MANUSCRIPT REPORT

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

BY

TROY C. NELSON[1]
DAVID ROBICHAUD[2]
TONY MOCHIZUKI[2]
JIM RISSLING[2]
KARL K. ENGLISH[2]
WILLIAM J. GAZEY[3]

FRASER RIVER STURGEON CONSERVATION SOCIETY

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[1] TCNelson Consulting, Sheldon, Queensland 4157 Australia (*troyaustralia@bigpond.com*)
[2] LGL Limited environmental research associates, 9768 Second Street, Sidney, BC V8L 3Y8
[3] W. J. Gazey Research, 1214 Camas Court, Victoria, BC V8X 4R1

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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 Fraser River White Sturgeon, raise public awareness of Fraser River White Sturgeon and their ecosystem, and produce reliable information regarding the status Fraser River White Sturgeon and their habitat. This report provides abundance and status assessments (as of January 2015) derived from the FRSCS' Lower Fraser River White Sturgeon Monitoring and Assessment Program. For additional information regarding the FRSCS, including status reports from previous years, visit the FRSCS web site (www.frasersturgeon.com).

Since April 2000, this 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 each of these sectors were trained to sample and tag White Sturgeon, and record and transfer data. By January 2016, volunteers had conducted 134,679 sturgeon sampling events, tagged and released 64,565 sturgeon, and documented 63,990 recapture events of tags applied by FRSCS volunteers.

A Bayesian mark-recapture model has been used since 2000 to provide reliable estimates of the abundance of White Sturgeon in the lower Fraser River core study area, by size/age group and location. The model includes information of tag distribution, seasonal mixing, and growth, and estimates of mortality, emigration, and observer error. Abundance estimates generated from the model were bounded by sturgeon samples 40-279 cm fork length (FL), a rolling data window of 24 months, and four spatial sampling regions, the combination of which comprised the core study area in the lower Fraser River. The model requires that any unique mark (for this study, a Passive Integrated Transponder or "PIT" tag) had to be encountered at least twice in a 24-month window to be deemed a recapture. Valid recaptures were thus defined as either of the following occurring within the defined 24-month sampling period: 1) an initial tag application/release and a subsequent recapture of that tag, or; 2) two (or more) separate recapture events for the same tag.

In 2015 we have commenced using the term "abundance" rather than "population" for these estimates. The change is based on our understanding that the estimates do not represent the entirety of the population, based on our knowledge regarding the known presence of sturgeon outside of the core study area used in the analyses, and the omission of both small (under 40 cm FL) and large (over 279 cm FL) sturgeon in those estimates. Total estimates could be considered a robust "index of abundance" that is generated from the same area, and for the same size groups of fish, that can then be compared between and among assessment years to detect trends within the total population.

Differences in reporting of previous estimates - Some of the model parameter values used to produce abundance estimates for the 2015 report were changed from values used to generate abundance estimates for previous years. Changes to the model resulted in the exclusion of fish outside the 40-279 cm FL size range. The bulk of sturgeon data used to produce estimates is from samples collected in the recreational fishery; over 90% of all data collected since 2000, and 96.9% of samples collected in 2014-15, were provided from the recreational fishery. A decision was made to exclude from the analyses the subsections of the population which are not reliably captured (too small or very large) using recreational fishing methods. In order to provide direct comparisons of current and historic estimates, all previous abundance estimates (after 1999) were recalculated using the new parameter values. Thus, there are some differences between values presented in this report and those from previous publications and reports.

Annual abundance estimates generated for this series of reports (2000-2015) represent the standing abundance of White Sturgeon within the lower Fraser River core study area at a point in time that is essentially the mid-point of the respective 24-month data windows. The 2015 abundance estimates presented in this summary report were generated from a 24-month data window that ran from January 2014 to December 2015; thus, the 2015 abundance estimates represent the standing abundance in January 2015. Although White Sturgeon are captured and sampled by FRSCS volunteers in locations outside the core study area (i.e., the entire North Arm and adjacent Middle Arm (north of Lulu Island) of the Fraser River, the lower Pitt River upstream of the Highway 7 Bridge, Pitt Lake, and Harrison Lake), samples used in the model to generate abundance estimates are those collected from the core study area only. The consistent and limited use of data collected from the core study area allows direct comparison of annual abundance estimates among years. Similarly, although we have lower confidence in abundance estimates generated for the 40-59 cm FL size group of White Sturgeon, we have included this size group in the total abundance estimate generated for 2015 in order to provide consistency and direct comparisons with previous estimates generated since 2001. A process has been initiated to produce abundance estimates from White Sturgeon samples greater than 59 cm FL for all assessment years since 2001; the generation and reporting of those estimates is expected to commence 2017.

As of January 2015, the mean abundance estimate for White Sturgeon from 40-279 cm FL in the lower Fraser River was 47,166 (95% CLs +/- 8.8% of the estimate). The average abundance of White Sturgeon in 2015 in the core study areas downstream of the Mission Bridge (sampling regions A and B) was 22,073 (46.8% of the total abundance estimate). In the core study areas upstream of the Mission Bridge (to Lady Franklin Rock near Yale; sampling regions C and D), the average abundance was 25,093 (53.2% of the total abundance estimate). The total 2015 abundance estimate for all sampling regions (A-D) is 3.1% higher than the respective estimate for the 2014 and 20.4% lower than the program's peak abundance estimate from 2003.

INTRODUCTION

Since the early 1900s, White Sturgeon (*Acipenser transmontanus*) has been identified as a species of concern in British Columbia (Lane 1991, Echols 1995). From 1995-1999, the BC government conducted studies to collect biological and ecological information on White Sturgeon throughout the Fraser River watershed (McKenzie 2000). However, information produced from that study regarding distribution and abundance in the lower Fraser River was viewed as preliminary due to inadequate sample sizes. Furthermore, the 1995-99 study did not include any assessments of White Sturgeon abundance or distribution downstream of the Mission Bridge, an extensive area that includes estuarine habitats and over 80 kilometers of Fraser River mainstem, plus additional sturgeon-bearing waters in the North Arm and Middle Arm of the Fraser River, and Pitt River/Pitt Lake (Figure 1). The lack of reliable abundance estimates and information on seasonal distribution and migration patterns for White Sturgeon in the lower Fraser River and estuary were acknowledged as serious information gaps by provincial fisheries managers (McKenzie 2000).

In response to these information needs, a proposal from the Fraser River Sturgeon Conservation Society (FRSCS), a not-for-profit registered society with a volunteer-based board of directors, was put forth to the British Columbia provincial government in November 1999 to develop more comprehensive and scientifically rigorous White Sturgeon abundance estimates for the lower Fraser River and estuary (Nelson et al. 1999). The two key components of this proposal were: 1) the ability of the FRSCS to successfully secure a large body of volunteer effort from the public to increase both the volume and geographic coverage of samples, and 2) the program's scientifically and technically rigorous study design. The Lower Fraser River White Sturgeon Monitoring and Assessment Program began in April 2000 and, as a result of continued success in achieving program objectives, has continued into 2016.

The primary objectives of the program are to:
1) obtain an estimate of abundance of sub adult and adult White Sturgeon in the lower Fraser River, with an emphasis on the section downstream of Hope (Figure 1);
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 science-based stewardship program has relied greatly on the in-kind efforts and contributions from angling guides, recreational, commercial, and Aboriginal fishermen, test fishery and enforcement personnel, students and academics, and various fishery monitors. Volunteers from each of these sectors were trained to perform all sturgeon sampling activities, and record, secure, and transfer data (to the field program manager).

History of Lower Fraser River White Sturgeon

White Sturgeon are part of the historical fabric of British Columbia. First Nations peoples of the Fraser River have songs and legends associated with the ancient fish, which was not only a welcome food source, but one that was available during the entire year; many other food sources, such as salmon (*Oncorhynchus*, sp.) and Pacific Eulachon (*Thaleichthys pacificus*), were seasonal. The Fraser River is named after Simon Fraser, the first European explorer to navigate the middle and lower mainstem of the river in 1808. In his journal, Simon Fraser wrote that during his first encounter with “friendly” Indians near Yale, he and his team of explorers were offered sturgeon meat - undoubtedly White Sturgeon (Lamb 1960).

Intensive commercial fishing pressure in the late 1800s to early 1900s reduced the abundance of White Sturgeon in the lower Fraser River to dangerously low levels (Semakula and Larkin 1968, Echols 1995). Since that time, lower Fraser River White Sturgeon have faced numerous obstacles on the path to population recovery (COSEWIC 2003; Hatfield et al. 2004); these include: 1) critical habitat degradation/reduction; 2) a reduction in overall food availability, including all salmon species and Pacific Eulachon (Hay et al. 1999); 3) harvest fisheries (commercial, recreational, First Nations) and illegal fishing/poaching; and 4) freshwater and estuarine pollution (Nelson and Levings 1995; Fraser River White Sturgeon Working Group 2005). In 1993 and 1994, an unexplained die-off of over 30 large, mature White Sturgeon occurred in the lower Fraser River over a relatively short period of time (McAdam 1995). The initial response to implement population protection and recovery initiatives came from Fraser River First Nations, who called on resource management agencies to eliminate all directed harvest of White Sturgeon in British Columbia.

In 1994, the province changed the recreational fishing regulations for sturgeon from limited retention to catch-and-release (non-retention), while all commercial fisheries (managed federally by Fisheries and Oceans Canada) were required to release all incidentally caught sturgeon. Also in 1994, First Nations imposed voluntary moratoriums on directed (Aboriginal) White Sturgeon fisheries and encouraged the live release of White Sturgeon intercepted as bycatch during Aboriginal salmon fisheries. Due to a lack of baseline information regarding White Sturgeon distribution and abundance in the Fraser River, a watershed-wide research and assessment program was initiated by the provincial government in 1995 (Echols 1995).

In 2003, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), in collaboration with the BC Ministry of Environment, concluded a review of the status of White Sturgeon in Canada. The COSEWIC review identified a total of six distinct stocks of White Sturgeon (all of which are in British Columbia) based on both geographic (watershed) separation and genetic distinction: 1) Kootenay River; 2) Columbia River; 3); Nechako River; 4) upper Fraser River; 5) middle Fraser River; and 6) lower Fraser River. Based on numerous criteria including abundance and stock status (for each individual stock), the COSEWIC review designated all six stocks of White Sturgeon in Canada as “Endangered” (COSEWIC 2003). The lower Fraser River population of White Sturgeon is the largest, by number, of any of the Canadian populations, and is the only Canadian population with direct access to the marine environment. Specific threats to the populations identified in the COSEWIC review included: 1) habitat degradation/loss as a result of dams, impoundments, channelization, dyking, and pollution; 2) population limiting as a result of illegal fishing and incidental catch; and 3) additional genetic, health, and ecological risks to wild populations from the developing commercial aquaculture industry (COSEWIC 2003; Hatfield et al. 2004).

FIELD AND ANALYTICAL METHODS

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, including recreational fishing boats, angling guide boats, First Nations and commercial fishing boats, enforcement (patrol) boats, and test fishery vessels. The sampling and tagging of at least one sturgeon was required to fulfill the training requirements; in most cases several sturgeon were captured and tagged during training exercises. Volunteers were trained to complete a standard sampling data sheet (Appendix A), scan captured sturgeon for the presence of a PIT tag, record all tag recapture data (from any PIT tag or external tag), apply new PIT tags, take fork length (FL) and girth measurements, revive and release sturgeon, and secure and transfer data.

Sturgeon capture, handling, and sampling procedures, designed to minimize stress and injury, were developed in partnership with provincial fishery managers, and volunteers were trained to apply those procedures when handling live sturgeon in the field. Volunteers who captured sturgeon by angling were asked to use adequate fishing equipment (strong rods and reels, line test of at least 100-pound breaking strength), and to sample all sturgeon over 1.5 m FL in the water without lifting the fish from the water. Juvenile and sub-adult sturgeon (less than 1.5 m in length) were placed in a custom "sturgeon sling" (much like a stretcher) that contained water and supported the fish being sampled. For commercial and First Nations net fishermen involved with the program, emphasis was placed on exercising extreme care when extricating sturgeon from gill nets (including the cutting of net, if needed), and efficient sampling practices to ensure that captured sturgeon were returned to the water as quickly as possible. From 2000-2005, some First Nations fishermen, in cooperation with FRSCS Lower Fraser River First Nations White Sturgeon Stewardship Program, placed captured sturgeon in floating enclosures (provided by the FRSCS) anchored in close proximity to the fishing locations. Program personnel were responsible for removing and sampling sturgeon from the enclosures on a daily basis.

Documentation of Capture Location

The core study area was divided into four sampling regions (two in the tidal section of the river below the Mission Bridge, and two upstream (Figure 1). Separate abundance estimates were produced by sampling region. A simple mapping system was established to assist volunteers document capture locations to the nearest 0.5 river kilometer (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 level (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) were established (Table 1). Zone boundaries were established based mainly on geographical elements (such as channel intersections, bridge crossings, and tributary confluences). Each zone comprised a unique set of rkms, and was unique to a specific sampling region (Table 2). Zones were used in the abundance model to redistribute available tagged sturgeon for capture for the purpose of abundance size estimates (see Abundance Estimation). The core study area used to produce abundance estimates was established in 2000; in order to provide direct comparisons between annual estimates, only data from this core study area were used in the analytical model (Figure 2).

Tagging

PIT (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 and BIO12.A.02 (both 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 sterilization purposes. Hypodermic needles, used to apply the tags, were also kept in small jars that contained ethyl alcohol.

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, has been used by sturgeon researchers in both Oregon and Washington, and measured tag retention has been close to 100% (Tom Rien, Oregon Dept. of Fish and Game, pers. comm.). Previous sturgeon tagging studies in the Fraser River watershed had applied PIT tags in body locations other than the head location (e.g., the dorso-lateral area or body cavity). Sturgeon recaptured during this study that had a PIT tag present in an area of the body other than the head location received an additional 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 the hand-held model MPR (distributed by Biomark Inc.) and the AVID Power Tracker (AVID Canada distributed by PETIDCO, Calgary, Alberta). The 125 kHz 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 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. The readers were also used to scan PIT tags prior to tag application (so that the tag number could be recorded), and, once inserted, to confirm the active status and number of the applied tag.

Tag Recoveries

An essential element of the abundance model used in this program was the positive identification and documentation of both tagged and non-tagged sturgeon in the sample. 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, and elsewhere have applied both PIT and various types of external tags to 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 outside this program were entered into the core program database, and in many cases original release data were obtained from respective research programs.

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 beneath the pectoral fins at a point just posterior to the insertion point of the pectoral fins.

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 captures (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 behavior, were scanned and measured, but released without a tag.

Data Management

Volunteers were trained to secure data sheets at the end of each sampling day. The original data 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 regulatory authority (BC Ministry of Environment), typically in February, as per the partnership and program permitting conditions set forth by that authority.

Abundance Estimation

The tagging program and lower Fraser White Sturgeon population have the following characteristics that demarcate the scope of the abundance estimation methodology and limitations of the estimates:

1) Sturgeon smaller than 40 cm FL and greater than 279 cm FL were not captured consistently (less than 2% of sampled sturgeon).

2) Since the histogram of lengths of sturgeon at release and recapture are similar (Nelson et al. 2004), size selectivity of the gears (net and angling) should not unduly bias abundance estimates pooled over size groups and gear (Seber 1982).

3) Sturgeon can grow over the life of the study into the size groups of interest (growth recruitment).

