Lake Superior Lake Sturgeon Index Survey: 2011 Status Report

A report of the Lake Superior Lake Sturgeon Work Group to the Great Lakes Fishery Commission, Lake Superior Technical Committee, and Binational Program Aquatic Community Committee

Lake Superior Lake Sturgeon Work Group Report 1

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SUMMARY

The value of lake sturgeon *Acipenser fulvescens* to the Lake Superior ecosystem and people of the region warrants rehabilitation efforts to restore populations. The goal of the Lake Superior Lake Sturgeon Index Survey was to address assessment, research, and management needs to facilitate lake sturgeon rehabilitation. The objectives were to 1) describe the current status, 2) establish an index of relative abundance, and 3) describe the biological characteristics of lake sturgeon in Lake Superior. This paper also evaluated the performance of the sampling design and protocol. Sampling efforts focused on mouths of historic and current spawning tributaries (19 tributaries, 17 sampling locations) which were grouped into Northern, Western, and Eastern regions based on previous genetic analyses. A target sample size of 8-16 net sets were randomly distributed within inner, middle, and outer strata at each tributary. Gill net gangs were set in water depths of 3-15 m and made of two identical monofilament gill nets of 11.4 cm, 20.3 cm, and 25.4 cm stretch mesh (304.8 m total net length). A total of 86, 158, and 121 lake sturgeon were captured in the Northern, Western, and Eastern regions, respectively. No lake sturgeon were caught off the Pigeon, Nipigon, and Gravel rivers. Most tributaries had low catch per unit effort (CPUE as catch per 304.8 m net; 0.0-1.0), but five had a CPUE of 1.0-3.0 (Wolf/Black Sturgeon, Pic/White, St. Louis, Bad, and Ontonagon rivers), and the Goulais River had a CPUE of 5.7. The smallest lake sturgeon was 355 mm and largest was 1,510 mm, but most were 400-1,000 mm total length. Age ranged from 2 to 28 years, but 76% were between 3 and 11 years. Condition varied little among regions. Mean length at age estimates were similar among regions at ages five and six, but diverged for 10 years and older, possibly due to age estimation error. CPUE was significantly higher in the inner strata than the middle or outer strata, validating the sampling premise that juveniles and sub-adults congregate near tributary mouths. Power analysis indicated a 50% increase in CPUE could be detected at three tributaries with 24 or fewer net sets, but power improved when data were amalgamated within regions. The Lake Sturgeon Index Survey demonstrated the ability to collect valuable biological information on an understudied segment of the population. This methodology could be standardized among all Great Lakes to provide a consistent assessment of lake sturgeon populations on a Great Lakes wide scale.

INTRODUCTION

Lake sturgeon *Acipenser fulvescens* are a valuable component of Lake Superior's native fish community and are culturally significant to the people of the region. The lake sturgeon is the largest and longest lived fish in Lake Superior and serves as an indicator species for ecosystem health and biodiversity. Between the mid-1800s and early-1900s, the combination of a targeted commercial fishery (Baldwin et al. 2009), habitat loss, pollution, and migration barriers, such as dams, decimated populations throughout Lake Superior as well as the other Great Lakes (Slade and Auer 1997, Auer 1999a). Although lake sturgeon populations around the Lake Superior basin are reduced from historic levels, lake sturgeons are a food source for Native American and First Nation subsistence fishers and fill an important spiritual role for these cultures (Holzkamm and Waisberg 2004). A small fishery also exists for state licensed sport anglers in Wisconsin, but with restrictive harvest regulations (i.e., one 50" fish per tag per year; WDNR 2013).

Protective measures for lake sturgeon were implemented in response to depressed populations of this valuable species by establishing restrictive harvest regulations, fishery closures, and run-of-river hydropower operations (Auer 1996; Slade and Auer 1997). Lake sturgeon is listed as threatened under the State of Michigan's Endangered Species Act and in the Great Lakes-Upper St. Lawrence River in Ontario by the Committee on the Status of Species at Risk in Ontario (COSSARO) (Golder Associates Ltd. 2011). Lake sturgeon is a species of special concern in Minnesota. Great Lakes lake sturgeon populations were identified as threatened by the Committee on the Status of Endangered Wildlife in Canada in 2008, though a formal listing decision under the Species at Risk Act in Canada has not yet been rendered. Lake sturgeon recovery and management plans are currently in place for many Lake Superior management jurisdictions (WDNR 2000; Auer 2003; Schreiner et al. 2006; Golder Associates 2011; Hayes and Caroffino 2012), but restoration goals have not been met for many populations. It has only been within the last 20 to 30 years that interest in lake sturgeon restoration has greatly increased.

The lake sturgeon rehabilitation plan for Lake Superior (Auer 2003) was developed by the Lake Sturgeon Subcommittee of the Lake Superior Technical Committee to outline rehabilitation goals and management strategies to re-establish or enhance lake sturgeon stocks. This plan categorized lake sturgeon ages 0-5 and 35-599 mm long as juveniles, ages 5-15 and 600-999 mm as sub-adults, and ages > 15 and >999 mm as adults. The rehabilitation plan also identified specific assessment, research, and management needs to help facilitate lake sturgeon rehabilitation. Some of the needs identified include development of a lake-wide sampling protocol for various lake sturgeon life stages, assessing the recruitment of juveniles to the adult population, assessing lake sturgeon abundance relative to major spawning tributaries, coordinating the collection, analysis, and reporting of biological information among agencies, and establishing a uniform marking and tagging database among agencies. These needs were also recognized by Holey et al. (2000) for lake sturgeon populations across the Great Lakes.

The goal of the Lake Superior Lake Sturgeon Index Survey, implemented through the Lake Superior Lake Sturgeon Work Group, was to address some of the needs identified in the Rehabilitation Plan. Specifically, the objectives were to 1) describe the current lake-wide status of juvenile and sub-adult lake sturgeon (ages ~4-15; total lengths ~500-999 mm), 2) establish an index of relative abundance to monitor recruitment, year class strength, and population trends over time, and 3) describe and compare the biological characteristics of lake sturgeon within and among locations throughout Lake Superior and over time. As lake sturgeon rehabilitation progresses, this survey will serve as a means by which to evaluate restoration progress on a broad-scale.

A secondary group of objectives for this paper was to evaluate the performance of the sampling protocol and design because this was the first time such a survey was conducted. These objectives were to determine if 1) the sampling gear effectively captured the target size and age range of lake sturgeon, 2) the sampling design met the premise that juvenile and sub-adult lake sturgeon tended to congregate near the mouth of spawning tributaries, 3) there will be sufficient power to detect changes in relative abundance in the future, and 4) understand patterns of by-catch on a lake-wide scale.

SPAWNING TRIBUTARIES

There have been 21 Lake Superior tributaries identified with either current or extirpated lake sturgeon populations which should be the focus of rehabilitation efforts (Holey et al. 2000; Auer 2003; Quinlan 2007; Pratt 2008; Figure 1). A population was considered extirpated if there has been no recent evidence of successful reproduction, which consisted of adults spawning, egg fertilization, hatched larvae, or young-of-year present. There are currently nine tributaries known to support reproducing populations (Holey et al. 2000; Auer 2003); the St. Louis, Bad (which includes the White River a tributary to the Bad River), Sturgeon, Goulais, Pic, White (Ontario), Nipigon, Black Sturgeon, and Kaministiquia rivers.

Sampling juveniles and sub-adults in Lake Superior proper near tributary mouths may provide a representative index of population levels by which managers can assess the current status of individual reproducing populations. Each spawning tributary is unique in its state of population health (e.g., extirpated, limited reproduction, self-sustaining) and specific impairments. This justifies the need for individual assessments near tributary mouths to monitor population trends related to tributary specific rehabilitation or management actions. When a tributary name is referenced in this paper regarding sampling efforts, we are referring to the main lake study area off the mouth of the tributary, not the actual riverine portion of the tributary.

Studies have indicated that some lake sturgeon demographic and biological characteristics are consistent among populations and warrant analysis at a regional scale (Harkness and Dymond 1961; Scott and Crossman 1973; Becker 1983; Peterson et al. 2002; Stewart and Watkinson 2004). To delineate biologically relevant regional units, Welsh et al. (2008) highlighted genetic similarity as a primary factor, but also identified straying, distance between sites, intervening habitat, and stocking as other factors to consider. Welsh et al. (2008) identified three upper level clusters for the Great Lakes based on genetics: 1) Northern Lake Superior, 2) Western Lake Superior (referred to as southern in Welsh et al. 2008), and 3) remaining Great Lakes locations. To make relevant lake-wide comparisons of biological characteristics within this report, we grouped spawning tributaries into three regions based on the genetic analysis of Welsh et al. (2008), proximity to nearby tributaries, and observed straying of recaptured fish through various fisheries assessments. The Northern Lake Superior region included the Pigeon, Kaministiquia, Wolf, Black Sturgeon, Nipigon, Gravel, Prairie, Pic, White, and Michipicoten rivers. The tributary mouths for the Wolf and Black Sturgeon, and Pic and White rivers were within 10 km of each other and were simultaneously sampled in pairs. The Western Lake Superior region consisted of the St. Louis, Bad, Montreal, Ontonagon, and Sturgeon (North and South entry) rivers. The Batchawana and Goulais rivers were genetically more similar to other Great Lakes populations than the Northern and Western regions of Lake Superior (Welsh et al. 2008). For this reason, these rivers were grouped into the Eastern Lake Superior region. Due to close proximity of the Tahquamenon and Chippewa rivers to the Batchawana and Goulais rivers, these two rivers were also grouped into the Eastern Lake Superior region, although they have not been genetically assessed. The Batchawana and Chippewa rivers were simultaneously sampled due to their close proximity. Harmony River and Stokely Creek, which both drain into Batchawana Bay and have extirpated populations (Holey et al. 2000), were also considered to be part of the Batchawana/Chippewa rivers assessment.

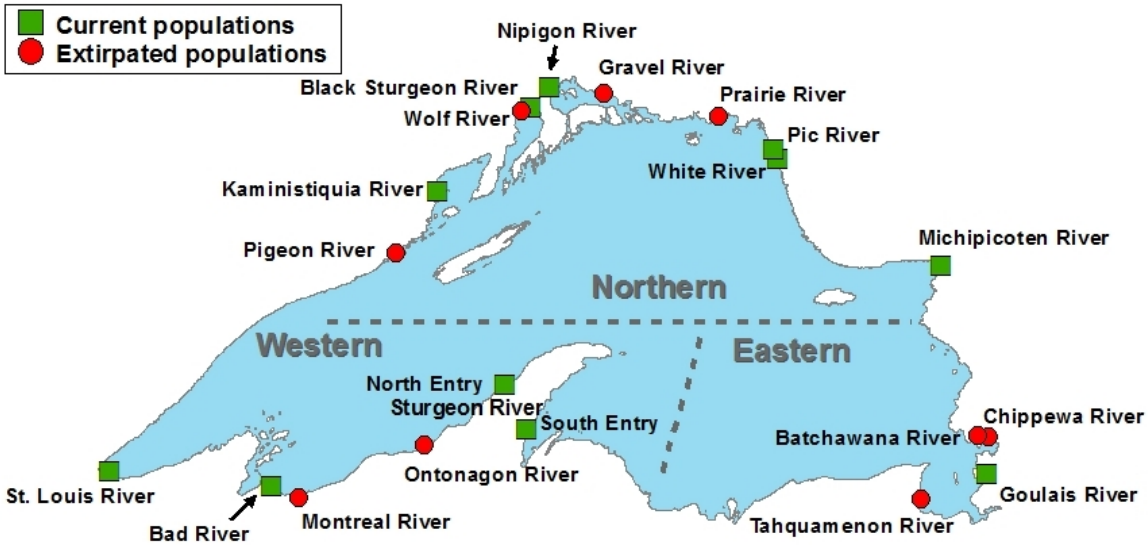

Figure 1. Lake Superior tributaries with current or extirpated lake sturgeon populations in three regions were sampled during the 2011 Lake Superior Lake Sturgeon Index Survey. Current populations were defined by recent evidence of natural reproduction.

METHODS

Sample design

The Lake Sturgeon Index Survey employed a stratified random sampling design where sampling effort was concentrated near tributary mouths. The underlying premise for this sampling design was that juvenile and sub-adult lake sturgeon tend to congregate near (<10 km) the mouth of the tributary where they hatched before they begin movements around Lake Superior as adults. Three circular shaped strata were developed around the tributary mouth to allocate sampling effort; the inner strata from 0-2 km, the middle strata from 2-5 km, and the outer strata from 5-10 km of the tributary mouth. Sample locations were restricted to water depths of 3-15 m within each strata. Target sample sizes were six, six, and four net sets for the inner, middle, and outer strata respectively, for a total of 16 net sets at each tributary location (eight net sets minimum). If fewer than 16 sets were made, the allocation was to be proportional to the target sample size for each strata. Sampling effort targets were set based on work-load capacity of a four person crew during one work week, vessel capabilities, and expected catch rates. Netting locations were randomly selected within each strata (ArcGIS 9.3, Hawth's Tools) during the first year of assessments. Gill nets were spaced a minimum of 0.5 km apart to reduce the probability of affecting catch rates in nets within close proximity. In a few locations, the lack of suitable

sampling sites required closer net spacing. A sampling time frame for the first year of surveys was set for mid-June to mid-August to minimize the duration of surveys while at the same time allowing adequate time for agencies to logistically conduct this spatially extensive survey.

Two identical 152.4 m gill nets were combined to form one 304.8 m continuous net (gang). Each 152.4 m gill net contained three panels arranged in order of ascending mesh size; 91.4 m of 11.4 cm stretch mesh, 30.5 m of 20.3 cm stretch mesh, and 30.5 m of 25.4 cm stretch mesh. When combined into a 304.8 m net, both gill nets were oriented in ascending order (hereafter the gill net gang will be referred to as a singular 304.8 m gill net). However, either end of the 304.8 m gill net could be considered the start of the net during deployment. The 11.4 cm stretch mesh was #104 monofilament (0.33 mm) and the 20.3 cm and 25.4 cm stretch mesh was #208 monofilament (0.52 mm). Net panels were 1.8 m in height.

Gill nets were set perpendicular to depth contours, unless restricted by water depths, during the day and retrieved the following day for a soak time of one net-night (~24 h). Global positioning system (GPS) coordinates were marked at the start and end of each net (GPS coordinates in decimal degrees, WGS 1984). Water depth (m) was recorded at the start and end of each panel. Surface water temperature (°C) was measured when the net was set and lifted. A substrate sample was taken at the start and end of each net using a ponar grab, with exceptions made for rough water conditions. The substrate sample was classified into percentages of clay, silt, sand, gravel, cobble, boulder, or other based on the Wentworth particle size classification as described in McMahon (1996).

Fish catches were separated by panel (i.e., net and mesh size) to identify depth and mesh size associations. All lake sturgeon captured were measured for total length (mm), fork length (mm), girth (mm; largest circumference posterior to pectoral fins), and weight (g). Each lake sturgeon was checked for t-bar anchor tags, monel tags, passive integrated transponder (PIT) tags, coded wire tags, and signs or scars that indicate a tag might have been lost. If the fish did not have a t-bar anchor tag or a PIT tag, it was given a new t-bar anchor tag near the base of the dorsal fin and a PIT tag just under the skin at the base of the skull about 3-4 cm right of center of the mid-dorsal ridge (Schloesser, in preparation). A 1.0-1.5 cm section of the left leading pectoral fin ray was taken from a sub-sample of 10 fish in each 25 mm length bin from each location for age estimation. A fin clip from the pectoral fin (approximately two cm^2) was collected for later genetic analysis and served as a secondary mark for within year recaptures. Each lake sturgeon was inspected for sea lamprey *Petromyzon marinus* and native lamprey (e.g., silver lamprey *Ichthyomyzon unicuspis*) marks or scars and classified according to Patrick et al. (2007). Other distinguishing features (e.g., curled or deformed fins) were also noted.

All non-target game fish were identified to species and measured for total length, weight, and sex determined if possible. All rough fish (e.g., suckers) were counted and released. Each non-target fish was inspected for sea lamprey marks and reported according to the classification of Ebener et al. (2006).

Fin ray sectioning and age reading was completed by staff from the U.S. Fish and Wildlife Service and Fisheries and Oceans Canada. Pectoral fin rays were air dried for at least four weeks from the time of collection before sectioning. Each fin ray had two 300 µm sections cut from it using a Buehler IsoMet low speed saw. Digital imaging software was used to amplify the fin ray section to estimate the number of annuli. Age was interpreted by two biologists who independently assessed both fin ray sections and decided on the most likely age. If their final age interpretations did not match, the biologists reassessed the sections together and reached a consensus.

Analytical methods

A variety of analytical methods were used to describe abundance, population structure, and biological characteristics of lake sturgeon populations at individual tributary locations and within regions. Standardized sampling methods among all tributary locations allowed for comparisons between sampling locations (Hubert and Fabrizio 2007). For each tributary, lake sturgeon catch per unit effort (CPUE) was calculated as number of fish per 304.8 m net night. CPUE was indexed as the geometric mean ($\log_e$ (CPUE+1) transformed (Hubert and Fabrizio 2007). A bootstrap procedure (SAS Institute 2008) was used to estimate the bootstrap mean CPUE and 95% confidence intervals on the $\log_e$ (CPUE+1) transformed data because most of the relative abundance data did not meet the assumptions of parametric tests (e.g., small sample sizes, non-normal distribution, skewed data). The original dataset from each tributary location was randomly sampled with replacement *N* times to produce 1,000 replicate bootstrap datasets, where *N* equals the total number of net sets at each tributary location. The bias-corrected and accelerated (BC_a) method was used to estimate the 95% lower and upper confidence intervals from the bootstrapped dataset (Smith 1997). The bootstrapped mean and 95% CIs were then back-transformed for ease of interpretation. We considered non-overlapping confidence intervals to indicate significant differences between tributaries.

Population structure (size and age) was used to index recruitment and year class strength, which may then be evaluated over time. Size and age structure were summarized by tributary location because these population characteristics could be highly dependent on specific environmental and habitat characteristics unique to each spawning tributary. Size structure was summarized using length frequency distributions to compare 50 mm total length classes, length ranges, minimum, and maximum total lengths. Age structure was estimated from the sub-sample of aged fish using Program AGEKEY and methods described in Isermann and Knight (2005). An age-length key was generated for each region using all the aged fish from that region. This allowed each fish to be assigned an age and avoided the problem of fractionally allocating a single fish among several age classes (Isermann and Knight 2005).

Growth and condition were summarized by region because sample sizes at the individual tributary level were generally too small to develop meaningful biological models. Growth was summarized by mean total length at age using the methods described in Bettoli and Miranda (2001). We did not apply an age correction factor to any age related analysis because our target age range was 3-15 years old and Bruch et al. (2009) found lake sturgeon ages estimated from pectoral fin spines accurate up to age 14. Condition was assessed using quantile regression of the linear Log_{10} transformed length-weight relationship (Cade et al. 2008; Cade et al. 2011). Quantile regression estimates for $\tau \in \{0.05, 0.6, \ldots, 0.94, 0.95\}$ of predicted weights were used to compare condition of the 95th, 75th, and 50th total length percentiles of lake sturgeon captured by region. The estimated 0.50 quantile from the linear model of each region was back-transformed and fit to the standard allometric length-weight model $W = \alpha L^{\beta}$ (Cade et al. 2008), where L is total length (mm) and W is weight (g).

Sampling design evaluation

Evaluation of sampling methods, design, and ability to detect changes within populations is important for a monitoring program to make sure objectives can be met. The first part of the evaluation was to determine if the three mesh sizes used were appropriate for the targeted size classes. To test for differences in mean length among the three mesh sizes, we used an analysis of variance (ANOVA) with a Bonferroni correction for multiple comparisons and also developed a length frequency by gill net mesh size (e.g., Paukert and Fisher 1999). Lake sturgeon from all regions were combined in the analysis to estimate the full size range each mesh size could effectively sample.

The premise that juvenile and sub-adult lake sturgeon tended to congregate near tributary mouths was the basis for allocating more sampling effort to the inner strata relative to the available sampling area in the outer strata. To evaluate whether this design was appropriate, we used a mixed model to test if CPUE differed among sampling strata. The mixed model accounts for the correlation in repeated samples among our fixed-effect parameter (strata) and random-effects parameter (tributary). The model was fit using the method of restricted maximum likelihood. CPUE data was $\log_e$ transformed to normalize the data.

