The Status of the Smallmouth Bass Recreational Fishery in Lake Nipissing

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EXECUTIVE SUMMARY

Smallmouth Bass (*Micropterus dolomieu* (Lacepède, 1802)) is an iconic freshwater fish that forms an important open water recreational fishery across Ontario. For over a quarter of a century Smallmouth Bass have been a prominent component of Lake Nipissing's diverse open water recreational fishery. This report summarizes angler survey and index netting data to provide population benchmarks and allows for the exploration of long-term trends in fisheries parameters. This multifaceted assessment provides the information necessary to inform sound management of the recreational fishery. Key benchmarks that depict the fishery profiles (e.g., angler effort, catch, catch rate, and harvest) and population parameters (e.g., abundance, growth, maturity, and mortality) were assessed across the temporal extent of the available data. These data were achieved through standardised sampling of the recreational fishers, as well as compiling sampling data from trap nets and gill nets to provide a more complete picture of the status of the species. The results from this data compilation indicates that Smallmouth Bass in Lake Nipissing have experienced increased abundance, good growth, and low mortality (and angler exploitation) over the last thirty years. Based upon these results, the possibility of adjusting the current protective season to provide consistency of regulation across Fisheries Management Zone 11 should be explored. Implementation of a long-term monitoring strategy, working with recreational fishers (to determine size of fish that are being released) as well as addressing research priorities (including understanding movement patterns, habitat use, species interactions, and trophic ecology) will be critical to the ongoing sustainability of the Lake Nipissing Smallmouth Bass recreational fishery into the future.

RÉSUMÉ

L'achigan à petite bouche (*Micropterus dolomieu* (Lacepède, 1802)) est un poisson d'eau douce emblématique qui constitue une importante pêche récréative en eau libre dans tout l'Ontario. Depuis plus d'un quart de siècle, l'achigan à petite bouche est une composante importante de la pêche récréative en eau libre diversifiée du lac Nipissing. Ce rapport résume les données du relevé des pêcheurs à la ligne et des filets indexés pour fournir des repères de population et permet d'explorer les tendances à long terme des paramètres de la pêche. Cette évaluation multiforme fournit les informations nécessaires pour éclairer une saine gestion de la pêche récréative. Les principaux repères qui décrivent les profils de pêche (p. Ex. Effort des pêcheurs à la ligne, capture, taux de prise et récolte) et les paramètres de population (p. Ex. Abondance, croissance, maturité et mortalité) ont été évalués dans l'étendue temporelle des données disponibles. Ces données ont été obtenues grâce à un échantillonnage normalisé des pêcheurs récréatifs, ainsi qu'à la compilation de données d'échantillonnage à partir de filets pièges et de filets maillants pour fournir une image plus complète de l'état de l'espèce.Les résultats de cette compilation de données indiquent que l'achigan à petite bouche dans le lac Nipissing a connaissent une abondance accrue, une bonne croissance et une faible mortalité (et exploitation des pêcheurs) au cours des trente dernières années. Sur la base de ces résultats, la possibilité d'ajuster la saison de protection actuelle pour assurer la cohérence de la réglementation dans la zone de gestion des pêches 11 devrait être étudiée. La mise en œuvre d'une stratégie de surveillance à long terme, la collaboration avec les pêcheurs récréatifs (pour déterminer la taille des poissons qui sont relâchés) ainsi que la prise en compte des priorités de recherche (y compris la compréhension des modèles de déplacement, l'utilisation de l'habitat, les interactions entre les espèces et l'écologie trophique) seront essentielles pour la durabilité continue de la pêche récréative de l'achigan à petite bouche du lac Nipissing à l'avenir.

THE STATUS OF THE SMALLMOUTH BASS RECREATIONAL FISHERY IN LAKE NIPISSING

INTRODUCTION

Recreational or sport fishing is a popular activity, involving an estimated 9% of Canada's adult population in 2015, with approximately 1.3 million Ontario residents participating in angling (Fisheries and Oceans Canada 2019). The recognition of recreational fisheries as a major stakeholder in the allocation of limited fisheries resources has long been acknowledged. Recreational fishing is a highly valued and economically important activity, generating jobs and significant revenue. However, even though the number of Ontario residents purchasing sport recreational fishing licences has remained steady since 2014, averaging slightly more than 610,000, the participation in recreational fishing of all kinds appears to be declining since 2005.

