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A Population Assessment Of the Lake of the Woods – Rainy River Lake Sturgeon Population, 2014

by

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INTRODUCTION

Lake Sturgeon *Acipenser fulvescens* have historical significance in the Lake of the Woods – Rainy River region. Lake Sturgeon were an important food resource for the Ojibway people inhabiting the area (Holzkamm *et al* 1988). Additionally, products derived from Lake Sturgeon were an important market commodity traded by the Ojibway to the Hudson's Bay Company during the 18th and 19th centuries (Holzkamm *et al* 1988). Lake of the Woods has been described as the greatest sturgeon pond in the world (Evermann and Latimer 1910) based on observations made during their fisheries survey of the lake and the Rainy River during 1908 and 1909. They also reported that, by the time of their survey, the Lake Sturgeon population had declined considerably from what it had been prior to the establishment of a rapidly expanding non-native commercial fishery in 1888.

Carlander (1942) summarized the commercial fishery yields of Lake Sturgeon in Minnesota and Ontario. The commercial yield of Lake Sturgeon for the first year that records are available, 1888, was 19,618 kg. Commercial yield approximately doubled annually from 1888 through 1893, when the yield peaked at 809,559 kg in 1893. During the peak harvest years (1892 through 1898), approximately 4,150,000 kg of Lake Sturgeon were harvested from Lake of the Woods. After 1896 yield declined sharply and steadily, so that by 1941 Lake Sturgeon were almost extinct from Lake of the Woods (Carlander 1942). Minnesota closed the commercial fishery for Lake Sturgeon after the 1941 season, although sport fishing remained open. With the exception of one license held in moratorium by the Rainy River First Nations, commercial fishing on the Ontario portion of Lake of the Woods and the Rainy River has been closed since 1995 (OMNR 2009)

Habitat degradation played a role in the decline, and prevented recovery, of Lake Sturgeon in Lake of the Woods and the Rainy River. Pulp mills were established at the head of the Rainy River in International Falls, Minnesota (1910), and Fort Frances, Ontario (1914). As early as 1918, industrial and municipal raw sewage discharges were identified as the source of gross pollution in the Rainy River (International Joint Commission 1918). Carlander (1942) reported that "…these spawning beds have long since been buried under blankets of pulp fiber", in reference to spawning sites on the Rainy River. Lake Sturgeon spawn in swift water or rapids (Scott and Crossman 1973), and the major locations of their spawning habitat in the Lake of the Woods system is within the Rainy River, and tributaries to the Rainy River. After hatching, the slower moving waters of the river are used as nursery habitat for juvenile Lake Sturgeon (Barth *et al* 2011). While the commercial fishery reduced the Lake Sturgeon population almost to extinction, the population could not recover due to pollution of the primary spawning and nursery habitat in the Rainy River (Schupp and Macins 1977).

Water and habitat quality improvements were observed as effective water pollution control laws were enacted through the 1960s and into the 1970s. Water quality improvements, combined with relatively light harvests, worked in concert to allow the Lake Sturgeon population to begin to recover. Mosindy (1987) reported increasing catch per unit of effort (CPUE) in the Ontario-based commercial fishery. In

Minnesota, ageing structures collected since 1990 indicated year classes were being produced consistently, beginning in the late 1960s (Heinrich 2008).

To collect the data required to effectively manage the recovering Lake Sturgeon population, a survey was conducted from 1987 through 1990 (Mosindy and Rusak 1991). Mosindy and Rusak (1991) estimated 16,910 (7,549 – 42,275, 95% confidence interval) Lake Sturgeon longer than 999 mm in Lake of the Woods and the Rainy River. In 1997 the Minnesota-Ontario Fisheries Technical Committee established a target harvest of 5,255 kg $year^{-1}$ (1,800 kg in Ontario, and 3,455 kg in Minnesota). This level of harvest would allow for some harvest of Lake Sturgeon, while allowing the population to recover.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the Lake of the Woods-Rainy River population as "Special Concern" in 2006, but a formal listing under the Species at Risk Act in Canada has not yet been made. The Northwestern Ontario population of Lake Sturgeon, which includes Lake of the Woods and the Rainy River, has been assigned a population status of "Threatened" by the Committee on the Status of Species at Risk in Ontario (COSSARO) (Golder Associates Ltd. 2011), and was formally listed as "Threatened" under Ontario's Species at Risk Act in 2009. The status of Lake Sturgeon in Minnesota has been as a species of "Special Concern" since 1984.

In Minnesota, a sport fishery targeting Lake Sturgeon expanded rapidly through the 1990s. Creel surveys of the Lake Sturgeon fishery showed that harvests were substantially higher than the target (Topp 1998). In 2001 sport fishing regulations were modified to reduce harvest. Topp and Stewig (2005) found that harvests continued to exceed the target harvest, so additional restrictions were proposed to be enacted on the sport fishery in 2004. These additional restrictions were met with criticism from many anglers who felt that the Lake Sturgeon population was robust, and the additional restrictions were not needed to allow population recovery. To address these concerns a Lake Sturgeon population assessment was planned for 2004.

Stewig (2005) estimated the population of Lake Sturgeon longer than 999 mm to be 59,050 (95% Confidence Limits, 30,736-121,372), in 2004. Stewig (2005) was also able to determine that the Lake Sturgeon population had not yet achieved the short-term recovery goals (Appendix 1) established by Border Waters Lake Sturgeon Technical Committee (Anonymous 2004). Utilizing Lake Sturgeon marked in 2004, and recaptured in the spring 2005, Heinrich (2006) followed up the 2004 population estimate with an estimate of 62,875 (36,819-118,460) Lake Sturgeon longer than 999 mm.

To formalize management activities and to monitor progress to recovery goals, from the Minnesota perspective, a Lake Sturgeon management plan for Lake of the Woods and the Rainy River was developed (Talmage *et al* 2009). In addition to refinement and better definition of the fishery goals, this document defined a set of objectives and strategies regarding assessment, habitat, enforcement, spawn-take operations, harvest management, recreational angling, and coordination.

In 2012, monitoring results suggested the Lake Sturgeon population had reached the short-term recovery goals (Appendix 1). These results were presented to the Border Waters Lake Sturgeon Technical committee, who recommended the Minnesota-Ontario Fisheries Technical Committee accept this finding. In April 2012, the Minnesota-Ontario Fisheries Technical Committee accepted that the short-term goals had been achieved, and that management would shift to achieving the long-term goals. In response to achieving short-term goals, the target harvest was increased to 5,310 kg (0 kg in Ontario, and 5,310 kg in Minnesota). This level of harvest is below the potential yield (20,025 kg, Appendix 2), and would allow continued recovery of the Lake Sturgeon population to the long-term goals. While the target harvest increased, expanding effort and harvest levels did not allow for liberalization of fishing regulations.

The current study was undertaken jointly by the Minnesota Department of Natural Resources (MNDNR) and the Ontario Ministry of Natural Resources and Forestry (OMNRF) to comply with a 10-year cycle of population estimates and assessment of size structure (Talmage *et al* 2009).   In addition to these outcomes, the development of a series of population estimates would allow the determination of an overall mortality rate. Finally, due to the expected sample sizes of aged and non-aged Lake Sturgeon from previous years, the impact of removing a section of the marginal pectoral fin ray on mortality will be evaluated. Results of this study will be used to determine progress to long-term recovery goals, and to provide a basis for management decisions.

METHODS

Study Area

Lake of the Woods lies in the Hudson Bay drainage basin at approximately 49° N, 95° W. The lake has a total surface area of 385,000 ha, and straddles the Canada-United States border, where it is shared between the Canadian provinces of Manitoba and Ontario, and the U. S. state of Minnesota. The Rainy River flows for 131 km along the Canada–United States border, from its source at Fort Frances, Ontario and International Falls, Minnesota, to its mouth at Fourmile Bay of Lake of the Woods. A hydroelectric dam located at the outflow of Rainy Lake controls the flow into the Rainy River. Major tributaries flowing into the Rainy River include the Big Fork, Little Fork, Black and Rapid rivers from Minnesota, and the Pinewood, Sturgeon and La Vallee rivers in Ontario.

Lake Sturgeon use different areas of the lake and river seasonally (Mosindy and Rusak 1991). During the spring, at ice-out in the Rainy River, many Lake Sturgeon concentrate in the lower Rainy River and Fourmile Bay-Inside Channel. From this staging area, spawning fish move upstream to their spawning sites while non-spawners move to their summer habitat. Primary summer Lake Sturgeon habitat includes the south-eastern portion of Lake of the Woods, and the Rainy River, up to the Fort Frances-International Falls dam.

Tagging sites were located where Lake Sturgeon concentrated at discrete locations on the Rainy River, Fourmile Bay-Inside Channel, and at four spawning sites in the main-stem of the Rainy River and three tributaries (Figure 1). Recapture sites were located through the primary summer habitat in Lake of the Woods and the entire length of the Rainy River.

Marking phase

The level of confidence in a population estimate is affected by the number of fish tagged and examined for tags (Robson and Regier 1964). Based on the estimated population size from the 2004 survey, the guidelines reported in Robson and Regier (1964) suggest if 1,000 Lake Sturgeon are tagged, then 1,000 should be examined for tags during the recapture phase. This level of tagging and examination of fish for tags will produce a population estimate that is within 50% of the true population size. Tagging more individuals would allow fewer to be examined for tags, and vice versa, while maintaining the same level of confidence in the estimate. Tagging and examining a greater number of individuals would improve confidence in the population estimate.

The goal of tagging at least 1,000 Lake Sturgeon, from a variety of locations, was established during planning. Due to differing environmental conditions, and opportunities available at each location, a variety of capture techniques were used.

Tagging progressed as the ice went out of the Rainy River and Fourmile Bay, and continued through the spawning period. Multifilament nylon gill nets were the primary sampling gear. Approximately equal-numbers of 102-, 127-, 152-, and 178-mm (bar measure) mesh nets were used. These nets were 1.8 m deep and 90.1 m long, and were set for approximately 24 hours (H).

A concentration of Lake Sturgeon was located in the Long Sault Rapids, between river km 63 and 65. To minimize problems associated with high current velocities, drifting debris, and to fit nets into relatively small fishable areas, a mixture of short nets (30 m-long) and standard nets (90.1 m-long) nets were fished. The nets were fished for short-term (2-4 H), or long-term (24 H) durations. Mesh sizes included 102-, 114-, 127-, 152-, and 178-mm gill nets.

Lake Sturgeon were tagged at three spawning sites in tributary streams. At the Rapid River site, equal numbers of 127-, 152-, and 178-mm mesh standard gill nets were set in a deep pool below the spawning rapids. These nets were the standard length (90.1 m-long) nets, set for approximately 24 H. Spawning Lake Sturgeon were also captured in the Big Fork and Sturgeon rivers by “hand-grabbing” and with 127-, 152-, and 178-mm mesh standard length gill nets (Big Fork River). When “hand-grabbing”, Lake Sturgeon were located visually, in shallow water, or by feeling with hands and feet, in deeper water. One member of the “catcher team” would select an individual, gently control it by hand, and quickly flip it into a large landing net held by another team member. Captured Lake Sturgeon were then brought to other members of the crew to be tagged.

