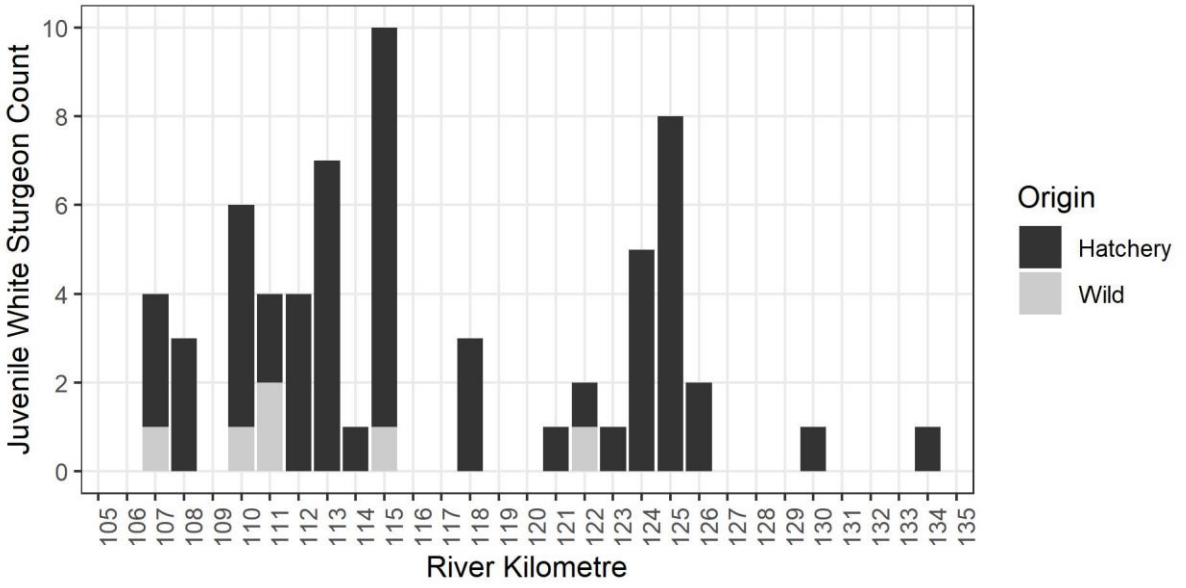


Figure 6. Number of juvenile white sturgeon captures by river kilometre during 2021 Core reach monitoring.

Overall catch per unit effort (CPUE) for Core reach sampling was 0.123 juvenile captures per 100 hook hours. Figure 7 shows CPUE by rkm was highest for rkm 115 at 0.547 juvenile sturgeon captures per 100 hook hours, followed by rkm 107 (CPUE = 0.544) then rkm 113 (CPUE = 0.460). CPUE was 0.276 for rkm 110, and CPUE for all other rkms was less than 0.200 juvenile sturgeon captures per 100 hook hours.

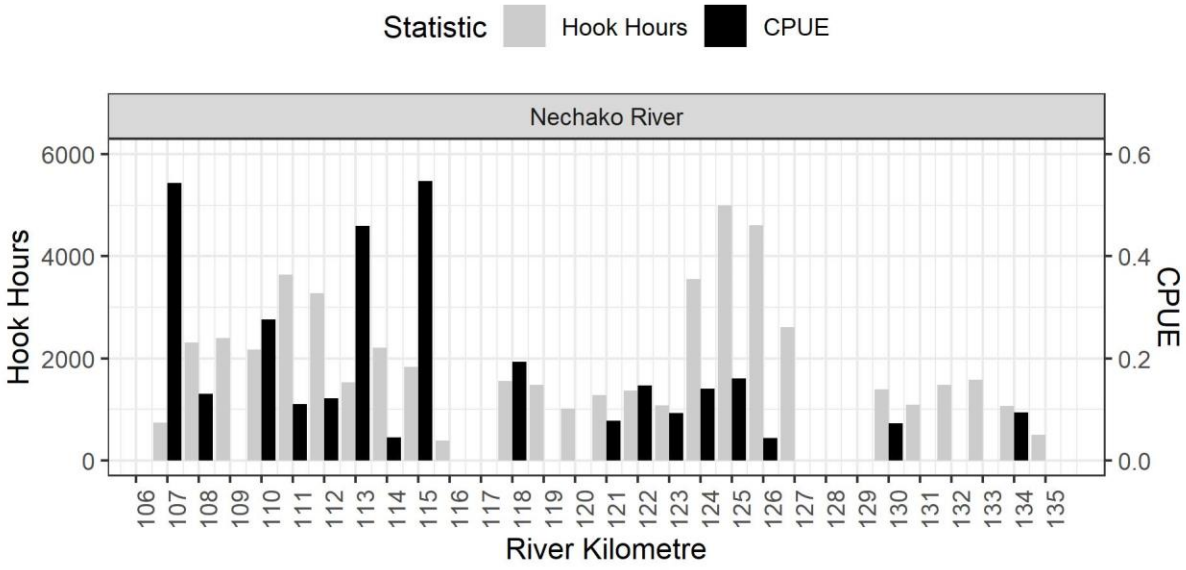


Figure 7. Spatial distribution of hook hours and catch per unit effort (# juvenile captures / 100 hook hours) for each river kilometre sampled during 2021 Core reach monitoring.

Findings

Sampling Conditions

Nechako River conditions during 2021 were relatively high discharge from earlier than May 1 to August 23, however 71% of sampling effort occurred after August 23 during declining discharge conditions. Water temperatures in the Core reach during 2021 sampling effort were moderate, except during three sampling days in August when recorded sampling temperatures were higher than 18.0°C. Effort applied to the Core reach in 2021 was well timed with river conditions.

Capture Sample

Overall Core reach CPUE in 2021 was high relative to 2020, however the capture sample size in 2021(63) was almost identical to the capture sample size in 2020 (65; CSTC 2021). A reduced amount of effort was applied during ideal river conditions in 2021 which likely biased results towards a higher CPUE. Additionally, effort was prioritized to blocks which contained at least one high CPUE rkm which resulted in missing some low CPUE rkms.

Numbers of juveniles captured from 2015, 2016, 2017 cohorts are low, ranging from 0 for the 2015 cohort to 10 for the 2016 cohort. The 2015 and 2017 cohort capture numbers were low but relatively stable from 2020 to 2021, but 2016 cohort captures have decreased by 65% from 2020 to 2021. All of the cohorts released before 2018 have shown decreasing and now small capture samples since their release. Recapture rates for 2016 and 2017 release cohorts have been above 50% since 2018 and 2020, respectively. Results from Peripheral and Fraser River sampling will help interpret the significant declines of these cohorts from the Core reach capture sample.

The 2018 and 2019 cohort Core capture samples are also low, ranging from four for the 2019 cohort to seven for the 2018 cohort. The 2018 cohort capture sample appears to have peaked in 2020 with 13 juveniles captured, and it decreased by 46% in 2021. The 2019 cohort Core capture sample has decreased by 75% since its peak of 16 captures in 2019, but appears relatively stable between 2020 and 2021. The recapture rates for 2018 (43%) and 2019 (50%) release cohorts were at a maximum in 2021.

The 2020 and 2021 cohorts showed large capture samples in 2021 relative to their release numbers, and they had larger capture samples compared to other cohorts in 2021 Core reach sampling. All individuals from the 2020 and 2021 cohorts were released within target size of the setline gear. All individuals from the latest cohorts are therefore available for capture the same year they are released, unlike hatchery cohorts released 2015-2019 where a significant number of individuals had to grow before they could be effectively captured. Capture sample size for the 2020 cohort in 2021 (N=15) was the same as 2020 and recapture rate increased from 20% in 2020 to 33% in 2021.

Section 3 – Nechako Watershed Peripheral Regions

Preface

In 2021 effort was applied to Fraser Lake and in the Nechako River mainstem from rkm 174 to rkm 176. Fraser Lake effort was systematically applied to four zones covering the entire circumference of the lake to a maximum of 10m depth. Overall effort was higher than previous years as a result. Effort was applied to one Peripheral region in Nechako River mainstem in late October when water temperatures were below 10°C. Setline sampling during these temperature conditions has poor efficacy and likely biased results in 2021.

An objective of 2021 Peripheral region sampling was to more thoroughly sample Fraser Lake relative to sampling in prior years. Hatchery juveniles have been released into Fraser Lake in recent years (N = 73 in 2020 and N = 80 in 2021). Collecting data to better understand juvenile sturgeon life history patterns in Fraser Lake may have important implications for survival of hatchery cohorts and thus recovery of the NWS population.

Results

Peripheral Regions Effort

One hundred setlines were applied to peripheral regions in Nechako watershed between July 12 and October 28 2021. The sum of setline soak hours applied to peripheral regions in the Nechako watershed was 2224.9 hours. The mean soak time for a setline deployment was 22.4 ± 1.5 hours. The mean number of hooks fishing per setline was approximately 23 (23.2 ± 1.5 hooks) and the median number of hooks fishing was 24. The sums of hook hours applied to Nechako River and Fraser Lake peripheral regions were 3,527 and 47,997 respectively. A total of 51,524 hook hours were applied to Nechako watershed peripheral regions in 2021.

Effort was only applied to a small section of Nechako River mainstem outside of the Core reach in 2021. A basal amount of hook hours was applied to rkm 176 and less than 1500 hook hours was applied to rkms 177 and 178 (3,527 hook hours in total) (Figure 8).

Effort (47,997 hook hours) was applied to the circumference of Fraser Lake, except the southeast bay, during the month of July. Additional effort was applied to the east end Fraser Lake, north of the Nautley River outlet in August (Figure 9).

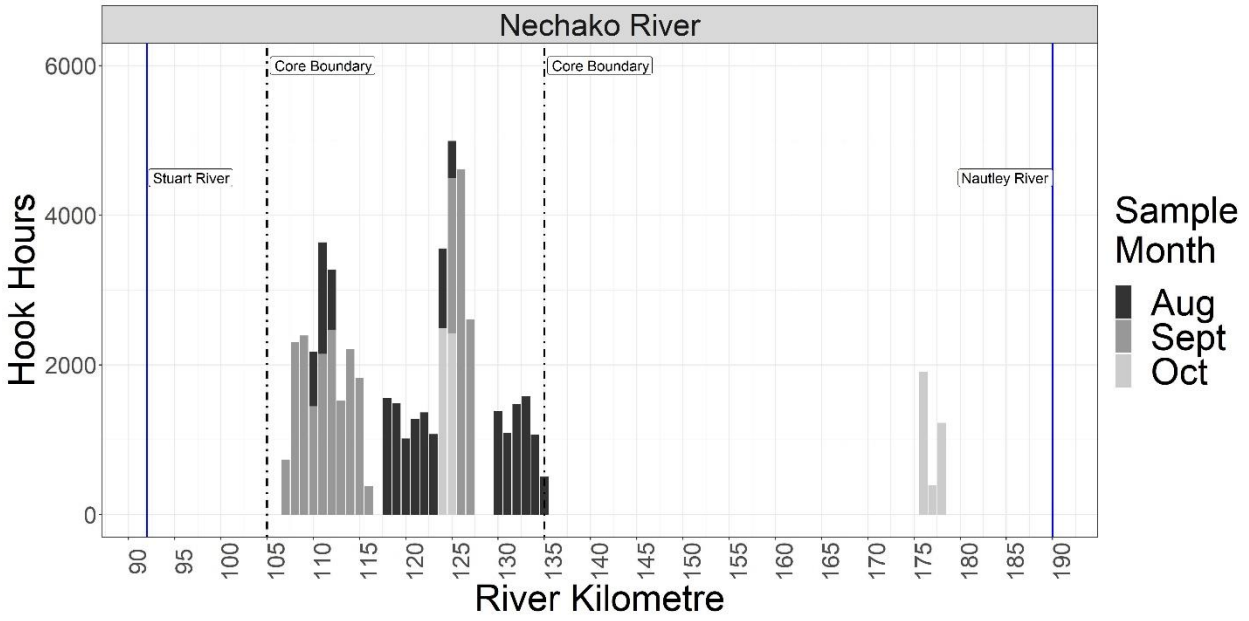


Figure 8. Spatial and temporal distribution of sampling effort applied to the Core reach and peripheral areas in Nechako River 2021. Vertical blue lines show Stuart and Nautley River confluences. Vertical dot-dash lines show boundaries of Core reach.