Smallmouth Bass (*Micropterus dolomieu* (Lacepède, 1802)) is an iconic freshwater fish that forms an important open water recreational fishery across Ontario (Ontario Ministry of Natural Resources and Forestry [OMNRF] 2015). In addition to providing a valuable food resource, the Smallmouth Bass recreational fishery contributes socially and economically to local communities during summer months. To ensure the benefits provided by the recreational fishery are maintained in the future, sustainable populations of the species are necessary, especially given the life-history behaviour of nesting male Smallmouth Bass showing a high degree of site fidelity which make them vulnerable to anglers (Ridgway et al. 2002). Whilst a range of conservation actions, such as water level and habitat management, might be necessary, it is acknowledged that sound management of the recreational fishery is critical to ensure long-term population sustainability. Despite the popularity of recreational fishing for Smallmouth Bass only limited aspects of the fishery have been subjected to detailed investigation.

The Lake Nipissing recreational fishery has a long history of regulation, with the most recent amendments, informed by research and monitoring of Ontario populations, occurring in 2014 (OMNRF 2014). Suski and Ridgway (2007) documented that climate change induced shifts in Smallmouth Bass seasonal phenology which causes Ontario populations to spawn earlier in the year. Based on this research the fishing season for Smallmouth Bass on Lake Nipissing was lengthened by one-week (i.e., by moving the opening day from the fourth Saturday in June to the third Saturday in June but still closing on November 30th, whereas the daily catch (six) and possession (six) limits have remained unchanged. [*Note: Lake Nipissing is closed to fishing for all species from December 1st to December 31st and March 16th to the third Saturday in May. There is no winter fishing season for Smallmouth Bass.*] There is no size limit for Smallmouth Bass. In 2020 the surrounding Fisheries Management Zone 11 (FMZ 11), amended the Bass fishing season to open on the third Saturday in May and close on the third Sunday in March (the next year). Although it is pragmatic to adopt consistent regulations across both Lake Nipissing and the FMZ 11 recreational fisheries, the effectiveness of their impact on the status and sustainability of Lake Nipissing Smallmouth Bass population remains unclear. This report helps to answer this key question through assessing population benchmarks and exploration of long-term trends in fisheries parameters. This multifaceted assessment provides some of the information necessary to inform sound management of the recreation fishery.

The key benchmarks describe fishery profiles (e.g., angler effort, catch, catch rate, and harvest) and population parameters (e.g., abundance, growth, maturity, and mortality) across the temporal extent of the available data. This was achieved through standardised sampling of the recreational fishers, as well as compiling sampling data from trap nets and gill nets to provide a more complete picture of the status of the species. The information will contribute to the ongoing debate on the relative importance of recreational fishing activity and will provide useful data for the development of new policies, management plans and recreational fishing legislation.

METHODS[1]

Study Area — Lake Nipissing (46° 16' 54", 80° 0' 0") is Ontario's seventh largest inland lake (87,325 ha) located in north-central Ontario approximately 350 km north of the city of Toronto between the Ottawa River and Georgian Bay. The Lake Nipissing watershed (≈13,100 km^2) is largely forested or rural and lies on Precambrian bedrock that is overlain in many areas by sand and clay deposits that is drained by 12 major rivers (Neary and Clark 1992). Four of these rivers drain almost three-quarters of the total watershed area (Sturgeon River 37%, Amateewakea River 13%, South River 11%, and Veuve River 10%). The lake is situated at a mean elevation of 196m above sea level. The productivity of this water body is classified as mesotrophic (2003-04 total phosphorus 17.5 $\mu \cdot L^{-1}$) and is slightly basic (2003-04 pH 7.1) as a consequence of the surrounding the surficial geology and watershed characteristics (Clark et al. 2010). The lake is shallow (average depth of 4.5m) with a maximum depth of 52m close to the French River which is Lake Nipissing's only outflow. Water levels are regulated by dams located on the French River (annual winter drawdown ≈1.2m) and water replacement time is less than one year (≈0.70 years).

Two communities (North Bay, population ≈54,000; West Nipissing, population ≈14,000) use Lake Nipissing for recreation. Dokis First Nation (population ≈200) and Nipissing First Nation (NFN) (population ≈1,400) are situated on the shoreline of Lake Nipissing. Both First Nations rely on the lake for subsistence fishing, while NFN also has a court-recognized treaty right to commercially fish the lake. There are also over 125 tourist establishments on Lake Nipissing (located mainly on the eastern and southern shores, and Northwest Bay) that depend primarily on the fisheries resources for their livelihood.