The ability to detect changes within a population is an important objective for any monitoring program. With 2011 being the first year of sampling efforts, it was important to determine if the sampling design could detect changes in future catch rates. The number of net sets required to detect a 50% increase in lake sturgeon CPUE (i.e., as recommended to meet the preliminary survey level defined by Robson and Regier (1964)) was estimated based on the 2011 observed mean CPUE and standard deviation (Steidl et al. 1997). This analysis was only completed on tributaries with adequate sample size (i.e., lake sturgeon in at least four net sets).

By-catch in gill net surveys can be problematic and monitoring programs should ensure their sampling activities are not detrimental to native species. The total catch of non-target species was tabulated by region and arithmetic mean CPUE was calculated as number of fish per 304.8 m net night to identify species that were particularly vulnerable to the graded mesh gill nets used in this survey. Only species with more than five individuals captured among all regions were reported.

RESULTS

Relative abundance

All tributary mouths were successfully sampled within the target effort range of 8-16 net sets, with the exception of the Wolf/Black Sturgeon rivers where sampling was stopped after five net sets due to concerns about by-catch. Sampling was largely completed during June 20 to August 17, with the exception of three days of surveys (14 net sets) at the Bad and Ontonagon rivers during September 7-9.

The 2011 sampling effort resulted in a total of 86 lake sturgeon captured in the Northern region, 158 in the Western region, and 121 in the Eastern region (Table 1). Within regions, lake sturgeon catch varied among tributaries from 0 to 104 fish (unstandardized raw catch numbers). In the Northern region there were three locations where no lake sturgeon were found; the Pigeon, Nipigon, and Gravel rivers. Most lake sturgeon in the Northern region were caught off the mouth of the Pic/White rivers (57 total individuals). Despite only five net sets near the Wolf/Black Sturgeon rivers, 12 lake sturgeon were captured. The Western region had three tributaries with relatively large catches; the St. Louis (34), Bad (46), and Ontonagon (56) rivers. Other tributaries had fewer than 10 fish caught, but at least one fish was caught near all the sampled tributaries in the Western region. The greatest number of fish caught at any tributary mouth was in the Eastern region at Goulais River with 104 total fish. Fewer fish were caught near the Batchawana/Chippewa rivers (16) and Tahquamenon River (1).

The bootstrapped mean CPUE exactly matched the geometric mean due to a large number of replicates. Geometric mean CPUE of lake sturgeon varied among tributaries with a range of 0.0 to 5.7 fish per net (Table 1). Mean CPUE at the Goulais River was significantly higher (i.e., non-overlapping confidence intervals) than nearly all other Lake Superior tributaries, with only a slight overlap in confidence intervals with the Bad River. Most tributaries had relatively low CPUE (0.0-1.0). Five tributaries had a CPUE range of approximately 1.0-3.0 fish per net, which included the Wolf/Black Sturgeon, Pic/White, St. Louis, Bad, and Ontonagon rivers. Generally,

tributaries with the highest CPUE also had the widest confidence intervals, indicating greater variability in the number of fish caught per gill net.

Table 1. Sampling dates and effort for each tributary mouth sampled during the 2011 Lake Sturgeon Index Survey. The geometric mean catch per unit effort (CPUE) of lake sturgeon was back transformed from a $\log_e$ transformation. Bias corrected and accelerated (BCa) 95% confidence intervals (CI) were calculated from 1,000 replicate bootstrap datasets.

Tributary	2011 sampling dates	# net sets	# lake sturgeon caught	Geometric mean CPUE	BCa 95% CI	
					Lower	Upper
Northern Lake Superior						
Pigeon	June 28 - July 8	16	0	0.00000	0.00000	0.00000
Kaministiquia	June 28 - July 6	16	1	0.04427	0.00000	0.24186
Wolf/Black Sturg.	July 7 - Aug. 9	5	12	1.86194	0.51572	3.44127
Nipigon	July 19 - July 22	15	0	0.00000	0.00000	0.00000
Gravel	Aug. 2 - Aug. 6	15	0	0.00000	0.00000	0.00000
Prairie	July 24 - July 26	16	8	0.33012	0.13879	0.76922
Pic/White	Aug. 4 - Aug. 7	16	57	1.55233	0.65556	3.53121
Michipicoten	July 19 - July 22	16	8	0.33012	0.11849	0.76922
Western Lake Superior						
St. Louis	July 26 - Aug. 17	16	34	1.19080	0.56386	2.38692
Bad	July 19 - Sept. 9	18	46	2.23831	1.00449	4.33896
Montreal	July 12 - July 14	9	8	0.60831	0.12983	1.47272
Ontonagon	Aug. 11 - Sept. 7	16	56	2.60931	1.47564	4.01338
North Entry Sturg.	Aug. 2 - Aug. 5	16	5	0.21973	0.09051	0.59348
South Entry Sturg.	Aug. 2 - Aug. 5	14	9	0.40771	0.16013	1.01349
Eastern Lake Superior						
Tahquamenon	July 26 - July 29	16	1	0.04427	0.00000	0.24186
Batchawana/Chip.	June 21 - June 26	16	16	0.62239	0.27373	1.25351
Goulais	July 5 - July 10	16	104	5.70523	4.25363	7.54358

Size structure

Length frequency distributions show that most (83%) lake sturgeon were 400-1,000 mm total length (Figure 2). The smallest lake sturgeon captured was 355 mm and largest was 1,510 mm. The 700 and 750 mm length classes had the greatest number of lake sturgeon captures for naturally reproducing populations, such as the Pic/White, Bad, and Goulais rivers, possibly indicating the length at which lake sturgeon become fully vulnerable to the sampling gear.

In Northern Lake Superior, most lake sturgeon were caught at the Pic/White river and 81% of those fish were 500-899 mm. The size distribution of lake sturgeon at the Prairie and Michipicoten rivers was similar, with all lake sturgeon being 600-1,150 mm in length. At the Wolf/Black Sturgeon rivers, 42% of lake sturgeon were shorter than 550 mm, which is a greater percentage than the other tributaries. The only fish captured in the Kaministiquia River was 620 mm long.

In Western Lake Superior the size distribution was relatively similar among all tributaries with the exception of the St. Louis River, which had much longer lake sturgeon. In the St. Louis River, no lake sturgeon smaller than 650 mm were captured. Instead, 91% were 800-1,299 mm in length, and 59% were greater than 1,000 mm. All other tributaries generally had lengths ranging from 500-1,000 mm. The Bad and Ontonagon rivers size structure was nearly identical, except for a few larger individuals at the Bad River. North and South Entries to the Sturgeon River also exhibited a similar size distribution to each other.

In Eastern Lake Superior, the minimum and maximum lengths were similar between Batchawana/Chippewa rivers and Goulais River, with the exception of one large fish caught at the Goulais River. However, 56% of Batchawana/Chippewa river lake sturgeon were 400-549 mm long, whereas only 7% of lake sturgeon at the Goulais River were within that same size range. The only lake sturgeon captured at the Tahquamenon River was 512 mm in length.

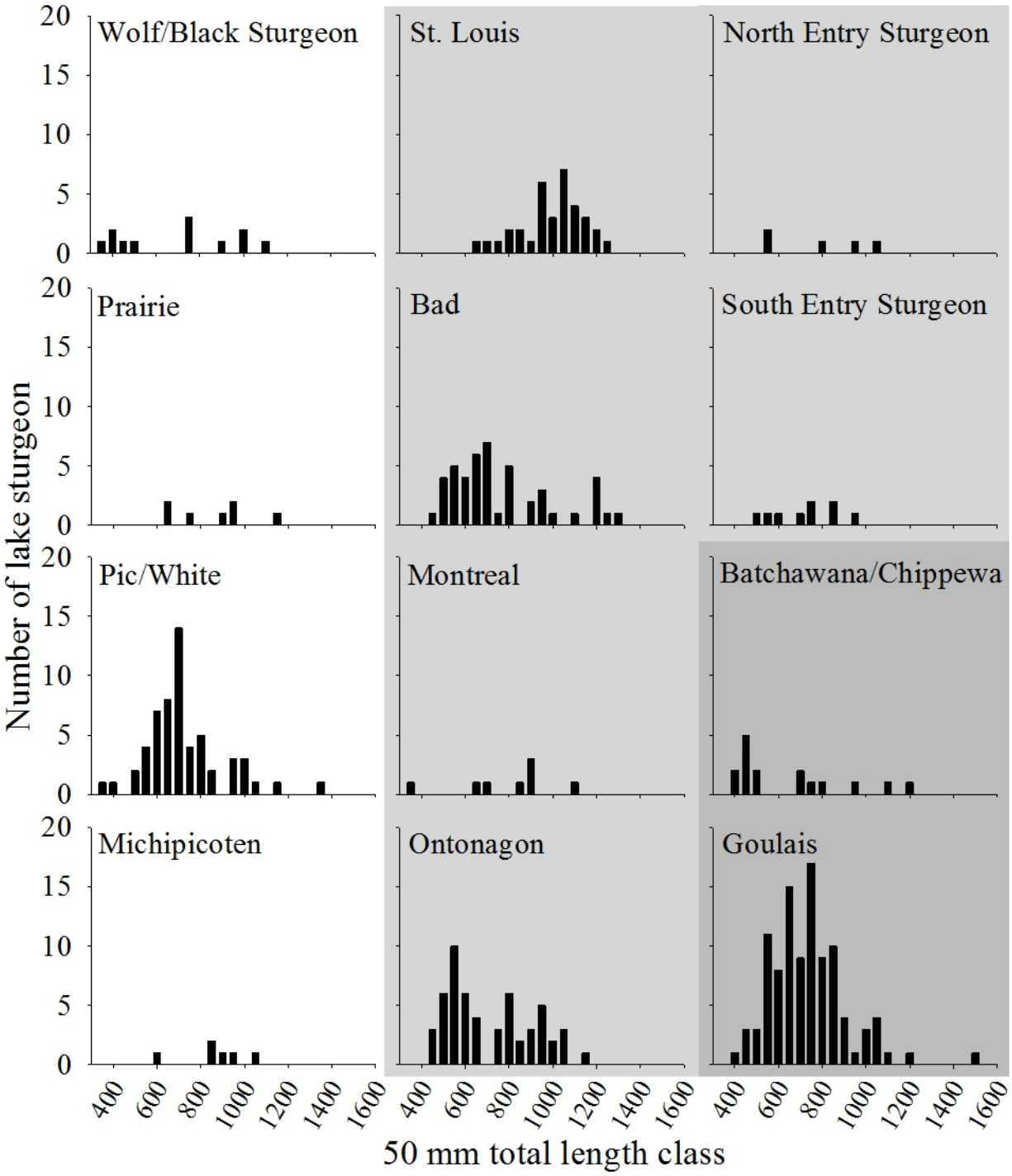

Figure 2. Length frequency distributions for lake sturgeon captured near tributary mouths in Northern (white background), Western (light grey background), and Eastern (dark grey background) regions of Lake Superior during the 2011 Lake Sturgeon Index Survey. One 620 mm lake sturgeon was caught at the Kaministiquia River and one 512 mm lake sturgeon was caught at the Tahquamenon River, which were not displayed graphically.

Age structure

Ages were determined from 80% of all lake sturgeon captured. Age ranged from 2 to 28 years (Figure 3). Juveniles (ages 0-5) and sub-adults (ages 5-15) dominated the catch across all tributaries, with 76% of all lake sturgeon captured falling between 3 and 11 years of age. Most individuals observed were assigned to the six, seven, and six year old age classes for the Northern, Western, and Eastern regions, respectively.

In Northern Lake Superior, most tributaries were represented by three or fewer individuals for any particular age class, which limits any inference about year class strength for those particular tributaries. In the Pic/White rivers, ages 6, 7, 8, 9, and 10 were represented by 15, 10, 9, 4, and 4 individuals, respectively.

A broader age structure was observed in Western Lake Superior than the other two regions. Older individuals were observed in the St. Louis River than in the other tributaries, with only six fish assigned to ages 5-9, but 27 fish to the 12-22 age classes. Conversely, the Bad River population consisted mostly of fish ages 3-7, but was also represented by one or two individuals in a variety of older age classes up to 28 years. The Ontonagon River was comprised primarily of fish ages 3-10, with the exception of one missing year class at age six where no fish were collected. The Montreal River and North and South Entries to the Sturgeon River had a variety of age classes, but not more than two individuals in any particular age class. The youngest fish at the Montreal River was six years old, and North Entry was seven years old.

The overall age structure in Eastern Lake Superior was dominated by the large catch near Goulais River where ages 3-13 represented 93% of the total catch. However, a broad range of ages were found at Goulais River, from age 2 to 25. Over half of the fish caught near the Batchawana/Chippewa rivers were either two or three years old, but fish up to 18 years old were captured. The only lake sturgeon caught at the Tahquamenon River was three years old.

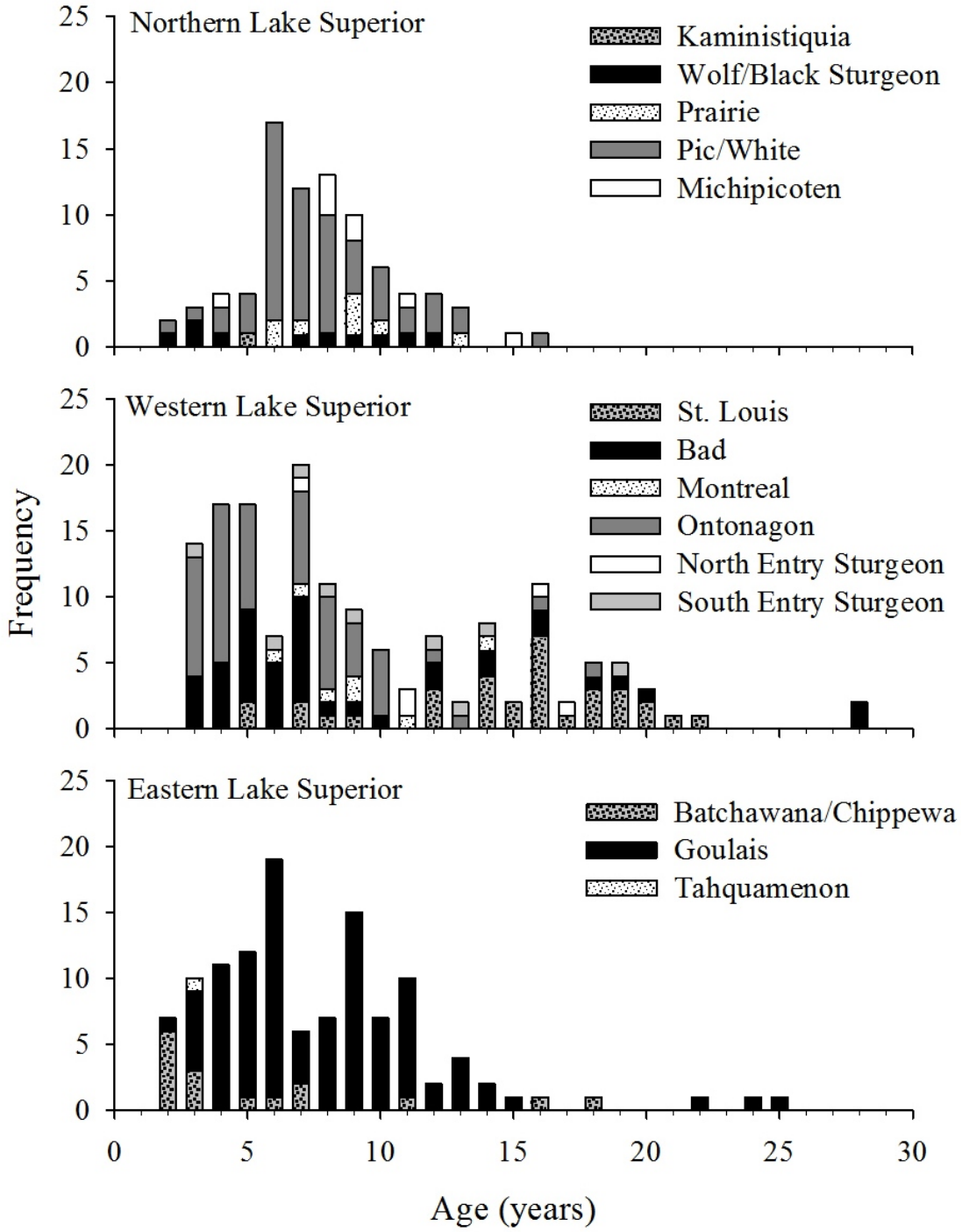

Figure 3. Age frequency for lake sturgeon captured in three regions of Lake Superior during the 2011 Lake Sturgeon Index Survey.

Growth

Mean total length at age was summarized by region to increase sample sizes, which were generally low for the youngest and oldest fish. This assumes that growth was similar among tributaries within regions. Mean length at age estimates from ages 2-10 align with the shape of the von Bertalanffy growth curve, but mean length at age estimates for ages >10 start to deviate from the expected shape of a growth curve (e.g., ages 10-13 in Western Lake Superior; Figure 4).

Across all regions, ages 5 and 6 had similar mean lengths with a maximum difference of 29.5 mm and 23.3 mm for each age, respectively (Table 2). At age nine, the Northern and Western regions remained similar, but the Eastern region was estimated to be nearly 80 mm smaller. For fish 10 years and older, mean length differed by as little as 58 mm (age 12) or as much as 379 mm (age 16), indicating the possibility of age estimation errors for fish 10 years or older or small sample sizes.

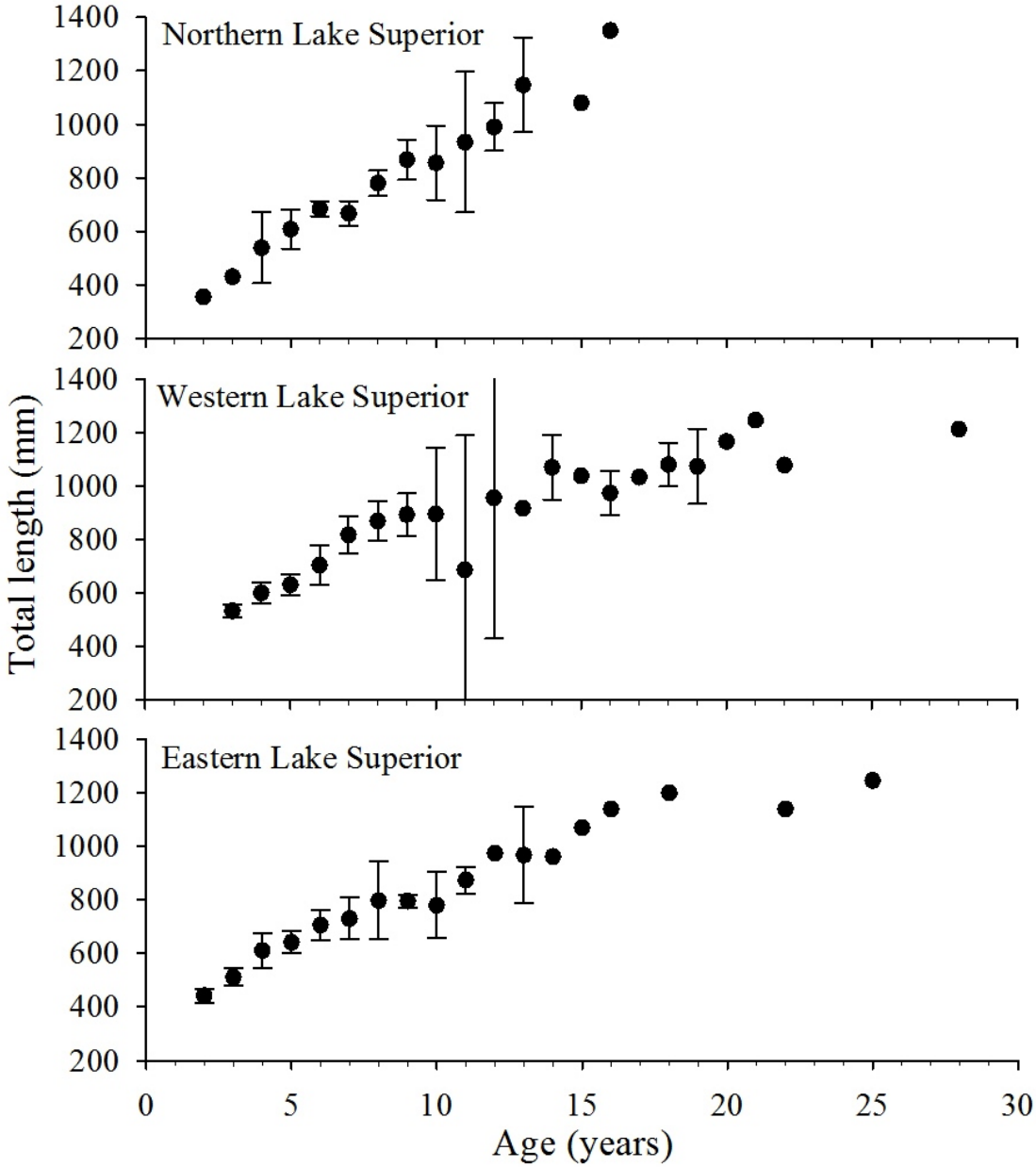

Figure 4. Estimated mean total length (mm) at age with 95% confidence intervals for lake sturgeon in the Northern, Western, and Eastern regions in Lake Superior.