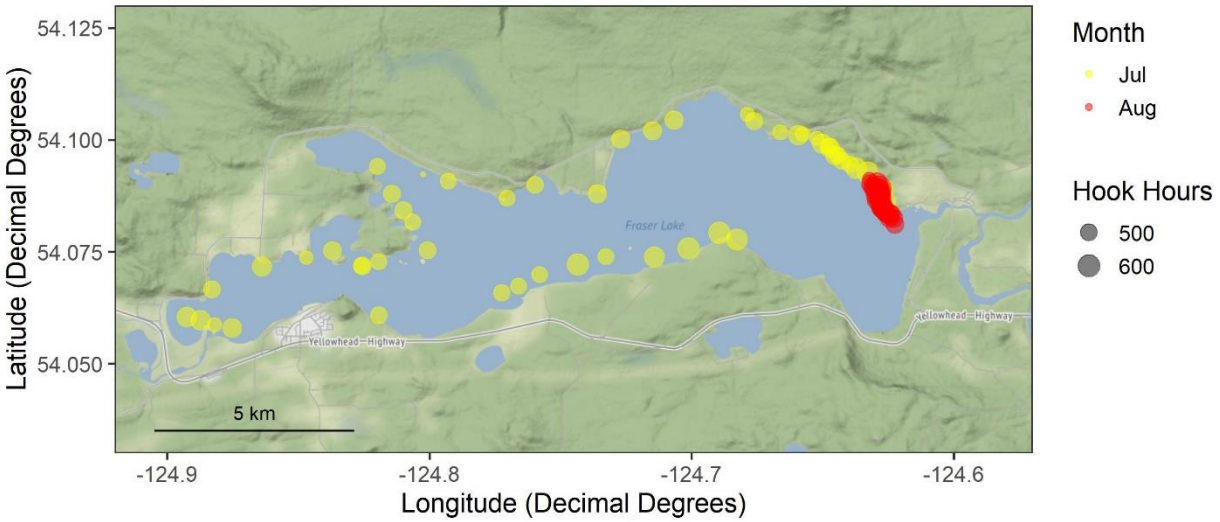


Figure 9. Spatial and temporal distribution of sampling effort applied to Fraser Lake in 2021.

Peripheral Regions Capture Sample

Three juvenile sturgeon were captured in Fraser Lake, and no juveniles were captured in peripheral regions of Nechako River mainstem. Two of the captured juveniles had been released in Fraser Lake in 2020. The other captured juvenile was a wild-experimental origin first-time capture. Table 3 below provides the number of first-time captures, recaptures, and number of

individuals captured more than once, and mean fork-length for captures from each release cohort in the 2021 Peripheral capture sample. No individuals from pilot (2006 to 2009) release cohorts, or 2015 to 2019 release cohorts were encountered during 2021 Peripheral sampling.

Table 3. Capture statistics from hatchery and wild-experimental juveniles in 2021 Peripheral capture sample. First-time captures + Recaptures = Total Captures including multiple captures.

Cohort	First-time Captures	Recaptures	Multiple Captures (within 2021)	Capture Mean ± SD Fork Length (cm)	Number of Juveniles Released
2015 release	0	0	0	NA	1247
2016 release	0	0	0	NA	9162
2017 release	0	0	0	NA	11518
2018 release	0	0	0	NA	7924
2019 release	0	0	0	NA	606
2020 release	0	2	0	73.6 ± 2.3	199
2021 release	0	0	0	NA	200
Wild-Experimental	1	0	0	77.5 ± NA	NA

Too few individuals were captured to provide meaningful cohort size distributions, however mean FL for the two 2020 released individuals is within one SD of the Core reach mean FL for 2020 released individuals. The largest capture in the 2021 Peripheral sample was wild origin (Table 3).

Too few individuals were captured to provide meaningful capture size distributions for hook sizes, but hook hours for each hook size are provided in Table 4.

Table 4. Summary of hook hours for hook sizes applied to peripheral regions in 2021.

Hook Size	4	2	1	1/0	4/0	5/0	6/0	8/0
Hook Hours	8039.6	8049.2	7695.4	8077.6	6477.2	0	6766.9	6448.8

All three captures in Fraser Lake were recorded in the east end of the lake, near the Nautley River outflow (Figure 10). The two captured juveniles released in 2020 were recaptures; each had been captured in Fraser Lake during 2020 juvenile monitoring. The one wild-experimental juvenile captured was a first time capture; this juvenile was tagged with an acoustic tag to track its movements in Fraser Lake using the array of acoustic receivers deployed as part of a University of Northern BC (UNBC) multi-species telemetry study.

Overall CPUE for 2021 peripheral monitoring was 0.006 juveniles per 100 hook hours. CPUE values in the Nechako mainstem were 0 largely due to limited effort applied during unfavorable conditions (Figure 11). CPUE in Fraser Lake was 0.006 (not shown in Figure 11) which was

influenced by higher than normal effort applied to new sampling sites throughout the lake where no fish were captured.

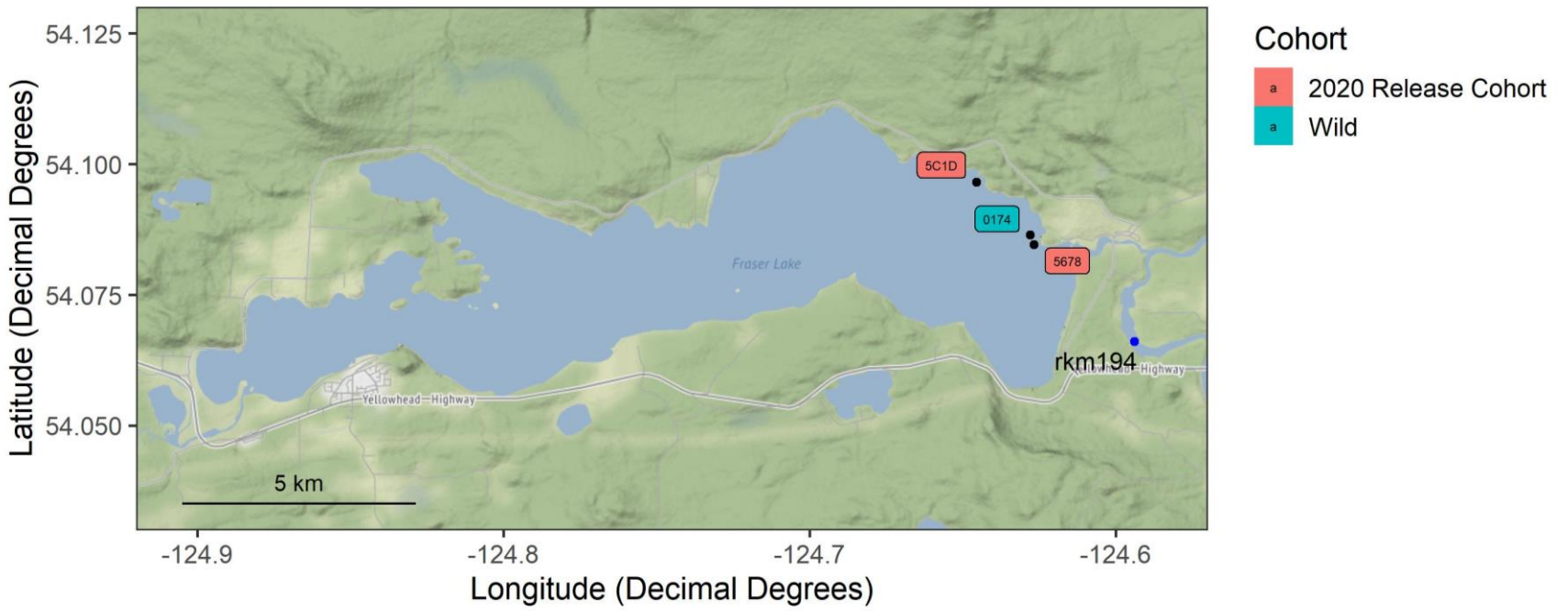


Figure 10. Locations of juvenile captures in Fraser Lake and nearby Nechako River. Capture sites are labeled with last four digits of their PIT identification and are colour-coded according to cohort of the captured juvenile. Nechako River rkm 194 is marked using a blue point.

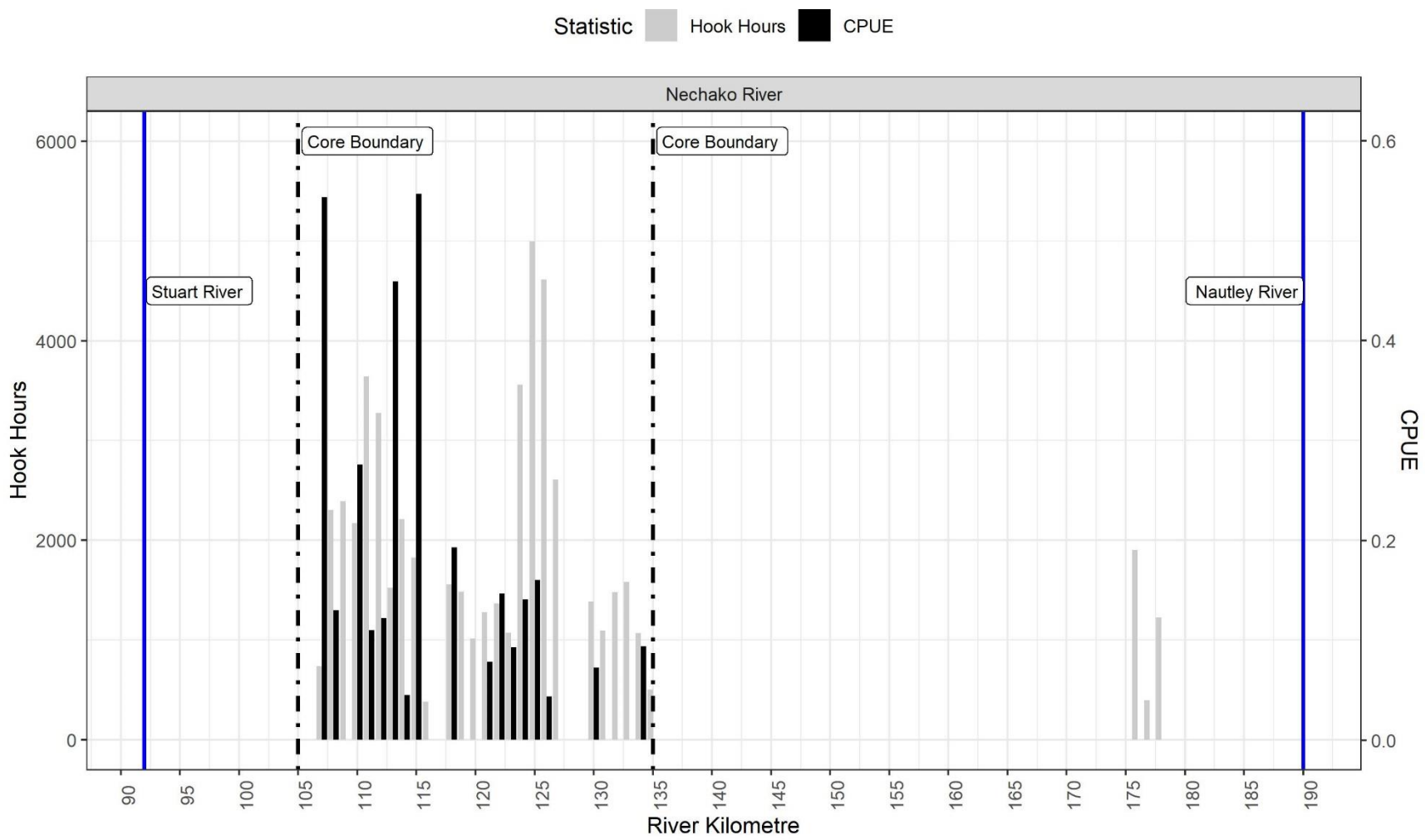


Figure 11. Spatial distribution of hook hours and catch per unit effort in Peripheral regions. CPUE is shown for each rkm that produced juvenile captures. Fraser Lake captures are not shown. Blue vertical lines show tributary confluences. Dot-dash vertical lines show Core reach boundaries. Core reach results are provided for context.