4) While sturgeon can move among watersheds (e.g., Fraser and Columbia rivers), tag recoveries indicate that this behavior is rare (in the past 12 years there have been six documented recoveries of sturgeon in the lower Fraser River that possessed tags applied in the Columbia River). Similarly, in-river movement upstream of Yale (Lady Franklin Rock) into the upper Fraser Canyon and/or upstream of Hells Gate is very rare (one documented occurrence). Tag recaptures from this study and results of a recent acoustic telemetry study indicate that some White Sturgeon move from the lower Fraser River into large lakes (Pitt and Harrison lakes) and marine environments that are outside the core study area. PIT tag data indicate that a very high proportion of these fish have returned to or migrated through the general study area at some point within each year, and results of the telemetry study indicate that 100% of acoustic tagged sturgeon (released within the general study area) that migrated to and/or seaward of the outer Fraser estuary returned within weeks or months to the general study area (Robichaud et al., in prep.).

5) Marked (PIT tagged) sturgeon can move to or remain in sections of the Fraser River where the chance of recapturing a marked fish will reflect the different concentrations of marked fish.

6) Because of periodic limitations in the availability of tags, approximately 5% of unmarked sturgeon encountered to date have been inspected for the presence of a tag, but released unmarked; thus, the encounter history of unmarked sturgeon is unknown.

7) Although varying by season, sampling tends to be continuous over time rather than episodic.

8) The number of recaptured marks is sparse on any given day or area.

In order to address these characteristics, we adapted a Bayesian mark-recapture model for closed populations (Gazey and Staley 1986) to accommodate growth, movement, mortality of marked sturgeon, non-detection of marks, and sparse recaptures on any given day or area. Detailed data assembly procedures and mathematical description of the mark-recapture model are provided in Nelson et al. (2004). In the text that follows we present a brief overview of the methodology: The abundance estimates were bounded by 40 to 279 cm FL, a rolling data window of two years (e.g., the 2015 estimate consists of data extracted from January 2014 to December 2015), and four spatial sampling regions (see Figure 1). 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.

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. We assumed von Bertalanffy growth (Fabens 1965; Table 3). Growth parameters were estimated from the mark-recapture data (length-at-release, length-at-recapture, and time-at-large). The estimated growth parameters 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.

Tagged sturgeon available for capture in a zone and day were based on the movement, removals, and an annual instantaneous mortality rate of 0.1. The number of recaptures in a zone and day were expanded by a non-detection rate of 1%. The estimated number of sturgeon sampled, marks available, and recaptures in each zone were summed into the associated sampling region (see Table 2). Note that the stratification of zones within a region influenced the distribution of available marks. Posterior distributions of abundance levels were generated assuming non-informative improper prior uniform distributions of abundance for the four sampling regions and a multinomial likelihood (sampling distribution) for the recapture of tagged sturgeon. Justification and sensitivity with respect to abundance levels from the assumed mortality and non-detection rates are further discussed below. The major assumptions required to estimate abundance are:

1) Abundance in the core study area does not change substantially within each two-year estimation period. Mortality of marked sturgeon must be specified. Sturgeon that are recruited into the size group of interest by growth can be excluded through calculation of a size criterion. Movement of sturgeon within the core study area is fully determined by the history of recaptured PIT tags (marks).

2) All sturgeon in a stratum (day and sampling region), whether marked or unmarked, have the same probability of being caught.

3) Sturgeon do not lose their marks over the period of the study.

4) All marks are reported when sturgeon are recaptured and scanned. If marks are not detected then the non-reporting rate must be specified.

The total abundance estimate for the core study area was obtained by summing the regional estimates. The confidence interval for the total abundance estimate was calculated by invoking a normal distribution under the central limit theorem with a variance equal to the sum of the variances for the sampling regions.

Abundance estimates were also made by 20-cm (FL) size intervals. The lack of recaptures for some of the size intervals in some of the sampling regions (A and D in particular) required the combination of all regions to generate reasonable estimates. This lack of stratification resulted in bias in the estimation of abundance (distribution of marks and size of sturgeon were not homogeneous over the study area). Also, some size categories (in particular, the 40–59 cm FL interval) still yielded highly skewed posterior distributions generated by sparse recaptures. The mean point estimate becomes unstable under these circumstances. In order to control bias and stability, the modes of the posterior distributions by size category were standardized (scaled such that they added up) to the Bayesian mean estimate for the core study area.

RESULTS

Sampling Effort for Mark-Recapture Abundance Estimates

From October 1999 through December 2015, volunteers for the Lower Fraser River White Sturgeon Monitoring and Assessment Program performed a total of 134,679 unique sturgeon sampling events that included the inspection of sturgeon for the presence of a PIT tag (Appendix B). Of this total sample, 64,565 sturgeon were tagged with a PIT tag (in the head location) and released. The total sample also included 63,990 recapture events, 52.4% of which were repeat recapture events (recaptures of tagged sturgeon that had been previously recaptured). In addition, the total sample includes 6,101 sturgeon that were sampled (examined for the presence of a PIT tag and measured), but were either: 1) not tagged due to a shortage of available PIT tags, 2) not released (i.e., a mortality) or, 3) not tagged prior to release (due to either poor physical condition of the fish; the bulk of these cases were for sturgeon removed from gill nets; Appendix B).

The annual number of White Sturgeon sampled was fairly consistent from 2000-2015 (average of 8,389 sturgeon examined per year, with a range from 4,385 to 12,118 (Appendix B). The relative monthly contribution to respective annual total samples has remained relatively consistent throughout all years (2000-2015; Figure 3). The variability of sample size between months is the result of three main factors: variability in fishing effort applied, catch-per-effort, and sturgeon catchability.

Three sources provided over 98% of samples over the term of the program through 2015: angling (90.5%), Albion Test Fishery (4.2%), and First Nations gill net (4.1%). An additional 0.6% of the total sample was provided by dedicated sampling efforts (tangle net) associated with the FRSCS Lower Fraser River Juvenile White Sturgeon Habitat Program (Glova et al. 2008), and approximately 0.6% of samples were provided by a mix of commercial net fisheries, enforcement (illegal retention/poaching) incidents, and both sourced and unsourced mortalities. All tag numbers of recaptured mortalities recovered were excluded from subsequent abundance analyses.

Recaptures of Tagged Sturgeon

Recapture data of tagged sturgeon provided positive determination of both direction and distance of movements for individual sturgeon, and in many cases multiple recapture events over time (years) provided patterns of movement and migration. Movements in relation to both size category and time of year (season) were explored and incorporated in the analytical processes of the program, as were the spatial distribution of samples over the course of the program. Recaptures of tagged sturgeon during this study confirm that movements and migrations occur throughout the entire lower Fraser general study area. Recapture locations of individuals vary and may be several kilometers apart, even over relatively short time periods. Many individual tagged sturgeon have been recaptured and sampled numerous times.

Mark Rates

An illustration of the annual numbers of tags applied, and reported number of tag recaptures within the core study area, is provided in Figure 4. The proportion of recaptures recorded in a given 24-month sampling period (i.e., the mark rate) has steadily increased each year over the 16 years of monitoring (Figure 4). Conversely, 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 the proportion was only 31% for the 2015 estimate (samples from 2014 and 2015; Figure 4).

In 2015, FRSCS volunteers applied 3,530 PIT tags and recaptured 7,620 tagged sturgeon (Appendix B). The mark rate for the general study area in 2015 varied from a low of 45.4% in February to a high of 73.1% in August; the overall mark rate for 2015 was 67.0% (Appendix B, Figure 4). Mark rates for sub-locations within the general study area differed from the respective overall mark rate; for example, the mark rate for sturgeon sampled from the Harrison River in 2015 was 85.5% (Figure 5).

Monthly variation in White Sturgeon mark rates was evident for each of the assessment years (Figure 6). As expected, the lines for each assessment year tended to be consistently higher than in the previous year, given the steadily increasing mark rate in the population (Figure 6). However, patterns of changing mark rates have emerged within years that appear to be influenced by season/month (Figure 6). The most striking of these is the lower mark rates observed during winter months (December through February); most annual winter mark rates after 2004 are approximately the August rate for a given year (Figure 6).

Abundance Estimates

Abundance estimates for each sampling region have been produced annually since 2001 (the first year that a complete set of 24 months of sampling data was available; Table 4). The abundance estimates for the first two years of the study were similar (close to 50,000) followed in 2003 by an increase to 59,220 (Figure 7). Since 2003, abundance estimates generated by the program indicate a general population decrease, with significant decreases in 2005 and again in 2009 (Table 4; Figure 7). The 2015 abundance estimate (47,166) is 20.4% lower than the 2003 estimate (significant decrease, as indicated by non-overlapping confidence bounds).

As noted previously, total annual abundance estimates were produced by summing regional abundance estimates. Because the core study area included four sampling regions (A-D; see Figure 1), two of which were located downstream of the Mission Bridge (sampling regions A and B), the program was able to produce the first-ever abundance estimates of White Sturgeon for the estuarine or tidal section of the lower Fraser River. In 2014-2015 (assessment year 2015), the average abundance of White Sturgeon within the core study area downstream of the Mission Bridge (sampling regions A and B) was 22,073 (46.8% of the total abundance estimate; Table 5, Figure 8). The average abundance of White Sturgeon within the core study area in 2015 upstream of the Mission Bridge (to Lady Franklin Rock near Yale; sampling regions C and D) was 25,093 (53.2% of the total abundance estimate; Table 5, Figure 8).

Posterior modes by 20-cm (FL) size group were scaled to the overall mean estimate for the core study area. Mean abundance estimates of White Sturgeon in the lower Fraser River, by 20-cm (FL) size group in 2015 are presented in Table 6 and illustrated in Figure 9). White Sturgeon abundance estimates and associated 95% HPD intervals, from 2004-2015, by 20-cm (FL) size category, are illustrated in Figure 10.

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. A comparison of average annual growth rates of White Sturgeon sampled from 2001-2015, by 20-cm (FL) size groups, suggests that annual growth rates for most size groups were greater before 2005 than after 2005 (Figure 11). Average annual growth for all size groups from 60-180 cm FL from 2005-2009 (3.8 cm/year) represented a 32% decrease from respective previous growth rates from 2001-2004 (5.6 cm/year). Average annual growth for all size groups increased in 2010 (4.7 cm/year) and 2012 (5.5 cm/year) before declining to an average of 4.2 cm/year in 2015. The combined average growth rate for 2010-2015 (4.6 cm/year) represented a 21.1% increase over the 2005-2009 average rate, and was 17.2% below the pre-2005 rate (Figure 12).

DISCUSSION

Study Design and Sustained Sampling Effort

The products of this long-term, stewardship-led monitoring and assessment program are both novel and useful. They include the first-ever estimates of the abundance of White Sturgeon in the Fraser River downstream of the Mission Bridge, and highly precise, reliable estimates of the abundance of White Sturgeon (that reside within the core study area) on an annual basis. Over time, we have been able to detect trends not only for the total population, but also for size categories within the population, which in turn provides insights regarding where to focus research and conservation efforts toward population recovery. The sustained level of sampling effort provided by volunteers over the 16 years of study has been an achievement in its own right. Since 2000, the delivery of continuous support for ongoing data collection, analysis, and annual reporting has been the result of strong program leadership and scientific oversight provided by the FRSCS. The FRSCS has organized a science and technical committee that is composed mostly of fishery science professionals. As a result of this available in-house expertise, FRSCS activities are guided by rigorous study designs and scientific principles.

In April 2000, the start-up program had 15 volunteer anglers,, a single test fishery operator, 10 PIT tag readers, and 2000 PIT tags. By June of 2000 those volunteers had applied tags to over 1400 White Sturgeon, and additional funds were secured by the FRSCS to purchase additional tags. By the end of 2000, volunteers had sampled 4844 sturgeon, applied 4386 PIT tags to live sturgeon, and recorded 218 recapture events. The estimated in-kind dollar value of volunteer contributions in 2000 was approximately $290,000 (labor and equipment provided to the program). Given the success of the initial year of the program, funding was secured to expand in 2001 with the purchase of an additional 10 PIT tag readers and 5000 more PIT tags. Additional anglers and angling guides were trained to sample and tag White Sturgeon, as were select First Nations fishermen, commercial salmon fishermen, enforcement officers, and post-secondary fishery students. The program continued to set and meet its goals and objectives, and by the end of 2005 had over 100 trained volunteers and approximately 60 PIT tag readers in circulation. By the end of 2015 over 120 trained volunteers had successfully delivered 134,679 sturgeon samples, tagged and released 64,565 sturgeon, and documented 63,990 recapture events of tags applied by FRSCS volunteers (Appendix B). In 2015 the value of in-kind contributions from volunteers was approximately $1.3M.

The abundance estimates presented in this report are estimates of the number of sturgeon in the 40-279 cm FL size range that resided within the core study area over during the 24-month data window. Although our study annually samples and applies tags to several sturgeon smaller than 40 cm FL and larger than 279 cm FL, the numbers of recaptured tags within those size ranges (within the 24-month assessment period) is typically too low for those samples to be included in our abundance analyses. In addition, some of the 40-279 cm FL lower Fraser River origin White Sturgeon may be located in marine and freshwater areas outside the core study area during the assessment period; thus, our estimates do not represent the entire population of lower Fraser River White Sturgeon. Other methods, such as Stock Reduction Analysis (Whitlock and McAllister 2009) and multi-year mark-recapture models, have been used to estimate both the trends and annual abundance for the entire population of lower Fraser White Sturgeon. These methods and associated assumptions have been the focus of on-going assessments under a separate project funded by the Habitat Conservation Trust Foundation (English and Bychkov 2013; Gazey and English 2014).

Freshwater areas accessible to lower Fraser River White Sturgeon that are outside the sampling regions used to generate abundance assessments include: the entire North Arm and adjacent

Middle Arm south of Lulu Island; the Pitt River (upstream of the Highway 7 bridge) and Pitt Lake; and Harrison Lake. All marine waters westward of the entrances of the Fraser River at Garry Point and Canoe Pass (Figure 1) are outside the sampling regions used to generate abundance assessments. 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/estuaries on southern and western Vancouver Island. Acoustic telemetry data have shown that a portion of lower Fraser River White Sturgeon may migrate to outer estuarine or marine areas beyond the shoreline front of the Fraser River, particularly during summer months (Robichaud et al., in prep.). Water and sturgeon fin ray/tissue samples from Puget Sound, the lower Fraser River, and major tributaries to the Fraser River are being collected for microchemistry and genetic analyses that could help determine the origin of individual fish, and thus further our understanding of the life history of White Sturgeon present in Puget Sound and other marine waters adjacent to the Fraser River.

Recaptures of tagged sturgeon during this study have confirmed that movements and migrations occur throughout the lower Fraser River general study area. Many of the sturgeon tagged during this program have been recaptured and sampled multiple times by program volunteers. Approximately 50.1% (28,204 individual fish) of all sturgeon tagged through December 2015 have been sampled multiple times since the beginning of the study (for example, 3,506 individual sturgeon have been sampled five times, and 29 sturgeon have been sampled 15 times); one individual sturgeon has been sampled 22 times since 2000. Documented capture rates are produced from data submitted by FRSCS volunteers and do not reflect actual levels of capture from all sources (non-retention recreational fishery, commercial net fisheries, First Nations fisheries, illegal fisheries). Multiple capture/sampling events of individual tagged sturgeon (by FRSCS volunteers) sturgeon can occur on an annual basis; individual fish have been captured and sampled up to six times in a single year.

Abundance Estimates

In 2015 we have commenced using the term “abundance” rather than “population” for these estimates. The change is based on our understanding that the estimates do not represent the entirety of the population, based on our knowledge regarding the known presence of sturgeon outside of the core study area used in the analyses, and the omission of both small (under 40 cm FL) and large (over 279 cm FL) sturgeon in those estimates. Total estimates could be considered a robust “index of abundance” that is generated from the same area, and for the same size groups of fish, that can then be compared between and among assessment years to detect trends within the total population.