Lake Nipissing supports a diverse fish community (42 species) dominated by Walleye (*Sander vitreus* (Mitchill, 1818)), Yellow Perch (*Perca flavescens* (Mitchill, 1814)), Northern Pike (*Esox luscius* (Linnaeus, 1758)) , and White Sucker (*Catostomus commersoni* (Lacepède, 1803)) with a significant Coregonid component [(Cisco, *Coregonus artedi* (Lesueur, 1818)) and Lake Whitefish, (*Coregonus clupeaformis* (Mitchill, 1818))]. Other culturally significant species include Muskellunge (*Esox masquinongy* (Mitchill, 1824)), Smallmouth Bass, Largemouth Bass (*Micropterus salmoides* (Lacepède, 1802)), and Lake Sturgeon (*Acipenser fulvescens* (Rafinesque, 1817)).

Open Water Creel Survey - Surveying recreational fishers' catch, in addition to that of commercial fishers, is vital to the assessment of the stock of fish in Lake Nipissing. The information is used by the government's fisheries managers to better understand the sustainability of our fisheries, and determine what, if any, controls are needed. Recreational fisheries data are usually collected over relatively short periods of time using a variety of methods. These include creel surveys (where catches of recreational fishermen are quantified in the field), roving surveys (where interviews are carried out in a systematic way in the field), log book surveys (where recreational fishermen keep records of their fishing activity in log books), telephone surveys, and mail surveys. The most reliable catch data are obtained by face to face interviews in the field (Pollock et al. 1994; National Research Council 2006). The different methods of surveying recreational catch can also be broken down into on-site and off-site methods. On-site surveys include boat ramp counts and intercept surveys, creel surveys, roving style surveys, and aerial over-flight surveys to observe boat activity. Off-site methods generally use interviews or self-reporting methods to measure fishing activity and harvest. Each method has its advantages and disadvantages in terms of species, spatial and temporal coverage, measurement accuracy and precision.

In 1970 the first open water roving creel survey of Nipissing's boat-based fishery across the entire lake was conducted. The same creel design was repeated in 1971, 1972, and 1973 and the resulting harvest estimates

1. The methods section of this report is modified from the Morgan (2019) Status of Lake Nipissing Northern Pike and associated fisheries 1967 to 2018 report.

were compared in detail. It was concluded that the recreational harvest estimates provided by the 1970 to 1973 surveys were reasonably accurate and fit for management purposes (Jorgensen 1979). The roving creel design was standardized in 1975 and has been conducted annually (Note: Due to budget constraints in 1992 the open water angler survey was only conducted in July and August and the 1993 open water angler survey only covered a portion of the lake, therefore only partial estimates of effort, catch, and harvest were available for these years). Consistent reporting of all the fishery profile data for the major fish species targeted by anglers (Walleye, Yellow Perch, Northern Pike, and Smallmouth Bass) began in 1990.

Open water angler surveys commenced on the opening day of the Walleye-Northern Pike season and ended on the Friday after Labour Day (early September). Fourteen sectors (Figure 1: Callander Bay – E1, 2880 ha; Manitou Islands – E2, 11719 ha; South Bay – E3, 3428 ha; North Bay shoreline – E4, 5060 ha; South Shore – E5, 7671 ha; Northeast shoreline – E6, 4305 ha; Iron Island – W1, 8813 ha; Goose Islands – W2, 10941 ha; Hardwood Islands – W3, 3904 ha; French River to Cross Point – W4, 3362 ha; Cache Bay to the mouth of the Sturgeon River – W5, 6682 ha; Middle West Bay – W6, 6718 ha; West Bay – W7, 4285 ha; and Northwest shoreline – W8, 2792 ha) were sampled. Three sectors were sampled each sampling day. The fishing day was stratified into an AM period (08:30 to 14:30 in May and June, and 09:30 to 15:30 from July to September) and PM period (14:30 to 20:30 in May and June, and 15:30 to 21:30 from July to September). Each sector was sampled a minimum of 8 times (2 time periods (AM and PM), 2 work days (Monday to Friday), and 2 non-work days (Saturday, Sunday or statutory holiday)) over the fishing season. A circuit was made of the sector and an activity count of the number of boats actively engaged in fishing was conducted. All anglers leaving or arriving during the survey were recorded. A sub-sample of angling parties, which was proportional to the time available to cover a sampling sector (2 hours·sector^{-1}), was interviewed by survey crews during each survey day. During angler interviews, information was collected on time spent actively angling, species preference (i.e., which fish species the anglers were targeting) species caught and harvested, number of anglers in the party, residency of the anglers, and their visitor type (e.g., permanent resident or resort guest, use of guide services, etc.).