Table 2. Estimated mean total length (mm) and standard error (SE) at age for lake sturgeon in the Northern, Western, and Eastern regions in Lake Superior.

Age	Northern			Western			Eastern		
	N	mean	SE	N	mean	SE	N	mean	SE
2	1	355.0					6	443.8	9.4
3	1	430.0		10	530.3	8.9	9	511.6	13.6
4	3	535.3	23.4	12	601.6	14.5	9	606.9	24.6
5	3	610.1	14.8	13	629.6	14.2	11	639.6	15.6
6	17	682.8	12.7	5	706.1	20.7	16	698.0	22.8
7	9	669.8	19.2	12	821.2	25.8	5	721.2	24.9
8	10	790.2	20.9	10	862.7	27.9	6	797.9	55.7
9	8	875.3	25.8	6	893.3	20.4	15	796.5	11.4
10	5	853.3	44.9	5	854.9	84.8	7	781.9	49.0
11	3	950.9	50.4	3	719.0	96.8	9	872.9	20.9
12	3	994.4	14.8	3	1,032.8	74.0	2	975.0	35.0
13	3	1,146.7	41.1	2	906.6	53.6	4	967.5	56.8
14				7	1,071.3	46.7	2	957.4	92.4
15	1	1,080.0		2	1,038.7	44.3	1	1,070.0	
16	1	1,350.0		9	971.9	32.7	1	1,140.0	
17				2	1,033.8	46.2			
18				3	1,071.3	15.6	1	1,200.0	
19				5	1,080.6	46.3			
20				2	1,191.1	59.4			
21				1	1,245.0				
22				1	1,077.0		1	1,140.0	
23									
24							1	1,510.0	
25							1	1,246.0	
26									
27									
28				1	1,211.0				

Condition

Lake sturgeon condition was calculated on a regional basis, similar to growth. Condition varied little among the three regions and any differences were only apparent for the largest fish (Figure 5). For example, a lake sturgeon 750 mm long averaged (0.5 quantile) 2,078, 2,195, and 2,089 g for the Northern, Western, and Eastern regions, respectively, which was a difference of only 117 g. When extrapolated to lake sturgeon 1,150 mm in length, the average (0.5 quantile) weight was 8,124, 8,364, and 7,661 g for the same regions, respectively. Western Lake Superior tended to have heavier fish per length, but the quantile regression estimates for all three regions overlapped at some value of τ (0.05-0.95), indicating any differences were not significant.

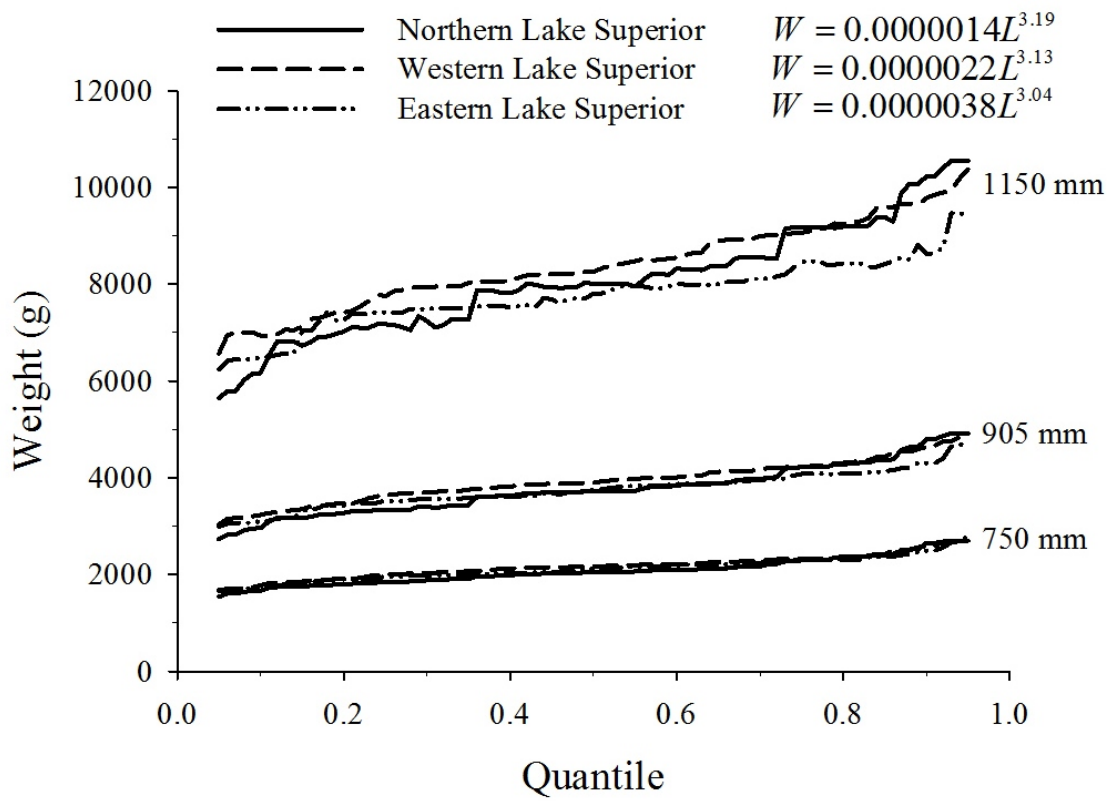

Figure 5. Quantile regression estimates for τ ϵ {0.05, 0.6, …, 0.94, 0.95} of predicted weights from the standard allometric length-weight model ($W = aL^b$). Total lengths of 1,150, 905, and 750 mm represent the 95th, 75th, and 50th percentiles, respectively, of all lake sturgeon captured during the juvenile index survey. The standard allometric length-weight relationship for the 0.50 quantile (mean) is presented next to the respective region at the top of the figure.

SURVEY EVALUATION

Size distribution by mesh size

Total length of lake sturgeon in the variable mesh gill nets ranged from 355 mm to 1,510 mm. The 11.4 cm mesh caught lake sturgeon from 355 mm to 1,080 mm, the 20.3 cm mesh from 665 mm to 1,270 mm, and 25.4 cm mesh from 870 mm to 1,510 mm total length (Figure 6). Analysis of variance indicated mean length of lake sturgeon captured in each mesh size differed, where mean total length increased with increasing mesh size ($P < 0.001$ for all pairwise comparisons; Table 3). Within the 11.4 cm mesh, 82% of lake sturgeon were between 500 mm and 849 mm. When coupled with mean length at age estimates (Table 2), most fish in the 11.4 cm mesh appear to be 4-10 years old. Additionally, the 650 and 700 mm length classes had the greatest number of individuals, indicating that lake sturgeon become fully vulnerable to capture at these lengths. The 20.3 cm and 25.4 cm mesh caught lake sturgeon less than 1,000 mm which should be less than 15 years old, but also captured fish greater than 1,200 mm, which are likely adults.

Table 3. Mean total length and standard error (SE) of lake sturgeon captured in three gill net mesh sizes during the 2011 Lake Superior Lake Sturgeon Index Survey. Mean total length (mm) was significantly different for all pairwise comparisons ($P < 0.001$).

Gill net mesh size (cm)	N	Mean total length (mm)	SE
11.4	258	678.4	8.1
20.3	77	1,002.5	12.9
25.4	27	1,123.4	25.6

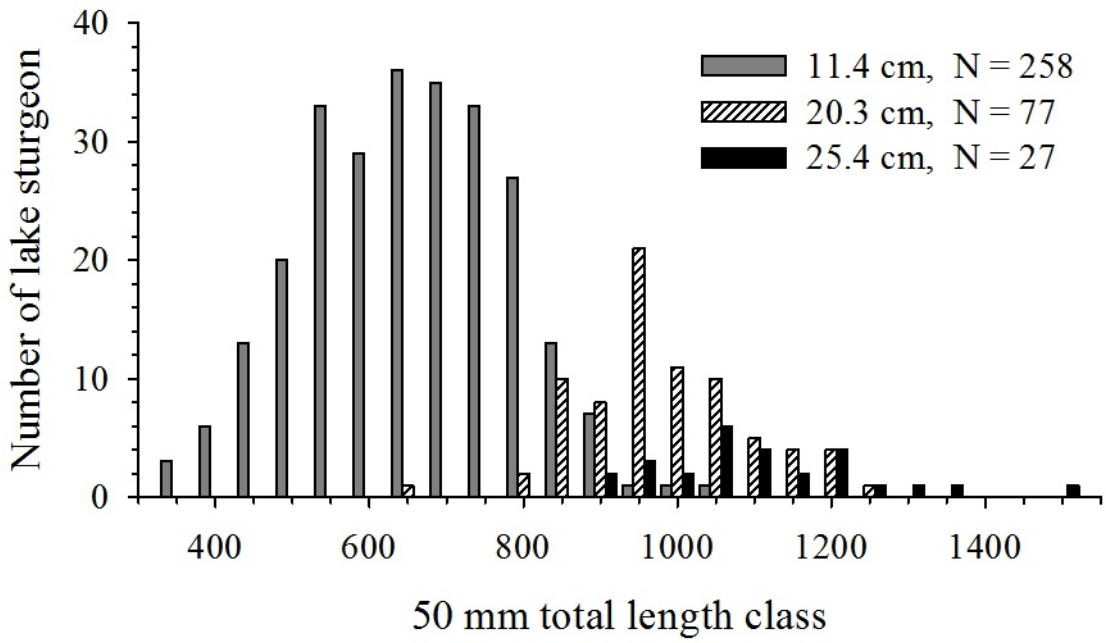

Figure 6. Length distribution of lake sturgeon collected in 11.4, 20.3, and 25.4 cm stretch monofilament gill net used during the 2011 Lake Superior Lake Sturgeon Index Survey.

Sampling strata evaluation

The stratified sampling design was based on the premise that lake sturgeon tended to remain near spawning tributary mouths, and was the basis for proportionally allocating more effort near tributary mouths. The mixed model indicated that CPUE was significantly higher in the inner strata than either the middle (P = 0.0329) or outer strata (P = 0.0082; Table 4). However, CPUE was not significantly different between the middle and outer strata even though CPUE was slightly higher in the middle strata (P = 0.5117).

Table 4. Log_e (Ln) transformed CPUE, standard error (SE), and pairwise comparisons from the inner, middle, and outer strata of all Lake Superior tributaries sampled for lake sturgeon in 2011.

Strata	Ln(CPUE)	SE	Pairwise comparison	P-value
Inner	0.7084	0.154	Inner vs Middle	0.0329
Middle	0.4137	0.155	Inner vs Outer	0.0082
Outer	0.3225	0.1589	Middle vs Outer	0.5117

Detecting change in abundance

The estimated number of net sets required to detect a 50% increase in lake sturgeon abundance varied greatly depending on the tributary and region (Figure 7). At the individual tributary level, the number of net sets required to achieve the recommended minimum power of 0.80 was as few as 12 net sets in Goulais Bay and as high as 112 net sets for the North Entry Sturgeon River. Only three tributaries (Goulais, Wolf/Black Sturgeon, and Ontonagon rivers) had sample size requirements where a 50% increase in relative abundance could be detected within agency resources for a lake sturgeon assessment (i.e., 24 or fewer net sets). Power improved when data were amalgamated at a broader spatial scale, with the exception of the Northern Lake Superior region where an estimated 364 net sets were needed (Figure 7). Sample sizes required to detect a 50% increase in abundance for the Western and Eastern regions and the lake-wide level were achievable with the current effort level (Western Lake Superior region estimate = 65 net sets; lake-wide estimate = 123 net sets) or a small increase in effort (Eastern Lake Superior region estimate = 67 net sets; Figure 7).

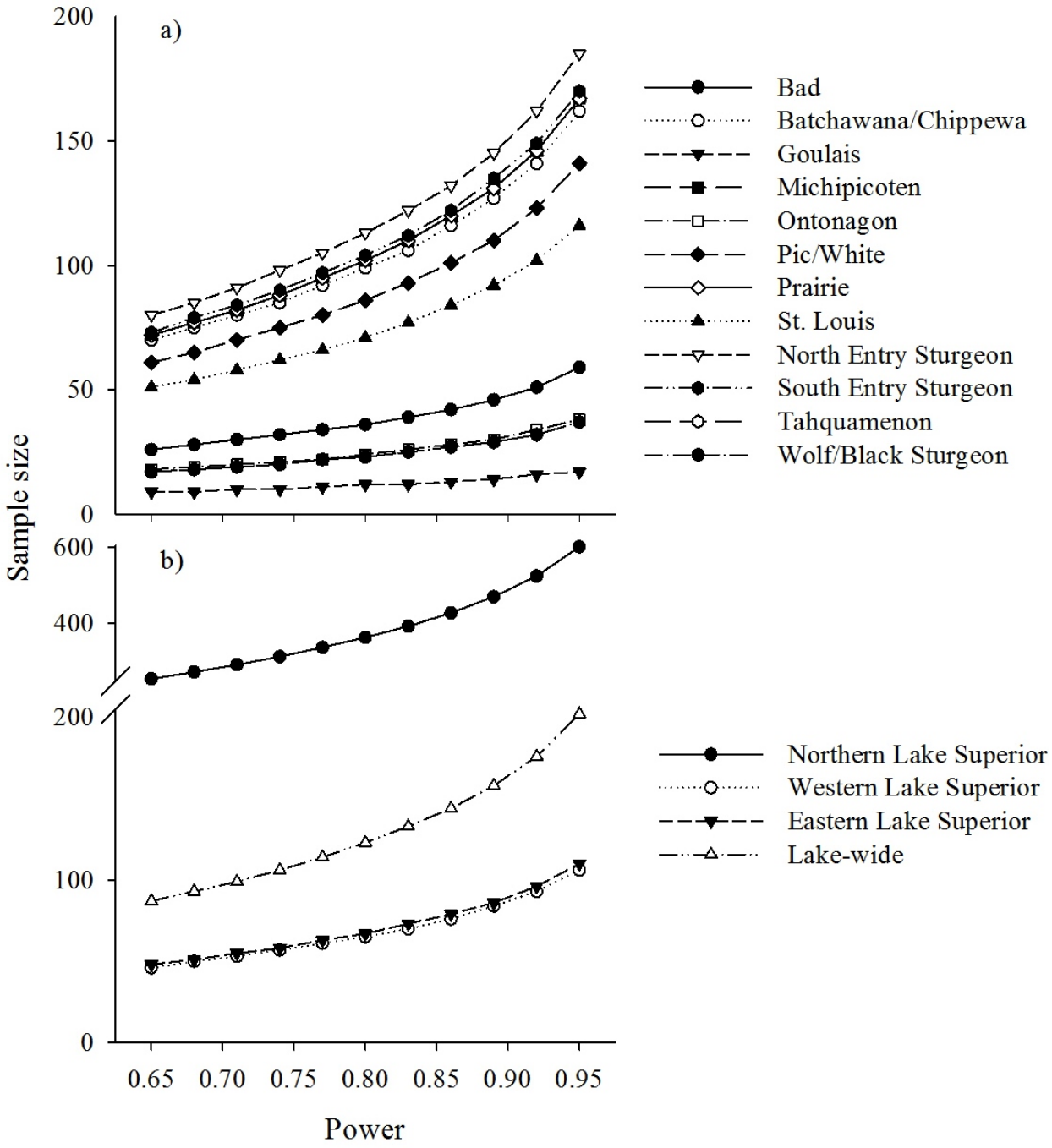

Figure 7. Sample sizes needed to detect a 50% increase in abundance of lake sturgeon from a) individual Lake Superior sampling tributaries, and b) data amalgamated by region and from all net sets (lake-wide).

Non-target fishes

Lake-wide, the non-target species most commonly encountered were lake trout *Salvelinus namaycush*, lake whitefish *Coregonus clupeaformis*, longnose sucker *Catostomus catostomus*, walleye *Sander vitreus*, and white sucker *Catostomus commersoni*, although these species were not distributed evenly among regions or even individual tributary locations (Table 5). White suckers were common throughout the lake, with a lake-wide average of five individuals per net. Northern region assessments had the greatest by-catch, with white sucker and lake whitefish being most common. Walleye caught at the Wolf/Black Sturgeon rivers accounted for 44% of the total walleye catch in the Northern region. Additionally, 38% of the total lake whitefish by-catch in the Northern region occurred at the Nipigon River. A total of 34 brook trout *Salvelinus fontinalis* were captured in the Northern region, which should be noted due to ongoing restoration efforts. Similar species were observed in the Western region as in the Northern region, except that more brown trout *Salmo trutta* and smallmouth bass *Micropterus dolomieui* were encountered in the Western region. Most walleye (25%) in the Western region came from the St. Louis River. By-catch in the Eastern region was exceptionally low for nearly all species, with the exception of white sucker.

By-catch was problematic to the point where sampling was halted at only one location. The number of walleye encountered in the Wolf/Black Sturgeon rivers assessment was deemed unacceptable due to ongoing rehabilitation efforts.

Table 5. Non-target species total catch in the Northern, Western, and Eastern regions and arithmetic mean CPUE (in parenthesis) per 304.8 m net night. Species with a total of five or fewer individuals among all regions were not displayed.

Species	Northern	Western	Eastern
Brook trout *Salvelinus fontinalis*	34 (0.3)	0 (0.0)	0 (0.0)
Brown trout *Salmo trutta*	0 (0.0)	60 (0.7)	1 (0.0)
Burbot *Lota lota*	22 (0.2)	45 (0.5)	8 (0.2)
Chinook salmon *Oncorhynchus tshawytscha*	5 (0.0)	0 (0.0)	4 (0.1)
Coho salmon *Oncorhynchus kisutch*	1 (0.0)	7 (0.1)	0 (0.0)
Lake trout *Salvelinus namaycush*	127 (1.1)	110 (1.2)	11 (0.2)
Lake whitefish *Coregonus clupeaformis*	433 (3.8)	11 (0.1)	11 (0.2)
Longnose sucker *Catostomus catostomus*	212 (1.8)	92 (1.0)	1 (0.0)
Northern pike *Esox lucius*	8 (0.1)	5 (0.1)	1 (0.0)
Round whitefish *Prosopium cylindraceum*	9 (0.1)	0 (0.0)	0 (0.0)
Silver redhorse *Moxostoma anisurum*	15 (0.1)	50 (0.6)	0 (0.0)
Smallmouth bass *Micropterus dolomieui*	2 (0.0)	73 (0.8)	11 (0.2)
Smallmouth buffalo *Ictiobus bubalus*	0 (0.0)	13 (0.1)	0 (0.0)
Walleye *Sander vitreus*	303 (2.6)	177 (2.0)	8 (0.2)
White sucker *Catostomus commersoni*	582 (5.1)	494 (5.6)	208 (4.3)

DISCUSSION

Lake sturgeon status

Lake sturgeon were encountered at 14 of the 17 locations sampled in Lake Superior during 2011. At two of the zero catch locations, the Nipigon and Pigeon rivers, lake sturgeon were previously captured in low numbers (Moore and Edwards 2009; Swainson 2001), but none were detected during 2011. Collectively, these results indicate that lake sturgeon are present throughout their historic range, but still exhibit signs of reduced populations at many locations. The Goulais, Bad, Ontonagon, Pic/White, and Black Sturgeon rivers had the highest relative abundance of juvenile and sub-adult lake sturgeon, which are all tributaries that support large adult populations or have been stocked with lake sturgeon in the past.