Abundance estimates presented in this paper are estimates of the mean number of White Sturgeon in the 40-279 cm FL size range that resided in the core study area over each two-year period. The large number of sturgeon tagged and examined for tags each year has resulted in very precise estimates (95% confidence intervals ±4.6-8.8 of the mean; see Table 4). The precision and accuracy of these estimates depended upon the input of point estimates for growth, movement, mortality, and undetected marks.

Differences in reporting of previous estimates - Some of the model parameter values used to produce abundance estimates for the 2015 report were changed from values used to generate abundance estimates for previous years. Changes to the model resulted in the exclusion of fish outside the 40-279 cm FL size range. The bulk of sturgeon data used to produce estimates is from samples collected in the recreational fishery; over 90% of all data collected since 2000, and 96.9% of samples collected in 2014-15, were provided from the recreational fishery. A decision was made to exclude from the analyses the subsections of the population which are not reliably captured (too small or very large) using recreational fishing methods. In order to provide direct comparisons of current and historic estimates, all previous abundance estimates (after 1999) were recalculated using the new parameter values. Thus, there are some differences between values presented in this report and those from previous publications and reports.

Nelson et al. (2004) demonstrated through sensitivity analysis that uncertainty associated with growth, mortality, and undetected marks had small impact on the precision of the abundance estimates primarily because of high mark rates (over 70% during some months in 2014 and 2015; Figure 6) and sampling rates (greater than 40% of the total abundance estimate sampled in most of the 24-month sampling windows). However, the response of abundance estimates to alternative movement proportions between and within river zones (Table 1) has not been evaluated. It is likely that the capture probabilities for sturgeon are heterogeneous within a sampling region, or a combination of regions) because of spatial aggregation (Walters et al. 2005; Whitlock and McAllister 2009) in contradiction to the homogeneous capture probability (multinomial distribution for the recapture of tagged sturgeon) assumed by our abundance estimation model. On the other hand, the impact of heterogeneity on precision is moderated as the magnitude of the mark rate increases. Again, note that the total annual mark rate has increased to approximately 67% over the history of the program (Figure 4). The implication is that the precision reported here should be viewed as minimal (i.e., confidence bounds are larger than stated), particularly for the older abundance estimates (2001-2003).

In addition, Nelson et al. (2004) concluded through sensitivity analysis that the most important factors for the accuracy of abundance estimates were mortality and undetected mark rates. The mortality rate of 0.1 is consistent with that used by Beamesderfer et al. (1995) for lower Columbia River White Sturgeon. For the lower Fraser River, Walters et al. (2005) reported that mortality ranged between 0.07 and 0.14, dependent on spatial aggregation. Whitlock and McAllister (2009) estimated total mortality from 0.08 to 0.10 depending on size class. Application of the catch-curve methodology described by Nelson et al. (2004) to the size-category estimates greater than 79 cm FL (see Figure 10) resulted in mortality estimates over the range 0.09 – 0.13. We estimate the rate of undetected marks is small because of frequent checking of tag reader operation and the high level of competence of trained volunteers. Nelson et al. (2008) opined that a 2% rate for undetected marks was extreme.

Mark Rate Variation

The differences in observed annual mark rates among seasons suggest a moderate rate of population segregation between winter (low mark rates) and summer-fall (high mark rates). The low number of preferred overwintering habitats may attract sturgeon from a wide area where the fish migrate and forage during the balance of the year; it is probable that sampling effort (i.e., tag applications) is not occurring, or occurring at a low rate, at some of those outer foraging areas, and thus fish from those areas have a lower probability of possessing a tag. When sturgeon from all areas concentrate in overwintering locations, the result is lower mark rates during that season.

Immigration and Emigration

It has been well documented that White Sturgeon are capable of extensive migrations both within and among major watersheds (the Sacramento River watershed in California, the Columbia River watershed of Oregon and Washington, and the Fraser River watershed in British Columbia). Tagging studies have confirmed sturgeon movements among these watersheds (Stockley 1981, Galbreath 1985, DeVore et al. 1995). Substantial tagging programs for White Sturgeon in the lower Columbia River have produced recaptures from several coastal bays and inlets of Oregon and Washington, including Puget Sound (located in Washington, directly south of the Fraser River mouth; Galbreath 1985). As of December 2015, there has been only one confirmed report of a White Sturgeon recaptured in the lower Columbia River that was originally tagged (by FRSCS volunteers) in the lower Fraser River; this sturgeon was originally tagged in the lower Fraser River in 2005-06, and was recaptured in the lower Columbia River near Astoria, Oregon, in 2012 (Tucker Jones, Oregon Department. of Fish and Wildlife, Clackamas, Oregon, pers. comm.). Since 2000 there have been eight confirmed recaptures of individual White Sturgeon in the lower Fraser River that were originally tagged and released in the lower Columbia River. Six of these recaptured sturgeon from the Columbia River were originally tagged and released near Astoria, Oregon; the other two were originally captured in the Columbia River below Bonneville Dam prior to being transported upstream and released in The Dalles Reservoir (approximately 340 km upstream from the river entrance; Tucker Jones, Oregon Department. of Fish and Wildlife, Clackamas, Oregon, pers. comm.).

Analytical techniques that use laser ablation sampling to determine levels of strontium in fin rays of Fraser River White Sturgeon (Vienott et al. 1999) suggest a low frequency of marine migrations for lower Fraser White Sturgeon. However, this work (Vienott et al. 1999) also suggests limited juvenile rearing in brackish waters (the Fraser estuary). Preliminary investigations to examine White Sturgeon dispersal behavior found that non-natal estuaries along the West Coast may contain White Sturgeon originating from each of the three known populations with ocean access (Drauch Schreier et al. 2012).

Since there will always be a portion of 40-279 cm FL lower Fraser River origin White Sturgeon located in marine and freshwater areas outside the core study area; the abundance estimates presented in this report do not represent the entire population. Freshwater areas accessible to lower Fraser River White Sturgeon that are outside the core study area include: the entire North Arm and adjacent Middle Arm (north of Lulu Island), the lower Pitt River upstream of the Highway 7 Bridge, Pitt Lake, and Harrison Lake (Figure 2). All marine waters westward of the entrance points of the Fraser River at Garry Point and Canoe Pass (Figure 1) are outside the study area.

Substantial 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. Although the origin (natal river) of White Sturgeon observed in marine waters adjacent to the Fraser 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 migrate to marine areas beyond the Fraser estuary, particularly during summer months (Robichaud et al., in prep.).

Abundance Trends

The abundance of White Sturgeon in the lower Fraser River has declined since 2003 (Table 4, Figure 7). A comparison of annual abundance estimates by 20-cm (FL) size group for 2004-2015 (Figure 10) indicates that since 2004 significant reductions have occurred in the smallest size groups (40-59 cm FL, 60-79 cm FL, and 80-99 cm FL), which suggests reduced levels of juvenile recruitment into the population (at those sizes) as compared to respective recruitment levels before 2004. By 2011, increases in abundance occurred in most size categories above 140 cm FL; this suggests survival and growth of individual sturgeon over time into larger size categories. Survival of sturgeon into and beyond the 160 cm FL size category has likely been positively influenced by regulations and broad-based support for non-retention of White Sturgeon in all British Columbia fisheries since 1994.

Our confidence in abundance estimates for the 40-59 cm FL size group is low (Figure 10). Although sample sizes are sufficient to produce estimates with confidence, the catchability of fish below 60 cm FL may have changed since the beginning of the program in 2000 due to changes in angling techniques (hook and bait size) and perhaps other factors. Small juvenile sturgeon (less than 60 cm) are not likely sampled by recreational angling gear (which has provided 90% of all data collected since 2000, and 96.9% of samples collected in 2014-15) as effectively as larger fish (i.e., they are not well-represented in the angled sample). Either these smaller fish are not as susceptible to angling (i.e., hook size or bait preference), or they are simply in low abundance within the population, or both; estimates provide no information on the mechanism. Regardless of the reason, the low numbers of small juvenile sturgeon observed in the samples means that our ability to detect change in the abundance of sturgeon from the smallest size groups is much less than sturgeon from the larger size groups. Although we have lower confidence in abundance estimates generated for the 40-59 cm FL size group of White Sturgeon, we have included this size group in the total abundance estimate generated for 2015 in order to provide consistency and direct comparisons with previous estimates generated since 2001. A process has been initiated to produce abundance estimates from White Sturgeon samples greater than 59 cm FL for all assessment years since 2001; the generation and reporting of those estimates is expected to commence 2017.

Confidence increases for estimates of sturgeon over 60 cm FL; the abundance of juvenile sturgeon (60-99 cm FL) in the lower Fraser River decreased 66.7% between 2004 and 2015 (Figure 10). Since 2004, declining recruitment and/or survival of fish from the smaller size groups has produced a trend toward decreasing average abundance in higher size groups (juvenile and sub-mature sturgeon), over time. Since 2012, the most notable decreases in abundance have been of sturgeon from 60-79 cm FL, 80-99 cm FL, and 100-119 cm FL (Figure 10). Since 2013, it appears that the declining abundance of fish from these smaller size groups has resulted in a decrease in the abundance of fish in the 120-139 cm FL group in 2015 (Figure 10). The estimated abundance or White Sturgeon over 140 cm FL has been generally trending upward since 2010. This is in part a result of fishery restrictions and retention closures enacted in 1994, but also survival and growth of fish from smaller size groups into larger size groups.

Estimates of abundance for juvenile (40-99 cm FL), sub-mature adult (100-159 cm FL), and mature adult (160-279 cm FL) White Sturgeon, from 2004-2015, are provided in Figure 13. The pooling of data for these three size groups, as opposed to 20-cm (FL) size groups (presented in Figure 10), provided a sufficient number of recaptures to use a spatially stratified approach that addresses observed differences in the mark rates and size of sturgeon caught in the four sampling regions. Since 2004, there has been a general decline in the abundance of White Sturgeon less than 100 cm FL (Figure 13). In 2015 there was a slight stabilization in the number of juvenile sturgeon less than 100 cm FL, and while this is not significant, it is encouraging (Figure 13). The abundance of sturgeon 100-159 cm FL was rather stable from 2004-2013, and may have declined in 2014 and 2015. Survival and growth of sub-mature fish (below 160 cm FL) has resulted in increases in the abundance of fish over 140 cm FL (Figure 10). The increase in the number of mature fish over 160 cm FL since 2011 (Figures 10 and 13) suggests the possibility of increased recruitment in future years.

The proportion of White Sturgeon sampled by angling less than 100 cm FL has decreased continually and significantly since the beginning of the program. Figure 14 presents the annual numbers of measured sturgeon captured by angling only, and the respective proportion of samples less than 100 cm FL. In 2001, 52.6% of sturgeon captured by angling were less than 100 cm FL; by 2015 this proportion had dropped to 23.5% (Figure 14). As mentioned, the decrease in the proportion of fish under 100 cm FL may be in part a result of a general change in angling gear (i.e., hook size), angling techniques, and fishing locations, as anglers seek out and target larger fish.

The Albion Test Fishery, a gillnet test fishery conducted at rkm 58 in the lower Fraser River (Figure 15), has provided additional suggestion that there has been a general decrease in overall abundance, and a declining proportion of White Sturgeon (less than 100 cm FL) over the course of the program. In 2000, 64.7% of all sturgeon captured in the Albion Test Fishery were less than 100 cm FL (Figure 15). Comparatively, by 2015, the number of sturgeon less than 100 cm FL in the Albion sample had dropped to 18.5% (Figure 15).

Comparisons of the total annual catch of White Sturgeon by the Albion Test Fishery from 2000-2015 are presented in Figure 16 (total annual catch) and Figure 17 (annual catch by month). The data used for Figures 16 and 17 are from Fisheries and Oceans Canada and are for assessment sets only. The total annual catch of White Sturgeon in the Albion Test Fishery has declined since 2006 (Figure 16). Although there has been variation in net size and deployment schedule for this test fishery over the years, the relative effort has been similar between years, and has been conducted in the same location (see “Albion Test Fishery,” Figure 1). The distinct pattern between years for monthly catch of White Sturgeon from the Albion Test Fishery since 2000 (Figure 17) suggests that sturgeon are moving past this point in the river during April and May, and again during September through November. The spring movement of White Sturgeon past the Albion Test Fishery site is likely explained by in-river foraging migrations from upstream overwintering locations into the lower river and estuary to feed on spawning Pacific Eulachon, and perhaps upstream movements to spring and early-summer spawning locations. Fall movements 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.

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TABLES

Table 1. Sampling zones used for abundance estimation of White Sturgeon, 2014-2015.

Zone	River Km	From	To
S*	0-25	Georgia Strait	Eastern Annacis Island
3, 5**	26-56.5 & P0-P4	Eastern Annacis Island	Albion Ferry Crossing
6, 7***	57-78	Albion Ferry Crossing	Mission Bridge
8	79-93	Mission 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 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)

Table 2. Sampling regions used for abundance estimates of White Sturgeon, 2014-2015.

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

Table 3. Parameter estimates for linear and non-linear sturgeon growth models from 2008-2009.

Parameter	Estimate	Std Error	R^2
Linear			
Daily Increment	8.212E-03	4.100E-04	0.158
Non-Linear von-Bertalanffy			
L_∞	532.6	15.8	
g	2.076E-05	1.003E-06	

Table 4. Abundance estimates of 40-279 cm FL White Sturgeon in sampling regions A-D of the lower Fraser River, 2001-2015.

Sampling Period	Assessment Year	Abundance Estimate	95% HPD[1] Low	95% HPD[1] High	Bounds as % of Abund. Est.	CV (%)[2]	Annual % Change
2000-2001	2001	48,950	45,461	52,439	7.1%	3.6%	
2001-2002	2002	50,081	46,486	53,676	7.2%	3.7%	2.3%
2002-2003	2003	59,220	54,403	64,037	8.1%	4.2%	18.2%
2003-2004	2004	55,579	52,108	59,050	6.2%	3.2%	-6.1%
2004-2005	2005	49,841	47,516	52,166	4.7%	2.4%	-10.3%
2005-2006	2006	48,064	45,671	50,457	5.0%	2.5%	-3.6%
2006-2007	2007	45,650	43,463	47,837	4.8%	2.4%	-5.0%
2007-2008	2008	45,212	42,893	47,531	5.1%	2.6%	-1.0%
2008-2009	2009	43,341	40,842	45,840	5.8%	2.9%	-4.1%
2009-2010	2010	45,091	42,126	48,056	6.6%	3.4%	4.0%
2010-2011	2011	44,361	42,371	46,351	4.5%	2.3%	-1.6%
2011-2012	2012	48,521	46,130	50,912	4.9%	2.5%	9.4%
2012-2013	2013	49,229	46,969	51,489	4.6%	2.3%	1.5%
2013-2014	2014	45,734	43,590	47,878	4.7%	2.4%	-7.1%
2014-2015	2015	47,166	43,033	51,299	8.8%	4.5%	3.1%

[1] HPD - Highest Probability Density (percent)

[2] CV - Coefficient of Variation (percent)

Table 5. Mean abundance estimates of 40-279 cm FL White Sturgeon in the lower Fraser River, by sampling region, 2015.

	Sampling Region From	Sampling Region To	Zone Codes[1]	Mean	Mode	95% HPD[2] Low	95% HPD[2] High	Std. Dev
A	Georgia Strait	East Annacis Island	S	7,769	6,939	4,523	11,620	1,911
B	East Annacis Island	Mission Bridge	3, 5, 6, 7	14,304	14,247	13,080	15,567	633
C	Mission Bridge	Hwy 1 Bridge (Hope)	8, 10, 12, 13	23,008	22,950	22,185	23,775	625
D	Hwy 1 Bridge (Hope)	Yale	14	2,085	2,078	1,944	2,232	73
			Total	47,166		43,033	51,299	2,109

[1] See Table 1

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

Table 6. Abundance estimates for White Sturgeon in sampling regions A-D of the lower Fraser River, by 20-cm (FL) size group, 2015. Scaled MLE values are calculated from the MLE of each size bin scaled to the mean total estimate (see Table 4). An illustration of these estimates and their associated HPD values is presented in Figure 5.

