LAKE STURGEON STEWARDSHIP & ENHANCEMENT PROGRAM

Results of a Lake Sturgeon Inventory Conducted in the Sea Falls to Sugar Falls Reach of the Nelson River - Fall, 2012

Report 12-03
December 2012

Manitoba Hydro

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A Report Prepared

For

Manitoba Hydro

December 2012

By

C.A. McDougall and D.J. Pisiak

North/South Consultants Inc.
Aquatic Environment Specialists

83 Scurfield Blvd.
Winnipeg, Manitoba, R3Y 1G4
Website: www.nscons.ca

Tel.: (204) 284-3366
Fax: (204) 477-4173
E-mail: nscons@nscons.ca

FOREWORD

Manitoba Hydro is committed to the conservation and enhancement of Lake Sturgeon populations in Manitoba. The Corporation has directed a substantial amount of effort towards this commitment through activities relating to existing and planned hydroelectric developments, post-project monitoring, applied and basic research and participation in multi-stakeholder sturgeon management boards. To ensure efficient and effective implementation of its sturgeon programs, the Corporation has developed a comprehensive "Lake Sturgeon Stewardship and Enhancement Plan" that will consolidate and build upon past efforts and guide new programs.

The vision of the Lake Sturgeon Stewardship and Enhancement Program is: "*To maintain and enhance Lake Sturgeon populations in areas affected by Manitoba Hydro's operations, now and in the future*." This vision will be achieved by ensuring that Manitoba Hydro's current activities do not contribute to a decline or jeopardize the sustainability of sturgeon populations in Manitoba.

The implementation strategy adopted by Manitoba Hydro for achieving the plan objectives includes developing an understanding of current Lake Sturgeon stocks and habitat in Manitoba. The following report presents the results of a Lake Sturgeon inventory conducted in the Sea Falls to Sugar Falls reach of the upper Nelson River during fall, 2012.

TECHNICAL SUMMARY

Lake Sturgeon stocking efforts were initiated in the Sea Falls to Sugar Falls reach of the upper Nelson River in 1994, at which time the species was thought to be near extirpated from this area. Since then, a total of 20,885 fingerlings (age 0, unmarked) and 1,107 yearlings (age 1, of which 1,014 were marked with Passive Integrated Transponder [PIT] tags) have been stocked in this reach. To begin to formally address the success of this stocking initiative, a Lake Sturgeon inventory study was conducted during fall, 2012.

A total of 1593.1 and 379.3 hours of gillnetting effort was conducted using juvenile Lake Sturgeon gillnet gangs and large mesh gillnet gangs, respectively, between 13 and 22 September, 2012, resulting in the capture of 91 unique Lake Sturgeon. Overall catch per unit effort was 1.4 and 0.4 LKST/100m/24h for juvenile and large mesh gillnet gangs, respectively. PIT tags were present in 74% (n = 67) of captured Lake Sturgeon, of which 30 fish were from the 2007 cohort (age 5, stocked in 2008), three were from the 2008 cohort (age 4, stocked in 2009), and 34 were from the 2010 cohort (age 2, stocked in 2011). In total, 97% of the PIT tagged fish (known age) were assigned correct ages using an interpreted consensus methodology, ascertaining that assessment of growth chronologies in juvenile Lake Sturgeon can be done accurately. Lake Sturgeon lacking PIT tags accounted for 26% (n = 24) of the catch. Of the 23 fish lacking PIT tags that were aged, 19 were determined to be from the 2007 cohort (age 5), one from the 2009 cohort (age 3), two from the 2010 cohort (age 2), and one from the 2002 cohort (age 10).

The 2007 cohort provided sufficient numbers of both PIT tagged and non-PIT tagged Lake Sturgeon to facilitate meaningful biological comparisons. The proportion of fish from this cohort with weak or absent “first” annuli (i.e. indicative of overwinter hatchery growth) was not significantly different between PIT tagged (100%, n = 29) and non-PIT tagged (89%, n = 19) fish (χ^2[1, n = 48] = 3.185, p=0.0743). Comparison of fork lengths among PIT tagged fish, non-PIT tagged fish with weak or absent “first” annuli, and non-PIT tagged fish with “first” annuli present revealed significant differences (ANOVA, $F_2 = 7.91$, $p = 0.0011$). Tukey’s HSD indicated that non-PIT tagged fish with jagged “first” annuli present were significantly smaller (mean = 608 mm, StDev = 31.8, n = 2) than PIT tagged (mean = 715 mm, StDev = 34.5, n = 30) and non-PIT tagged fish (mean = 693, StDev = 47.1, n = 17) with weak or absent “first” annuli. The length-at-age regression generated from data collected in this study highlights a rapid rate of juvenile growth for Sea Falls Lake Sturgeon, which far exceeds growth rates for all Nelson River juvenile populations for which comparative ageing data exists.

The finding that 74% of the Lake Sturgeon captured during the study possessed PIT tags is perhaps the most important. Considering only fish from the 2006 – 2011 cohorts (those reasoned to be catchable by

juvenile gangs), a total of 6,769 fingerlings (age 0, untagged) and 1,107 yearlings (age 1, of which 1,014 were PIT tagged) were stocked during this time frame. Pooling year-classes, ignoring the fact that ~8% of the yearlings stocked lacked PIT tags (i.e. all 1,107 yearlings included), and assuming that PIT tag loss and natural juvenile recruitment are both negligible, data collected in this study seems to indicate that relative recruitment success (defined here as: [proportion of fish present in catch] / [number of fish stocked]) would be 17.4 times as great for age 1 ($6.68e^{-4}$) versus age 0 ($3.84e^{-5}$) stocked fish. Furthermore, because a very high proportion of non-PIT tagged fish were observed to have growth chronologies consistent with known hatchery fish (i.e. weak or absent jagged "first" annuli), it can be reasoned that these were also stocked as age 1. The observation that PIT tagged and non-PIT tagged fish of the 2007 cohort which had weak or absent first annuli were not significantly different in size further supports this suspicion. Therefore, relative recruitment success could actually be skewed even further towards age 1 stocked fish. Including both known PIT tagged as well as those assumed to have been stocked as age 1 based on growth chronologies, the proportion of age 1 stocked fish present in the catch would actually be 95.5% (86 of 90), and relative recruitment success would be 128.4 times as great for age 1 ($8.62e^{-4}$) versus age 0 ($6.72e^{-6}$) stocked fish.

Results of this study indicate that stocking has resulted in the re-establishment of a small juvenile Lake Sturgeon population in the Sea Falls to Sugar Falls reach of the upper Nelson River, which is encouraging from a stewardship perspective. Given the information available at present, stocking initiatives conducted at northern latitudes should focus on rearing Lake Sturgeon to age 1, since these fish appear far more likely to survive and grow than those fish released as age 0.

STUDY TEAM

Data Collection

Craig McDougall

Darcy Pisiak

Harold Wilson

Langford McKay

Leon Simpson

Pierre Wilson

Data Analysis, Report Preparation, and Report Review

Craig McDougall

Darcy Pisiak

Mark Blanchard

Claire Hrenchuk

Laura Henderson

James Aiken

Cam Barth

Don MacDonell

ACKNOWLEDGMENTS

We would like to thank Manitoba Hydro and the Nelson River Sturgeon Board, with the support of an Environment Canada Habitat Stewardship Program grant, for the opportunity and resources to conduct this study. In particular, Don MacDonald, Marilynn Kullman, Cheryl Klassen and Shelley Matkowski are thanked for their assistance and logistical support. Reg Waterman of the Grand Rapids Hatchery is thanked for providing overwinter thermal regime data.

The collection of biological samples described herein was authorized under Scientific Collection Permit #50-12, as issued by the Manitoba Water Stewardship Aquatic Ecosystem Section.

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1.0 INTRODUCTION

Lake Sturgeon have been recommended by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to be listed as an endangered species in certain Designated Units (DU) across Canada under the Species At Risk Act (SARA). Within Manitoba this status has been recommended for most DUs, including for the populations present in the Nelson River (DU3). In addition, the species has been designated as a heritage species by the Government of Manitoba.

Manitoba populations of Lake Sturgeon were severely depleted by extensive commercial fisheries dating back to the late 1800s. Manitoba Lake Sturgeon fisheries were characterized by large initial harvests, followed by a drastic reduction in numbers and subsequent closures. The majority of the commercial fisheries were shut down by the 1930s; however, it was not until 1993 that the last Lake Sturgeon fishery was closed. Subsistence harvest for Lake Sturgeon continues to occur. Manitoba Lake Sturgeon populations were further impacted by hydroelectric development, which commenced on the Nelson River in 1957 with the construction of the Kelsey Generating Station (GS). A total of five Nelson River generating stations currently operate, while other developments (i.e. Keeyask, Conawapa, Gillam Island) are planned. Lake Winnipeg Regulation has also altered Nelson River flow patterns.

Due to a combination of historical and contemporary factors, Lake Sturgeon populations in many reaches of the Nelson River likely exist at a small fraction of historic levels, and natural population recoveries are uncertain. Hatchery rearing and stocking of early life stages is viewed as a potential recovery (and mitigative) tool aimed at supplementing natural recruitment; however, there has been little formal investigation of its utility in large river systems. Even in Great Lakes tributary systems (vastly different aquatic environments from which the bulk of the Lake Sturgeon literature is derived), survival of stocking efforts has been poorly quantified, and successful reproduction of stocked fish has only recently been ascertained in one population.

In the early 1990s, in response to near or total extirpation of Lake Sturgeon from several reaches of the Nelson River, stocking was determined to be a critical component of the restoration strategy (D. MacDonald pers. comm.). Between 1994 and 2011, spawn was collected intermittently from wild adults at the Landing River (a tributary of the Nelson River) spawning site. Eggs were fertilized and progeny were reared at the Grand Rapids hatchery and then stocked at various Nelson River locations (Table 1). In total, 20,885 fingerlings (age 0, unmarked) and 1,107 yearlings (age 1, of which 1,014 were marked with Passive Integrated Transponder [PIT] tags) were stocked in the Sea Falls to Sugar Falls reach of the Nelson River, a stretch reasoned to have been decimated by commercial exploitation during the mid-late 1800s and early 1900s. The stocking program is an initiative of the Nelson River Sturgeon Board that has been supported by Manitoba Fisheries Branch and Manitoba Hydro. Recently, there have been several reports of Lake Sturgeon captures by local resource users in this area (D. MacDonald pers.

comm.), which may be indicative that stocked fish are surviving well. To begin to formally address the success of this stocking initiative, a Lake Sturgeon inventory study was conducted during fall, 2012.

2.0 STUDY AREA

2.1 Physical Setting

The Nelson River exits Playgreen Lake via two channels; a western channel historically referred to as "God's River" and an eastern channel known as "Sea River". The present study was conducted on the ~19 km section of the eastern channel stretching from Sea (River) Falls to Sugar Falls (Figure 1).

2.2 Historic and Contemporary Lake Sturgeon Information

Little is definitively known about the Lake Sturgeon population historically occurring in the Sea Falls to Sugar Falls reach of the Nelson River, but the body of evidence suggests it was large. Petch (1992) explained, based on archaeological evidence, that Lake Sturgeon fishing was a proven part of the prehistoric and early historic subsistence economy in the Sea River Falls area. Anecdotal records in the Hudson Bay Company Archive suggest that Lake Sturgeon were historically "*caught with ease in the Sea River (Falls) area*" (Northern Lights Heritage Services 1994). Along with Lake Whitefish, Lake Sturgeon comprised the bulk of the subsistence fish harvest of indigenous people in the Norway House area between 1815 and 1864 (Northern Lights Heritage Services 1994).

Furthermore, areas immediately upstream (i.e. Lake Winnipeg, Playgreen Lake) and downstream (i.e. Cross Lake, Sipiwesk Lake) supported large populations and were the focus of much commercial harvest (MacDonell 1997; Stewart 2009). Commercial harvest was underway on Lake Winnipeg by 1884, with annual harvest peaking at 446,000 kg (~29,733 fish assuming an average weight of 15 kg/fish) in 1900 (MacDonell 1997; Stewart 2009). By 1910/11, the Lake Winnipeg Lake Sturgeon catch was only 13,699 kg (~913 fish) and the fishery was closed. Periodic re-openings occurred over the course of the next 80 years, but previous levels of production were never attained. Nelson River commercial harvest (which included Playgreen Lake) began in 1902. Annual harvest peaked at 99,792 kg (~6,653 fish) in 1903, but fell to 9,702 kg (~646 fish) by 1909/10 (Stewart 2009). Amid periodic closures, significant Nelson River sturgeon production continued through the next eight decades at least in part sustained, particularly in the early years, by exploiting stocks in progressively further downstream reaches. While it is assumed that the Sea Falls to Sugar Falls area was targeted (and decimated) during the early days of the Lake Winnipeg and Nelson River commercial fisheries, records do not differentiate harvest locations.

At the time Lake Sturgeon stocking efforts were initiated (1994), the species was assumed to be nearly extirpated from the Sea Falls to Sugar Falls area (D. MacDonald pers. comm.). Although there have been several reports of smaller (presumably juvenile) Lake Sturgeon being captured by local resource users in recent years (D. Macdonald pers. comm.), the consensus amongst Norway House based field staff (H. Wilson and P. Wilson, pers. comm.) and residents encountered during the field survey (who often took interest in the research program), was that Lake Sturgeon were extremely rare contemporarily in the Sea Falls area.

3.0 METHODS

3.1 Physical Data and Habitat

Water temperature (°C) was measured daily using the temperature sensor of a Lowrance HDS-5 Sonar/GPS (Lowrance Electronics Inc., Tulsa, Oklahoma). As little has been documented about aquatic habitat in the Sea Falls to Sugar Falls reach of the Nelson River, we also detail general observations made at the time of the survey.

Bathymetric maps were generated from Lowrance HDS-5 sonar log files recorded during travel to and from gillnetting sites using Dr. Depth version 5.0 (Prefix Elektronik, Gothenburg, Sweden). Sonar logs were algorithm filtered and manually inspected to remove erroneous data. Output bathymetric maps were generated based on interpolation and extrapolation limits of 50 and 5 m, respectively.

3.2 Gillnetting and Biological Sampling

To capture Lake Sturgeon, bottom-set gillnetting was conducted by two field crews during September 2012. Juvenile Lake Sturgeon and large mesh gillnet gangs were used in this study. Juvenile Lake Sturgeon gangs consisted of 22.9 m (25 yd) long by 2.5 m (2.7 yd) deep panels of 25, 51, 76, 127 and 152 mm (1, 2, 3, 5, and 6 inch) twisted nylon stretched mesh. To facilitate capture of larger and smaller juveniles at both ends of the gang, mesh sizes were staggered (i.e. ordered 1-5-2-6-3 inch). Prior to the start of the program, juvenile gangs (which had recently been deployed elsewhere on the Nelson River) were disinfected in a 10% chlorine bleach solution for 15 minutes, so as to minimize the risk of invasive species transfer. Gangs were rinsed with clean water prior to deployment. Juvenile gillnetting efforts were focused explicitly on deep-water habitats, which are known to be utilized by juvenile Lake Sturgeon in large riverine systems (Barth et al. 2009; McDougall 2011a; McDougall 2011b). Deep-water habitats were located using the Lowrance HDS-5 described above.

Large mesh gangs consisted of 22.9 m (25 yd) long by 2.5 m (2.7 yd) deep panels of 203, 229, 254 and 305 mm (8, 9, 10 and 12 inch) twisted nylon stretched mesh. Large mesh gangs had previously been desiccated (90+ days), so chlorine disinfection was not necessary. All gangs were set over night and, weather permitting, checked at approximately 24 hour intervals. Occasionally inclement weather resulted in longer set durations of up to 50 hours. A total of 44 juvenile gangs and 18 large mesh gangs were set over the duration of the study.