All Lake Sturgeon captured in gill nets were briefly stored in a tank without circulating water before sampling. Lake Sturgeon were measured for length (fork length (FL) and total length (TL)) and fish longer than 999 mm (TL) were tagged with a yellow, five-digit, individually numbered Carlin disk dangler dag (Floy Tag, Inc., Seattle WA. USA), which was attached to the mid-base of the dorsal fin with 0.53 mm stainless steel lockwire (Malin Co., Brookpark OH USA). Tag return information, on the back of the tag, reads, “MN DNR, FISH & WILDLIFE DIV.”. Sex was recorded if flowing gametes were observed. If a Lake Sturgeon had a fleshy protuberance at the vent, it was recorded as a presumed female. After being tagged, Lake Sturgeon were released near the capture site. Tagging site, water temperature, and capture gear were also recorded for each capture event.

When anglers in U.S. waters were experiencing good success, they were approached by MNDNR or MNRF staff, and asked to donate the Lake Sturgeon they would not be harvesting to the project for tagging. Lake Sturgeon have been tagged in the Lake of the Woods-Rainy River system since 1990 and anglers report up to 200 tags annually to the MNDNR.   Tagged Lake Sturgeon, reported as released by anglers, were also included as marked for the population estimate, if the angler reported the sturgeon as being longer than 999 mm.

Recapture Phase

The primary summer habitat was divided into six sampling strata for the recapture phase of the project. These strata reflected a slight modification of those used by Stewig (2005). General descriptions of the strata were: The Big Traverse – nearshore stratum was within 1 km of the shoreline, and typically to 6.1 m deep, Big Traverse – offshore stratum was generally deeper than 6.1 m, Ontario Stratum was to approximately 6.1 m deep, on the Canadian Shield, and the Fourmile Bay – Inside Channel Stratum included the shallow waters (typically less than 2 m deep) between Pine and Sable islands and the mainland (Figure 2). The Rainy River was divided into two strata of equal length (lower and upper Rainy River) at the Long Sault Rapids (river km 64 [Figure 3]).

The recapture phase was conducted using 90.1 m long gill nets, of 102-, 127-, 152-, and 178-mm mesh as the capture gear. Equal numbers of nets of each mesh size were used. Lake of the Woods had 400 net lifts assigned, and 320 net lifts were assigned to the Rainy River. The amount of effort to be expended in each stratum during the recapture phase was based on the catch per unit of effort (CPUE; fish/net) of each stratum reported by Stewig (2005). Strata that had a high CPUE would receive more effort than strata that had a low CPUE. Based on the gill net CPUE reported by Stewig (2005), it was felt this level of effort would meet the goal of sampling 1,000 Lake Sturgeon during this phase. All nets were set for approximately 24 H.

Recapture sites were assigned randomly on Lake of the Woods and in the Rainy River. In Lake of the Woods a matrix of potential sites was created in ArcMap 10.2 (ESRI. Redlands CA, USA) using the Jenness Tool (Jenness Enterprises, Flagstaff AZ, USA) add-in. Individual sampling locations were randomly selected from the matrix using Microsoft Excel (2010). A single gill net was set on each of the sampling sites, so that equal numbers of each mesh size were fished through the recapture phase in each stratum. Nets were set parallel to the wind direction.

The Rainy River was divided into 130 reaches that were 1,000-m long. Forty reaches above the Long Sault Rapids, and 40 reaches below the Long Sault Rapids, were randomly selected to be sampled. One net of each mesh size (102-, 127-, 152-, and 178-mm mesh) was set within each reach. If water depth (too low) or current velocity (too high) prevented the full complement of four nets from being set in a reach, the reach was dropped from sampling and not replaced. Orientation of the net, with respect to current direction, was at the discretion of the crew, with the goal of maximizing the number of captured Lake Sturgeon.

The recapture phase was initiated four weeks after the completion of the marking phase. This period of time was felt to be adequate to allow tagged Lake Sturgeon to disperse and mix with non-tagged individuals, and is consistent with the dispersal time used by Stewig (2005). All captured Lake Sturgeon had FL, TL, and existing tag numbers recorded. Non-tagged Lake Sturgeon longer than 999 mm (TL) were tagged using the previously described methods. Additionally, the date, capture location, water temperature, and mesh size of the net were recorded.

Analysis

Population estimate. The population size of Lake Sturgeon longer than 999 mm was estimated using the Chapman modification of the Petersen Estimate (Equation 1) as recommended by Ricker (1975). The confidence interval around *N* was estimated by assuming *R* to have a Poisson distribution, and obtaining the confidence interval around *R* from a table (Ricker 1975). These values were then substituted into Equation 1 in place of *R*.

Equation 1.

$$N = \frac{(M+1)(C+1)}{R+1}$$

Where: N=population estimate

M=number of marked fish

C=number of fish examined for marks during the recapture phase

R=number of marked fish captured during the recapture phase

Length-based subsets of the population estimate were based on the length distribution collected during the recapture phase.

Size Structure. The population size structure was monitored through the recapture phase, since equal numbers of each mesh size were used, and the samples were based on random net locations. To determine if samples collected from Lake of the Woods could be pooled with samples from the Rainy River, the size structures of the samples were compared using the Kolmogorov-Smirnov two-sample test (SAS Institute Inc. 2008), with $P<0.05$ required for significance. If a difference was found between those size distributions, the between-year samples would be evaluated by whether they were collected from Lake of the Woods or the Rainy River.

To evaluate for changes in the size structure from the 2004 sample, the length distributions of Lake Sturgeon longer than 999 mm were compared between surveys. Differences were compared using the Kolmogorov-Smirnov two-sample test (SAS Institute Inc. 2008), with $P<0.05$ required for significance. When comparing across years, the Lake Sturgeon sampled with the 178-mm mesh were excluded from the 2014 sample because that mesh size was not used in 2004 during the recapture phase.

Mortality. Mortality rate is based on the current population estimate, and the 2004 estimate (Stewig 2005). Since Lake Sturgeon were not aged in the current study, a length-at-age relationship was developed from an existing data set maintained at the MNDNR fisheries office in Baudette MN (Equation 2).

Equation 2.

$$L = 490.8 \ln Age - 255.9$$

Where: L=total length in mm

Age=Age in years

Based on Equation 2, a Lake Sturgeon of 1,000 mm TL would be age-13, thus the population estimate produced in 2004 was a population estimate of Lake Sturgeon of age-13 and older. These Lake Sturgeon would be, at least, age-23 in 2014, which would be 1,283 mm TL, or longer. The instantaneous rate of annual mortality (Z) was calculated as in Equation 3.

Equation 3.

$$Z = -\frac{lnN_{2014} - lnN_{2004}}{10}$$

Where: Z=instantaneous rate of mortality

N_{2014}=the age-23 and older (1,283 mm and longer) population estimate in 2014

N_{2004}=the age-13 and older (1,000 mm and longer) population estimate in 2004

Impact of marginal pectoral fin ray removal on survival. In 2004, 455 sampled Lake Sturgeon had a section of the left marginal fin ray removed for age assessment, while 964 did not (Stewig 2005). The relative survival of these two groups of Lake Sturgeon, from 2004 to 2014, was assessed using a 2x2 Chi-Square test, where $\rho<0.05$ was required for significance. It was expected that 32% of the Lake Sturgeon that were tagged in 2004, and recaptured in 2014, would have had a section of the pectoral fin ray removed, while 68% would not. The determination of whether the fin ray had been removed was based on the unique tag number that was applied to the Lake Sturgeon, rather than by inspection of the fin ray. All Lake Sturgeon tagged in 2004, and recaptured in the tagging and recapture phases, were included in this analysis. It was assumed that the rate of tag loss was similar for these two groups.

RESULTS

Marking Phase.

The Lake Sturgeon marking phase took place from April 9 through May 24, 2014. Overall, 1,291 Lake Sturgeon longer than 999 mm were tagged (850 from gill nets, 351 from angler donations, and 90 from tag reports) in Lake of the Woods, the Rainy River, and at three spawning sites in tributary streams (Table 1). Sampling with gill nets was initiated in the plunge pool below the Fort Frances – International Falls dam (river km 131) on April 9, when water temperature was 1.6 ° C. Additional downstream sites were sampled as the Rainy River became ice-free. Sampling in the main-stem Rainy River with gill nets, above the Manitou Rapids (river km 74), was unproductive and became increasingly difficult as discharge increased (Figure 4). By April 15, only 10 Lake Sturgeon had been captured and tagged between the Manitou Rapids and Fort Frances - International Falls using gill nets. Sampling with gill nets in this area was terminated in favor of other sites and capture methods after April 15.

Sampling in Fourmile Bay with gill nets began on April 26, when water temperature was 2.8 ° C. Sampling in Fourmile Bay was unproductive, and labor intensive, due to debris accumulation in the gill nets. Gill nets were used in Fourmile Bay for three days, yielding 7 Lake Sturgeon. Sampling with gill nets in Fourmile Bay was discontinued after May 2. The Inside Channel was sampled using gill nets from May 2 through May 19, when water temperature ranged from 3.5 to 8.1 ° C. Gill nets were more effective on the Inside Channel than in Fourmile Bay, and less debris accumulated in them. Sampling in the Inside Channel yielded 77 Lake Sturgeon.

The Long Sault Rapids were sampled from April 25 through May 23, when water temperature increased from 3.3 to 8.9 ° C (Figure 4). Four hundred eight Lake Sturgeon were tagged in this area. Actively spawning individuals were not observed, but 12 males and 48 suspected females were identified. Debris accumulation in the gill nets was a problem through the sampling period, but debris accumulation declined as flows declined after May 16.

Sampling at spawning locations commenced on May 6, at the Rapid River site. Water temperature from May 6 through May 9 ranged from 5.8 to 6.9 ° C. Actively spawning Lake Sturgeon were not noted through this period, and only 21 Lake Sturgeon were tagged. Sampling was suspended from May 10 through May 18 due to several rain events, which caused flows to increase to where sampling was not possible (Figure 5). Sampling on the Rapid River resumed on May 19, and was initiated on the Bigfork and Sturgeon Rivers on May 20. Sampling on the Rapid River continued through May 24, when water temperatures increased from 11.1 to 14.4 ° C. Water temperature remained at 13.9 ° C from May 20 to 22 on the Bigfork River, and increased from 12.2 to 12.8 ° C from May 20 to 21 on the Sturgeon River. Actively spawning Lake Sturgeon were observed at all three sites through this sampling period.

Concentrations of anglers targeting Lake Sturgeon were located at discrete areas from Fourmile Bay to Fort Frances – International Falls. Actively soliciting Lake Sturgeon from anglers began on April 18 and continued through May 5. Three hundred fifty-one angler-caught Lake Sturgeon were given to, and were tagged, by MNDNR and OMNRF personnel. An additional 90 Lake Sturgeon, which had been tagged in previous years, were reported by anglers and included as marked fish in the population estimate. These previously tagged Lake Sturgeon were reported throughout the system from Fourmile Bay to Fort Frances - International Falls.

The length distributions of Lake Sturgeon tagged in the three general locations were similar; the modal length was in the 1,300 mm interval for all three groups (Figure 6). Approximately 30% of the Lake Sturgeon from the Four Mile Bay – Inside Channel grouping were less than 1,200 mm in length, whereas only 3% of the Lake Sturgeon tagged at spawning sites, and 12% of the Lake Sturgeon tagged from the Rainy River, were less than 1,200 mm in length. The overall length distribution of tagged Lake Sturgeon had a mode in the 1,300 mm length interval (Figure 7). The longest Lake Sturgeon tagged was 1,830 mm, and was captured at the Rapid River spawning site.