Lake sturgeon abundance has typically been measured by the size of annual spawning runs (Holey et al. 2000; Auer and Baker 2007; Schloesser and Quinlan 2011) and rehabilitation goals set according to minimum adult population size (Auer 2003). However, evaluation of rehabilitation activities may be better suited toward the juvenile and sub-adult stage where a response would be detected sooner than at the adult stage, which may take 20 years. It may be possible to use juvenile abundance as an index to predict future adult abundance. For example, we found relatively high juvenile CPUE corresponding to large adult spawning runs in the Bad River (estimated 844 spawning individuals in 2010; Schloesser and Quinlan 2011), the Black Sturgeon River (estimated 89 adults in 2003 and 96 in 2004; Friday 2004), and in the White River, ON (82 captured in 2011 and 9 in 2010; Ecclestone 2012). To the contrary, relatively low juvenile CPUE was observed at the Sturgeon River (estimated 350-400 adults in 2004; Auer and Baker 2007) and Kaministiquia River (estimated 160 and 188 river resident adults in 1998 and 2001, respectively; Friday and Chase in preparation), which are known to have annual spawning runs.

The Sturgeon River mouth is located in Portage Lake, which is connected to Lake Superior via the North and South Entries of the Keweenaw Waterway. Our survey was designed to sample Lake Superior waters, and therefore we sampled around the entries and not within Portage Lake. Prior research has shown that juvenile lake sturgeon use Portage Lake (Holtgren and Auer 2004). It is likely that many juveniles produced in the Sturgeon River remain in Portage Lake, thus reducing their vulnerability to capture in this survey. The Sturgeon River is the only tributary with two assessments directed at the same spawning population. Consideration might be given to sampling only one location to index the population, likely the South Entry due to closer proximity to spawning and rearing grounds and more favorable juvenile and sub-adult habitat in that study area.

Telemetry work in the Kaministiquia River has shown that adult lake sturgeon remain in the river year-round and ascend the river to spawn on their normal cycle (Friday and Chase in

preparation). Cullis et al. (1987) also captured lake sturgeon 9–18 km upstream from the mouth of the Kaministiquia River that had a mean age of 5.1 years. These findings have led fishery managers to speculate that Kaministiquia River lake sturgeon may be river residents. However, the capture of a single juvenile lake sturgeon in Lake Superior off the mouth of the Kaministiquia River suggests that some juveniles are also leaving the river system.

Large catches of juvenile and sub-adult lake sturgeon near the mouth of the Goulais River suggest a large adult spawning population exists. However, spawning run surveys in the Goulais River have not detected large numbers of adults to date, which may be due in part to limited sampling effort and difficult sampling conditions (S. Greenwood, OMNR, personal communication). Evaluation of the Goulais River spawning population continues to be an information need. A genetic analysis of lake sturgeon caught near the Goulais River during this survey will provide valuable information on the river of origin for these individuals.

Stocking at the Ontonagon River and St. Louis River is responsible for some of the highest catch rates observed among all Lake Superior tributaries. A high proportion of fish with coded wire tags (59% in Ontonagon River and 32% in St. Louis River) and the age structure of the population indicate the majority of fish captured in these locations were from stocking. Undetected tags or tag loss was suspected at the Ontonagon River because no tags were found in some lake sturgeon with “fin curl” (a condition developed from fins rubbing on hatchery rearing tanks), when all stocked lake sturgeon were given a coded wire tag. The Ontonagon River was stocked during 1998 to 2004 and again in 2007 and 2008 (Wilson 2008) making these fish between 3 and 13 years old at the time of the 2011 survey. Over 96% (54 of 56) of lake sturgeon caught near the Ontonagon River during this survey were within the age range for stocked fish. The absence of the six year old year class corresponds with one of the missed years of stocking, indicating this survey has the ability to detect missing cohorts. Stocking in the St. Louis River occurred from 1983-1994 and again from 1998-2000 (Schram et al. 1999; Schram 2007). The observed large size and age structure for the St. Louis River, with more than 80% of fish greater than 12 years old, coincides with stocking years. Without the contribution of stocking, fewer lake sturgeon would have been captured in these two locations, demonstrating the importance of stocking to enhance rehabilitation efforts.

The presence of lake sturgeon less than 10 years old in the St. Louis River suggests that natural reproduction has occurred in the St. Louis River over the past decade. Successful spawning was confirmed in the St. Louis River in 2010 when larval lake sturgeon were captured by biologists with the Fond du Lac Band of Lake Superior Chippewa and the 1854 Treaty Authority. The St. Louis River Estuary system is spatially complex with suitable habitat for juvenile lake sturgeon. Schram et al. (1999) found stocked lake sturgeon had moved out of the river system and into Lake Superior (where our study area is located) within two years, but that some fish remained in the estuary for up to five years. This might be one reason for lower catch rates of juveniles, but also provides evidence that lake sturgeon utilize our study area in Lake Superior. Schram (2007)

also concluded that the majority of those lake sturgeon stocked in the St. Louis River remained within the far Western area of Lake Superior.

Lake sturgeon were caught off the mouths of the Prairie, Tahquamenon, and Montreal rivers where lake sturgeon populations are believed to be extirpated. Movement along the south shore of Lake Superior has been observed up to 280 km for adults (Auer 1999b), but Holtgren and Auer (2004) observed a much smaller range for juveniles of 15.5 km over 100 days. Caution should be exercised when assuming a fish caught near a tributary mouth hatched from that river. A genetic analysis or other method (e.g., stable isotopes) is warranted to assign juvenile fishes to the tributary of origin in order to fully assess whether a population is reproducing in a tributary. It may be worthwhile to sample for adults or larvae to check if spawning may be occurring in some of the tributaries from which populations are listed as extirpated.

Many broadly distributed age classes were observed at tributaries where lake sturgeon abundance was highest. Tributaries such as the Pic/White, Bad, and Goulais rivers had every year class from age 3 to 10 represented by at least one individual, suggesting natural reproduction occurred on an annual basis. However, most other tributaries had missing year classes which could be due to variation in recruitment, variable environmental conditions, low spawner abundance, missed age classes during sampling, or miss-assigned ages. Variable recruitment has been observed in Rainy Lake, MN and ON (Adams et al. 2006), the Groundhog and Mattagami rivers, ON (Noakes et al. 1999), and in Lake Winnebago, WI (Priegel and Wirth 1975).

Ageing error is known to occur when using pectoral fin rays for sub-adult and adult lake sturgeon and could bias age frequencies and mean length at age estimates. Pectoral fin spines were found to be accurate up to age 14, but underestimated the true age beyond age 14 unless a correction factor is applied to estimate true age (Bruch et al. 2009). We did not apply an age correction factor because 88% of all aged fish were less than or equal to 14 years old and our targeted ages were between 4 and 15 years old. It would be expected that the calculated age frequencies for fish older than 14 years may underestimate the true age structure of the population. In addition, mean length at age estimates (i.e., growth) for fish older than 14 years would be overestimated without applying a correction factor.

The mean length at age estimates appear reasonable up to about age 10, after which standard errors increase and estimates tend to diverge more from the expected shape of the von Bertalanffy growth curve. Some variation in mean length at age could be attributed to combining data from multiple tributary locations into a single region. However, low sample sizes for the youngest and oldest age classes could have greatly affected the accuracy and precision of mean length at age estimates (Isermann and Knight 2005). Mean length at age estimates for juvenile and sub-adult lake sturgeon in the Great Lakes are not common in the literature (one example is Johnson et al. 1998), but studies have been reported on age zero and adults (Auer 1999b; Friday 2006; and Schloesser and Quinlan 2011). This index survey provides

the only known estimates for mean length at age for juvenile and sub-adult lake sturgeon in Lake Superior, filling an information gap in the life history of this species.

Sampling design

Implementation of the first lake-wide status assessment for juvenile and sub-adult lake sturgeon was a challenging endeavor in regards to survey development and implementation because distribution and biological information on juvenile and sub-adult lake sturgeon in Lake Superior was lacking in many areas. Only at a few locations (i.e., St. Louis, Bad, Ontonagon, Goulais, and Batchawana/Chippewa rivers) had previous surveys been completed for juvenile and sub-adult lake sturgeon. The first year of any long term monitoring program is potentially the least informative year, because there is no data from previous years to detect changes within the population. The value of the first year of any survey comes from the baseline data gathered on each population.

The variable mesh gill nets used effectively sampled the size and age range of lake sturgeon targeted for this study. All three mesh sizes should continue to be used in future assessments because the 11.4 cm mesh alone did not effectively capture fish over 10 years old. Those age classes can be sampled using the 20.3 cm and 25.4 cm mesh. While the 25.4 cm mesh primarily captured lake sturgeon >999 mm, it can still be useful to assess whether adults are present in the area and if juveniles and sub-adults are surviving to the adult stage. It is important to recognize that these mesh sizes do not have the ability to effectively capture lake sturgeon less than three years old due to gill net selectivity (Hamley 1975). Unequal lengths of mesh sizes in each gill net heavily biased catch rates towards juveniles compared to sub-adult or adult lake sturgeon. However, this is non-problematic as all gill nets were standardized to the same dimensions and the goal was to develop a relative index of the population size, not quantitatively estimate total abundance.

The premise for concentrating sampling effort near tributary mouths was based on previous fishery surveys that encountered relatively large numbers of juvenile and sub-adult lake sturgeon in those areas. Caroffino et al. (2009) had strong evidence that age zero juvenile lake sturgeon left natal riverine habitats in the Peshtigo River, WI for lentic environments in Green Bay, WI. In the Sturgeon River and Portage Lake system, Holtgren and Auer (2004) observed a total range for juveniles of 11.0 km^2, which is similar to the sampling area in our study. Schram (2007) also observed a mean travel distance of 26 km from the mouth of the St. Louis River for stocked lake sturgeon less than 1,000 mm in length (Auer 1999b).

Detecting changes within a population is important for any survey so that managers can better understand population responses to management or rehabilitation actions. The ability to detect an increasing trend in relative abundance over time appears possible in at least three of the surveyed tributaries, each of which had relatively high catch rates. Future surveys should be

conducted during the same time of year within a location to minimize temporal variation in catch rates, which may improve the power to detect trends. Additionally, the randomly selected sites during the first year of surveys should become fixed sites in future assessments to eliminate any confounding effects habitat may have on catch rates.

Detecting any change in relative abundance may be limited for tributaries with low catches, primarily due to many zero catches, which are problematic for detecting trends (e.g., Berry et al. 2005). Locations with a high proportion of zero catches should be evaluated further to determine if low or zero catches accurately reflect true abundance, or if juvenile lake sturgeon may be using different areas than those sampled in this survey. Even though we demonstrated higher concentrations of juveniles near tributary mouths, the possibility of adjusting sampling areas should not be disregarded if catch rates can be improved to provide a better reflection of true population status (i.e., fewer zero catches). Monitoring population changes could also be accomplished using the proportion of detections (i.e., presence/absence), which may be a more responsive index than relative abundance for tributaries with many zero lake sturgeon catches (Hubert and Fabrizio 2007).

Consideration should be given to assessing population response to rehabilitation actions on a specific group of cohorts. Without knowing the true population structure, it appears lake sturgeon between 5 and 10 years old (approximately 630-850 mm in length) were most vulnerable to our sampling methods. Using grouped five year cohorts (e.g., ages 5-9 or 6-10) versus individual year classes may reduce variability from particularly strong or weak year classes, eliminate autocorrelation in a trend analysis of the entire sampled population, reduce biases associated with age estimation error, and match the five year rotation of Coordinate Science and Monitoring Initiative years of intensive monitoring. In addition, any population response to management or rehabilitation activities would be best evaluated using lake sturgeon ages 5 to 10 as opposed to waiting for fish to reach the adult stage or sampling age zero fish that are known to be susceptible to high rates of natural mortality (Maceina and Pereira 2007; Crossman et al. 2009). One disadvantage of using grouped cohorts is that some information could be lost when assessing individual year class strength.

By-catch of non-target fishes was problematic to the point where sampling was stopped at only one location, the Wolf/Black Sturgeon rivers. During the development of this assessment, field biologists collectively recognized that by-catch could be problematic at some tributaries, but that the lake sturgeon assessment should be carried out and evaluated after the initial year of surveys. One important consideration before survey modifications occur is that this assessment may only occur every five years, lessening the impact on sensitive species.

The 2011 Lake Superior Lake Sturgeon Index Survey demonstrated the ability to collect valuable biological information on a segment of the population previously understudied. With interest in lake sturgeon rehabilitation increasing, especially over the last 20 years (e.g., Great Lakes Fishery Trust), evaluation of our progress is critical in determining effective programs and

strategies. However, a standardized methodology to evaluate rehabilitation efforts across, and even within, the Great Lakes is lacking (Holey et al. 2000). Expansion of the Lake Superior Lake Sturgeon Index Survey to other Great Lakes would provide a consistent assessment by which to evaluate lake sturgeon populations on a Great Lakes-wide scale.

ACKNOWLEDGMENTS

Implementation and development of the first Lake Superior Lake Sturgeon Index Survey was a cooperative effort involving U.S. and Canadian federal, state, provincial, tribal, and academic agencies working under the guidance of the Lake Superior Lake Sturgeon Work Group. Participating agencies included Fisheries and Oceans Canada (DFO), Ontario Ministry of Natural Resources (OMNR), U.S. Fish and Wildlife Service (USFWS), Minnesota Department of Natural Resources (DNR), Wisconsin DNR, Michigan DNR, Great Lakes Indian Fish and Wildlife Commission, 1854 Treaty Authority, Fond Du Lac, Grand Portage, Red Cliff, Bad River, Keweenaw Bay, and Bay Mills Bands of Lake Superior Chippewa, Métis Nation of Ontario, the Anishinabek/Ontario Fisheries Resource Centre, Ontario Parks, Parks Canada, U.S. Forest Service Ottawa National Forest, Lake Superior State University, and Michigan Technological University.

Each field office contributed agency funds through staff wages, operating expenses, and field equipment to carry out field surveys. Great Lakes Restoration Initiative (GLRI) funds were used to purchase gill nets and PIT tags which were distributed to agencies for use during 2011 and future index surveys. GLRI also funded a USFWS fish biologist to assist with development, field season coordination, processing of fish samples, and final report preparation. The Canada-Ontario Agreement respecting the Great Lakes ecosystem basin facilitated OMNR participation by supporting a field technician, vessel and truck operation costs, and other field expenses. Species At Risk Committee En Peril (SARCEP) funds were used to support DFO efforts.

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APPENDIX A (netting coordinates)

ST. LOUIS RIVER

Table A1. Gill nets for the St. Louis River assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	46.79393	-92.08453	13.6	1.030	46.79435	-92.07952	10.1	1.030
2	Inner	46.77618	-92.08535	4.7	1.030	46.77627	-92.08116	10.7	1.030
3	Inner	46.76667	-92.07954	4.3	1.030	46.76789	-92.07582	9.2	1.030
4	Inner	46.71417	-92.02458	6.4	1.030	46.71615	-92.02128	9.3	1.030
5	Inner	46.71215	-92.02143	5.7	1.030	46.71408	-92.01793	8.8	1.030
6	Inner	46.70242	-91.99670	4.7	1.030	46.70490	-91.99448	9.6	1.030
7	Middle	46.80349	-92.06355	3.7	>256	46.80089	-92.06547	16.7	1.030
8	Middle	46.79876	-92.07476	6.2	0.045	46.79916	-92.06995	16.5	0.550
9	Middle	46.76230	-92.07274	13.5	1.030	46.76365	-92.06908	7.8	1.028
10	Middle	46.72600	-92.03712	7.8	1.030	46.72763	-92.03333	11.9	1.030
11	Middle	46.71938	-92.02597	10.0	1.030	46.72152	-92.02220	13.6	1.030
12	Middle	46.69553	-91.97167	12.2	1.030	46.69803	-91.96933	15.1	1.030
13	Outer	46.83604	-92.00510	3.8	1.030	46.83598	-92.00031	10.7	1.225
14	Outer	46.74489	-92.05524	14.4	1.030	46.74670	-92.05211	9.0	1.030
15	Outer	46.68902	-91.96860	6.2	1.030	46.69043	-91.96508	9.2	1.030
16	Outer	46.68448	-91.93525	5.0	1.030	46.68725	-91.93673	6.9	1.030

BAD (WHITE) RIVER

Table A2. Gill nets for the Bad River assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	46.64577	-90.65668	2.3	1.030				
2	Inner	46.63632	-90.64342	1.1	1.030				1.030
3	Inner	46.64631	-90.65557	6.1	0.013	46.64890	-90.65406	8.2	0.024
4	Inner	46.64640	-90.64769	8.8	0.024	46.64948	-90.64575	11.9	1.030
5	Inner	46.63505	-90.64180	6.7		46.63713	-90.63877	13.7	
6	Inner	46.63353	-90.63687	11.9		46.63530	-90.63288	16.2	
7	Middle	46.65717	-90.65970	12.5	0.003	46.65977	-90.65814	14.3	0.656
8	Middle	46.65561	-90.65549	13.1	0.007	46.65760	-90.65250	14.6	0.045
9	Middle	46.64550	-90.63503	12.9	1.030	46.64633	-90.63048	14.8	0.753
10	Middle	46.63933	-90.62105	15.2		46.63597	-90.62252	12.5	
11	Middle	46.63182	-90.61488	12.6	0.753	46.63468	-90.61218	14.3	0.753
12	Middle	46.62297	-90.62222	5.4		46.62570	-90.62102	13.4	
13	Outer	46.67242	-90.69507	13.7		46.67000	-90.69482	10.4	
14	Outer	46.66772	-90.69548	5.5				11.4	
15	Outer	46.61633	-90.58537	13.3	0.753	46.61747	-90.58200		0.753
16	Outer	46.61048	-90.59170	8.2	0.002	46.61243	-90.58850	10.5	0.002

MONTREAL RIVER

Table A3. Gill nets for the Montreal River assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	46.56402	-90.43297	5.0	1.030			7.3	0.508
2	Inner	46.57133	-90.43278	11.7	1.030	46.57416	-90.43155		1.030
3	Inner	46.56608	-90.42646	5.6	160.0	46.56801	-90.42364		0.960
4	Inner	46.56741	-90.42003	4.6	16.2	46.56951	-90.41725	7.9	
5	Inner	46.57181	-90.42200	10.1	1.030	46.57431	-90.42217		1.030
7	Middle	46.57907	-90.45275	14.6	1.111	46.57605	-90.45354	12.2	1.030
8	Middle	46.56892	-90.43639	9.8	0.863	46.57176	-90.43621		0.863
13	Outer	46.58387	-90.48599	6.1	1.030	46.58616	-90.48383	9.6	1.030
14	Outer	46.57969	-90.47988	4.5	1.030	46.58172	-90.47725	8.6	1.030

ONTONAGON RIVER

Table A4. Gill nets for the Ontonagon River assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	46.87398	-89.33928	6.1	0.863	46.87678	-89.34083	8.6	0.863
2	Inner	46.87707	-89.33232	3.5	33.0	46.87988	-89.33395	7.1	0.863
3	Inner	46.87832	-89.32428	2.9	0.863	46.88092	-89.32607	5.9	0.863
4	Inner	46.88803	-89.32213	9.4	1.030	46.89128	-89.32285	12.8	0.863
5	Inner	46.88227	-89.31627	5.9	0.863	46.88505	-89.31702	7.1	0.863
6	Inner	46.88350	-89.31495	6.6		46.88638	-89.31492	8.7	
7	Middle	46.86890	-89.34697	4.9	1.030	46.87167	-89.34858	8.6	1.030
8	Middle	46.87415	-89.34938	13.9	0.357	46.87662	-89.35182	11.7	0.357
9	Middle	46.86958	-89.34392	3.0	33.0	46.87218	-89.34568	7.7	0.723
10	Middle	46.89443	-89.31543	14.2	1.030	46.89750	-89.31587	14.3	1.030
11	Middle	46.88890	-89.30068	5.5	72.7	46.89148	-89.30292	10.3	0.863
12	Middle	46.89118	-89.29995	7.2	1.030	46.89407	-89.30040	11.8	1.030
13	Outer	46.85562	-89.39888	7.5	33.0	46.85853	-89.39985	10.6	33.0
14	Outer	46.86587	-89.38417	14.3	33.0	46.86882	-89.38513	12.4	33.0
15	Outer	46.85925	-89.37882	4.3	33.0	46.86217	-89.38093	6.3	33.0
16	Outer	46.90323	-89.25807	3.4	33.0	46.90597	-89.25957	5.6	160.0