Lake Sturgeon were measured for fork length, total length and weight. Each fish was scanned for previously applied PIT tags using a Biomark 601 Reader (Biomark Inc., Boise, Idaho). Lake Sturgeon of sufficient size (≥ 300 mm fork length) were marked with an individually numbered Floy FD-94 T-bar anchor tag (Floy Tag and Manufacturing Company, Seattle, Washington). Tags were inserted between the basal pterygiophores of the dorsal fin using a Dennison Mark II tagging gun.

A small pelvic fin clip (1 – 2 cm^2) was removed from each Lake Sturgeon and preserved in 95% Biological Grade Ethanol for future genetic analysis. The first ray of the right pectoral fin was removed immediately distal to the fin articulation for subsequent ageing. After drying, fin rays were dipped in epoxy resin (Cold Cure™) and allowed to harden. Using a Struers Minitom™ (Struers Inc, Cleveland, Ohio) low speed sectioning saw, two 0.7 mm sections of the fin ray were cut within 5 mm of the 'knuckle'. The fin sections were then permanently mounted on a labeled glass slide using Cytoseal-60™ (Thermo Scientific, Waltham, Massachusetts), and viewed under a dissecting microscope (30 – 40x magnification). Following preliminary examination of several ageing structures, it was observed that the "jagged" first annuli (typical in wild Lake Sturgeon growth chronologies; Figure 2) tended to be weak or absent. Given the nature of hatchery growth patterns (i.e. growth might not cease during winter as it would in the wild), readers were asked to explicitly note any fish observed to have a weak or missing first annuli. Ageing structures were assessed by three readers, without knowledge of length or weight of the fish or the ages assigned by other readers. Ages were reported both as "counts" (no missing annuli assumed), and "interpreted" (missing "first" annuli assumed when appropriate). Both "count" and "interpreted" final ages were determined by modal consensus or the median value if all three readers assigned different ages. Digital photographs of representative ageing structures were captured using a dissecting microscope in combination with a Nikon D5100 (Nikon Corp., Tokyo, Japan).

Fish of other species were enumerated and measured for fork length (total length for Burbot).

3.3 Catch and Effort Analysis

Effort (gillnet hours) was calculated based on the duration (in hours) of the net set, multiplied by the total length of the gang (in meters), and divided by 100 m (the standardized net length):

Effort (gillnet hours) = set duration * (net length/100m)

Catch-per-unit-effort (CPUE) was calculated separately for Lake Sturgeon and for all other species combined as the total number of captures per 100 m of gill net per 24 hours of set duration. For example, a five panel juvenile Lake Sturgeon gang (total length of 114.5 m) set for 18 hours and catching seven Lake Sturgeon (LKST) would have a CPUE of:

CPUE = #LKST/(net length/100m)/(set duration/24h)
= 7/(114.5/100)/(18/24)
= 8.2 LKST/100m/24h

Length frequency distributions for Lake Sturgeon were generated using 50 mm fork length intervals (e.g., 450 – 499 mm, 500 – 549 mm, etc.), and plotted.

3.4 Age Based Analysis and Biological Comparisons

Accuracy of the “count” and “interpreted” ageing methods was assessed by age-class using a χ^2 test, based on fish of known age (i.e. those fish which were implanted with PIT tags prior to stocking). These results were used to determine if it was more appropriate to use “count” or “interpreted” ages in subsequent analyses. Ageing precision was described using the frequency of three reader agreement and modal age assignment.

Growth chronologies of PIT tagged versus non-PIT tagged Lake Sturgeon of the same cohort were compared by examining the proportion of fish with weak/absent jagged “first” annuli using a χ^2 test, as it was believed that this test might provide some insight into whether fish lacking PIT tags were stocked as age 0 or age 1 (and PIT tag loss or malfunction occurred). Comparisons of fork length were made to see if PIT tagged fish tended to be larger (or smaller) than non-PIT tagged fish (further separated into two logical groups based on the presence of true “first” annuli) of the same cohort using Analysis of Variance (ANOVA), and Tukey’s Honestly Significant Differences (HSD). A cohort-frequency histogram and a length-at-age growth curve are also presented. All statistical analysis was conducted in JMP 8.0 (SAS software, Cary, North Carolina) to a significance level of 0.05.

4.0 RESULTS

4.1 Physical Data and Habitat Description

Water temperature declined from 13.5 to 11.9°C over the duration of the study, conducted from 13 to 22 September 2012.

In general, shorelines in the Sea Falls to Sugar Falls reach are bedrock dominated and lined with old-growth boreal forest. Dense macrophyte beds are typical in near-shore areas. Much of this reach consists of low velocity main channel habitat, however in some sections many islands and reefs occur, resulting in braided channel habitat. Water velocity at these locations would best be described as moderate. Water levels in Lake Winnipeg’s north basin and Playgreen Lake combined with wind conditions (direction and strength) influence water levels in the Sea Falls to Sugar Falls reach (H. Wilson, Norway House, pers. comm.). Based on daily observation relative to high-water lines, water-levels were quite stable during the study, fluctuating within an approximately 0.3 m range.

The bathymetric map generated from opportunistic data collection provides some insight into habitat types and relative quantity between Sea Falls and Sugar Falls (figures 3a and 3b). Much of the main channel habitat surveyed was of moderate depth (5 – 10 m) with pockets of relatively deep-water habitat (>10 m) interspersed throughout much of the reach.

4.2 Catch and Effort

A total of 1593.1 and 379.3 hours of gillnetting effort was conducted using juvenile Lake Sturgeon and large mesh gangs, respectively, between 13 and 22 September, 2012. A list of fish species captured in the Sea Falls to Sugar Falls reach of the upper Nelson River is presented in Appendix 1. Lake Sturgeon comprised 25.8% of the juvenile gang catch (n = 368), followed by Burbot (21.2%) and White Sucker (20.9%) (Appendix 2). Longnose Sucker, Northern Pike, Sauger, Shorthead Redhorse, Trout-Perch, Walleye and Yellow Perch were also captured. Lake Sturgeon comprised 60% of the large mesh gang catch (n = 10), while Northern Pike accounted for the remainder (40%). A total of 91 unique Lake Sturgeon were captured over the duration of the study. Eight of these were captured twice, and one was captured a total of three times, for a total of 101 Lake Sturgeon captures (Table 2, Figure 4). Juvenile gangs accounted for 95 captures, and produced an overall mean CPUE of 1.4 LKST/100m/24h (range: 0 – 11.0). Large mesh gangs accounted for 6 captures, and produced an overall mean CPUE of 0.4 LKST/100m/24h (range: 0 – 4.6). Floy tags were applied to a total of 58 Lake Sturgeon, both PIT tagged and non-PIT tagged (Appendix 3). Two Lake Sturgeon mortalities occurred.

Lake Sturgeon captured in juvenile gangs ranged from 254 to 775 mm FL, while only one of the six fish captured in large mesh gangs exceeded 800 mm (1062 mm, Appendix 3). The length frequency distribution for juvenile gangs was bimodal, peaking at 300 – 349 mm (27.4%) and 700 – 749 mm (22%) fork length intervals (Figure 5). Given the mesh sizes utilized, Lake Sturgeon between 400 and 500 mm were notably absent from the catch.

4.3 Age Based Analysis

4.3.1 PIT Tagged Lake Sturgeon

PIT tags were present in 74% (n = 67) of the 91 unique Lake Sturgeon captured. Of these, 30 sturgeon were from the 2007 cohort (age 5, stocked in 2008), three were from the 2008 cohort (age 4, stocked in 2009), and 34 were from the 2010 cohort (age 2, stocked in 2011; Table 3). Two fish could not be aged; one due to pectoral fin deformities (no structure collected), and another because the sectioned structure was crystalline. It is unclear why this happens, but a small proportion of Lake Sturgeon from locations throughout Manitoba produce crystalline structures. Reader consensus was that 97% (n = 63) of the 65 PIT tagged fish (stocked as age 1) had weak or absent "first" annuli (Appendix 4). Only two of the aged PIT tagged fish had jagged "first" annuli, and both of these were from the 2008 cohort.

Using fish of known age (n = 65), accuracy of the "interpreted" ageing method was considerably higher (97%) than the "count" ageing method (6%), with data being highly significant ($\chi^2[1, n = 65] = 31.5$, $p < 0.0001$; Table 3). Based on this finding, all subsequent results consider only "interpreted" ages (i.e. weak or absent "first" annuli inferred when deemed appropriate by the readers). Ageing precision of PIT tagged fish was high in terms of modal assignment rate (97%). Only in one instance did ageing assignments differ by more than one year, when one known 2007 cohort (age 5) fish was read as 4, 5 and 6 years old. Three reader agreement for known age fish averaged 77%, and varied by cohort (χ^2[2, n = 65] = 11.4, p = 0.0034; Table 4). Three reader agreement was 90% for the 2007 cohort (n = 29), 100% for the 2008 cohort (n = 2), and 65% for the 2010 cohort (n = 34). Lack of agreement on ages assigned to the 2010 cohort (age 2) fish was apparently due to a tendency to include "false" annuli, with all three readers noting indecision on assigning some 2010 cohort fish as either age 2 or age 3 (2010 or 2009 cohorts). Indeed, two of the 34 (6%) known 2010 cohort Lake Sturgeon (age 2) were assigned incorrect ages (2009 cohort, age 3), highlighting the difficulties in interpreting these structures. Three reader agreement did not occur for either of the two fish inaccurately aged. All of the 29 known 2007 (age 5) cohort fish were assigned correct ages, as were both of the aged 2008 cohort (age 4) fish (Table 3).

4.3.2 Non-PIT Tagged Lake Sturgeon

Lake Sturgeon lacking PIT tags accounted for 26% (n = 24) of the 91 unique Lake Sturgeon captured. One fish could not be aged because the sectioned structure was crystalline. Of the 23 fish aged, four different cohorts were represented (Table 5). Nineteen fish were determined to be from the 2007 cohort (age 5), one was determined to be from the 2009 cohort (age 3), two were determined to be from the 2010 cohort (age 2), and the largest individual captured (1062 mm FL) was determined to be from the 2002 cohort (age 10). Reader consensus determined that 19 of the 23 (87%) aged fish had weak or absent first annuli. In contrast, the largest Lake Sturgeon captured (2002 cohort, age 10), along with two fish determined to be from the 2007 cohort (age 5), and one fish determined to be from the 2010 cohort had strong "first" annuli.

The lone non-PIT tagged Lake Sturgeon determined to be from the 2009 cohort (age 3) measured 545 mm (FL), considerably larger than all of the fish known or determined to be from the 2010 cohort (range: 255 – 379 mm). Based on this observation (and three reader agreement for this fish), despite two instances of known 2010 cohort (age 2) fish being inaccurately assigned as age 3, the assignment of this fish to the 2009 cohort does not appear to reflect a similar circumstance.

4.3.3 Biological Comparisons

Only the 2007 cohort provided sufficient numbers of both PIT tagged and non-PIT tagged Lake Sturgeon to facilitate meaningful comparisons. For this cohort, the proportion of fish with weak or absent "first" annuli was not significantly different between the PIT tagged (100%, n = 29) and non-PIT tagged (89%, n = 19) groups (χ^2[1, n = 48] = 3.185, p = 0.074). Comparing fork lengths of fish divided into three groups (PIT tagged, non-PIT tagged with weak or absent "first" annuli, and non-PIT tagged with "first" annuli present) revealed significant differences (ANOVA, F_2 = 7.91, p = 0.0011). Tukey's HSD indicated that non-PIT tagged with jagged "first" annuli present were significantly smaller (mean = 608 mm, StDev = 31.8, n = 2) than the PIT tagged (mean = 715 mm, StDev = 34.5, n = 30) and non-PIT tagged with weak or absent "first" annuli (mean = 693, StDev = 47.1, n = 17) groups (Table 6).

Considering all PIT tagged and non-PIT tagged Lake Sturgeon, 83 of 88 (94.3%) fish aged were deemed (based on modal consensus) to have missing or weak "first" annuli (Figure 6).

The length-at-age regression generated from data collected in this study highlights a rapid rate of juvenile growth for Sea Falls Lake Sturgeon, which far exceeds growth rates for all Nelson River juvenile populations for which comparative ageing data exists (Figure 7). Age 5 Lake Sturgeon ranged in size from 585 to 775 mm (FL), while the lone older fish (age 10) captured was 1062 mm (FL).

5.0 DISCUSSION

This study details the first contemporary assessment of the Lake Sturgeon population between Sea Falls and Sugar Falls, a stretch of the upper Nelson River reasoned to have been decimated (and essentially extirpated) due to historical exploitation. A stocking program that commenced in 1994 has intermittently seen Landing River progeny transferred into the Study Area, but prior to 2012, the success of these initiatives remained largely unknown. Deep-water habitats, comparable to those utilized by juvenile Lake Sturgeon in other large riverine systems (Barth et al. 2009; McDougall 2011a; McDougall 2011b), were located using sonar and sampled with gill nets designed to target a wide size range of juvenile/sub-adult Lake Sturgeon. A lack of adult captures (only one fish >800 mm [FL]) using large mesh gangs set throughout the upper portion of the Study Area at the onset of the study, prompted increased focus on the juvenile segment of the population.

The finding that 74% of the Lake Sturgeon captured during the study possessed PIT tags is perhaps the most important. Considering only fish from the 2006 – 2011 cohorts (those reasoned to be catchable by juvenile gangs), a total of 6,769 fingerlings (age 0, untagged) and 1,107 yearlings (age 1, of which 1,014 were PIT tagged) were stocked where the PR 373 ferry crosses the Nelson River (Table 1). Pooling year-classes, ignoring the fact that ~8% of the yearlings stocked lacked PIT tags (i.e. all 1,107 yearlings included), and assuming that PIT tag loss and natural juvenile recruitment are both negligible, data collected in this study seems to indicate that relative recruitment success (defined here as: [proportion of fish present in catch] / [number of fish stocked]) would be 17.4 times as great for age 1 ($6.68e^{-4}$) versus age 0 ($3.84e^{-5}$) stocked fish. Furthermore, because a very high proportion of non-PIT tagged fish were observed to have growth chronologies consistent with known hatchery fish (i.e. weak or absent jagged "first" annuli), it can be reasoned that these were also stocked as age 1. The observation that PIT tagged and non-PIT tagged fish of the 2007 cohort which had weak or absent first annuli were not significantly different in size further supports this suspicion. As noted previously, a small number of yearlings (n = 93, all from the 2011 cohort) were stocked without PIT tags. It is also possible that PIT tag loss or malfunction may have occurred since stocking, or although unlikely, that active tags were somehow missed during field scanning. Therefore, relative recruitment success could actually be skewed even further towards age 1 stocked fish. Including both known PIT tagged as well as those assumed to have been stocked as age 1 based on growth chronologies, the proportion of age 1 stocked fish present in the catch would actually be 95.5% (86 of 90), and relative recruitment success would be 128.4 times as great for age 1 ($8.62e^{-4}$) versus age 0 ($6.72e^{-6}$) stocked fish.

There are certainly other indications in the data collected to suggest that age 0 stocked fish make up a very small proportion of the Sea Falls to Sugar Falls juvenile population, pointing towards the latter scenario. Based on known age fish, it was determined that our methods of ageing juvenile Lake Sturgeon were highly accurate, in this case, despite growth chronology complications (i.e. missing or weak "first annuli) attributed to atypical over-winter hatchery thermal regimes. Only one 2009 cohort fish (157 stocked as age 0) and zero 2011 cohort fish (4,063 stocked as age 0) were identified in the catch (Table 1; Figure 7). Considering these observations and the length-frequency distribution observed in this study, juvenile cohorts stocked only as age 0 appear to be extremely rare in the Study Area. Furthermore, while 14,116 age 0 Lake Sturgeon were stocked in the Study Area between 1994 and 2003 (Table 1), only one adult-sized fish (1062 mm FL, 2002 cohort) was captured in 18 large mesh gillnet sets.