Recapture Phase

Environmental conditions precluded sampling the recapture strata located on Lake of the Woods simultaneously with those on the Rainy River. The four Lake of the Woods strata were sampled from June 23 through August 11 (number of sets=378). Of the 308 Lake Sturgeon longer than 999 mm examined for tags, 6 had been tagged during the marking phase (Table 2). The recapture phase on the Rainy River was initiated on August 12, when flow declined sufficiently so that gill nets could be set (Figure 8), and was completed on September 17 (number of sets=306). None of the 191 Lake Sturgeon sampled from the Rainy River, which were examined for tags, had been tagged during the marking phase of the project (Table 2). At completion of the recapture phase, 499 Lake Sturgeon had been examined for tags, and of these, 6 had been tagged during the marking phase.

Twelve Lake Sturgeon, ranging in length from 1,166 to 1,610 mm (TL), died during the recapture phase. Seven mortalities took place in nets set on Lake of the Woods. Five of these seven mortalities were from nets that had been set for 48 H. These nets were left out beyond the 24 H set period due to windy conditions that prevented safe retrieval. Five additional mortalities occurred in nets set in the Rainy River for the prescribed 24 H period. Overall, two of the 12 mortalities were captured in 127-mm mesh nets, while the remainder were caught in 102-mm mesh nets.

Catch per unit of effort was not uniform across the Lake of the Woods strata (Table 2). The highest CPUE was recorded from the Ontario stratum (1.3 fish/net), while the lowest was from the Big Traverse – offshore stratum (0.33 fish/net). The CPUE in the Rainy River was essentially the same across the lower and upper strata (0.62 and 0.63 fish/net, respectively). Catch per unit of effort also varied by mesh size. Within each Lake of the Woods stratum, the 127-mm mesh had the highest CPUE. The mesh size with the lowest CPUE within a stratum was the 178-mm mesh in three of the four strata. In the Big Traverse – Offshore stratum, the 152-mm mesh had the lowest CPUE. In the two Rainy River strata, the 102-mm mesh had the highest CPUE, though in the Upper Rainy River there was essentially no difference in CPUE between the 102- and 127-mm mesh nets.

Analysis

Population estimate. Based on the number of tagged Lake Sturgeon (M=1,291), the number of Lake Sturgeon examined for tags (C=499), and the number of tagged, and recaptured, Lake Sturgeon (R=6), the estimated population size of Lake Sturgeon longer than 999 mm is 92,286 (95% Confidence Limits: 45,816 – 201,875).

Size Structure. The mean length (TL) and the length frequency distributions of Lake Sturgeon sampled during the recapture phase varied with gill net mesh size (Figures 9-12). Mean length and the modal length interval both increased as gill net mesh size increased. Since approximately equal numbers of each mesh size were used through the recapture phase, samples from all mesh sizes were pooled for analysis.

Length frequency distributions were pooled across the Lake of the Woods (Big Traverse off-shore, Big Traverse near-shore, Ontario, and Fourmile Bay-Inside Channel) and Rainy River (Lower Rainy River, and Upper Rainy River) strata. Over 20% of the Lake Sturgeon sampled from the Rainy River were in the 1,000-mm length interval, compared to only 13% of those sampled in Lake of the Woods (Figure 13). The mean total length of Lake Sturgeon sampled in the Rainy River (1,255 mm) was smaller from those sampled from Lake of the Woods (1,300 mm); the Kolmogorov-Smirnov two-sample test found the size distributions to be significantly different (ρ=0.0360). Since there were differences in the size distributions of Lake Sturgeon sampled from Lake of the Woods and those sampled from the Rainy River, evaluation of size distribution changes between 2004 and 2014 were stratified by grouping the Lake of the Woods recapture strata, and the Rainy River recapture strata.

In 2004, 39.9% of all Lake Sturgeon sampled from the Rainy River were in the 1,000 mm length interval, while only 22.9% of those sampled in 2014 were in the 1,000 length interval (Figure 14). The mean length of Lake Sturgeon sampled from the Rainy River in 2004 (1,157 mm) was smaller than the mean length of Lake Sturgeon sampled from the Rainy River (1,243 mm) in 2014, and significant differences (ρ<0.0001) in the length frequency distributions were detected.

The length frequency of Lake Sturgeon sampled from Lake of the Woods in 2004 had a greater proportion of individuals in the 1,000 and 1,100 mm intervals than did the distribution collected in 2014 (Figure 15). Lake Sturgeon sampled from Lake of the Woods in 2004 had a shorter mean length than those sampled in 2014 (1,204 mm and 1,279 mm, respectively), and significant differences (ρ<0.0001) in the length frequency distributions were again detected.

Mortality. Forty-seven percent of the Lake Sturgeon sampled during the recapture phase exceeded 1,283 mm (age-23, and older). Based on the population estimate of 92,286, the proportional estimate of Lake Sturgeon longer than 1,283 mm (age-23 and older) is 43,374 individuals in 2014. Thus, the 59,050 (N_{2004}) Lake Sturgeon longer than 999 mm estimated in 2004 declined to 43,374 (N_{2014}) in 2014. Substituting these values into Equation 3 yields an instantaneous rate of mortality (Z) of 0.03, and an annual mortality (A) of 3%.

Impact of marginal pectoral fin ray removal on survival. Thirty-eight Lake Sturgeon tagged in 2004 were recaptured during the tagging and recapture phases of the project. Of these, 12 had a section of the marginal pectoral fin ray previously removed, and 26 did not (Table 4). Chi-square analysis indicates that there is no significant difference (ρ=0.9448) between the observed and expected number of recaptured Lake Sturgeon that had a marginal pectoral spine removed in 2004.

DISCUSSION

Population Estimate

Lake Sturgeon abundance continued to increase in the Lake of the Woods and Rainy River system. The increase in abundance of Lake Sturgeon longer than 999 mm over the previous two population estimates (Mosindy and Rusak 1991, Stewig 2005) suggests that the population continues to recover from the over-harvest (which collapsed the population), and the subsequent water pollution that prevented recovery. The series of population point estimates are consistent with anecdotal reports that suggest an increase in Lake Sturgeon abundance since 1990. Broad confidence limits around each of these population estimates (Table 5) suggest caution should be exercised with the estimates. The primary source of the broad confidence limits around the current estimate was that the goal of recapturing at least 1,000 Lake Sturgeon during the recapture phase was not achieved. If 1,000 Lake Sturgeon had been sampled during the recapture phase, and the proportion of marked fish remained constant (R=12, 95% CL 6.2 and 21.0), the population estimate would have remained essentially unchanged, but the 95% confidence limits would have narrowed to 58,669-179,265.

The weighted random sampling design was executed, but sampling yielded lower catches than expected in parts of the system. The number of net sets needed to capture the minimum of 1,000 Lake Sturgeon during the recapture phase was based on the CPUE reported by Stewig (2005). This plan included two oversights. The first was that the CPUE reported by Stewig (2005) included all captured Lake Sturgeon, rather than just Lake Sturgeon longer than 999 mm. This inflated the number of Lake Sturgeon expected to be captured. The second oversight was that Stewig (2005) did not use 178-mm mesh nets during his survey. When the number of required nets was calculated, the potentially lower CPUE for the 178-mm nets was not taken into account.

Despite these issues, the overall CPUE documented in 2014 was similar to that encountered in 2004, after the 2004 catch rates were corrected to include only Lake Sturgeon longer than 999 mm (Table 6). Departures from the 2004 population estimate in 2014 are: the CPUE of Lake Sturgeon sampled from the strata located in Lake of the Woods was over 50% higher than in 2004, and the CPUE of the Rainy River strata was only about 50% of that found in 2004.

The recapture period and environmental conditions varied slightly between 2014 and 2004. Sampling of the Lake of the Woods strata was conducted during a similar time frame, late-June through mid-August, in both 2004 and 2014, so the higher CPUE documented in 2014 may reflect the higher population estimate produced from the 2014 survey. However, the time frame in which the Rainy River strata were sampled, and the river flows during the sampling period, varied greatly between the 2004 and the 2014 population estimates.

In 2004, sampling on the Rainy River was initiated on June 25, and was completed by September 2 (Stewig 2005). In 2004 discharge was far lower than at any point during the 2014 population estimate recapture phase (Figures 8 and 12). The higher discharge caused higher velocity. The higher velocity influenced the locations where nets could be set, and their orientation, relative to current direction. Additionally, crews noted that nets set perpendicular to the current produced higher CPUE then nets set parallel to the current. Due to the great difference in timing of the recapture events between these years, and the differences in discharge, the CPUE documented from the Rainy River may not reflect changes in the abundance of Lake Sturgeon between 2004 and 2014.

If the mortality of marked fish exceeds that of non-marked fish, the population estimate derived from the experiment will be biased high (Youngs and Robson 1978). Post-release mortality of marked Lake Sturgeon was assumed to be negligible for this experiment, as Stewig (2005) found no short-term mortality of marked Lake Sturgeon. However, crew observations at the Rapid River spawning site noted some Lake Sturgeon appeared stressed (did not immediately regain equilibrium and swim away), post release. The stress was likely a combination of being held without circulating water and the rapid rise in air and water temperatures. Any Lake Sturgeon which did not regain equilibrium were held upright until they could maintain an upright orientation. No Lake Sturgeon were judged to have died at this site, however the possibility of post-marking mortality cannot be ignored, or quantified. As such, the population estimate should be viewed as a maximum estimate. To minimize potential post-release mortality, future marking efforts should explore the use of flow-through water in the holding tanks with supplementary oxygen.

Size Structure

The pooled lake and river samples both showed an increase in Lake Sturgeon longer than 1,300 mm, from 2004 to 2014. Due to differences between the size structures of Lake Sturgeon sampled from the Lake of the Woods strata and those sampled from the Rainy River, it would not be appropriate to pool the samples across these stratum groupings for between-year comparisons. The increase in mean length, and in the proportion of "larger" Lake Sturgeon, indicates that progress to recovery goals (Appendix 1) continues.

Mortality

The estimated mortality rate from this study was much lower than those reported by Mosindy and Rusak (1991), and Stewig (2005) for the Lake of the Woods – Rainy River Lake Sturgeon population. Both of these studies relied on catch-curves to estimate mortality rate. Under non-uniform recruitment, catch-curve analysis will not provide a correct estimate of the instantaneous mortality rate (Ricker

1975). The Lake of the Woods – Rainy River population of Lake Sturgeon was expanding through the period of these earlier studies. A population in a state of expansion has recent year classes which are more abundant than earlier year classes, causing the descending limb of the catch-curve to become steeper than if the population was stable. Under this scenario, the use of catch-curves will overestimate the instantaneous rate of mortality.

The method employed to estimate mortality in this study assumes that the growth rates have not changed since the ageing structures were collected, and that the population estimate is not biased, relative to the earlier studies. Change in growth rate cannot be assessed, since ageing structures were not collected during this study. As described earlier, the population estimate has broad confidence limits, and should be used as a maximum estimate. If the true population is much smaller than the estimate used to generate the mortality, the estimate of mortality would increase. However, even if the population estimate had not changed since 2004, the resulting annual mortality would be only 7.3%.

