EA4011

Lower Fraser River White Sturgeon Monitoring and Assessment Program 2019:

Summary of Sampling Results, Distribution, Growth, and Abundance Estimates Derived From 24-Month Bayesian Mark Recapture Modelling

Prepared for:

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KEY POINTS AND FINDINGS

1. This is a long-term, large-scale, volunteer-driven assessment program

- The Lower Fraser White Sturgeon Monitoring and Assessment Program, delivered by the Fraser River Sturgeon Conservation Society, has been ongoing continuously since April 2000.
- White Sturgeon sampling data are collected by over 60 trained volunteers within a core assessment area that covers over 200 linear river kilometers of the lower Fraser River and its tributaries downstream of Hells Gate; since 2000, approximately 99% of samples collected were from the core assessment area.
- In 2019, the overall mark rate for White Sturgeon (60-279 cm FL) sampled in the core assessment area of the lower Fraser was 75.3%. This high overall mark rate varied by size group: 60-99 cm FL juveniles (51.4%); 100-159 cm FL sub-adults (79.0%); and 160-279 cm adults (83.0%).

2. Two separate abundance models are run each year

- The program uses two separate models to generate abundance estimates: 1) a Bayesian mark-recapture model (BMR24, described in this report); and 2) an Integrated Spatial and Age-structured Mark-Recapture (ISAMR) model, reported separately (Challenger et al. 2020).
- The BMR24 model uses a 24-month rolling data window (run separately over 24-month sets), while the ISAMR model considers all current and historical captures in a single analysis.
- Commencing in 2018, the BMR24 model was modified with a 30-day minimum time-at-large (30-d minTAL) restriction. This was applied retroactively to all assessment years from 2001 onwards; BMR24 abundance estimates from past years may differ between this report and reports from before 2018.
- Heterogenous sampling biases have arisen in recent years which affect the BMR24 model more than the ISAMR model; as such, we suggest that the ISAMR model currently provides the best estimates of abundance of Lower Fraser River White Sturgeon.

3. The BMR24 and ISAMR models gave similar estimates that the abundance of Lower Fraser White Sturgeon has substantially declined over the last 20 years

- Both the BMR24 and ISAMR models indicate that the abundance of 60-279 cm fork length (FL) White Sturgeon in the lower Fraser River has been in a continual state of decline since 2006.
- The 2019 BMR24 abundance estimate for 60-279 cm FL White Sturgeon was 29,858 (95% CLs ± 6.9% of the estimate); this estimate is 51.2% lower than the program's highest annual abundance estimate in 2003, 40.3% lower than the 2006 estimate and 10.7% lower than the 2018 estimate.
- The 2019 ISAMR abundance estimate for 60-279 cm FL (age 7-55) White Sturgeon was 44,809 fish, which is 24.7% lower than the 2006 ISAMR estimate and 3.9% lower than the 2018 ISAMR estimate.
- The ISAMR model, which provides abundance forecasts based on age-7 recruitment rates and standing age structure, predicts that if estimates of age-7 recruitment for (2019) remain static at current (2019) levels the downward trend in abundance for 60-279 cm FL White Sturgeon will continue at an average annual rate decline of 1.4% per year over the next 30 years (through 2050).
- Both models estimated similar levels of decline in abundance over the past 15 years (2004-2019) for 60-99 cm FL juvenile White Sturgeon (BMR24: 77.9% decline; ISAMR: 70.5% decline).
- Both models estimated significant declines in abundance have occurred for 100-159 cm FL sub-adult White Sturgeon in the past six years (2013-2019) (BMR24: 50.9% decline; ISAMR: 43.1% decline).
- The BMR24 and ISAMR models differ regarding recent (2015-2019) abundance trends for adult (160-279 cm FL) sturgeon; the BMR24 model indicates that adult abundance peaked in 2015, whereas the ISAMR model suggests adult abundance continued to increase through 2019.

4. Aside from abundance model results, there are other concerning demographic indicators

- The proportion of juvenile White Sturgeon less than 100 cm FL in total annual measured samples captured by the Albion Test Fishery decreased 62.8% between 2000 and 2019.
- The average annual growth rate for 60-179 cm FL White Sturgeon in 2019 (3.6 cm/year) was 36.8% lower than the respective average annual growth rate in 2002 (5.7 cm/year).

EXECUTIVE SUMMARY

The Fraser River Sturgeon Conservation Society (FRSCS), a not-for-profit charitable organization founded in 1997, has a mandate to conserve and restore wild Fraser River White Sturgeon, raise public awareness of Fraser River White Sturgeon and their ecosystem, and produce reliable information regarding the status of Fraser River White Sturgeon and their habitat. This report summarizes the FRSCS' Lower Fraser River White Sturgeon Monitoring and Assessment Program activities for 2019.

Originally developed in 1999, this program uses a true "stewardship" approach to address objectives and generate field data. Since April 2000, the program has relied on the volunteer contributions of angling guides, recreational, commercial, and Aboriginal fishermen, test fishery and enforcement personnel, and various fishery monitors. Volunteers from these sectors were trained to sample and tag White Sturgeon, and record and transfer data. By January 2020, volunteers had conducted 165,524 sampling events (9,687 in 2019), tagged and released 74,167 sturgeon (3,625 in 2019), and documented 84,724 recapture events of tags applied by FRSCS volunteers within the general study area in the lower Fraser River (5,958 in 2019). The core assessment area for this project includes 187 km of the lower Fraser River mainstem downstream of Lady Franklin Rock (near Yale), the lower sections of the Pitt and Stave rivers, and the Harrison River downstream from Harrison Lake. Although White Sturgeon are captured and sampled by FRSCS volunteers throughout the general study area, approximately 99% of all samples collected from all sources and locations since 2000 have been taken within the core assessment area.

Abundance Models: BMR24 and ISAMR

The mark recapture data collected under the Monitoring and Assessment Program are inputted into two separate models to generate abundance estimates. The methods and outputs of one model, a Bayesian mark-recapture model (BMR24), are described in this report, whereas those of the second model, the Integrated Spatial and Age-structured Mark-Recapture (ISAMR) model, are reported elsewhere (Challenger et al. 2020). Both the BMR24 and ISAMR models only use sampling data that were collected from the core assessment area, and only consider sturgeon of 60-279 cm fork length (FL). Both models use Bayesian estimation to provide abundance estimates and credible intervals; however, the two models have very different population modelling structures: 1) the BMR24 model employs size groups while the ISAMR model uses age classes; and 2) the BMR24 model assigns individual fish to a size-class for each 24-month analysis period, while the ISAMR model reconstructs and tracks the transition of fish through the available age classes over time. The two models also differ in how sampling selectivity is handled: 1) the BMR24 model does not include differential selectivity by age, and assumes that selectivity within a size group is consistent over the 24-month sampling period; and 2) the ISAMR model applies a selectivity-at-age relationship that is estimated based on the data. In addition, the BMR24 model uses a 24-month rolling data window and is run separately for each set of 24 months, while the ISAMR model considers all current and historical (2000-2019) captures in a single analysis. Commencing in 2018, we applied a 30-day minimum time-at-large (30-d minTAL) restriction to the BMR24 model. The 30-d minTAL restriction was also applied retroactively to all previous assessment years, and revised (i.e., different from what was published in Nelson et al. 2018 or any older project report) historical abundance estimates are included in this report.

Heterogenous sampling biases have arisen in recent years, which affect the BMR24 model more than the ISAMR model. As such, we suggest that the ISAMR model currently provides the best estimates of abundance of Lower Fraser River White Sturgeon within the core assessment area. We refer readers to Challenger et al. (2020) for details regarding ISAMR model methods and results for 2019.

Mark Rates, Abundance Estimates, Trends, and Forecasts

In 2019, FRSCS volunteers applied 1,623 PIT tags and recaptured 5,143 tagged sturgeon (60-279 cm FL) in the core assessment area. The overall mark rate for the core assessment area in 2019 was 75.3%; mark rates for sub-locations within the core assessment area differed from the respective overall mark rate; for example, the mark rate for sturgeon sampled from the Harrison River in 2019 was 90.8%. Mark rates in 2019 also varied by the size group of sampled sturgeon; the adult (160-279 cm FL) group had the highest mark rate (83.0% possess a PIT tag applied under this program), followed by the sub-adult (100-159 cm FL) group (79.0% are tagged) and the juvenile (60-99 cm FL) group (51.4% are tagged).

The current (2019) abundance estimates for 60-279 cm FL White Sturgeon in the core assessment area are 29,858 fish (95% CLs ± 6.9% of the estimate) for the BM24 model, and 44,809 fish (95% CIs ± 4.2% of the estimate) for the ISAMR model. Currently, the ISAMR estimate is considered to be the more reliable of the two estimates (due to heterogenous sampling biases that have arisen in the past few years, which affect the BMR24 model more than the ISAMR model). Additional details regarding the reasons why the estimates derived from these two models have diverged in recent years have been provided in Nelson et al. (2019).

Recent abundance estimates generated by both the BMR24 and ISAMR models indicate that the abundance of 60-279 cm FL White Sturgeon in the core assessment area of the lower Fraser River is well below historic levels and has been declining continually since 2006. The 2019 BMR24 abundance estimate for 60-279 cm FL White Sturgeon was 51.2% lower than the program's highest annual abundance estimate in 2003, 40.3% lower than the 2006 estimate, and 10.7% lower than the 2018 estimate.

Comparatively, the 2019 ISAMR abundance estimate for 60-279 cm FL (age 7-55) White Sturgeon was 24.7% lower than the model's highest annual ISAMR abundance estimate in 2006, and 3.9% lower than the 2018 estimate. The ISAMR model, which produces abundance forecasts by size/age group, indicates that at current (2019) recruitment rates this downward trend in population abundance will continue at an average rate of 1.4% per year from 2020 onward through 2050 (Challenger et al. 2020).

Both the BMR24 and ISAMR models suggest that the observed decline in the total abundance of White Sturgeon in the core assessment area of the lower Fraser River since 2003 has been driven mostly by declines in the number of fish entering the sampled population (ages 7+); the mechanisms for this decline are currently unknown. Both models agree that in the past 15 years (2004-2019) significant declines in abundance have occurred for 60-99 cm FL juvenile sturgeon (BMR24, 77.9% decline; ISAMR, 70.5% decline). Both models estimate a decline in the abundance of sub-adult White Sturgeon (100-159 cm FL) in the past six years (2013 to 2019; BMR24, 50.9% decline; ISAMR, 43.1% decline). In addition, both models indicate that the abundance of adult sturgeon (160-279 cm FL) within the core assessment area trended upward from 2000 to 2015, as surviving sub-adult sturgeon (100-159 cm FL) grew into the adult size group over this time period. However, the two models differ on the recent (2015-2019) trend of adult sturgeon (>160 cm FL). The estimates from the BMR24 model suggest that the abundance of adult sturgeon declined from 2015 to 2019, while those from the ISAMR model indicate that the abundance of adult sturgeon has continued to increase during this time period. This divergence in the abundance estimates for 160-279 cm FL adult sturgeon accounts for 67% of the difference between the total yearly abundance estimates from the two models since 2015 (Challenger et al. 2020).

The Albion Test Fishery provides additional evidence of significant reductions in the abundance of juvenile sturgeon since 2004. The proportion of juvenile White Sturgeon less than 100 cm FL in the total measured sample captured by the Albion Test Fishery decreased 62.8% between 2000 and 2019.

Recaptures

Many individual tagged sturgeon have been recaptured and sampled numerous times. For example, by December 2019, 2,497 individual fish had been sampled five times, 176 fish had been sampled 10 times; three individual sturgeon have been sampled 27 times. Several individual tagged sturgeon have been sampled multiple times within the same year (up to 10 times in 2019) and over consecutive years (up to 18 times over a two-year period). The number of times each individual sturgeon is captured is likely higher than the number for which we have records. Program volunteers include only a fraction of the total number of active sturgeon anglers (anglers not participating do not scan fish or report their catch to the program), and annual numbers of capture events from gill net fisheries are not known (and could be significant in some years, especially when in-river salmon fishery openings are allowed).

Recaptures of tagged sturgeon during this study confirmed that movements and migrations occur throughout the entire lower Fraser general study area. Recapture locations of individual sturgeon varied, and were sometimes several kilometers apart, even when the fish was at large for a relatively short time period. Several tagged White Sturgeon have been documented passing both upstream and downstream of Hells Gate on the mainstem Fraser River. Hells Gate is located at rkm 212 in provincial management Region 3, approximately 17 km upstream from the Region 2 boundary at Spuzzum (rkm 195). Hells Gate is considered to be a Designated Unit (DU) boundary that separates discrete populations of White Sturgeon within the Fraser River watershed (COSEWIC 2012). White Sturgeon downstream of Hells Gate have been assigned to the "Lower Fraser" DU, whereas the White Sturgeon upstream of Hells Gate (including all tributaries to the Fraser River, including the Nechako River) have been assigned to the "Upper Fraser" DU. Reliable estimates of abundance have not been produced for the Upper Fraser DU.

In 2019 there was a single observation of a tagged sturgeon that migrated upstream past Hells Gate and 13 observations of tagged White Sturgeon that migrated downstream past Hells Gate. The single upstream migrant was sampled at rkm 115 (Fraser Valley near Chilliwack) in September 2016 and recaptured at rkm 335 (Lillooet near Bridge River confluence) in October 2019. The 13 cases of downstream movement past Hells Gate in 2019 is much higher than respective records from any previous monitoring year; there were three respective cases in 2018, two in 2017, and six total cases prior to 2017. All 13 of the downstream recoveries in 2019 had been previously observed in Region 3 near Lillooet (approximately 120 kilometers upstream form Hells Gate). Only one of the 2019 downstream recoveries was previously seen during the same year; this sturgeon was sampled in Region 3 near Lillooet (rkm 321) in May 2019, five months prior to the recapture event near Mission (at rkm 77) in October 2019. It should be noted that the number of tags applied in Region 3 has increased, which may contribute to the increase in observations of downstream movements.

Growth

Average annual growth rates for most size groups of 60-179 cm FL White Sturgeon were greater before versus after 2005. The average growth rate for all size groups in 2019 (3.6 cm/year) was the second-lowest annual growth rate observed since the beginning of the program and is 36.8% lower than the average annual growth rate of 5.7 cm/year estimated for 2002.

Mortalities

Each year, observations of dead sturgeon are reported by program volunteers, enforcement officers, recreational anglers, First Nations fishers, and the general public. There were seven reported and confirmed (sampled) individual sturgeon mortalities in the lower Fraser River in 2019; this number was the lowest since 2001, and much lower than the number of reported and sampled mortalities in 2018 (46 and 31, respectively) and 2017 (31 and 21, respectively). All sampled mortalities in 2019 possessed a PIT tag, and all but one (a 145 cm FL fish) were mature fish over 160 cm FL.

Cover Photo: "Scanned for the presence of a PIT tag" *photo by Chad Hammond, Volunteer - Lower Fraser River White Sturgeon Monitoring and Assessment Program.*

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INTRODUCTION

Given conservation concerns for White Sturgeon (*Acipenser transmontanus*) in the lower Fraser River (e.g., COSEWIC 2012) there is a need for long-term monitoring of the population, including comprehensive and scientifically rigorous estimates of abundance. To that end, the Lower Fraser River White Sturgeon Monitoring and Assessment Program was initiated by the Fraser River Sturgeon Conservation Society (FRSCS) in April 2000 and has continued into 2020. The primary objectives of the program are to: 1) obtain abundance estimates of White Sturgeon in the lower Fraser River; 2) produce reliable information regarding seasonal abundance of White Sturgeon, by location, in the lower Fraser River; 3) ascertain seasonal migration and movement patterns of White Sturgeon in the lower Fraser River; and 4) increase public awareness regarding the conservation and preservation of White Sturgeon in British Columbia. The program uses a volunteer-based “stewardship” approach, initially developed in 1999 (Nelson et al. 2000), to address objectives and generate field data. Since 2000, the program has relied on the contributions of volunteers from several sectors, including recreational anglers, angling guides (including licensed, unlicensed, and assistant guides), First Nations and commercial fishers, test fishery staff (including the Albion and Pacific Salmon Commission test fisheries), fishery monitors (First Nation and federal), enforcement officers (First Nation, provincial, and federal), students, academic researchers, and provincial staff from the BC Ministry of Forests, Land, Natural Resource Operations, and Rural Development (FLNRORD) and the BC Ministry of Environment (MOE).

This summary report presents the findings of the Lower Fraser River White Sturgeon Monitoring and Assessment Program for the 2019 assessment year. For additional information regarding the biology of White Sturgeon and history of Fraser River White Sturgeon, see Hildebrand et al. (2016) and Nelson et al. (2013a).

FIELD AND ANALYTICAL METHODS

Study Area

The general study area for the Lower Fraser River White Sturgeon Monitoring and Assessment Program includes the Fraser River watershed downstream of Hell’s Gate (located at river kilometer (rkm) 212 on the mainstem Fraser River), the Harrison River and Harrison Lake, and the Pitt River and Pitt Lake (Figure 1). The general study area is essentially the extent of known and observed White Sturgeon distribution in both the mainstem Fraser River and all tributaries and lakes connected to the lower Fraser River, downstream of Hell’s Gate. For the purpose of abundance estimation associated with this project, we have defined a “core assessment area” within the general study area; this area includes 187 km of the lower Fraser River mainstem downstream of Lady Franklin Rock (near Yale), the lower sections of major tributaries (Pitt and Stave rivers), and the Harrison River (Figure 1). The core assessment area is a subset of the general study area; it excludes areas of known White Sturgeon distribution, including all marine waters, the entire North Arm and adjacent Middle Arm of the Fraser River, the lower Pitt River upstream of the Highway 7 Bridge, Pitt Lake, Harrison Lake, and the section of the upper Fraser Canyon between Lady Franklin Rock and Hell’s Gate. Although White Sturgeon are captured and sampled by FRSCS volunteers throughout the general study area, approximately 99% of all samples collected since 2000 have been taken within the core assessment area. Since the beginning of the program in 2000, sampling data used for abundance modelling have been limited to those samples collected within the boundaries of the core assessment area, thus allowing direct comparison of annual abundance estimates among assessment years.

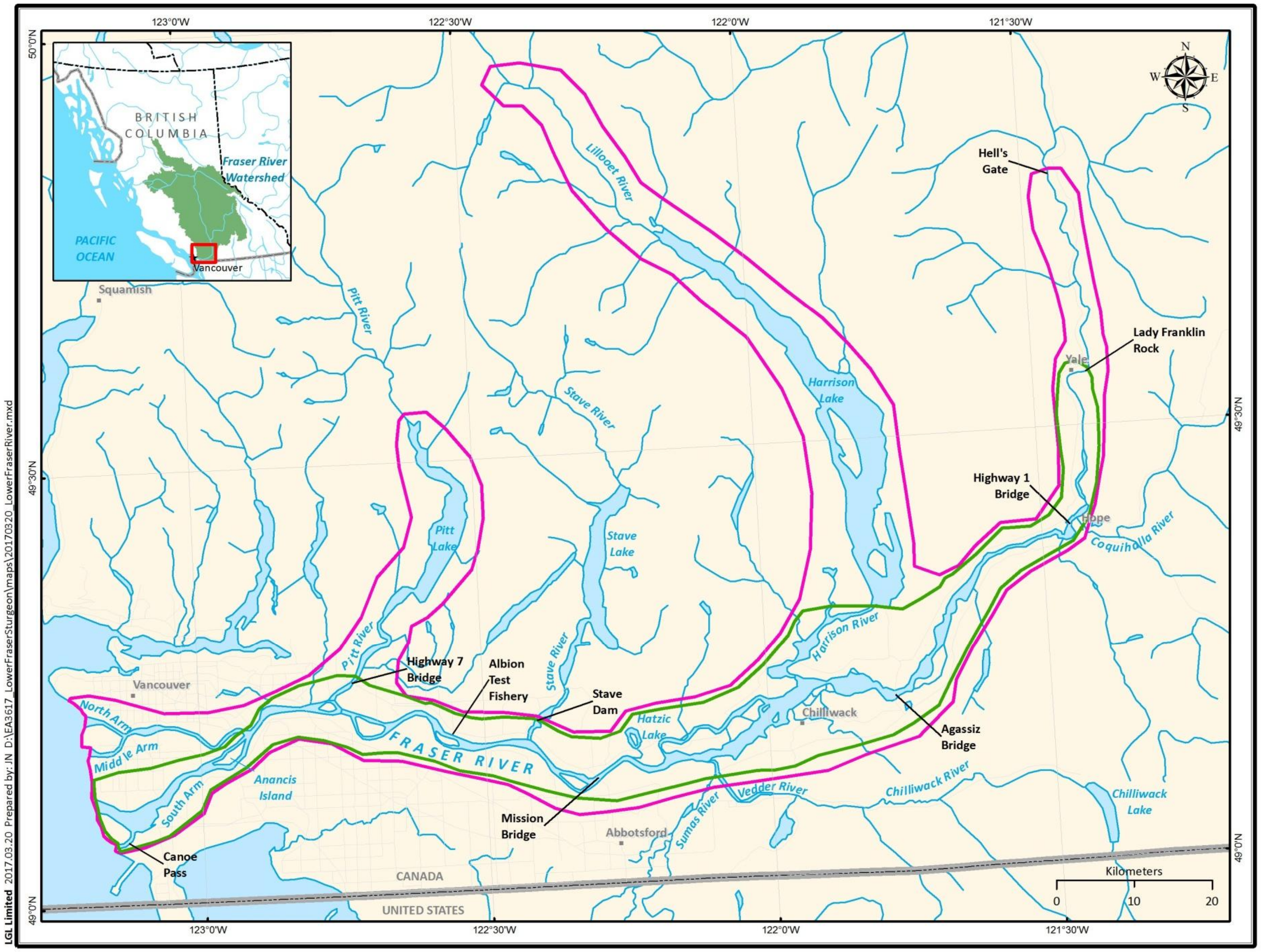


Figure 1. General study area (area within red line), and the core assessment area (area within green line; used for the production of White Sturgeon abundance estimates presented in this report). The general study area as illustrated presents the extent of known/observed White Sturgeon distribution in the lower Fraser River watershed downstream of Hell's Gate.

Sturgeon Capture and Handling Procedures

Program staff trained all volunteers that contributed to the tag and recapture database. Volunteers were trained in the field, typically on their own boat. Sturgeon capture, handling, and sampling procedures, designed to minimize stress and injury (McLean et al. 2016), were developed in partnership with provincial biologists. Scientific sampling permits, issued by both provincial and federal regulatory authorities, included the specified handling procedures as conditions of the respective permits. Accordingly, program volunteers were trained to use specific handling procedures when sampling live sturgeon. The sampling and tagging of at least one sturgeon was required to fulfill the training requirements, but in most cases several sturgeon were captured and tagged during training exercises.