The results of this study suggest that very few of the Lake Sturgeon stocked as age 0 into the Sea Falls to Sugar Falls reach remain there today. It is possible that, following stocking, age 0 Lake Sturgeon moved downstream out of the Study Area, perhaps seeking lacustrine habitats, a pattern observed in wild Great Lakes populations during fall (Kempinger 1996; Holtgren and Auer 2004; Benson et al. 2005). Pipestone Lake would be first true lacustrine habitat encountered in the downstream trajectory, and would be the logical location to assess if age 0 Lake Sturgeon have moved downstream out of the Study Area. However, given that low-velocity, deep-water habitats exist in the Sea Falls to Sugar Falls reach, and because there are no strong indications that Lake Sturgeon populations in large riverine systems (e.g. the Winnipeg or Nelson rivers) exhibit this type of behaviour (Barth et al. 2011; North/South Consultants unpublished data), the likelihood of downstream dispersal is small. Rather, it is more likely that age 0 fish have survived poorly following stocking.

Unfortunately, no studies have been conducted on age 0 versus age 1 Lake Sturgeon stocking success from which we can draw meaningful insight. Indeed, it has been noted that stocking initiatives "*have not been adequately evaluated and many programs rely on intermittent, short-term, or anecdotal indicators of program success*" (Smith 2009). One study conducted in the Black Lake, Michigan area determined that a minimum of 40% of stocked age 0 sturgeon survived their first winter (Crossman et al. 2009). This study was based on a very small sample size (n = 40), and due to uncertainties with the data (some acoustic tags may not have worked properly) overwinter survival may actually have been considerably higher. However, age 0 Lake Sturgeon stocked in the Crossman et al. (2009) study ranged in size from ~252 to 297 mm (fork length, converted from total length), which is considerably larger than the size of the age 0 Lake Sturgeon stocked in the Sea Falls area (~83 to 164 mm FL based on 2007 and 2010 cohort data; Appendix 4). This difference could well be important, since overwinter energy reserves are likely correlated (+) with body size, and the discrepancy compounded because winter lasts considerably longer at northern latitudes.

Poor survival of age 0 stocked fish could also relate to open-water habitat requirements not being met, and one aspect frequently discussed is the presence of sand substrate. Sand is the preferred substrate of young-of-the-year Lake Sturgeon in Great Lakes tributaries (Kempinger 1996; Holtgren and Auer 2004; Smith and King 2005) and in laboratory settings (Peake 1999), and it is unknown if sand substrate exists in the Sea Falls to Sugar Falls reach. However, inferring habitat requirements of age 0 Lake Sturgeon in large riverine systems based on observations made in Great Lakes tributaries should be done cautiously, as results have not always been consistent. For example, on the Winnipeg River, natural juvenile Lake Sturgeon recruitment is occurring in the Great Falls Reservoir (McDougall 2011b), despite a lack of sand dominated substrate (Murray and Gillespie 2011). Still, a focused habitat survey of the Sea Falls to Sugar Falls reach might reveal areas likely to be conducive to age 0 survival and fish stocked directly into these areas.

Regardless of why age 0 survival has been so low, results of the current study show that stocking has resulted in the re-establishment of a small juvenile Lake Sturgeon population in the Sea Falls to Sugar Falls area, which is encouraging from a stewardship perspective. Certainly, the explanation behind low survival of stocked age 0 Lake Sturgeon should be pursued and the success of similar stockings in other areas of the upper Nelson River (Jenpeg, Cross Lake, Duck Rapids, and the Landing River area) formally assessed to see if results are consistent with those observed in the current Study Area. Still, given the information available at present, Lake Sturgeon stocking initiatives conducted at northern latitudes should strongly consider rearing Lake Sturgeon to age 1, since these fish appear far more likely to survive and grow in the wild.

Indeed, the growth rate of Lake Sturgeon in the Sea Falls to Sugar Falls reach is rapid, with the 2007 cohort far exceeding that of other Nelson River populations by age 5 (Figure 7). Based on observations of highly variable growth rates amongst geographically close sections of the Winnipeg River, rapid growth of juveniles in the Sea Falls to Sugar Falls Reach (relative to other Nelson River populations) may reflect a combination of factors, including juvenile density, forage availability, and water-velocity influenced energetics (Barth 2011; McDougall 2011b). However, because the two Lake Sturgeon from the 2007 cohort which possessed a "first" annuli (and can therefore be reasoned to have been stocked as age 0) were significantly smaller than those fish from the same cohort that exhibited weak or absent "first" annuli (both PIT tagged and non-PIT tagged), the head-start afforded by over-winter hatchery growth also appears to be important. Not only do age 1 stocked Lake Sturgeon appear to survive considerably better than those stocked as age 0, it is conceivable that Lake Sturgeon stocked as age 1 may also reach maturity faster or be more fecund upon reaching maturity (because they are larger for a given age) than their age 0 counterparts. Considering the rapid growth rate of these fish, we may not be that far away from being able to address one of the major data gaps relating to stocking: will hatchery reared Lake Sturgeon stocked into large riverine systems locate spawning sites, successfully reproduce, and make meaningful contributions to subsequent generations?

As the understanding of Lake Sturgeon ecology improves, recovery strategies are implemented, and populations begin to slowly climb, we must remember that due to lengthy generation times (20-25 years in most localities) meaningful population recoveries will take decades. In the Sea Falls to Sugar Falls reach, data collected in this study indicates a small and therefore fragile juvenile population. Because the relative contribution of age 0 fish to the overall population appears to be almost negligible, it is unlikely that the maximum number of juvenile Lake Sturgeon located in the Sea Falls to Sugar Falls reach at the time of the study would exceed 1,107 (the number of yearlings stocked). Therefore, any contemporary mortality (including harvest) in this and other formerly extirpated populations will hinder recoveries. Knowing what we do now about exclusivity of juvenile/sub-adult Lake Sturgeon to deep-water habitat (Barth et al. 2009; McDougall and MacDonell 2009; McDougall 2011b), it would be relatively easy to target this segment of the population prior to them reaching maturity, which of course would be devastating. Indeed, in a 10-day study designed to survey all deep-water habitat in the Sea Falls to Sugar Falls reach, based on growth chronology analysis, we were able to recapture 86 out of 1,107 (7.8%) Lake Sturgeon stocked as age 1.

The same 7.8% value could also be used to describe the minimum estimate of first year survival of Lake Sturgeon stocked as age 1 into the Sea Falls to Sugar Falls reach. Essentially, this would assume that we captured all the juvenile Lake Sturgeon stocked into the reach during the current program, which is of course not true. A very rough Lincoln-Peterson estimate, indeed one that violates several assumptions, could be generated, based on the number of age 1 stocked fish (known or reasoned via growth chronologies) captured (n = 86) and subsequently recaptured (n = 8) during the current study. The resulting recapture rate of 9.3% would be synonymous with the proportion of the Lake Sturgeon sampled in the reach during that study, yielding a population estimate of 924. First year survival would then be calculated as approximately 83.5%. This estimate would also be slightly conservative, in that it assumes negligible mortality in years subsequent to stocking. While this rationale is certainly not ideal, it provides a decent first approximation in the absence of a true encounter history study.

The last subject of discussion relates to ageing structure interpretation and hatchery growth patterns. Following completion of data analysis, we learned that detailed thermal and biological data records have been kept by staff of the Grand Rapids Hatchery, allowing us to ascertain our suspicion that the over-winter hatchery thermal regime under which PIT tagged Lake Sturgeon were raised was markedly different from conditions fish would experience in the wild. Referring to age 1 stocked fish only, the 2007 cohort was raised at water temperatures ranging from 15.1 to 17.5 °C between October 2007 and June 2008, while the 2010 cohort was raised at water temperatures ranging from 10.3 to 13.0 °C between October 2010 and May 2011 (Appendix 4). In large riverine systems occurring at northern latitudes, water temperature during winter falls to ~0°C, and remains there for several months. The 2008 cohort was raised in aquariums and little is definitively known about thermal conditions, which is unfortunate given that the two PIT tagged fish from this cohort that were aged both possessed "first" annuli (Appendix 5).

The 2007 cohort fish grew rapidly while in the hatchery overwinter, and measured on average 344 mm fork length (range: 317 – 383 mm) when stocked (Appendix 4). In contrast, the 2010 cohort grew slower, and fish measured on average only 209 mm (range: 141 – 243 mm) when stocked. Although it is unknown if other variables influenced growth rates of the two cohorts, water temperature has been correlated to growth rates in a variety of cold water fish species.

In conclusion, results of this study suggest that Lake Sturgeon stocked into the Sea Falls – Sugar Falls reach at age 1 have survived far better than those stocked at age 0. Additional research is needed to diagnose the mechanisms of age- and size-related survival of stocked Lake Sturgeon, and refine the understanding of post-stocking survival rates via mark-recapture encounter histories. Still, the highly skewed relative recruitment success observed in this study suggests that in the interim, stocking programs conducted at northern latitudes should focus on rearing Lake Sturgeon to age 1 in order to enhance survival.

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TABLES

Table 1. Summary of Nelson River Lake Sturgeon stocking, 1994 – 2011. Numbers in brackets represent the cohort year for stocked yearlings. With the exception of 2011, all yearlings were implanted with PIT tags. *In 2011, 498 of the 591 yearlings stocked received PIT tags.

Year	Sea Falls		Jenpeg	Cross Lake	Duck Rapids	Landing River
	Fingerlings	Yearlings*	Fingerlings	Fingerlings	Fingerlings	Fingerlings
1994	1,025					
1995						
1996						
1997						
1998				346		141
1999	324					
2000	2,034			1,500		1,767
2001	4,600		4,600		4,672	4,675
2002	1,681		1,681			
2003	4,452		2,940		5,210	
2004			1,300			
2005						
2006	436		1,320			
2007	500					
2008	469	471 (2007)				
2009	157	45 (2008)				
2010	1,144					
2011	4,063	*591 (2010)				
Total	**20,885**	**1,107**	**11,841**	**1,846**	**9,882**	**6,583**

Table 2. Catch-per-unit-effort for Lake Sturgeon and by-catch in juvenile gillnet gangs set in the Sea Falls to Sugar Falls area during fall, 2012.

Site	Set Date	Pull Date	Duration (hours)	Effort (gillnet hours)	# of LKST	CPUE (#LKST/100m/24h)	# of non-LKST	CPUE (#non-LKST/100m/24h)
Juv-001	13-Sep-12	14-Sep-12	22.25	25.5	0	0	31	29.2
Juv-002	13-Sep-12	14-Sep-12	22.75	26.0	0	0	12	11.1
Juv-003	13-Sep-12	14-Sep-12	22.38	25.6	0	0	12	11.2
Juv-004	13-Sep-12	14-Sep-12	22.50	25.8	2	1.9	9	8.4
Juv-005	14-Sep-12	15-Sep-12	24.55	28.1	1	0.9	5	4.3
Juv-005.1	15-Sep-12	16-Sep-12	23.67	27.1	1	0.9	3	2.7
Juv-006	14-Sep-12	15-Sep-12	24.75	28.3	13	11.0	7	5.9
Juv-006.1	15-Sep-12	16-Sep-12	21.65	24.8	4	3.9	7	6.8
Juv-006.2	16-Sep-12	17-Sep-12	21.63	24.8	2	1.9	8	7.8
Juv-007	14-Sep-12	15-Sep-12	25.15	28.8	1	0.8	4	3.3
Juv-008	14-Sep-12	15-Sep-12	23.92	27.4	0	0	9	7.9
Juv-009	15-Sep-12	16-Sep-12	21.75	24.9	7	6.7	5	4.8
Juv-009.1	16-Sep-12	17-Sep-12	20.72	23.7	2	2.0	0	0.0
Juv-009.2	17-Sep-12	18-Sep-12	23.93	27.4	3	2.6	1	0.9
Juv-009.3	18-Sep-12	20-Sep-12	47.13	54.0	1	0.4	5	2.2
Juv-010	15-Sep-12	16-Sep-12	22.25	25.5	0	0	7	6.6
Juv-011	16-Sep-12	17-Sep-12	19.45	22.3	1	1.1	2	2.2
Juv-012	16-Sep-12	17-Sep-12	19.82	22.7	6	6.3	2	2.1
Juv-013	16-Sep-12	17-Sep-12	21.00	24.0	2	2.0	2	2.0
Juv-013.1	17-Sep-12	18-Sep-12	23.87	27.3	1	0.9	7	6.1
Juv-013.2	18-Sep-12	20-Sep-12	48.63	55.7	0	0	4	1.7
Juv-013.3	20-Sep-12	22-Sep-12	46.92	53.7	3	1.3	3	1.3
Juv-014	17-Sep-12	18-Sep-12	23.75	27.2	0	0	6	5.3
Juv-015	17-Sep-12	18-Sep-12	23.42	26.8	1	0.9	2	1.8
Juv-016	18-Sep-12	20-Sep-12	47.08	53.9	2	0.9	3	1.3
Juv-017	18-Sep-12	20-Sep-12	44.17	50.6	0	0	12	5.7
Juv-018	20-Sep-12	22-Sep-12	48.87	56.0	7	3.0	3	1.3
Juv-019	20-Sep-12	22-Sep-12	48.50	55.5	3	1.3	2	0.9
Juv-020	20-Sep-12	22-Sep-12	46.25	53.0	1	0.5	7	3.2
Juv-100	16-Sep-12	17-Sep-12	19.75	22.6	0	0	5	5.3
Juv-101	16-Sep-12	17-Sep-12	19.75	22.6	0	0	10	10.6
Juv-102	16-Sep-12	17-Sep-12	19.00	21.8	0	0	1	1.1
Juv-103	17-Sep-12	18-Sep-12	23.92	27.4	3	2.6	13	11.4
Juv-103.1	18-Sep-12	20-Sep-12	47.25	54.1	2	0.9	10	4.4
Juv-103.2	20-Sep-12	22-Sep-12	49.67	56.9	5	2.1	8	3.4

Table 2. Continued.

Site	Set Date	Pull Date	Duration (hours)	Effort (gillnet hours)	# of LKST	CPUE (#LKST/100m/24h)	# of non-LKST	CPUE (#non-LKST/100m/24h)
Juv-104	17-Sep-12	18-Sep-12	25.33	29.0	3	2.5	7	5.8
Juv-104.1	18-Sep-12	20-Sep-12	47.42	54.3	0	0	6	2.7
Juv-104.2	20-Sep-12	22-Sep-12	48.33	55.3	0	0	7	3.0
Juv-105	17-Sep-12	18-Sep-12	23.00	26.3	2	1.8	6	5.5
Juv-106	17-Sep-12	18-Sep-12	22.83	26.1	3	2.8	3	2.8
Juv-106.1	18-Sep-12	20-Sep-12	47.17	54.0	7	3.1	5	2.2
Juv-106.2	20-Sep-12	22-Sep-12	48.08	55.1	2	0.9	7	3.1
Juv-107	18-Sep-12	20-Sep-12	47.25	54.1	1	0.4	4	1.8
Juv-107.1	20-Sep-12	22-Sep-12	49.92	57.2	3	1.3	1	0.4
Juvenile Gang Total			**1391.4**	**1593.1**	**95**	**1.4**	**273**	**4.1**
LMG-001	13-Sep-12	14-Sep-12	21.75	19.9	0	0	0	0
LMG-001.1	14-Sep-12	15-Sep-12	24.67	22.6	0	0	2	2.1
LMG-002	13-Sep-12	14-Sep-12	22.17	20.3	0	0	0	0
LMG-002.1	14-Sep-12	15-Sep-12	24.08	22.1	0	0	1	1
LMG-003	13-Sep-12	14-Sep-12	22.42	20.5	1	1.2	0	0
LMG-003.1	14-Sep-12	15-Sep-12	23.58	21.6	0	0	0	0
LMG-004	13-Sep-12	14-Sep-12	22.25	20.4	0	0	0	0
LMG-004.1	14-Sep-12	15-Sep-12	24.25	22.2	0	0	0	0
LMG-005	13-Sep-12	14-Sep-12	22.17	20.3	0	0	0	0
LMG-005.1	14-Sep-12	15-Sep-12	24.33	22.3	0	0	0	0
LMG-006	13-Sep-12	14-Sep-12	22.25	20.4	1	1.2	0	0
LMG-006.1	14-Sep-12	15-Sep-12	24.25	22.2	0	0	0	0
LMG-007	15-Sep-12	16-Sep-12	22.75	20.8	0	0	0	0
LMG-008	15-Sep-12	16-Sep-12	22.75	20.8	4	4.6	1	1
LMG-009	15-Sep-12	16-Sep-12	22.75	20.8	0	0	0	0
LMG-010	15-Sep-12	16-Sep-12	22.75	20.8	0	0	0	0
LMG-011	15-Sep-12	16-Sep-12	22.33	20.5	0	0	0	0
LMG-012	15-Sep-12	16-Sep-12	22.58	20.7	0	0	0	0
Large Mesh Gang Total			**414.1**	**379.3**	**6**	**0.4**	**4**	**0.3**

Table 3. Accuracy of "count" and "interpreted" ageing methodologies, based on PIT tagged fish of known age stocked and subsequently recaptured in the Sea Falls to Sugar Falls area. Numbers in brackets refer to the cohort of which fish were assigned to in cases of inaccuracy.