Exploitation can have a significant impact on overall mortality, through angler harvest and hooking mortality. The number of tagged Lake Sturgeon anglers report from harvested individuals can be used to estimate exploitation of this population. Of the 1,696 Lake Sturgeon tagged in 2004, anglers reported the harvest of 47, from 2004 through 2014 (MNDNR records), but the degree of non-reporting is not known. A variety of sources (Margetts 1963; Rawstron 1971; Matlock 1981; Thomas and Haas 2000) have estimated reporting rates from 28% to 60%. Utilizing the minimum reporting rate estimate suggests that the actual number of Lake Sturgeon harvested from the original pool of tagged fish could be up to 168 individuals, or approximately 10%. Thus, up to 1% of the tagged fish were harvested annually through the 10-year period, yielding a maximum exploitation rate estimate of 1%.

While the overall mortality rate of 3% may be an underestimate, it is closer to the mortality of Lake Sturgeon in Lake Winnebago, Wisconsin, which experienced a total annual mortality of 8.8% (Bruch 2008), than the earlier estimates (Mosindy and Rusak 1991; Stewig 2005). A contributing factor to the low overall mortality is the low exploitation rate, which is even lower than that reported by Bruch (2008) for Lake Sturgeon on Lake Winnebago (2.3%). The mortality and exploitation rates found in this study are sustainable, and allow for continued population expansion and recovery.

Impact of Marginal Pectoral Fin Ray Removal on Survival

Collins and Smith (1996) found no evidence of increased mortality due to spine removal in Atlantic Sturgeon *A. oxyrinchus oxyrinchus* or Shortnose Sturgeon *A. brevirostrum*. Their study was conducted in a hatchery environment over a 6-month period, with the largest sturgeon being 715 mm TL. In contrast, Kohlhorst (1979) found substantial mortality in the first year following removal of the marginal pectoral fin ray of White Sturgeon *A. transmontanus*. The Kohlhorst (1979) study was based on White Sturgeon with a minimum length of 1,016 mm TL, which were released *in situ*, and was similar to methods employed in previous evaluations of the Lake Sturgeon population in the Lake of the Woods-Rainy River system.

The similarity in the proportions of recovered Lake Sturgeon that had a section of the marginal pectoral fin ray removed in 2004, and those that did not, indicates there is no difference in the mortality rate between the groups. As such, there is no reason to discontinue the removal of this structure due to concerns about increased mortality. Caution should however be used if the structure is removed from actively spawning fish. The function of the marginal pectoral fin ray seems to be to add rigidity to the fin, likely, to aid in navigation through the turbulent water in which Lake Sturgeon spawn. Removal of the fin ray at this time may impede the ability of actively spawning Lake Sturgeon to navigate within the spawning sites, and may then influence reproductive success. Further study would be needed to evaluate this possibility.

The history of decline of the Lake of the Woods – Rainy River Lake Sturgeon population is typical of the dramatic declines in Lake Sturgeon stocks documented throughout much of their historical range. In this case, commercial over-exploitation reduced the population to "extinction levels" and habitat alterations to spawning and nursery sites prevented recovery. The increase in the adult population that has been described suggests that this population is in a state of continuing recovery which demonstrates the resiliency of the species when perturbations are addressed and habitat remains intact.

ACKNOWLEDGEMENTS

A project of this magnitude could not have been accomplished without the contributions of numerous individuals. The authors would like to extend their gratitude to the employees of the OMNRF (Fort Frances, Kenora, and Thunder Bay offices) and MNDNR (Aitkin, Baudette, Bemidji, and International Falls offices) for their dedication to working long hours in difficult conditions. Additionally, numerous sport anglers provided Lake Sturgeon to be tagged, and several interested individuals volunteered time to assist with the marking effort. Phil Talmage and Dennis Topp provided editorial comments and content advice.

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TABLES

TABLE 1 – The number of Lake Sturgeon, longer than 999 mm, marked at each site, by sex. The Rainy River site represents the total number marked at three discrete sites on the main-stem Rainy River. Sites identified with an * are sites at which actively spawning Lake Sturgeon were observed.

Sex	Fourmile Bay - Inside Channel	Rainy River	Big Fork River *	Sturgeon River *	Rapid River *	Total
Male	0	12	54	72	64	202
Female	0	3	3	19	0	25
Suspected Female	0	48	3	1	58	110
Unknown	266	556	6	15	111	954
Total	266	619	66	107	233	1,291

TABLE 2 – The number of Lake Sturgeon, longer than 999 mm, sampled during the recapture phase, by stratum and gill net mesh size (bar measure). CPUE is the mean number of Lake Sturgeon caught per gill net lift.

		Fourmile Bay – Inside Channel	Ontario	Big Traverse - Nearshore	Big Traverse - Offshore	Lower Rainy River	Upper Rainy River	Total
Number of Net Sets, by Mesh Size	102-mm	19	35	25	12	38	36	165
	127-mm	19	35	25	13	42	37	171
	152-mm	19	35	25	11	41	37	168
	178-mm	19	35	25	12	38	37	166
Number of Lake Sturgeon Sampled, by Mesh Size	102-mm	7	49	15	2	42	35	150
	127-mm	15	95	39	10	33	35	227
	152-mm	7	25	18	1	15	19	85
	178-mm	3	13	6	3	8	4	37
CPUE, by Mesh Size	102-mm	0.37	1.40	0.60	0.17	1.11	0.97	0.91
	127-mm	0.79	2.71	1.56	0.77	0.79	0.95	1.33
	152-mm	0.37	0.71	0.72	0.09	0.37	0.51	0.51
	178-mm	0.16	0.37	0.24	0.25	0.21	0.11	0.22
Number Captured		32	182	78	16	98	93	499
Overall CPUE		0.42	1.30	0.78	0.33	0.62	0.63	0.74
Number Recaptured		0	6	0	0	0	0	6

TABLE 3 – Inputs used to generate the annual mortality rate estimate. The mean length of age-13 Lake Sturgeon is 1,000 mm, and the mean length of age-23 Lake Sturgeon is 1,283 mm.

	Age-13 and Older (1,000 mm and Longer)	Proportion ≥ Age-23 and Older (1,283 mm and Longer)	Age-23 and Older (1,283 mm and Longer)
2004 Population Estimate	59,050	---	---
2014 Population Estimate	92,286	0.47	43,374

TABLE 4 – The observed number of Lake Sturgeon, which were tagged in 2004, and recaptured in 2014, by whether the marginal pectoral fin ray had been removed. Expected frequencies are based on the relative number of Lake Sturgeon which had, or did not have, the marginal pectoral fin ray removed for ageing in 2004.

	Expected Ratio	Observed Recaptures	Expected Recaptures	$(O - E)^2 / E$
Fin Ray Removed	0.32	12	12.2	0.0033
Fin Ray Intact	0.68	26	25.8	0.0016
Total	1.00	38	38	0.0048

TABLE 5 – Three population estimates, with 95% confidence limits, for the Lake of the Woods – Rainy River Lake Sturgeon population.

Year	Population Estimate	Lower 95% Limit	Upper 95% Limit	Source
1988-89	16,910	7,549	42,275	Mosindy and Rusak (1991)
2004	59,050	30,736	121,372	Stewig (2005)
2014	92,286	45,816	201,875	Current Study

TABLE 6 – The recapture phase catch per unit of effort (CPUE) for Lake Sturgeon longer than 999 mm, from the 2004 population estimate (Stewig 2005) and the current study.

Results shown for Stewig (2005) are recalculated to reflect only Lake Sturgeon longer than 999 mm. For comparison with the strata used by Stewig (2005), the Big Traverse – Shallow and the Ontario strata are combined for the 2014. Effort is the number of lifts of 91 m-long gill nets. CPUE is the number of Lake Sturgeon captured per lift.

Stratum	2004 Population Estimate			2014 Population Estimate		
	Effort	Number of Lake Sturgeon	CPUE	Effort	Number of Lake Sturgeon	CPUE
Big Traverse – Offshore	118	20	0.14	48	16	0.33
Big Traverse Nearshore and Ontario	133	88	0.62	240	260	1.08
Fourmile Bay – Inside Channel	87	63	0.67	76	32	0.42
Lower Rainy River	78	235	2.91	159	98	0.62
Upper Rainy River	180	64	0.34	147	93	0.63
Lake Strata Total	338	171	0.51	364	308	0.85
River Strata Total	258	299	1.16	306	191	0.62
Overall Total	596	470	0.79	670	499	0.74

FIGURES

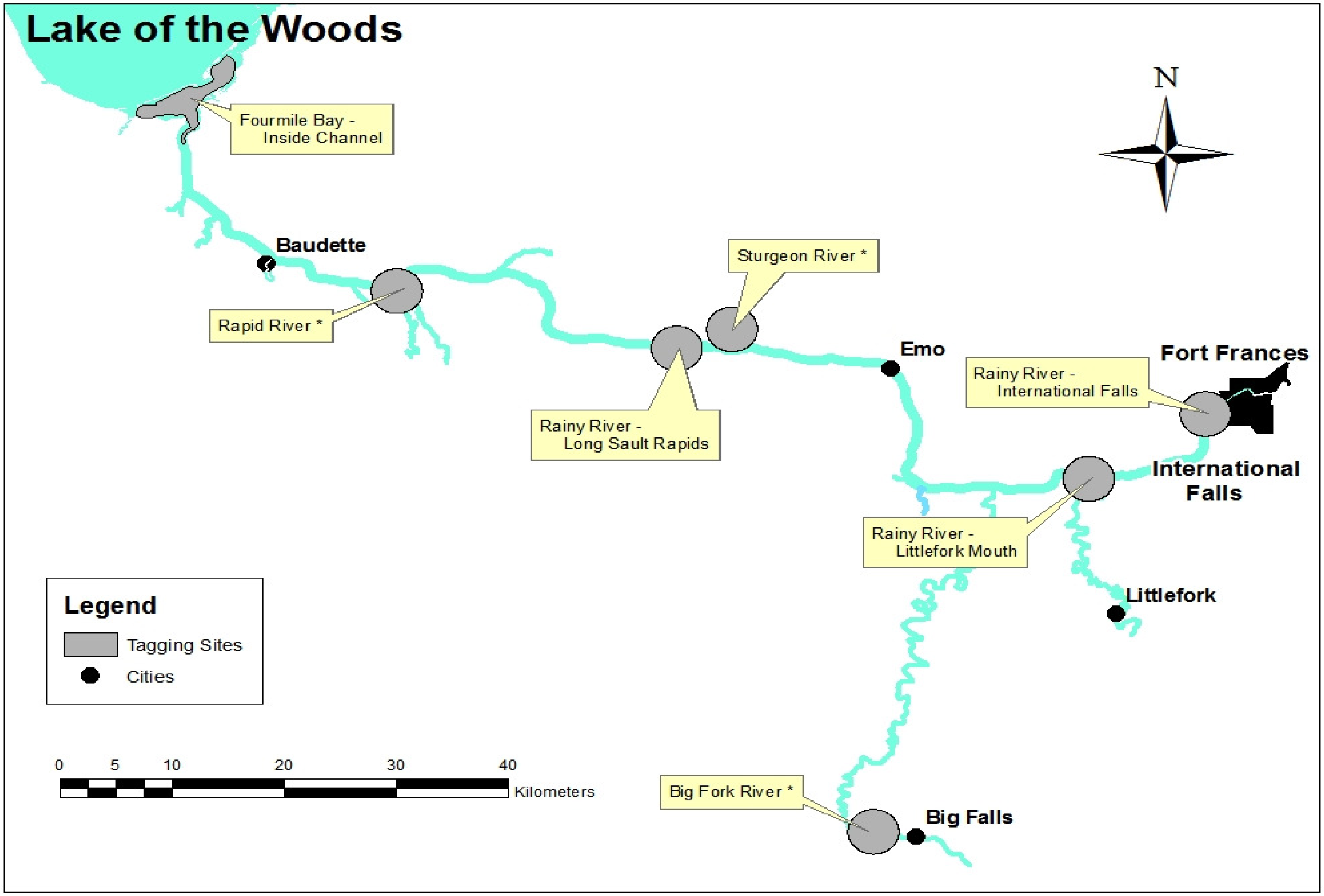

FIGURE 1 – Lake Sturgeon tagging sites in the Lake of the Woods – Rainy River basin. Tagging sites identified with an * had actively spawning Lake Sturgeon during the tagging event.