Size Class (cm)	Scaled MLE[1]	Percent	HPD[2] (percent) Low	HPD[2] (percent) High	CV[3] (%)
40-59	2,671	5.7	1983.5	3759.5	16.4
60-79	3,199	6.8	2869.6	3595.9	5.7
80-99	5,324	11.3	4936.1	5760.0	3.9
100-119	6,721	14.3	6270.2	7217.4	3.6
120-139	6,525	13.8	6077.4	7018.5	3.6
140-159	6,925	14.7	6465.5	7445.7	3.6
160-179	5,218	11.1	4816.5	5675.8	4.2
180-199	4,160	8.8	3739.9	4657.8	5.6
200-219	2,997	6.4	2563.3	3539.8	8.2
220-239	2,038	4.3	1610.0	2635.3	12.6
240-259	1,149	2.4	800.7	1751.6	20.3
260-279	239	0.5	118.4	677.4	47.7
Total	47,166	100.0			4.5

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

FIGURES

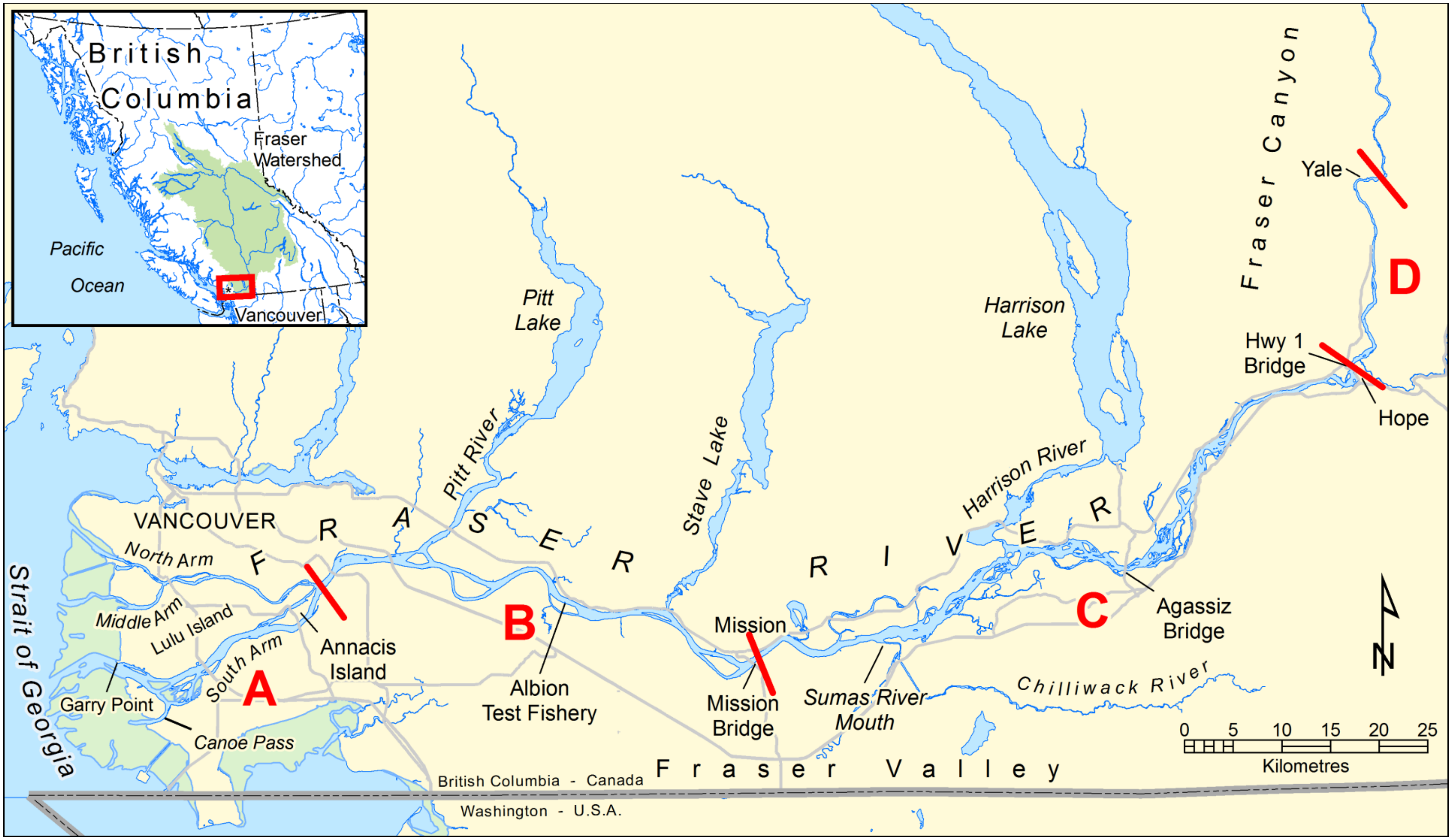

Figure 1. Illustration of the general study area and the location of the four sampling regions (A, B, C, and D) used to generate abundance estimates of White Sturgeon presented in this report. Each sampling region is made up of individual sampling zones used in the analytical model to stratify tag release 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.

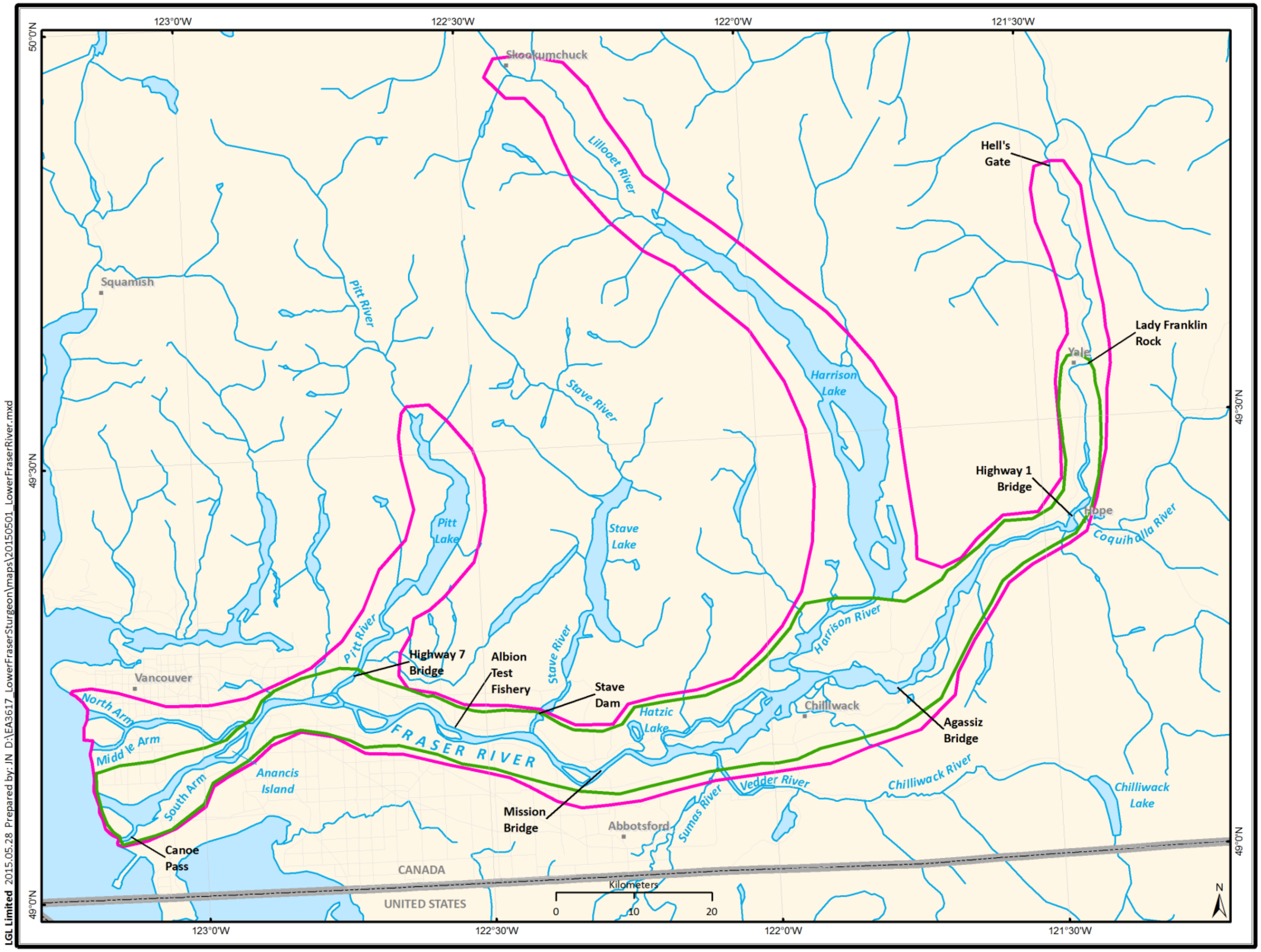

Figure 2. Comparison of the core study area (area within green line) used to produce White Sturgeon abundance estimates (comprised of sampling regions A-D; see Figure 1 and Table 2) with the general study area (area within red line), which is the area of known White Sturgeon distribution in the lower Fraser River watershed downstream of Hell's Gate.

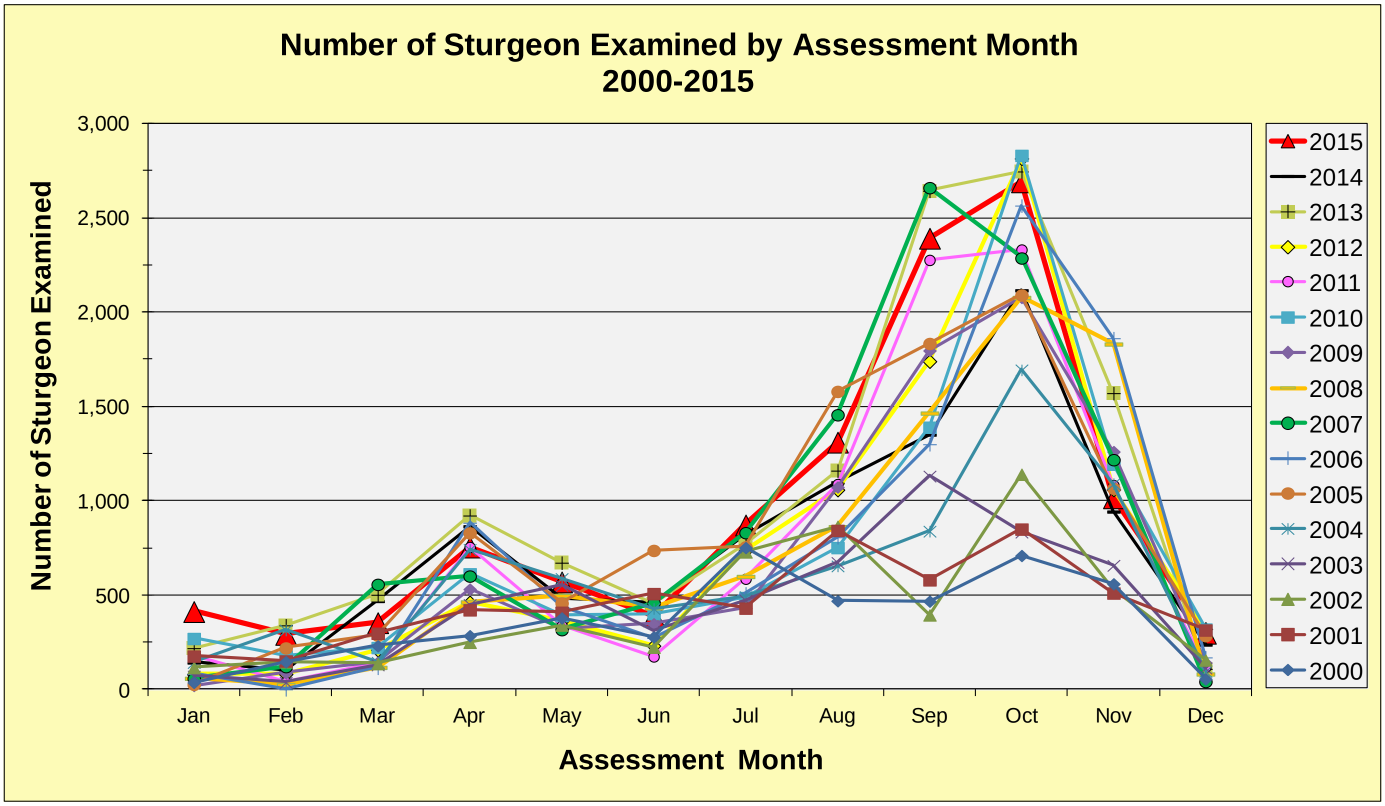

Figure 3. Number of sturgeon examined for the presence of a PIT tag, by month, 2000-2015.

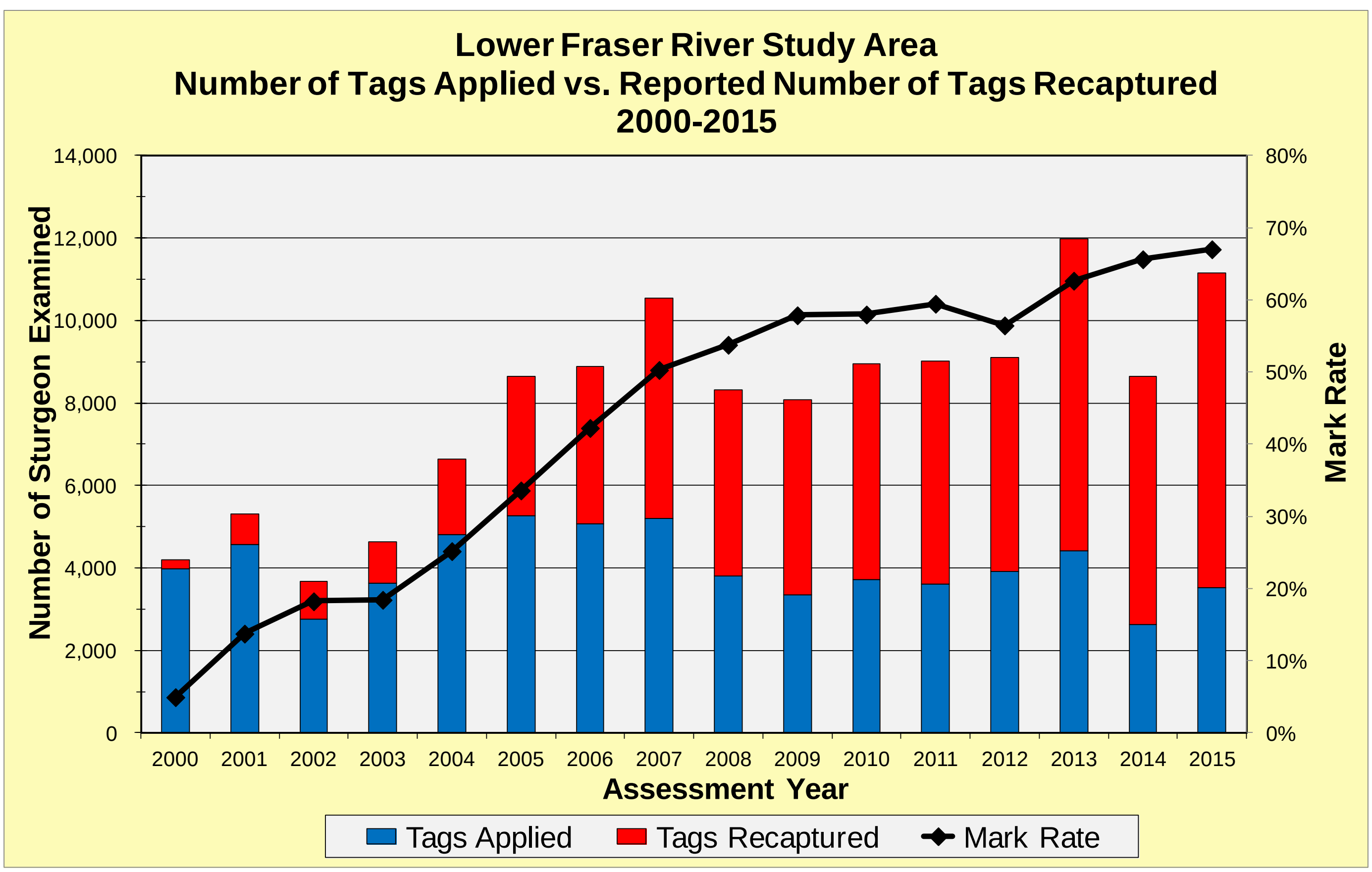

Figure 4. Number of tags applied and reported number of tags recaptured, and the annual mark rate, by assessment year, 2000-2015.