STURGEON RIVER NORTH ENTRY

Table A5. Gill nets for the Sturgeon River North Entry assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	47.23068	-88.64478	5.3	>256	47.23298	-88.64667	10.4	1.030
2	Inner	47.22962	-88.63730	2.9	1.030	47.23198	-88.63977	6.6	1.030
3	Inner	47.23473	-88.63992	9.9	1.030	47.23758	-88.64024	13.0	1.030
4	Inner	47.24100	-88.63084	13.1	>256	47.24397	-88.63085	14.8	1.030
5	Inner	47.23882	-88.62756	11.1	1.030	47.24177	-88.62778	11.8	>256
6	Inner	47.23480	-88.62043	4.4	1.030	47.23730	-88.62275	8.6	>256
7	Inner	47.23912	-88.62065	8.3	160.0	47.24172	-88.62213	11.7	1.030
8	Middle	47.22587	-88.65918	3.1	1.326	47.22875	-88.65961	7.9	1.030
9	Middle	47.22848	-88.65524	5.1	Bedrock	47.23075	-88.65759	11.2	1.030
10	Middle	47.22950	-88.64996	3.9	Bedrock	47.23228	-88.64968	9.4	Bedrock
11	Middle	47.23082	-88.64910	4.3	160.0	47.23287	-88.64920	11.6	1.225
12	Middle	47.24322	-88.58943	3.0	1.030	47.24625	-88.58955	8.4	1.030
13	Outer	47.21755	-88.68380	5.8	160.0	47.22003	-88.68557	13.5	160.0
14	Outer	47.24448	-88.58315	3.3	1.030	47.24707	-88.58492	7.6	1.030
15	Outer	47.25185	-88.58238	9.4	1.030	47.25448	-88.58413	10.6	1.030
16	Outer	47.26503	-88.57547	12.8	1.030	47.26728	-88.57765	13.7	1.030

STURGEON RIVER SOUTH ENTRY

Table A6. Gill nets for the Sturgeon River South Entry assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	46.97442	-88.41978	3.7	1.030	46.97181	-88.41862	8.5	0.723
2	Inner	46.97343	-88.42890	2.8	1.030	46.97168	-88.42589	5.2	3.636
3	Inner	46.96398	-88.44355	2.9	1.030	46.96530	-88.43990	3.4	5.830
4	Inner	46.95836	-88.44515	3.0	160.0	46.95819	-88.44065	6.5	1.030
7	Middle	46.98382	-88.39825	10.2	64.5	46.98118	-88.39666	14.8	64.5
8	Middle	46.96865	-88.41352	13.7	1.030	46.96564	-88.41499	11.7	1.030
9	Middle	46.95032	-88.42871	14.4	5.830	46.95329	-88.42793	14.2	0.426
10	Middle	46.94408	-88.44009	11.2	1.030	46.94442	-88.43554	13.5	1.030
11	Middle	46.94925	-88.44322	7.0	1.030	46.95033	-88.43874	8.7	1.030
12	Middle	46.95366	-88.44579	3.1	179.9	46.95477	-88.44126	6.9	1.030
13	Outer	46.99826	-88.38844	2.9	64.5	46.99601	-88.38636	10.3	>256
14	Outer	46.98779	-88.39211	15.6	45.3	46.98607	-88.38939	12.6	45.3
15	Outer	46.93204	-88.44008	12.8	1.030	46.93143	-88.43553	13.6	1.030
16	Outer	46.92226	-88.45312	3.7	>256	46.92097	-88.44863	10.5	1.030

TAHQUAMENON RIVER

Table A7. Gill nets for the Tahquamenon River assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	46.56506	-85.01850	3.2	1.030	46.56511	-85.01431	3.4	1.030
2	Inner	46.55957	-85.01457	3.0	1.030	46.55854	-85.01065	3.7	1.030
3	Inner	46.55442	-85.01134	3.2	1.030	46.55472	-85.00681	4.0	1.030
4	Inner	46.54751	-85.00877	3.0	1.030	46.54804	-85.00403	4.0	1.030
5	Inner	46.54295	-85.00691	3.2	1.030	46.54351	-85.00274	3.7	1.030
6	Middle	46.57766	-85.02687	2.9	1.030	46.57839	-85.02303	4.1	1.030
7	Middle	46.57123	-85.01050	4.7	1.030	46.57180	-85.00614	5.1	1.030
8	Middle	46.54174	-84.98256	6.4	1.030	46.54224	-84.97844	5.8	1.030
9	Middle	46.54077	-84.99242	4.6	1.030	46.54202	-84.98824	5.7	1.030
10	Middle	46.53740	-85.00083	4.4	1.030	46.53791	-84.99611	4.3	1.030
11	Outer	46.61422	-85.00294	12.8	1.030	46.61489	-85.00739	11.3	1.030
12	Outer	46.60198	-85.03167	3.4	1.030	46.60318	-85.02789	4.7	1.030
13	Outer	46.58846	-85.02969	3.3	1.030	46.59021	-85.02580	4.6	1.030
14	Outer	46.53185	-84.95279	4.8	1.030	46.53208	-84.95699	5.9	1.030
15	Outer	46.51586	-85.02094	2.6	0.061	46.51310	-85.02022	2.9	0.061
16	Outer	46.50493	-85.01200	3.9	1.030	46.50388	-85.00817	4.4	1.030

GOULAIS RIVER

Table A8. Gill nets for the Goulais River assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	46.70390	-84.44317	4.9	1.030	46.70142	-84.44586	8.5	0.176
2	Inner	46.70382	-84.45229	10.6	0.013	46.70403	-84.45635	11.7	0.013
3	Inner	46.71168	-84.45681	5.9		46.71394	-84.45503	4.5	0.030
4	Inner	46.71717	-84.45872	8.2	0.045	46.71941	-84.46113	8.4	
5	Inner	46.71978	-84.45529	4.9	0.008	46.71869	-84.45896	7.5	0.013
6	Inner	46.72193	-84.46880	6.4		46.72254	-84.45678	7.8	0.176
7	Middle	46.68417	-84.43658	6.1		46.68511	-84.44027	6.4	
8	Middle	46.69324	-84.46188	14.2	1.030	46.69412	-84.47583	16.8	1.030
9	Middle	46.72488	-84.46487	8.1	0.006	46.72442	-84.46882	9.3	0.006
10	Middle	46.73151	-84.46739	7.2	0.176	46.72879	-84.46579	7.2	0.176
11	Middle	46.73335	-84.45251	3.6	0.030	46.73059	-84.45402	4.9	0.030
12	Middle	46.73438	-84.45524	4.8	0.030	46.73280	-84.45852	5.6	0.030
13	Middle	46.73740	-84.45240	3.6	0.030	46.73490	-84.45443	4.7	0.030
14	Middle	46.73809	-84.46388	5.1	0.157	46.73629	-84.46687	6.1	
15	Outer	46.67395	-84.47206	7.2	1.030	46.67630	-84.47007	10.5	1.030
16	Outer	46.64449	-84.49984	6.0	1.030	46.64265	-84.50249	4.3	1.030

BATCHAWANA AND CHIPPEWA RIVERS

Table A9. Gill nets for the Batchawana/Chippewa rivers assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	46.91349	-84.43645	26.0	0.024	46.91578	-84.43643	16.6	0.024
2	Inner	46.91579	-84.44507	26.0	0.030	46.91578	-84.44092	21.5	0.030
3	Inner	46.92910	-84.44880	11.5	0.003	46.92660	-84.44752	8.0	0.003
4	Inner	46.91885	-84.53525	3.9	1.030	46.91622	-84.53668	4.8	1.030
5	Inner	46.92192	-84.53525	2.2	1.030	46.91922	-84.53490	3.5	1.030
6	Inner	46.92844	-84.53896	6.9		46.93014	-84.53599	2.2	
7	Middle	46.90444	-84.44787	8.9	0.008	46.90658	-84.44542	13.7	0.176
8	Middle	46.93304	-84.46957	5.6	0.030	46.93324	-84.46575	9.7	0.002
9	Middle	46.90738	-84.49849	7.5	0.030	46.90825	-84.50215	4.1	
10	Middle	46.90692	-84.54372	5.5	>256	46.90658	-84.53974	5.0	1.030
11	Middle	46.90351	-84.54873	9.8	0.030	46.90586	-84.55095	12.1	0.030
12	Middle	46.90203	-84.54983	9.8		46.90351	-84.55322	16.0	
13	Outer	46.82225	-84.40819	11.5	0.008	46.82059	-84.40500		0.008
14	Outer	46.82430	-84.41912	11.0	0.030	46.82694	-84.41860	15.6	0.008
15	Outer	46.82781	-84.50263	4.9	0.294	46.82754	-84.50655	4.1	0.254
16	Outer	46.83006	-84.50595	5.4	0.045	46.82750	-84.50621	4.4	0.045

MICHIPICOTEN RIVER

Table A10. Gill nets for the Michipicoten River assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	47.92431	-84.84362	4.2	1.030	47.92177	-84.84212	6.5	1.030
2	Inner	47.93803	-84.85269	9.4	1.030	47.93532	-84.85284	6.7	1.030
3	Inner	47.94016	-84.84736	9.1	33.0	47.94144	-84.85097	11.1	1.457
4	Inner	47.94185	-84.84619	4.7	1.030	47.94329	-84.84942	8.9	1.030
5	Inner	47.94604	-84.85058	5.9	1.030	47.94404	-84.84775	6.4	1.030
6	Inner	47.94584	-84.85096	9.0	1.030	47.94785	-84.85385	9.2	1.030
7	Middle	47.91407	-84.84041	4.2	1.030	47.91276	-84.84399	20.1	>256
8	Middle	47.91718	-84.84053	8.8	1.030	47.91981	-84.84105	8.0	1.030
9	Middle	47.95426	-84.85917	6.4		47.95225	-84.85618		
10	Middle	47.95343	-84.86250	11.2	Bedrock	47.95575	-84.86445	13.4	>256
11	Middle	47.95525	-84.86111	5.7	33.0	47.95412	-84.86478	12.5	>256
12	Middle	47.95713	-84.89213	10.8	0.002	47.95570	-84.88852	11.6	33.0
13	Outer	47.95625	-84.90052	8.3	0.002	47.95365	-84.89957	13.5	0.176
14	Outer	47.95602	-84.90163	8.4	0.298	47.95466	-84.90541	4.7	>256
15	Outer	47.95422	-84.90351	9.8	0.508	47.95206	-84.90561	4.2	4.708
16	Outer	47.95304	-84.92285	6.7	1.030	47.95302	-84.92657	13.4	1.030

PIC AND WHITE RIVERS

Table A11. Gill nets for the Pic/White rivers assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	48.54690	-86.27093	11.9	>256	48.54412	-86.27015	17.7	1.030
2	Inner	48.58952	-86.30680	5.5	1.030	48.59222	-86.30860	8.2	0.002
3	Inner	48.59508	-86.30583	4.5	1.030	48.59545	-86.31009	7.0	0.002
4	Inner	48.59779	-86.31144	7.4	0.045	48.59983	-86.30881	3.8	1.030
5	Inner	48.60533	-86.31742	5.4	1.030	48.60302	-86.31539	6.0	1.030
6	Inner	48.60598	-86.32261	6.5	1.030	48.60366	-86.32516	9.5	1.030
7	Middle	48.56734	-86.27354	4.2	1.030	48.56511	-86.27121	10.0	1.030
8	Middle	48.58576	-86.28334	6.7	0.030	48.58608	-86.28760	6.8	>256
9	Middle	48.59102	-86.28057	4.0	0.030	48.59128	-86.28479	5.7	0.030
10	Middle	48.60858	-86.34263	13.6	>256	48.61121	-86.34128	23.1	0.002
11	Middle	48.61924	-86.34271	9.0	>256	48.62163	-86.34074	4.5	>256
12	Middle	48.62500	-86.31700	5.9		48.62755	-86.31871	11.0	1.030
13	Outer	48.48737	-86.25041	12.6	>256	48.48488	-86.24851	15.2	>256
14	Outer	48.50007	-86.24676	4.3	>256	48.50159	-86.25009	12.6	33.0
15	Outer	48.64231	-86.31902	10.1	91.9	48.64112	-86.32335	14.9	0.002
16	Outer	48.64961	-86.31025	5.1	1.030	48.64760	-86.31323	7.2	0.002

PRAIRIE RIVER

Table A12. Gill nets for the Prairie River assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	48.77733	-86.77070	7.0	33.0	48.77473	-86.77107	13.4	0.002
2	Inner	48.77880	-86.77444	7.0		48.77770	-86.77828	9.7	1.030
3	Inner	48.78053	-86.77678	4.0		48.77824	-86.77898	9.0	1.030
4	Inner	48.78080	-86.77945	3.9	Bedrock	48.77836	-86.78185	11.8	1.030
5	Inner	48.77999	-86.78308	7.9	0.061	48.77821	-86.77996	10.6	0.030
6	Inner	48.78046	-86.78784	5.1	Bedrock	48.77799	-86.78954	7.8	1.030
7	Inner	48.77821	-86.77929	15.1	2.060	48.77608	-86.77690	9.4	1.030
8	Middle	48.78573	-86.74478	11.0	>256	48.78370	-86.74215	5.8	>256
9	Middle	48.78054	-86.75307	3.9	0.031	48.77967	-86.75679	9.7	160.0
10	Middle	48.77620	-86.75721	11.9	0.254	48.77412	-86.75988	5.2	
11	Middle	48.77564	-86.79483	9.4	33.0	48.77823	-86.79486	6.4	1.030
12	Middle	48.77289	-86.79683	7.9	Bedrock	48.77052	-86.79895	5.1	Bedrock
13	Outer	48.80963	-86.70314	4.8		48.80691	-86.70373	11.6	0.008
14	Outer	48.75151	-86.84327	4.4	>256	48.74957	-86.84588	10.1	>256
15	Outer	48.74992	-86.85228	11.9	1.030	48.74829	-86.85532	5.1	Bedrock
16	Outer	48.75054	-86.85233	7.0	Bedrock	48.74862	-86.85527	11.3	>256

GRAVEL RIVER

Table A13. Gill nets for the Gravel River assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	48.90687	-87.77962	10.1	0.002	48.90775	-87.78383	14.3	0.002
2	Inner	48.90936	-87.78896	12.2	0.002	48.91215	-87.79072	10.6	0.002
3	Inner	48.91544	-87.77631	6.5	0.003	48.91429	-87.78029	13.8	0.003
4	Inner	48.91513	-87.78239	14.5	0.003	48.91397	-87.78646	14.3	0.002
5	Inner	48.91849	-87.78633	4.2	0.002	48.91559	-87.78672	14.6	0.002
6	Inner	48.92199	-87.78257	2.6	0.003	48.92103	-87.78690	3.5	0.003
7	Middle	48.89833	-87.75565	2.7	0.003	48.89567	-87.75435	21.0	0.003
8	Middle	48.90620	-87.78483	12.3	0.003	48.90619	-87.78962	21.3	0.003
9	Middle	48.91193	-87.79292	10.6	0.002	48.90909	-87.79181	13.9	0.002
10	Middle	48.91053	-87.80666	5.5	0.003	48.90774	-87.80471	19.0	0.003
11	Middle	48.91948	-87.79813	3.2	0.002	48.91661	-87.79722	9.1	0.002
13	Outer	48.89323	-87.69389	15.7	0.003	48.89087	-87.69579	12.4	0.003
14	Outer	48.90487	-87.71489	2.8	0.006	48.90257	-87.71772	19.5	0.006
15	Outer	48.90156	-87.81857	12.2	0.002	48.89880	-87.81763	15.2	0.002
16	Outer	48.90362	-87.83791	9.5	0.002	48.90092	-87.84022	11.6	0.002

NIPIGON RIVER

Table A14. Gill nets for the Nipigon River assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	48.96189	-88.24801	17.3	0.002	48.95912	-88.24898	7.3	0.002
2	Inner	48.95353	-88.25213	12.4	0.002	48.95605	-88.24976	12.7	
3	Inner	48.95168	-88.24812	13.8	0.002	48.95453	-88.24690	13.1	0.002
4	Inner	48.94598	-88.24724	2.1	0.002	48.94845	-88.24483	17.8	0.002
5	Inner	48.95557	-88.22812	7.6		48.95286	-88.23008	12.9	
6	Inner	48.94068	-88.24216	3.2	0.002	48.94297	-88.23952	19.1	0.002
7	Middle	48.95483	-88.22392	9.4	0.002	48.95189	-88.22545	13.7	0.002
8	Middle	48.93654	-88.23866	2.3	0.002	48.93806	-88.23491	20.1	0.002
9	Middle	48.93832	-88.21824	16.7	0.002	48.93962	-88.21426	15.7	0.002
10	Middle	48.95206	-88.20683	9.2	0.003	48.94907	-88.20794	11.6	0.003
11	Middle	48.93939	-88.20998	15.5	0.002	48.94207	-88.20762	15.3	0.002
13	Outer	48.95652	-88.19487	6.1	0.003	48.95352	-88.19592	6.9	0.003
14	Outer	48.94393	-88.16775	5.2	0.003	48.94108	-88.16711	16.8	0.003
15	Outer	48.91164	-88.19704	9.3	0.003	48.91093	-88.20148	18.5	0.003
16	Outer	48.91214	-88.18659	6.4	0.003	48.91389	-88.18317	8.3	0.003

WOLF AND BLACK STURGEON RIVERS

Table A15. Gill nets for the Wolf/Black Sturgeon rivers assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
7	Middle	48.81907	-88.41570	4.0	0.003	48.81666	-88.41299	4.2	0.003
8	Middle	48.82711	-88.43616	3.4	0.003	48.82431	-88.43682	3.8	0.003
9	Middle	48.84027	-88.44894	2.8	0.003	48.83842	-88.44567	2.8	0.003

KAMINISTIQUIA RIVER

Table A16. Gill nets for the Kaministiquia River assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	48.36152	-89.20765	2.9	0.003	48.36230	-89.20345	4.4	0.002
2	Inner	48.35961	-89.20470	4.8	0.002	48.36135	-89.20816	2.9	0.002
3	Inner	48.36006	-89.19945	7.9	0.003	48.35917	-89.19483	6.7	0.003
4	Inner	48.35604	-89.20324	5.9	0.002	48.35732	-89.20773	3.5	0.002
5	Inner	48.35576	-89.19966	7.0	0.003	48.35618	-89.20447	5.3	0.002
6	Inner	48.35378	-89.20679	3.5	0.002	48.35240	-89.20274	5.0	0.003
7	Middle	48.37512	-89.17115	12.9	0.002	48.37523	-89.17579	12.2	0.002
8	Middle	48.36744	-89.19257	6.1	0.033	48.36680	-89.18823	7.7	
9	Middle	48.36460	-89.19563	6.1	0.002	48.36463	-89.20025	5.0	0.002
10	Middle	48.36140	-89.19571	7.3	0.003	48.36283	-89.19967	5.9	
11	Middle	48.35289	-89.18629	10.2	0.003	48.35261	-89.19098	9.0	0.002
12	Middle	48.34317	-89.18686	7.1	0.002	48.34550	-89.18416	10.9	0.002
13	Outer	48.36173	-89.14867	15.0	0.003	48.36119	-89.14414	6.2	0.003
14	Outer	48.35601	-89.15640	14.6	0.002	48.35609	-89.15157	9.1	0.002
15	Outer	48.31069	-89.19675	5.2	0.033	48.31142	-89.19254	8.6	
16	Outer	48.30527	-89.20251	3.0	0.002	48.30539	-89.19831	7.4	0.002

PIGEON RIVER

Table A17. Gill nets for the Pigeon River assessment were set in one of three strata based on proximity to the tributary mouth: 0-2 km, 2-5 km, and 5-10 km. All GPS coordinates are in WGS 1984 decimal degrees. Water depth (m) was recorded at the start and end of each gill net deployment. Substrate samples were classified into percentages of clay (<0.0039 mm), silt (0.0039-0.0625 mm), sand (0.0625-2 mm), gravel (2-64 mm), cobble (64-256 mm), or boulder (>256 mm) and summarized by geometric mean diameter (D_g; mm) of the sample.