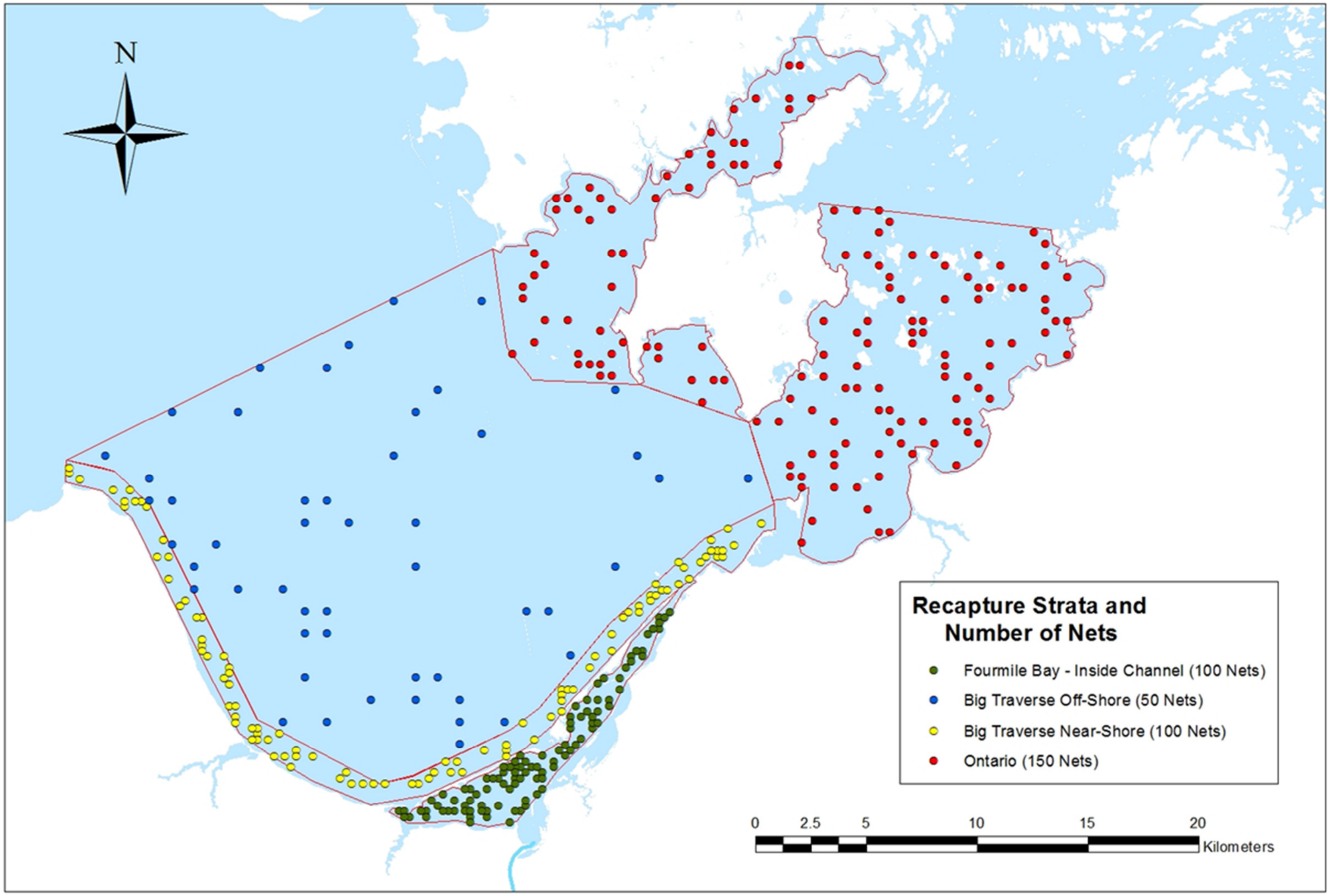

FIGURE 2 – Recapture strata and net locations in Lake of the Woods.

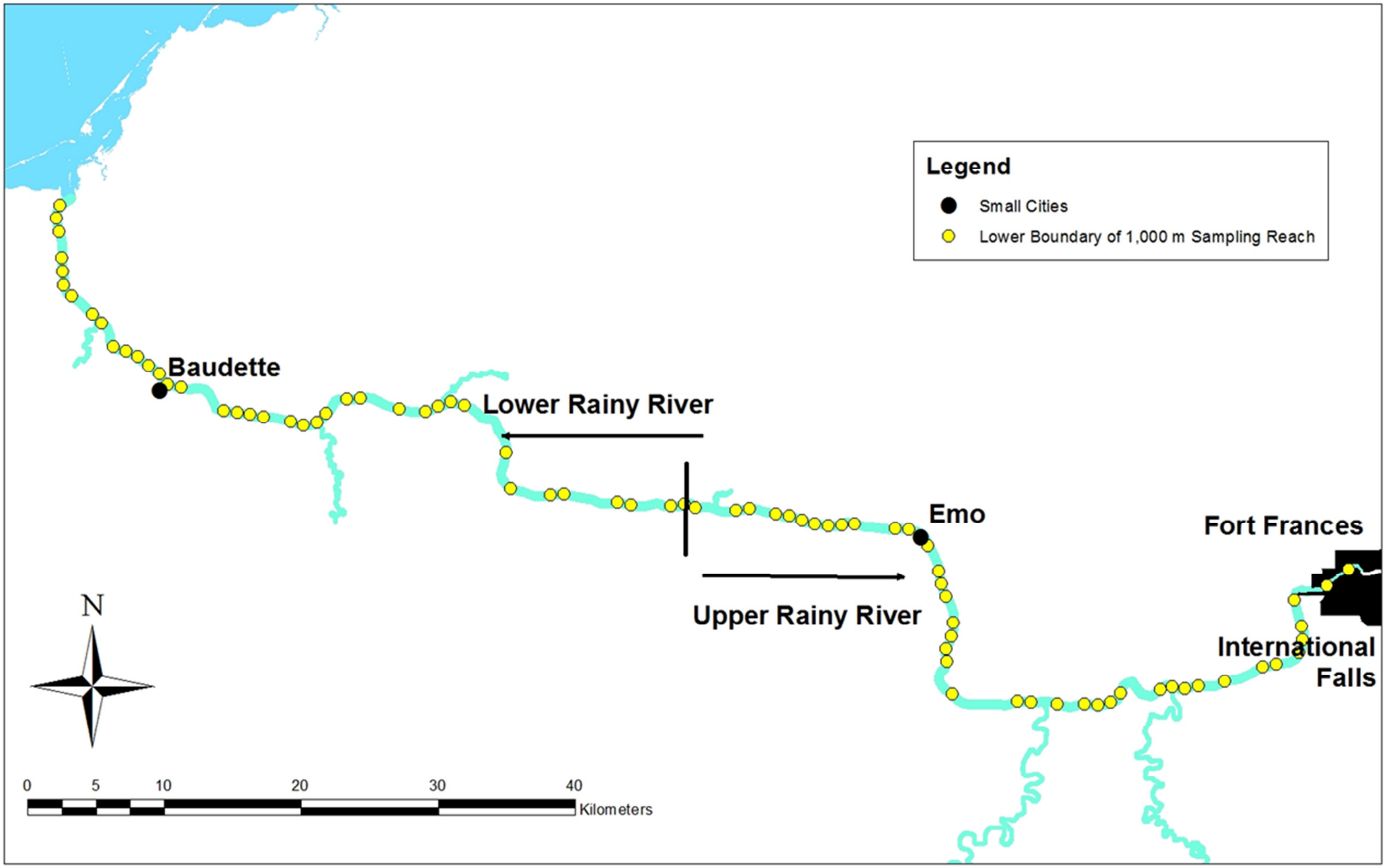

FIGURE 3 - Recapture strata and 1,000 m reach locations in the Rainy River. The locations noted are at the downstream end of the 1,000 m reaches.

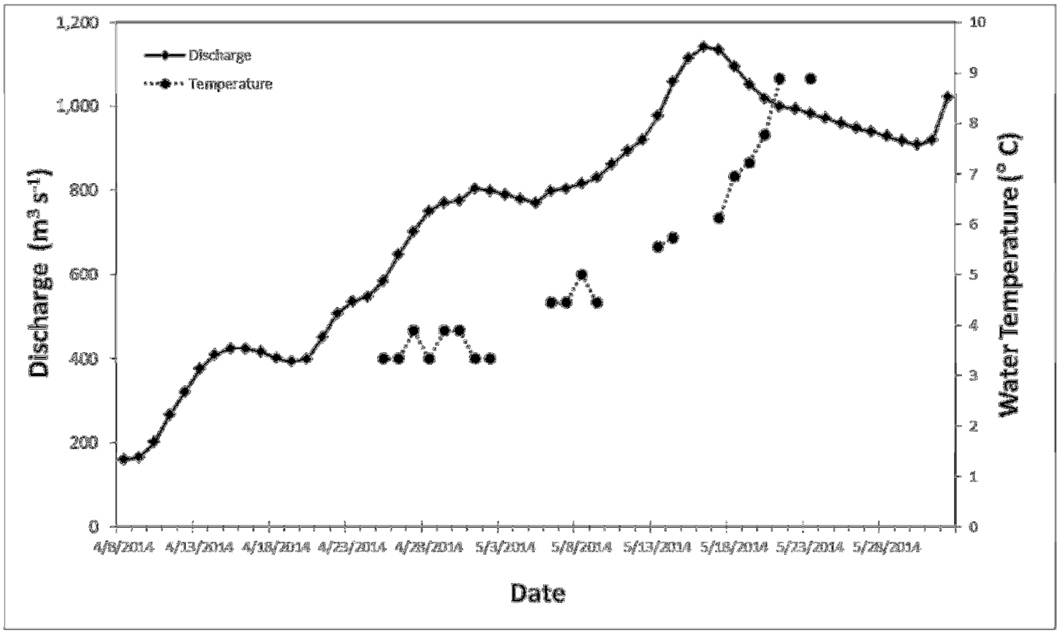

FIGURE 4 – Rainy River discharge (m^3 s^{-1}) and water temperature (℃), from April 8 to June 1, 2014. Discharge was measured at the United States Geological Survey (USGS) gaging station at Manitou Rapids (site 05133500). Water temperatures were recorded on days the Rainy River was sampled.