Cohort year	Stocking year	# captured	# aged	Weak or absent "first" annuli		Count age method			Interpreted age method		
				#	%	Correct	Incorrect	% Correct	Correct	Incorrect	% Correct
2007	2008	30	29	29	100%	0	29 (2008)	0%	29	0	100%
2008	2009	3	2	0	0%	2	0	0%	2	0	100%
2010	2011	34	34	34	100%	2	32 (2009)	6%	32	2 (2009)	94%
Total		**67**	**65**	**63**	**97%**	**4**	**61**	**6%**	**63**	**2**	**97%**

Table 4. Ageing precision metrics for PIT tagged fish of known age stocked and subsequently recaptured in the Sea Falls to Sugar Falls area.

Cohort year	# of fish aged	Modal consensus		Three reader agreement		Fork length range (mm)
		#	%	#	%	
2007 (all correct)	29	28	97%	26	90%	600 - 775
2008 (all correct)	2	2	100%	2	100%	595 - 632
2010						
Correct age assigned	32	32	100%	22	69%	270 - 379
Incorrect age assigned	2	2	100%	0	0%	255 - 300
Total	**65**	**64**	**98%**	**50**	**77%**	**270 - 775**

Table 5. Ageing precision metrics for non-PIT tagged fish captured in the Sea Falls to Sugar Falls area.

Cohort year	# of fish aged	Weak or absent "first" annuli		Modal consensus		Three reader agreement		Fork length range (mm)
		#	%	#	%	#	%	
2002	1	0	0%	1	100%	1	100%	1062
2007	19	17	89%	19	100%	19	100%	585 - 763
2009	1	1	100%	1	100%	1	100%	545
2010	2	1	50%	2	100%	2	100%	278 - 304
Total	**23**	**19**	**83%**	**23**	**100%**	**23**	**100%**	**278 - 1062**

Table 6. Size comparison of PIT tagged (known age), non-PIT tagged with weak or absent "first" annuli, and non-PIT tagged with "first" annuli present Lake Sturgeon captured in the Sea Falls to Sugar Falls area. Only the 2007 cohort was captured in sufficient numbers so as to facilitate meaningful comparisons. Data are summarized by number of fish (n), mean fork length (FL), standard deviation of fork length (StDev), and the ranked order of significant differences as determined by Tukey`s HSD (Rank). Zones which share the same rank (1 or 2) are not significantly different. Grey shaded cells represent the slowest growing fish.

Cohort year	PIT tagged				Non-PIT tagged, no "first" annuli present				Non-PIT tagged, "first" annuli present			
	n	FL	StDev	Rank	n	FL	StDev	Rank	n	FL	StDev	Rank
2007	30	715	34.5	1	17	693	47.1	1	2	608	31.8	2

FIGURES

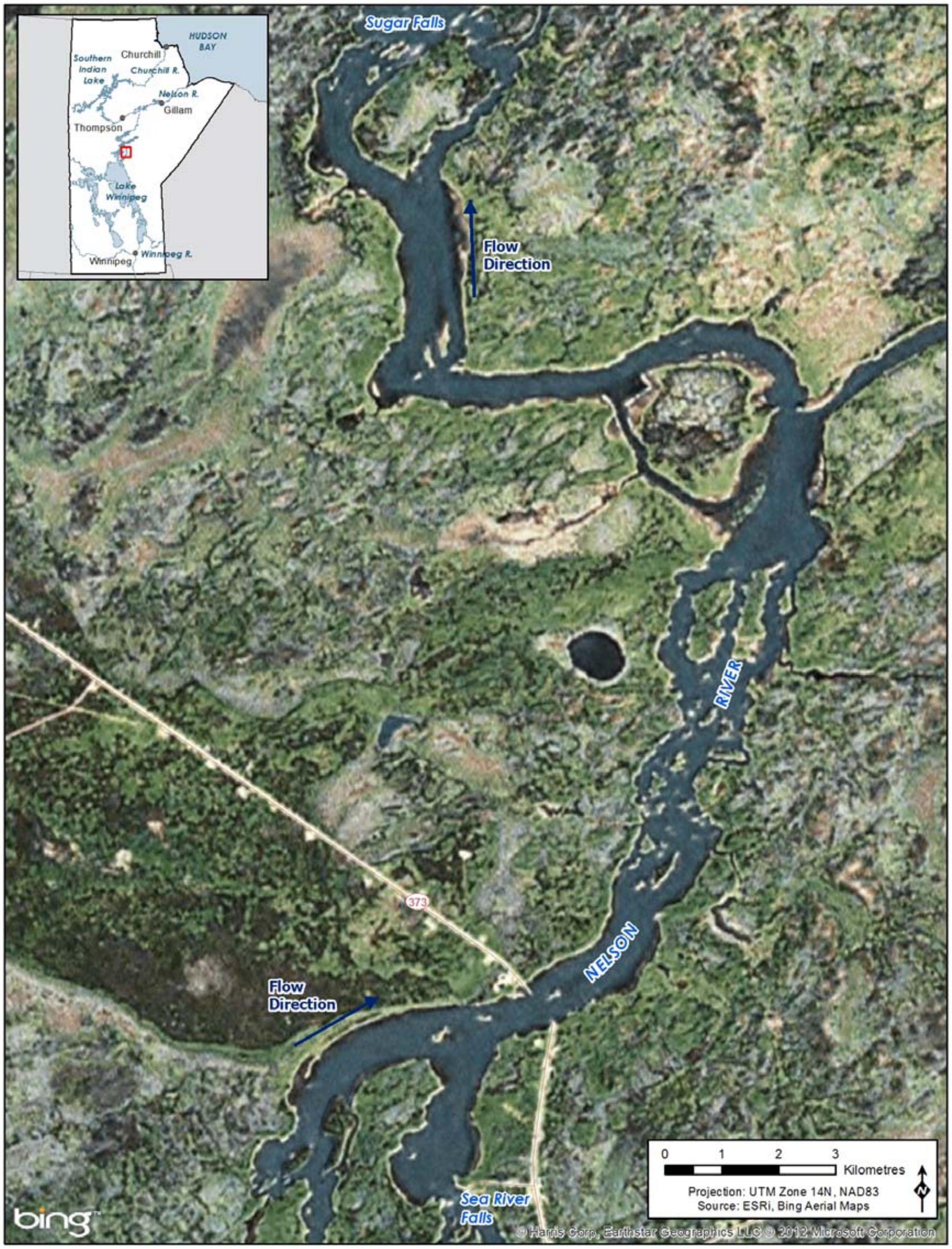


Figure 1. The Sea (River) Falls to Sugar Falls Study Area.

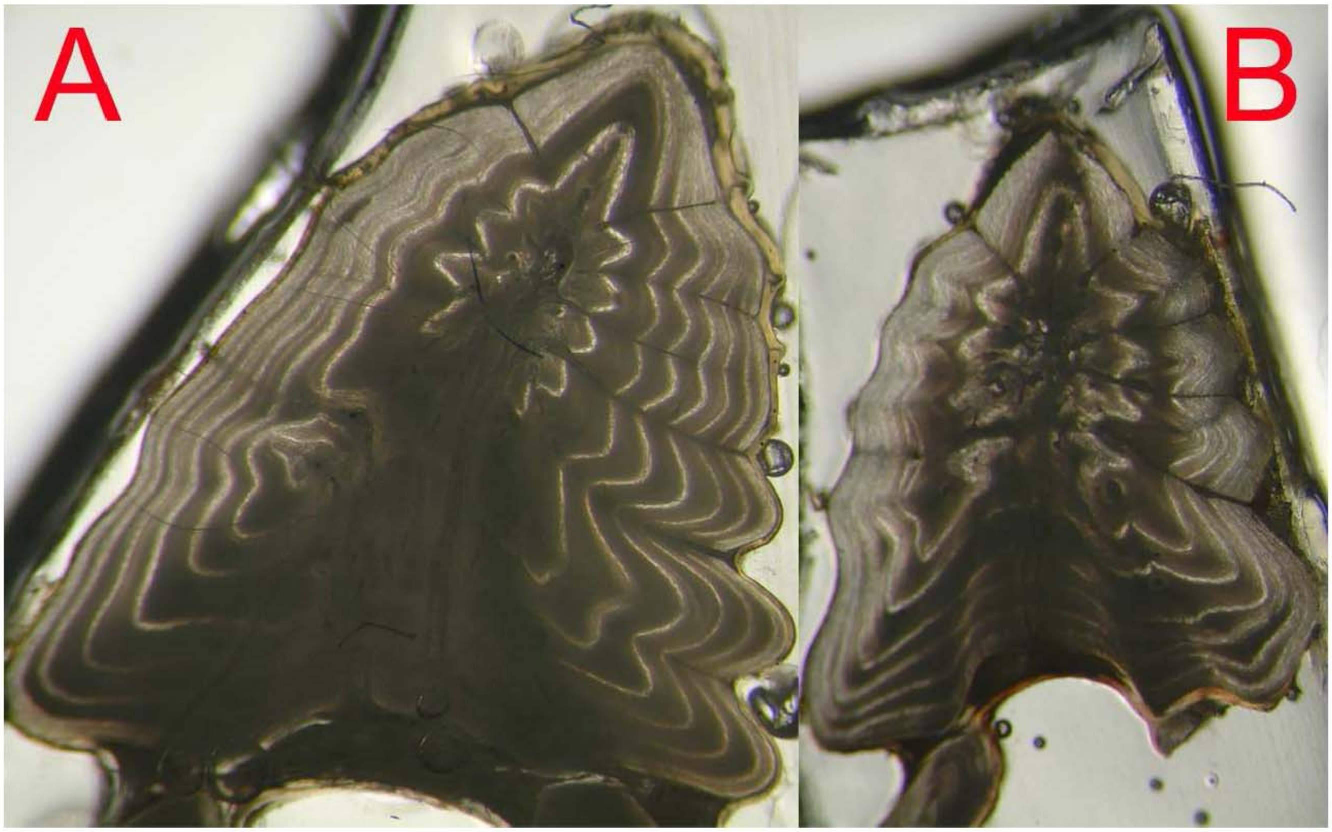


Figure 2. Examples of Lake Sturgeon pectoral fin-ray sections from fish captured in the Winnipeg River, Manitoba. Panel A is from a typical fast-growing age 8 captured from the Slave Falls Reservoir, and panel B is from a typical slow-growing age 7 captured downstream of the Slave Falls Generating Station. Both photo's are taken at 40x magnification. Excerpt from McDougall (2011a). Note the presence of a jagged "first" (interior) annuli present on both structures.

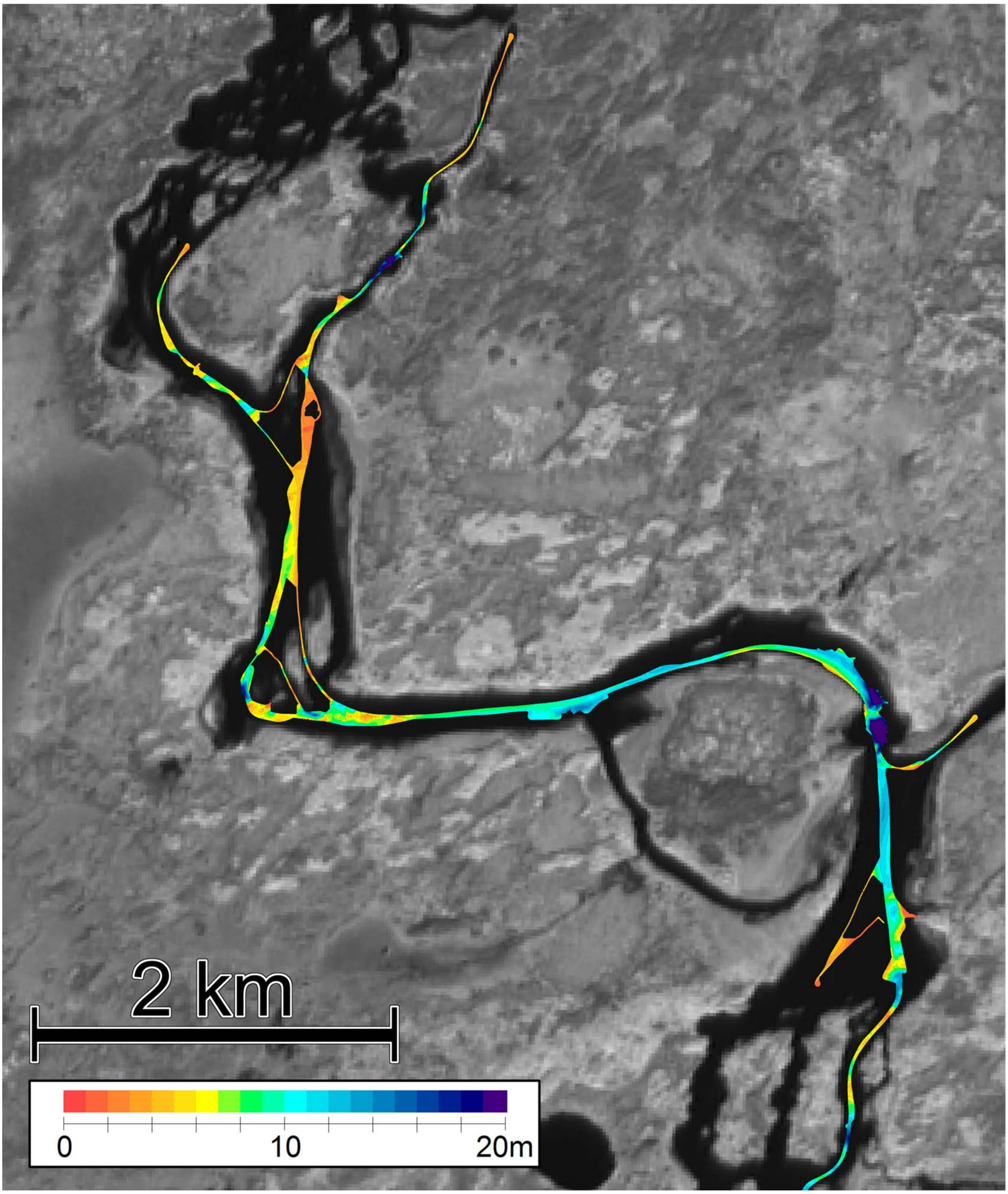


Figure 3a. Preliminary bathymetric map of the Sea Falls to Sugar Falls area (north section), based on opportunistic data collected during fall, 2012.