Findings

Sampling Conditions

Sampling within peripheral areas of the Nechako River in 2021 was very limited and occurred during cold, unfavorable river conditions in late October.

Sampling within Fraser Lake was more comprehensive than previous years. The modified sampling approach in 2021 deployed setlines in July and August. Sampling locations were evenly distributed around the circumference and within 10m depth in Fraser Lake. Sites near the east end of Fraser Lake were sampled again in August to match effort applied to that area in 2020.

Capture Sample

Only three juveniles were captured in Fraser Lake in 2021 despite similarities between effort applied to the east end high CPUE habitat identified in 2020 (i.e. similar amount of hook hours during similar time of the year). The factors related to interannual CPUE variation in Fraser Lake are unclear at this time. A large-scale acoustic monitoring array tracking acoustically tagged juvenile sturgeon was operational in Fraser Lake in 2021 and detected 20 hatchery reared releases from 2021 and one wild fish that was tagged in 2021 (Spendlow, pers.comm.). Results from that study may provide insight on juvenile sturgeon habitat use in Fraser Lake, but are not expected until late 2022 or early 2023.

Section 4 – Fraser River Regions

Preface

This report defines regions of the Fraser River in the context of the white sturgeon populations that inhabit the Fraser River. The middle and upper Fraser River passes through three provincial resource management units. Starting at Hell's Gate (rkm 212) and travelling upstream, the middle Fraser River passes through Region 3 then Region 5 and ends at the Blackwater River confluence (rkm 700), which is also the northern boundary of Region 5. The upper Fraser River begins at rkm 700 and runs through Region 7A (hereafter Region 7) upstream to the headwaters of the Fraser River (approximately rkm 1300).

There are no physical barriers in the Fraser River that are impassable to white sturgeon. Hell's Gate is a boundary that separates the lower Fraser River from the middle Fraser River. Mark-recapture data indicate white sturgeon can pass this hydrological feature, but there is no evidence to suggest white sturgeon normally migrate through Hell's Gate and genetic evidence suggests it is a major influence on gene flow.

The Nechako River confluence is in the upper Fraser River at rkm 798. There are no physical barriers between the Nechako River, the upper Fraser River, and the middle Fraser River that would impede white sturgeon movements. The NWSRI juvenile monitoring program was expanded in 2017 to monitor habitat in the middle and upper Fraser River in Region 5 and Region 7, respectively.

Longworth canyon is a unique habitat feature in Region 7 near rkm 954. Previous juvenile monitoring reports have summarized sampling in Longworth separately from the rest of Region 7 with an understanding that this habitat was a unique critical juvenile rearing habitat for the Upper Fraser sturgeon population.

The specific objectives of Fraser River monitoring in 2021 included:

1. To document the distribution of Nechako hatchery juveniles in the Fraser River.
2. Sample "index" sites which were identified in previous years of sampling to contribute to the NWSRI juvenile sturgeon mark-recapture dataset.
3. Collect finray and tissue samples for microchemistry and genetic studies on Fraser River white sturgeon meta-population structure, and hatchery and wild fish measurements.
4. Identify new sites that produce juvenile captures in the Fraser River.

Results

Region 5 Effort

Seventy-five setlines were applied to Fraser River Region 5 between July 13 and September 23 2021. Ten setlines were deployed overnight (i.e. overnight sets), and 65 setlines were deployed and pulled on the same day (i.e. day sets). The mean ± SD soak time for an overnight set was 21.6 ± 3.3 hours and the mean ± SD soak time for a day set was 4.0 ± 1.2 hours. Sums of soak hours

for overnight and day sets were 215.8 hours and 249.2 hours respectively, for a total of 465.0 soak hours applied to Region 5. Mean ± SD and median number of hooks fishing for overnight and day sets was 24.4 ± 2.2 and 25. The sum of hook hours applied using overnight sets was 4,880.0, and the sum of hook hours applied using day sets was 5872.3 for a total of 10,752.3 hook hours applied to Region 5 in 2021.

Setlines were applied to areas between rkm 477 and rkm 690. A relatively small number of hook hours were applied to a relatively large number of rkms in Region 5. There was a greater number of hook hours applied to sites near rkm 550 and rkm 650. Sampling activity was spread out over July and August for most of the sampling sites. Sampling sites near rkm 550 were sampled in September as well.

Region 7 and Longworth Effort

Thirty-five setlines were applied to Fraser River Region 7 between August 03 and September 19, and 21 setlines were applied to Longworth between September 3 and September 6, for a total of 56 setlines applied to Region 7 including Longworth in 2021. The mean ± SD soak time for a setline deployment in Region 7 was 22.3 ± 2.5 hours. The sum of soak hours applied to Region 7 excluding Longworth was 794.8, and the sum of soak hours applied to Longworth was 456.5 hours. The mean number of hooks fishing per line was 18.7 ± 2.2 hooks and 18.8 ± 1.7 hooks for Region 7 and Longworth, respectively. The sum of hook hours applied to Region 7 excluding Longworth was 14,837 and the sum of hook hours applied to Longworth was 8,603.5. A total of 23,421 hook hours were applied to the Fraser River Region 7 including Longworth.

Setlines in Region 7 including Longworth were applied to three areas: one area was between rkm 740 and rkm 761, and the second was between rkm 825 and rkm 836, and the third was Longworth near rkm 956. Sampling activity was spread out over August and September near rkm 760 and focussed in September for the other two areas.

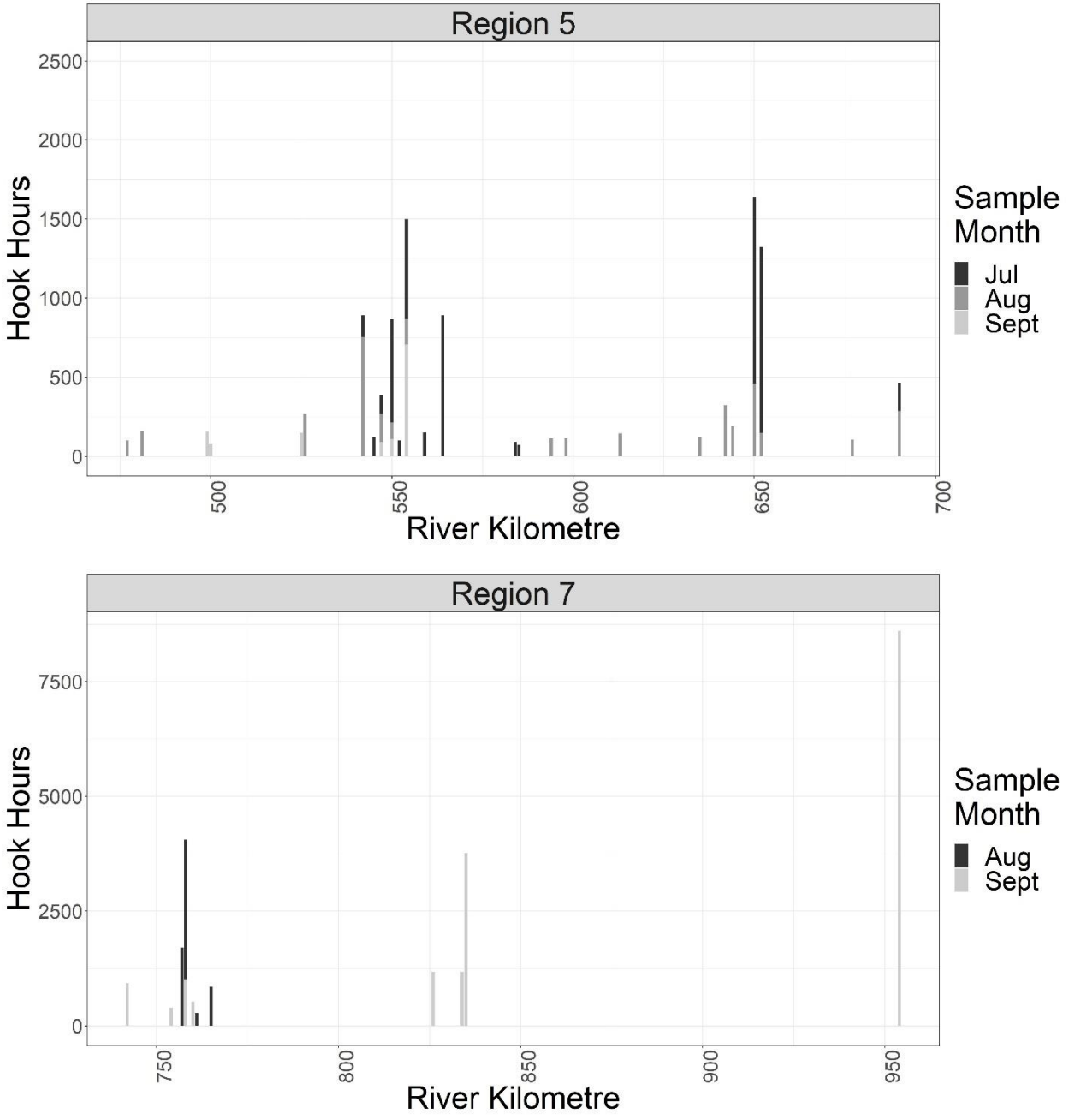


Figure 12. Spatial and temporal distribution of sampling effort applied to Fraser River Region 5 and Region 7 including Longworth canyon.

Region 5 Capture Sample

Seventeen hatchery juveniles and 54 wild juveniles were captured in Region 5 sampling. Two hatchery and four wild juveniles were captured twice within 2021 for a total of 77 juvenile capture events in Region 5 sampling. Eight wild juveniles were released without marks or tags that will identify them if subsequently captured.

The hatchery juvenile captures had the following release-year cohort structure: 13 juveniles were 2016 releases, three juveniles were 2017 releases, one juvenile was a 2018 release, and two juveniles were 2020 releases (Table 5). Six hatchery juvenile captures were recaptures and 13 were first-time captures. The recaptured 2020 release was captured in the Nechako River twice in 2020; one capture near rkm 194 on August 21, and the second capture near rkm 125 on October 09. The other five hatchery recaptures were first captured in Fraser River Region 5. Forty-five wild juvenile captures were first-time captures and 13 wild juvenile captures were recapture events.

Table 5. Capture statistics from hatchery and wild juveniles in 2021 Region 5 capture sample. First-time captures + Recaptures = Total Captures including multiple captures.