Volunteers were trained to scan captured sturgeon for the presence of a Passive Integrated Transponder (PIT) tag, record all tag recapture data (from any PIT tag or external tag), apply new PIT tags (if one is not already present), measure fork length (FL) and girth (see PHOTOGRAPHS), complete a standard sampling data sheet (Appendix A), and secure and transfer data. Although volunteers were trained to sample all sturgeon captured, some sturgeon were not sampled due to time constraints and conflicting priorities (e.g., safety concerns). Volunteers who captured sturgeon by angling were required to use adequate fishing equipment (strong rods and reels, line test of at least 130-pound breaking strength), and to keep all sturgeon over 150 cm FL in the water while sampling. Sturgeon less than 150 cm FL were placed in a custom "sturgeon sling" (much like a stretcher) that contained water and supported the fish being sampled. For volunteers involved with commercial and First Nations net fisheries, emphasis was placed on exercising extra care when extricating sturgeon from gill nets (including the cutting of net, if needed) to reduce capture impacts and increase the rate of post-release survival. From 2000-2005, field data collections included sturgeon sampled as part of the FRSCS' Lower Fraser River First Nations White Sturgeon Stewardship Program; those sturgeon, intercepted in salmon gill nets, were placed in floating enclosures (provided by the FRSCS and anchored in close proximity to the fishing locations) and were removed, sampled, and released by program personnel on a daily basis (Nelson et al. 2008).

Green Sturgeon (*Acipenser medirostris*) are also present in the lower Fraser River and volunteers were provided with information to assist species identification (there have been only seven confirmed Green Sturgeon observations by this program since 2000).

Documentation of Capture Location

A simple mapping system was established to facilitate the documentation of capture locations to the nearest 0.5 rkm. Waterproof maps, delineated with rkms, were provided to all volunteers as part of the tagging equipment kit. Documentation of sturgeon capture location at this scale (closest 0.5 rkm) was important to confirm sturgeon presence at specific locations and habitat types, by season.

In order to document the general location of applied angler effort and catch, a series of sampling zones (adjacent sections of the river) was established within the core assessment area (Table 1). Zone boundaries were established based mainly on stationary geographical elements such as channel intersections, bridge crossings, and tributary confluences. Each sampling zone comprised a unique set of rkms, and was assigned to a specific sampling region (A, B, C, and D; Table 2, Figure 2). Two of the sampling regions (A and B; Figure 2) were in the designated "tidal" waters downstream of the Mission Railway Bridge, where recreational fisheries are managed by Fisheries and Oceans Canada. The remaining two sampling regions (C and D; Figure 2) were in the designated "non-tidal" waters upstream of the Mission Railway Bridge, where FLNRORD manages the recreational fisheries.

Table 1. Sampling zones used for abundance estimation of White Sturgeon, 2000-2019.

Zone	River Km	From	To
S*	0-25	Garry Point	Eastern Annacis Island
3, 5**	26-56.5 & P0-P4	Eastern Annacis Island	McMillan Island (Glover Road)
6, 7***	57-78	McMillan Island (Glover Road)	Mission Railway Bridge
8****	79-93	Mission Railway Bridge	Mouth of Sumas River
10	H0-H21	Confluence Fraser River	Outlet of Harrison Lake
12	94-122	Mouth of Sumas River	Agassiz Bridge
13	123-158	Agassiz Bridge	Hwy 1 Bridge (Hope)
14	159-187	Hwy 1 Bridge (Hope)	Lady Franklin Rock (Yale)

* Zone S is the Main (South) Arm of the Fraser River including Canoe Pass
** Zone 5 includes the lower 4 kms of the Pitt River, from the Fraser mainstem to the Hwy 7 Bridge (rkm P0-P4)
*** Zone 7 is the lower 2 kms of the Stave River, downstream of the dam (rkm ST0-ST2)
**** Zone 8 includes Hatzic Slough downstream of the water control weir located approximately 1.5 km from the Fraser confluence

Table 2. Sampling regions (A, B, C and D) used for abundance estimation of White Sturgeon, 2000-2019. Individual sampling regions are comprised of unique sampling zones (Table 1). The core assessment area is comprised of all four sampling regions (Figure 2) and includes the Harrison River and portions of the lower Pitt and lower Stave rivers (Figure 1).

Region	Zones	Description
A	S	South Arm of Fraser River; Garry Point to Eastern Annacis Island including Canoe Pass
B	3, 5, 6, 7	E. Annacis Is. to Mission Railway Bridge; lower 4 km of Pitt River (below Hyw 7 bridge); lower Stave River (below dam)
C	8, 10, 12, 13	Mission Railway Bridge to Hope including Hatzic Slough and the Harrison River
D	14	Hwy 1 Bridge (Hope) to Lady Franklin Rock (Yale)

Tagging

The marking of White Sturgeon with PIT tags has been used for movement and abundance analyses by researchers and resource managers since the early 1990s (Rein et al. 1994, Nelson et al. 2013b). PIT tags used in the study (distributed by Biomark Inc., Boise, Idaho) were injected beneath the skin of sturgeon with a specialized hand-held syringe and hypodermic needle. PIT tag models used in this study were TX1400L, BIO12.A.02, and BIO12.A.03V1 (12 mm long), and TX1405L (14 mm long); all tag types were 2 mm in diameter. When scanned with a tag reader, these glass-bodied tags emit a unique 10-digit alphanumeric code at a frequency of 125 kHz. PIT tags were kept in small glass or plastic jars that contained ethyl alcohol for disinfection purposes. Hypodermic needles, used to apply the tags, were also kept in small jars that contained ethyl alcohol.

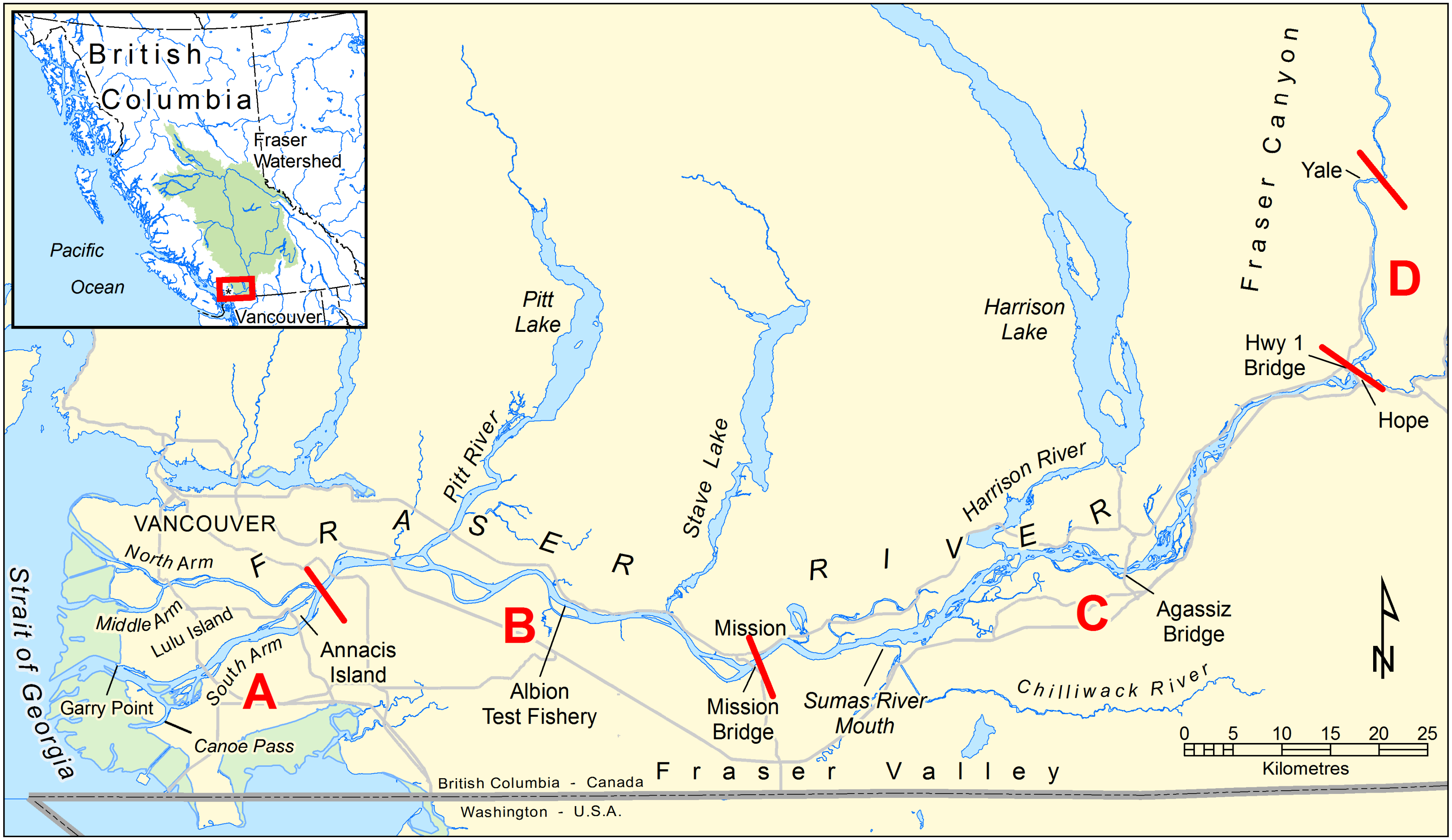


Figure 2. **Boundaries of the four sampling regions (A, B, C, and D) that comprise the core assessment area used to generate abundance estimates of White Sturgeon presented in this report. Each sampling region is made up of individual sampling zones used in the analytical model to stratify tag release and recapture data; see Table 1 for a description of sampling zone locations. See Table 2 for a description of the boundaries for each sampling region. See Figure 1 for an illustration of the core assessment area.**

PIT tags were injected just posterior to the sturgeon's bony head plate, left of the dorsal line, near the first dorsal scute. This PIT tag insertion location, referred to as the "head" location (see PHOTOGRAPHS), has been used by sturgeon researchers in both Oregon and Washington, and measured tag retention has been close to 100% (T. Rien, Oregon Dept. of Fish and Game, pers. comm.). Not all West Coast sturgeon tagging studies have applied PIT tags to the head location; other tag locations include the dorsolateral area, or body cavity near the dorsal fin. Volunteers were trained to scan all alternative areas, and sturgeon recaptured during this study that had a PIT tag in a non-standard location received a new tag in the head location. Tag-recapture data for all tags, regardless of tag type or body location, were recorded and entered in the recapture database.

The tag readers (scanners) used for the program were hand-held models from Biomark, Inc.; model MPR (125 kHz), and models GPR Plus and HPR.LITE.01V1 (both dual-frequency 125 kHz and 134.2 kHz). The program also used hand-held tag readers from AVID Canada distributed by PETIDCO, Calgary, Alberta; model Power Tracker (125 kHz) and Power Tracker V (dual-frequency 125 kHz and 134.2 kHz). The tag readers were battery-powered and displayed the tag numbers on a small screen. PIT tags were detected by the reader at a maximum distance of approximately 15 cm; an audible beep was emitted by the reader when a tag was detected. When a captured sturgeon was ready for sampling, a reader was activated and slowly passed over the length of the sturgeon, close to the body. If a tag was detected in the head location, the tag number was recorded on a data sheet as a "head" recapture. If a PIT tag was detected in any other location on the sturgeon, the number was recorded and a comment was made regarding the physical location of the tag, and a new PIT tag was applied in the head location. If no tags were detected, a new PIT tag was applied in the head location. The readers were also used to scan PIT tags prior to tag application (so that the tag number could be recorded), and, once inserted into the sturgeon, to confirm the active status and number of the applied tag (prior to the release of the sturgeon).

Tag Recoveries

An essential element of the abundance models used in this program was the positive identification and documentation of both tagged and non-tagged sturgeon in the sample. These data provide information on capture history (including movement), proportion of recaptures and non-tagged individuals, as well as growth and survival through time. PIT tag readers were used exclusively to determine the presence of a PIT tag. The only sturgeon used in the mark-recapture analyses were sturgeon that had been properly scanned for the presence of a PIT tag. In addition, the only recaptures used in the analyses were tags applied in the head location by this program. Other sturgeon tagging projects in the Fraser River, the Columbia River (Oregon and Washington), and elsewhere (California) have applied PIT tags and various types of external tags to both White Sturgeon and Green Sturgeon. Volunteers were trained to record all PIT tag and external tag information observed; for external tags, they recorded the tag type, color, attachment location, and all legible text/numbers. Recapture data from tags applied outside of this program were entered into the core program database, and in most cases the agencies and/or research programs that applied the tags were identified and contacted such that original tag release data were obtained (and entered into the database) and, reciprocally, all recapture details were shared.

Biosampling

All sturgeon included in the sampling program were measured with a flexible measuring tape for:

1) fork length to the nearest 0.5 cm, measured from tip of snout to fork in tail, measured along the side (lateral line); and
2) girth to the nearest 0.5 cm, measured around the body with the tape placed posterior to the insertion point of the pectoral fins (see PHOTOGRAPHS).

The general condition of each sturgeon was assessed prior to tagging, and a record was made of the condition of each fish at the time of release (ranking of 1 to 5: 1 = “vigorous, no bleeding;” 2 = “vigorous, bleeding;” 3 = “lethargic, no bleeding;” 4 = “lethargic, bleeding;” and 5 = “dead”). In addition, all visible wounds, scars, and physical deformities were identified on the data form, and comments were provided to document uncommon or unique observations regarding individual fish (specific morphological features, deformities, injuries, parasites, markings, etc.). A small number of captured sturgeon that exhibited serious wounds or deformities, or were assessed to be in some state of poor condition that could be potentially fatal or affect their normal movement and behaviour, were scanned and measured, but released without a tag.

Mortalities – When dead sturgeon were encountered by program volunteers, FLNRORD staff were contacted to conduct necropsies. When FLNRORD staff were unavailable, volunteers followed a sampling protocol that was developed in coordination with FLNRORD: sturgeon were scanned for the presence of a PIT tag, measured, and often sexed, assessed for level of maturity, and examined for stomach contents. Comments were provided regarding the state of the mortality (e.g., approximate number of days since death, any obvious wounds or cause of death) prior to “marking” the mortality carcass (as having been properly sampled) by removing the tail and opening the body cavity (the latter enables the carcass to more easily sink). PIT tag numbers recorded from dead sturgeon were marked in the database such that they were not considered to be available for recapture (by abundance models) following the mortality sampling event.

Data Management

Volunteers were trained to secure data sheets at the end of each sampling day. Data sheets were transferred to the field program manager for review; copies of data sheets were retained by the respective volunteer for filing. It was important that all volunteers retained a copy of the data that they provided, not only as a data security measure but also for future reference. The original (paper) data were reviewed by the field program coordinator and transferred to a data management technician for electronic entry. The electronic data were backed up on a secure hard drive; database updates were transferred back to the program manager on a regular basis for review. Annually, a complete (updated) database was provided to the provincial data managers at FLNRORD, typically in February, as per the partnership and program permitting conditions.

Abundance Estimation

We derived abundance estimates using two different mark-recapture models: 1) a Bayesian mark-recapture (BMR24) model that uses data from 24 consecutive months (Nelson et al. 2004, 2013a, 2016, 2019); and 2) an Integrated Spatial Age Mark Recapture (ISAMR) model (Challenger et al. 2017, 2019) that uses the full 20-year time series of data (2000-2019) to derive annual estimates of abundance by area and age category. One important difference between these two models is the BMR24 model uses every sampling event within a rolling two-year (24-month) sampling period whereas the ISAMR model only uses a single recapture event for each tagged fish in a given year. Therefore, a single individual marked sturgeon can only contribute once to the ISAMR model analysis in a given year, whereas it can contribute multiple times to the mark rates used in the BMR24 model. This difference will create a bias in the BMR24 model if marked fish are not given the chance to mix with the population of unmarked fish (e.g., the same locations are frequently sampled), which would mean there was a higher probability of sampling the same individual sturgeon multiple times than sampling other (random) individual sturgeon. This potential bias was reduced by applying a minimum time-at-large (minTAL) restriction to the model, such that marked fish must be “at-large” (and allowed time to mix within the population) for a period of 30 days before they were included in the mark-rate sample (Nelson et al. 2019).

24-month Bayesian Mark Recapture Model

Detailed data assembly procedures and mathematical descriptions of the BMR24 mark-recapture model and model assumptions are provided in Nelson et al. (2004, 2013a, 2016); in the text that follows we present a brief overview of the methodology:

Abundance estimates were generated for each assessment period (a rolling data window of two years; e.g., the 2019 estimate consists of data extracted from 1 January 2018 to 31 December 2019) from 2000 to 2019. Note that a sturgeon had to be encountered at least twice in the two-year window to be deemed a recapture; valid recaptures were thus defined as either of the following occurring within a defined 24-month sampling period: 1) an initial tag application/release and one (or more) subsequent recapture(s) of that tag, or; 2) two (or more) separate recapture events for the same tag.

For any given 24-month assessment period, the BMR24 model inputs were limited to:

1) samples from the core assessment area;
2) samples of White Sturgeon that would have been within the 60-279 cm FL size range at some point during the 24-month assessment period;
3) samples collected via gear types that had been deployed relatively consistently over the assessment period (specifically, set lines (2018) and angling gear that specifically targeted small/juvenile sturgeon were excluded from the 2018 and 2019 assessment year analyses; no other gear restrictions were applied for any other assessment year); and
4) samples for fish that had been at large for more than the minTAL.

As described in Nelson et al. (2004), estimates of the number of sturgeon sampled, tagged sturgeon available for capture, and recaptures by sampling zone (see Table 1) and day were based on deterministic (assumed known) representations of growth, movement, mortality, and non-detection of marked sturgeon. As is standard practice, we assumed that growth followed a von Bertalanffy curve (see Fabens 1965). Growth parameters were estimated from the mark-recapture data (length-at-release, length-at-recapture, and time-at-large). The estimated growth parameters (Table 3) were used to define an increasing size criterion for sampled sturgeon over the two-year window. Movement was defined by the distribution of recaptured tags, weighted by number of sturgeon examined, in eight sets of sampling zones over the two-year window.

Abundance estimates for 60-279 cm FL White Sturgeon in the core assessment area of the lower Fraser River are presented in this report as follows:

1) "regional estimates": abundance estimates for each of the four sampling regions: A, B, C, and D (in this report, we present results for the 2019 assessment year only);

Table 3. Parameter estimates for non-linear von-Bertalanffy sturgeon growth model (estimated from the 2008-2009 dataset) applied to abundance analyses for assessment year 2019.

Parameter	Estimate	Std Error
L_∞	532.6	15.8
g	2.076E-05	1.003E-06

2) "total abundance estimates": total abundance for the core assessment area. The regional estimates were summed to calculate the total abundance for the core assessment area. Confidence intervals were calculated by invoking a normal distribution under the central limit theorem with a variance equal to the sum of the variances of the regional estimates. Estimates were produced for each year from 2001 onwards;

3) "size-specific regional estimates": because sample sizes were large, we were able to subdivide the dataset, and produce abundance estimates for each of three size groups (60-99 cm FL, 100-159 cm FL, and 160-279 cm FL) within each sampling region. Within each region in each year, the three size-specific relative abundances were scaled such that they summed to the "regional estimate" for the given region in the given year. Estimates were produced for each year from 2004 onwards; and

4) "size-binned estimates": abundance estimates by 20-cm size group. When the dataset was divided into such small bins, sample sizes were insufficient for spatial stratification, hence the sampling regions were disregarded for this analysis. Within each year, the relative abundances of the size-binned estimates were scaled such that they summed to the "total abundance estimate" for the given year. Estimates were produced for each year since 2004.

Because the core assessment area included four sampling regions (A-D; see Table 2 and Figure 2), two of which were located downstream of the "tidal" boundary at the Mission Railway Bridge (sampling regions A and B), the program also produced separate abundance estimates of White Sturgeon for the "tidal" and "non-tidal" sections of the lower Fraser River.

<u>Integrated Spatial and Age Mark Recapture (ISAMR) Modelling</u>

In addition to abundance estimates produced by the BMR24 model, the program generates separate abundance estimates from a second model, the Integrated Spatial and Age-structured Mark-Recapture (ISAMR) model, which was developed under this program from 2015-17. See Challenger et al. (2017, 2019) for a description of the ISAMR model. Both the BMR24 and ISAMR models only use sampling data that were collected from the core assessment area, and only consider sturgeon of 60-279 cm FL. Both models use Bayesian estimation to provide abundance estimates and credible intervals; however, the two models have very different population modelling structures: 1) the BMR24 model employs size groups while the ISAMR model uses age classes; and 2) the BMR24 model assigns individual fish to a size-class for each 24-month analysis period, while the ISAMR model reconstructs and tracks the transition of fish through the available age classes over time. The two models also differ in how sampling selectivity is handled: 1) the BMR24 model does not include differential selectivity by age, and assumes that selectivity within a size group is consistent over the 24-month sampling period; and 2) the ISAMR model applies a selectivity-at-age relationship that is estimated based on the data. In addition, the BMR24 model uses a 24-month rolling data window, and is run separately for each set of 24 months, while the ISAMR model considers all current and historical (2000-2019) captures in a single analysis.

Growth Analyses

Fork length data for individual recaptured (tagged) sturgeon were analyzed to determine daily growth rates, based on the number of days-at-large between release and subsequent recapture events. Daily growth rates were expanded to provide estimates of annual growth, and these estimates were pooled and averaged by size group for comparative purposes. Exploratory analyses determined how the years of growth data would be pooled: by minimizing least squares we determined how the breaks between groupings would occur, and whether three, four, or five groupings would be used.

RESULTS

Sampling Effort

From October 1999 through December 2019, program volunteers working in the general study area of the Lower Fraser River White Sturgeon Monitoring and Assessment Program (Figure 1) performed a total of 165,524 unique sturgeon sampling events that included the inspection (scanned with a PIT tag reader) of White Sturgeon (all sizes, and captured by all sampling gear types) for the presence of a PIT tag (Appendix B). Of this total sample from the general study area, 74,167 sturgeon were tagged with a PIT tag (in the head location) and released. The total sample also includes 84,724 recapture events. In addition, the total sample includes 5,415 sturgeon that were sampled (examined for the presence of a PIT tag and measured) but not tagged (Appendix B), because of a shortage of available PIT tags, safety concerns, or because the fish was considered to be in poor physical condition (bleeding, wound, or other significant physical injury) when it was sampled.