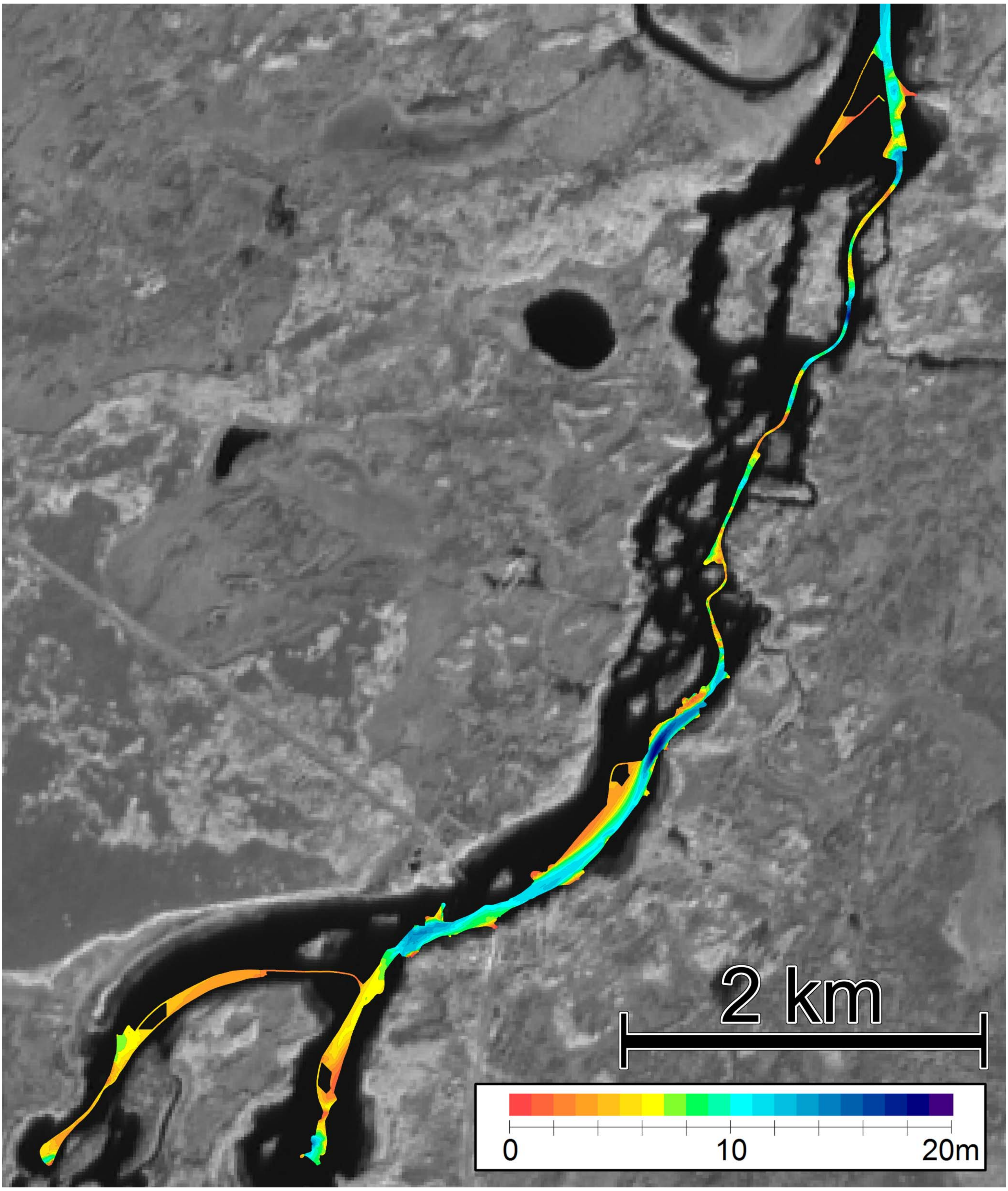


Figure 3b. Preliminary bathymetric map of the Sea Falls to Sugar Falls area (south section), based on opportunistic data collected during fall, 2012.

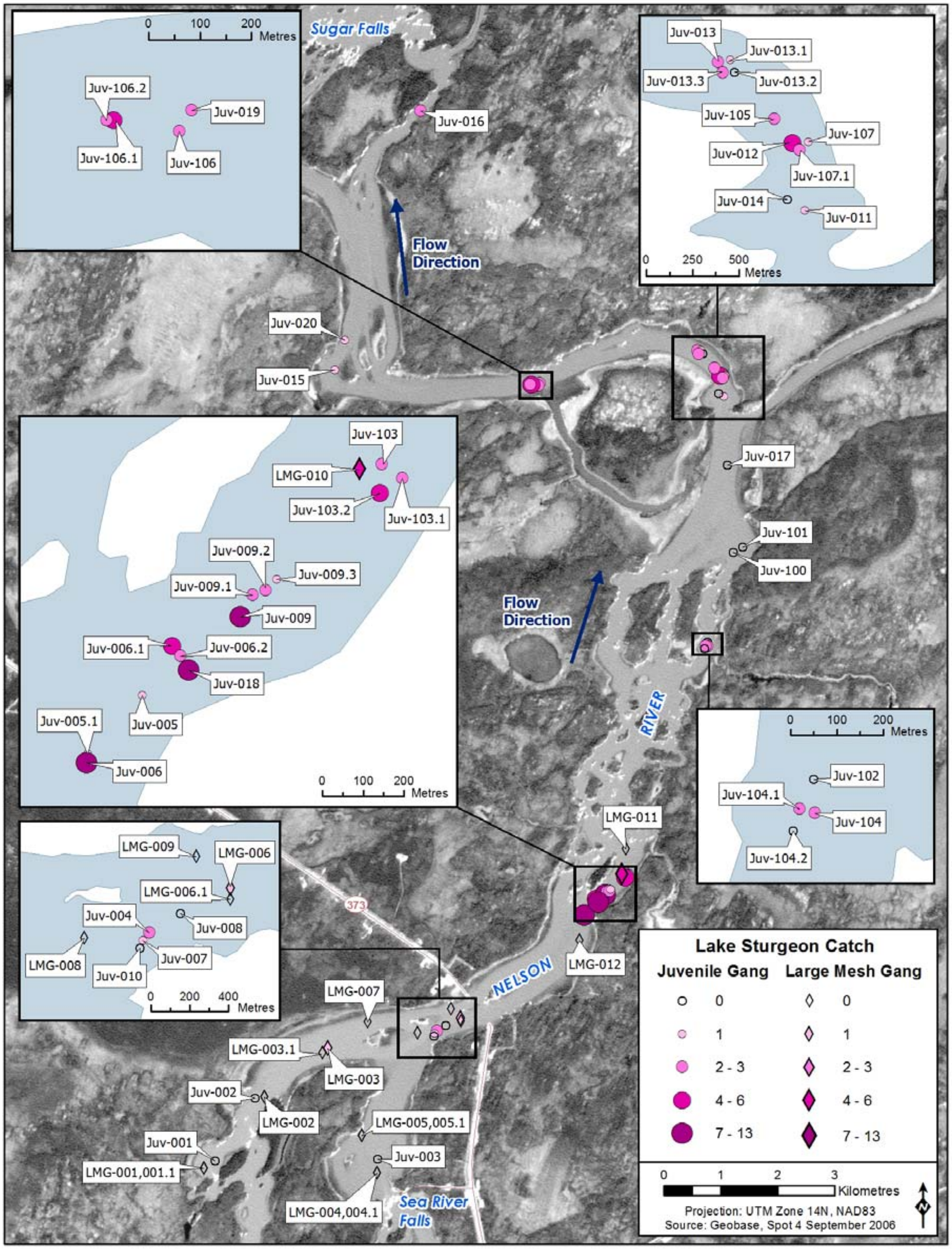


Figure 4. Sea Falls to Sugar Falls gill net and Lake Sturgeon capture locations, fall 2012.

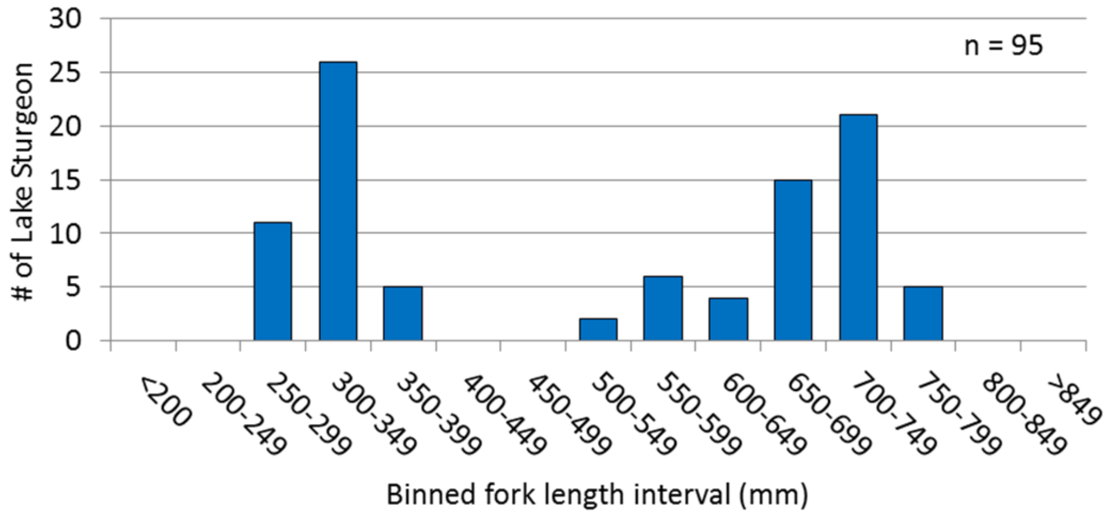


Figure 5. Length-frequency histograms for Lake Sturgeon captured in juvenile gangs set in the Sea Falls to Sugar Falls area, fall 2012. Fish captured multiple times are included herein.

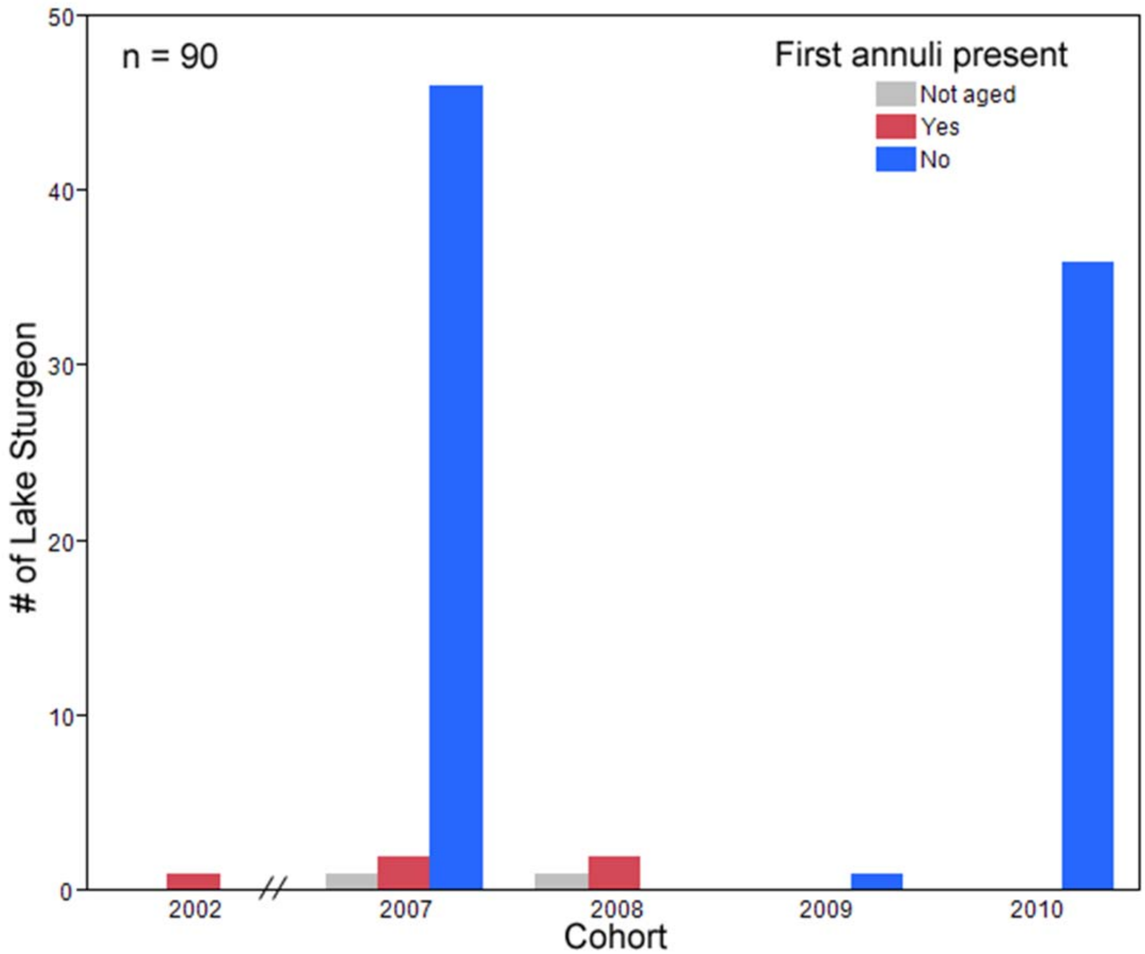


Figure 6. Cohort-frequency histogram for Lake Sturgeon captured in the Sea Falls to Sugar Falls area during fall, 2012. Fish identified as possessing jagged “first” annuli (typical of wild reared Lake Sturgeon) are shown in red, while those with weak or missing “first” annuli are shown in blue. Fish not aged but for which age was known based on PIT tags (n = 2) are shown in grey.

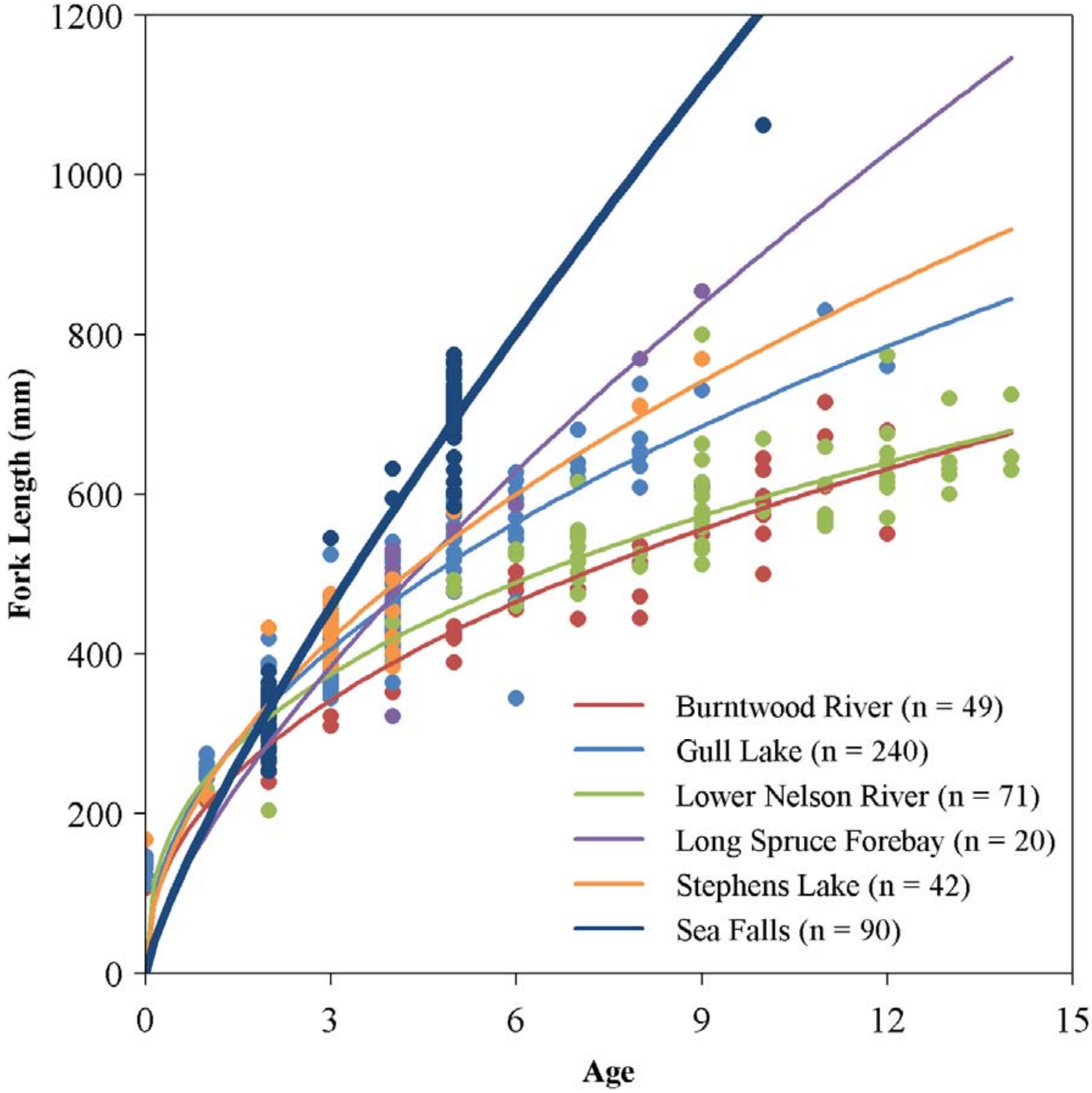


Figure 7. Length-at-age growth comparison between the Sea Falls (to Sugar Falls) reach and other Nelson River locations based on data collected between 2007 – 2012. Data for each locality were fitted using a power relationship: Fork Length = $a(\text{age})^b$.