Cohort	First-time Captures	Recaptures	Multiple Captures (within 2021)	Capture Mean ± SD Fork Length (cm)	Number of Juveniles Released
2015 release	0	0	0	NA	1247
2016 release	9	4	2	52.1 ± 3.4	9162
2017 release	2	1	0	48.0 ± 3.3	11518
2018 release	1	0	1	39.5 ± NA	7924
2019 release	0	0	0	NA	606
2020 release	1	1	0	71.9 ± 1.7	199
2021 release	0	0	0	NA	200
Wild	45	13	4	59.1 ± 15.2	NA

Mean ± SD FL for 2016 release cohort in the 2021 Region 5 capture sample was 52.1 cm ± 3.4 cm, which is 15.4 shorter than the mean ± SD FL of cohort conspecifics captured in the Nechako River Core sample. Too few individuals were captured from 2017, 2018, and 2020 release cohorts to make meaningful cohort size comparisons. Wild fish had the largest mean and SD FL in the Region 5 capture sample with individuals ranging from 24.5 cm to 83.0 cm FL. The wild FL distribution is bimodal with peak frequency counts between 30 and 35 cm FL (N = 5), as well as between 65 and 70 cm FL (N = 10) (Figure 13).

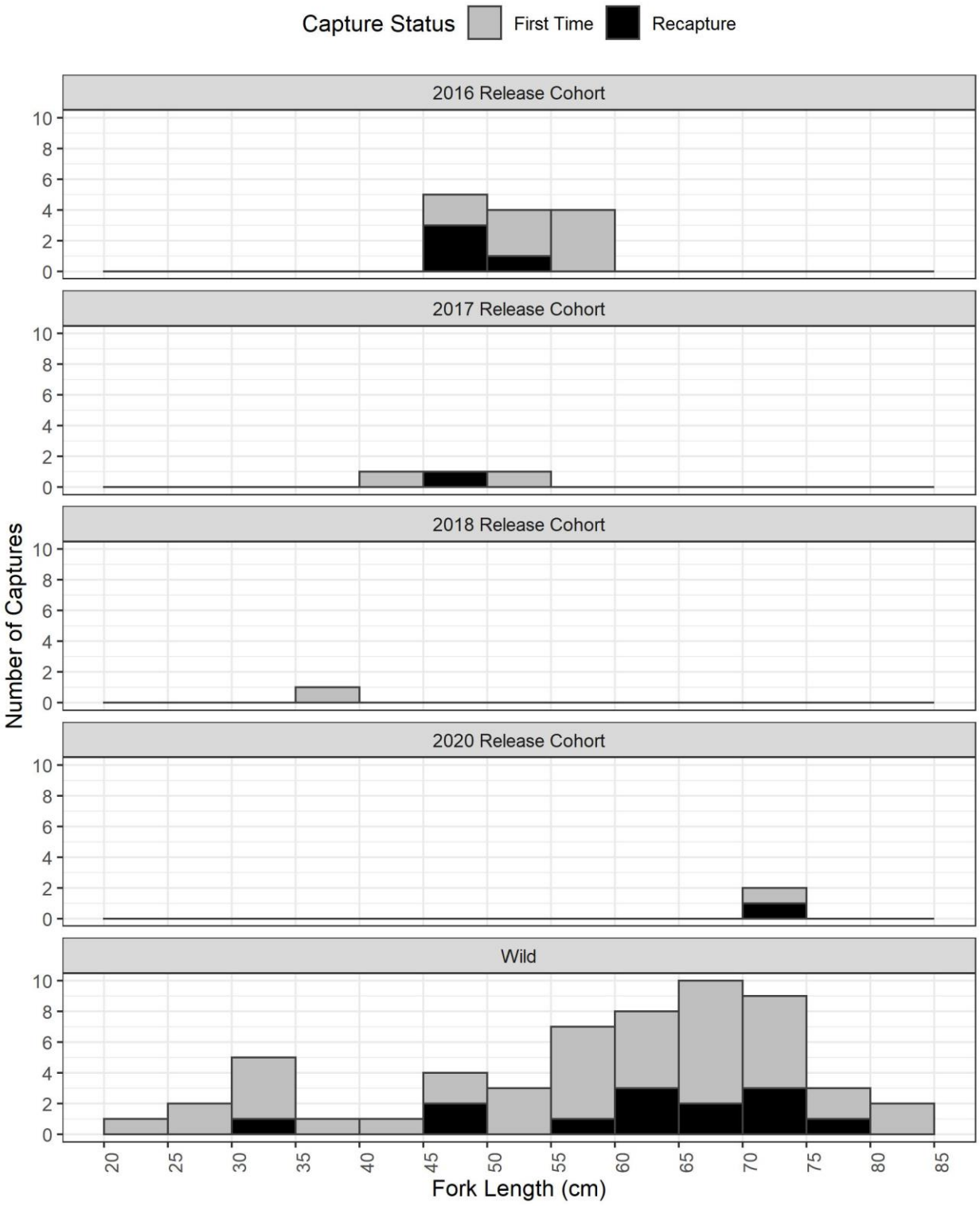


Figure 13. Fork length distributions for juvenile sturgeon cohorts captured in 2021 Region 5 sampling.

Region 7 and Longworth Capture Sample

Thirty-one unique juveniles were captured in Region 7 sampling excluding Longworth. Fourteen juveniles were hatchery origin and 17 juveniles were wild origin. Two wild juveniles were captured twice in 2021 for a total of 19 wild capture events and a total of 33 capture events in Region 7 sampling excluding Longworth.

The hatchery juvenile captures had the following release-year cohort structure: eight juveniles were 2016 releases, five juveniles were 2017 releases, and one juvenile was a 2018 release. Three hatchery juvenile captures were recaptures and 11 were first-time captures. All wild juvenile captures were first-time captures excluding the multi-capture events (Table 6). Two of the hatchery juvenile recaptures each had capture histories in Fraser River near Stone Creek. The capture from the 2017 hatchery cohort was previously captured in Nechako River at rkm 28.6.

Table 6. Capture statistics from hatchery and wild juveniles in 2021 Region 7 capture sample excluding Longworth. First-time captures + Recaptures = Total Captures including multiple captures.

Cohort	First-time Captures	Recaptures	Multiple Captures (within 2021)	Capture Mean ± SD Fork Length (cm)	Number of Juveniles Released
2015 release	0	0	0	NA	1247
2016 release	6	2	0	47.4 ± 3.5	9162
2017 release	4	1	0	47.7 ± 5.1	11518
2018 release	1	0	0	42.0 ± NA	7924
2019 release	0	0	0	NA	606
2020 release	0	0	0	NA	199
2021 release	0	0	0	NA	200
Wild	17	2	2	53.4 ± 12.4	NA

The mean FL for 2016 release hatchery juveniles captured in Fraser River Region 7 is 20.1 cm shorter than the mean FL for 2016 release juveniles captured in the Nechako River Core region. The mean FL for 2017 release juveniles captured in Fraser River is 11.2 cm shorter than the mean FL for 2017 release juveniles captured in the Nechako River Core region. The wild juvenile size distribution ranged from 30 cm FL to 80 cm FL. The wild juvenile FL distribution was normally distributed with mean, median and mode statistics between 50cm and 55 cm FL, however no wild juveniles between 40 cm and 45 cm FL were captured (Figure 14).

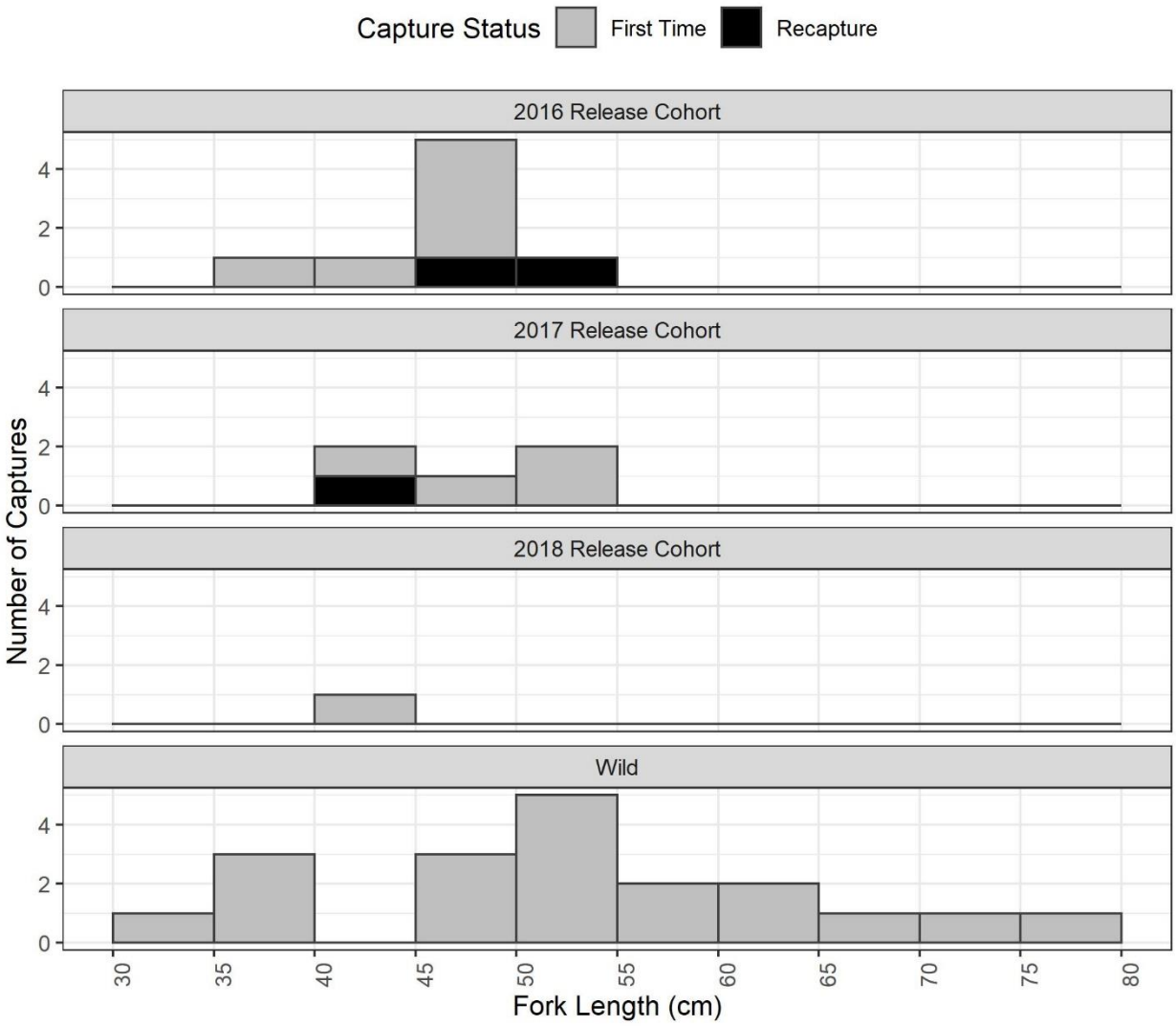


Figure 14. Fork length distributions for juvenile sturgeon cohorts captured in 2021 Region 7 sampling excluding Longworth.

Fifty-six unique juveniles were captured in Longworth, and one juvenile was captured twice for a total of 57 capture events in 2021 Longworth sampling. All captures were wild origin. Twenty wild juveniles were recaptures which is a 35% recapture rate.

One wild recapture in 2021 was originally tagged, measured, and aged at Longworth in 2008 (FL = 70.0 cm, age = 13+ years) and then recaptured near Fraser River rkm 900 in 2015 (FL = 82.3 cm). This individual's FL (91.5 cm in 2021) increased 21.5 cm since 2008. A finray from this individual was sampled in 2021 for aging and microchemistry analysis. The remaining 19 wild juvenile recaptures were originally tagged through juvenile monitoring programs between 2018 and 2020.