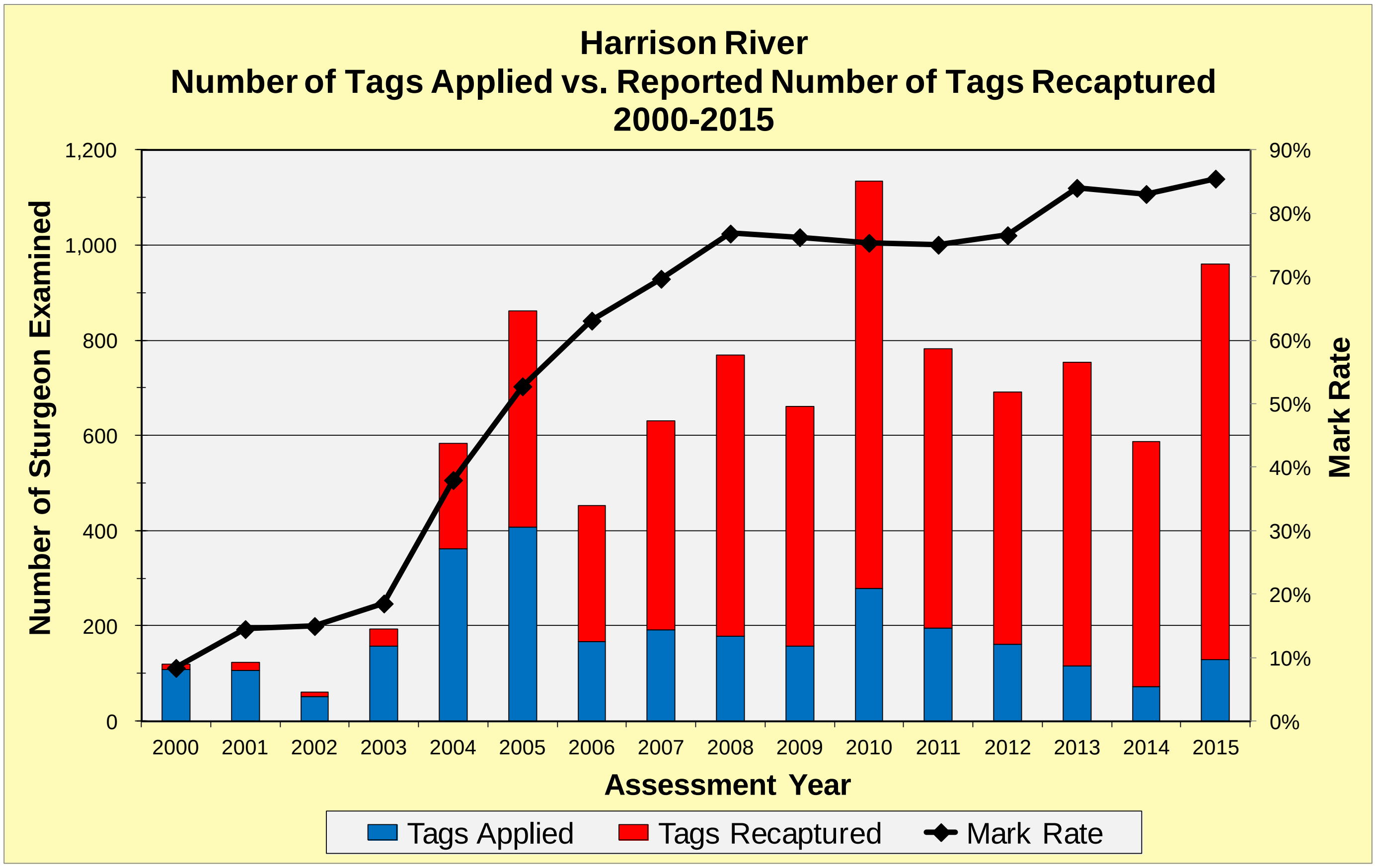

Figure 5. Number of tags applied and reported number of tags recaptured, and the annual mark rate, by assessment year, in the Harrison River, 2000-2015.

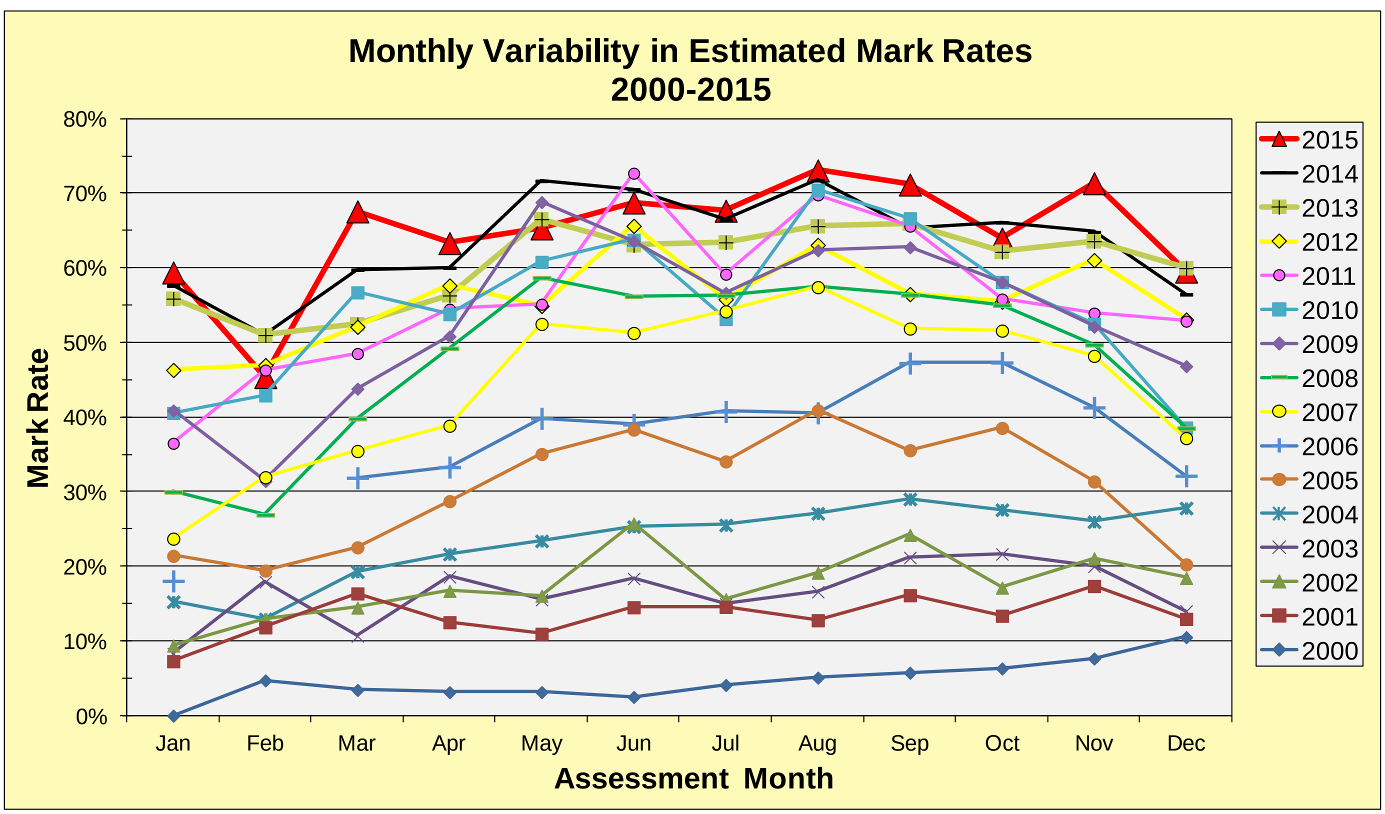

Figure 6. Monthly variability in estimated mark rates for White Sturgeon, 2000-2015.

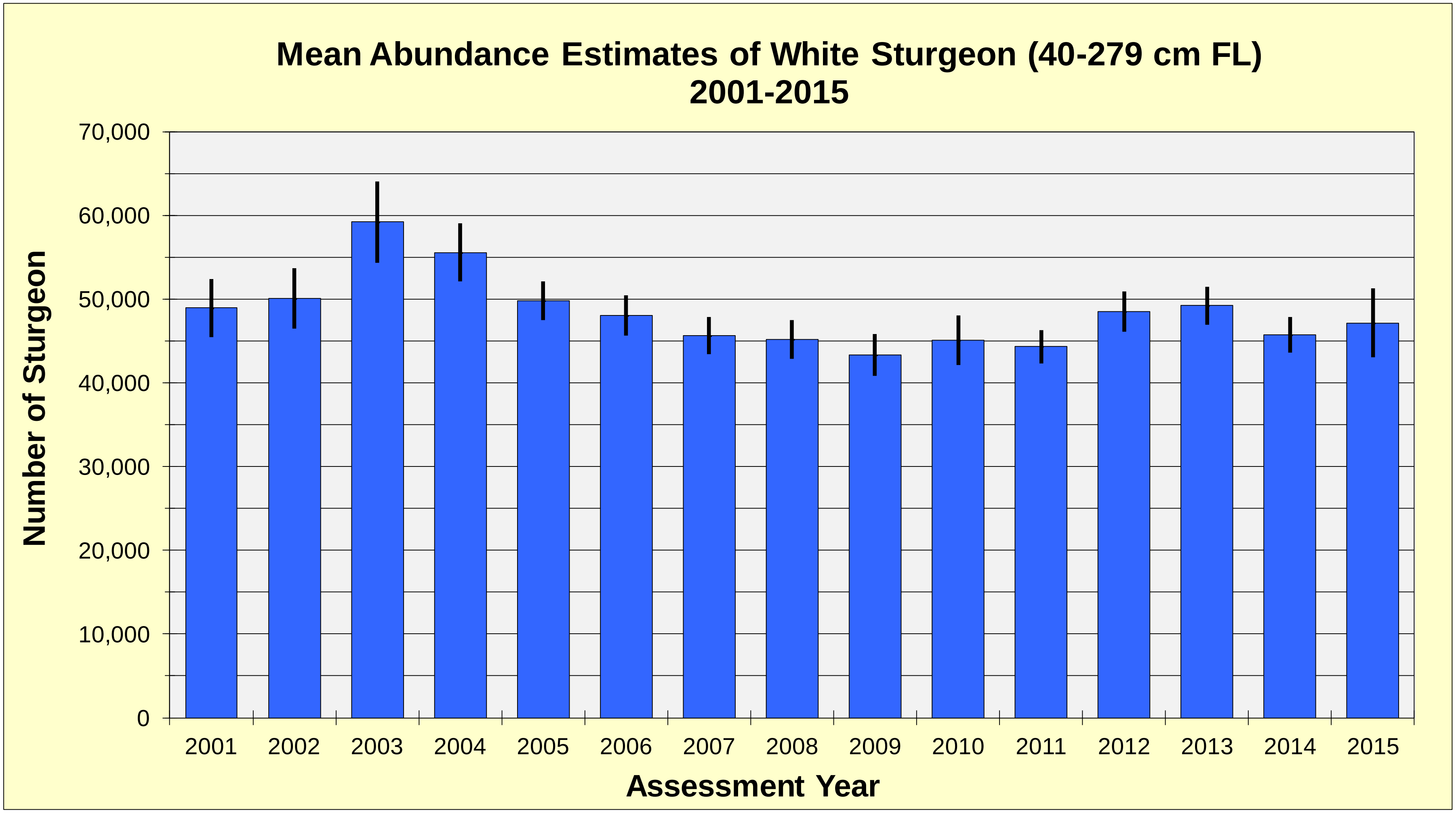

Figure 7. Comparison of mean annual abundance estimates of 40-279 cm FL White Sturgeon in sampling regions A-D of the lower Fraser River, 2001-2015. Confidence ranges show the 95% Highest Probability Density. All sampling regions are combined for this analysis. The 2015 abundance estimate is 20.4% lower than the peak abundance estimate generated for 2003.

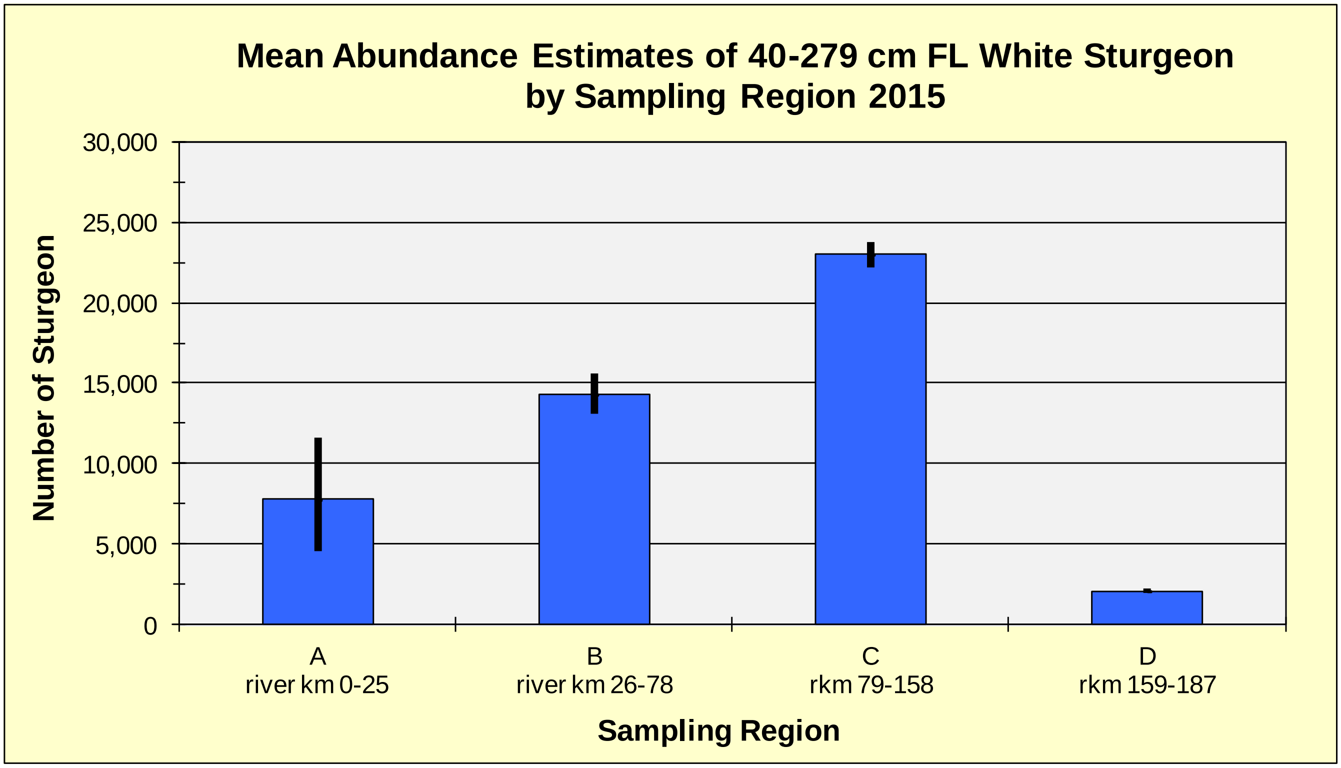

Figure 8. Mean abundance estimates of 40-279 cm FL White Sturgeon in the lower Fraser River, by sampling region, 2015 (see Table 4). Ranges show the 95% Highest Probability Density. Sturgeon movement and migration within the study area will result in a proportional redistribution of these mean abundance estimates, by season.