APPENDICES

Appendix 1. Scientific names, common names and abbreviations for fish species captured in the Sea Falls to Sugar Falls area, fall, 2012. Phylogenetic ranking and taxonomy after Stewart and Watkinson (2004) and Integrated Taxonomic Information System.

Family	Common Name	Scientific Name	ID Code
Acipenseridae	Lake Sturgeon	*Acipenser fulvescens*	LKST
Catostomidae	Longnose Sucker	*Catostomus catostomus*	LNSC
	White Sucker	*Catostomus commersonii*	WHSC
	Shorthead Redhorse	*Moxostoma macrolepidotum*	SHRD
Esocidae	Northern Pike	*Esox lucius*	NRPK
Gadidae	Burbot	*Lota lota*	BURB
Percidae	Sauger	*Sander canadensis*	SAUG
	Walleye	*Sander vitreus*	WALL
	Yellow Perch	*Perca flavescens*	YLPR
Percopsidae	Trout-Perch	*Percopsis omiscomaycus*	TRPR

Appendix 2. Summary of species captured in gill nets set in the Sea Falls to Sugar Falls reach during fall, 2012. Species abbreviations are presented in Appendix 1.

Site	BURB	LKST	LNSC	NRPK	SAUG	SHRD	TRPR	WALL	WHSC	YLPR	Total
Juv-001			1	5		1	5	17	2		**31**
Juv-002	2		3		1	2			4		**12**
Juv-003	5		6						1		**12**
Juv-004	5	2			1				3		**11**
Juv-005	1	1						1	3		**6**
Juv-005.1		1	1					1	1		**4**
Juv-006	2	13	2					1	2		**20**
Juv-006.1	2	4		1				1	3		**11**
Juv-006.2	4	2	2						2		**10**
Juv-007	3	1						1			**5**
Juv-008	7					1			1		**9**
Juv-009		7	1					1	3		**12**
Juv-009.1		2									**2**
Juv-009.2		3							1		**4**
Juv-009.3		1	2	1					2		**6**
Juv-010	7										**7**
Juv-011		1	1						1		**3**
Juv-012	2	6									**8**
Juv-013	1	2							1		**4**
Juv-013.1	1	1	1					3	2		**8**
Juv-013.2	2								2		**4**
Juv-013.3	1	3						1	1		**6**
Juv-014	2							2	2		**6**
Juv-015	2	1									**3**
Juv-016		2	1	1					1		**5**
Juv-017			2			1		2	7		**12**
Juv-018		7	1	1					1		**10**
Juv-019	1	3						1			**5**
Juv-020		1		1		1			5		**8**
Juv-100	3		2								**5**
Juv-101	2		1					4	3		**10**
Juv-102				1							**1**
Juv-103	7	3			2				4		**16**
Juv-103.1	2	2	2			2			4		**12**
Juv-103.2	4	5	2	1					1		**13**
Juv-104	1	3	1	1			2		2		**10**
Juv-104.1	2	2	2					2			**8**
Juv-104.2	2					1		3	1		**7**

Appendix 2. Continued.

Site	BURB	LKST	LNSC	NRPK	SAUG	SHRD	TRPR	WALL	WHSC	YLPR	Total
Juv-105	1	2		1	1			1	2		**8**
Juv-106		3							3		**6**
Juv-106.1	2	5			1				2		**10**
Juv-106.2	1	2				1	2		3		**9**
Juv-107	1	1	1						1	1	**5**
Juv-107.1		3	1								**4**
Juvenile Gang Totals	**78**	**95**	**36**	**14**	**6**	**10**	**9**	**42**	**77**	**1**	**368**
% Captures	**21.2%**	**25.8%**	**9.8%**	**3.8%**	**1.6%**	**2.7%**	**2.4%**	**11.4%**	**20.9%**	**0.3%**	**100%**
LMG-001											**0**
LMG-001.1				2							**2**
LMG-002											**0**
LMG-002.1				1							**1**
LMG-003		1									**1**
LMG-003.1											**0**
LMG-004											**0**
LMG-004.1											**0**
LMG-005											**0**
LMG-005.1											**0**
LMG-006		1									**1**
LMG-006.1											**0**
LMG-007											**0**
LMG-008				1							**1**
LMG-009											**0**
LMG-010		4									**4**
LMG-011											**0**
LMG-012											**0**
Large Mesh Gang Totals	**0**	**6**	**0**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**10**
% Captures	**0%**	**60.0%**	**0%**	**40.0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**100%**

Appendix 3. Biological and tagging data for Lake Sturgeon captured in the Sea Falls to Sugar Falls reach during fall, 2012. Grey cells indicate Lake Sturgeon captured multiple times during the current program. Age and cohort based on known age for PIT tagged fish, and interpreted age for non-PIT tagged fish.

Date	Site ID	Fish #	Fork Length (mm)	Total Length (mm)	Weight (g)	Age	Cohort	Floy Tag ID	PIT Tag ID	Comments
14/09/2012	Juv-004	1	646	741	2150	5	2007	02855		
14/09/2012	Juv-004	2	686	763	1850	5	2007	02856	985 121 012 053 846	
15/09/2012	Juv-005	3	325	370	175	2	2010	02275	982 000 196 028 154	
15/09/2012	Juv-006	4	710	815	2650	5	2007	02857		
15/09/2012	Juv-006	5	310	350	200	2	2010	02858	982 000 196 028 608	
18/09/2012	Juv-103	5						02858	982 000 196 028 608	
15/09/2012	Juv-006	6	700	790	2325	5	2007	02859		
15/09/2012	Juv-006	7	545	625	1200	3	2009	02860		
22/09/2012	Juv-018	7						02860		
15/09/2012	Juv-006	8	255	285	110	2	2010	-	982 000 196 028 510	
15/09/2012	Juv-006	9	595	675	1450	2	2010	02861	985 121 013 710 102	
15/09/2012	Juv-006	10	555	635	1200	2	2010	02862		
15/09/2012	Juv-006	11	335	380	230	5	2007	02863	982 000 196 028 312	
22/09/2012	Juv-018	11						02863	982 000 196 028 312	
15/09/2012	Juv-006	12	300	340	150	5	2007	-	982 000 196 028 617	
15/09/2012	Juv-006	13	715	815	2740	5	2007	02864		
15/09/2012	Juv-006	14	710	810	2460	5	2007	02865	985 121 012 048 516	
15/09/2012	Juv-006	15	730	825	2500	5	2007	02866/02867		Double Floy tagged
15/09/2012	Juv-006	16	710	815	2420	5	2007	02868		
15/09/2012	Juv-007	17	690	785	-	5	2007	02869	985 121 013 714 943	
16/09/2012	Juv-005.1	18	755	855	2800	5	2007	02870	985 121 013 708 635	
16/09/2012	Juv-006.1	19	745	850	2750	5	2007	02871	985 121 013 699 100	
16/09/2012	Juv-006.1	20	690	770	2080	2	2010	02872		
16/09/2012	Juv-006.1	21	735	830	2680	2	2010	02873		

Appendix 3. Continued.

Date	Site ID	Fish #	Fork Length (mm)	Total Length (mm)	Weight (g)	Age	Cohort	Floy Tag ID	PIT Tag ID	Comments
16/09/2012	Juv-006.1	22	295	340	180	2	2010	-	982 000 196 028 219	
18/09/2012	Juv-009.2	22						-	982 000 196 028 219	
16/09/2012	Juv-009	23	330	372	210	2	2010	-	982 000 196 028 540	
16/09/2012	Juv-009	24	335	380	220	5	2007	-	982 000 196 028 289	
16/09/2012	Juv-009	25	310	355	200	5	2007	-	982 000 196 028 147	
16/09/2012	Juv-009	26	775	860	3150	5	2007	02874	985 121 013 711 976	
16/09/2012	Juv-009	27	768	860	2950	5	2007	02875	985 121 013 701 245	
16/09/2012	Juv-009	28	600	680	1720	2	2010	02826	985 121 012 028 553	
17/09/2012	Juv-009.1	28						02826	985 121 012 028 553	
16/09/2012	Juv-009	29	715	810	2590	2	2010	02827	985 121 012 051 909	
17/09/2012	Juv-009.1	30	270	305	110	2	2010	-	982 000 196 028 197	Deformed LPEC
17/09/2012	Juv-011	31	332	376	200	2	2010	-	982 000 196 028 239	
17/09/2012	Juv-012	32	330	384	200	2	2010	-	982 000 196 028 524	
17/09/2012	Juv-012	33	365	410	280	5	2007	02828	982 000 196 028 447	
17/09/2012	Juv-012	34	290	325	150	5	2007	-	982 000 196 028 189	
18/09/2012	Juv-105	34						-	982 000 196 028 189	
17/09/2012	Juv-012	35	630	725	1800	2	2010	02829		
17/09/2012	Juv-012	36	690	750	2450	2	2010	02830	985 121 013 716 664	
17/09/2012	Juv-012	37	728	800	2310	2	2010	02831	985 121 012 026 879	
17/09/2012	Juv-013	38	310	355	170	5	2007	-	982 000 196 028 505	
18/09/2012	Juv-105	38						-	982 000 196 028 505	
22/09/2012	Juv-013.3	38						-	982 000 196 028 505	
17/09/2012	Juv-013	39	304	316	170	2	2010	-		
18/09/2012	Juv-009.2	40	379	429	270	5	2007	02832	982 000 196 028 356	
18/09/2012	Juv-009.2	41	720	810	2620	5	2007	02833		
18/09/2012	Juv-015	42	342	388	210	2	2010	-	982 000 196 028 177	
18/09/2012	Juv-013.1	43	698	789	2400	2	2010	02834	985 121 012 048 507	

Appendix 3. Continued.

Date	Site ID	Fish #	Fork Length (mm)	Total Length (mm)	Weight (g)	Age	Cohort	Floy Tag ID	PIT Tag ID	Comments
20/09/2012	Juv-009.3	44	698	789	2340	5	2007	02835	985 121 013 705 169	Deformed RPEC
20/09/2012	Juv-016	45	325	372	200	5	2007	-	982 000 196 028 439	
20/09/2012	Juv-016	46	585	665	1400	2	2010	02836		Deformed LPEC, RPEC
22/09/2012	Juv-018	47	300	340	170	5	2007	-	982 000 196 028 546	
22/09/2012	Juv-018	48	710	800	2440	5	2007	02837	985 121 013 713 557	
22/09/2012	Juv-018	49	720	815	2650	5	2007	02838	985 121 012 048 547	
22/09/2012	Juv-018	50	710	810	2260	5	2007	02839	985 121 013 701 666	
22/09/2012	Juv-103.2	51	334	380	220	5	2007	-	982 000 196 028 203	
22/09/2012	Juv-103.2	52	755	845	2840	5	2007	02840	985 121 013 701 414	
22/09/2012	Juv-103.2	53	734	820	2850	2	2010	02841	985 121 012 050 111	
22/09/2012	Juv-103.2	54	708	795	2630	5	2007	-	985 121 013 703 622	Fish was Floy tagged (02842), but tag found in boat
22/09/2012	Juv-103.2	55	672	772	1940	5	2007	02843		
14/09/2012	LMG-003	1001	755	830	-	5	2007	02501	985 121 013 700 865	
14/09/2012	LMG-006	1002	1062	1190	-	5	2007	02502		
16/09/2012	LMG-010	1003	632	718	-	2	2010	02504	985 121 008 492 129	
16/09/2012	LMG-010	1004	725	836	-	2	2010	02505	985 121 013 712 227	
16/09/2012	LMG-010	1005	615	697	-	5	2007	02506	985 121 008 552 692	No ageing structure - PEC fins severely deformed
22/09/2012	Juv-018	1005						02506	985 121 008 552 692	Deformed LPEC, RPEC
16/09/2012	LMG-010	1006	319	357	-	5	2007	-	982 000 196 028 130	
17/09/2012	Juv-006.2	1007	692	780	2100	2	2010	02507		
17/09/2012	Juv-006.2	1008	603	688	1850	2	2010	02509		
18/09/2012	Juv-103	1009	737	835	3150	5	2007	02510	985 121 013 702 119	
18/09/2012	Juv-103	1010	763	856	3500	2	2010	02511		
18/09/2012	Juv-106	1011	328	371	200	2	2010	-	982 000 196 028 206	
18/09/2012	Juv-106	1012	278	293	200	5	2007	-		
18/09/2012	Juv-106	1013	706	793	2600	2	2010	02512	985 121 011 991 544	
18/09/2012	Juv-104	1014	697	805	1800	2	2010	02513	985 121 013 701 161	

Appendix 3. Continued.

Date	Site ID	Fish #	Fork Length (mm)	Total Length (mm)	Weight (g)	Age	Cohort	Floy Tag ID	PIT Tag ID	Comments
18/09/2012	Juv-104	1015	325	375	250	2	2010	-	982 000 196 028 212	
18/09/2012	Juv-104	1016	324	375	250	2	2010	-	982 000 196 028 339	
20/09/2012	Juv-103.1	1017	749	838	3000	5	2007	02515	985 121 013 702 969	
20/09/2012	Juv-103.1	1018	347	392	300	5	2007	-	982 000 196 028 142	
20/09/2012	Juv-107	1019	313	359	250	2	2010	-	982 000 196 028 600	
22/09/2012	Juv-107.1	1019						-	982 000 196 028 600	
20/09/2012	Juv-106.1	1020	685	777	2250	5	2007	02516	985 121 012 032 304	
20/09/2012	Juv-106.1	1021	364	412	350	5	2007	-	982 000 196 028 430	
20/09/2012	Juv-106.1	1022	254	-	100	2	2010	-	982 000 196 028 583	No total length, end of caudal missing
20/09/2012	Juv-106.1	1023	357	407	150	5	2007	-	982 000 196 028 624	
20/09/2012	Juv-106.1	1024	352	404	150	5	2007	-	982 000 196 028 321	
20/09/2012	Juv-104.1	1025	712	808	2000	5	2007	-	985 121 013 703 454	Mortality: ~20 small crayfish in stomach
20/09/2012	Juv-104.1	1026	671	768	1850	5	2007	02517		
22/09/2012	Juv-020	1027	284	324	-	2	2010	-	982 000 196 028 616	
22/09/2012	Juv-106.2	1028	745	850	3200	2	2010	02518		
22/09/2012	Juv-106.2	1029	734	835	2600	4	2008	02519	985 121 011 983 126	
22/09/2012	Juv-019	1030	267	303	-	5	2007	-	982 000 196 028 383	
22/09/2012	Juv-019	1031	680	785	2600	5	2007	02520	985 121 011 981 957	
22/09/2012	Juv-019	1032	585	663	1500	10	2002	02521		
22/09/2012	Juv-013.3	1033	680	786	2150	4	2008	02522	985 121 013 701 998	
22/09/2012	Juv-013.3	1034	692	780	2300	-	-	02523		
22/09/2012	Juv-107.1	1035	338	380	250	5	2007	-	982 000 196 028 504	Mortality:~10 ephemeroptera, 2 freshwater shrimp
22/09/2012	Juv-107.1	1036	342	385	300	5	2008	-	982 000 196 028 478	

Appendix 4. Over-winter thermal regime and mean size of Lake Sturgeon from (A) the 2007 cohort and (B) the 2010 cohort reared at the Grand Rapids hatchery and stocked at Sea Falls. Only total lengths were measured, but for consistency with report data we calculated fork lengths based on the following equation: TL = 1.1278(FL) + 2.0719, generated from Sea Falls length data.