Appendix C presents a summary of White Sturgeon sampled in the core assessment area of the lower Fraser River that were 60-279 cm FL when sampled, by month and year, from October 2019 through December 2019. A total of 152,614 60-279 cm FL White Surgeon were sampled in the core assessment area since 1999. This total includes 64,944 sturgeon that were tagged with a PIT tag (in the head location) and released, and 81,874 recaptures of sturgeon with a PIT tag in the head location. The number of 60-279 cm FL White Surgeon samples collected annually from 2000-2019 has ranged from a minimum of 3,785 in 2000 to a maximum of 11,238 in 2013 and has averaged 7,574 samples per year over the 20-year span. The number of samples collected within the core assessment area had been declining in recent years (6,210 samples in 2017, 4,990 samples in

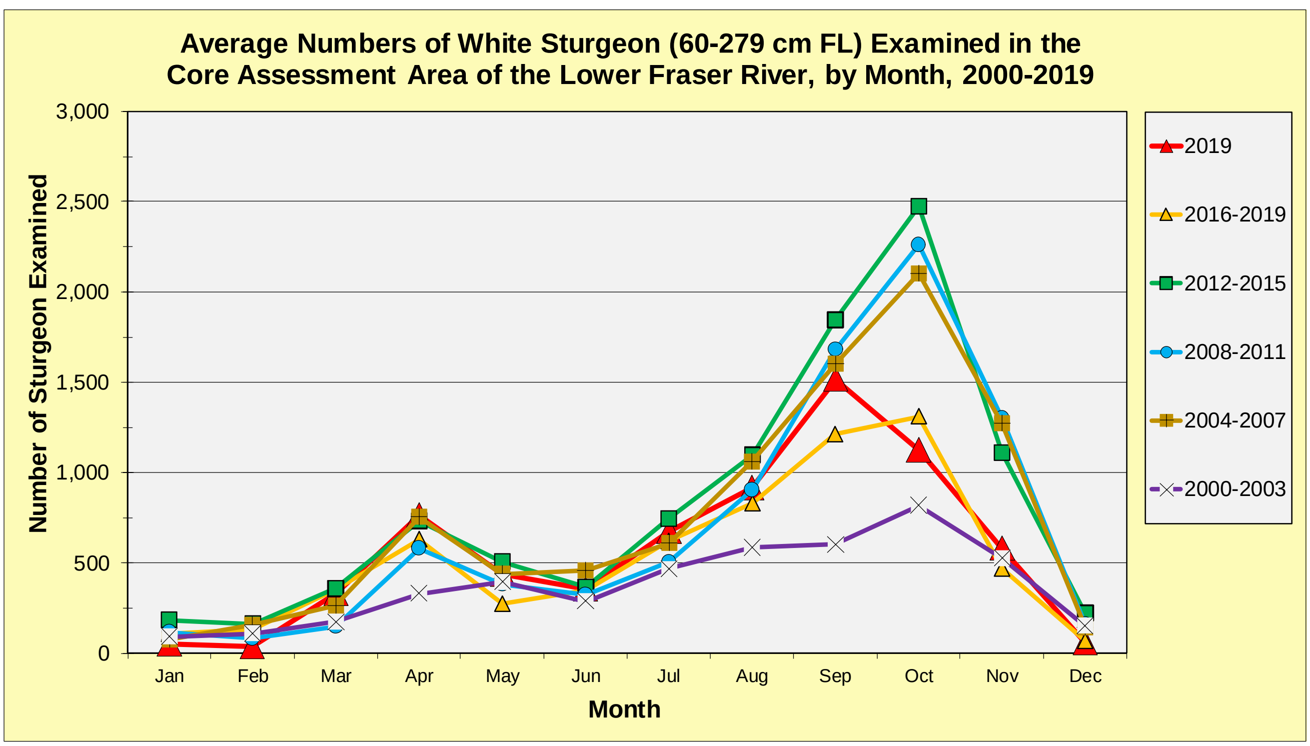


Figure 3. Average numbers of White Sturgeon (60-279 cm FL) examined for the presence of a PIT tag in the core assessment area of the lower Fraser River, presented by month and by 4-year period from 2000-2019.

2018) but increased (6,832 samples) in 2019 (Appendix C). The relative monthly contribution to respective annual total samples (Figure 3) has remained relatively consistent throughout all years (2000-2019). The variability of sample size among months is the result of variability in two main factors: fishing effort applied, and sturgeon catchability.

Recaptures of Tagged Sturgeon

Recapture data provided positive determination of both direction and distance of movements for individual tagged sturgeon. In many cases, multiple recapture events over years provided patterns of movement and migration. For the BMR24 model, movements (defined by the distribution of recaptured tags, weighted by number of sturgeon examined, in eight zones over the 24-month window) were incorporated in the analytical processes, as were the spatial distribution of samples over time (see Nelson et al 2013a). Recaptures of tagged sturgeon during this study confirmed that movements and migrations occur throughout the entire lower Fraser general study area. Recapture locations of any given individual varied, and were sometimes several kilometers apart, even when the fish was at large for relatively short time periods. In addition, several tagged White Sturgeon have been observed to move across the supposed boundary between sturgeon populations (Upper and Lower Fraser River populations) at Hells Gate (rkm 212), either being tagged upstream of Hells Gate and recaptured downstream, or the reverse (see DISCUSSION section).

Many individual tagged sturgeon have been recaptured and sampled numerous times. For example, by December 2019, 2,497 individual fish had been sampled five times, 176 fish had been sampled 10 times; three individual sturgeon have been sampled 27 times (Appendix D). Several individual tagged sturgeon have been sampled multiple times during the same year (up to 10 times in 2019) and over consecutive years (up to 18 times over a two-year period). The number of times each individual sturgeon is captured is likely higher than the number for which we have records; program volunteers represent only a fraction of the total number of active sturgeon anglers, and annual numbers of capture events from gill net fisheries are not known (see DISCUSSION section).

Mark Rates

An illustration of the annual numbers of tags applied, and reported number of tag recaptures, for 60-279 cm FL White Sturgeon sampled within the core assessment area from 1999-2019, is provided in Figure 4. The proportion of recaptures recorded in a given 12-month sampling period (i.e., the annual mark rate) has steadily increased each year over the 20 years of monitoring. Concomitantly, the proportion of newly released tags has declined over time, as the pool of marked fish available for recapture has increased. Over 86% of the samples included in the 2001 abundance model calculations (samples from 2000 and 2001) were new tags applied, whereas only 23% of the samples from 2018 and 2019 (Appendix C, Figure 4) were new tags applied.

In 2019, FRSCS volunteers applied 1,623 PIT tags and recaptured 5,143 tagged sturgeon (60-279 cm FL) in the core assessment area (Appendix C, Figure 4). The overall mark rate for the core assessment area in 2019 was 75.3% (Figure 4). Mark rates for sub-locations within the core assessment area differed from the respective overall mark rate; for example, the mark rate for sturgeon sampled from the Harrison River in 2019 was 90.8% (Figure 5). Mark rates in 2019 also varied by the size group of sampled sturgeon; the adult (160-279 cm FL) group had the highest mark rate (83.0% possess a PIT tag applied under this program), followed by the sub-adult (100-159 cm FL) group (79.0% are tagged) and the juvenile (60-99 cm FL) group (51.4% are tagged).

Monthly variation in White Sturgeon mark rates within the core assessment area was evident for each of the assessment years (Appendix C, Figure 6), and patterns have emerged that suggest an influence of season on mark rates. For example, winter mark rates (January-February) after 2009 have in some years been 10-20% lower than summer mark rates (July-September; Appendix C,

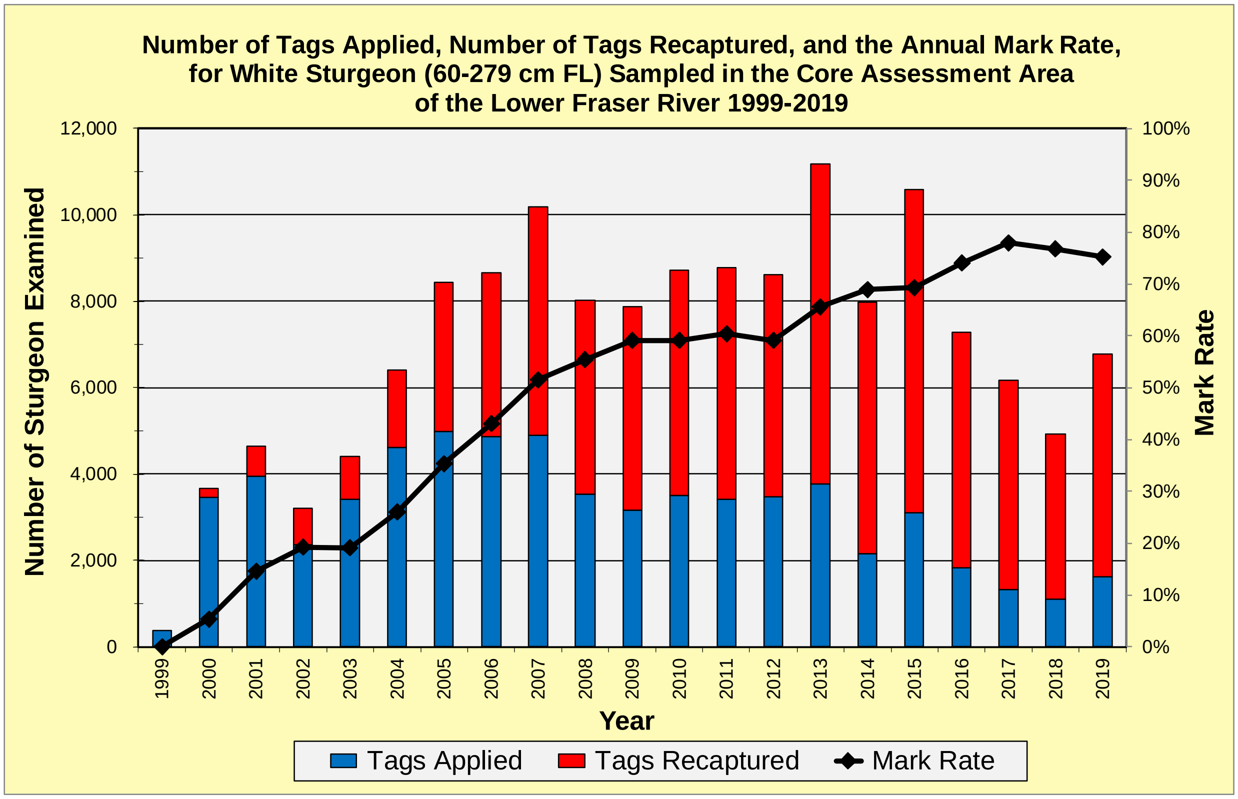


Figure 4. **Number of tags applied, reported number of tags recaptured, and the annual mark rate for White Sturgeon (60-279 cm FL) sampled in the core assessment area, by year, 1999-2019.**

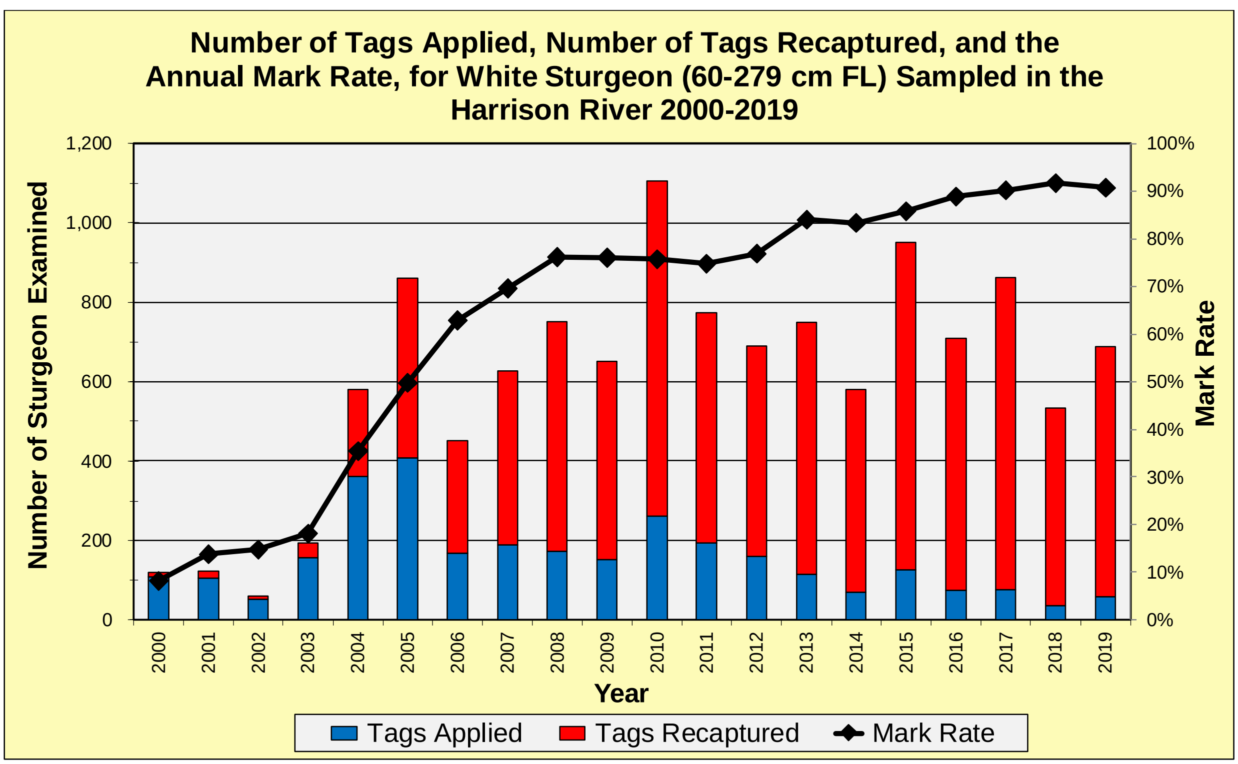


Figure 5. **Number of tags applied, reported number of tags recaptured, and the annual mark rate for White Sturgeon (60-279 cm FL) sampled in the Harrison River, by year, 2000-2019.**

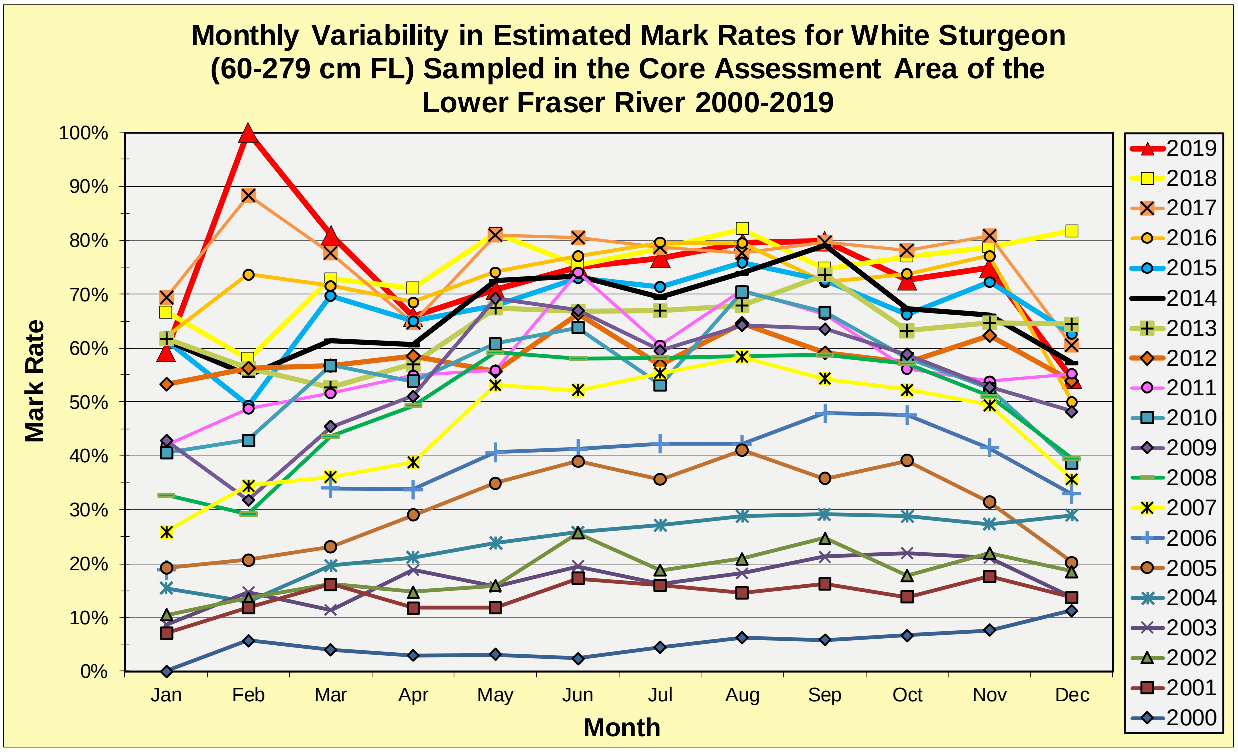


Figure 6. Monthly variability in estimated mark rates for White Sturgeon (60-279 cm FL) sampled in the core assessment area of the lower Fraser River 2000-2019.

Figure 6). Mark rates for winter months (January, February, March, and December) in 2019 were likely not representative given that they were based on relatively low sample sizes from limited fishing locations (Appendix C, Figure 6). Most of the sampling effort in winter months of 2018 and 2019 were part of a new juvenile sampling program and those data are not included in Appendix C or used to produce the results presented in this report. The results from the juvenile sturgeon sampling efforts are provided in a separate report (English and Robichaud 2020).

Abundance Estimates

<u>24-month Bayesian Mark Recapture Model</u>

Sample sizes for the BMR24 model were a subset of the overall dataset (Appendix B). Appendix C represents an approximation of the samples used in the BMR24 modelling. While Appendix C summarizes only samples collected in the core assessment area, it does not exclude samples based on time-at-large, and it does not account for growth (the BMR24 model allows samples to be included if the fish would have been in the 60-279 cm FL size range at any point during the 24-month assessment period, whereas the data in Appendix C include only those fish that were within the 60-279 cm FL size range at the time of measurement).

The BMR24 model produced an abundance estimate for 60-279 cm FL White Sturgeon of 29,858 (95% CLs ± 6.9% of the estimate; Table 4) as of January 2019 in the core assessment area of the lower Fraser River. The estimated abundance of White Sturgeon within the core assessment area downstream of the Mission Railway Bridge (sampling regions A and B; see Figure 2) was 13,129 fish (44.0% of the total abundance estimate; Table 4, Figure 7). In the core assessment area upstream of the Mission Railway Bridge (to Lady Franklin Rock near Yale; sampling regions C and D; see Figure 2), the abundance estimate was 16,792 fish (56.0% of the total abundance estimate; Table 4, Figure 7).

Table 4. BMR24 abundance estimates of 60-279 cm FL White Sturgeon in the lower Fraser River, by sampling region, from 1 January 2018 to 31 December 2019.

	Sampling Region		Zone			95% HPD[2]		
	From	To	Codes[1]	Mean	Mode	Low	High	Std. Dev
A	Georgia Strait	East Annacis Island	S	3,410	3,203	2,330	4,633	602
B	East Annacis Island	Mission CPR Bridge	3, 5, 6, 7	9,719	9,596	8,264	11,252	764
C	Mission CPR Bridge	Hwy 1 Bridge (Hope)	8, 10, 12, 13	14,725	14,702	13,976	15,488	384
D	Hwy 1 Bridge (Hope)	Yale	14	2,004	1,994	1,835	2,178	87
			Total	29,858		27,803	31,913	1,049

[1] See Table 1

[2] HPD - Highest Probability Density. See Nelson et al. 2004 for explanation of this statistic.

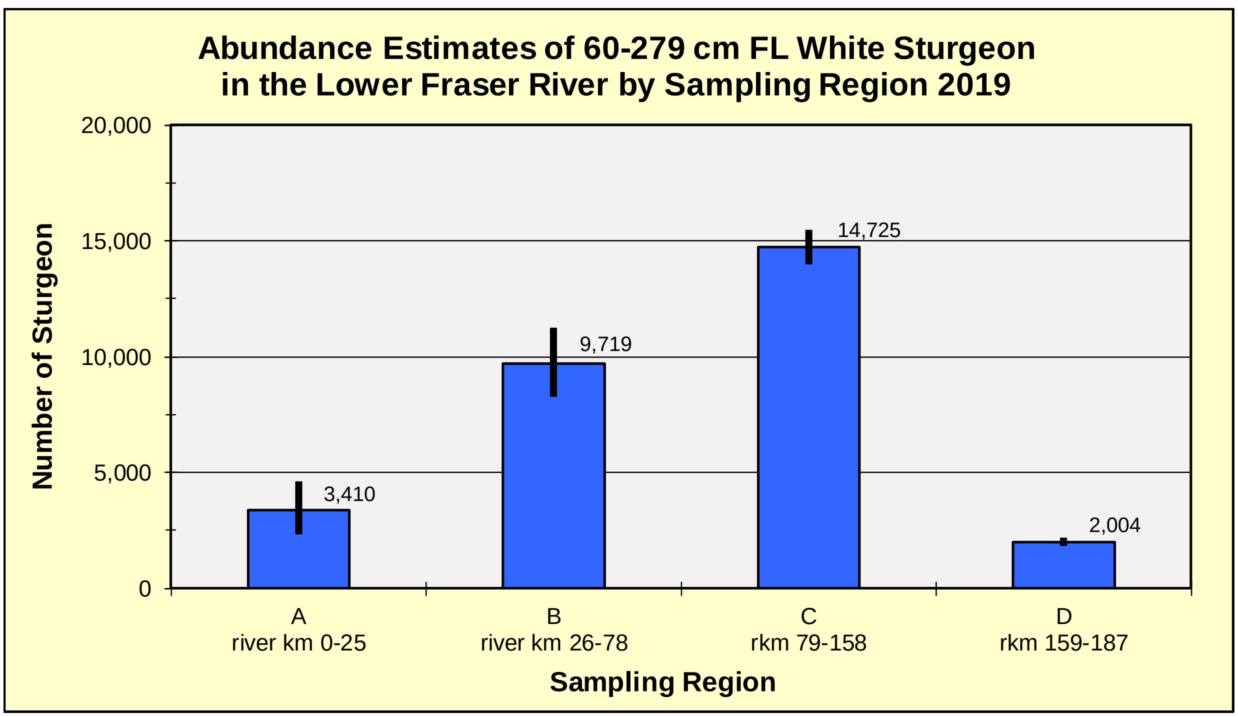


Figure 7. BMR24 abundance estimates of White Sturgeon (60-279 cm FL) in the lower Fraser River, by sampling region (A, B, C, and D, 2019; see Table 4 and Figure 1). Ranges show the 95% Highest Probability Density. Sturgeon movement and migration within the core assessment area will result in a proportional redistribution of these mean abundance estimates, by season.

The 2019 total abundance estimate was 10.7% lower than the respective 2018 estimate, and 51.2% lower than the program's peak abundance estimate in 2003 (Table 5, Figure 8). Annual abundance estimates for the first two years of the study were similar to each other (difference of 2.9%) and were followed in 2003 by an increase of 25.6% (Table 5, Figure 8). Since 2003, total annual abundance estimates indicated a general population decrease, with significant decreases between 2003 and 2005, between 2005 and 2008, and again between 2008 and 2019 (Table 5; Figure 8). The total annual abundance in 2019 was significantly lower than all other annual estimates except 2018 (Table 5; Figure 8).

Table 5. BMR24 abundance estimates of 60-279 cm FL White Sturgeon in the core assessment area of the lower Fraser River, by assessment year, 2001-2019.