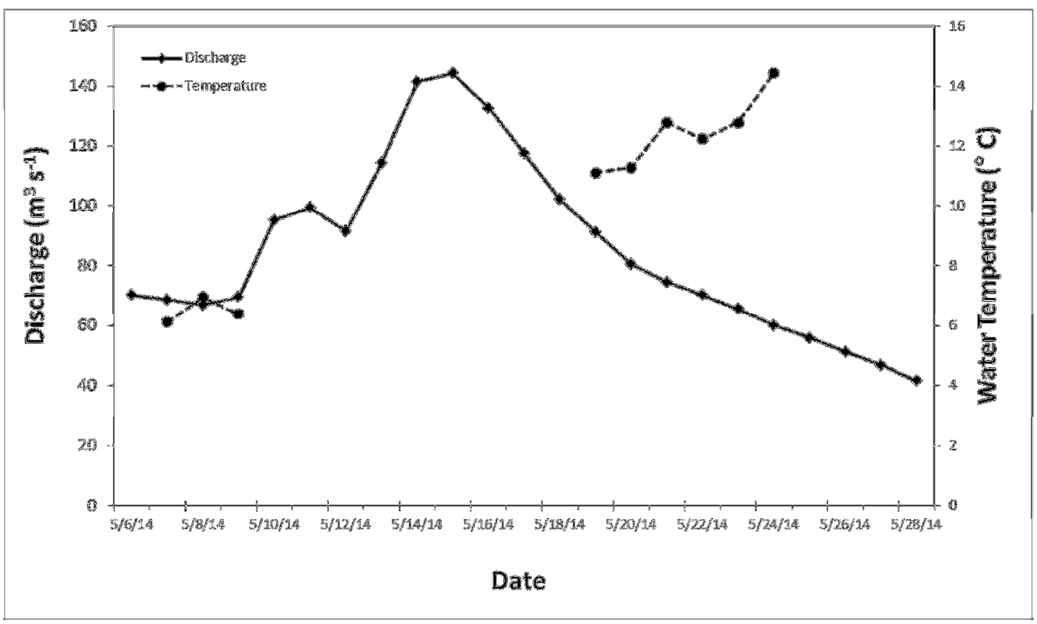

FIGURE 5 – Rapid River discharge (m^3 s^{-1}) and water temperature (℃), May 6 to May 28, 2014. Discharge was measured at the Minnesota Department of Natural Resources (MDNR) – Minnesota Pollution Control Agency (MPCA) cooperative gage (site 78007001). Water temperatures were recorded on days the Rapid River was sampled.

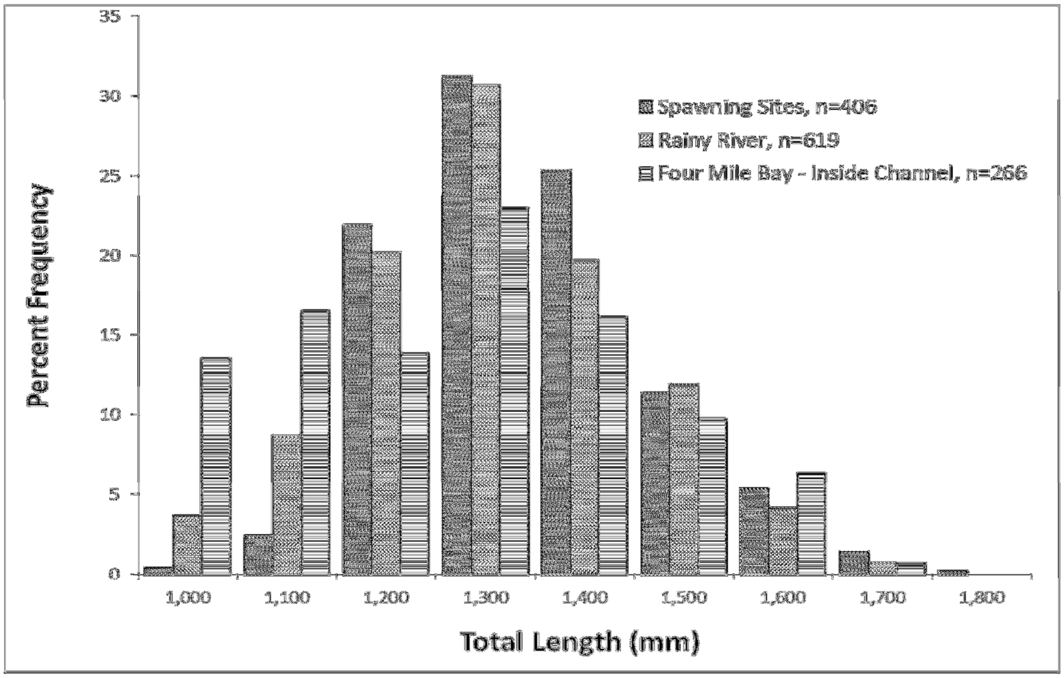

FIGURE 6 – Length frequency distribution of tagged Lake Sturgeon (100 mm intervals) by the area from which they were tagged. Spawning sites include the Rapid River, Sturgeon River and Bigfork River. The Rainy River includes the entire length of the river.

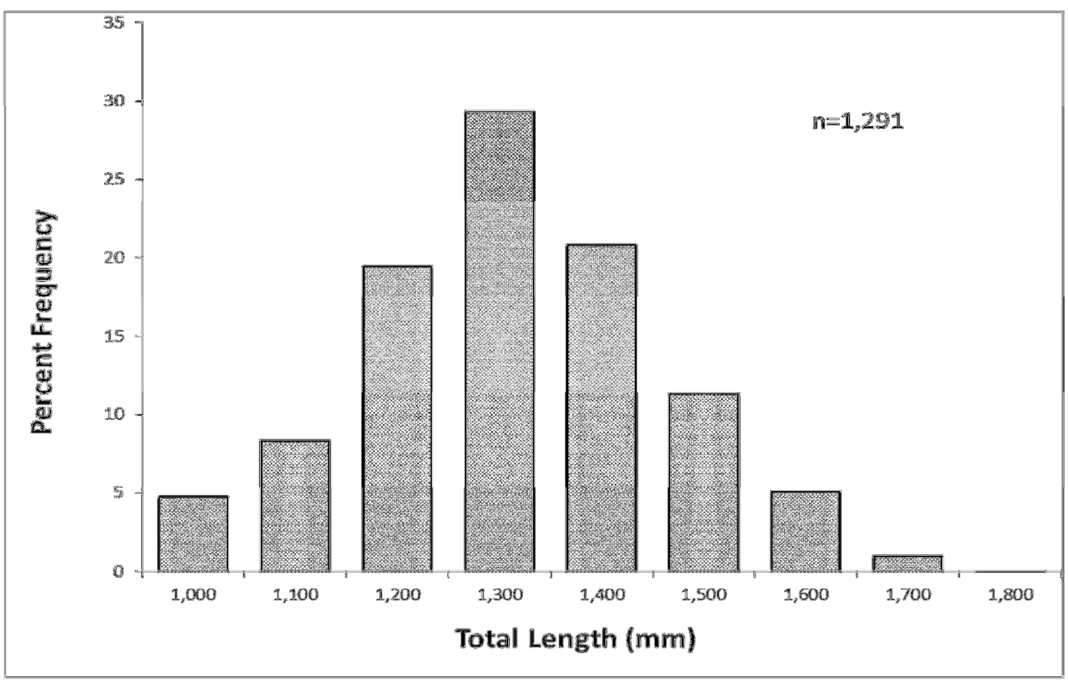

FIGURE 7 – Overall length frequency distribution (100 mm intervals) of tagged Lake Sturgeon.

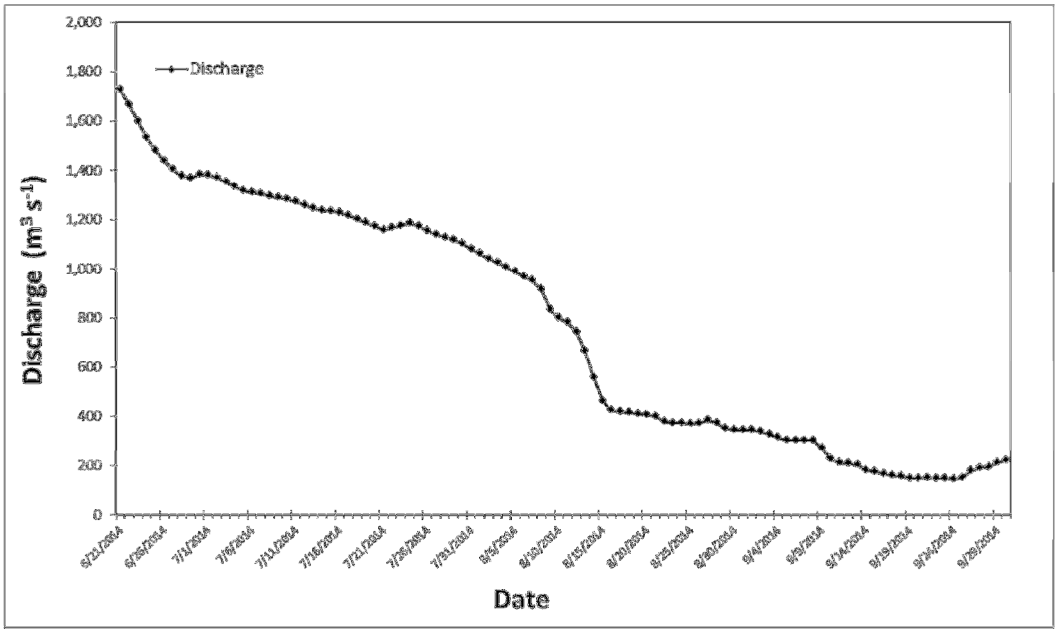

FIGURE 8 - Rainy River discharge (m^3 s^{-1}) from June 21 through September 30, 2014, measured at the USGS gaging station at Manitou Rapids (site 05133500).

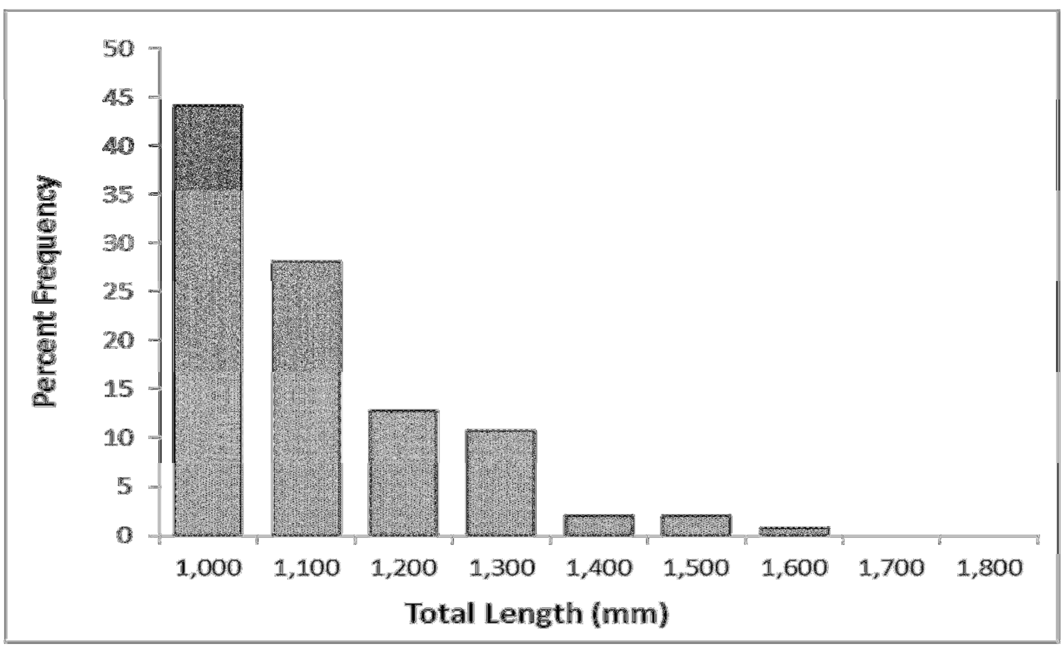

FIGURE 9 – Length frequency distribution (100 mm intervals) of Lake Sturgeon sampled during the recapture phase, in the 102-mm (bar measure) gill nets.