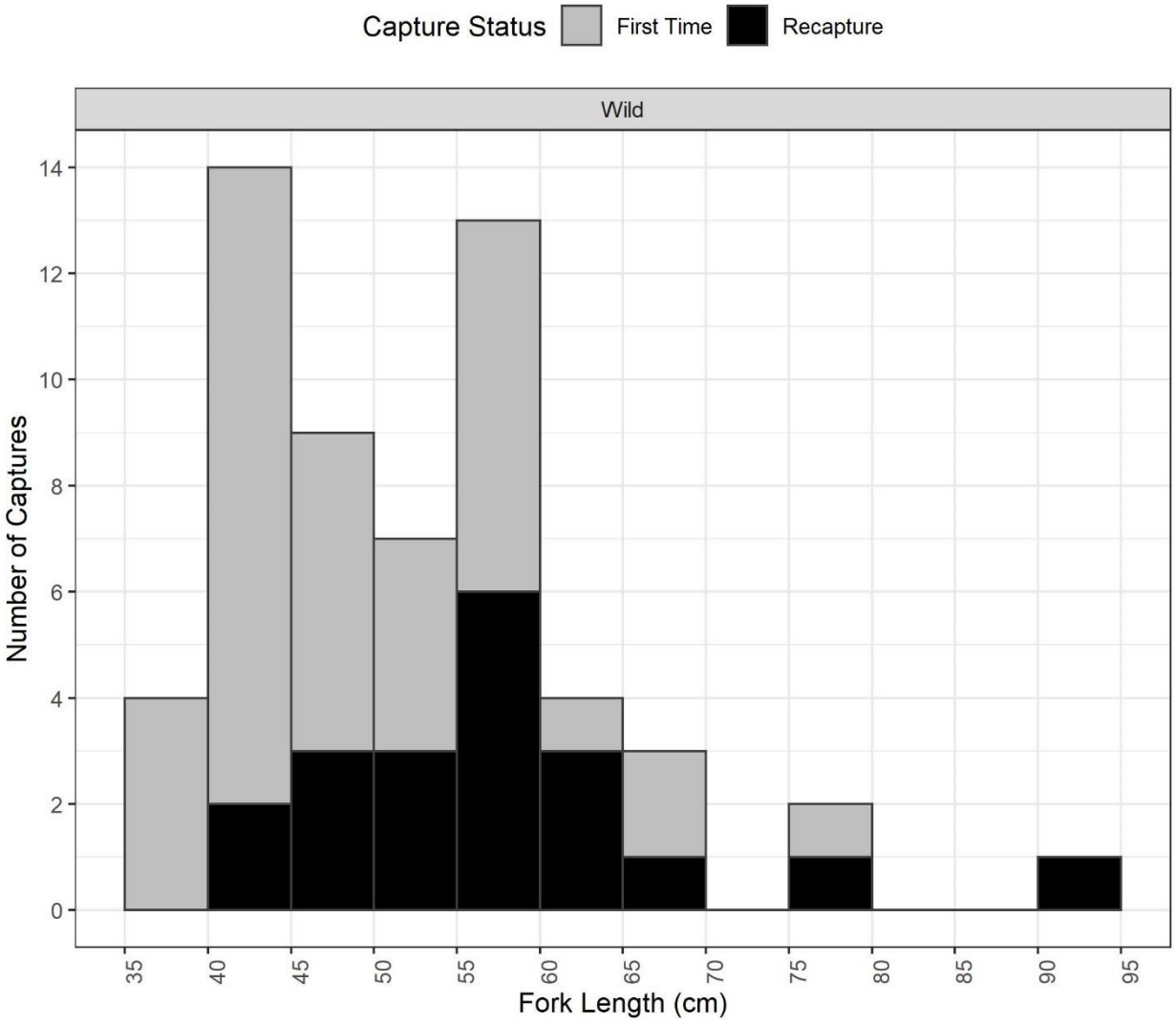


Figure 15. Fork length distribution for juvenile sturgeon cohorts captured in 2021 Longworth sampling.

Catch per unit effort in Fraser River Region 5 and Region 7 is shown in Figure 16. Juveniles were captured throughout most of the habitat sampled in Region 5. CPUE was above 1.25 for 7 of 12 rkms with juvenile captures in Region 5. Habitat downstream of Soda Creek confluence was most productive for juvenile captures.

Juveniles were captured in all three Region 7 habitat units sampled in 2021: 1) Stone Creek – Redrock or rkm 755 to rkm 765, 2) Willow River reach or rkm 825 to rkm 835, and 3) Longworth canyon or rkm 950 to rkm 960. All three habitat units contained rkms that produced CPUE values above 0.25 juveniles per 100 hook hours. The highest CPUE values were recorded in the Stone Creek – Redrock area and were between 0.22 and 0.77 fish/100 hook hours. Longworth CPUE values were between 0.51 and 0.67 fish/100 hook hours.

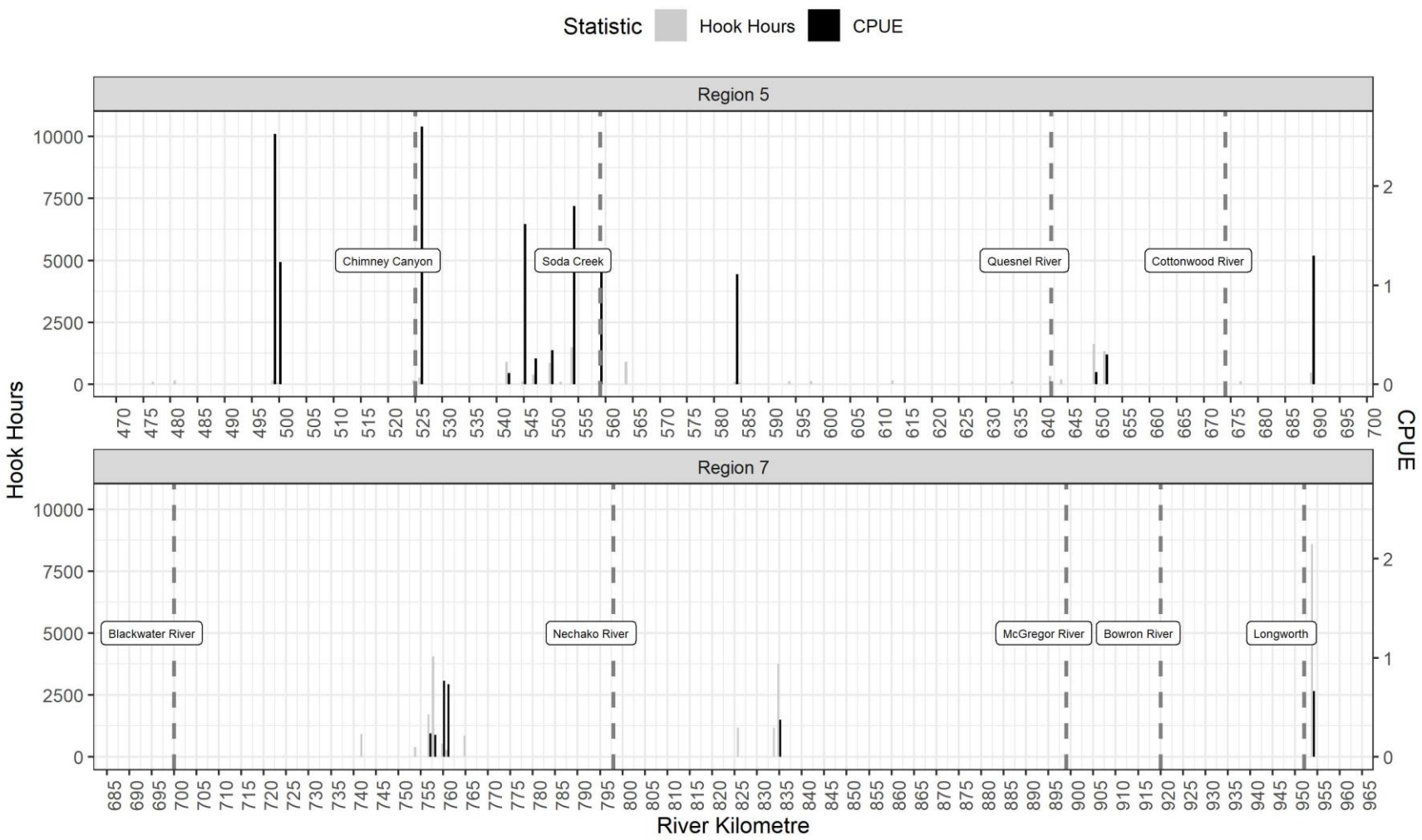


Figure 16. Spatial distribution of hook hours and catch per unit effort (CPUE) in Fraser regions for each rkm sampled in 2021. Dashed vertical lines show confluences of major tributaries to the Fraser River as well as Chimney and Longworth canyons.

Findings

Sampling Conditions

Region 5 sampling was targeted during the descending summer hydrograph (i.e. after freshet). Water temperature and discharge conditions are generally suitable for juvenile sturgeon sampling during this period each year. Region 7 sampling was also targeted during the descending summer hydrograph in 2021.

Capture Samples

Juvenile sturgeon from the 2016, 2017, 2018, and 2020 release cohorts were captured in the Fraser River in 2021. Recapture rate in the Fraser River is low for all cohorts. Several explanations are possible for a low recapture rate in the Fraser River, including; a) hatchery juveniles too small for setline capture moved to the Fraser River early in their life history. Slow growth in the Fraser River is resulting in those individuals more gradually recruiting to the setline capture gear, or b) additional hatchery juveniles are moving to the Fraser River on an annual basis.

Reduced numbers of fish being released from each annual cohort and larger sizes at release appears to have reduced the numbers of those fish appearing in the catch record in the Fraser River. Juvenile sturgeon from the 2019 and 2021 release cohorts have not been captured in Fraser River to date, but 2019 and 2020 radio tagged juveniles have been detected in the Fraser River (Spendlow, pers. comm.). Two juveniles from the 2020 release cohort were captured in Region 5 in 2021. Movement between the Nechako River and the Fraser River has been documented for both hatchery and wild origin juvenile sturgeon. The historical extent of movements of this nature are not understood, and efforts are underway to understand the implications of the movement to and residence of hatchery fish in the Fraser River. This process is discussed in Section 6.

CSTC reported juveniles that moved to the Fraser River had a slower growth rate than juveniles from the same cohort that stayed in the Nechako River (CSTC 2020, 2021). The same trend has been observed in 2021. Mean FLs for all cohorts in the Fraser River are smaller than their cohort-counterparts captured in the Nechako River.

Several new sampling sites were explored in Region 5 in 2021. The downstream extent of sampling in 2021 was extended to rkm 477. The downstream extent of hatchery juvenile captures was rkm 524.

No new sampling sites were identified in Region 7 in 2021. The sites represented in this report cover a reasonably broad scope of habitat in Region 7 and monitoring should continue in these habitat units. Sampling habitat units further downstream towards the Blackwater River confluence should be continued to provide better spatial trends of hatchery juvenile habitat occupancy.

Section 5 – Juvenile Telemetry

Preface

Ongoing juvenile telemetry and tag recovery results have demonstrated a higher-than-expected number of radio tagged juveniles being confirmed as mortalities due to predation (CSTC 2020). PIT tag recoveries from otter latrines also demonstrate a minimum of 1,088 PIT tagged juveniles have been consumed by river otters in Nechako River (Babey et al. 2020, TWG Minutes 2020-08-26). The tag recovery efforts indicate predation is a factor affecting late juvenile sturgeon (sized up to 80 cm FL) in the Nechako River. One PIT tag recovered from a latrine was associated with a 2019 release juvenile measuring 69.8 cm FL at release, and one recovered PIT tag was associated with a wild juvenile originally tagged in the upper Fraser River in 2001; this wild juvenile was last captured in the upper Fraser River in 2012 and measured 69.1 cm at the time. It is not clear when the wild juvenile was preyed on, or how large it was when it was preyed on.