Assessment Year	Sampling Period	Abundance Estimate	95% HPD[1]		Bounds as % of Abundance Estimate	CV (%)[2]	Annual % Change
			Low	High			
2001	2000-2001	47,320	43,319	51,321	8.5%	4.31%	
2002	2001-2002	48,690	44,708	52,672	8.2%	4.17%	2.9%
2003	2002-2003	61,135	55,383	66,887	9.4%	4.80%	25.6%
2004	2003-2004	57,084	52,967	61,201	7.2%	3.68%	-6.6%
2005	2004-2005	52,046	49,183	54,909	5.5%	2.81%	-8.8%
2006	2005-2006	50,002	47,131	52,873	5.7%	2.93%	-3.9%
2007	2006-2007	46,965	44,319	49,611	5.6%	2.87%	-6.1%
2008	2007-2008	46,050	43,113	48,987	6.4%	3.25%	-1.9%
2009	2008-2009	43,614	40,640	46,588	6.8%	3.48%	-5.3%
2010	2009-2010	45,604	42,318	48,890	7.2%	3.68%	4.6%
2011	2010-2011	45,015	42,699	47,331	5.1%	2.62%	-1.3%
2012	2011-2012	48,772	45,789	51,755	6.1%	3.12%	8.3%
2013	2012-2013	48,792	46,038	51,546	5.6%	2.88%	0.0%
2014	2013-2014	45,380	42,918	47,842	5.4%	2.77%	-7.0%
2015	2014-2015	47,399	42,433	52,365	10.5%	5.35%	4.4%
2016	2015-2016	44,289	40,442	48,136	8.7%	4.43%	-6.6%
2017	2016-2017	39,841	34,076	45,606	14.5%	7.38%	-10.0%
2018	2017-2018	33,452	30,260	36,644	9.5%	4.87%	-16.0%
2019	2018-2019	29,858	27,803	31,913	6.9%	3.51%	-10.7%

[1] HPD - Highest Probability Density

[2] CV - Coefficient of Variation

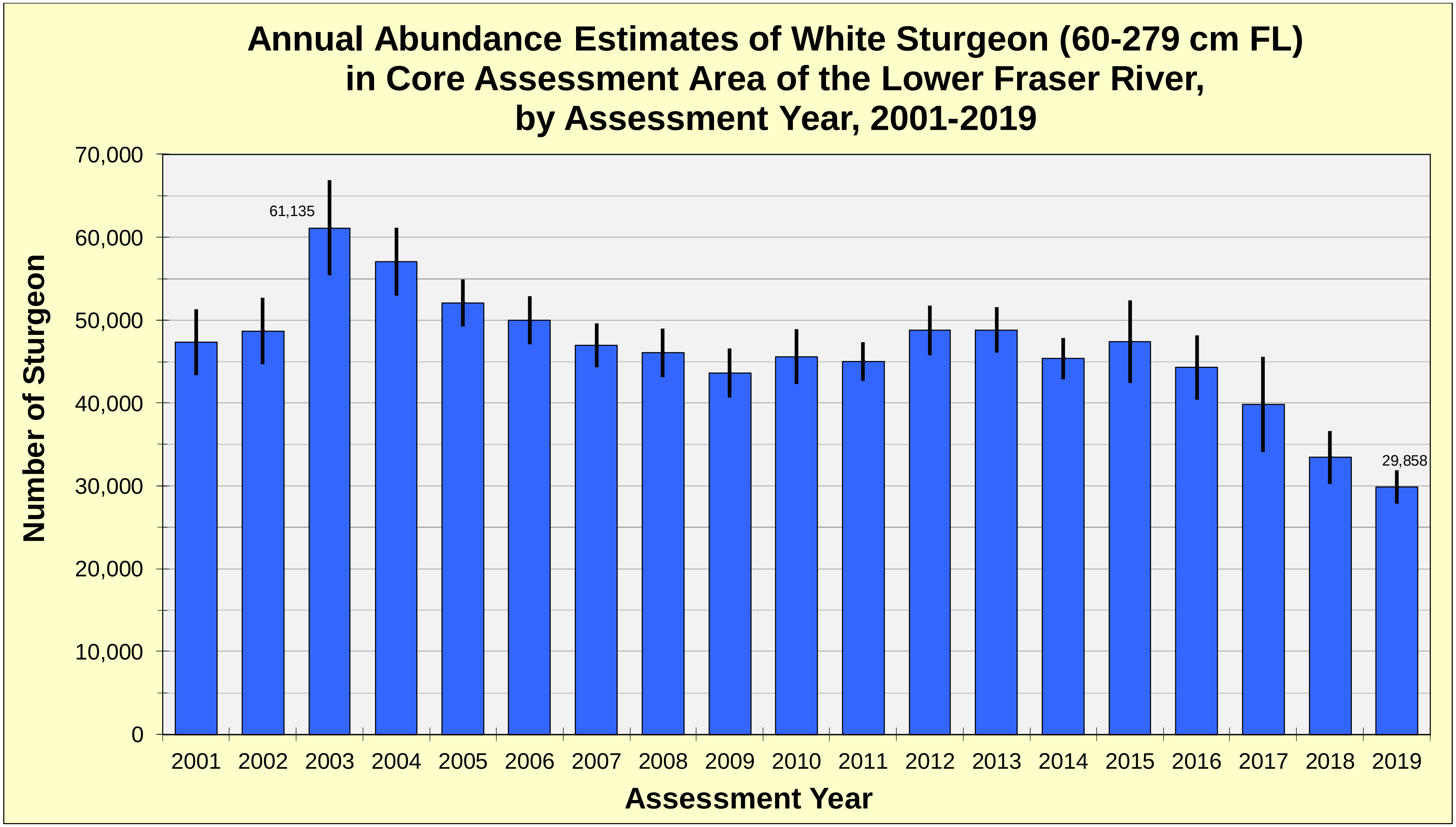


Figure 8. **Annual BMR24 abundance estimates of White Sturgeon (60-279 cm FL) in the core assessment area of the lower Fraser River, by assessment year, 2001-2019. See Table 5. Confidence ranges show the 95% Highest Probability Density. All sampling regions are combined for this analysis. The 2019 abundance estimate is the lowest estimate generated since the inception of the program, and is 10.7% lower than the respective 2018 estimate and 51.2% lower than the peak abundance estimate generated for 2003.**

The BMR24 model estimates have been used to monitor trends in abundance for three size categories of sturgeon (60-99 cm FL, 100-159 cm FL, and 160-279 cm FL). In 2019, the BMR24 estimated abundance of 60-99 cm FL juvenile White Sturgeon was 5,570 fish (Table 6), which represented a 15.3% decline from the respective estimate in 2018 (6,575 fish; Figure 9). The estimated abundance of both 100-159 cm FL and 160-279 cm FL sturgeon in 2019 also declined from respective 2018 estimates (15.0% and 3.9%, respectively). Since 2004 there have been significant declines in the BMR24 estimates of abundance for 60-99 and 100-159 cm FL juvenile and sub-adult sturgeon (77.9% and 51.9%, respectively). Concurrently, there has been a significant increase (68.9%) in the BMR24 estimates of abundance for 160-279 cm FL adult fish (Figure 9). The recent declining trends in the BMR24 estimates for adult sturgeon are not consistent with the results from the ISAMR model and are believed by biased by recent changes in sampling by some program volunteers which have resulted in higher probabilities of recapturing marked fish than unmarked fish in this largest size category (see Nelson et al. 2019). It should also be noted that lower sampling rates (fewer fish examined) in sampling region A (see Table 2 and Figure 2) resulted in relatively large CVs for all size groups in this region (Table 6).

BMR24 abundances for 2019 by 20-cm (FL) size group are presented in Table 7 and Figure 10. Figure 11 displays the temporal trends for each 20-cm size bin from 2004-2018.

Table 6. BMR24 abundance estimates for three size groups of White Sturgeon within each of the four sampling regions that make up the core assessment area of the lower Fraser River, 2019. Within each sampling region, MLE values were scaled so that they summed to the mean regional estimate (Table 4).

Size Group (cm)	Sampling Region	Scaled MLE[1]	HPD[2]		CV(%)[3]
			Low	High	
60-99	A	1,217	560	2,069	35.5
	B	1,668	1,262	2,114	13.1
	C	2,399	2,082	2,732	6.9
	D	287	232	345	10.2
	Total	5,570	4,566	6,575	9.2
100-159	A	1,270	685	1,987	28.2
	B	4,113	3,151	5,150	12.4
	C	5,970	5,438	6,519	4.6
	D	422	362	486	7.4
	Total	11,776	10,436	13,115	5.8
160-279	A	924	271	1,938	51.3
	B	3,938	2,584	5,479	19.4
	C	6,356	5,912	6,812	3.6
	D	1,295	1,135	1,465	6.5
	Total	12,512	10,684	14,340	7.5

[1] MLE - Maximum Likelihood Estimate

[2] HPD - Highest Probability Density

[3] CV - Coefficienct of Variation

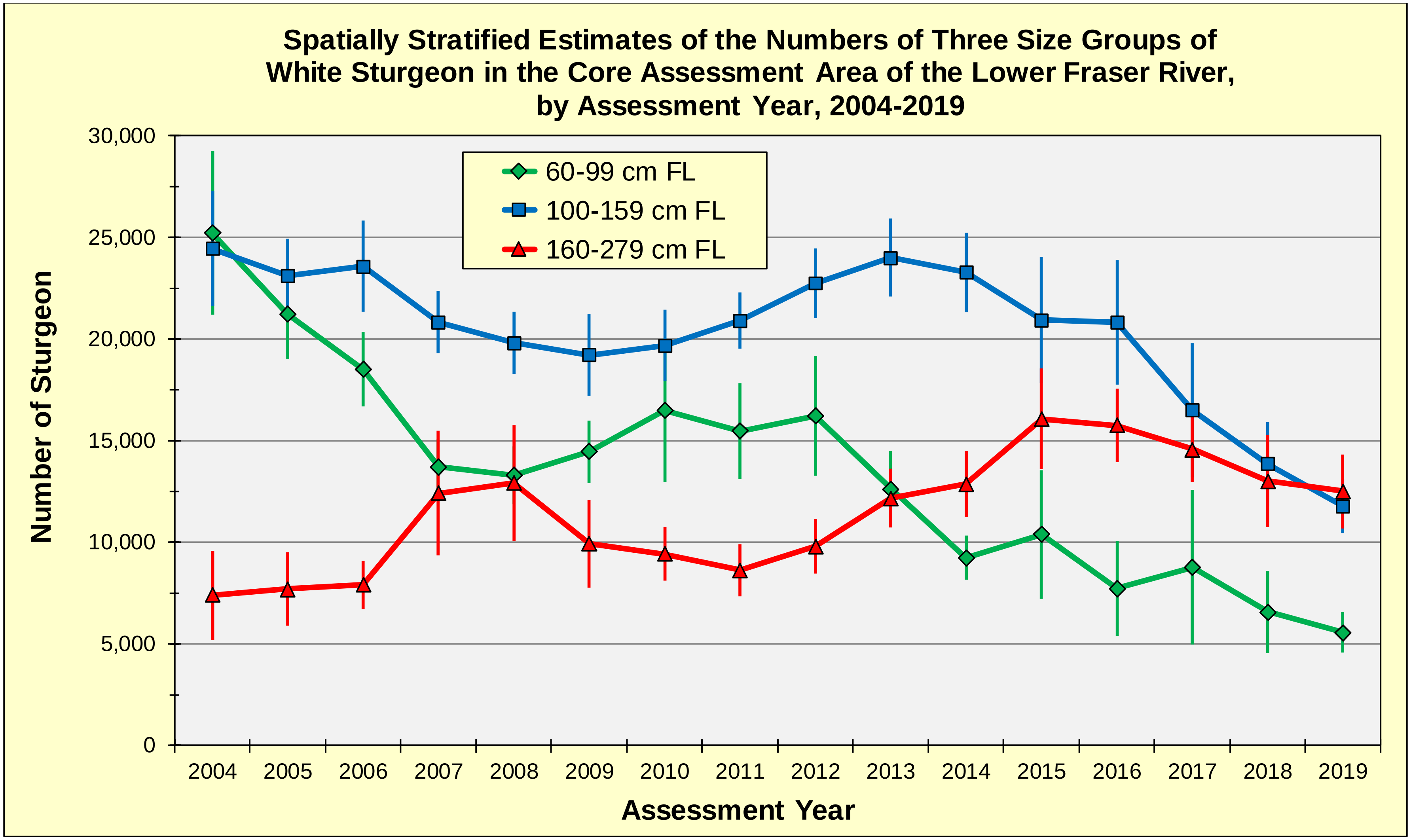


Figure 9. **BMR24 abundance estimates for three size groups (60-99 cm FL, 100-159 cm FL, and 160-279 cm FL) in the core assessment area of the lower Fraser River, by assessment year, 2004-2019. The error bars indicate the 95% CLs for each estimate. Within each sampling region in each year, the relative abundances have been scaled such that the size-specific estimates summed to the total estimated abundance of 60-279 cm FL sturgeon in that sampling region for that year.**

Table 7. BMR24 abundance estimates for 60-279 cm FL White Sturgeon in the core assessment area of the lower Fraser River, by 20-cm (FL) size group, 2019. Scaled MLE values were calculated by estimating MLE for each size bin, and then scaling the results so that they sum to the mean total estimate (Table 4). An illustration of these estimates and their associated HPD values is presented in Figure 10.

Size	Scaled		95% HPD[2]		
Group (cm)	MLE[1]	Percent	Low	High	CV[3] (%)
60-79	2,957	9.9	2,597	3,395	6.8
80-99	2,910	9.7	2,481	3,466	8.5
100-119	3,805	12.7	3,294	4,448	7.6
120-139	4,598	15.4	4,008	5,324	7.2
140-159	3,633	12.2	3,248	4,090	5.8
160-179	3,246	10.9	2,889	3,673	6.1
180-199	2,850	9.5	2,528	3,245	6.4
200-219	2,460	8.2	2,171	2,814	6.6
220-239	1,742	5.8	1,480	2,089	8.8
240-259	1,239	4.2	976	1,624	13.0
260-279	417	1.4	267	726	26.4
Total	29,858	100.0			3.5

[1] MLE - Maximum Likelihood Estimate
[2] HPD - Highest Probability Density
[3] CV - Coefficient of Variation

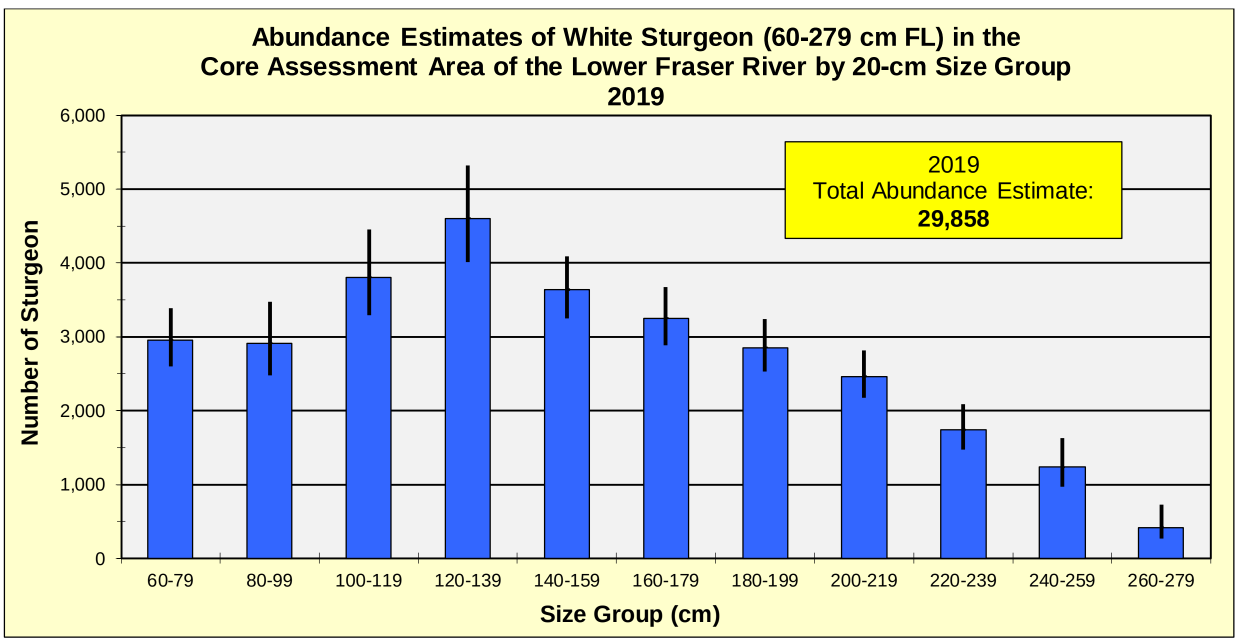


Figure 10. BMR24 abundance estimates of White Sturgeon (60-279 cm FL) in the core assessment area of the lower Fraser River, by 20-cm (FL) size group, 2019. Error bars show the 95% Highest Probability Density; see Table 7.

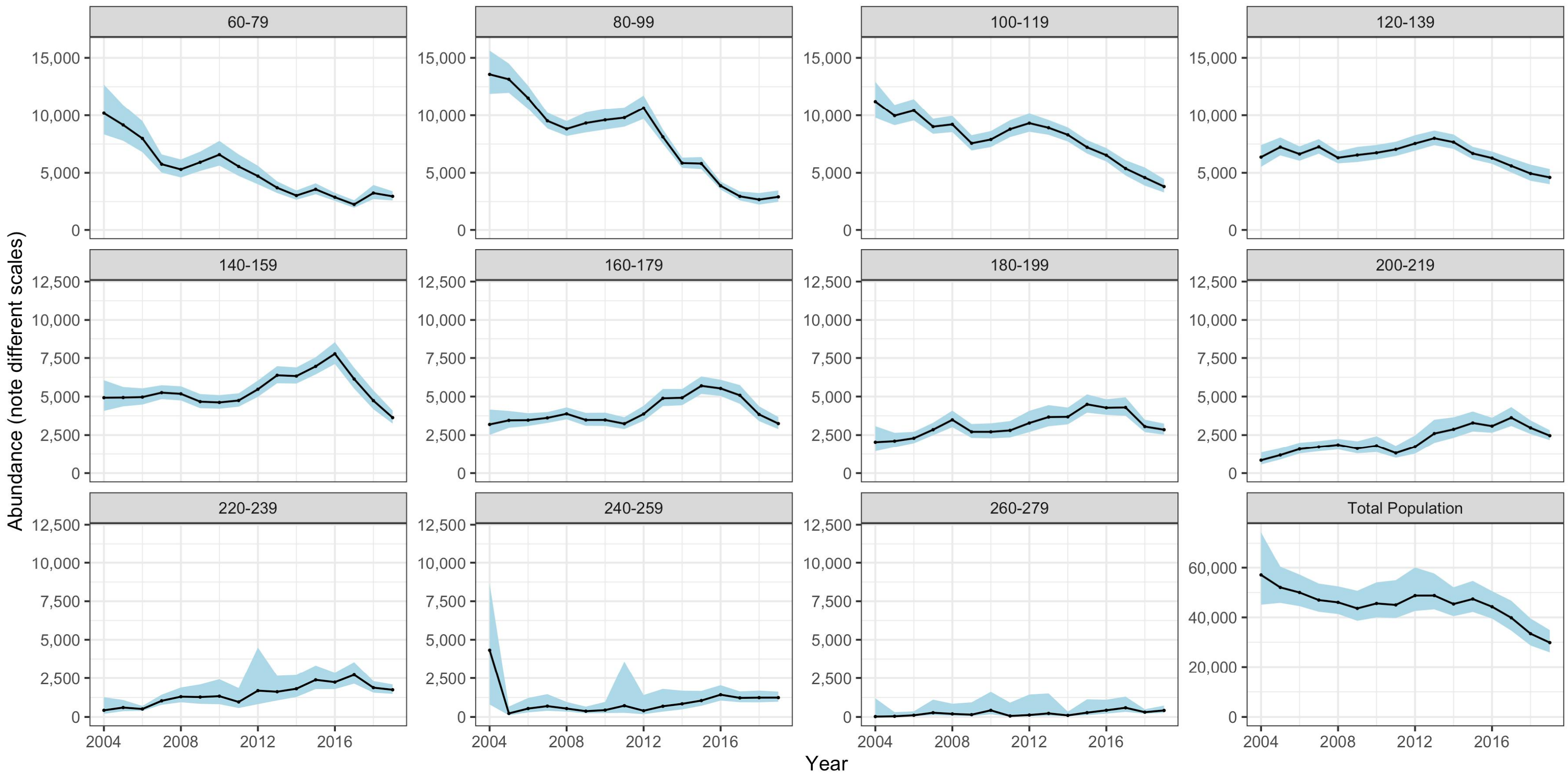


Figure 11. BMR24 abundance estimates of White Sturgeon (60-279 cm FL) in the core assessment area of the lower Fraser River, by 20-cm (FL) size group, for assessment years 2004 through 2019. Error bars show the 95% Highest Probability Density. Within each year, the relative abundances were scaled such that the size-specific estimates summed to the total estimated abundance of 60-279 cm sturgeon in the core assessment area for that year.

Integrated Spatial and Age Mark Recapture (ISAMR) Modelling

See Challenger et al. (2020) for a complete presentation of ISAMR results for 2019. Comparisons of results from BMR24 and ISAMR model outputs are presented in the DISCUSSION section of this report.

Growth Analyses

A comparison of average annual growth rates of White Sturgeon from 60-179 cm FL sampled from 2001-2018, by 20-cm FL size groups, suggested that annual growth rates for most size groups were greater before versus after 2005 (Figure 12). The average growth rate for all size groups in 2019 (3.6 cm/year) represented the second lowest annual growth rate observed since the beginning of the program; the program's lowest growth estimates were from 2017 (3.0 cm/year; Nelson et al. 2017). Both the 2018 and 2019 growth rates were well below the highest average annual growth rate of 5.7 cm/year observed in 2002 (Figure 12); the 2019 average growth rate for all size groups of White Sturgeon is 36.8% lower than the respective rate in 2002 (Figure 12).

Figure 13 provides average annual growth increments of 60-179 cm FL White Sturgeon in the lower Fraser River by 20-cm FL size group during five time periods: 2001-04, 2005-09, 2010-12, 2013-15, and 2016-19. Average annual growth from 2005-2009 for all size groups (3.8 cm/year) represented a 29.6% decrease from respective previous growth rates from 2001-2004 (5.4 cm/year; Figure 13).