Mean total length is 1,152 mm, n=150.

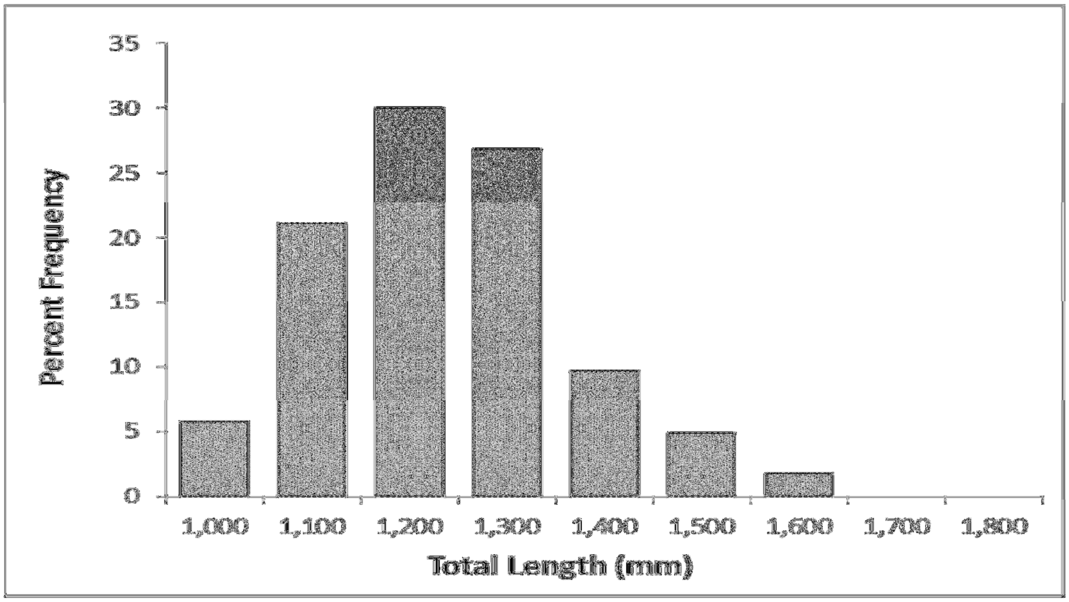

FIGURE 10 – Length frequency distribution (100 mm intervals) of Lake Sturgeon sampled during the recapture phase, in the 127-mm (bar measure) gill nets.

Mean total length is 1,284 mm, n=277.

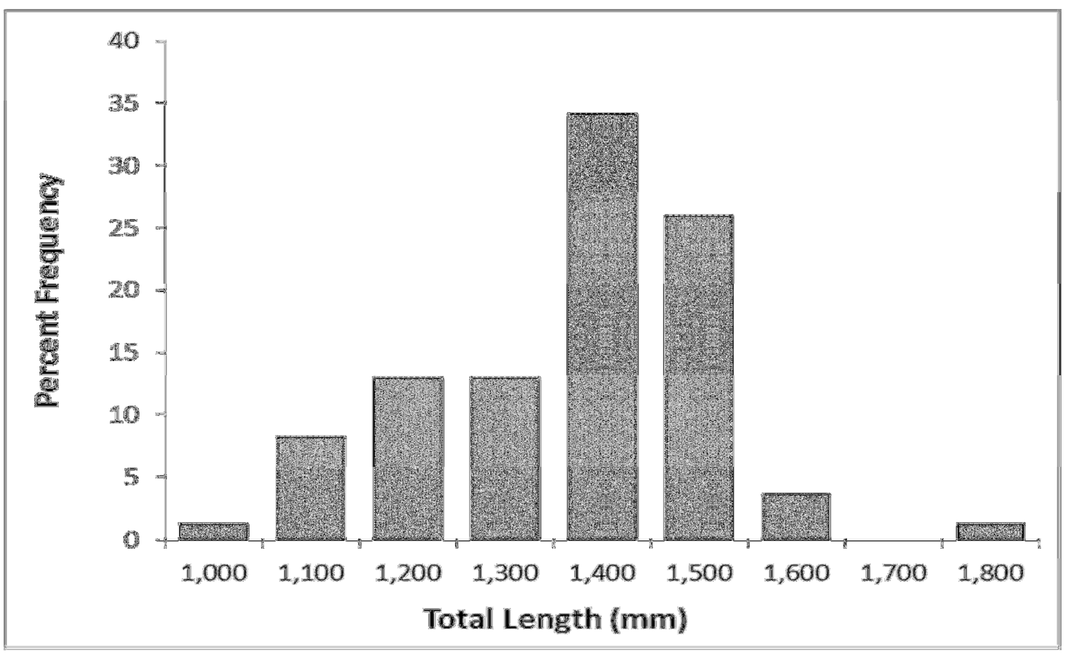

FIGURE 11 – Length frequency distribution (100 mm intervals) of Lake Sturgeon sampled during the recapture phase, in the 152-mm (bar measure) gill nets.

Mean total length is 1,413 mm, n=85.

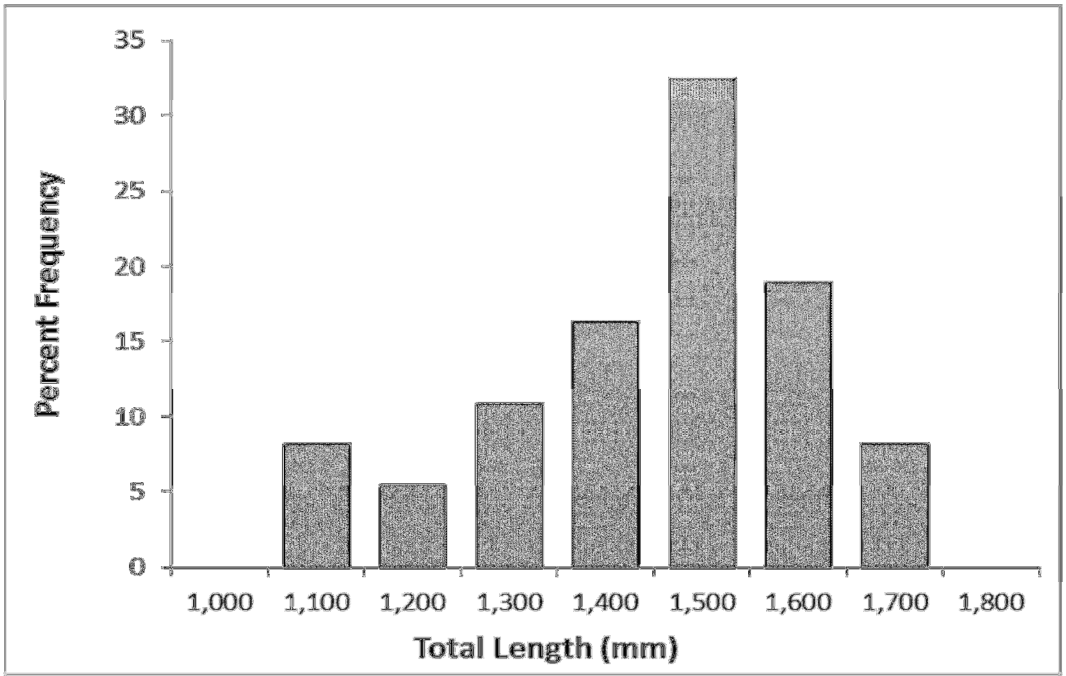

FIGURE 12 – Length frequency distribution (100 mm intervals) of Lake Sturgeon sampled during the recapture phase, in the 178-mm (bar measure) gill nets.

Mean total length is 1,499 mm, n=37.

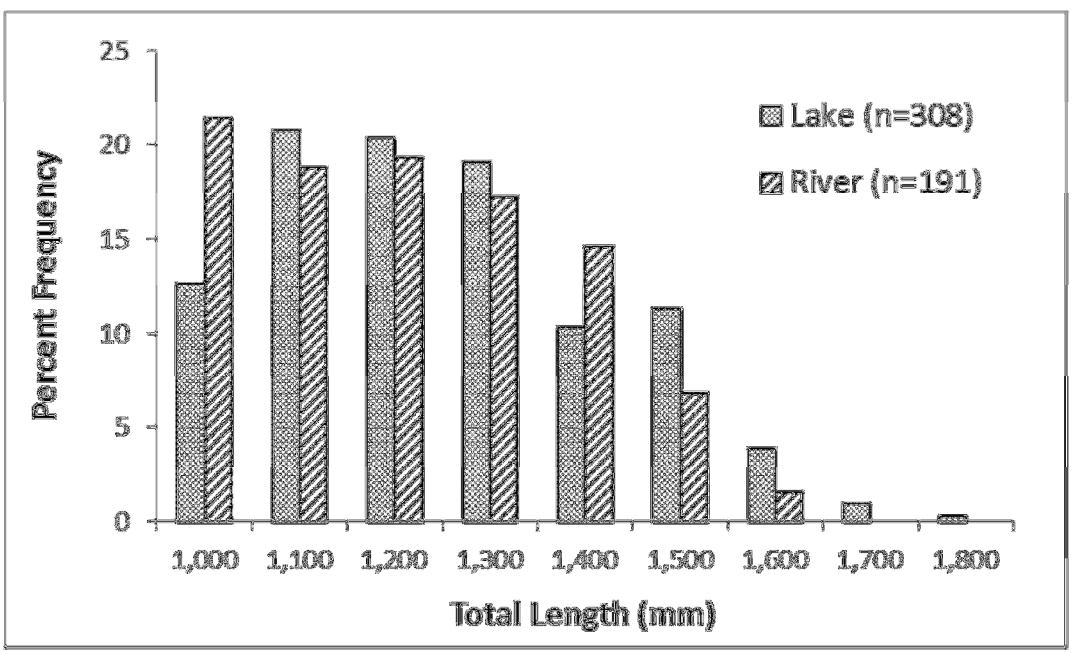

FIGURE 13 – Length frequency distribution (100 mm intervals) of Lake Sturgeon captured during the recapture phase of the population estimate, by location.