Set #	Strata	Start				End			
		Latitude	Longitude	Depth (m)	Substrate D_g (mm)	Latitude	Longitude	Depth (m)	Substrate D_g (mm)
1	Inner	48.00897	-89.56444	3.5	11.7	48.00644	-89.56607	5.4	1.023
2	Inner	48.00900	-89.57011	2.2	1.030	48.00654	-89.56865	4.1	1.030
3	Inner	48.00584	-89.57419	2.2	1.030	48.00512	-89.57121	3.3	1.030
4	Inner	48.00357	-89.56964	3.0	1.030	48.00364	-89.56476	5.1	1.030
5	Inner	47.99916	-89.56539	2.8	1.030	48.00187	-89.56384	6.1	1.030
6	Inner	47.99970	-89.55702	9.4	202.4	48.00270	-89.55689	15.2	1.030
7	Middle	48.01821	-89.55037	3.3	12.8	48.01577	-89.54870	15.2	120.3
8	Middle	48.01752	-89.55401	3.2	202.4	48.01520	-89.55176	10.7	202.4
9	Middle	48.01511	-89.55669	5.0	2.060	48.01542	-89.55246	9.1	2.060
10	Middle	48.01375	-89.55411	6.3	160.0	48.01647	-89.55374	7.5	160.0
11	Middle	48.01366	-89.55088	3.5	202.4	48.01653	-89.55108	8.3	202.4
12	Middle	48.01370	-89.54998	5.4	233.0	48.01583	-89.54748	15.6	9.362
13	Outer	48.03257	-89.49145	3.3	64.1	48.03025	-89.49256	14.6	4.647
14	Outer	48.02929	-89.50087	2.5	2.060	48.03129	-89.50225	3.0	2.060
15	Outer	47.98933	-89.57201	2.4	143.2	47.98863	-89.56792	11.6	143.2
16	Outer	47.98643	-89.61323	2.3	0.723	47.98817	-89.61669	7.4	0.723

APPENDIX B (netting maps)

ST. LOUIS RIVER

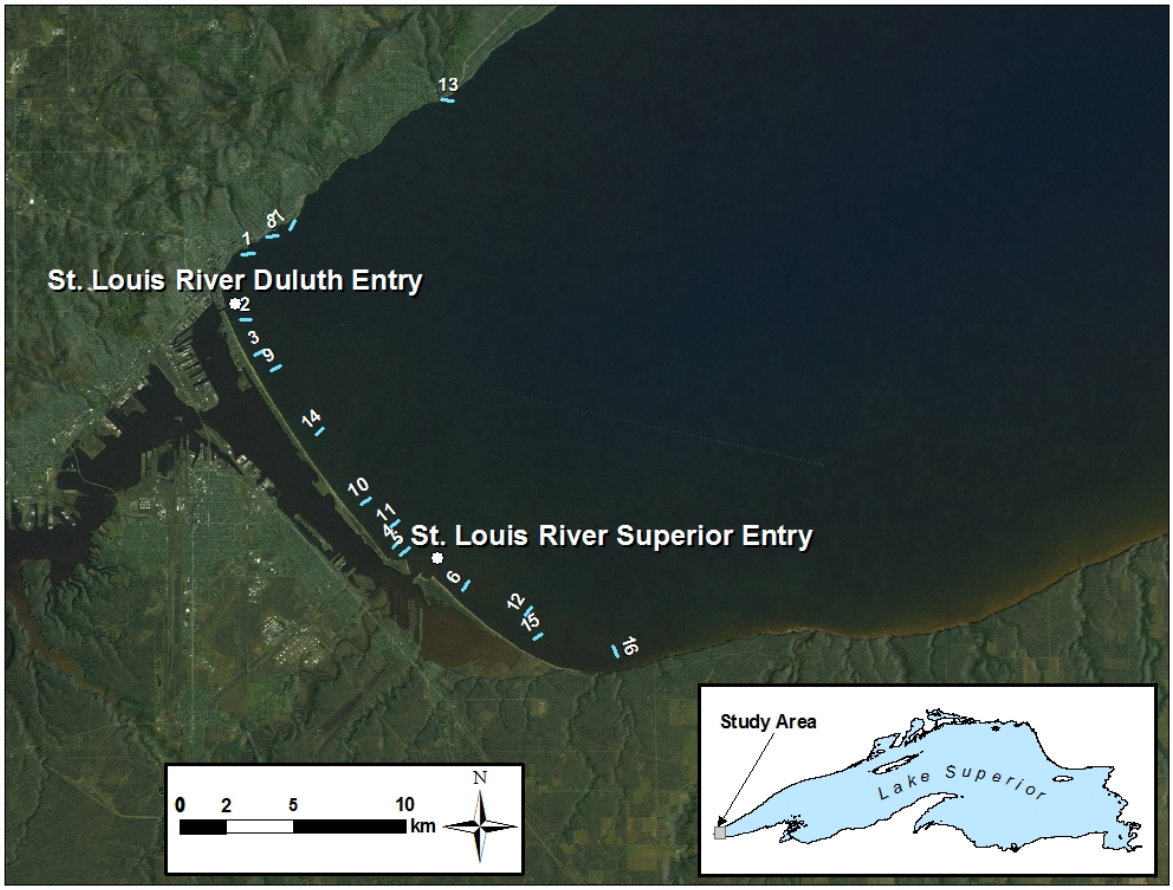

Figure B1. Gill net locations for the St. Louis River assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during July 26 to August 17, 2011.

BAD (WHITE) RIVER

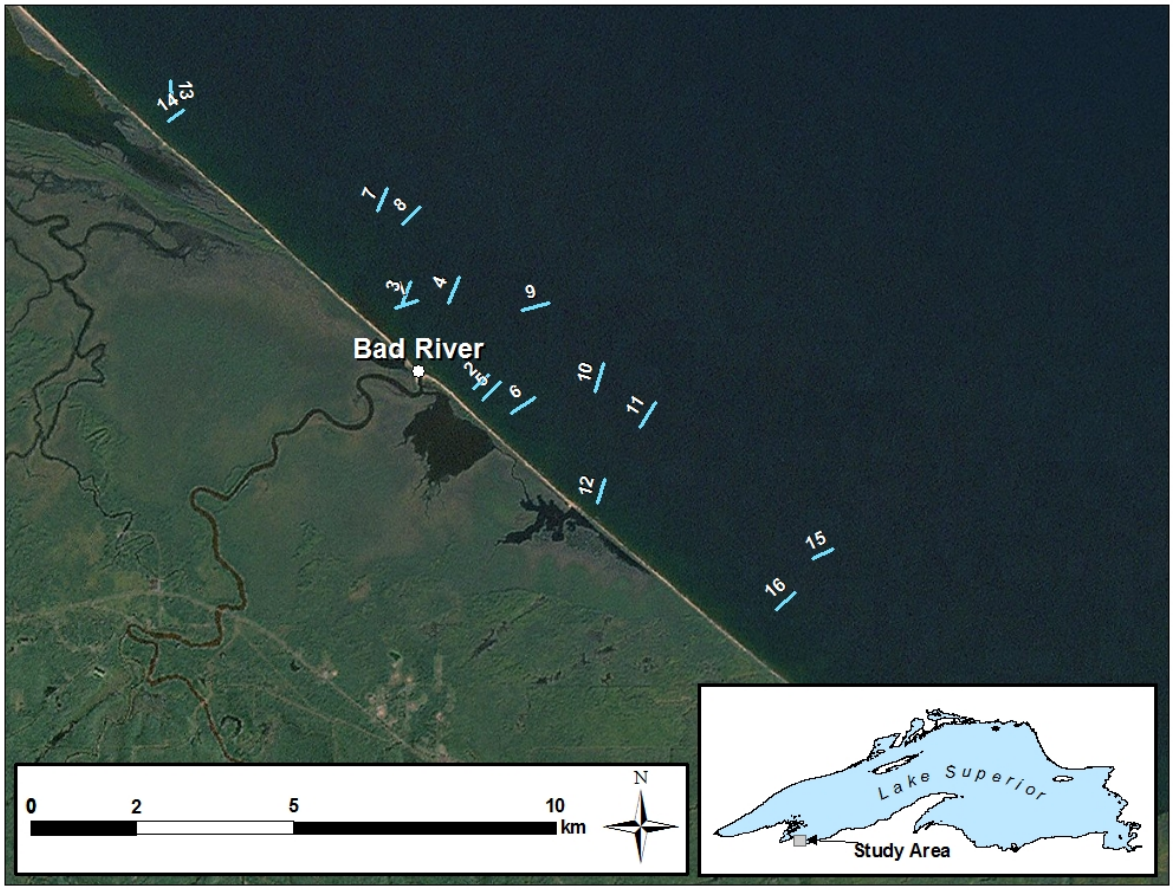

Figure B2. Gill net locations for the Bad River assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during July 19 to September 9, 2011.

MONTREAL RIVER

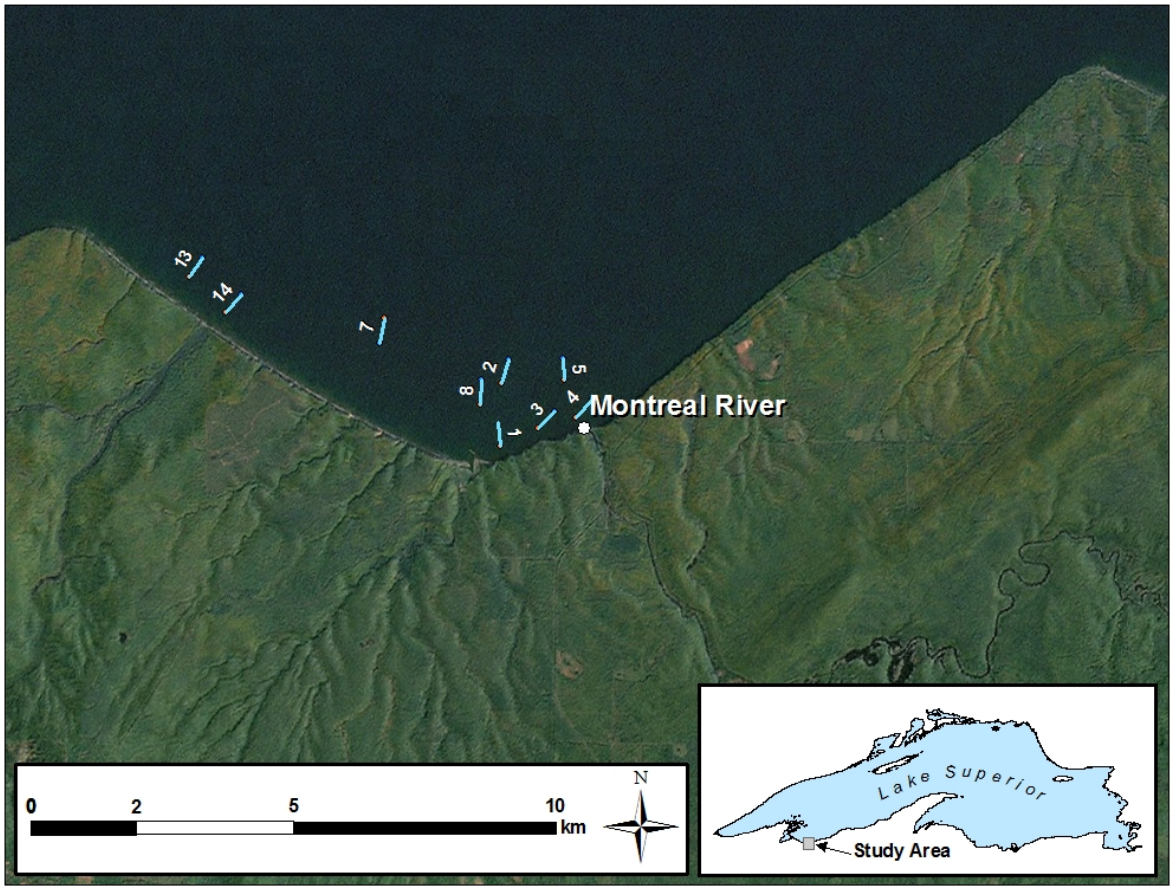

Figure B3. Gill net locations for the Montreal River assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during July 12 to July 14, 2011.

ONTONAGON RIVER

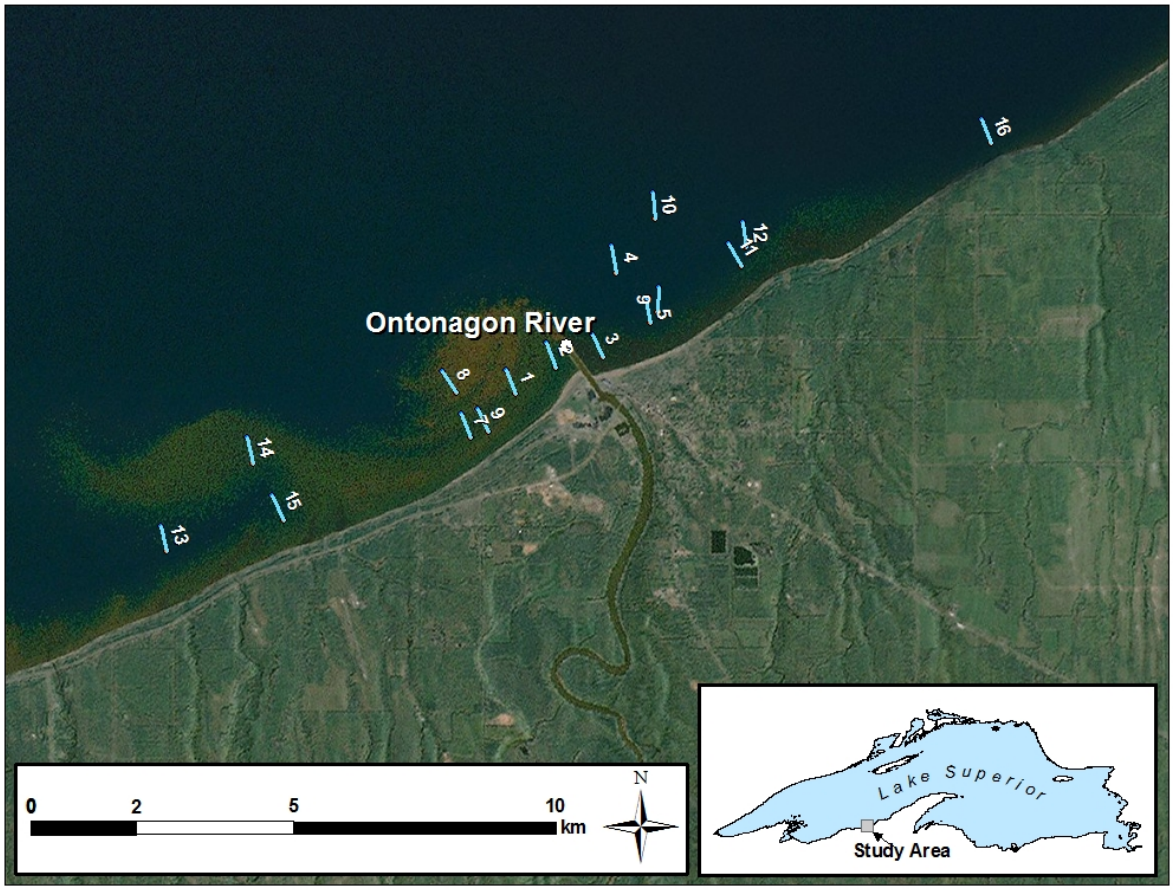

Figure B4. Gill net locations for the Ontonagon River assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during August 11 to September 7, 2011.

STURGEON RIVER NORTH ENTRY

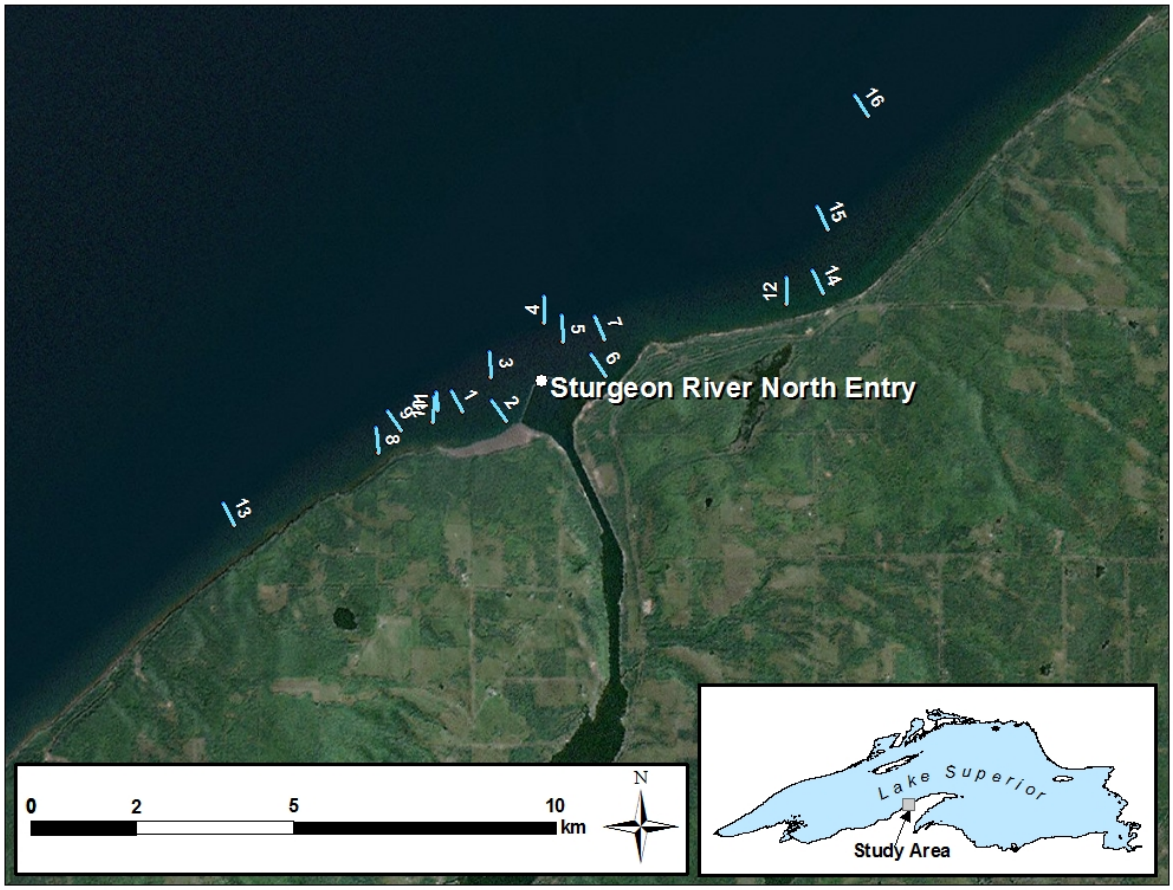

Figure B5. Gill net locations for the Sturgeon River North Entry assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during August 2 to August 5, 2011.