(A)

		Fork Length (mm)			Total Length (mm)		
Month	Mean Temp. (°C)	Mean	Min.	Max.	Mean	Min.	Max.
Oct-07	15.9	156	149	164	178	170	187
Nov-07	17.4	195	179	213	222	204	242
Dec-07	17.5	222	189	246	253	215	280
Jan-08	17.5	248	233	278	282	265	316
Feb-08	16.8	265	245	301	301	278	342
Mar-08	17.2	285	241	317	323	274	360
Apr-08	17.3	296	255	335	336	290	380
May-08	16.2	315	264	344	357	300	390
Jun-08	15.1	338	300	405	383	340	459
Sept-08 (stocked size)	**-**	**344**	**317**	**383**	**390**	**360**	**434**

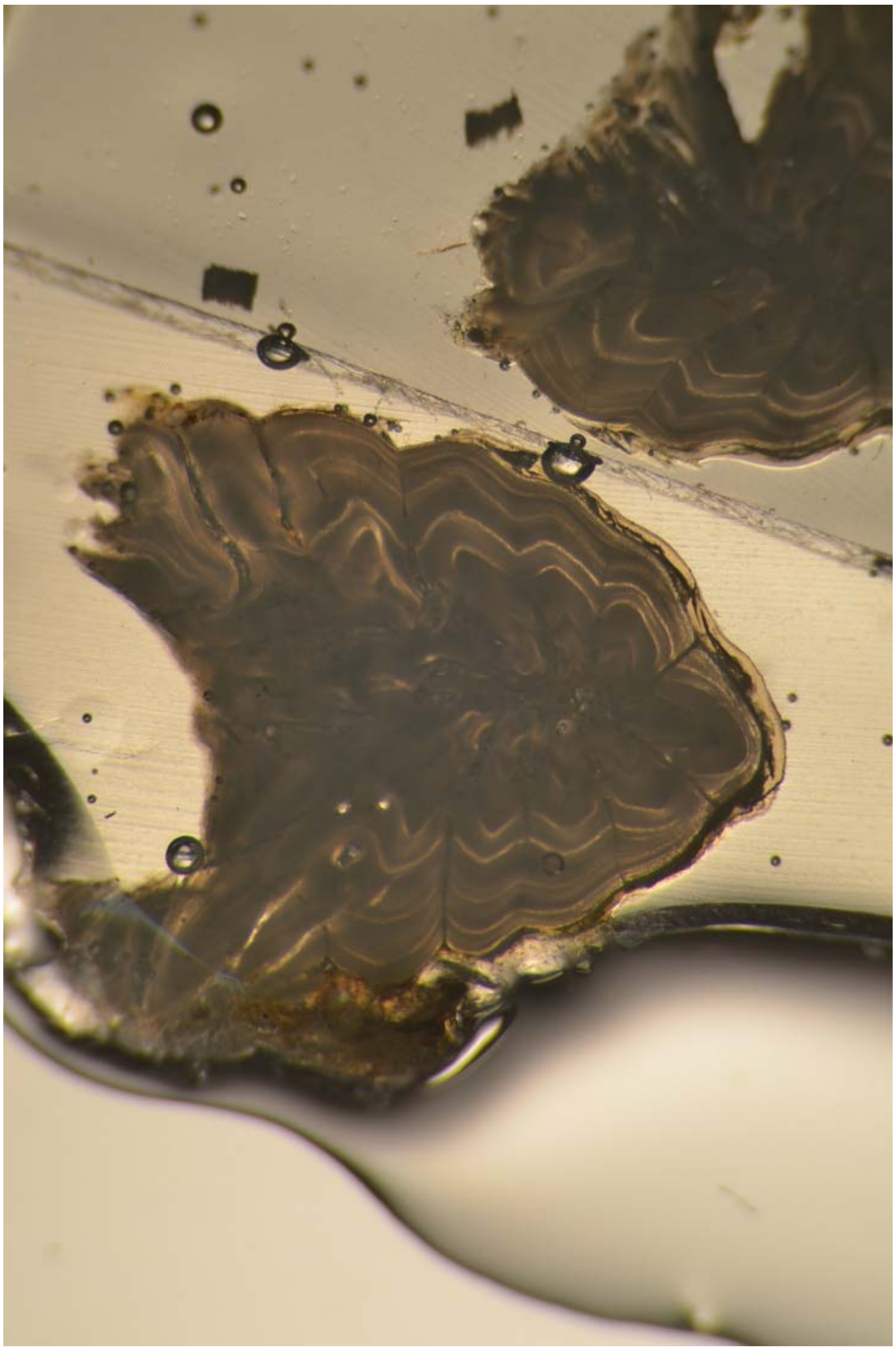
NOTE: On 6 June, 2008, fish were taken off recirculated well water and put on straight flow through Forebay water.

(B)

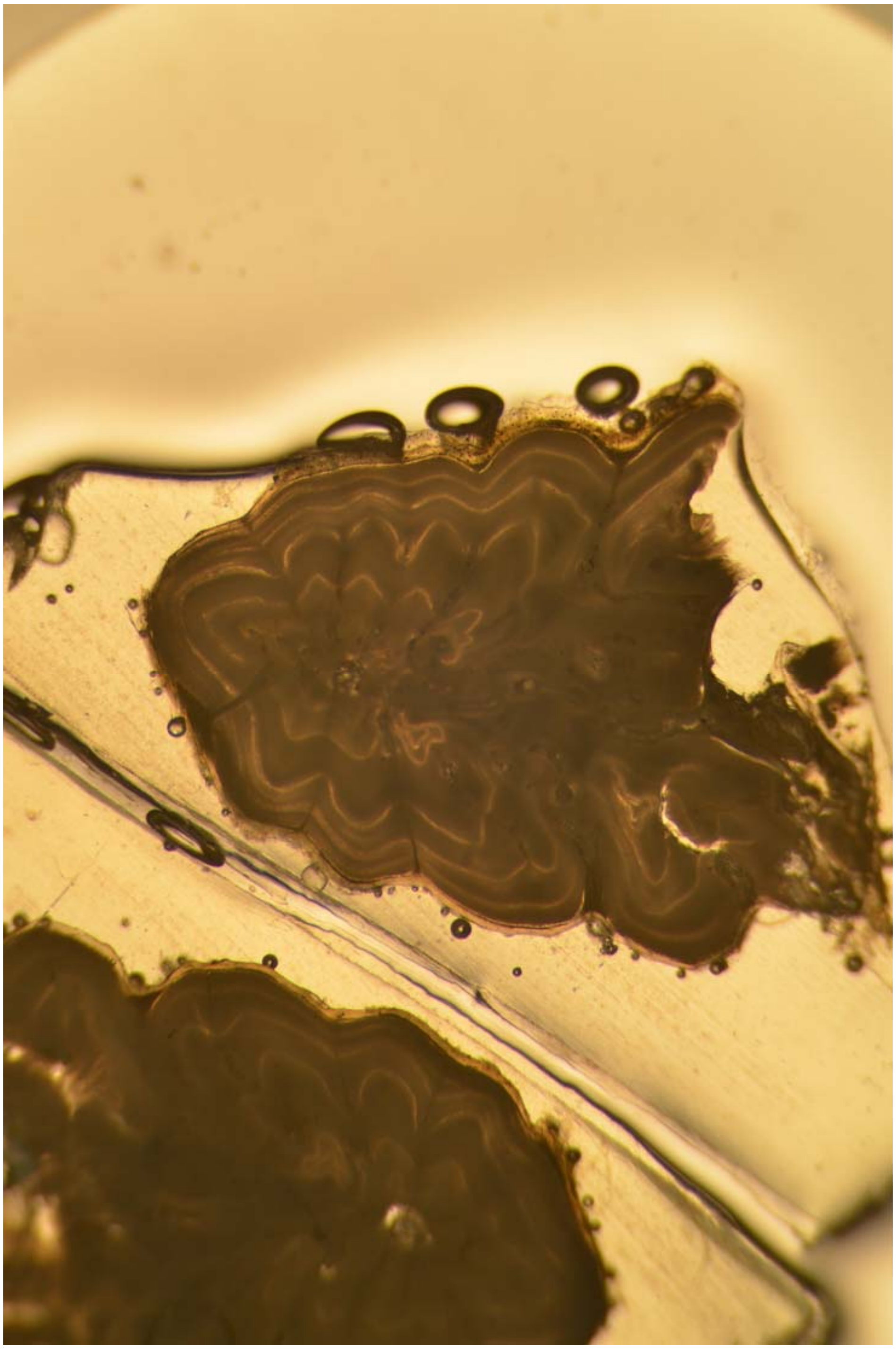
		Fork Length (mm)			Total Length (mm)		
Month	Mean Temp. (°C)	Mean	Min.	Max.	Mean	Min.	Max.
Oct-10	13.0	92	83	106	106	96	122
Nov-10	11.3	-	-	-	-	-	-
Dec-10	12.3	113	83	137	130	96	157
Jan-11	12.0	113	87	131	130	100	150
Feb-11	12.4	-	-	-	-	-	-
Mar-11	12.0	134	109	158	153	125	180
Apr-11	12.2	-	-	-	-	-	-
May-11	10.3	-	-	-	-	-	-
Oct-11 (stocked size)	**-**	**209**	**141**	**243**	**238**	**161**	**276**

NOTE: On 1 March, 2011, fish were taken off recirculated Forebay water and put on recirculated well water. On 1 May, 2011, recirculated well water was again changed to straight flow through Forebay water.

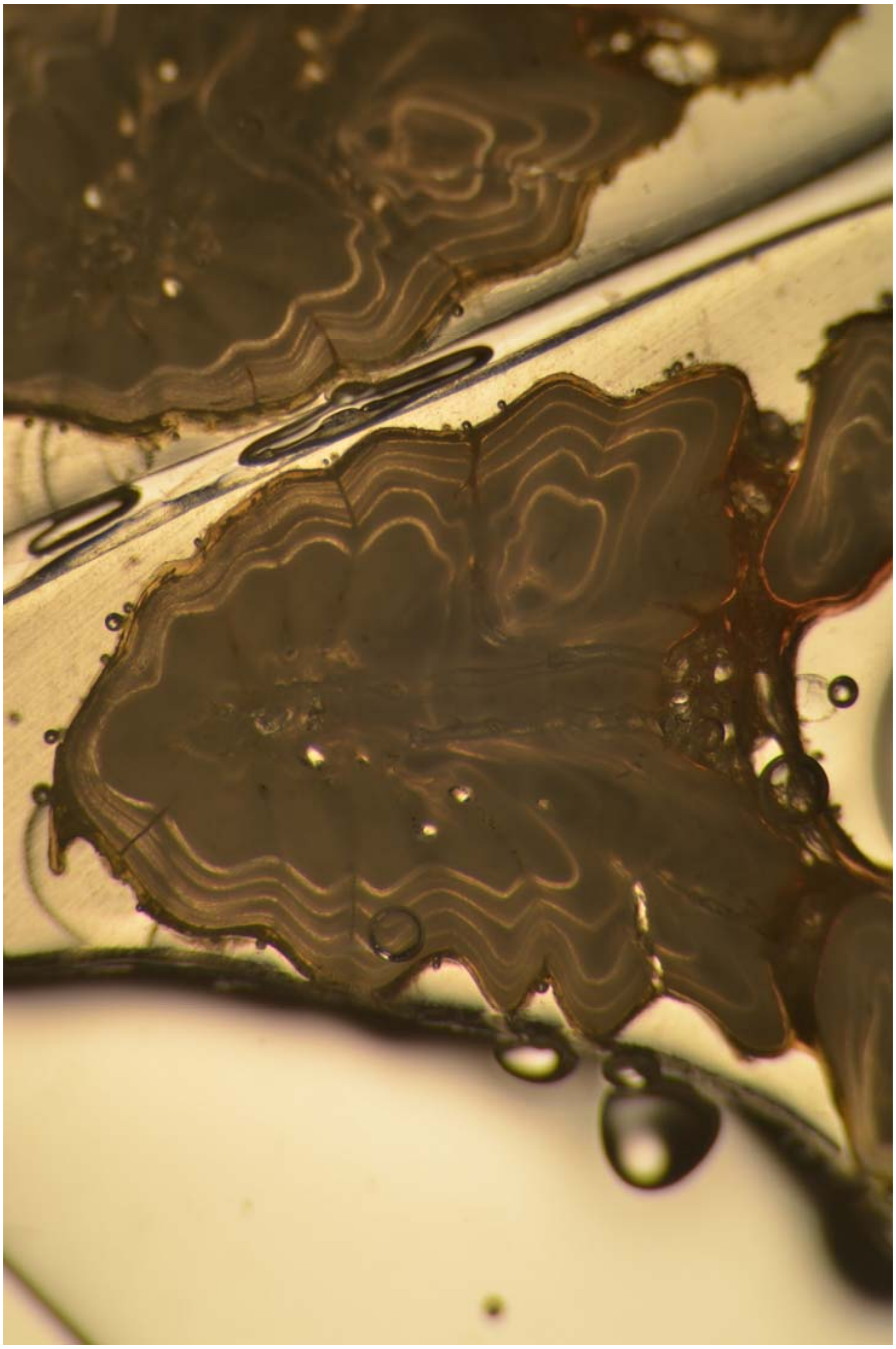
Appendix 5. Ageing structures of representative Lake Sturgeon captured in the Sea Falls to Sugar Falls reach during fall, 2012. Shown below is LKST #1 (646 mm FL), which was not PIT tagged and determined to be from the 2007 cohort (age 5). Readers inferred a weak or absent "first" annuli.