Variables that described the fishing process (e.g. effort, catch, and harvest) were estimated using the two-stage method (Lester and Trippel 1985, Lester and Korver 1996). These data were entered, archived, and managed using the OMNR FISHNET software package (Lester et al. 1989). Effort was estimated for each stratum-day sampled by combining observed angling activity with the average duration (hours) of a fishing trip reported by interviewed anglers. This estimate was multiplied by observed catch and harvest-per-unit effort to estimate daily catch and harvest by species. Daily estimates were then averaged for each stratum and expanded by the stratum size (i.e., total number of stratum-days) to obtain estimates of effort, catch, and harvest for the survey period. These estimates were summed to generate estimates for the overall fishery (Sutton and Lennox 2020).

All fish caught by the respondents, whether released or retained, were recorded. Where fish were retained (kept), they were identified and measured by survey clerks. Mass of fish was determined using standard length-mass regressions. Some species were sub-sampled for total length measurements with minimum sampling target of the first 75 Walleye, Yellow Perch, and Northern Pike encountered in each month. Smallmouth Bass were tallied but not sampled until 2010. Additionally, scales and dorsal spines were collected from Smallmouth Bass harvested by anglers during the open water seasons of 2014 to 2019 for later age interpretation (Mann 2004).

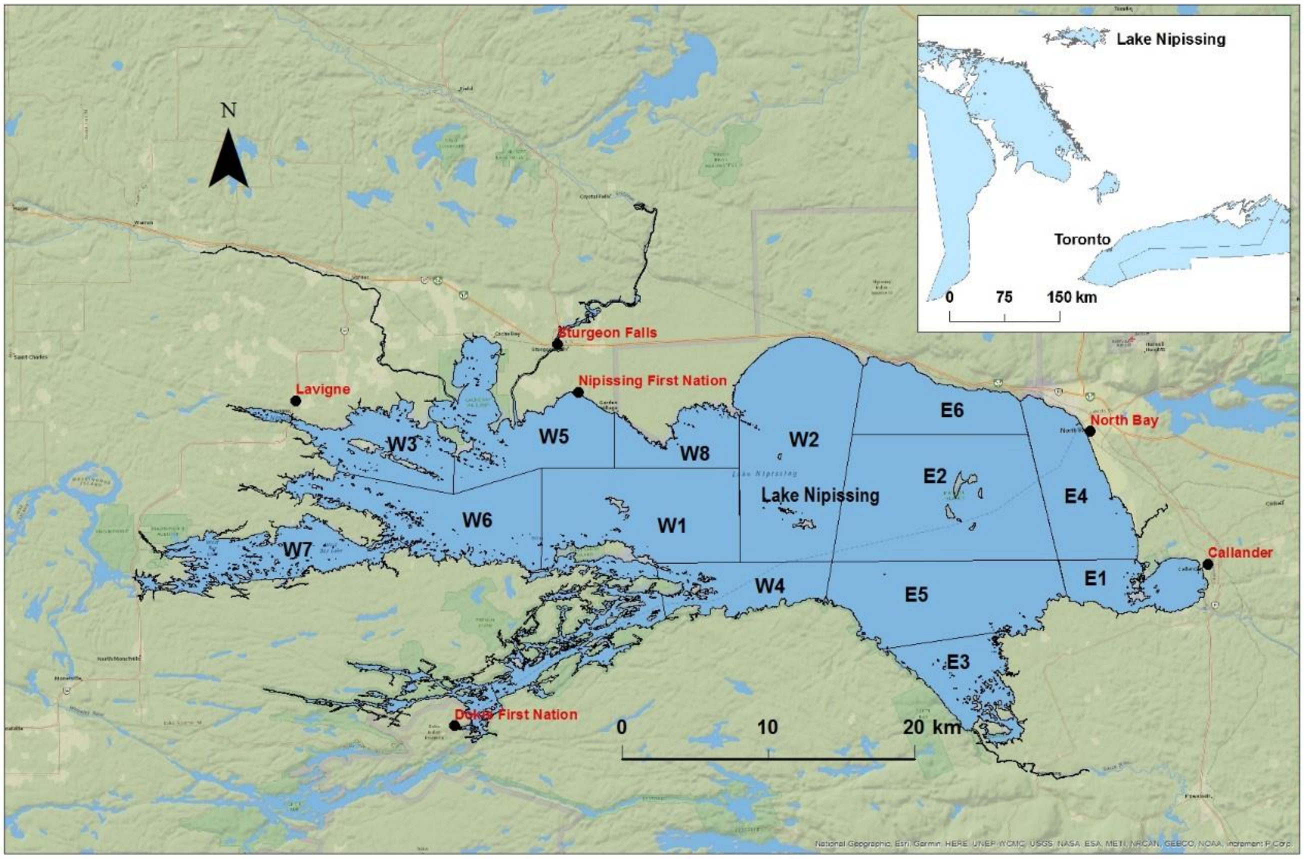


Figure 1. Lake Nipissing open water creel survey sampling sectors.

Ice Out Trap Netting (IOTN) — Ice out trap netting was identified as the recommended technique of Northern Pike and Muskellunge ("Esocids") during the Lake Nipissing assessment plan workshops held jointly by the Anishinabek/Ontario Fisheries Resource Centre (A/OFRC) and the Ontario Ministry of Natural Resources (OMNR). Subsequently, A/OFRC and OMNR co-authored a ten-year assessment plan for Lake Nipissing (2000-2009) which included ice out trap netting as an assessment technique worthy of evaluation to see if it could provide the data required to determine stock status and make appropriate management decisions (Rowe and Seyler 2000). Ice out trap netting projects (targeting Northern Pike and Muskellunge) were conducted in partnership by OMNRF, NFN, and A/OFRC. Different areas of Lake Nipissing known to contain appropriate Esocid nearshore habitat were sampled in each sample year — 1999 (creel sectors E1 and E3; Callander and South Bay, respectively), 2000 (South Bay), 2001 (South Bay), 2007 (creel sector W8; Northwest Shore), 2013 (Callander Bay), 2014 (Callander Bay), and 2016 (South Bay). The sampling program commenced as soon as the ice had receded from the shore of Lake Nipissing (nets first set on April 19th in 1999, April 14th in 2000, April 25th in 2001, April 16th in 2007, April 30th in 2013, May 6th in 2014, and May 2nd in 2016).