STURGEON RIVER SOUTH ENTRY

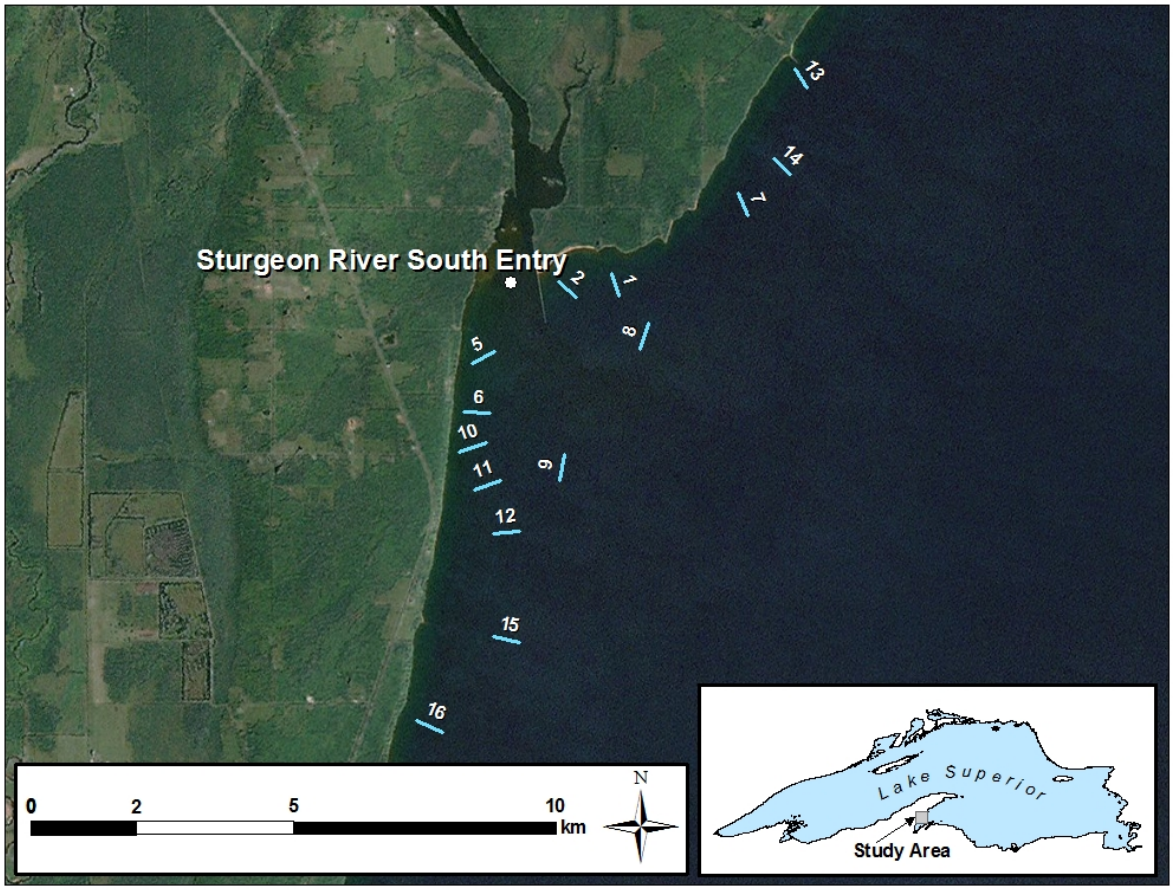

Figure B6. Gill net locations for the Sturgeon River South Entry assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during August 2 to August 5, 2011.

TAHQUAMENON RIVER

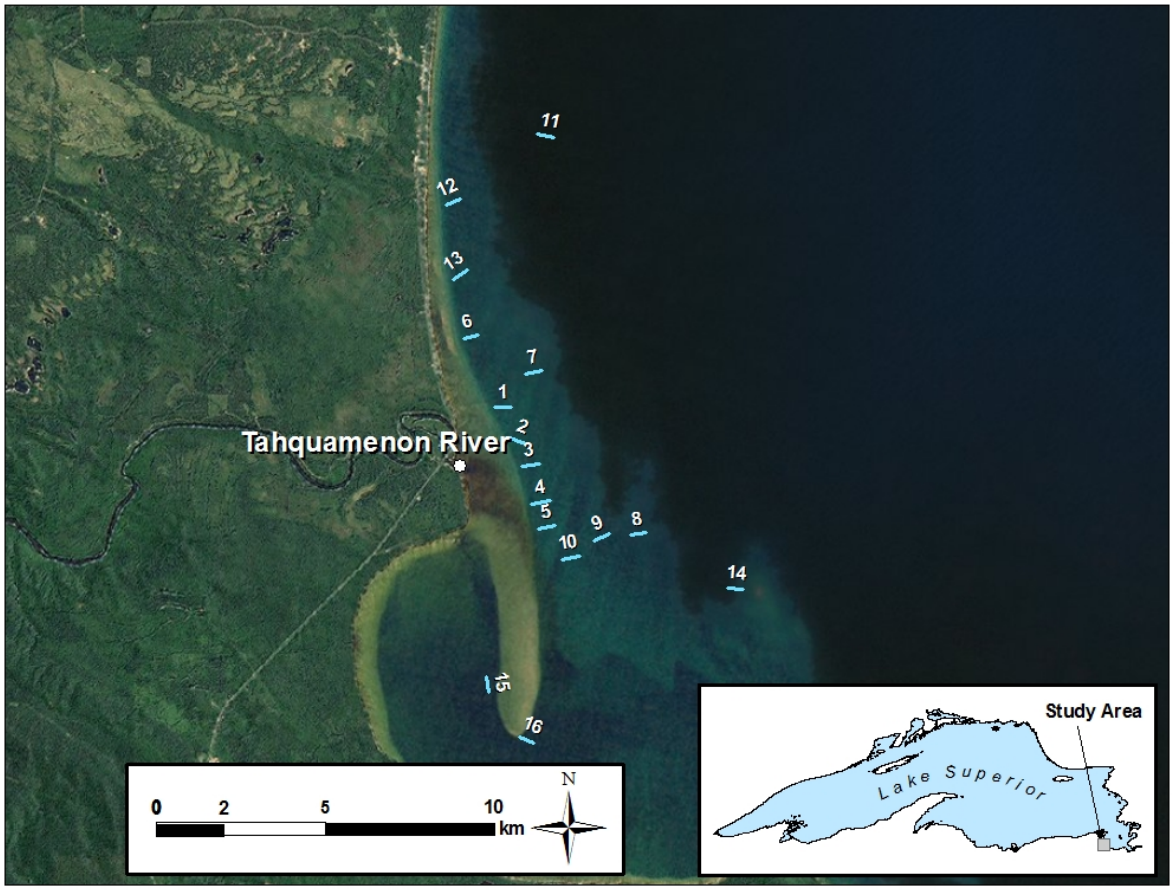

Figure B7. Gill net locations for the Tahquamenon River assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during July 26 to July 29, 2011.

GOULAIS RIVER

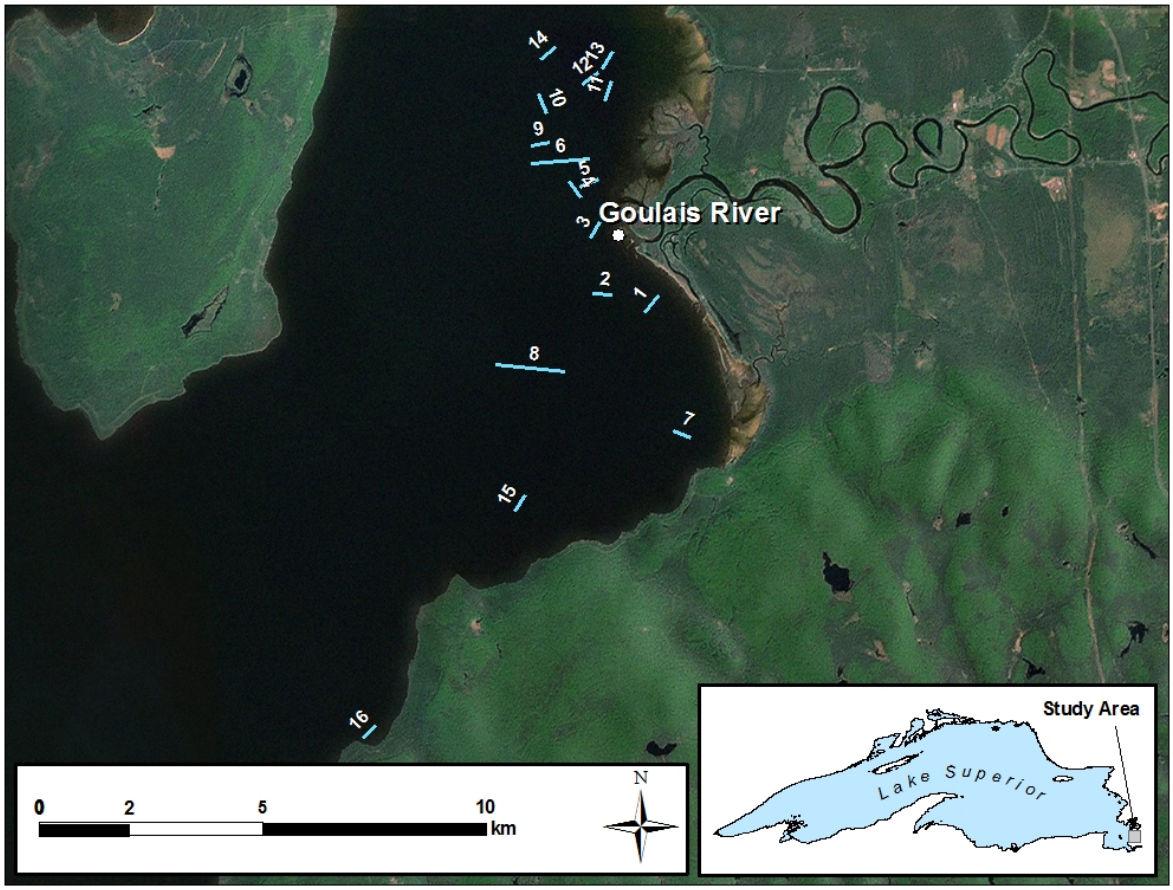

Figure B8. Gill net locations for the Goulais River assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during July 5 to July 10, 2011.

BATCHAWANA AND CHIPPEWA RIVERS

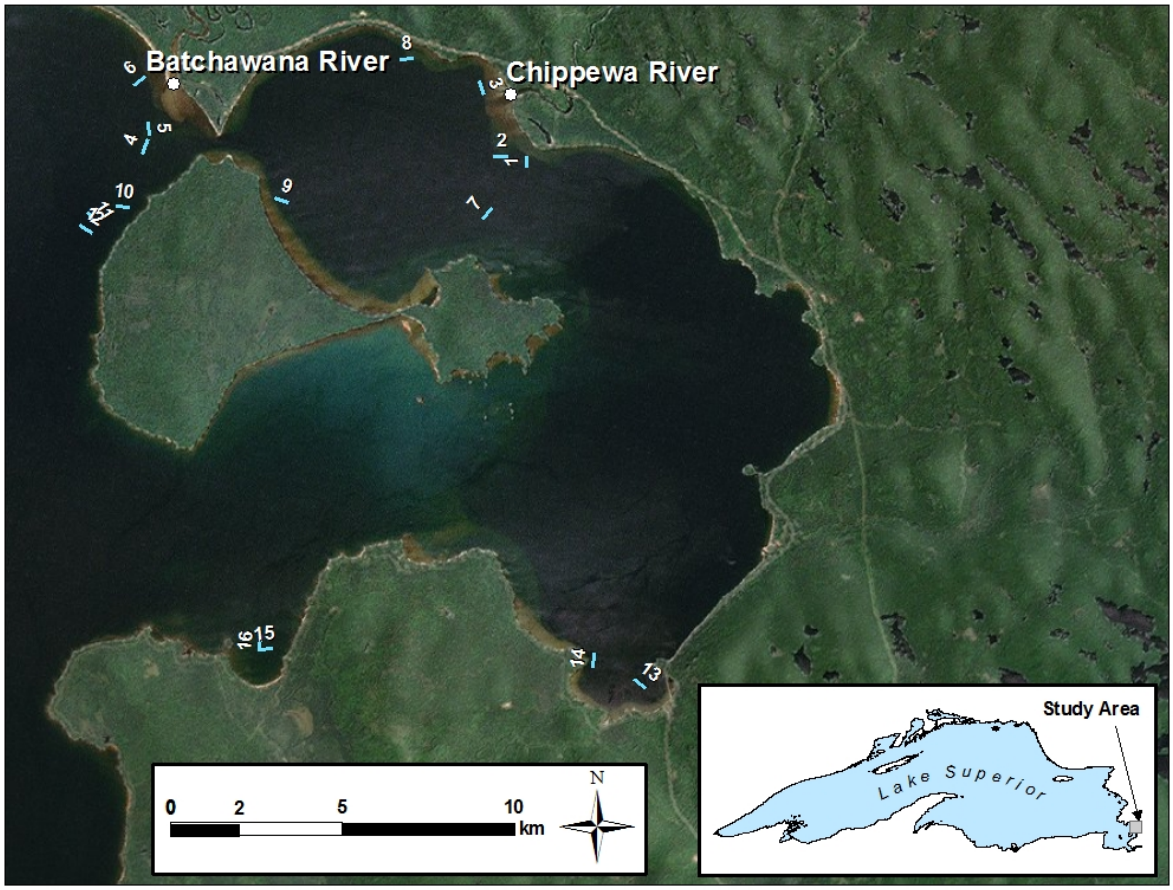

Figure B9. Gill net locations for the Batchawana/Chippewa rivers assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during June 21 to June 26, 2011.

MICHIPICOTEN RIVER

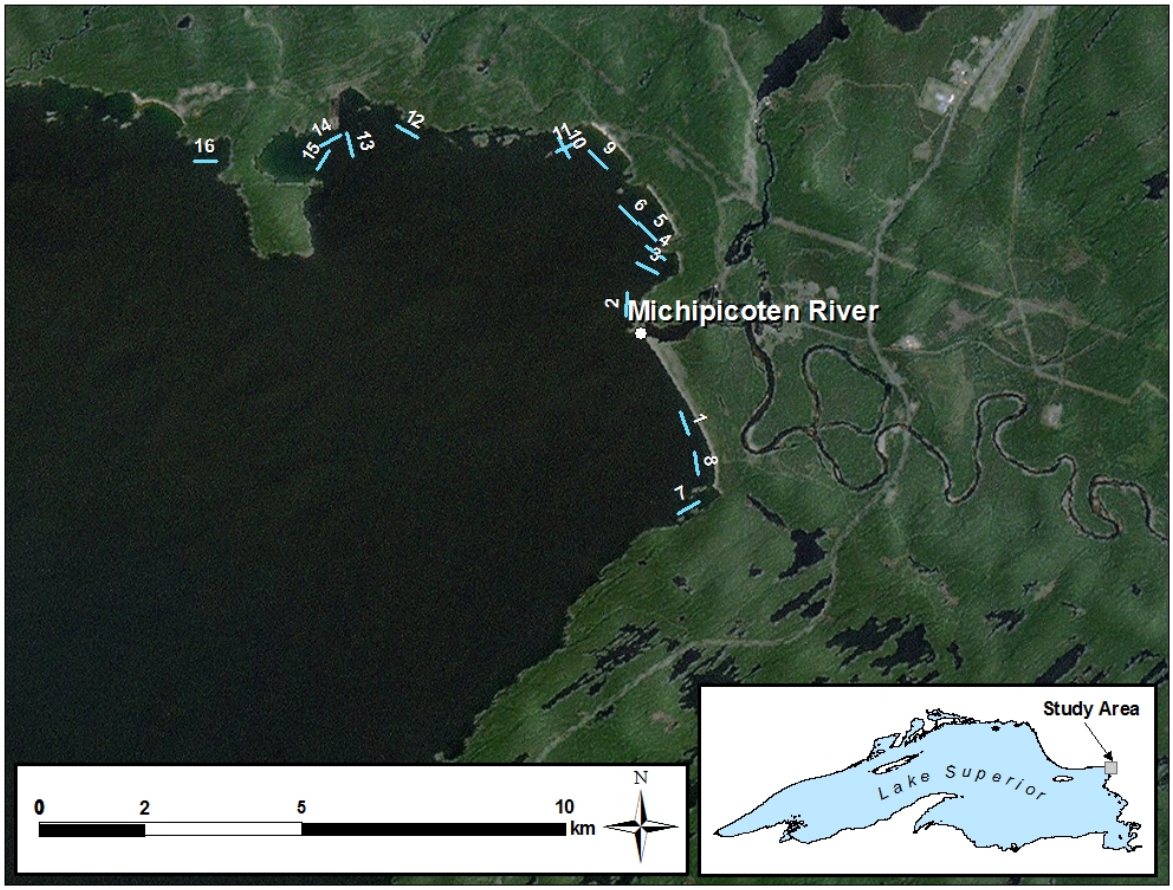

Figure B10. Gill net locations for the Michipicoten River assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during July 19 to July 22, 2011.

PIC AND WHITE RIVERS

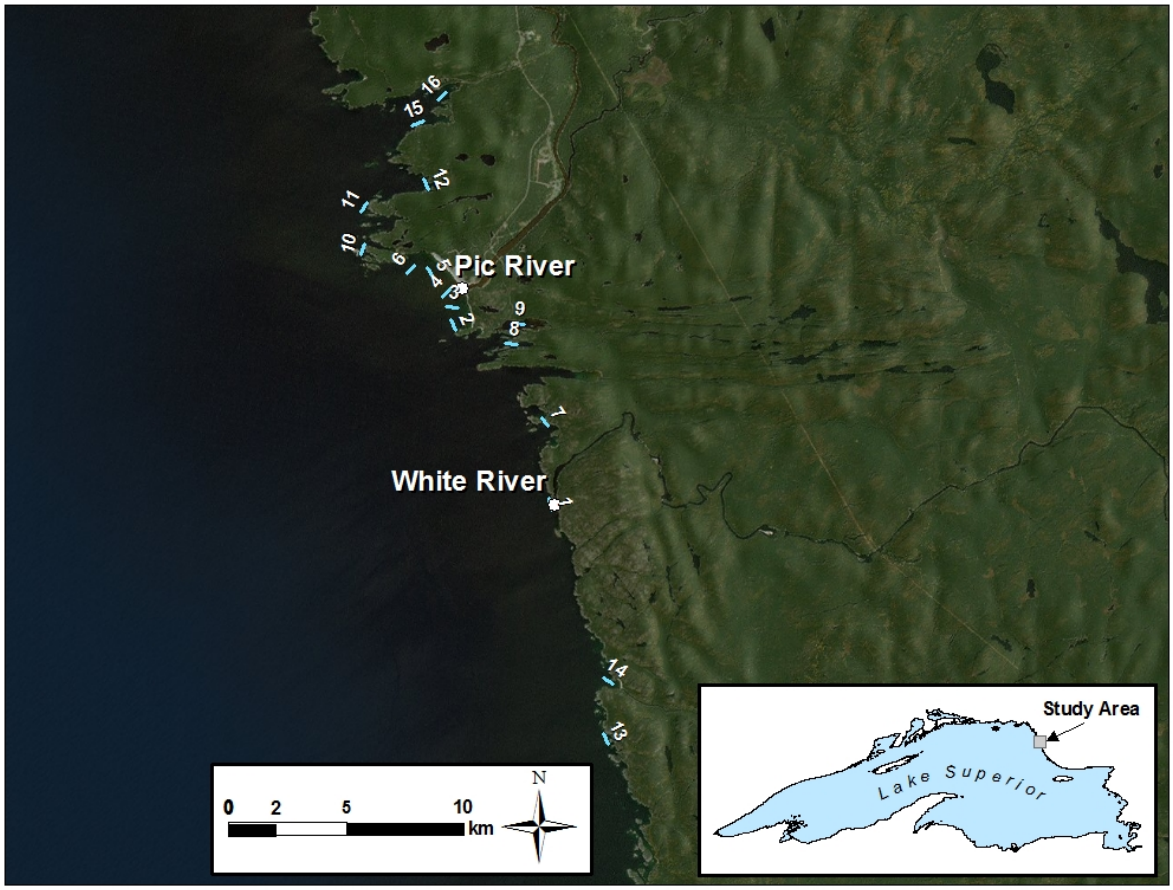

Figure B11. Gill net locations for the Pic/White rivers assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during August 4 to August 7, 2011.