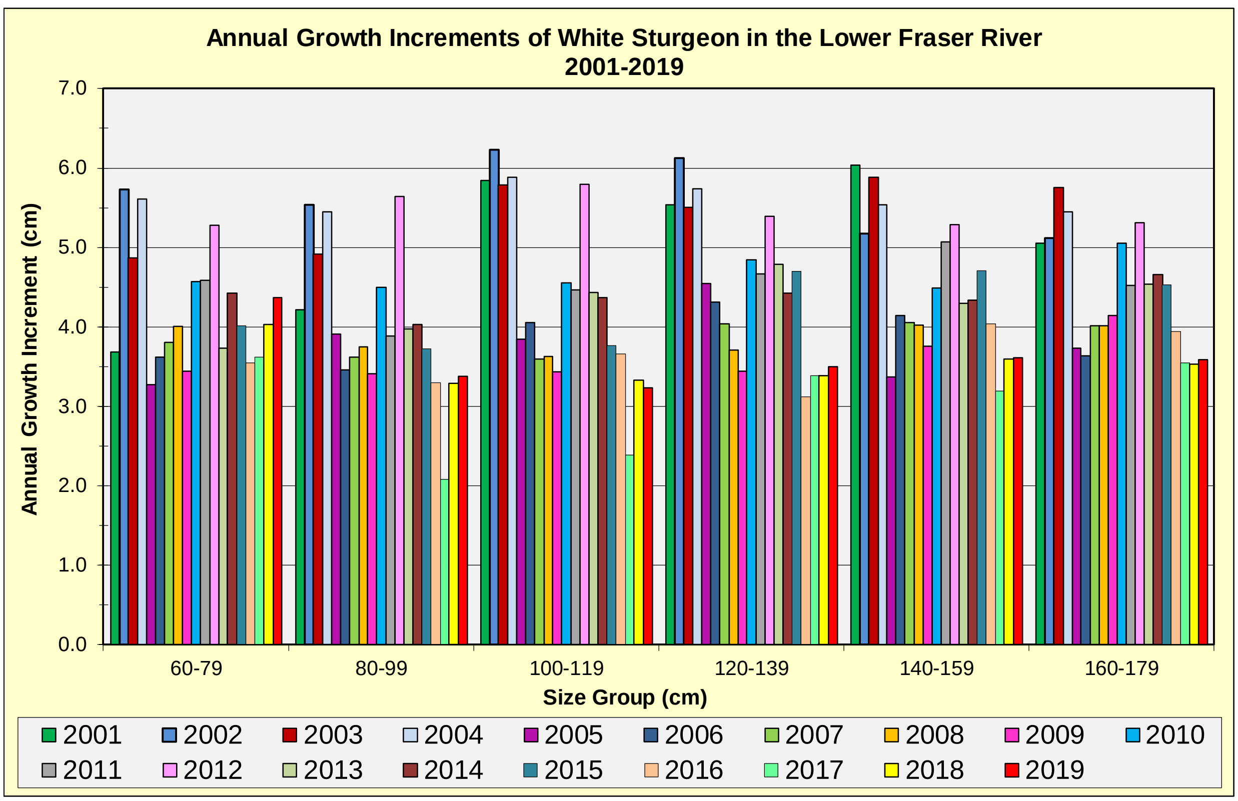


Figure 12. Average annual growth increments (cm) of 60-179 cm FL White Sturgeon in the lower Fraser River, by 20-cm (FL) size group, 2001-2019. Annual growth was determined from measurements obtained from individual tagged sturgeon that were subsequently recaptured.

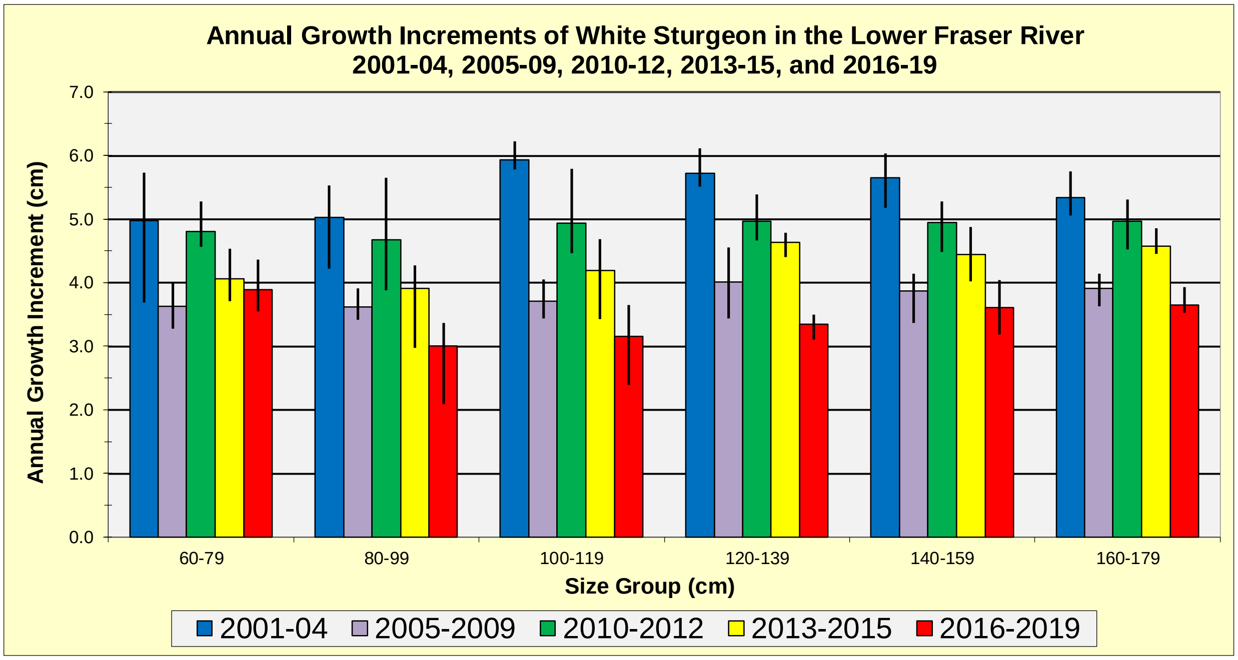


Figure 13. Average annual growth increments (cm) of 60-179 cm FL White Sturgeon in the lower Fraser River, by 20-cm (FL) size group, during five time periods: 2001-04, 2005-09, 2010-12, 2013-15, and 2016-19. The error bars show the range of mean annual growth estimated for the years within each time period.

Average annual growth for all size groups increased during 2010-2012 (4.9 cm/year) before declining to an average of 4.3 cm/year from 2013-2015, and decreasing again to 3.4 cm/year during 2016-19 (Figure 13).

Mortalities

Each year, observations of dead sturgeon are reported by program volunteers, enforcement officers, recreational anglers, First Nations fishers, and the general public. There were seven reported and confirmed (sampled) individual sturgeon mortalities in the lower Fraser River in 2019; this number was the lowest since 2001, and much lower than the number of reported and sampled mortalities in 2018 (46 and 31, respectively) and 2017 (31 and 21, respectively). sampled mortalities in 2019 possessed a PIT tag, and all but one (a 145 cm FL fish) were mature fish over 160 cm FL. Sturgeon mortality sampling events in 2019 occurred in April, May, and September, with the majority occurring in September. Although the likely cause of death could not be determined for all samples, boat (propeller) strikes and gill net captures were noted by samplers as possible causes for most 2019 mortalities.

DISCUSSION

Sampling Sources

Three sources provided 97.1% of all scanned samples from the core assessment area over the term of the program through 2019: angling (90.4%), Albion Test Fishery (3.6%), and First Nations gill nets (3.0%; Figure 14). An additional 0.6% of the total sample was provided through dedicated sampling efforts using tangle nets associated with both the FLNRORD Lower Fraser Juvenile White Sturgeon Habitat Indexing Program, and the FRSCS Lower Fraser River Juvenile White Sturgeon Habitat Program (Glova et al. 2008). Additionally, approximately 2.3% of samples were provided by other sources including PSC Test Fishery, unsourced mortalities, juvenile angling gear, set line, fishwheel, ghost net, river guardian, and enforcement (Figure 14).

Repeated Recaptures

Many individual tagged sturgeon have been recaptured and sampled numerous times. For example, by December 2019, 2,497 individual fish had been sampled five times, 176 fish had been sampled 10 times; three individual sturgeon have been sampled 27 times (Appendix D). Several individual tagged sturgeon have been sampled multiple times during the same year (up to 10 times in 2019; Table 8) and over consecutive years (up to 18 times over a two-year period; Appendix D). The number of times each individual sturgeon is captured is likely higher than the number for which we have records. Program volunteers include only a fraction of the total number of active sturgeon anglers (anglers not participating do not scan fish or report their catch to the program), and annual numbers of capture events from gill net fisheries are not known (and could be significant in some years, especially when in-river salmon fishery openings are allowed).

Immigration, Emigration, and Movements

Since there will always be a portion of 60-279 cm FL lower Fraser River origin White Sturgeon located in marine and freshwater areas outside the core assessment area; the abundance estimates presented in this report do not represent the entire population (Nelson et al. 2016). Freshwater areas accessible to Lower Fraser River White Sturgeon that are outside the core assessment area

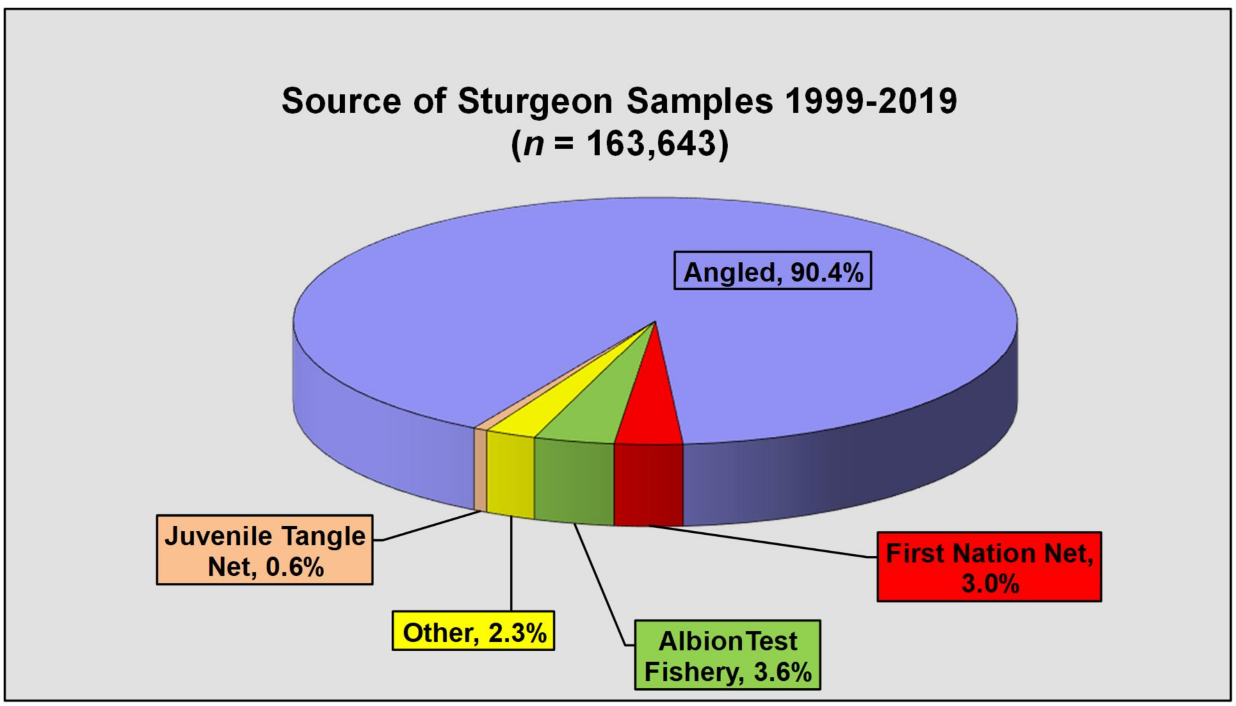


Figure 14. Summary of sources of sturgeon samples (all sizes) scanned for the presence of a PIT tag that were captured within the core assessment area of the Lower Fraser River White Sturgeon Monitoring and Assessment Program 1999-2019. *Other sources include: PSC Test Fishery, unsourced mortalities, commercial net, juvenile angling gear, set line, fishwheel, ghost net, river guardian, and enforcement.

Table 8. Numbers of unique (individual) tagged sturgeon sampled by anglers with standard angling gear, presented by the number of sampling events (encounters, identified by PIT tag number), within the general study area of the lower Fraser River, by year from 2000-2019. In 2019, 75 individual sturgeon were sampled three times, 14 individual sturgeon were sampled four times, and one sturgeon was sampled 10 times. The number of sampling events for individual sturgeon are not cumulative; for example, the 14 sturgeon sampled four times in 2019 are not included in the count of sturgeon sampled three times (n = 75) in 2019.

INDIVIDUAL STURGEON Number of Sampling Events	Numbers of Individual Sturgeon Sampled by Year																			
	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
1	5,685	4,116	5,228	6,097	8,626	6,670	9,197	7,529	7,367	7,152	6,453	6,572	7,898	6,490	5,918	4,897	3,201	2,261	3,531	2,886
2	510	407	463	572	873	662	983	612	601	619	538	597	872	619	630	317	128	109	201	137
3	75	49	75	89	134	84	107	55	60	78	45	69	108	81	78	19	2	6	15	6
4	14	11	8	27	23	13	15	5	5	11	7	11	29	5	17	1			1	
5	5	1	2	5	10	4	5	2	3	3	2	3	5		3					
6	1		1	1	6		1					1								
7	1			1			1													
8		1			1															
9				1																
10	1																			
Number of Individual Sturgeon Sampled	6,292	4,585	5,777	6,793	9,673	7,433	10,309	8,203	8,036	7,863	7,045	7,253	8,912	7,195	6,646	5,234	3,331	2,376	3,748	3,029
Number of Sampling Events	7,034	5,134	6,427	7,663	10,960	8,318	11,582	8,948	8,784	8,683	7,702	8,038	10,107	7,991	7,495	5,592	3,463	2,497	3,982	3,178
Percent Sampled Once Only	90.4%	89.8%	90.5%	89.8%	89.2%	89.7%	89.2%	91.8%	91.7%	91.0%	91.6%	90.6%	88.6%	90.2%	89.0%	93.6%	96.1%	95.2%	94.2%	95.3%

include: the entire North Arm and adjacent Middle Arm (north of Lulu Island (~23 km), the lower Pitt River upstream of the Highway 7 Bridge (~17 km), Pitt Lake (~27 km), Harrison Lake (~55 km), and the section of the upper Fraser Canyon between Lady Franklin Rock and Hell's Gate (25 km; Figure 1). All marine waters westward of the entrance points of the Fraser River at Garry Point and Canoe Pass (Figure 1) are also outside the core assessment area.

Numbers of White Sturgeon have been observed and captured in the bays and mouths of rivers in northern Puget Sound, with additional sightings and captures in the Southern Strait of Georgia and inlets/estuarine habitats on southern and western Vancouver Island (Nelson et al. 2013a). Although the origin (natal river) of White Sturgeon observed in marine waters adjacent to the Fraser River estuary is currently unknown, their proximity to the Fraser River suggests that at least some are of Fraser origin. Acoustic telemetry data have shown that a portion of lower Fraser White Sturgeon may briefly migrate to marine areas beyond the Fraser estuary, particularly during summer months (Robichaud et al. 2017).

The distinct pattern for monthly catch of White Sturgeon from the Albion Test Fishery since 2000 (Figure 15) suggests that sturgeon are moving past this point in the river (Figure 1) during April and May, and again during September through November. The spring movement (downstream) of White Sturgeon past the Albion Test Fishery site is likely explained by in-river foraging migrations from upstream overwintering locations into foraging areas in the lower river and estuary (in particular, areas that support spawning Pacific Eulachon, *Thaleichthys pacificus*), and perhaps upstream movements to late-spring and early- summer spawning locations. Late-summer and fall movements of White Sturgeon past the Albion Test Fishery site are likely both upstream and downstream migrations of sturgeon seeking out returning salmon stocks, and sturgeon returning to overwintering locations from summer/fall foraging areas.

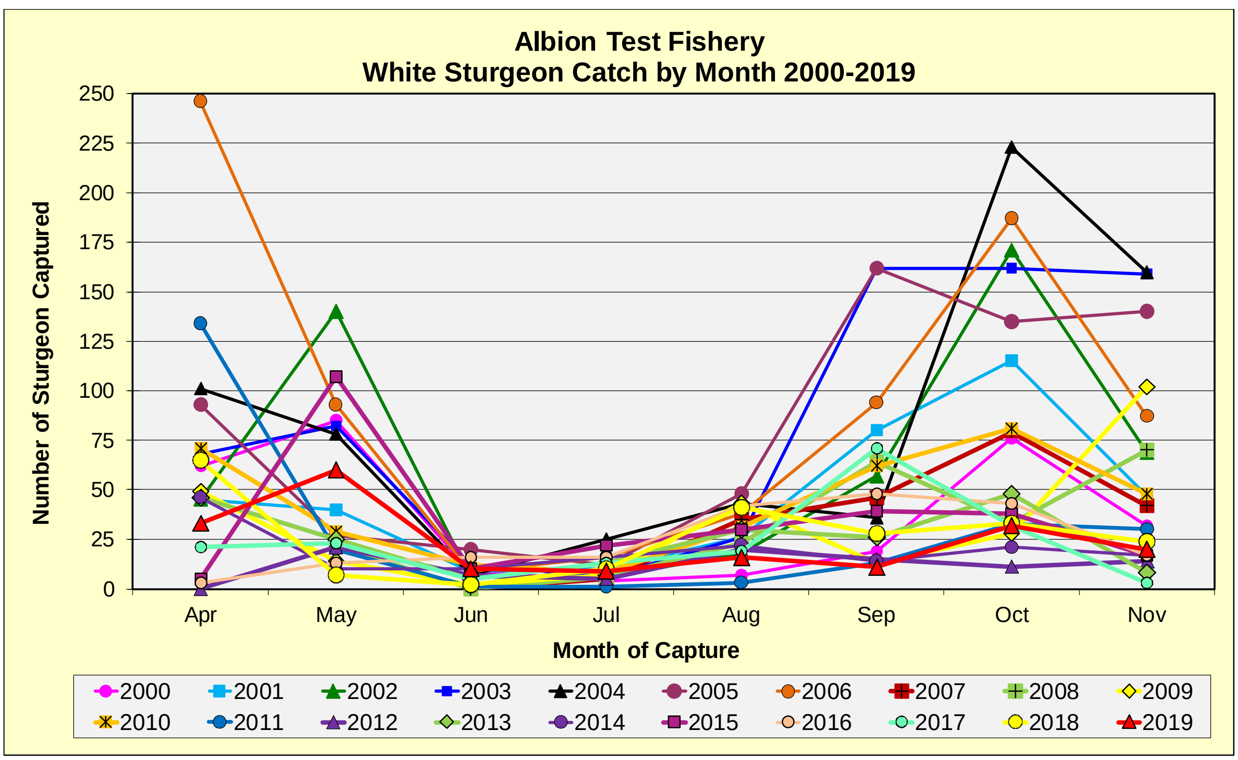


Figure 15. The number of White Sturgeon (all sizes) captured in the Albion Test Fishery during assessment net sets, by month of capture, 2000-2019. Data from Fisheries and Oceans Canada.

Movements past Hells Gate

Several tagged White Sturgeon have been documented passing both upstream and downstream of Hells Gate on the mainstem Fraser River (Appendix B). Hells Gate is located at rkm 212 in provincial management Region 3, approximately 17 km upstream from the Region 2 boundary at Spuzzum (rkm 195). Hells Gate is considered to be a Designated Unit (DU) boundary that separates discrete populations of White Sturgeon within the Fraser River watershed (COSEWIC 2012). White Sturgeon downstream of Hells Gate have been assigned to the "Lower Fraser" DU, whereas the White Sturgeon upstream of Hells Gate (including all tributaries to the Fraser River, including the Nechako River) have been assigned to the "Upper Fraser" DU. Reliable estimates of abundance have not been produced for the Upper Fraser DU.

Although there has been limited sampling effort upstream of the DU boundary since 2000, over 80% of which has occurred in a 10-km section of the middle Fraser River near Lillooet (the location of a concentrated recreational sturgeon fishery that includes both guided and non-guided anglers), there are nevertheless three tagged White Sturgeon that are known to have moved upstream past Hells Gate (Appendix B). These include tagged sturgeon observed in Region 2 (from locations including the tidal section of the river below Mission and the lower Fraser Valley) that were subsequently recaptured in Region 3 (near Lillooet, over 120 kms upstream of Hells Gate; Appendix D). Also, 24 tagged White Sturgeon are known to have moved downstream past Hells Gate. These include: one sturgeon tagged and released near Williams Lake River (Region 5) that moved downstream to the upper Fraser Valley near Hope and 18 sturgeon tagged and released near Lillooet (Region 3) that moved downstream to various locations in Region 2 (including the Fraser Canyon, the lower Fraser Valley, and the tidal section of the river below Mission).

In 2019, there was a single observation of a tagged sturgeon that migrated upstream past Hells Gate and 13 observations of tagged White Sturgeon that migrated downstream past Hells Gate (Appendix B). The single upstream migrant was sampled at rkm 115 (Fraser Valley near Chilliwack) in September 2016 and recaptured at rkm 335 (Lillooet near Bridge River confluence) in October 2019. The 13 cases of downstream movement past Hells Gate in 2019 is much higher than respective records from any previous years of monitoring; there were three respective cases in 2018, two in 2017, and six total cases (single, annual) prior to 2017 (Appendix B). All 13 of the downstream-migrating sturgeon in 2019 had been previously observed in Region 3 near Lillooet (approximately 120 kilometers upstream form Hells Gate). Only one of the 2019 downstream recoveries was previously seen during the same year; this sturgeon was sampled in Region 3 near Lillooet (rkm 321) in May 2019, five months prior to the recapture near Mission (at rkm 77) in October 2019. It should be noted that the number of tags applied in Region 3 has increased, which may contribute to the increase in observations of downstream movements.

Growth

The variability and periodicity of growth rates (depicted in Figure 12) are likely associated with the availability of food (prey). For example, the relatively large returns of Pink and Chum salmon in 2001, 2003, and 2011 likely provided a substantial increase in the amount of food available to Lower Fraser River White Sturgeon, either directly through the consumption of eggs and carcasses, or indirectly as a result of consuming organisms that benefited from the increased nutrient inputs brought into the rivers via salmon returns during those years. Conversely, after 2012, the low abundance of returning Pacific Eulachon and most species of salmonids may have resulted in a nutrient deficit in the lower Fraser River ecosystem, which may have translated to declining and lower-than-average growth rates for resident White Sturgeon over the same time period.

Other impact factors that can result in reduced growth are physical and physiological stress. High capture rates in nets and by angling can result in immediate and latent physical trauma that can result in reduced feeding success, and/or ability to migrate to optimal feeding locations.

Physiological stress induced by warm water temperatures and low oxygen levels, especially in combination with physical stress induced by capture events (McLean et al. 2016; 2019; 2020), could result in a reduction in feeding success.

The low growth rates observed in 2019 are similar to the low growth rates observed in 2017 and 2018. The average growth rate for 60-179 cm FL White Sturgeon assessed in 2019 was 36.8% lower than the respective average growth rate observed in 2002. In the 1960s, the reported average growth rate for Lower Fraser River White Sturgeon up to age 25 was approximately 5.1 cm/year (Semakula and Larkin 1968), which is 29.4% higher than the average growth rate (3.6 cm/year) for the comparable size groups of sturgeon sampled in 2019 (Figure 12). Growth is a quantitative indicator of the general health and condition of a sturgeon population; based on 2019 growth rates, the current condition of White Sturgeon in the lower Fraser River is poorer than that estimated for earlier study years.

Mark Rate Variation

The differences in observed annual mark rates among seasons suggest a potential population segregation between winter (low mark rates) and summer-fall (high mark rates). Preferred overwintering habitats may attract sturgeon from a wide area where sturgeon migrate and forage during the balance of the year, including locations outside the core assessment area. It is probable that sampling effort (i.e., tag applications) is not occurring, or occurring at a lower rate, at some of those other foraging and rearing areas, and thus fish from those areas have a lower probability of possessing a tag. When sturgeon from all areas concentrate in known overwintering locations within the core assessment area, the result could be a lower mark rate during the winter season. In addition, in recent years there has been less angling effort using “normal” (as opposed to “juvenile”) angling gear and methods during winter months.