When a juvenile radio tag location is detected in possible sturgeon habitat (i.e. in water), but its detection history makes it appear stationary, the lack of observable movement (LOM) over time is inferred to indicate tagged juvenile mortality. If a radio tag is detected at the same location over a certain period (usually several months) without showing signs of movement, the juvenile is assigned LOM status. Boat surveys near the end of the field season target LOM tags to record the precise tag location and possibly recover the tag. If a LOM tag is confirmed on shore at low water conditions, it is counted as a mortality even if it is not recovered.

Since 2018 the hatchery release strategy seeks to minimize risks associated with downstream movements of hatchery fish to the Fraser River, and investigate improved hatchery juvenile survival by increasing juveniles' size at release. A number of juveniles from each of the 2018, 2019, 2020 and 2021 cohorts have been radio tagged and telemetry efforts have been relatively intense through the open water season since this approach was adopted.

Fifty hatchery juveniles released in 2021 had radio tags. Radio tagged sturgeon ranged from 66.0 cm FL to 86.4 cm FL, mean ± SD = 76.7 ± 4.6 cm FL. Thirty radio tags were released at three sites in Nechako River mainstem (10 per site): rkm 196.4, rkm 136.4, and rkm 117.2. Twenty radio tags were released at two sites in Fraser Lake: the west end of Fraser Lake near White Swan Regional Park, the east end of Fraser Lake near Beaumont Provincial Park. Movements and survival of the Fraser Lake radio tagged juveniles are considered separate from movements and survival of the Nechako River radio tagged juveniles.

Table 7. Release statistics for radio tagged juvenile cohorts released in the Nechako watershed from 2018 to 2021.

Release Year	Release Number	Mean ± SD Fork Length (cm)	Release Date	Release Locations (rkm)	Radio Tag Frequency	ID Codes
2018	32	55.0 ± 2.9	2018-07-20	136.4	151.42	25, 27, 29, 30, 31, 32, 33, 35, 36, 37, 38, 39, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89
2019	30	69.0 ± 6.1	2019-06-05	116.9 136.4 196.4	151.42	90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119
2020	30	67.4 ± 3.7	2020-06-18	116.9 136.4 196.4	151.42	175, 167, 161, 168, 151, 173, 147, 164, 151, 133, 140, 163, 148, 154, 143, 152, 156, 159, 176, 169, 138, 166, 172, 142, 151, 130, 149, 134, 131, 135
	20	69.4 ± 4.3	2020-06-19	Beaumont, White Swan	151.42	146, 165, 137, 157, 171, 158, 178, 132, 145, 162, 170, 160, 136, 144, 155, 179, 139, 153, 177, 174
2021	30	76.8 ± 4.6	2021-06-16	117.2 136.4 196.4	151.42	120, 121, 122, 180, 181, 182, 183, 184, 185, 186, 123, 124, 125, 187, 188, 189, 190, 191, 192, 193, 126, 127, 194, 195, 196, 197, 198, 199, 202, 128
	20	76.5 ± 4.8	2021-06-17	Beaumont, White Swan	151.48	10, 11, 12, 13, 14, 15, 16, 18, 19, 17, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29

Results

Results from 2021 radio telemetry monitoring are forthcoming in a BC-FLNRORD technical report expected mid-year 2022.

Section 6 – Observations, Discussion and Recommendations

The following section outlines observations from data collected in 2021, and from the multi-year monitoring dataset. Ongoing and emergent data gaps and information needs are described, and findings are discussed with associated recommendations, which consider those provided in prior years. Recommendations are listed throughout the discussion subsections using roman numerals.

Observations

Key observations from sampling in 2021 include:

1. Small capture samples with less than 10 individuals continued for 2015 to 2019 hatchery release cohorts within the Core reach. Core reach CPUE increased in 2021 due to a reduction in effort applied, while recapture rate remained relatively stable compared to 2020 results (Section 2 – Nechako River Core Reach and Appendix A, Tables 9/10).
2. Hatchery fish released in 2021 (N = 200) were similar size to the 2020 release cohort. They were released at three locations in the Nechako River and two locations in Fraser Lake, and were the most captured cohort in the Nechako watershed in 2021 (16 individuals captured). This result is similar to the 2020 release cohort and 2020 capture sample and is likely mediated by larger individuals' susceptibility to capture gear at release. The result also confirmed the setline methodology effectively targets size-classes released by the hatchery program. The monitoring data being generated is reflective of the juvenile population greater than 50 cm FL available for capture (Section 2 – Nechako River Core Reach).
3. The 2016 hatchery release cohort demonstrated reduced capture sample size in the Nechako watershed compared to previous years, however it is still the most captured hatchery cohort in the Fraser River. Recapture rates for the 2016 release cohort remain relatively high (60% in 2021) in the Nechako River Core Reach. (Section 2 – Nechako River Core Reach, Section 4 – Fraser River Regions).
4. Extensive sampling effort applied to Fraser Lake revealed juvenile sturgeon CPUE is very low in Fraser Lake except for one habitat area on the eastern end of the lake. It is unclear why the capture sample was small (N = 3) in 2021 despite similarities with 2020 sampling at the east end of Fraser Lake.
5. Sampling within the Fraser River Region 7 captured 14 hatchery juveniles from 2016 – 2019 release cohorts in 2021. Hatchery recapture rates are relatively low in Fraser River Region 7; 100% of hatchery juveniles in the Fraser River were captured downstream of the Nechako confluence in 2021.
6. Sampling within the Fraser River Region 5 captured 19 hatchery juveniles from 2016, 2017, 2018, and 2020 release cohorts in 2021. Hatchery recapture rate was higher in Region 5 (32%) compared to Region 7 (21%).

7. Hatchery fish within the Fraser River continue to demonstrate slower growth rates compared to cohort counterparts in the Nechako River (Section 4 – Fraser River Regions).

Key observations from the NWSRI multi-year, multi-program dataset include:

a. Pilot hatchery releases (2006 to 2009) capture numbers in the annual catch declined after 2014 and have not been represented in the Nechako or Fraser juvenile sampling since 2017 (one fish) despite increasing effort. Although data proves one individual from the 2006 release cohort has recruited to sub-adult life stage, the pilot hatchery releases are presumed to have had very low survival success.
b. The trend of declining capture numbers for hatchery and wild cohorts in the Nechako River Core reach has continued. (Appendix A Table 9)
c. Catch and CPUE for wild-experimental juveniles in the Nechako River Core reach increased in 2021 relative to 2020. This CPUE value continues to vary between 0.00 and 0.339 since the adoption of the new sampling standard in 2017, suggesting conditions in some years do allow for wild sturgeon recruitment in the Nechako River. Movements of juvenile sturgeon from neighbouring Upper and Middle Fraser populations may also contribute to apparent wild recruitment in the Nechako River.
d. CPUE for wild-experimental fish has been highly variable and has generally declined since 2009. (Appendix A Table 11).
e. Individuals from each release cohort since 2016 continue to occupy and grow in Nechako Core reach and in Peripheral habitats, however no individuals were captured from the oldest 2015 1-year old release cohort. The trend in 2015 release cohort capture sample size reflects the trend observed in pilot hatchery release cohorts.
f. Hatchery juvenile recapture rates have been increasing or consistently high in the Nechako Core reach since 2018. Although hatchery juvenile recapture rate in 2021 did decrease relative to 2020, this is likely the result of several factors including a) decreasing numbers of 2015 – 2019 release cohort individuals available for capture, and b) increasing proportion of larger individuals (i.e. fully susceptible to setline gear) from 2020 and 2021 cohorts available for capture.
g. Annual growth among release cohorts observed in the Nechako Core reach suggests resources are not limited, however growth statistics have not been recently documented. The addition of a hatchery population, and an improved dataset of wild sturgeon captures warrant a new investigation into growth rates in the Nechako River and upper Fraser River.
h. Five years of sampling within Nechako peripheral habitats has occurred in what are believed to be the highest use areas in the Nechako River outside of the Core reach, and in Fraser Lake. Capture numbers within Peripheral regions remain significantly smaller than capture numbers within the Core reach (Appendix A, Table 9).
i. Radio tagged hatchery release groups from 2019 and 2020 were grown to larger sizes but have demonstrated lower than anticipated survival rates and appear to be susceptible to

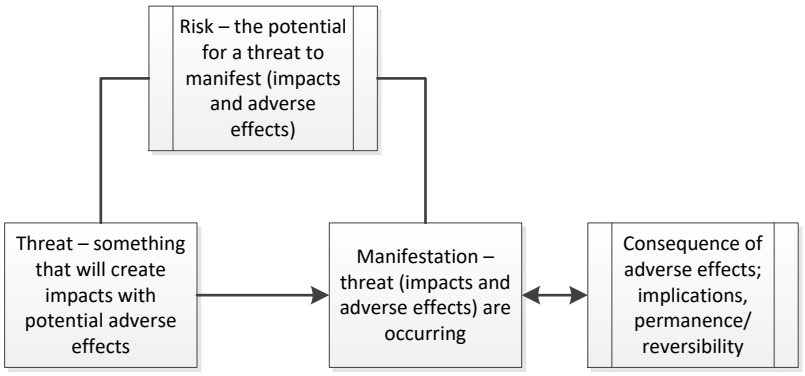
predation at relatively large, late juvenile size range. Telemetry data from 2021 not been analyzed yet; results are expected in an upcoming FLNRORD report.

j. Hatchery fish have been documented within the Fraser River over four years of sampling and appear to be present in similar numbers to wild juvenile sturgeon in certain Fraser River habitat downstream of the Nechako River confluence (Section 4 – Fraser River Regions).
k. Captures of hatchery juveniles in the Fraser River are more numerous in habitats closer to and downstream of the Nechako River confluence (Section 4 – Fraser River Regions).
l. Recapture rates on hatchery fish within the Fraser remain relatively low after four years of sampling.
m. Sampling effort in Region 5 was applied as far downstream as rkm 477. The downstream extent of hatchery juvenile captures in the Fraser River was rkm 524 in 2021.
n. This report incorporates standardized juvenile-focused sampling undertaken in 2021 in the middle and upper Fraser, and the Nechako. Additional juvenile sturgeon sampling effort (outside the scope of this report) was applied downstream of Region 5 in 2021, including juvenile sturgeon sampling projects conducted in Regions 2 and 3 (T. Nelson, pers comm, 2023).
o. Sampling in Region 2 in 2021 resulted in the recapture of a juvenile white sturgeon that originated from the Nechako White Sturgeon Conservation Centre. This fish was recaptured on June 6, 2021 at Fraser rkm 177, about 5 kms downstream of Yale (T. Rhodes, pers comm 2022). This is the first documented recapture of a hatchery-origin sturgeon in the Fraser River watershed downstream of Fraser rkm 524. The fish was recaptured over 730 kms downstream of its initial release location in the Nechako River. The fish was 35.6 cm FL when initially released on May 3, 2016 at Nechako rkm 116.9, and 55.5 cm FL when recaptured 5 years later in the lower Fraser River (T. Nelson, pers comm, 2023).

Threats and Risks Related to Hatchery Fish in the Fraser River

The movement of Nechako-origin hatchery fish into the Fraser River and their occupation of habitats in the Fraser River may pose several threats to individuals from the upper and middle Fraser River stock groups. They may also pose threats to the viability and genetic integrity of upper and middle Fraser River stock groups. The primary threats are competition for food and habitats, and interbreeding. Resource competition may cause adverse effects on the growth, fitness and viability of white sturgeon born in the Fraser River. This threat has potential to be occurring now and into the future.