PRAIRIE RIVER

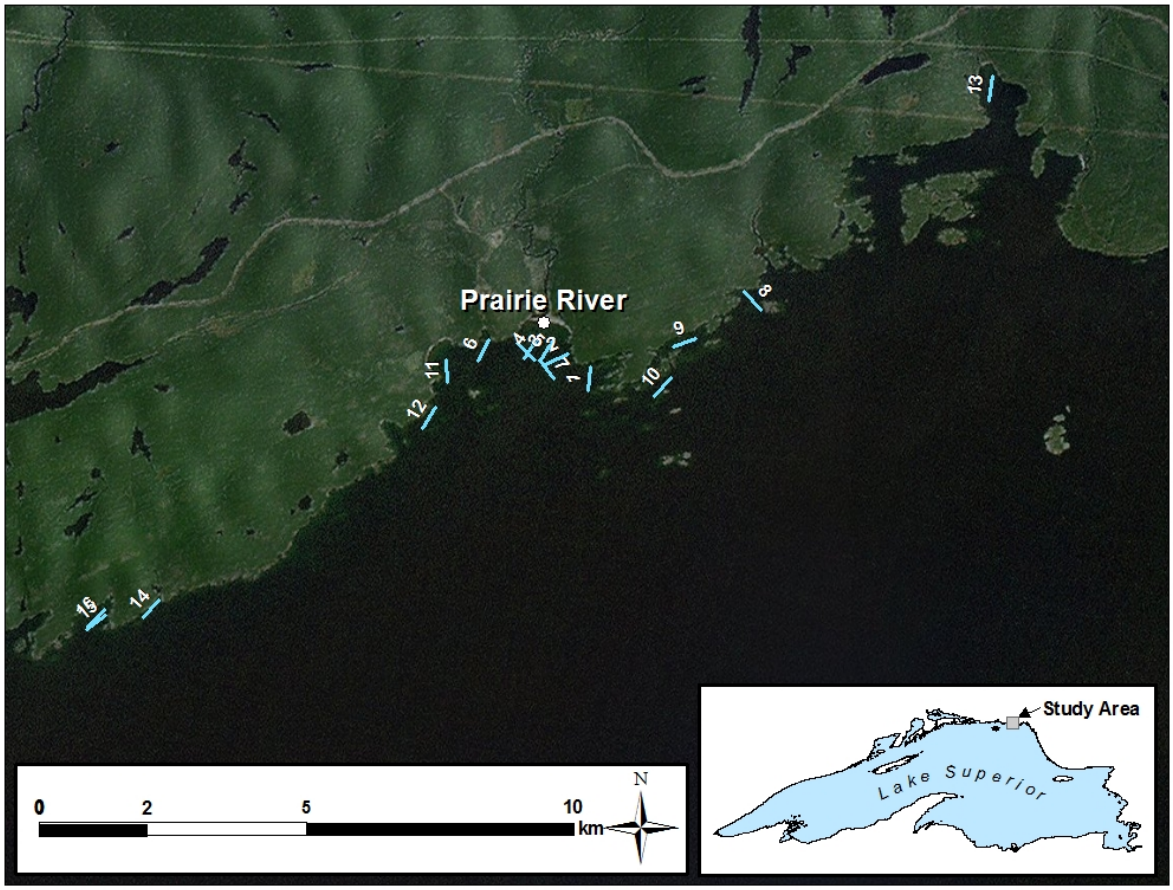

Figure B12. Gill net locations for the Prairie River assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during July 24 to July 26, 2011.

GRAVEL RIVER

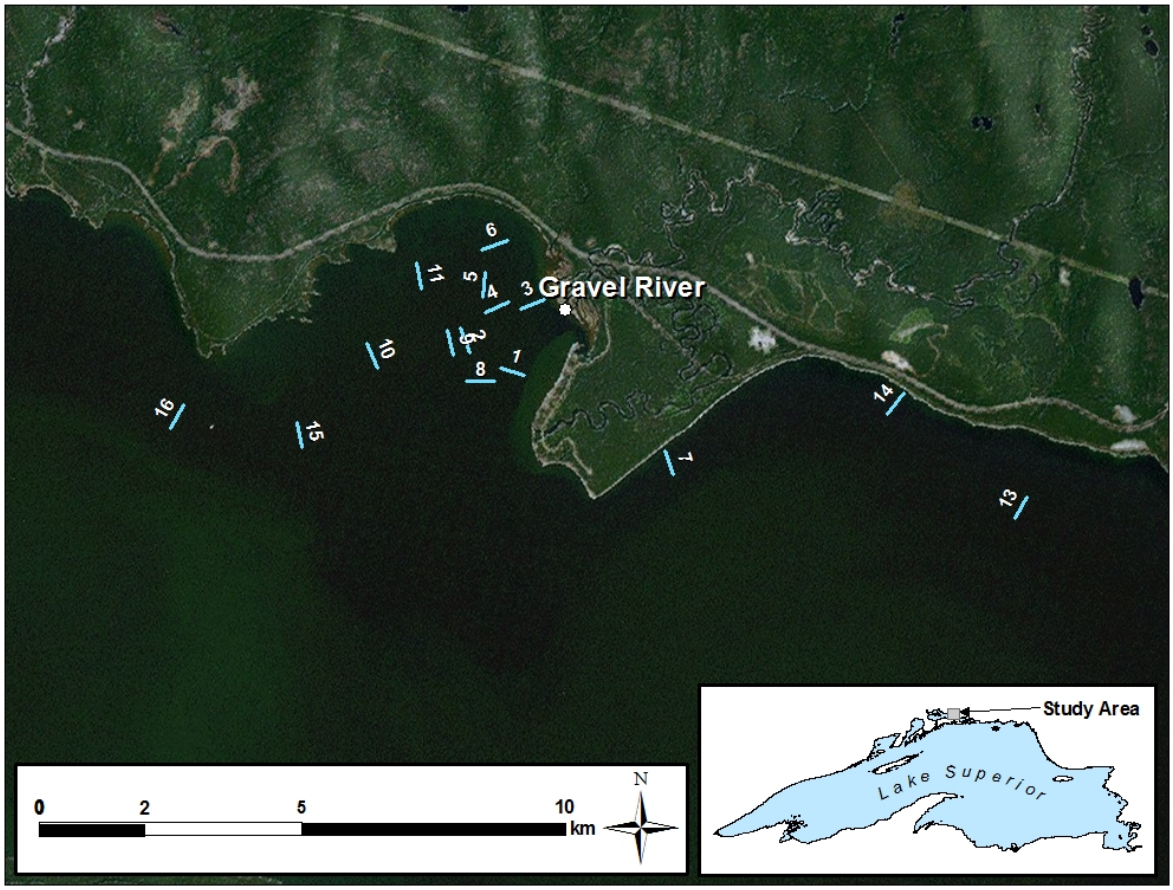

Figure B13. Gill net locations for the Gravel River assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during August 2 to August 6, 2011.

NIPIGON RIVER

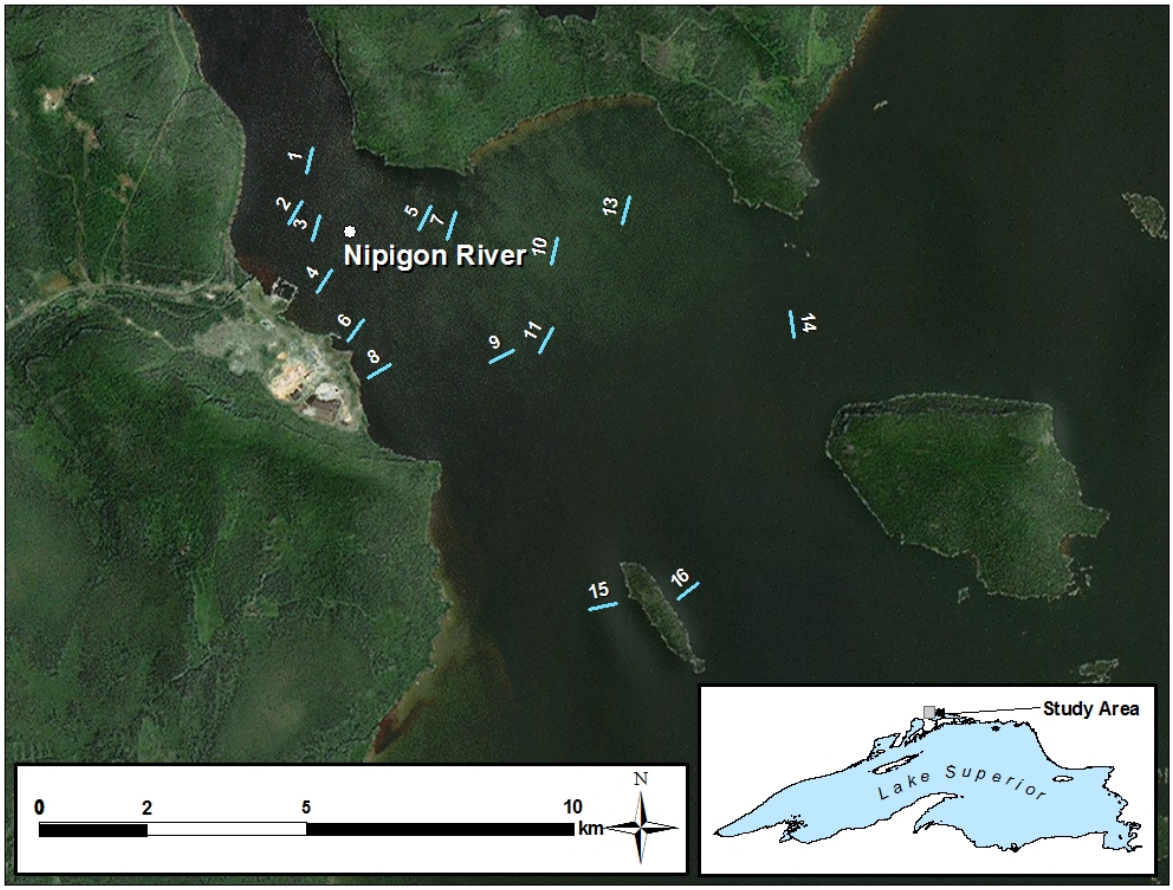

Figure B14. Gill net locations for the Nipigon River assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during July 19 to July 22, 2011.

WOLF AND BLACK STURGEON RIVERS

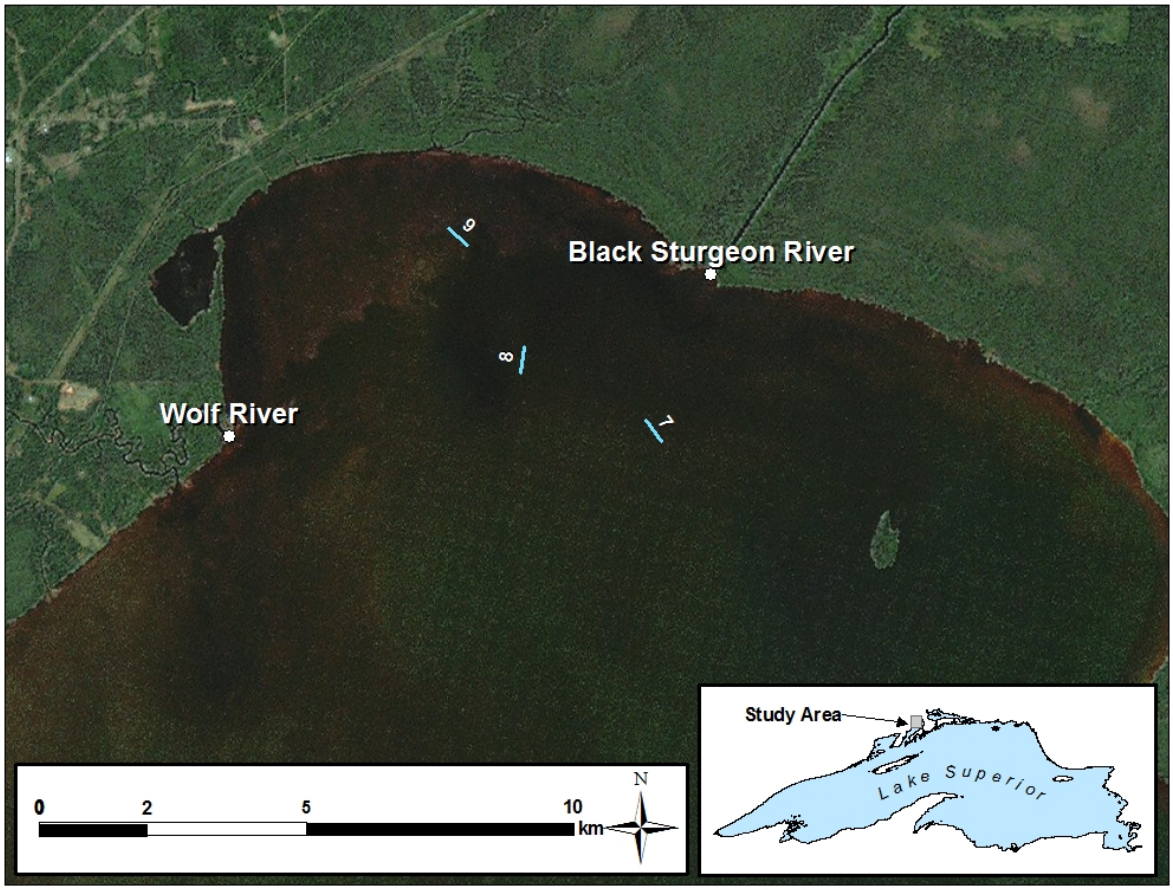

Figure B15. Gill net locations for the Wolf/Black Sturgeon rivers assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during July 7 to August 9, 2011.

KAMINISTIQUIA RIVER

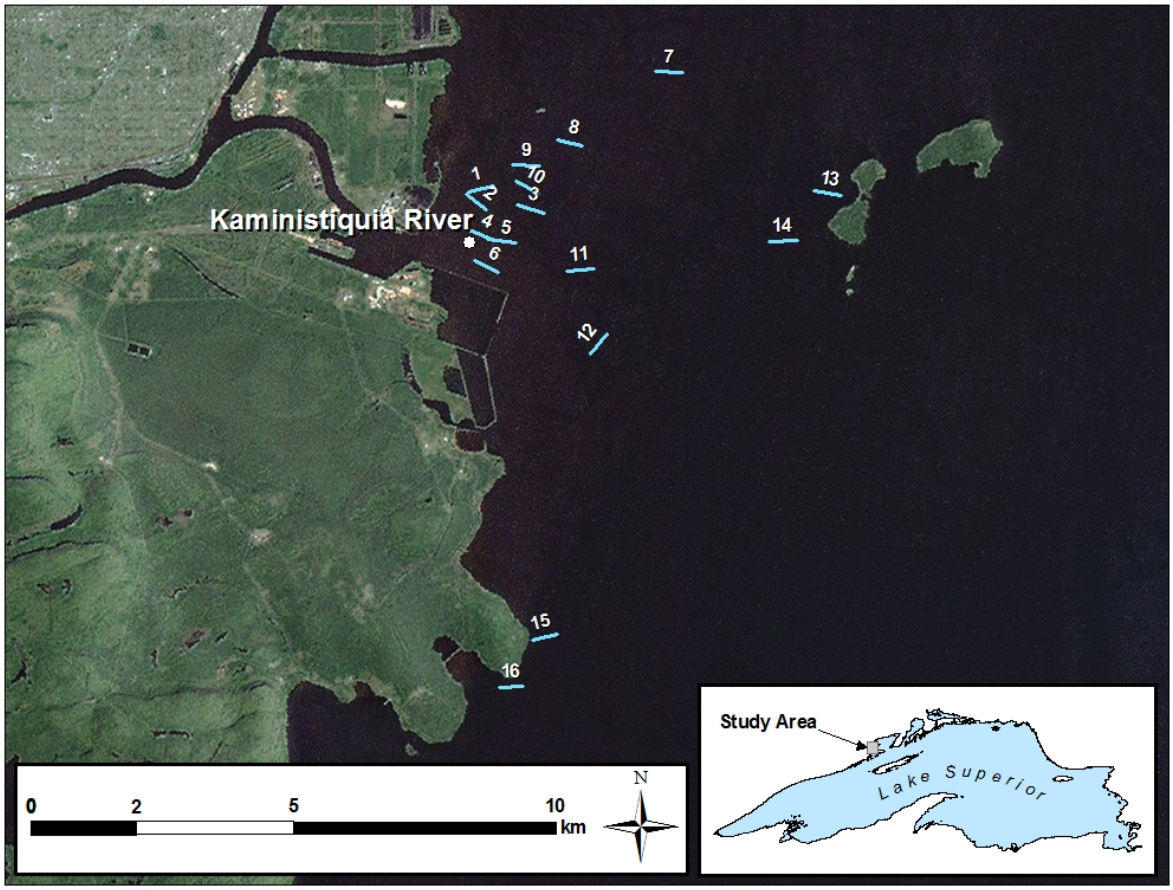

Figure B16. Gill net locations for the Kaministiquia River assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during June 28 to July 6, 2011.

PIGEON RIVER

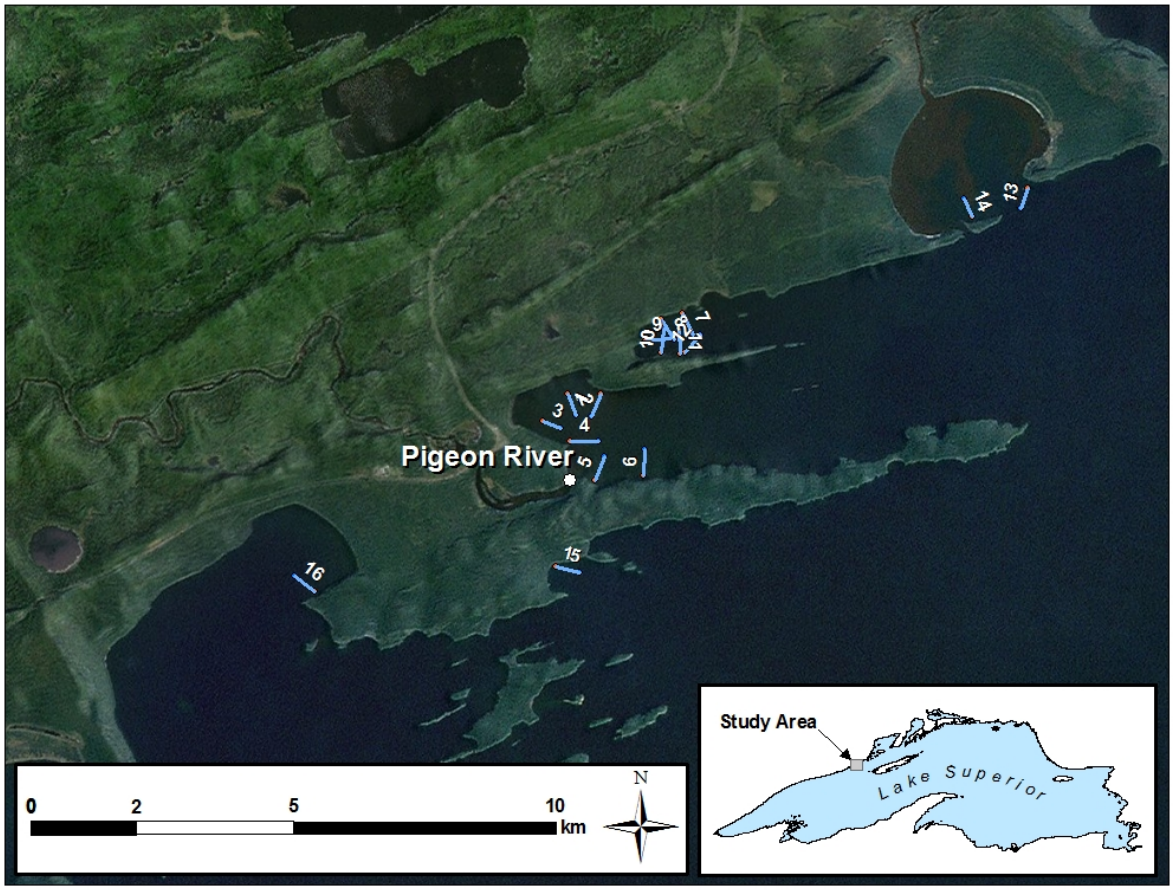

Figure B17. Gill net locations for the Pigeon River assessment are identified with blue lines to scale of the 305 m net. Sampling occurred during June 28 to July 8, 2011.