Mark rates for 60-279 cm FL sturgeon sampled in the core assessment area were generally increasing from 2000-2017 (Figure 4). In 2018 and 2019, mark rates declined slightly from previous respective years. This could be associated with a request to program volunteers to ensure that all sizes (juvenile, sub adult, and adult) of sturgeon were “targeted” during sampling efforts. This request was in response to suggestions that some volunteers, especially commercial guides, were targeting larger sturgeon (using larger hooks and baits, and with the assistance of electronic detection equipment). Starting in 2018, a juvenile sampling project was also initiated to specifically target small juvenile sturgeon (English and Robichaud 2020).

Abundance Estimates

The BMR24 abundance estimates reported here do not represent the entirety of the population. This is based on our knowledge regarding the known presence of sturgeon outside of the core assessment area, and the omission of both small (under 60 cm FL) and large (over 279 cm FL) sturgeon from our estimates. However, our abundance estimates can be considered representative “indices of abundance” (as they have been generated consistently, using the same area and the same size groups of fish each year), which can be compared between and among assessment years to detect abundance trends within the total population.

The BMR24 abundances presented in this report are estimates of the mean number of White Sturgeon in the 60-279 cm FL size range that resided in the core assessment area over each two-year assessment period. The large number of sturgeon tagged and examined for tags each year has resulted in relatively precise estimates (Table 5). The precision and accuracy of these estimates depended upon the input of point estimates for growth, movement, mortality, undetected marks, and obtaining a representative sample of the mark rate.

Comparison of BMR24 and ISAMR Model Results

The current (2019) abundance estimates for 60-279 cm FL White Sturgeon in the core assessment area are 29,858 fish (95% CLs ± 6.9% of the estimate) for the BM24 model, and 44,809 fish (95% CIs ± 4.2% of the estimate) for the ISAMR model. Currently, the ISAMR estimate is considered to be the more reliable of the two estimates (due to heterogenous sampling biases that have arisen in the past few years, which affect the BMR24 model more than the ISAMR model). The size/age structure of the White Sturgeon population in the lower Fraser River in 2019 was comparable for the BMR24 and ISAMR models, with relatively few (18.7% vs 21.0%) juveniles (60-99 cm FL), and more (39.4% vs 30.6%) sub-adults (100-159 cm FL), and (41.9% vs 48.4%) adults (160-279 cm FL), respectively.

Recent abundance estimates generated by both the BMR24 and ISAMR models indicate that the abundance of White Sturgeon in the core assessment area of the lower Fraser River is well below historic levels and has been declining since 2006. The 2019 BMR24 abundance estimate for 60-279 cm FL White Sturgeon was 29,858 (95% CLs ± 6.9% of the estimate); this estimate is 51.2% lower than the program's highest annual abundance estimate in 2003, 40.3% lower than the 2006 estimate, and 10.7% lower than the 2018 estimate. Comparatively, the 2019 ISAMR abundance estimate for 60-279 cm FL (age 7-55) White Sturgeon was 44,809 (95% CIs ± 4.2% of the estimate). The 2019 ISAMR abundance estimate was 24.7% lower than the model's highest respective annual abundance estimate in 2006 and 3.9% lower than the 2018 estimate.

Both the BMR24 and ISAMR models suggest that the observed decline in the total abundance of White Sturgeon in the core assessment area of the lower Fraser River since 2004 has been driven mostly by declines in juvenile recruitment into the population. Both models agree that in the past 15 years (2004-2019) significant declines in abundance have occurred for 60-99 cm FL juvenile sturgeon (BMR24, 77.9% decline; ISAMR, 70.5% decline). Both models also agree that the abundance of sub-adult White Sturgeon (100-159 cm FL) has declined significantly in the past six years (2013 to 2019; BMR24, 50.9% decline; ISAMR, 43.1% decline; Figure 16). In addition, both models indicate that the abundance of adult sturgeon (160-279 cm FL) within the core assessment area trended upward until 2015, as surviving sub-adult sturgeon (100-159 cm FL) grew into the adult size group over this time period. However, the two models differ on the recent (2015-2019) trend of adult sturgeon (>160 cm FL); while the BMR24 model indicates that the abundance of adult sturgeon commenced its predicted decline in 2015, the ISAMR model suggests that the abundance of adult sturgeon has continued to increase during this time period (Figure 16). This divergence in the abundance estimates for 160-279 cm FL adult sturgeon accounts for 67% of the difference between the total yearly abundance estimates from the two models since 2015 (Challenger et al. 2020). Reasons for the differences between the estimates for 160-279 cm FL sturgeon in recent years have been provided in Nelson et al. (2019) along with the conclusion that the ISAMR model provides the more-reliable estimates for this size/age category.

The ISAMR model also provides an ability to make projections for each size/age category based on age-specific survival rates and recent levels of age-7 recruitment (Figure 17). The ISAMR model indicates that at current (2019) juvenile recruitment rates the recent downward trend in abundance will continue at an average rate of 1.4% per year from 2019 through 2050. The methods used to estimate the uncertainty associated with these forecast trends are provided in Challenger et al. (2020).

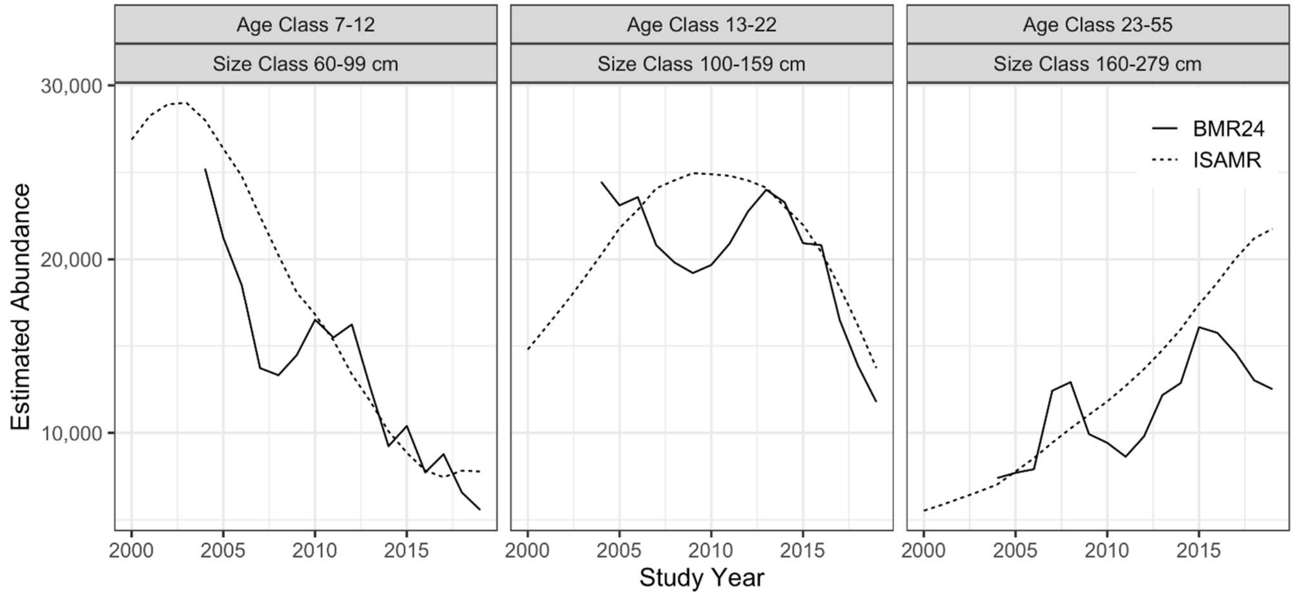


Figure 16. Comparison of the ISAMR (adjusted) and BMR24 model estimates of abundance for three size/age categories of Lower Fraser River Sturgeon. From Challenger et al. (2020).

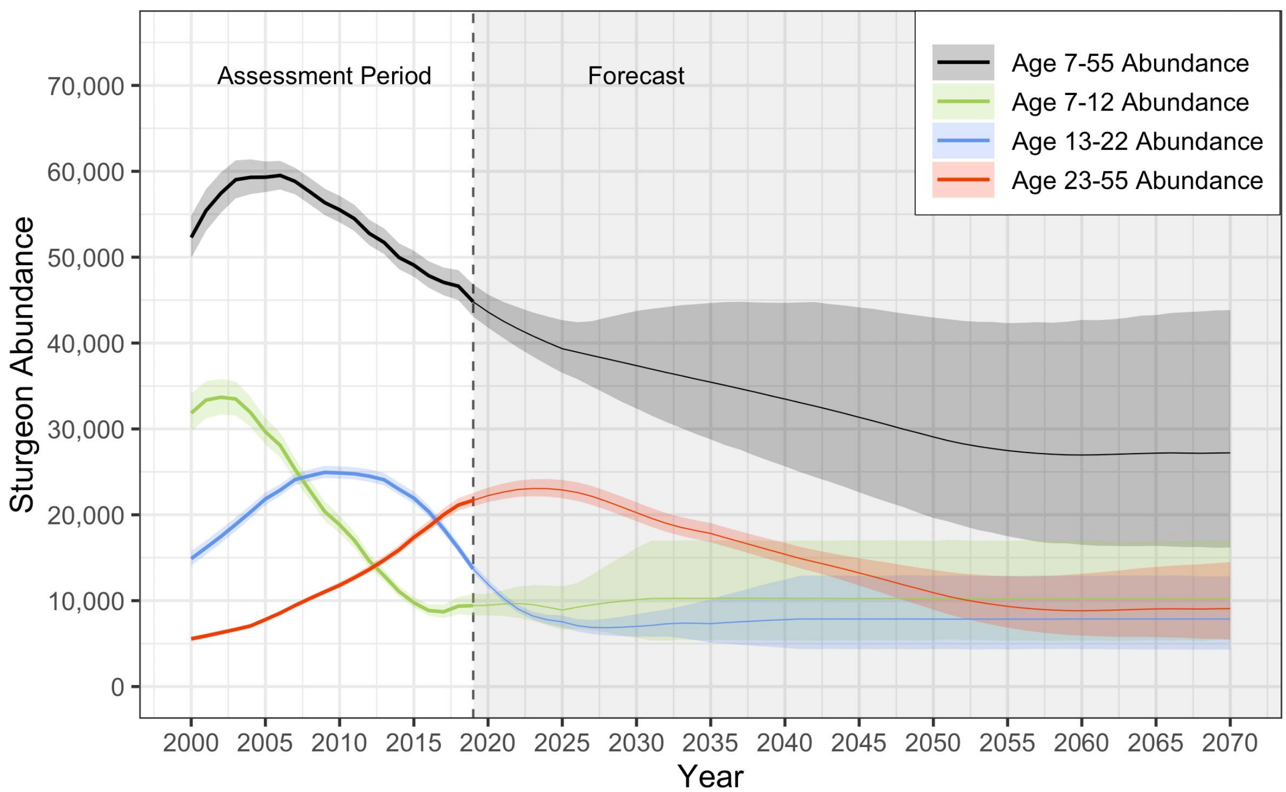
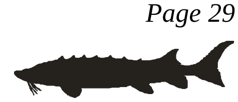


Figure 17. Abundance estimates for Lower Fraser River White Sturgeon for 2000-2019, and abundance projections for 2020-2070 (assuming that annual age-7 recruitment remains the same as recent estimates (e.g., 2012-2019 recruitment). Grey shading indicates projected years. From Challenger et al. (2020).



Abundance Trends

The BMR24 estimates of the abundance of White Sturgeon in the lower Fraser River presented in this report indicate that population abundance declined from 2003 to 2009, was variable from 2004 to 2015, and further declined from 2016 to 2019 (Table 5, Figure 8). This general and specific state of population decline has been reflected in several reports and publications (COSEWIC 2012, Nelson et al. 2013a, Hildebrand et al. 2016, Challenger et al. 2019).

A comparison of size-specific annual abundances from 2004-2019 reflects that there was a significant decline in the abundance of juvenile 60-99 cm FL sturgeon in the lower Fraser River between 2004 and 2008 (Figures 9 and 11). A subsequent decline in the abundance estimates for the 60-99 cm FL size group started in 2013 and has continued through 2019. The declines in estimated abundance of 60-99 cm FL sturgeon within the core assessment area are most likely due to reduced levels of recruitment of young juveniles into the population. Note that 60-99 cm FL White Sturgeon in the lower Fraser River are likely between 6-16 years old; the average age for this size group is 10.7 years (age-length data from the 1995-99 provincial White Sturgeon study; RL&L 2000). There could be a number of factors limiting juvenile recruitment into the population, including:

- Reductions in spawning activity or spawning success. Reduced spawning activity could result from increased physiological stress, such as that caused by capture or handling (especially at high water temperatures, see McLean et al. 2016). Sturgeon captures by recreational angling have a low incidence of direct mortality (Robichaud et al. 2006); however, the non-lethal impacts of angling are not known. Sturgeon captured in gill nets (that target migrating salmon) can die or be seriously injured (Robichaud et al. 2006); unfortunately, reliable estimates of gill net interceptions, including the number of sturgeon killed/retained during commercial and First Nation salmon fisheries in the lower Fraser River, and the number of sturgeon released from those fisheries, are not available. Spawning success could be limited by reduced food supply, which could result in sub adequate physiological condition for mature female (and perhaps male) sturgeon reproductive development. Reduced spawning success could also be the result of decreases in available spawning habitat, or by reductions in spawning habitat quality, such as gravel structure or size.
- Increased mortality during early life stages (larval and post larval/fry). Early life mortality could result from sub-optimal environmental conditions (water temperature, water chemistry, etc.), high levels of predation, limited availability of food, or by reductions in suitable feeding or rearing habitat.
- Increased mortality of age-0 to age-4+ fish. Sturgeon of this size require specific rearing habitats that support suitable prey items, both of which are limited in the lower Fraser River. Juvenile sturgeon in this size group (up to approximately 35 cm FL) are also vulnerable to elevated salinity levels present in the lower Fraser River estuary (exposure to salinities over 16 ppt can result in high levels of mortality for small sturgeon; Amari et al. 2009).

The declines in the BMR24-estimated abundance of 60-99 cm FL sturgeon in recent years is likely due to an exclusion of juvenile sturgeon sampling data from these analyses, and also due to the small amount of sampling effort that used normal angling methods[1] that has occurred during winter months in the last two years. Other factors that affect the sample size for 60-99 cm FL sturgeon

[1] Normal angling methods use hook sizes and baits that have been used for many years and are effective at catching sub-mature and adult sturgeon, and exclude the methods recently developed for targeting juvenile sturgeon using small hooks and baits as part of the 2018-2019 juvenile sturgeon sampling projects (English and Robichaud 2020).

include: smaller fish being less vulnerable to our primary sampling gear (normal angling methods); program volunteers changing their angling behaviour (e.g., fishing methods and locations that target large fish); and increased proportions of small fish residing outside of the core assessment area (or in less well-sampled portions of the core assessment area).

The BMR24 and ISAMR abundance estimates for adult White Sturgeon over 160 cm FL had been generally trending upward from 2011 to 2015, and the ISAMR estimates (the most reliable estimates for this size category) continue to trend upward through 2019 (Figure 9). While a stable or increasing number of adult sturgeon provides potential short-term security for population rebuilding, this can only be realized if effective spawning and subsequent juvenile recruitment is occurring at a level sufficient to maintain and grow the population over time.

The proportion of small (< 100 cm FL) White Sturgeon sampled by angling has decreased continually and significantly since the beginning of the program (Figure 18). In 2000, over half of all sturgeon captured by angling (53.4%) were less than 100 cm FL; by 2008 this proportion dropped to 34.6%; and by 2019 this proportion further declined to 22.9% (which is a 59.3% decrease from 2000). Prior to 2018, the decline in the proportion of angled sturgeon under 100 cm FL was probably the result of changes in angler behaviour (particularly angling guides), who may have become more successful in targeting the largest fish possible using new technologies, (including high-resolution electronic sonar viewing systems), fishing tackle and terminal gear that increases the likelihood of hooking and capturing large sturgeon, and newly available information regarding large fish locations and behaviour quickly shared via electronic media. Targeted sampling of adult (large)

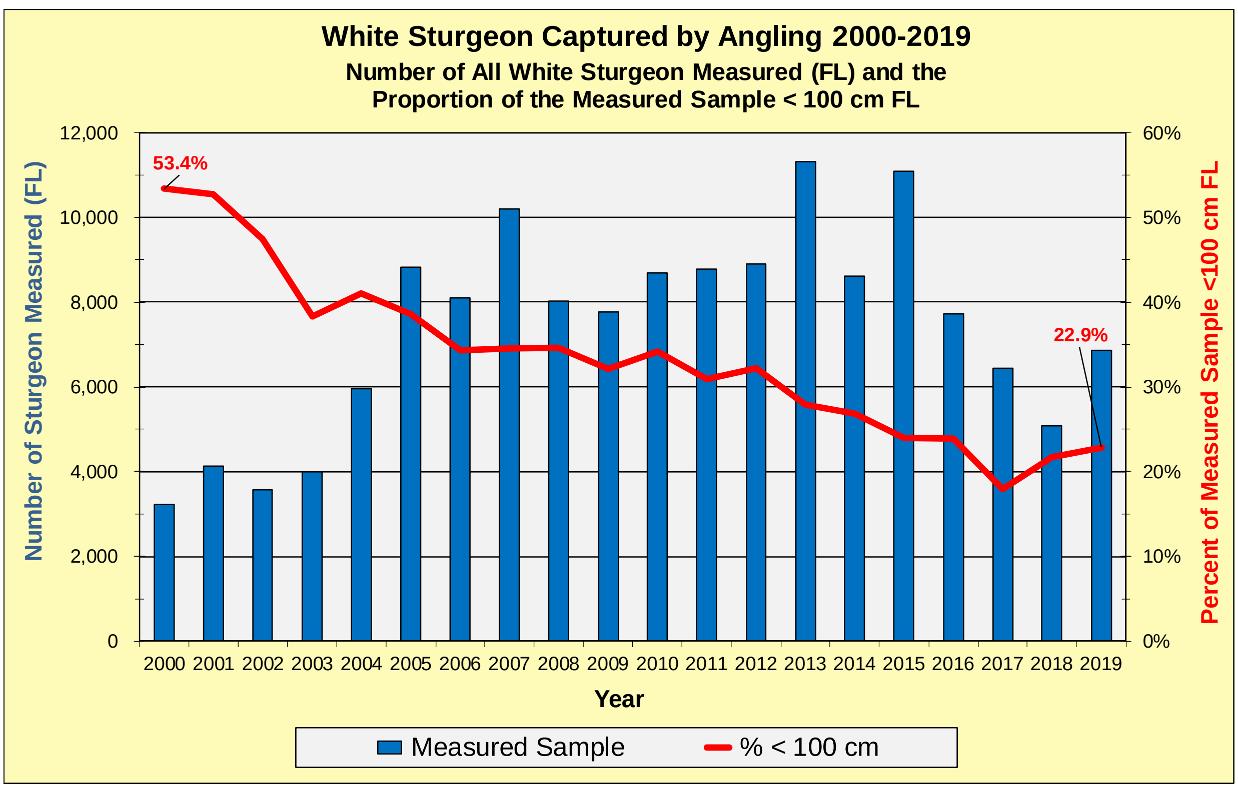


Figure 18. The annual proportions of White Sturgeon less than 100 cm FL from all measured samples captured by standard angling gear, 2000-2019. Declines reflected in this figure may be associated with declining numbers of small (< 100 cm FL) sturgeon and to changes in angler behavior.

sturgeon occurs within in volunteer angling behaviour, especially during summer and fall sampling periods and with volunteers that are guides for the recreational angling fishery. Conversely, there are several new research projects have been using angling guides that apply specialized “juvenile” angling gear and methods to target small sturgeon in the lower Fraser River, which has affected the number of juvenile sturgeon sampled in 2018 and 2019 using “normal” angling gear and methods. Data from the juvenile sturgeon sampling program will be incorporated into the analytical models over the next few years to provide more precise estimates of the number of juvenile sturgeon in the Lower Fraser River study area (English and Robichaud 2020).

In contrast to the angling data described above, the Albion Test Fishery (a gillnet test fishery conducted at rkm 58 in the lower Fraser River, see Figure 1) is conducted in a relatively rigorous and consistent manner among years, and changes in the proportion of juvenile sturgeon observed in the gill net sample could certainly be a direct reflect ion of the numbers of juvenile sturgeon present in the Lower Fraser River population. And indeed, the Albion Test Fishery data provide evidence that over the course of the monitoring and assessment program there has been a declining proportion of juvenile sturgeon less than 100 cm FL within the population. In 2000, 53.8% of all sturgeon captured in the Albion Test Fishery were less than 100 cm FL; by 2008 this proportion dropped to 50.5%, and in 2019 it further declined to 20.0% (which is a 62.8% decrease from 2000; Figure 19). While there have been minor methodological changes for this test fishery over the years

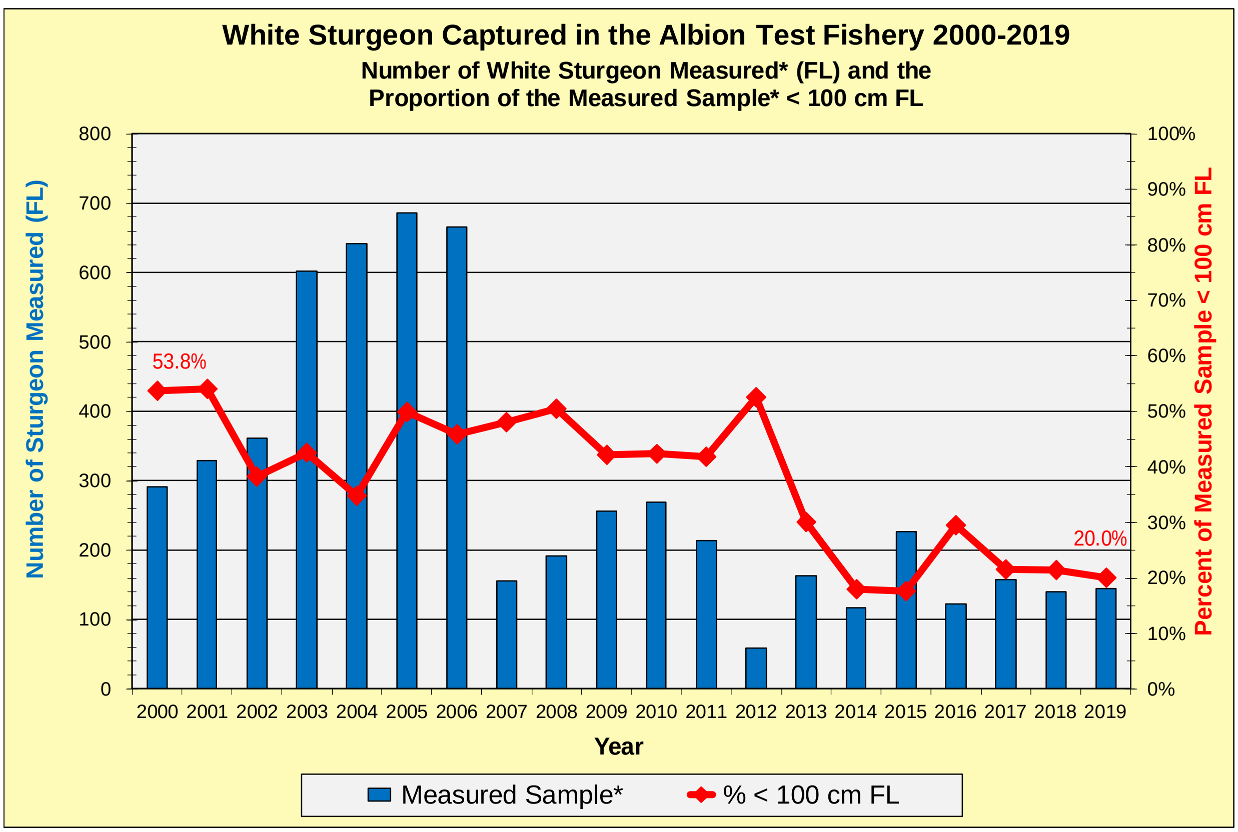


Figure 19. The annual proportions of White Sturgeon less than 100 cm FL from all measured samples captured in the Albion Test Fishery, 2000-2019. Since 2000, there has been a 62.8% decrease in the abundance of juvenile White Sturgeon present in total measured samples of sturgeon from the Albion Test Fishery. Methodological changes to the test fishery over the years do not explain the declines in small sturgeon proportions, especially since 2012.