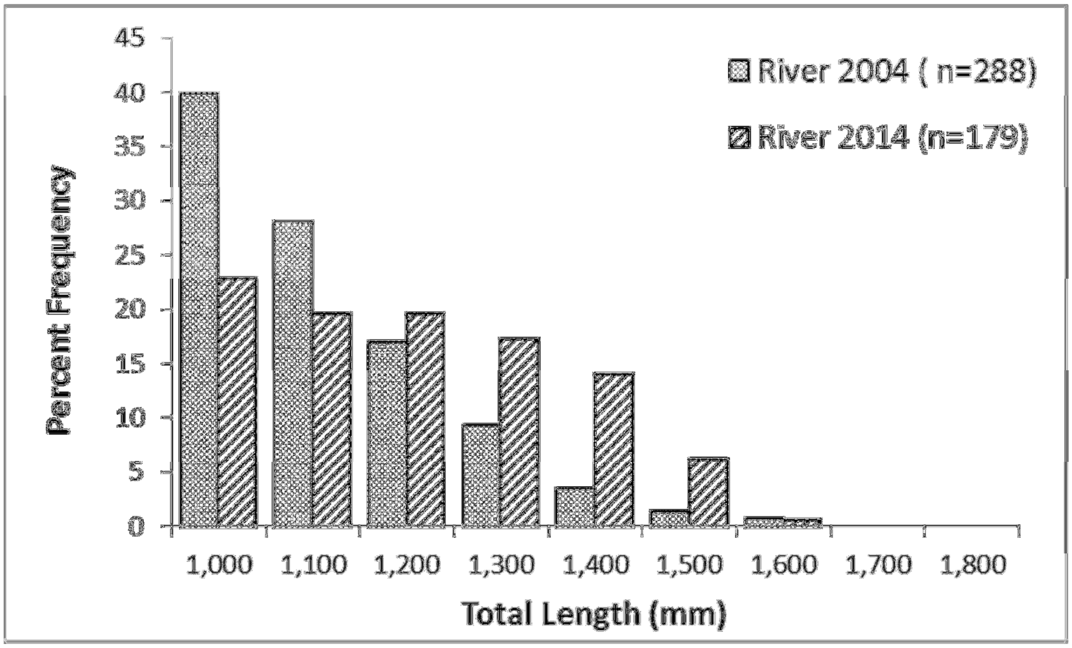

FIGURE 14 – Length frequency distribution (TL, 100 mm intervals) of Lake Sturgeon sampled from all Rainy River strata during the recapture phases of the 2004 and 2014 population estimates. Lake Sturgeon sampled in the 178-mm mesh (bar measure) gill nets in 2014 were excluded from the figure.

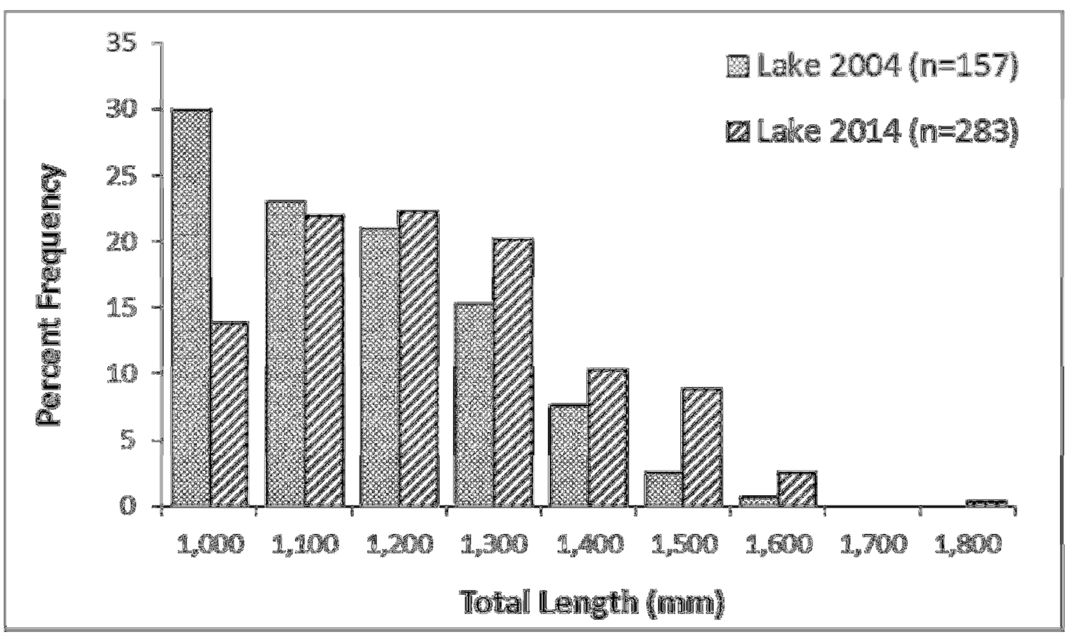

FIGURE 15 - Length frequency distribution (TL, 100 mm intervals) of Lake Sturgeon sampled from all Lake of the Woods strata during the recapture phases of the 2004 and 2014 population estimates. Lake Sturgeon sampled in the 178-mm mesh (bar measure) gill nets in 2014 were excluded from the figure.

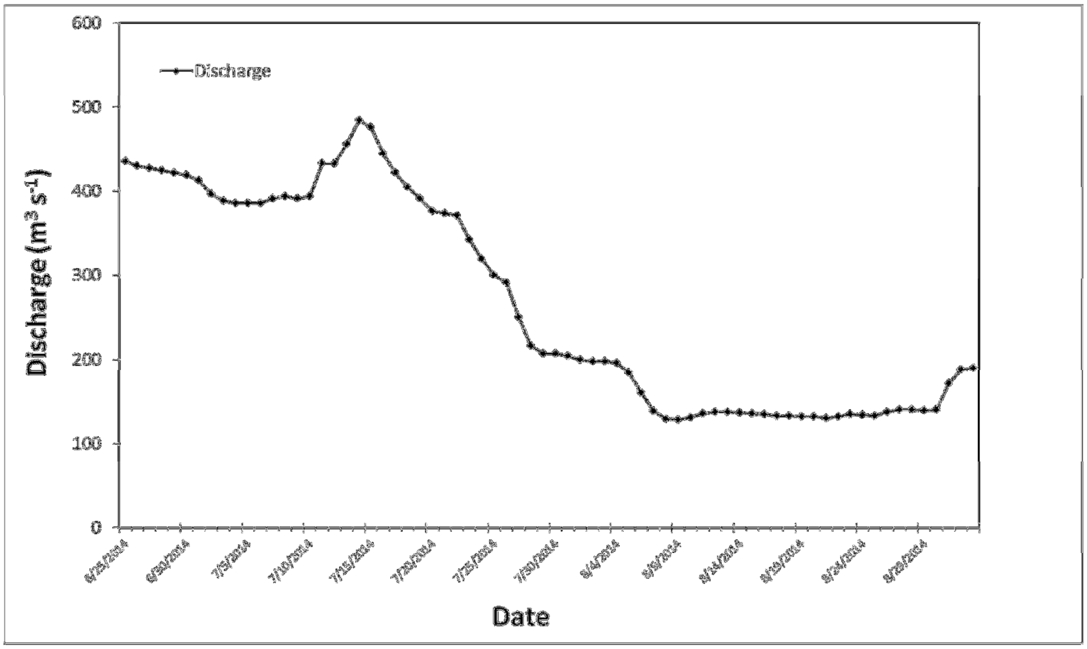

FIGURE 16 - Rainy River discharge (m^3 s^{-1}) from June 25 through September 2, 2004, measured at the USGS gaging station at Manitou Rapids (site 05133500).

APPENDIX

APPENDIX 1 – Long-range and short-range goals for Lake Sturgeon population recovery.

These goals were established by the Border Waters Lake Sturgeon Technical Committee of the Minnesota-Ontario Fisheries Technical Committee in March 2003. The short-range goals were achieved in April 2012, and harvest, in Minnesota, is currently based on 0.045 kg ha^{-1} (0.04 pounds per acre). Harvest of Lake Sturgeon is not legal in Ontario due to their status as a species of "Special Concern". Lake Sturgeon habitat is defined as any water less than 12.2 m deep. There are 60,000 ha of Lake Sturgeon habitat in Ontario, and 118,000 ha in Minnesota.

Long-range Goals (20-30 years)

Rehabilitate and maintain healthy, self-sustaining stocks of lake sturgeon that will provide subsistence and recreational harvests. The lake sturgeon populations will have the following characteristics:

- Male fish up to age 40.
- Female fish up to age 70.
- 10-15% are mature fish.
- Female fish exceeding 2,030 mm (80 inches) total length.
- At least 40 year classes.
- Densities of Age 2+ fish at 156 fish km^{-1} (250 fish/mile) in rivers and 3.8 fish ha^{-1} (1.5 fish/acre) in lake systems.
    - Note: *This goal is based on rehabilitated populations in other States/Provinces. Appropriateness for Lake of the Woods/Rainy River will need to be determined along with development of population estimators.*
- Fishing mortality less than 5 percent.
- Support harvests at 0.1125 kg ha^{-1} (0.10 pounds per acre) of available habitat.

Short-range Goals (next 5-10 years)

Rehabilitate self-sustaining stocks of lake sturgeon that will provide limited subsistence and recreational harvests. The lake sturgeon populations will have the following characteristics during rehabilitation:

- Male fish up to age 30.
- Female fish up to age 50.
- Female fish exceeding 70 inches total length.
- At least 30 year classes.
- Support harvests at 0.045 kg ha^{-1} (0.04 pounds per acre) of available habitat.
    - Note: *Present target harvest is 0.028 kg ha^{-1} (0.025 pounds per acre).*

APPENDIX 2 – Lake Sturgeon yield (kg ha^{-1}) based on the stage of recovery the population is in.

Stage of Recovery	Yield (kg ha^{-1})	Ontario 60,000 ha	Minnesota 118,000 ha	Total 178,000 ha
Enhanced Recovery Period (Prior to Short-Range Goals Achievement)	0.028	1,680	3,304	4,984
Short Range Goals Achieved (Allow population to continue recovery)	0.045	2,700	5,310	8,010
Long Range Goals Achieved (Potential Yield)	0.1125	6,750	13,275	20,025

APPENDIX 3 – Future sampling considerations.

-conduct planning and coordination meetings with all involved parties in December prior to field season

-conduct sampling protocol meeting approximately 1 month prior to field season

-consider conducting a follow-up survey the following spring to produce an independent population estimate, or to produce a Schnabel PE using the fish marked during the marking phase, and the fish marked during the recapture phase as two marking events

- avoid sampling flowing waters under rising conditions, if possible

    -if sampling under rising conditions, plan for additional time to clean nets

-set nets perpendicular to the current in rivers, when possible

-minimum gill net crew size is 3 to minimize handling time

-minimum hand-grab crew size is 5 (2 catchers, 2 processers, 1 data recorder)

-complete sampling in Rainy River by September 15, due to leaf fall

-allow tagged lake sturgeon to disperse for approximately 30 days prior to starting the recapture phase

-consider using boats larger/more seaworthy than a 20-foot Lund Alaskan to sample Lake of the Woods

-start sampling Fourmile Bay as soon as the ice goes out

-Lake Sturgeon are actively spawning by 11 ° C, but start to stage prior to that

    -under low flow conditions, Lake Sturgeon will delay spawning until flows improve

-spawning in the Rapid River and Sturgeon River (Ontario) seems to take place during the same period

-utilize a flow-through holding tank when high catches are expected

    -consider adding O_2 to the holding tank

-permits required in 2014

    -immigration

        -I-68, from USA

        -Remote Area Border Crossing Permit, from Canada

- fish collection (natural resource agencies)
    - Scientific Collection Permit, from Minnesota
    - permit to work in infested waters (requires equipment be tagged), from Minnesota
    - License to Collect Fish for Scientific Purposes, from Ontario
    - Permit for Species Protection or Recovery 17(2)(b), from Ontario
    - register the project under Species at Risk Act, from Ontario

-crews on LotW can plan to lift 8 nets per day during the recapture phase

-crews on the Rainy River can plan to lift 8 to 12 nets per day during the recapture phase

-expect to work long days, weekends, and holidays, especially during the marking phase

- you have to catch fish when they are available, once gone, they are gone

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A Population Assessment Of the Lake of the Woods – Rainy River Lake Sturgeon Population, 2014

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