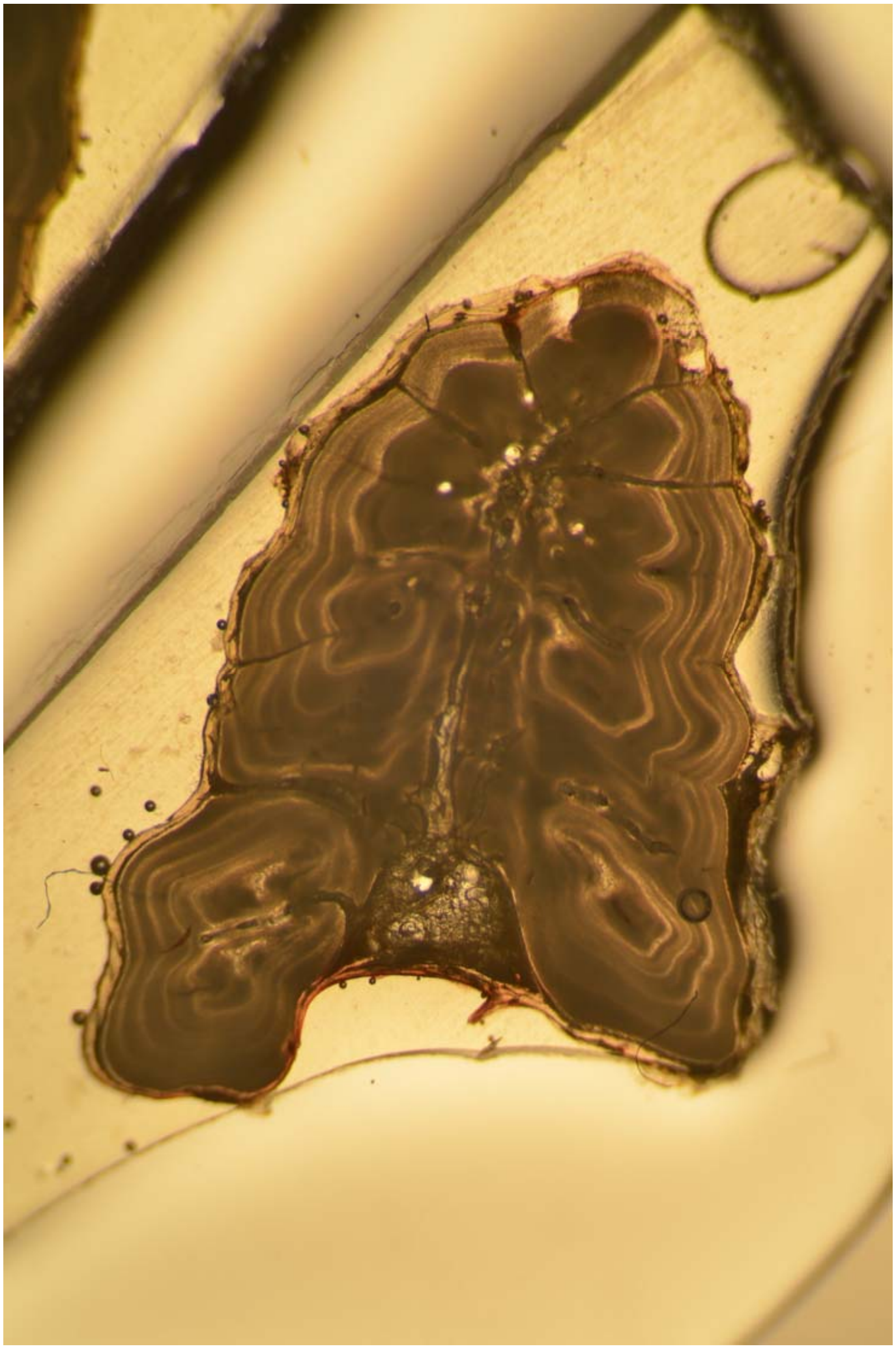
Appendix 5. Continued. Shown below is LKST #9 (595 mm FL), which was PIT tagged and determined (accurately) to be from the 2008 cohort (age 4). Readers noted the presence of a “first” annuli.



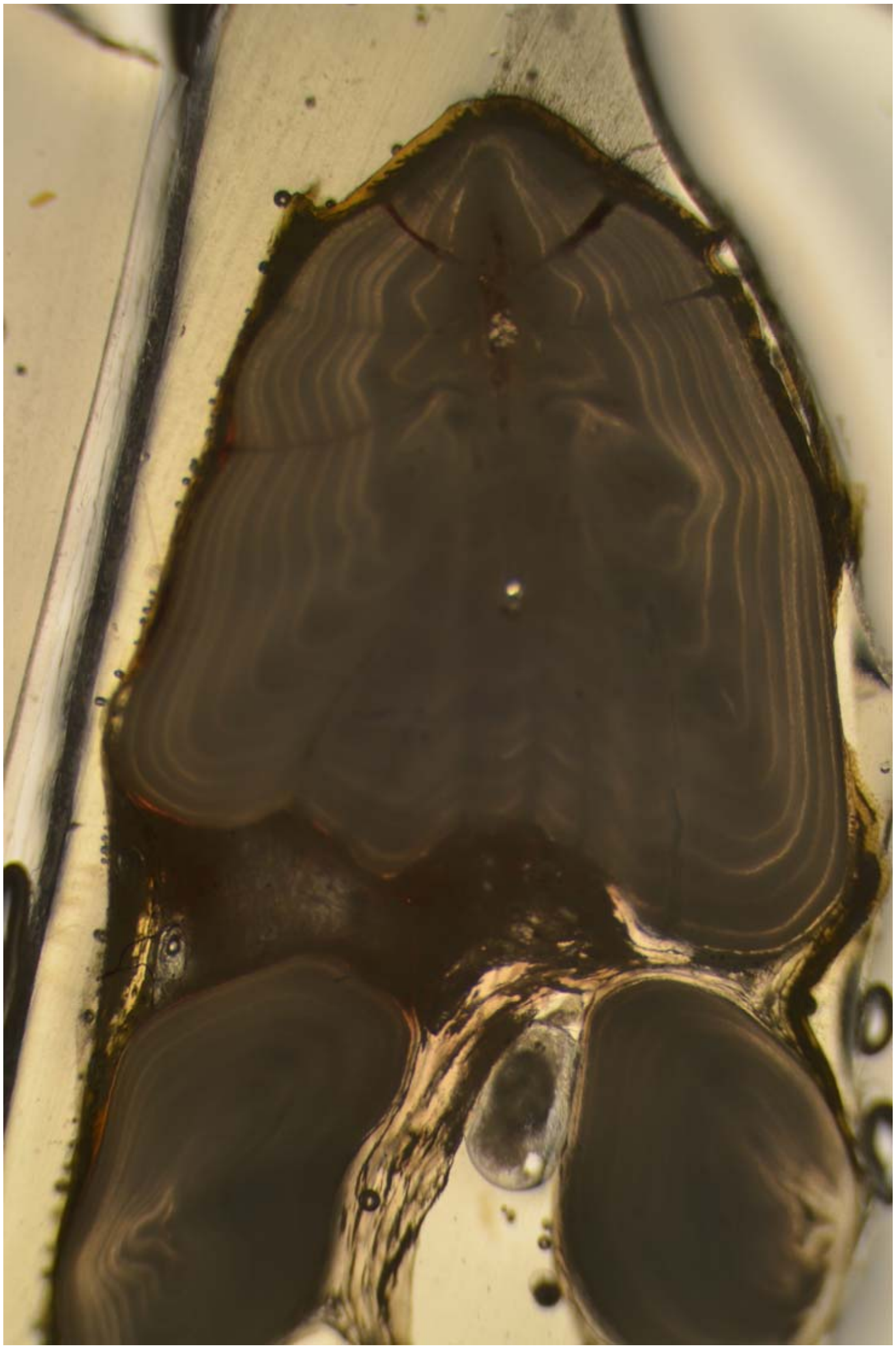
Appendix 5. Continued. Shown below is LKST #16 (710 mm FL), which was not PIT tagged and determined to be from the 2007 cohort (age 5). Readers inferred a weak or absent "first" annuli.



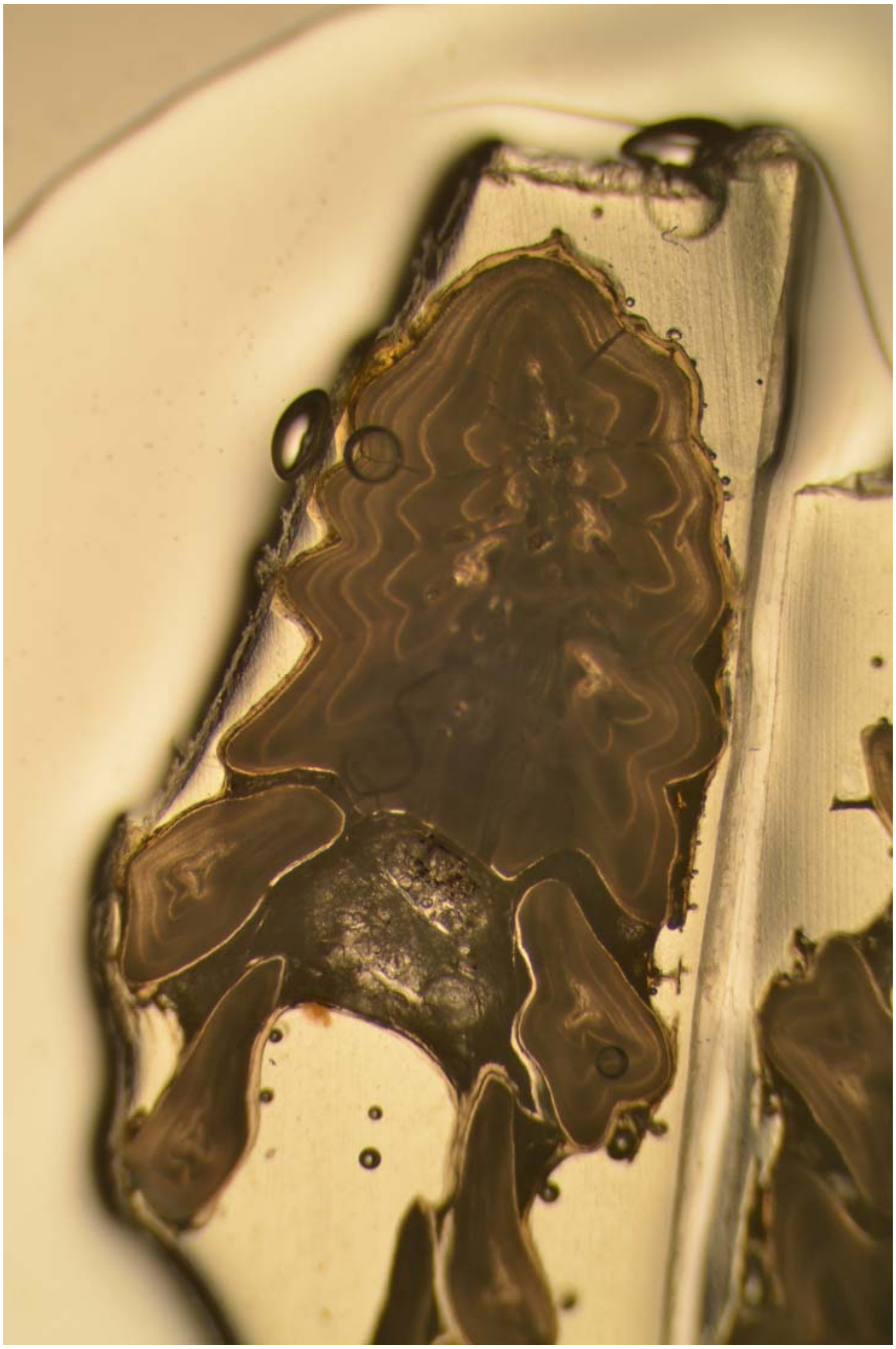
Appendix 5. Continued. Shown below is LKST #1001 (755 mm FL), which was PIT tagged and determined (accurately) to be from the 2007 cohort (age 5). Readers inferred a weak or absent "first" annuli.



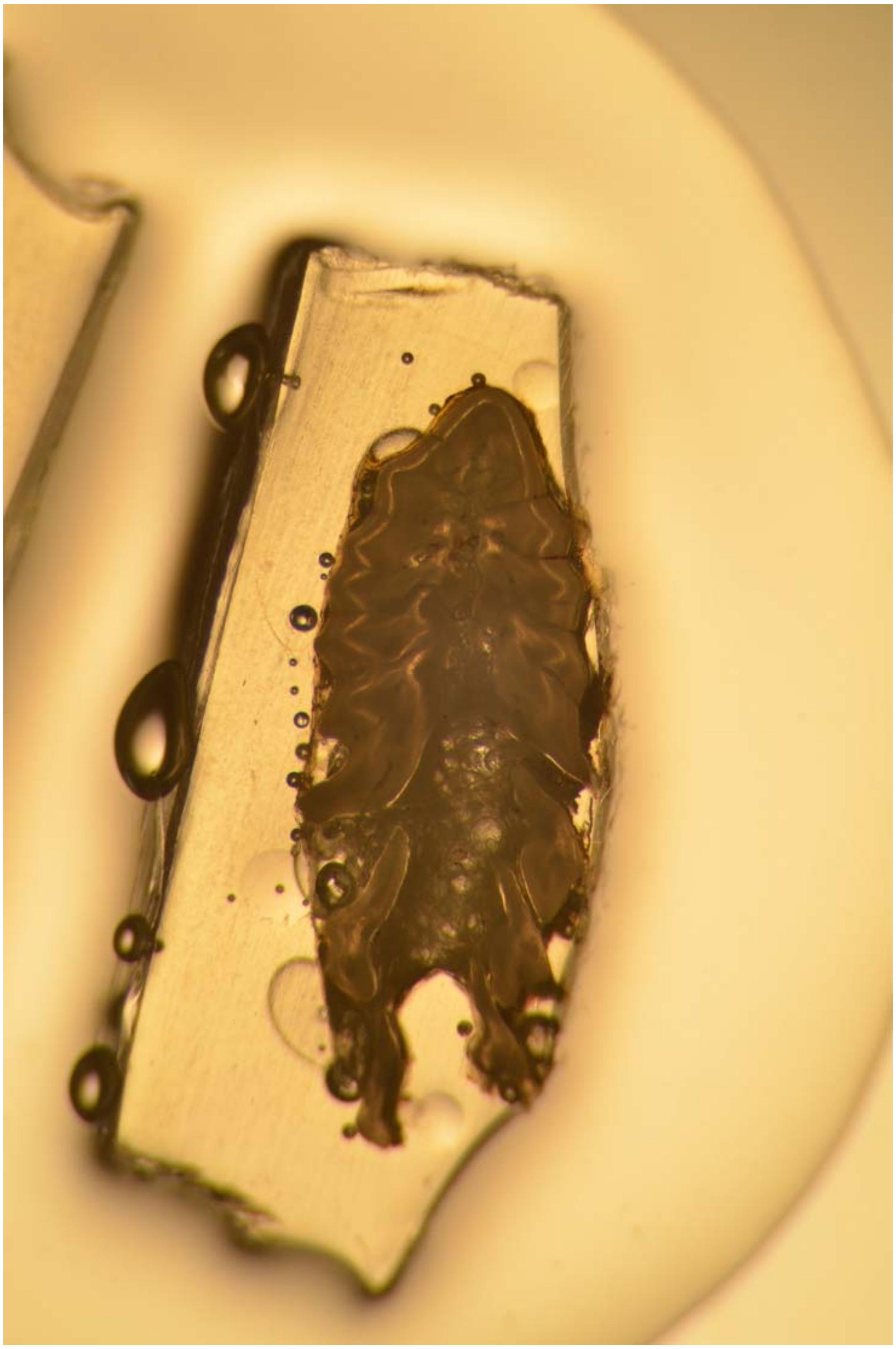
Appendix 5. Continued. Shown below is LKST #1002 (1062 mm FL), which was not PIT tagged and determined to be from the 2002 cohort (age 10). Readers noted the presence of a "first" annuli.



Appendix 5. Continued. Shown below is LKST #1003 (632 mm FL), which was PIT tagged and determined (accurately) to be from the 2008 cohort (age 4). Readers noted the presence of a “first” annuli.



Appendix 5. Continued. Shown below is LKST #1019 (313 mm FL), which was PIT tagged and determined (accurately) to be from the 2010 cohort (age 2). Readers inferred a weak or absent "first" annuli.



Appendix 5. Continued. Shown below is LKST #1021 (364 mm FL), which was PIT tagged and determined (accurately) to be from the 2010 cohort (age 2). Readers inferred a weak or absent "first" annuli. Both sections cut are shown.