(especially between 2006 and 2007), including variation in net size, effort, and deployment schedules, and habitat changes have resulted from dredging activities in the test fishery area, these cannot explain the observed declines in the proportion of small sturgeon sampled (especially since 2012; Figure 19). We believe that these data supply independent evidence of declining numbers of juvenile sturgeon present in the Lower Fraser River population of White Sturgeon.

Model Comparisons

There was a strong agreement between estimates of population abundances, trends in abundance, and spatial distribution of abundances, when the two modelling frameworks (BMR24 and ISAMR) were compared across the three size groupings. Nevertheless, there were also noticeable deviations, especially when combining size groupings. The BMR24 analysis model followed the same overall trends produced by the ISAMR analysis but tended to show more year-to-year variation in abundances (the ISAMR abundance estimates also produced relatively smoother trajectories). These differences in abundance estimates likely relate to underlying differences in the populations of interest and model structuring. The BMR24 analysis model uses a 24-month analysis window, and as such the biological population of inference are sturgeon that have used the lower Fraser River within that 24-month period. In contrast, the ISAMR model considers captures from all years, with a population of inference being sturgeon that have used the lower Fraser River throughout the entire 2000-2019 period. Individuals that temporarily emigrate will still be considered part of the population of interest, and as such ISAMR-derived abundance estimates should show more stability. This is especially true if a large proportion of temporary emigration events last longer than 24 months.

There is less year-to-year variability in abundance in the ISAMR model outputs than in the BMR24 model outputs. The estimates produced by the ISAMR model are for all sturgeon in the selected size range that were tagged in the core assessment area and believed to be alive in a given year, regardless of whether they were in the core assessment area or elsewhere in a given year. Because the ISAMR model employs an age-structured population matrix where individual recruitment cohorts are tracked over time, the structuring can result in more inertia in the annual abundance estimates. Furthermore, the ISAMR model uses a shared mortality-at-age curve across modeled years which represents the average age-specific mortality. Year-to-year variation in age-specific mortality rates are not considered by the ISAMR, and as such the abundance estimates will not reflect short term changes in mortality rate. If age-specific mortality rates change as data are added to the model, the estimated mortality curve will also change in response to the new data added each year. While annual changes to age-specific mortality curve will be small, they will nevertheless result in adjustments to the abundance estimates across the entire time series.

Abundance Forecasts

Abundance forecasts from the ISAMR model indicate that immediate action should be implemented to improve recruitment to age 7, which is currently at a level approximately one third that of levels 15-20 years prior (Challenger et al. 2020). If age-7 recruitment stays at its current level, the recent downward trend in abundance will continue at an average rate of 1.4% per year from 2019 through 2050 (Figure 17, Challenger et al. 2020). Even with improved recruitment the 100-159 cm FL (i.e., age 13-22) group is projected to decline until the mid to late 2020's resulting in an abundance level that is one third of the 2010 abundance. Larger sturgeon (i.e., 160-279 cm FL) abundances would be predicted to peak in the mid 2020's, then decline until approximately 2055, which could further reduce already low age-7 recruitment levels.

Medium- and long-term targets for rebuilding the Lower Fraser River White Sturgeon population should be based on recent abundance levels. The abundance of 60-279 cm FL sturgeon has approached 60,000 fish as recently as 2005, making 60,000 a reasonable interim population recovery goal for this size group. Similarly, the spawning component (160-279 cm FL) is projected to reach an abundance of approximately 20,000 fish by the early 2020’s, before the projected decline. Given the current low recruitment levels, we recommend that 20,000 is identified as another recovery goal for spawning-age sturgeon. Indications that progress has been made to achieve these interim goals would be a significant increasing trend in abundance of 60-99 cm FL sturgeon by 2025.

Importance of Annual Data Review, Analysis, and Reporting

In-season data review and annual analyses are essential components of the ongoing Lower Fraser River White Sturgeon Monitoring and Assessment Program and are two of the key reasons why the program is considered to be both credible and world-class. Thousands of data records are submitted by program volunteers each year, during all months, from throughout the large study area. A thorough review of these data is critical to ensure that data forms submitted by volunteers are complete and accurate. Despite the best efforts of volunteers, our data review procedures do indeed identify erroneous or missing data, which we attempt to correct by promptly following up with the volunteers in question. These follow-ups are only effective when they occur in a timely manner, underpinning the need for constant and regular data review. Moreover, data inconsistencies and data entry errors have been identified while running the abundance models, highlighting the need for timely analyses as a critical part of our quality control and quality assessment procedures.

Running the abundance models annually is important, and not just as a quality assessment procedure. Results from the mark-recapture models provide relatively current estimates of abundance and growth rates for the Lower Fraser River White Sturgeon population; timely information regarding population change, status, and trends are of high value for government personnel tasked with the conservation and recovery of White Sturgeon and their habitat. In addition, it is very important to communicate updated results to program volunteers, program sponsors, local First Nations, sturgeon recovery teams, government personnel, and members and directors of the Fraser River Sturgeon Conservation Society. Results from annual analyses have been reported in a variety of forms, including: peer-reviewed journal articles, detailed technical reports, summary reports, press releases, PowerPoint presentations, and HCTF project reports. The production of reporting products on an annual basis is critically important for maintaining essential stewardship contributions to the program. Moreover, ongoing feedback that is encouraged and received following reporting events helps identify where the program and deliverables can be improved, and how we can be more effective at achieving our goals related to conservation and ultimate recovery of the population.

Recommendations have not been included in this report. However, the authors continue to support recommendations provided in previous reports (Nelson et al. 2018, 2019) and are hopeful that the Recovery Potential Assessment for Lower Fraser River White Sturgeon (in preparation at the release of this report) will consider those recommendations to support population recovery.

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Much of the success of this program has been the result of scientific oversight provided by the Science and Technical Committee of the FRSCS which is composed mostly of fishery science professionals; the committee provides key input regarding program design and direction and conducts critical reviews of program results. Individuals from the FRSCS Science and Technical Committee also serve on the Lower and Middle Fraser River White Sturgeon Technical Working Group and the National Recovery Team for White Sturgeon in Canada.

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REFERENCES

Challenger, W., K.K. English, and T. Carruthers. 2017. Integrated spatial and age mark recapture (ISAMR) model (v2.0) for Lower Fraser River White Sturgeon. Report for the Habitat Conservation Trust Foundation, Victoria, BC.

Challenger, W., K.K. English, D. Robichaud, and T.C. Nelson. 2020. Status of White Sturgeon in the lower Fraser River in 2019 derived using an integrated spatial and age mark recapture (ISAMR) model. Report for the Fraser River Sturgeon Conservation Society, Vancouver, BC, and BC Ministry of Forest, Lands, Natural Resource Operations, and Rural Development, Surrey, BC.

COSEWIC. 2012. COSEWIC assessment and status report on the White Sturgeon *Acipenser transmontanus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario.

English, K.K. and D. Robichaud. 2020. Lower Fraser Juvenile White Sturgeon Monitoring Program using size-selective angling techniques, 2019-2020. Report for Fraser River Sturgeon Conservation Society, Vancouver, BC and Habitat Conservation Trust Foundation, Victoria, BC.

Fabens, A.J. 1965. Properties and fitting of the von Bertalanffy growth curve. Growth 29:265-289.

Glova, G., T. Nelson, K. English, and T. Mochizuki. 2008. A preliminary report on juvenile White Sturgeon habitat use in the lower Fraser River, 2007-2008. Report for the Fraser River Sturgeon Conservation Society, Vancouver, BC. http://www.frasersturgeon.com/media/juvenile-habitat-2008.pdf

Hildebrand, L.R., A.D. Schreier, L. Lepla, S.O. McAdam, J. McLellan, M.J. Parsley, V.L. Paragamian, and S.P. Young. 2016. Status of White Sturgeon (*Acipenser transmontanus* Richardson, 1863) throughout the species range, threats to survival, and prognosis for the future. Journal of Applied Ichthyology 32 (Suppl. 1): 261-312.

McLean, M.F., K.C. Hanson, S.J. Cooke, S.G. Hinch, D.A. Patterson, T.L. Nettles, and G.T. Crossin. 2016. Physiological stress response, reflex impairment, and delayed mortality of White Sturgeon *Acipenser transmontanus* exposed to simulated fisheries stressors. Conservation Physiology 4(1): cow031;doi:10.1093/conphys/cow031.

McLean, M.F., Litvak, M.K., Cooke, S.J., Hanson, K.C., Patterson, D.A., Hinch, S.G., Crossin, G.T., 2019. Immediate physiological and behavioural response from catch-and-release of wild white sturgeon (*Acipenser transmontanus* Richardson, 1836). Fish. Res. 214, 65–75. https://doi.org/10.1016/j.fishres.2019.02.002

McLean, M.F., M.K. Litvak, E.M. Stoddard, S.J. Cooke, D.A. Pattersom, S.G. Hinch, D.W. Welch, and G.T. Crossin. 2020. Linking environmental factors with reflex action mortality predictors, physiological stress, and post-release movement behaviour to evaluate the response of White Sturgeon (*Acipenser transmontanus* Richardson, 1836) to catch-and-release angling. Comparative Biochemistry and Physiology, Part A 240 (2020) 110618.

Nelson, T.C., K.K. English, and M.L. Rosenau. 2000. Design of a stewardship project to supplement information required to assess the status of white sturgeon in the lower Fraser River. Report for the Fraser River Sturgeon Conservation Society, Richmond, BC, and BC Ministry of Fisheries, Conservation Section, Victoria, BC.

Nelson, T.C., W.J. Gazey, M.L. Rosenau, and K.K. English. 2004. Status of White Sturgeon in the lower Fraser River: Report on the findings of the lower Fraser River White Sturgeon monitoring and assessment program 1999-2004. Report for the Fraser River Sturgeon Conservation Society, Vancouver, BC. http://www.frasersturgeon.com/media/LFRWS-manuscript-2004.pdf

Nelson, T.C., W.J. Gazey, and K.K. English. 2008. Status of White Sturgeon in the lower Fraser River: Report on the findings of the lower Fraser River White Sturgeon monitoring and assessment program 2007. Report for the Fraser River Sturgeon Conservation Society, Vancouver, BC. http://www.frasersturgeon.com/media/LFRWS-manuscript-2007.pdf

Nelson, T.C., W.J. Gazey, K.K. English, and M.L. Rosenau. 2013a. Status of White Sturgeon in the Lower Fraser River, British Columbia. Fisheries 38: 197-209.

Nelson T.C., P. Doukakis, S.T. Lindley, A.D. Schreier, J.E. Hightower, L.R. Hildebrand, R.E. Whitlock, and M.A.H. Webb. 2013b. Research tools to investigate movements, migrations, and life history of sturgeons (*Acipenseridae*), with an emphasis on marine-oriented populations. PLoS ONE 8(8): e71552 doi:10.1371/journal.pone.0071552.

Nelson, T.C., D. Robichaud, T. Mochizuki, J. Rissling, K.K. English, and W.J. Gazey. 2016. Status of White Sturgeon in the lower Fraser River: Report on the findings of the Lower Fraser River White Sturgeon Monitoring and Assessment Program 2015. Report for the Fraser River Sturgeon Conservation Society, Vancouver, BC.

Nelson, T.C., D. Robichaud, T. Mochizuki, J. Rissling, K.K. English, and W.J. Gazey. 2017. Status of White Sturgeon in the lower Fraser River: Report on the findings of the Lower Fraser River White Sturgeon Monitoring and Assessment Program 2016. Report for the Fraser River Sturgeon Conservation Society, Vancouver, BC.

Nelson, T.C., D. Robichaud, W. Challenger, T. Mochizuki, J. Rissling, K.K. English, and W.J. Gazey. 2018. Status of White Sturgeon in the lower Fraser River in 2017 with abundance estimates derived from 24-month Bayesian analyses and integrated spatial and age mark recapture (ISAMR) modeling. Report for the Fraser River Sturgeon Conservation Society, Vancouver, BC.

Nelson, T.C., D. Robichaud, W. Challenger, K.K. English, T. Mochizuki, T. Thibault, J. Rissling, and W.J. Gazey. 2019. Lower Fraser River White Sturgeon Monitoring and Assessment Program: Status of White Sturgeon in the lower Fraser River in 2018 with abundance estimates derived from 24-month Bayesian mark recapture modeling. Report for the Fraser River Sturgeon Conservation Society, Vancouver, BC.

RL&L. 2000. Fraser River white sturgeon monitoring program: Comprehensive report (1995-1999). Report for BC Fisheries, Victoria, BC.

Robichaud, D., K.K. English, R.C. Bocking, and T.C. Nelson. 2006. Direct and delayed mortality of white sturgeon caught in three gear-types in the lower Fraser River. Report for Tsawwassen First Nation Fisheries, Delta, BC.

Robichaud, D., K.K. English, and T.C. Nelson. 2017. Annual movements of acoustic-tagged White Sturgeon in the lower reaches of the Fraser River and its tributaries. Transactions of the American Fisheries Society 146: 611-625. DOI: 10.1080/002847.2017.1204542.

Semakula, S.N. and P. A. Larkin. 1968. Age, growth, food and yield of the white sturgeon (*Acipenser transmontanus*) of the Fraser River, British Columbia. Journal of the Fisheries Research Board of Canada 25: 2589-2602.

APPENDICES

Appendix A. Sturgeon biosampling, tagging, and recapture data entry form

FRASER RIVER STURGEON CONSERVATION SOCIETY FAX to Tyler Thibault : 604-200-5430 (phone: 604-613-6231)

WHITE STURGEON BIOSAMPLING, TAGGING, AND MARK- RECAPTURE RECORDS tyler.thibault18@gmail.com Page:______of

Name of Person that Recorded Data:____________________________________ Phone number: _______________

Date (dd/mmm/yy______________Sampling Area:____________________ Weather:_________________________ No. Passengers: _______________

Vessel Information: Vessel Name_____________ Launch Location________________Launch Time:_______________ Return Time: _______________

Angling/Sampling Effort		Start Time	End Time	Total Minutes	Start Time	End Time	Total Minutes	Start Time	End Time	Total Minutes	Grand Total (Minutes)
Rod/Gear 1 (Name)											
Rod/Gear 2 (Name)											
Rod/Gear 3 (Name)											
Rod/Gear 4 (Name)											

COMPLETE FOR ALL STURGEON CAPTURED						TAGS APPLIED	RECAPTURES	OTHER	
Fish No.	**River Km (Captured)**	**Was the Sturgeon Scanned? (Yes/No)**	**Fork Length (cm)**	**Girth (cm)**	**Deformity / Wound Code[1]**	**Verified (Scanned at release) Tag Number**	**Tag Number**	**Condition code for sturgeon at release[2]**	**Comments**

Comments:

[1]Deformity/wound/scar codes: DEF = physical deformity; BLED = bleeding; BITE = seal bite; CUT = slice or tear; NET = net scar; OTHER = other (note in comments)

[2]Condition codes: 1 = vigorous, no bleeding; 2 = vigorous, bleeding; 3 = lethargic, no bleeding; 4 = lethargic, bleeding; 5 = dead

Appendix B. Summary of White Sturgeon (all sizes) sampled in the general study area of the lower Fraser River, from all sources and sampling gear types, 1999-2019

Appendix B. Summary of White Sturgeon (all sizes) sampled in the general study area of the lower Fraser River (see Figure 2), from all sources and sampling gear types, 1999-2019. A subset of these sampling records were used to generate annual abundance estimates (see Appendix C). Included is a summary of sturgeon sampled (under this program) outside the Fraser River watershed. See notes at bottom of sheet (page 2) for additional information.

Assessment Year	No. Scanned for PIT Tag (All) (A)	No. Tagged and Released with PIT Tag (Head) (B)	No. Recaptured with PIT Tag (Head) (C)	No. Scanned, Not Tagged, Not Recaptured (D)	No. Sampled, Not Scanned (E)	No. Recaptured With Dorsal Tag (First Recapture Only) (F)	No. Mortalities Sampled (G)	No. Moved Upstream Past Hells Gate (H)	No. Moved Downstream Past Hells Gate (I)	No. Tagged in Fraser, Recovered Outside Fraser Watershed (J)	No. Recaptures from WA or OR (First Recapture Only) (K)	No. Green Sturgeon Observed (L)	No. Scanned Outside of Fraser Watershed (M)	No. Tagged Outside of Fraser Watershed (N)
1999	459	413		11	1	36								
2000	4,387	3,966	219	134	73	58	18							
2001	5,508	4,552	752	147	39	52	24							2
2002	5,043	2,744	913	1,283	32	32	75			1	1		3	
2003	5,432	3,627	1,004	685	16	27	96							
2004	7,240	4,797	1,822	561	102	16	45				1			
2005	10,188	5,260	3,542	1,272	63	20	80					1		
2006	9,030	5,071	3,816	104	32	17	19							
2007	10,637	5,205	5,329	71	32	20	8	1	1		1	1	8	7
2008	8,566	3,873	4,585	51	41	16	10						15	11
2009	8,256	3,355	4,785	68	64	20	7		1		1	2	17	3
2010	9,097	3,746	5,264	56	71	5	7		1					
2011	9,135	3,602	5,433	67	78	11	5				2			
2012	9,195	3,861	5,250	32	92	9	9			1	1			
2013	12,155	4,437	7,590	60	48	13	11		1			2		
2014	9,186	2,637	6,018	473	96	5	13					1		
2015	11,416	3,558	7,644	153	113	7	20		1		1			
2016	7,919	2,174	5,637	71	72	13	14		1			1		
2017	6,781	1,706	4,993	39	63	14	25	1	2			1		
2018	6,207	1,958	4,170	28	47	3	29		3	1			1	
2019	9,687	3,625	5,958	49	96	0	7	1	13					
Totals	165,524	74,167	84,724	5,415	1,271	394	522	3	24	3	8	9	44	23

Appendix B - Column Notes

(A) Numbers of White Sturgeon sampled by lower Fraser River sturgeon projects scanned for the presence of a PIT tag; includes samples that were not tagged or recaptured, and scanned mortalities

(B) Numbers of White Sturgeon sampled by lower Fraser River sturgeon projects and tagged with a PIT tag in the head location and released; includes head tagging of dorsal-tag recaptures

(C) Numbers of White Sturgeon sampled by lower Fraser River sturgeon projects that were recaptured and possessed a PIT tag located in the head location upon recovery

(D) Numbers of White Sturgeon scanned, but no tag applied, and not a recapture (tag not applied due shortage of available PIT tags, safety concerns, or because the fish was considered to be in poor physical condition when sampled

continued

Appendix B - Column Notes

(E) Number of White Sturgeon sampled but not scanned for a PIT tag (typically, these cases where the result of tag reader malfunction due to power issue)

(F) Numbers of first recapture events of White Sturgeon that possessed a "dorsal" PIT tag and/or external tag (tag applied in the dorsal area of the sturgeon during the 1995-99 provincial sturgeon study); most of these "dorsal" sturgeon received "head" PIT tags under this program and are thus considered a head recapture following the initial head tag release

(G) Numbers of dead White Sturgeon (mortalities) sampled; includes mortalities that were not scanned, but were sampled/observed (does not included reported mortalities that were not sampled); does not include all mortalities from ghost net and provincial tangle net projects; the majority of mortalities observed from 2000-2005 were captured in set gill nets (First Nation fisheries)

(H) Numbers of recaptured White Sturgeon that moved upstream past rkm 212 (Hells Gate). Includes movements from Region 2 (lower Fraser Valley above and below Mission) to Region 3 near Lillooet.

(I) Number of recaptured White Sturgeon that moved downstream past rkm 212 (Hells Gate); includes movements from Region 5 (near Williams Lake River) to Region 2 (near Hope) and movements from Region 3 (near Lillooet) to Region 2 (lower Fraser Valley above and below Mission)

(J) Number of White Sturgeon tagged in the lower Fraser River and recovered outside the Fraser watershed (two sturgeon were recovered as mortalities in Boundary Bay and Mud Bay, respectively, south of the Fraser River; a third sturgeon was recaptured and released in the Columbia River near Astoria on 12 July 2012)

(K) Numbers of White Sturgeon tagged (PIT or external tag) in the Columbia River (Oregon or Washington) and recovered in the lower Fraser River (first observation only)

(L) Numbers of Green Sturgeon observed by this program in the lower Fraser River (confirmed observations only)

(M) Numbers of White Sturgeon scanned (under this program) outside the Fraser watershed; includes live and dead samples from commercial seine vessel (Strait of Georgia), Skagit River Tribe (WA), and Puget Sound (WA; WDFG)

(N) Numbers of White Sturgeon PIT tagged and released (under this program) outside the Fraser watershed; includes samples from commercial seine vessel (Strait of Georgia), Skagit River Tribe (WA), and Puget Sound (WA; WDFG)

Appendix C. Summary of White Sturgeon sampled in the core assessment area of the lower Fraser River that were 60-279 cm FL when sampled, by month and year, 1999-2019

Appendix C. Summary of White Sturgeon samples used in the generation of the BMR24 TAL30 model, 1999-2019. Samples limited to sturgeon 60-279 cm FL captured within the core assessment area of the lower Fraser River (see Table 2 and Figure 2).