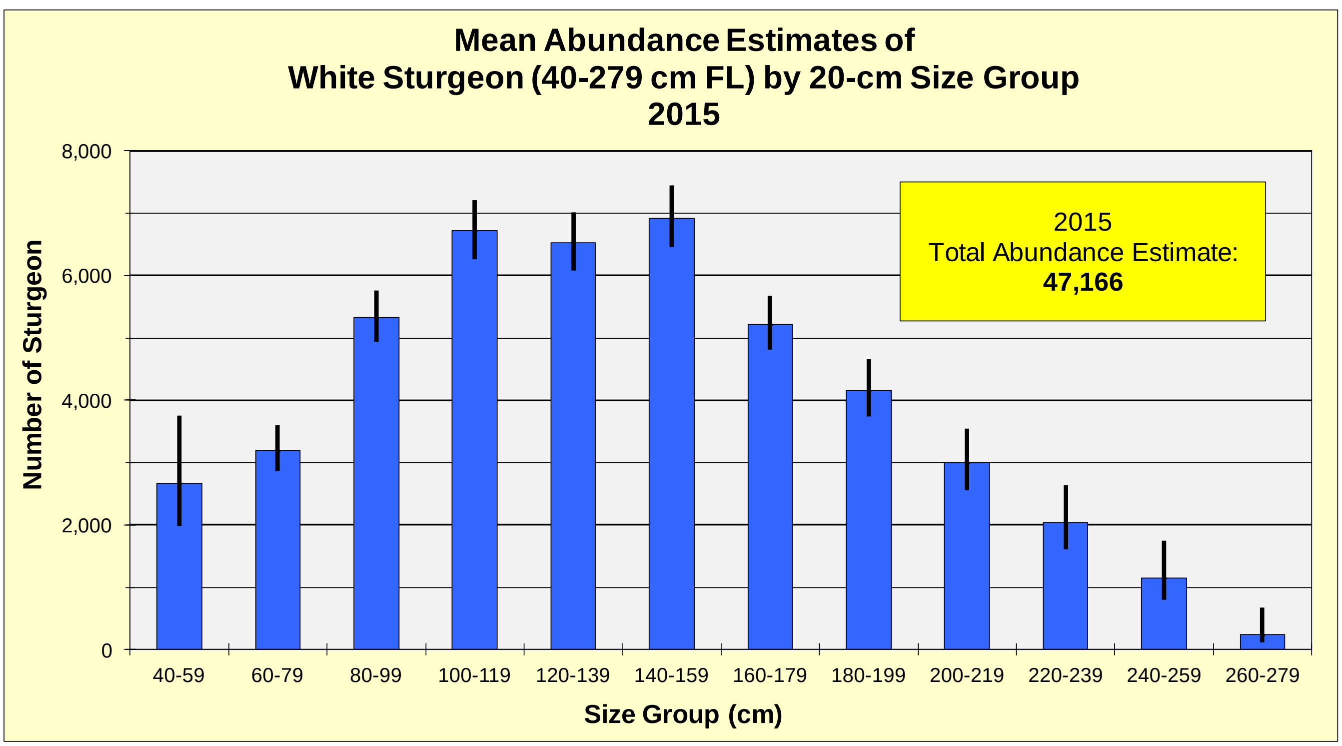

Figure 9. Mean abundance estimates of White Sturgeon in the lower Fraser River, by 20-cm (FL) size group, 2015. Ranges show the 95% Highest Probability Density. Relative abundances are scaled to the annual total estimated abundance of 40-279 cm sturgeon in sampling regions A-D (see Table 2 and Figure 1). All sampling regions are combined for this analysis.

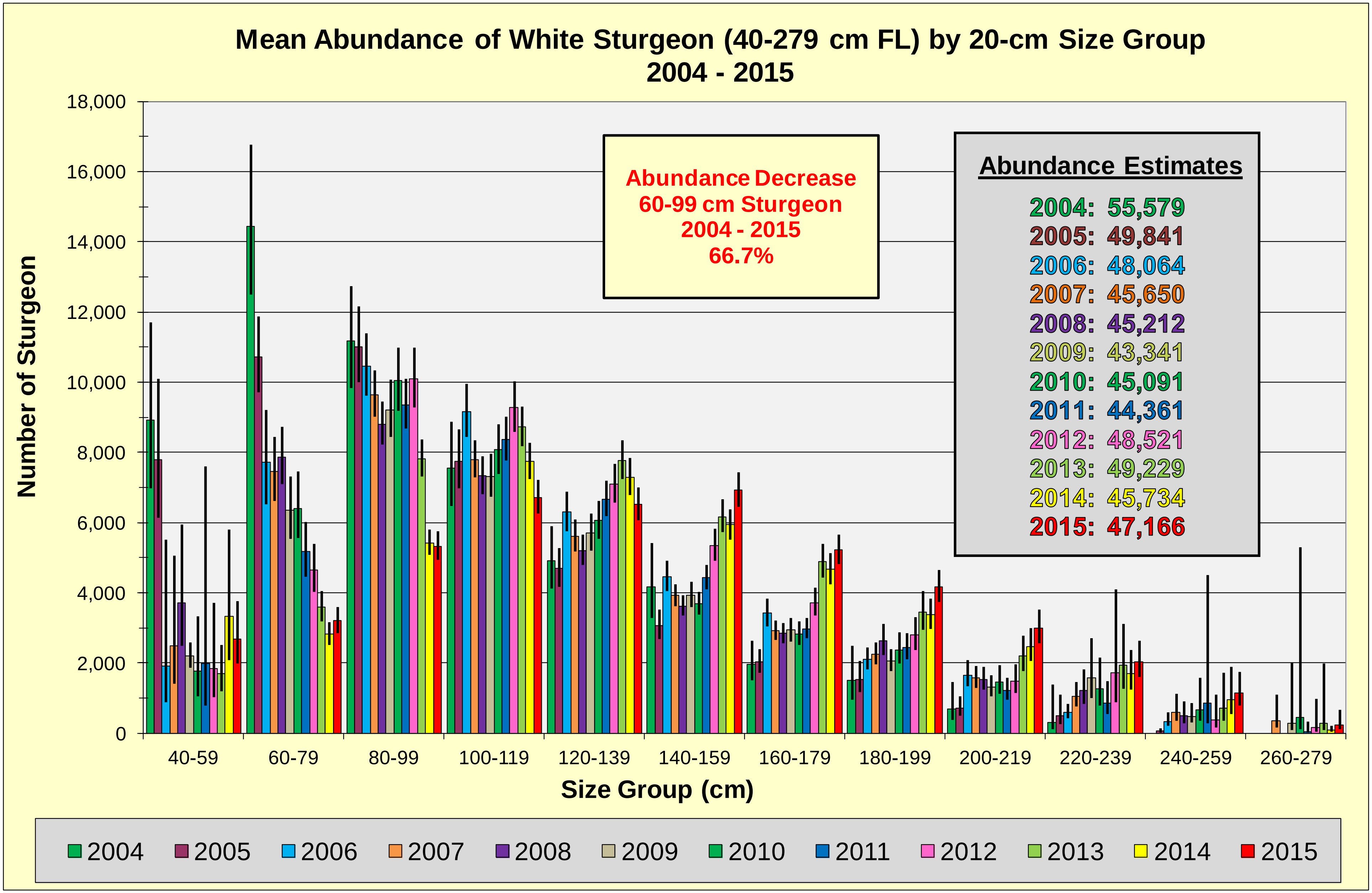

Figure 10. Comparison of mean abundance estimates of White Sturgeon in the lower Fraser River, by 20-cm (FL) size group, for assessment years 2004 through 2015. Confidence ranges show the 95% Highest Probability Density. Within-year values are scaled to the annual total estimated abundance of 40-279 cm sturgeon in sampling regions A-D (see Table 2 and Figure 1). The abundance of juvenile sturgeon (60-99 cm FL) in the lower Fraser River decreased 66.7% between 2004 and 2015.

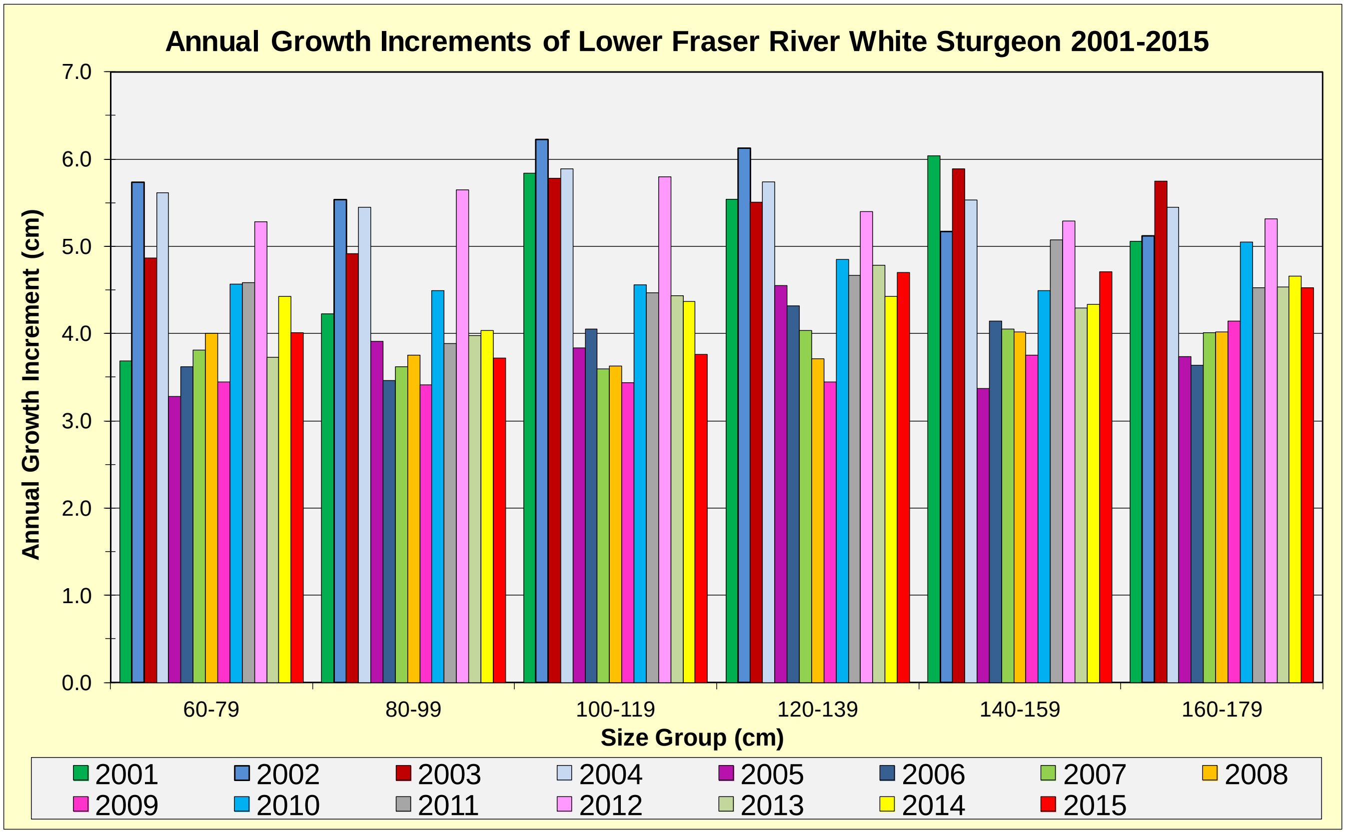

Figure 11. Comparison of average annual growth increments (cm) of White Sturgeon, by 20-cm (FL) size group, 2001-2015. Annual growth was determined from measurements obtained from individual tagged sturgeon that were subsequently recaptured.

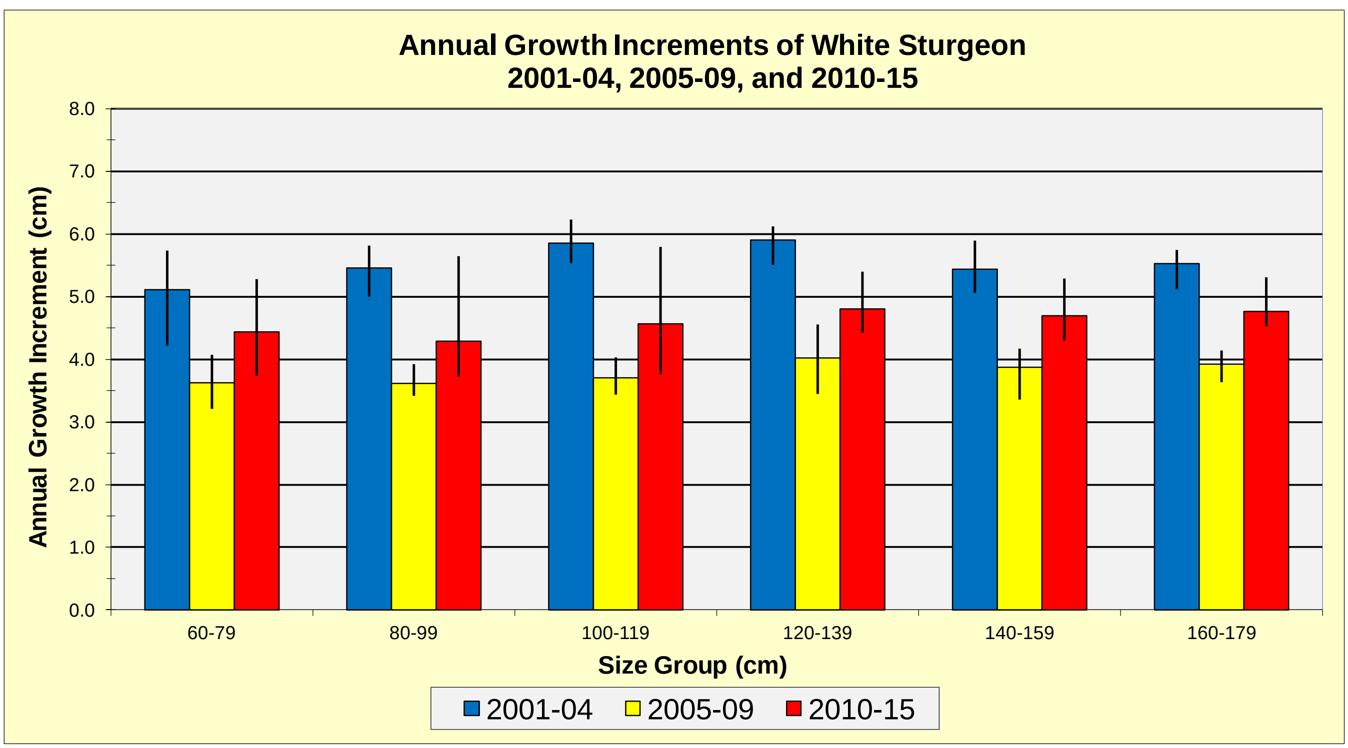

Figure 12. Comparison of average annual growth increments of White Sturgeon (cm), by 20-cm (FL) size group, in the lower Fraser River during three time periods: 2001-04 (averaged), 2005-09 (averaged), and 2010-15 (averaged). The bars at the top of each estimate show the range of mean annual growth estimated for the years within each time period.