Interbreeding could result in an increase in gene flow between Nechako and Fraser stock groups with adverse consequences on the Fraser River stock groups' genetic fitness. This threat can only manifest on a longer timeline and may or may not be related to the downstream movement of hatchery fish that is currently being observed. There may be risk of these threats manifesting in the lower Fraser stock group as well.



Key information required to evaluate the risks and threats posed by "competition" are presently not well understood. Key information requirements include:

- An understanding of whether Nechako-origin juveniles historically occupied Fraser habitats as a component of their life history, and how common that strategy was.
- Growth rates of juveniles and subadults in the upper and middle Fraser River and Nechako River.
- Downstream extent of hatchery fish in the Fraser River (now and over time).
- The distribution and origin of wild fish less than 50cm FL within the middle Fraser River.
- An improved understanding of the genetic relatedness between the Nechako, middle Fraser and upper Fraser stock groups.
- An understanding (or confirmation) of the genetic integrity of the Nechako hatchery juveniles relative to the Nechako stock group.

This information would allow for a more complete understanding of the threats posed and the associated risks of out migrants in relation to competition and potential adverse effects.

Key information required to evaluate the risks associated with the threats posed by "interbreeding" are presently not well understood. Key information requirements include:

- An improved understanding of the genetic relatedness between the Nechako, middle Fraser River and upper Fraser River stock groups, including the degree to which the three stock groups may interbreed.
- An understanding (or confirmation) of the genetic integrity of the Nechako hatchery juveniles relative to the Nechako stock group.

Data and information required to fully evaluate threats and their consequences may never be complete. Impacts and potential risks will therefore require adaptive management approaches. The following are recommendations to help predict threats related to hatchery sturgeon in the Fraser River:

I. Completion of a thorough risk assessment is recommended in relation to the threats Nechako-origin hatchery fish pose to other Fraser white sturgeon stock groups. That assessment would identify a multi-year strategy to address data and information gaps, and manage risk as understanding and knowledge is developed. The recommendations below are anticipated to compliment that strategy.

II. Continued sampling in the middle Fraser River is required to monitor hatchery and wild juveniles and provide samples. Near-term priorities should include identifying the downstream extent of hatchery fish in the Fraser River and identifying "nursery areas" with the smallest age-classes of wild juveniles.

    a. Ensure standardization of sampling equipment and methodologies with Nechako and Fraser River sampling (hook models and hook size arrays, etc.), as well as data collected (morphological anomalies, weights, tissue samples, finray samples, etc.).

III. Develop and implement an interim plan for removing hatchery juveniles captured in the Fraser River. That plan would consider existing and emerging data related to downstream risk in the context of options related to removal, spatial boundaries, triggers/thresholds, costs, and implementation, etc.

    a. Piloting removal/repatriation in 2021 would be important for gaining experience, overcoming challenges, and understanding the scale and scope of risk mitigation that may be possible.

IV. Collecting additional data from hatchery and wild juveniles captured in the Fraser River, including weight and girth will be critical to understanding growth and resource competition between hatchery and wild juveniles.

V. Collecting tissue and finray samples from wild juveniles captured in the Fraser River (mixing area – particularly Region 5) is necessary to provide data to understand genetic stock group markers, annual growth, size-at-age, and microchemistry analyses.

    a. Confirming the stock composition of juvenile sturgeon in the middle Fraser River is required to understand the threat hatchery juvenile presence may pose.

VI. Refining the understanding of genetic relatedness between Nechako and mid and upper Fraser stock groups will inform both threats identified.

VII. Refining the understanding of juvenile sturgeon growth and condition in Nechako and Fraser rivers. This would include analyzing capture and tag recovery data from upper Fraser, middle Fraser, and Nechako datasets.

Telemetry and capture data has demonstrated hatchery and wild-origin Nechako juveniles migrate between the Fraser River and Nechako River, despite relatively limited sampling in the Fraser River. Additional years of monitoring are needed to better understand movements of juveniles and subadults between the Nechako and Fraser rivers, and between putative stock group habitats.

VIII. Applying radio tags to hatchery and wild juveniles captured in the Fraser River may expedite the understanding of downstream movements and emigration risks.

Monitoring Survival of Hatchery Cohorts & Achievement of Stop-Gap Objectives

There is evidence that hatchery fish in the Nechako are experiencing lower survival rates than anticipated based on other hatchery programs and available literature (NWSRI 2004, DFO 2014). This observation is based on trends evident from annual monitoring, including:

a. Failure of the 2006 to 2009 pilot hatchery releases to show significant numbers in the catch record at any point during monitoring, and the failure of those that did appear to persist in the capture record. One exception is a 2006 hatchery release that recruited to subadult life stage and was captured in 2020 adult sampling.

b. Documentation of ongoing wild juvenile production and the failure of the few wild fish that are captured to persist in the capture record beyond late juvenile life stage.

c. Declining catch, CPUE and increasing recapture rates for hatchery fish released at one and two years old (particularly within the Core reach).

d. Small capture samples of wild and hatchery fish within Nechako peripheral regions.

e. Monitoring of radio tagged individuals in multiple size categories, which has documented high mortality rates on fish up to approximately 80 cm FL.

Given the importance of achieving the hatchery stop-gap objectives, continuing to monitor these trends and generating data to create a mark-recapture survival estimate are both important, but consideration of the habitat limitations that are resulting in recruitment-limiting survival constraints on wild and hatchery origin juveniles and sub-adults should be a priority.

IX. Sampling within the Nechako's Core reach and upper Fraser should continue as in 2021, informed by prior recommendations related to gear/methodology, timing and effort distribution, sample collection, etc..

e. Continue to improve sampling schedule in relation to water temperature and Nechako River discharge conditions (e.g. access to Peripheral regions during STMP period vs. post-STMP period)

f. Ensure the morphological anomalies (fins etc.) protocol is standardized and followed by all sampling crews.

g. Recommended 90,000 hook hours applied to the Core reach, 90,000 – 100,000 hook hours applied to peripheral areas in Nechako watershed including newly identified Fraser Lake site, and a minimum of 30,000 hook hours applied to Fraser River Region 7 including Longworth canyon and new sampling sites in McGregor and Bowron reaches in the upper Fraser River.

h. Ensure habitat between Stone Creek and Cottonwood River confluence in the Fraser River are thoroughly sampled.

X. Sampling within the Nechako watershed's peripheral habitats should continue and be expanded. Fully understanding the distribution of hatchery fish is important to refining survival estimates. This must include greater understanding of their movement patterns and distribution in the larger lakes within the Nechako watershed.

XI. Investigating the habitat limitations that are resulting in recruitment-limiting survival constraints on wild and hatchery origin juveniles and sub-adults should be undertaken.

    a. Summarizing the two decades of work (and related findings) that have been completed in the context of NWS recovery should be completed (juvenile monitoring, hatchery introductions, adult sampling, telemetry, substrate experiments and spawn monitoring) to inform the current state of knowledge regarding habitat, and prioritize and guide ongoing actions.

    b. Develop and implement a plan to refine an understanding of survival constraints for various life history stages (<3-years) of white sturgeon (linked to the capacities provided by the CFC).

Hatchery Rearing and Release Strategy Guidance

As described above, there are concerning trends indicating that hatchery rearing and release strategies attempted to date will be challenged to achieve the stop-gap objectives, which are critical components of NWS recovery. Evidence from recapture data sets and radio tagging studies increasingly indicate that Nechako River juvenile sturgeon (wild and hatchery) experience unexpectedly high rates of mortality into late juvenile life stage.

XII. It is not advisable to increase annual juvenile stocking rates given potential downstream risks and emerging data and trends within the Nechako. Any additional juvenile stocking creates increased downstream risk. These downstream risks must be balanced with recovery objectives. At present the information required to fully assess and balance risks is incomplete.

The authors previously proposed an alternative rearing and release strategy to the TWG that incorporated consideration of the best available information related to juvenile monitoring to August 2018. That approach included, for an interim period:

a. Reduce or eliminate the number of 1-year olds being released for an interim period;

b. During the "interim period" annually release a much smaller number of hatchery fish (same familial equalization targets) grown to a larger size (greater than 80 cm FL);

c. During the "interim period" annually release fertilized eggs, larvae and other early-stage juveniles (less than three months old) in support of early life history research objectives.

This approach has generally been adopted except 'c'. Increasing sample sizes of radio tagged individuals of larger sizes will expedite our ability to understand if survival can be improved by increasing release size of hatchery juveniles.

XIII. Additional releases of cultured juveniles should be grown to the largest target-size practical, and a large proportion should be radio tagged and intensively monitored to understand movements, migration, and survival/predation.

b. Culturing fish for longer periods will increase hatchery effects and may influence post release behavior.

XIV. If releases of cultured juveniles are not going to continue, the recovery approach, strategy and actions should be reconsidered (see Recommendations XIV and XV below).

If trends continue and hatchery release strategies are unable to produce cohorts that can survive beyond "a late juvenile survival bottleneck" then hatchery augmentation of the Nechako River may not achieve stop-gap objectives without increasing risks to Fraser River wild sturgeon populations. Preparing for this potential situation is urgent because adapting could take considerable time and effort.

XV. Management of the primary predator (river otter) identified as the major contributor to mortality and low survival of late juvenile and sub-adult life stages may be a means of facilitating better survival of hatchery cohorts and successfully achieving stop-gap objectives in the short term. This approach will bring with it multiple challenges and uncertainties including:

e. Potential for unintended ecosystem consequences (e.g. worsening early life history survival challenges linked to recruitment failure, increasing downstream movements to the Fraser River, etc.);

f. Failure to address the persistent conditions that have set up to allow predator-prey imbalance.

g. Socio-political and socio-cultural ramifications; and

h. Unknown costs and unknown potential for success.

Stop-Gap and Recovery Objectives

The TWG should contemplate a situation with failure to achieve the hatchery stop-gap objectives and what other recovery options are tenable. The knowledge developed through juvenile sampling, hatchery introductions, substrate experiments and spawn monitoring suggest that there are multiple factors contributing to ongoing recruitment failure, and they may be active from early life history (incubation) stages to much later stages (late juvenile and subadult). They are acute and persistent across some or all of these life history stages and cumulative over time, as indicated by the ongoing recruitment collapse.

The scope of recovery activities has been relatively narrow to date, which might pose a challenge in the context of achieving the broader recovery objective. Early recommendations for NWSRI recovery actions outlined 12 possible factors contributing to recruitment failure. Almost all those

factors cited flow alterations and suggest managing flows for sturgeon may provide a means of reversing recruitment failure (Korman and Walters 2001). Reversing recruitment failure was an immediate need given the estimated 150 spawning females in the remaining population were modeled to decline to 25 by 2025, based on RL&L sampling from 1995-2000. This urgent timeline led to the recommendation of an "all-in approach" to recovery (i.e. attempting a number of different restoration strategies at the same time to achieve successful recruitment, and removing measures in a sequential fashion to determine which activity, or combination of activities, caused the successful recruitment).

Over time, that all-in approach has been quelled by the challenges inherent in defining and rationalizing a "sturgeon flow regime". These challenges include the real and perceived legal, economic, and logistical challenges to achieving a different discharge regime, including uncertainty and species trade-offs. The initiation of conservation-based fish culture operations was seen, in part, as affording a longer timeline for restoring natural recruitment (assuming stop-gap objectives would be achieved). That is reflected in the "modified single-species adaptive management approach" that is recommended in the 2014 Recovery Strategy and has been followed by the TWG, rather than an "ecosystem approach".

XVI. The TWG should reconsider the complexities and timelines inherent in pursuing recruitment restoration through the single-species adaptive management approach (i.e. conservation fish culture), given the emerging understanding the Nechako's recruitment collapse.

    b. Key questions may include how can the single-species adaptive management approach (including hatchery augmentation) be broadened and/or combined with an ecosystem-based approach?