Month	No. Scanned (All)	No. Released With Tag (Head)	No. Scanned, Not Tagged, Not Recaptured	No. Recaptured (Head Tag)	Mark Rate (%)	Year	No. Scanned (All)	No. Released With Tag (Head)	No. Scanned, Not Tagged, Not Recaptured	No. Recaptured (Head Tag)	Mark Rate (%)
Oct-99	87	81	6	0	0.0%						
Nov-99	183	161	22	0	0.0%						
Dec-99	143	132	11	0	0.0%	**1999**	413	374	39	0	**0.0%**
Jan-00	36	36	0	0	0.0%						
Feb-00	122	110	5	7	5.7%						
Mar-00	173	164	2	7	4.0%						
Apr-00	272	254	10	8	2.9%						
May-00	357	331	15	11	3.1%						
Jun-00	249	234	9	6	2.4%						
Jul-00	585	540	19	26	4.4%						
Aug-00	351	314	15	22	6.3%						
Sep-00	430	399	6	25	5.8%						
Oct-00	645	573	29	43	6.7%						
Nov-00	512	464	9	39	7.6%						
Dec-00	53	41	6	6	11.3%	**2000**	3,785	3,460	125	200	**5.3%**
Jan-01	154	143	0	11	7.1%						
Feb-01	135	119	0	16	11.9%						
Mar-01	273	226	3	44	16.1%						
Apr-01	390	317	27	46	11.8%						
May-01	364	315	6	43	11.8%						
Jun-01	400	325	6	69	17.3%						
Jul-01	337	272	11	54	16.0%						
Aug-01	666	556	13	97	14.6%						
Sep-01	531	439	6	86	16.2%						
Oct-01	795	659	26	110	13.8%						
Nov-01	482	391	6	85	17.6%						
Dec-01	284	181	64	39	13.7%	**2001**	4,811	3,943	168	700	**14.5%**
Jan-02	105	53	41	11	10.5%						
Feb-02	140	42	79	19	13.6%						
Mar-02	124	59	45	20	16.1%						
Apr-02	216	96	88	32	14.8%						
May-02	327	171	104	52	15.9%						
Jun-02	206	118	35	53	25.7%						
Jul-02	532	361	71	100	18.8%						
Aug-02	736	517	65	154	20.9%						
Sep-02	352	134	131	87	24.7%						
Oct-02	1,019	544	294	181	17.8%						
Nov-02	492	173	211	108	22.0%						
Dec-02	151	93	30	28	18.5%	**2002**	4,400	2,361	1,194	845	**19.2%**
Jan-03	69	52	11	6	8.7%						
Feb-03	34	19	10	5	14.7%						
Mar-03	123	81	28	14	11.4%						
Apr-03	440	280	77	83	18.9%						
May-03	529	371	75	83	15.7%						
Jun-03	287	159	72	56	19.5%						
Jul-03	415	260	88	67	16.1%						
Aug-03	592	403	81	108	18.2%						
Sep-03	1,096	737	126	233	21.3%						
Oct-03	815	580	56	179	22.0%						
Nov-03	620	388	101	131	21.1%						
Dec-03	109	93	1	15	13.8%	**2003**	5,129	3,423	726	980	**19.1%**
Jan-04	142	120	0	22	15.5%						
Feb-04	303	259	5	39	12.9%						
Mar-04	137	107	3	27	19.7%						
Apr-04	723	565	5	153	21.2%						
May-04	574	430	7	137	23.9%						
Jun-04	415	300	8	107	25.8%						
Jul-04	445	323	1	121	27.2%						
Aug-04	610	393	41	176	28.9%						
Sep-04	825	570	15	240	29.1%						
Oct-04	1,609	882	263	464	28.8%						
Nov-04	1,016	595	143	278	27.4%						
Dec-04	93	60	6	27	29.0%	**2004**	6,892	4,604	497	1,791	**26.0%**

continued

Appendix C. Summary of White Sturgeon samples used in the generation of the BMR24 TAL30 model, 1999-2019. Samples limited to sturgeon 60-279 cm FL captured within the core assessment area of the lower Fraser River (see Table 2 and Figure 2).

Month	No. Scanned (All)	No. Released With Tag (Head)	No. Scanned, Not Tagged, Not Recaptured	No. Recaptured (Head Tag)	Mark Rate (%)	Year	No. Scanned (All)	No. Released With Tag (Head)	No. Scanned, Not Tagged, Not Recaptured	No. Recaptured (Head Tag)	Mark Rate (%)
Jan-05	26	20	0	5	19.2%						
Feb-05	208	165	0	43	20.7%						
Mar-05	272	208	1	63	23.2%						
Apr-05	824	565	20	239	29.0%						
May-05	446	267	23	156	35.0%						
Jun-05	710	417	16	277	39.0%						
Jul-05	701	432	19	250	35.7%						
Aug-05	1,451	714	141	596	41.1%						
Sep-05	1,784	732	414	638	35.8%						
Oct-05	2,050	928	321	801	39.1%						
Nov-05	1,054	410	313	331	31.4%						
Dec-05	272	127	90	55	20.2%	**2005**	9,798	4,985	1,358	3,454	**35.3%**
Jan-06	80	65	0	15	18.8%						
Feb-06	2	2	0	0	0.0%						
Mar-06	106	67	3	36	34.0%						
Apr-06	871	570	7	294	33.8%						
May-06	425	243	9	173	40.7%						
Jun-06	259	146	6	107	41.3%						
Jul-06	485	267	13	205	42.3%						
Aug-06	768	414	30	324	42.2%						
Sep-06	1,270	650	12	608	47.9%						
Oct-06	2,520	1,302	19	1,199	47.6%						
Nov-06	1,834	1,035	38	761	41.5%						
Dec-06	167	112	0	55	32.9%	**2006**	8,787	4,873	137	3,777	**43.0%**
Jan-07	54	40	0	14	25.9%						
Feb-07	113	74	0	39	34.5%						
Mar-07	540	343	2	195	36.1%						
Apr-07	593	356	7	230	38.8%						
May-07	314	144	3	167	53.2%						
Jun-07	450	214	1	235	52.2%						
Jul-07	807	356	4	447	55.4%						
Aug-07	1,421	582	10	829	58.3%						
Sep-07	2,523	1,125	28	1,370	54.3%						
Oct-07	2,232	1,051	14	1,167	52.3%						
Nov-07	1,184	588	11	585	49.4%						
Dec-07	42	27	0	15	35.7%	**2007**	10,273	4,900	80	5,293	**51.5%**
Jan-08	55	37	0	18	32.7%						
Feb-08	24	17	0	7	29.2%						
Mar-08	103	53	5	45	43.7%						
Apr-08	458	224	8	226	49.3%						
May-08	490	193	7	290	59.2%						
Jun-08	417	172	3	242	58.0%						
Jul-08	579	237	0	337	58.2%						
Aug-08	818	327	13	478	58.4%						
Sep-08	1,375	550	17	808	58.8%						
Oct-08	1,963	828	0	1,122	57.2%						
Nov-08	1,744	840	14	890	51.0%						
Dec-08	81	49	0	32	39.5%	**2008**	8,107	3,527	67	4,495	**55.4%**
Jan-09	21	12	0	9	42.9%						
Feb-09	88	60	0	28	31.8%						
Mar-09	141	77	0	64	45.4%						
Apr-09	517	246	7	264	51.1%						
May-09	312	95	1	216	69.2%						
Jun-09	312	98	5	209	67.0%						
Jul-09	407	161	4	242	59.5%						
Aug-09	1,018	349	15	654	64.2%						
Sep-09	1,748	620	17	1,111	63.6%						
Oct-09	2,039	813	26	1,200	58.9%						
Nov-09	1,234	565	18	651	52.8%						
Dec-09	139	57	15	67	48.2%	**2009**	7,976	3,153	108	4,715	**59.1%**

continued

Appendix C. Summary of White Sturgeon samples used in the generation of the BMR24 TAL30 model, 1999-2019. Samples limited to sturgeon 60-279 cm FL captured within the core assessment area of the lower Fraser River (see Table 2 and Figure 2).

Month	No. Scanned (All)	No. Released With Tag (Head)	No. Scanned, Not Tagged, Not Recaptured	No. Recaptured (Head Tag)	Mark Rate (%)	Year	No. Scanned (All)	No. Released With Tag (Head)	No. Scanned, Not Tagged, Not Recaptured	No. Recaptured (Head Tag)	Mark Rate (%)
Jan-10	259	150	0	109	42.1%						
Feb-10	169	95	0	74	43.8%						
Mar-10	220	90	4	126	57.3%						
Apr-10	606	271	6	329	54.3%						
May-10	383	141	3	239	62.4%						
Jun-10	387	127	3	257	66.4%						
Jul-10	467	213	4	250	53.5%						
Aug-10	728	212	2	514	70.6%						
Sep-10	1,360	423	17	920	67.6%						
Oct-10	2,743	1,089	23	1,631	59.5%						
Nov-10	1,159	526	12	621	53.6%						
Dec-10	307	181	3	123	40.1%	**2010**	8,788	3,518	77	5,193	**59.1%**
Jan-11	131	76	0	55	42.0%						
Feb-11	39	20	0	19	48.7%						
Mar-11	120	58	0	62	51.7%						
Apr-11	740	327	6	407	55.0%						
May-11	331	143	3	185	55.9%						
Jun-11	170	44	0	126	74.1%						
Jul-11	568	220	4	344	60.6%						
Aug-11	1,054	303	5	746	70.8%						
Sep-11	2,237	742	12	1,483	66.3%						
Oct-11	2,300	973	37	1,290	56.1%						
Nov-11	1,064	466	24	574	53.9%						
Dec-11	114	49	2	63	55.3%	**2011**	8,868	3,421	93	5,354	**60.4%**
Jan-12	60	28	0	32	53.3%						
Feb-12	48	21	0	27	56.3%						
Mar-12	171	74	0	97	56.7%						
Apr-12	447	181	4	262	58.6%						
May-12	354	156	1	197	55.6%						
Jun-12	229	76	1	152	66.4%						
Jul-12	713	302	5	406	56.9%						
Aug-12	1,003	345	10	648	64.6%						
Sep-12	1,646	662	11	973	59.1%						
Oct-12	2,703	1,123	31	1,549	57.3%						
Nov-12	1,002	369	9	624	62.3%						
Dec-12	304	139	1	164	53.9%	**2012**	8,680	3,476	73	5,131	**59.1%**
Jan-13	167	63	1	103	61.7%						
Feb-13	252	110	0	142	56.3%						
Mar-13	473	222	2	249	52.6%						
Apr-13	908	375	15	518	57.0%						
May-13	654	209	4	441	67.4%						
Jun-13	428	138	4	286	66.8%						
Jul-13	694	227	2	465	67.0%						
Aug-13	1,098	341	12	745	67.9%						
Sep-13	2,325	587	26	1,712	73.6%						
Oct-13	2,660	945	32	1,683	63.3%						
Nov-13	1,523	525	12	986	64.7%						
Dec-13	101	36	0	65	64.4%	**2013**	11,283	3,778	110	7,395	**65.5%**
Jan-14	122	46	1	75	61.5%						
Feb-14	80	36	0	44	55.0%						
Mar-14	454	175	0	279	61.5%						
Apr-14	846	327	6	513	60.6%						
May-14	473	125	5	343	72.5%						
Jun-14	438	112	5	321	73.3%						
Jul-14	768	227	8	533	69.4%						
Aug-14	1,049	165	108	776	74.0%						
Sep-14	1,118	98	137	883	79.0%						
Oct-14	1,974	519	127	1,328	67.3%						
Nov-14	913	258	52	603	66.0%						
Dec-14	206	65	23	118	57.3%	**2014**	8,441	2,153	472	5,816	**68.9%**

continued

Appendix C. Summary of White Sturgeon samples used in the generation of the BMR24 TAL30 model, 1999-2019. Samples limited to sturgeon 60-279 cm FL captured within the core assessment area of the lower Fraser River (see Table 2 and Figure 2).

Month	No. Scanned (All)	No. Released With Tag (Head)	No. Scanned, Not Tagged, Not Recaptured	No. Recaptured (Head Tag)	Mark Rate (%)	Year	No. Scanned (All)	No. Released With Tag (Head)	No. Scanned, Not Tagged, Not Recaptured	No. Recaptured (Head Tag)	Mark Rate (%)
Jan-15	388	110	40	238	61.3%						
Feb-15	269	125	11	133	49.4%						
Mar-15	330	93	7	230	69.7%						
Apr-15	731	245	11	475	65.0%						
May-15	541	170	4	367	67.8%						
Jun-15	363	93	5	265	73.0%						
Jul-15	808	226	6	576	71.3%						
Aug-15	1,236	288	11	937	75.8%						
Sep-15	2,286	587	39	1,660	72.6%						
Oct-15	2,558	814	50	1,694	66.2%						
Nov-15	1,000	262	16	722	72.2%						
Dec-15	273	100	2	171	62.6%	**2015**	10,783	3,113	202	7,468	**69.3%**
Jan-16	259	98	0	161	62.2%						
Feb-16	315	76	7	232	73.7%						
Mar-16	654	179	7	468	71.6%						
Apr-16	865	263	9	593	68.6%						
May-16	305	75	4	226	74.1%						
Jun-16	527	114	7	406	77.0%						
Jul-16	851	158	16	677	79.6%						
Aug-16	726	138	11	577	79.5%						
Sep-16	920	247	8	665	72.3%						
Oct-16	1,452	368	14	1,070	73.7%						
Nov-16	490	108	4	378	77.1%						
Dec-16	4	1	1	2	50.0%	**2016**	7,368	1,825	88	5,455	**74.0%**
Jan-17	75	23	0	52	69.3%						
Feb-17	121	14	0	107	88.4%						
Mar-17	170	38	0	132	77.6%						
Apr-17	346	120	2	224	64.7%						
May-17	174	29	4	141	81.0%						
Jun-17	252	48	1	203	80.6%						
Jul-17	422	89	1	332	78.7%						
Aug-17	838	167	20	651	77.7%						
Sep-17	1,663	335	4	1,324	79.6%						
Oct-17	1,596	343	7	1,246	78.1%						
Nov-17	444	83	2	359	80.9%						
Dec-17	109	43	0	66	60.6%	**2017**	6,210	1,332	41	4,837	**77.9%**
Jan-18	42	12	2	28	66.7%						
Feb-18	50	21	0	29	58.0%						
Mar-18	254	65	4	185	72.8%						
Apr-18	543	153	4	386	71.1%						
May-18	181	33	1	147	81.2%						
Jun-18	268	60	6	202	75.4%						
Jul-18	541	110	7	424	78.4%						
Aug-18	841	141	10	690	82.0%						
Sep-18	750	181	9	560	74.7%						
Oct-18	1,069	236	10	823	77.0%						
Nov-18	358	73	3	282	78.8%						
Dec-18	93	17	0	76	81.7%	**2018**	4,990	1,102	56	3,832	**76.8%**
Jan-19	49	20	0	29	59.2%						
Feb-19	35	0	0	35	100.0%						
Mar-19	329	62	1	266	80.9%						
Apr-19	763	245	16	502	65.8%						
May-19	436	119	8	309	70.9%						
Jun-19	357	84	5	268	75.1%						
Jul-19	672	154	3	515	76.6%						
Aug-19	915	181	6	728	79.6%						
Sep-19	1,514	294	12	1,208	79.8%						
Oct-19	1,124	296	11	817	72.7%						
Nov-19	579	141	4	434	75.0%						
Dec-19	59	27	0	32	54.2%	**2019**	6,832	1,623	66	5,143	**75.3%**
					Totals All Years	**1999-2019**	**152,614**	**64,944**	**5,777**	**81,874**	**53.6%**

Notes – Appendix C: This appendix presents the bulk of the samples used in the BMR24 models. These records do not account for fish that grew into or out of the 60-279 cm FL range during respective assessment periods, whereas the BM24 modelling does account for growth. Also, some of the observations presented in this table were excluded from the BM24 analyses, based either on their time at large or the gear type used in capture.

Appendix D. Numbers of unique (individual) tagged sturgeon sampled, presented by the number of times encountered (sampling events), within the general study area of the lower Fraser River, over 21 time periods from 1999-2019

Appendix D. Numbers of unique (individual) tagged sturgeon sampled, presented by the number of times encountered (sampling events), within the general study area of the lower Fraser River, over 21 time periods from 1999-2019. In 2019, 135 individual sturgeon were sampled three times, and one sturgeon was sampled 10 times. From 1999-2019, 2,497 individual sturgeon were sampled five times, and 35 sturgeon were sampled 15 times.

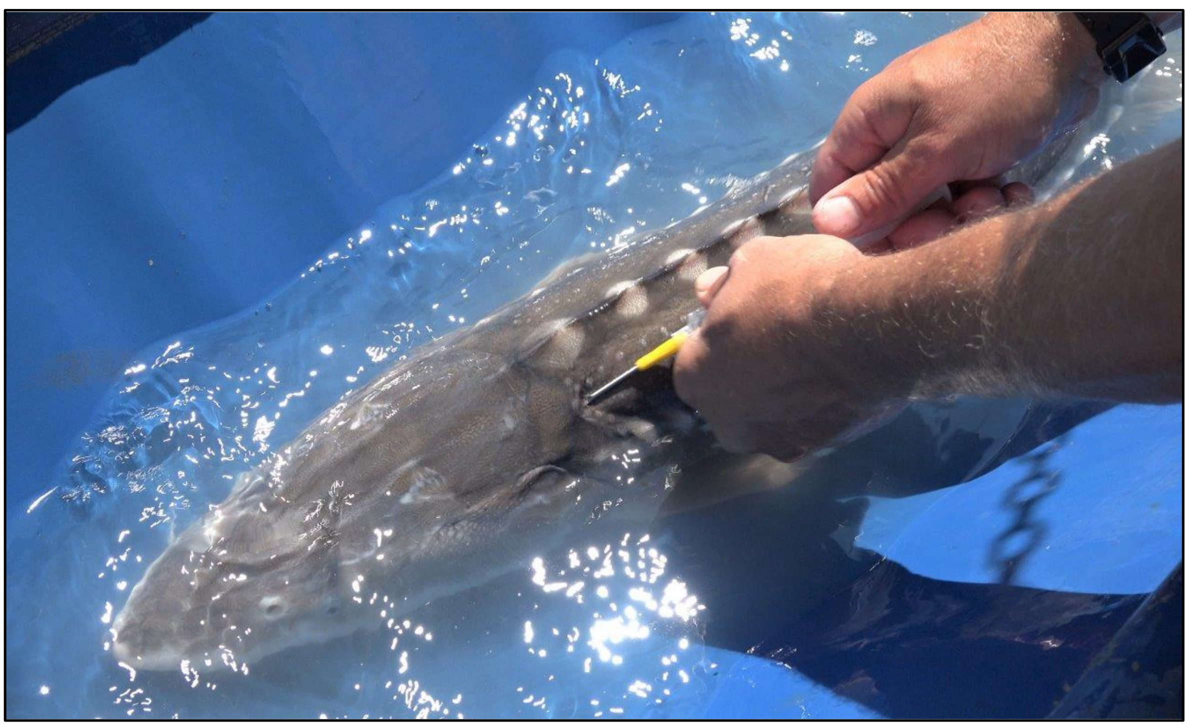
INDIVIDUAL STURGEON Number of Sampling Events	Numbers of Individual Sturgeon Sampled																					
	No. Years	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*
	Range of Years	2019	2018-2019	2017-2019	2016-2019	2015-2019	2014-2019	2013-2019	2012-2019	2011-2019	2010-2019	2009-2019	2008-2019	2007-2019	2006-2019	2005-2019	2004-2019	2003-2019	2002-2019	2001-2019	2000-2019	1999-2019
1		8,543	12,016	15,308	18,320	22,029	24,308	27,207	29,066	30,510	31,721	32,577	33,583	34,603	35,543	36,661	37,894	38,999	39,950	41,243	42,233	42,330
2		920	1,907	3,031	4,200	5,820	6,946	8,621	9,825	10,834	11,709	12,548	13,214	14,117	14,756	15,405	15,890	16,193	16,455	16,890	17,199	17,228
3		135	385	802	1,240	1,822	2,344	3,050	3,606	4,329	4,880	5,438	5,954	6,523	6,963	7,494	7,783	7,998	8,202	8,425	8,557	8,579
4		23	102	232	413	648	857	1,209	1,560	1,864	2,202	2,472	2,782	3,137	3,444	3,699	3,947	4,119	4,233	4,434	4,554	4,561
5		8	29	71	173	292	429	573	714	884	1,073	1,238	1,424	1,648	1,843	1,988	2,120	2,224	2,282	2,351	2,490	2,497
6		2	9	30	57	119	182	282	359	437	562	676	793	947	1,113	1,202	1,277	1,316	1,342	1,391	1,421	1,432
7		0	4	14	20	53	89	151	178	222	282	352	430	556	634	722	775	798	827	856	891	897
8		1	0	6	19	35	43	69	92	125	165	203	259	300	353	432	467	491	513	545	570	568
9		0	2	2	10	15	27	39	52	73	87	104	119	186	213	248	277	293	298	312	326	325
10		1	0	1	6	9	16	25	26	28	44	65	70	79	125	141	143	148	156	166	173	176
11			1	0	0	12	13	18	27	35	42	52	64	67	77	95	109	117	119	133	130	130
12			0	1	3	2	6	11	14	16	28	33	40	57	57	73	74	78	78	75	82	83
13			0	0	0	1	7	6	8	9	12	14	21	30	44	49	56	58	66	67	67	66
14			0	0	0	2	3	6	6	6	12	15	28	33	33	38	41	45	44	52	52	52
15			0	0	1	0	1	4	5	7	4	9	12	13	18	19	22	21	24	29	35	35
16			0	0	0	2	3	0	3	3	6	3	4	12	18	22	22	23	21	19	16	17
17			0	0	0	0	1	5	3	4	7	6	6	6	6	10	13	16	16	15	19	19
18			1	1	1	2	1	2	3	3	2	6	6	3	2	8	10	11	12	15	15	14
19							0	0	1	4	2	3	4	5	4	3	6	6	6	5	5	6
20							0	0	1	0	1	1	3	5	4	4	3	2	3	4	4	4
21							1	0	0	1	0	1	1	3	3	3	2	3	2	2	3	3
22								1	2	1	3	0	1	1	3	1	2	2	3	4	3	3
23								0	0	1	1	3	2	3	2	3	5	4	4	4	4	4
24								0	0	0	1	0	0	0	1	2	2	3	3	3	3	3
25								0	0	0	0	2	3	0	1	1	1	0	0	0	1	1
26								1	1	1	1	1	2	5	4	3	3	4	4	4	4	4
27															1	3	3	3	3	3	3	3

PHOTOGRAPHS

"White Sturgeon in wetted sling – ready for sampling" *photo by Tony Nootebos, Volunteer - Lower Fraser River White Sturgeon Monitoring and Assessment Program.*

"*Confirming PIT tag code prior to release*" *photo by Rob Dieleman, Volunteer - Lower Fraser River White Sturgeon Monitoring and Assessment Program.*

"PIT tag and tag applicator" *photo by Rick Hansen, Volunteer - Lower Fraser River White Sturgeon Monitoring and Assessment Program.*



"Applying a PIT tag in the head location" *photo by Rick Hansen, Volunteer - Lower Fraser River White Sturgeon Monitoring and Assessment Program.*

"Taking girth measurement" *photo by Rob Dieleman, Volunteer - Lower Fraser River White Sturgeon Monitoring and Assessment Program.*

"Taking fork length measurement" *photo by Rob Dieleman, Volunteer - Lower Fraser River White Sturgeon Monitoring and Assessment Program.*

"Lower Fraser River First Nations - White Sturgeon Monitoring and Assessment" *photo by Jim Rissling, Volunteer - Lower Fraser River White Sturgeon Monitoring and Assessment Program.*

"Sampled and released in good condition" *photo by Rick Hansen, Volunteer - Lower Fraser River White Sturgeon Monitoring and Assessment Program.*