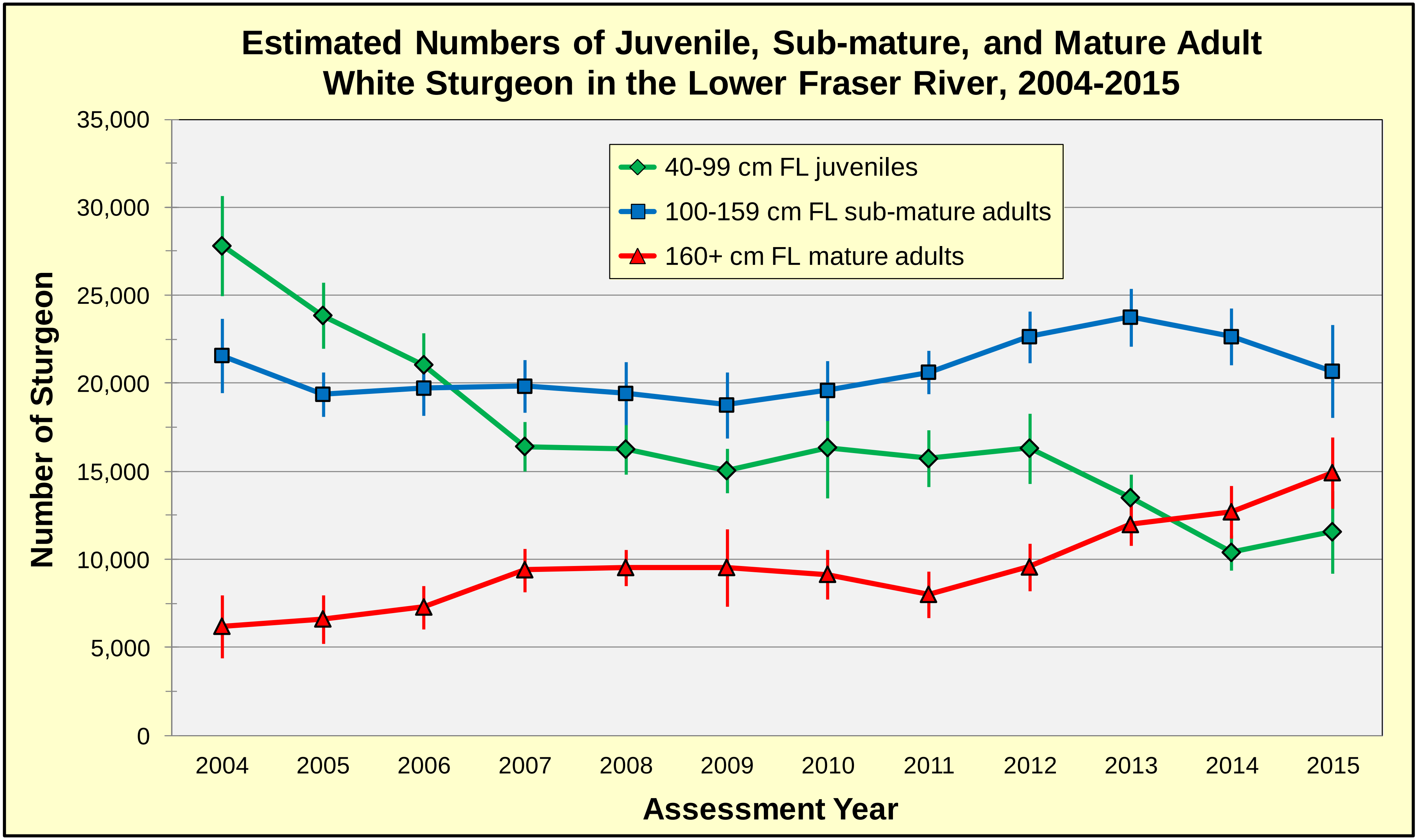

Figure 13. Estimated numbers of juvenile sturgeon (40-99 cm FL), sub-mature sturgeon (100-159 cm FL), and mature adult sturgeon (>160 cm FL) in sampling regions A-D of the lower Fraser River, 2004-2015. Pooling of data for three size groups, as opposed to 20-cm size groups (presented in Table 5 and Figure 6), provided a sufficient number of recaptures to use a spatially stratified approach that addresses observed differences in the mark rates and size of sturgeon caught in the four sampling regions. The vertical bars indicate the 95% CLs for each estimate. Within-year values are scaled to the annual total estimated abundance of 40-279 cm sturgeon in sampling regions A-D (see Table 2 and Figure 1).

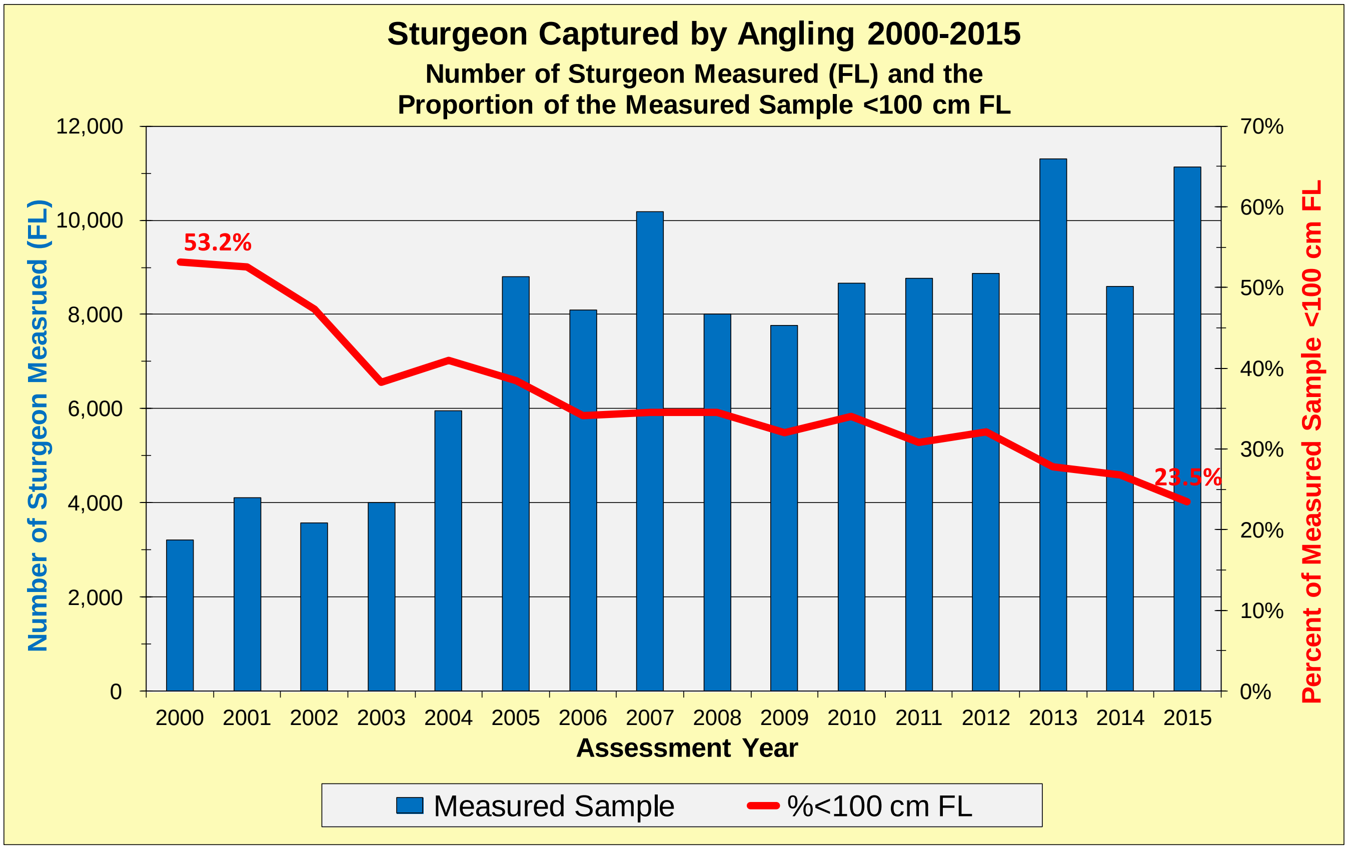

Figure 14. Illustration of the changes in the annual proportions of sturgeon less than 100 cm FL from all measured samples captured by angling, 2000-2015.

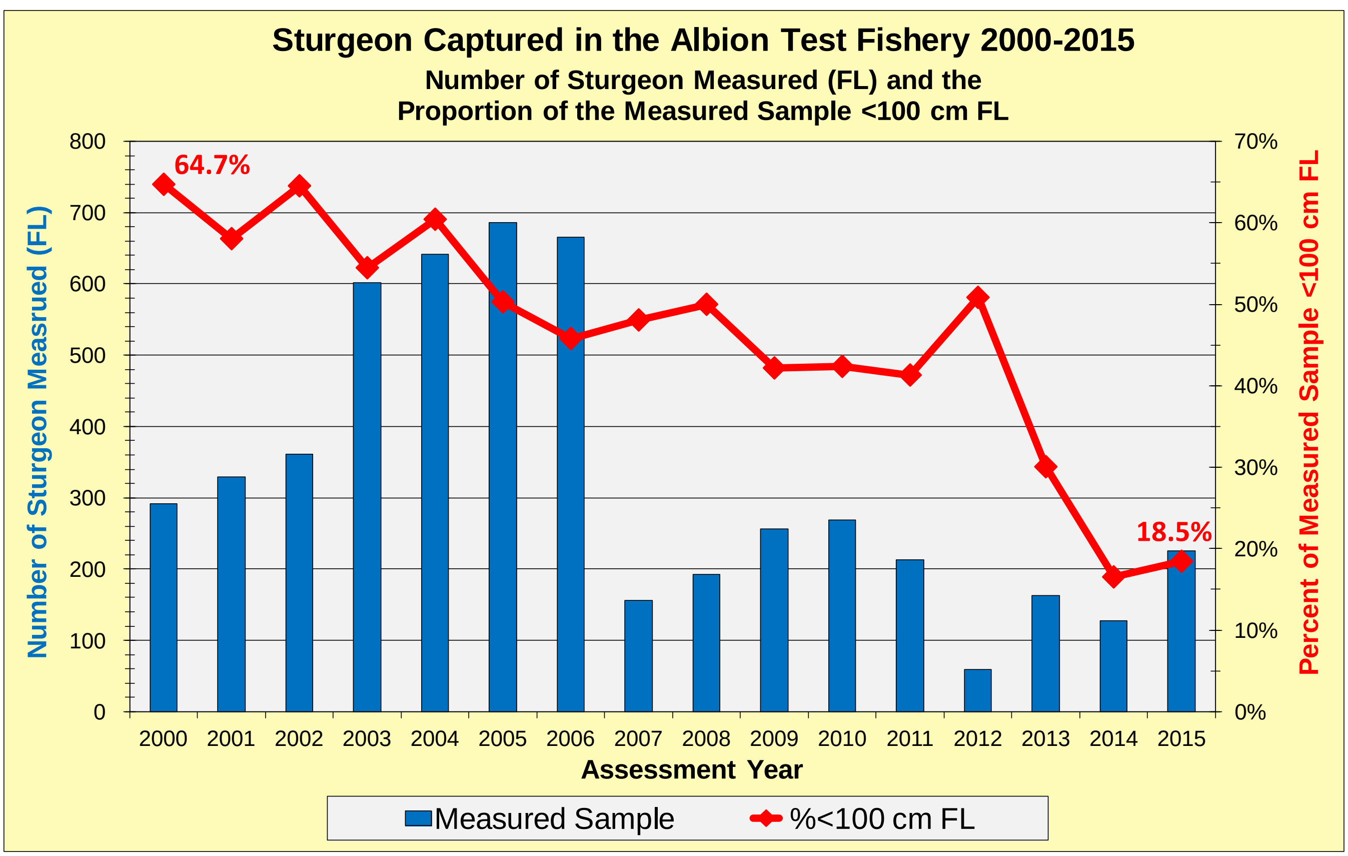

Figure 15. Illustration of the changes in the annual proportions of sturgeon less than 100 cm FL from all measured samples captured in the Albion Test Fishery, 2000-2015.

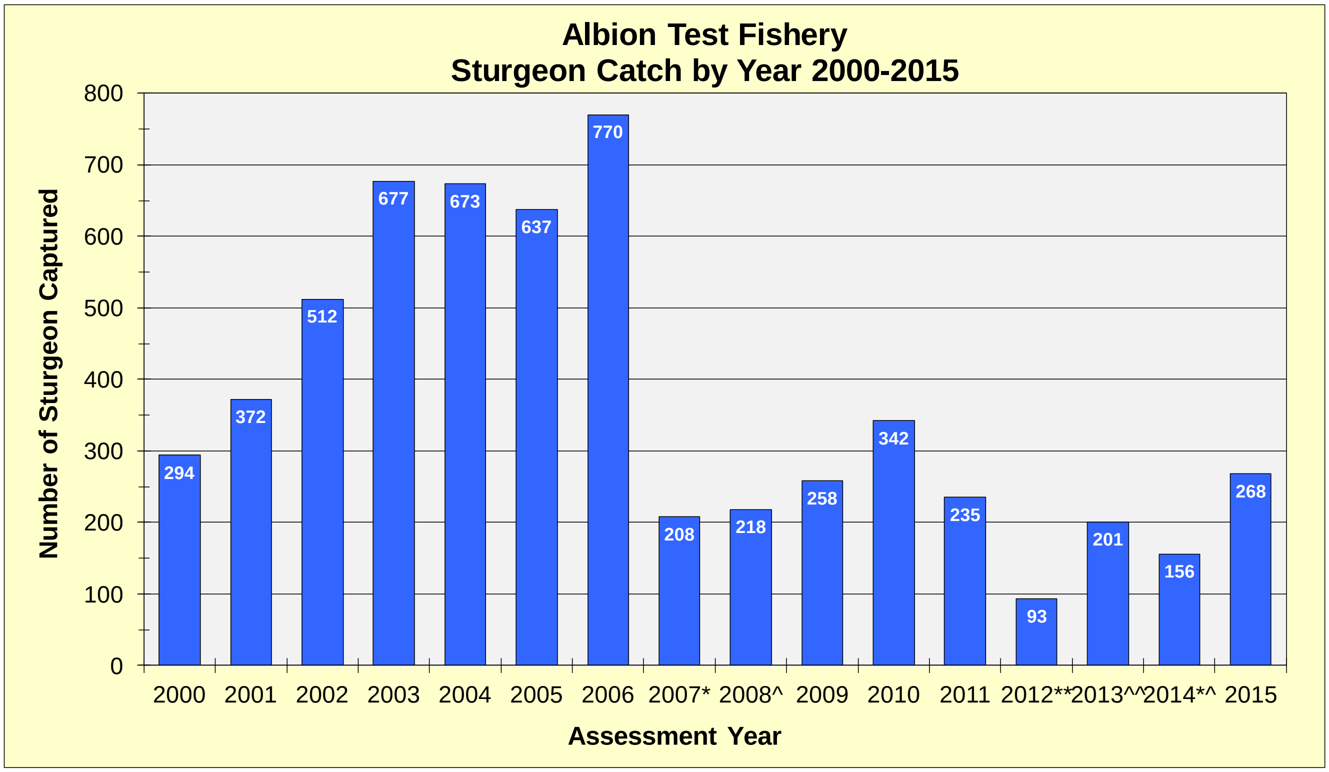

Figure 16. Comparison of the number of White Sturgeon (all sizes) captured in the Albion Test Fishery, 2000-2015. Data (from Fisheries and Oceans Canada) are the total number of sturgeon sampled by the Albion Test Fishery during assessment net sets.