XVII. An updated assessment of the Nechako's adult population size and demographics should be undertaken to inform consideration of the timelines of various recovery actions and the associated ramifications of success or failure (incorporating updated inter-NSP movement data (Williamson et al 2021), population data, capture data, mortality assumptions, spawning periodicity data, etc.).

References

Babey, C. N. (2022). Fate of hatchery-reared juvenile Nechako white sturgeon (*Acipenser transmontanus*): Assessment of predation by river otters (*Lontra canadensis*). doi:https://doi.org/10.24124/2022/59276

Carrier Sekani Tribal Council, 2020. 2019 Nechako/Upper-Mid Fraser Watershed Juvenile White Sturgeon Monitoring. Prepared for DFO Aboriginal Funds for Species at Risk in May 2020.

Carrier Sekani Tribal Council, 2021. 2020 Nechako/Upper-Mid Fraser Watershed Juvenile White Sturgeon Monitoring. Prepared for DFO Aboriginal Funds for Species at Risk in May 2021.

Carruthers, T.R., D.S.O. McAdam, C. Williamson, & C. Schwarz. 2017. Estimating spatial distribution, population size and trajectory of Nechako River white sturgeon using a parametrically concise spatial capture-recapture model. Unpub. Draft manuscript.

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

Nelson, T. 2023. Personal Communication (February 2023). Sturgeon Biologist, Fraser River Sturgeon Conservation Society

Rhodes, T. 2022. Personal Communication (November 2022). Associate Director, Fish & Wildlife Branch, Integrated Resource Operations Division, BC Ministry of Forests

Spendlow, I. 2021. Reg. 7A Juvenile telemetry update. PDF file shared with NWSRI TWG November 2021.

Nechako White Sturgeon Recovery Initiative. 2004. Recovery Plan for Nechako White Sturgeon. Prepared by Golder Associates Ltd. 82 pp + App.

Appendix A – Supplemental Tables

Table 8. Summary statistics of hatchery cohorts released between 2006 and 2021.

Release (Cohort) Year	Brood Year	Number Released	Release Cohort Characteristics	Mean ± SD Fork Length at Release
2006	2006	4133	October and November release of 5-6 month old juvenile sturgeon	13.96 ± 1.47
2007	2007	4473	October and November release of 5-6 month old juvenile sturgeon	14.27 ± 1.29
2008	2008	5626	September and October release of 5-6 month old juvenile sturgeon	14.43 ± 1.37
2009	2008	59	June release of 1-year old juvenile sturgeon included 31 acoustic tagged juveniles	20.79 ± 2.28
2011	2011	300,000	Embryos placed on newly added substrate (remediated substrate); placed on “middle pad”	NA
2015	2014	1247	April and May release of 1-year old juvenile sturgeon included 30 radio tagged juveniles	41.77 ± 4.78
2016	2015	9162	April and May release of 1-year old juvenile sturgeon included 30 radio tagged juveniles	33.63 ± 3.64
2016	2016	250,000	May release of embryos placed on cleaned remediated substrate; placed on “lower pad”	NA
2017	2016	11518	April and May release of 1-year old juvenile sturgeon included 15 radio tagged juveniles and 30 acoustic tagged juveniles	30.6 ± 2.45
2018	2017	4332	April and May release of 1-year old juvenile sturgeon	29.4 ± 2.19
2018	2017	32	July release of “large” radio tagged 1-year old juvenile sturgeon	55.0 ± 2.90
2018	2018	3560	November and December release of 5-6 month old juvenile sturgeon	25.2 ± 3.9
2019	2018	500	May release of 1-year old juvenile sturgeon	34.8 ± 3.9
2019	2016-2017	106	June release of wild-fertilized eggs that had been collected and reared, including 30 radio tagged juveniles	58.3 ± 11.5
2020	2018	127	June release of 2-year old juvenile sturgeon in Nechako River including 15 wild spawned-hatchery reared juveniles and 30 radio tagged juveniles	67.5 ± 7.4
2020	2018	73	June release of 2-year old juvenile sturgeon in Fraser Lake including 20 radio tagged juveniles	69.7 ± 4.4

2021	2019	120	June release of 2-year old juvenile sturgeon in Nechako River	74.4 ± 7.1
2021	2019	80	June release of 2-year old juvenile sturgeon in Fraser Lake	74.9 ± 5.8
2021	2021	250,000	May release of 250,000 NWS embryos for egg drift study	NA

Table 9. Summary of juvenile monitoring program capture results from 2009 to 2021.

SAMPLE YEAR	SPATIAL PROGRAM (HKHOURS)	ORIGIN	FIRST TIME CAPTURES	RE-CAPTURES	CPUE (# JUV / 100 HOOK HOURS)	MIN. FORK LENGTH (CM)	MAX. FORK LENGTH (CM)	N CAPTURES
2009	Core	Wild	13	6	0.340	37.7	176.5	19
5 560 HKHRS	(5 560)	Hatchery	1	0	0.010	29.6	29.6	1
2010	Core	Wild	23	7	0.200	46.5	98.5	30
14 912 HKHRS	(14 912)	Hatchery	10	0	0.067	40.5	64.0	10
2011	Core	Wild	5	3	0.029	39.0	71.3	8
27 327 HKHRS	(27 327)	Hatchery	13	6	0.070	48.3	79.6	19
2012	Core	Wild	13	8	0.117	43.8	83.0	21
17 886 HKHRS	(17 886)	Hatchery	4	3	0.039	51.8	76.5	7
2013	Core	Wild	16	8	0.035	36.2	74.3	8
22 898 HKHRS	(22 898)	Hatchery	3	4	0.031	62.3	78.7	7
2014	Core	Wild	13	3	0.043	42.1	87.5	16
37 589 HKHRS	(37 589)	Hatchery	0	0	0.000	-	-	0
2015	Core	Wild	5	5	0.021	47.7	109.5	10
48 779 HKHRS	(48 779)	Hatchery	21	2	0.047	38.7	87.1	23
2016	Core	Wild	12	4	0.044	43.5	79.8	16
36 014 HKHRS	(36 014)	Hatchery	85	9	0.261	34.9	72.2	94
2017	Core	Wild	8	5	0.017	49.2	130.2	13

SAMPLE YEAR	SPATIAL PROGRAM (HKHOURS)	ORIGIN	FIRST TIME CAPTURES	RE-CAPTURES	CPUE (# JUV / 100 HOOK HOURS)	MIN. FORK LENGTH (CM)	MAX. FORK LENGTH (CM)	N CAPTURES
147 806 HKHRS	(75 713)	Hatchery	216	41	0.339	31.4	76.3	257
	Peripheral	Wild	3	0	0.005	49.6	69.9	3
	(55 880)	Hatchery	10	1	0.020	32.1	51.1	11
	Fraser (7)	Wild	0	0	0.000	-	-	0
	(16 213)	Hatchery	0	0	0.000	-	-	0
2018 243 347 HKHRS	Core	Wild	5	12	0.015	51.0	113.5	17
	(112 109)	Hatchery	120	77	0.176	31.0	68.6	197
	Peripheral	Wild	2	3	0.007	50.0	121.4	5
	(71 339)	Hatchery	18	5	0.032	32.8	58.4	23
	Fraser (7)	Wild	17	1	0.047	36.7	76.0	18
	(38 168)	Hatchery	5	0	0.013	36.4	47.4	5
	Fraser (5)	Wild	39		0.308	?	?	39
	(12 669)	Hatchery	6		0.047	?	?	6
	Longworth	Wild	76	5	0.894	32.0	122.0	81
	(9062)	Hatchery	0	0	0.000	-	-	0
2019 246 927 HKHRS	Core	Wild	4	2	0.007	36.8	73.3	6
	(88 482)	Hatchery	57	49	0.120	33.4	81.5	106
	Peripheral	Wild	3	4	0.008	45.6	118.0	7
	(93 061)	Hatchery	15	2	0.018	33.9	73.0	17
	Fraser (7)	Wild	20	5	0.100	35.5	118.0	25
	(24 917)	Hatchery	9	1	0.040	35.5	46.0	10
	Fraser (5)	Wild	47	7	0.158	32.0	120.0	54
	(34 481)	Hatchery	33	3	0.102	34.0	49.0	36
	Longworth	Wild	34	14	0.963	33.0	96.0	48

SAMPLE YEAR	SPATIAL PROGRAM (HKHOURS)	ORIGIN	FIRST TIME CAPTURES	RE-CAPTURES	CPUE (# JUV / 100 HOOK HOURS)	MIN. FORK LENGTH (CM)	MAX. FORK LENGTH (CM)	N CAPTURES
	(4 986)	Hatchery	0	0	0.000	-	-	0
2020 270 079 HKHRS	Core	Wild	0	0	0.000	-	-	0
	(107 513)	Hatchery	32	33	0.060	37.8	76.0	65
	Peripheral	Wild	0	2	0.002	84.5	104.0	2
	(84 399)	Hatchery	17	3	0.024	59.0	84.6	20
	Fraser (7)	Wild	38	7	0.158	35.0	84.0	45
	(28 364)	Hatchery	10	0	0.035	43.3	50.5	10
	Fraser (5)	Wild	19	19*	0.069**	25.5	85.0*	38
	(43 381)	Hatchery	17	4	0.048	38.1	52.8	21
	Longworth	Wild	69	16	1.324	28.9	84.5	85
	(6 422)	Hatchery	1	0	0.016	47.9	47.9	1
2021 126 100 HKHRS	Core	Wild	4	2	0.012	46.5	76.0	6
	(51 136)	Hatchery	38	19	0.111	46.5	86.1	57
	Peripheral	Wild	1	0	0.002	77.5	77.5	1
	(51 524)	Hatchery	0	2	0.004	72.0	75.2	2
	Fraser (7)	Wild	17	2	0.128	32.0	78.0	19
	(14 837)	Hatchery	11	3	0.094	40.0	53.5	14
	Fraser (5)	Wild	45	13	0.540[1]	24.5	83.0	58
	(10 752)	Hatchery	13	6	0.177[1]	39.5	73.1	19
	Longworth	Wild	37	20	0.663	38.0	91.5	57
	(8 603)	Hatchery	0	0	-	-	-	0

* Eight of the 19 wild recaptures in Region 5 were adult sturgeon greater than 140 cm FL.

** CPUE value does not include adult captures.

[1] Hook hours were applied using day setline deployments and overnight setline sets

Table 10. Summary of 2021 juvenile monitoring capture samples for all regions.

Monitoring Region	Cohort	First Time Captures	Recaptures	Total Captures
Core 51,136 hook hours	Wild-Exp.	4	2	6
	2015	0	0	0
	2016	4	6	10
	2017	2	3	5
	2018	4	3	7
	2019	2	2	4
	2020	10	5	15
	2021	16	0	16
Peripheral 51,524 hook hours	Wild-Exp.	1	0	1
	2015	0	0	0
	2016	0	0	0
	2017	0	0	0
	2018	0	0	0
	2019	0	0	0
	2020	0	2	2
	2021	0	0	0
Fraser Region 5 10,752 hook hours	Wild	45	13	58
	2015	0	0	0
	2016	9	4	13
	2017	2	1	3
	2018	1	0	1
	2019	0	0	0
	2020	1	1	2
	2021	0	0	0
Fraser Region 7 14,837 hook Hours	Wild	17	2	19
	2015	0	0	0
	2016	6	2	8
	2017	4	1	5
	2018	1	0	1
	2019	0	0	0
	2020	0	0	0
	2021	0	0	0
Longworth 8,603 hook hours	Wild	37	20	57
Total	\	166	67	233