Notes:
* In 2007 the test fishery operated from 18 June through 30 November (applies to Figures 16 and 17)
^ In 2008 the test fishery operated from 5 May through 30 November (applies to Figures 16 and 17)
** In 2012 the test fishery operated from 25 April through 30 November (applies to Figures 16 and 17)
^^ In 2013 the test fishery operated from 21 April and on alternate days from 10-23 November
*^ In 2014 the test fishery operated from 22 April and on alternate days from 10-23 November

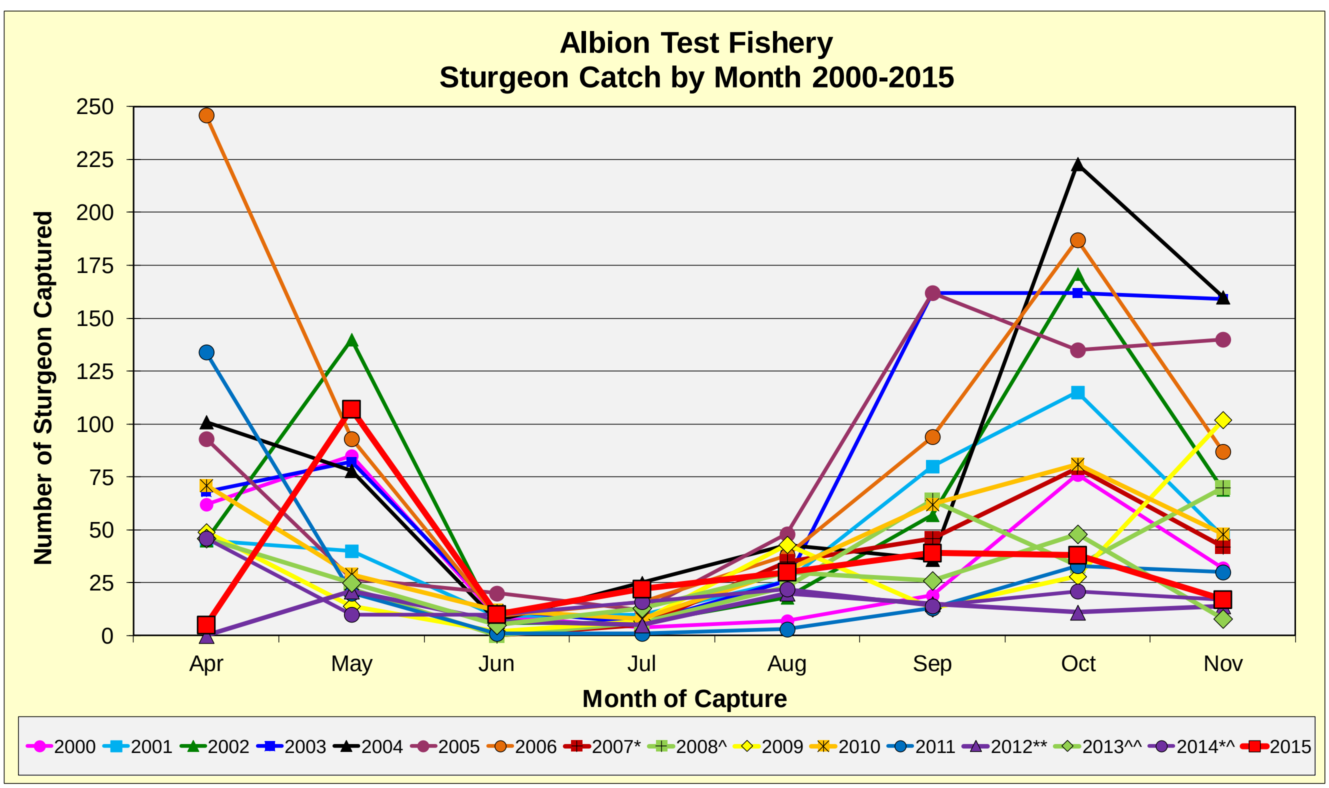

Figure 17. Comparison of the number of White Sturgeon (all sizes) captured in the Albion Test Fishery, by month, 2000-2015. See the footnote in Figure 16 for additional information.

APPENDIX A

Sturgeon biosampling, tagging, and recapture data entry form

FRASER RIVER STUGEON CONSERVATION SOCIETY FAX to Jim Rissling: 604-792-2630 (phone: 604-792-4368)

WHITE STURGEON BIOSAMPLING, TAGGING, AND MARK- RECAPTURE RECORDS Page:______ of ________

Name/Phone Number of Person that Recorded Data:______________________

Phone No:______________________

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	tn2OTHER	
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

Lower Fraser River sturgeon sampling, tagging, and recapture summary, by month and year, 1999-2015

Appendix B. Lower Fraser River* sturgeon sampling, tagging, and recapture summary, by month and year, 1999-2015.

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	96	89	7	0	0.0%						
Nov-99	206	182	24	0	0.0%						
Dec-99	157	143	14	0	0.0%	**1999**	459	414	45	0	**0.0%**
Jan-00	38	37	1	0	0.0%						
Feb-00	148	135	6	7	4.7%						
Mar-00	232	191	33	8	3.4%						
Apr-00	286	265	12	9	3.1%						
May-00	380	351	17	12	3.2%						
Jun-00	279	257	15	7	2.5%						
Jul-00	753	695	27	31	4.1%						
Aug-00	471	424	23	24	5.1%						
Sep-00	469	437	5	27	5.8%						
Oct-00	711	629	37	45	6.3%						
Nov-00	561	506	12	43	7.7%						
Dec-00	57	45	6	6	10.5%	**2000**	4385	3972	194	219	**5.0%**
Jan-01	178	165	0	13	7.3%						
Feb-01	152	134	0	18	11.8%						
Mar-01	299	250	0	49	16.4%						
Apr-01	423	340	30	53	12.5%						
May-01	410	360	5	45	11.0%						
Jun-01	509	427	8	74	14.5%						
Jul-01	432	355	14	63	14.6%						
Aug-01	844	717	19	108	12.8%						
Sep-01	582	484	4	94	16.2%						
Oct-01	851	711	26	114	13.4%						
Nov-01	512	417	6	89	17.4%						
Dec-01	316	197	78	41	13.0%	**2001**	5508	4557	190	761	**13.8%**
Jan-02	117	60	46	11	9.4%						
Feb-02	147	45	83	19	12.9%						
Mar-02	138	65	53	20	14.5%						
Apr-02	251	107	102	42	16.7%						
May-02	342	173	114	55	16.1%						
Jun-02	225	131	36	58	25.8%						
Jul-02	730	529	87	114	15.6%						
Aug-02	866	622	78	166	19.2%						
Sep-02	396	149	151	96	24.2%						
Oct-02	1142	582	364	196	17.2%						
Nov-02	531	187	232	112	21.1%						
Dec-02	157	97	31	29	18.5%	**2002**	5042	2747	1377	918	**18.2%**
Jan-03	72	55	11	6	8.3%						
Feb-03	39	20	12	7	17.9%						
Mar-03	131	89	28	14	10.7%						
Apr-03	451	290	77	84	18.6%						
May-03	553	383	84	86	15.6%						
Jun-03	310	180	73	57	18.4%						
Jul-03	474	311	92	71	15.0%						
Aug-03	674	473	89	112	16.6%						
Sep-03	1132	758	134	240	21.2%						
Oct-03	835	585	69	181	21.7%						
Nov-03	659	395	132	132	20.0%						
Dec-03	114	97	1	16	14.0%	**2003**	5444	3636	802	1006	**18.5%**
Jan-04	144	122	0	22	15.3%						
Feb-04	316	271	4	41	13.0%						
Mar-04	145	114	3	28	19.3%						
Apr-04	743	575	7	161	21.7%						
May-04	589	446	5	138	23.4%						
Jun-04	430	313	8	109	25.3%						
Jul-04	493	362	5	126	25.6%						
Aug-04	656	434	44	178	27.1%						
Sep-04	840	582	14	244	29.0%						
Oct-04	1695	916	311	468	27.6%						
Nov-04	1092	603	205	284	26.0%						
Dec-04	97	64	6	27	27.8%	**2004**	7240	4802	612	1826	**25.2%**
Jan-05	28	22	0	6	21.4%						
Feb-05	221	178	0	43	19.5%						
Mar-05	288	222	1	65	22.6%						
Apr-05	831	572	20	239	28.8%						
May-05	459	279	19	161	35.1%						
Jun-05	738	438	17	283	38.3%						
Jul-05	757	479	20	258	34.1%						
Aug-05	1581	786	148	647	40.9%						
Sep-05	1835	767	415	653	35.6%						
Oct-05	2092	965	320	807	38.6%						
Nov-05	1067	420	312	335	31.4%						
Dec-05	286	136	92	58	20.3%	**2005**	10183	5264	1364	3555	**34.9%**

continued

Appendix B. Lower Fraser River* sturgeon sampling, tagging, and recapture summary, by month and year, 1999-2015.

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-06	83	68	0	15	18.1%						
Feb-06	2	2	0	0	0.0%						
Mar-06	116	76	3	37	31.9%						
Apr-06	885	582	8	295	33.3%						
May-06	439	254	10	175	39.9%						
Jun-06	274	161	6	107	39.1%						
Jul-06	510	289	13	208	40.8%						
Aug-06	808	450	30	328	40.6%						
Sep-06	1301	676	10	615	47.3%						
Oct-06	2566	1337	14	1215	47.3%						
Nov-06	1863	1054	38	770	41.3%						
Dec-06	171	116	0	55	32.2%	**2006**	9018	5065	132	3820	**42.4%**
Jan-07	59	45	0	14	23.7%						
Feb-07	122	83	0	39	32.0%						
Mar-07	558	359	1	198	35.5%						
Apr-07	602	363	5	234	38.9%						
May-07	318	148	3	167	52.5%						
Jun-07	460	222	2	236	51.3%						
Jul-07	832	378	3	451	54.2%						
Aug-07	1457	614	6	837	57.4%						
Sep-07	2661	1244	36	1381	51.9%						
Oct-07	2288	1091	16	1181	51.6%						
Nov-07	1219	614	17	588	48.2%						
Dec-07	43	27	0	16	37.2%	**2007**	10619	5188	89	5342	**50.3%**
Jan-08	60	42	0	18	30.0%						
Feb-08	26	18	1	7	26.9%						
Mar-08	118	66	5	47	39.8%						
Apr-08	465	231	5	229	49.2%						
May-08	499	200	6	293	58.7%						
Jun-08	434	185	5	244	56.2%						
Jul-08	600	253	0	338	56.3%						
Aug-08	864	353	14	497	57.5%						
Sep-08	1466	618	21	827	56.4%						
Oct-08	2079	922	0	1144	55.0%						
Nov-08	1832	906	15	911	49.7%						
Dec-08	83	51	0	32	38.6%	**2008**	8526	3845	72	4587	**53.8%**
Jan-09	22	13	0	9	40.9%						
Feb-09	89	61	0	28	31.5%						
Mar-09	146	82	0	64	43.8%						
Apr-09	533	254	8	271	50.8%						
May-09	321	100	0	221	68.8%						
Jun-09	349	124	3	222	63.6%						
Jul-09	434	183	5	246	56.7%						
Aug-09	1074	389	15	670	62.4%						
Sep-09	1798	654	15	1129	62.8%						
Oct-09	2079	847	24	1208	58.1%						
Nov-09	1262	588	16	658	52.1%						
Dec-09	143	61	15	67	46.9%	**2009**	8250	3356	101	4793	**58.1%**
Jan-10	271	161	0	110	40.6%						
Feb-10	178	102	0	76	42.7%						
Mar-10	223	92	4	127	57.0%						
Apr-10	614	277	6	331	53.9%						
May-10	393	146	2	245	62.3%						
Jun-10	402	140	4	258	64.2%						
Jul-10	488	225	4	259	53.1%						
Aug-10	753	219	6	528	70.1%						
Sep-10	1391	448	16	927	66.6%						
Oct-10	2832	1156	26	1650	58.3%						
Nov-10	1195	556	11	628	52.6%						
Dec-10	321	194	3	124	38.6%	**2010**	9061	3716	82	5263	**58.1%**
Jan-11	178	113	0	65	36.5%						
Feb-11	41	22	0	19	46.3%						
Mar-11	138	71	0	67	48.6%						
Apr-11	756	336	8	412	54.5%						
May-11	339	148	4	187	55.2%						
Jun-11	176	48	0	128	72.7%						
Jul-11	588	236	4	348	59.2%						
Aug-11	1090	325	4	761	69.8%						
Sep-11	2278	771	12	1495	65.6%						
Oct-11	2333	995	35	1303	55.9%						
Nov-11	1084	475	24	585	54.0%						
Dec-11	121	55	2	64	52.9%	**2011**	9122	3595	93	5434	**59.6%**

continued

Appendix B. Lower Fraser River* sturgeon sampling, tagging, and recapture summary, by month and year, 1999-2015.											
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-12	82	44	0	38	46.3%						
Feb-12	83	44	0	39	47.0%						
Mar-12	211	101	0	110	52.1%						
Apr-12	463	192	4	267	57.7%						
May-12	364	163	1	200	54.9%						
Jun-12	233	79	1	153	65.7%						
Jul-12	738	322	4	412	55.8%						
Aug-12	1060	379	12	669	63.1%						
Sep-12	1741	744	13	984	56.5%						
Oct-12	2816	1225	28	1563	55.5%						
Nov-12	1061	404	9	648	61.1%						
Dec-12	322	149	2	171	53.1%	**2012**	9174	3846	74	5254	**57.3%**
Jan-13	220	97	2	121	55.0%						
Feb-13	342	166	1	175	51.2%						
Mar-13	503	237	2	264	52.5%						
Apr-13	923	387	16	520	56.3%						
May-13	673	221	4	448	66.6%						
Jun-13	455	164	4	287	63.1%						
Jul-13	769	279	2	488	63.5%						
Aug-13	1161	384	15	762	65.6%						
Sep-13	2644	871	31	1742	65.9%						
Oct-13	2746	1002	36	1708	62.2%						
Nov-13	1572	558	15	999	63.5%						
Dec-13	110	44	0	66	60.0%	**2013**	12118	4410	128	7580	**62.6%**
Jan-14	144	60	1	83	57.6%						
Feb-14	102	50	0	52	51.0%						
Mar-14	470	188	1	281	59.8%						
Apr-14	866	339	7	520	60.0%						
May-14	484	133	5	346	71.5%						
Jun-14	460	129	5	326	70.9%						
Jul-14	819	261	11	547	66.8%						
Aug-14	1098	192	119	787	71.7%						
Sep-14	1371	316	161	894	65.2%						
Oct-14	2135	587	137	1411	66.1%						
Nov-14	961	286	56	619	64.4%						
Dec-14	254	81	27	146	57.5%	**2014**	9164	2622	530	6012	**65.6%**
Jan-15	414	126	42	246	59.4%						
Feb-15	293	149	11	133	45.4%						
Mar-15	355	108	7	240	67.6%						
Apr-15	756	265	12	479	63.4%						
May-15	571	194	4	373	65.3%						
Jun-15	391	117	5	269	68.8%						
Jul-15	873	276	6	591	67.7%						
Aug-15	1312	342	11	959	73.1%						
Sep-15	2393	645	44	1704	71.2%						
Oct-15	2692	915	55	1722	64.0%						
Nov-15	1017	274	17	726	71.4%						
Dec-15	299	119	2	178	59.5%	**2015**	11366	3530	216	7620	**67.0%**
					Totals All Years	**1999-2015**	**134,679**	**64,565**	**6,101**	**63,990**	**47.5%**

* Lower Fraser River samples only for sturgeon captured downstream of rkm 188 (Yale).