From 1999 to 2007, two standard six-foot spring-haul trap nets were set along the shoreline each day at pre-determined sites in specific areas of the lake. Each selected site was fished for two consecutive nights (but sampled daily), after which time they were moved to another pre-selected location. No attempt was made to randomize trap-net effort; rather, effort was directed at sampling the greatest number of fish possible with a minimum target sample size of 25 trap net sets. Nets were placed in suitable spawning habitat that is not uniformly distributed and some spatial clumping of net locations occurred.

From 2013 to 2016, the method was changed to follow the standardized OMNR End of Spring Trap Netting (ESTN) protocol (Skinner and Ball 2004). Net set locations were randomized, the nets were allowed to soak for 24 hours, and then subsequently moved the following day.

Trap net effort varied between years, ranging from 28 to 58 sets·year^{-1}, effort differing with the duration of the Esocid spawning season. The fieldwork was terminated in early to mid- May (last nets were lifted on May 6th in 1999, May 5th in 2000, May 18th in 2007, May 17th in 2013, May 27th in 2014, and May 12th in 2016).

Standard trap nets have 64mm black, polypropylene mesh on the leader and top and bottom of house and heart; and 44mm mesh on the rest of the head nets (Stirling 1999; Skinner and Ball 2004). They have rectangular frames (3.45m long, 1.83m wide, and 1.83m high), one throat (sometimes referred to as the tunnel) 25cm in diameter, and a 45.7m long by 1.83m high lead that extended onto the shore. The trap nets were left to fish for approximately 24 hours (acceptable daily sampling duration of ±4 hrs) after which time they were lifted and the fish were sampled.

Fish sampling included counts of all species captured with detailed biological data collected for the target species, Northern Pike and Muskellunge, as well as other sport fish species including Smallmouth Bass. Smallmouth Bass were measured for fork and total length to the nearest mm, weighed to the nearest 5 g using spring scales, and had scales samples (5 to 10 scales) removed from behind the left pectoral fin (after wiping away mucus and dirt) for age interpretation (Mann 2004).

Fall Walleye Index Netting (FWIN) — The annual Walleye population assessment begins in the autumn when water surface temperatures have cooled to 15°C (and stops when water temperatures decrease to <10°C) using a standard index netting method (Morgan 2002). Benthic multimesh monofilament gill nets (60.8m long by 1.8m deep) are set perpendicular to shore at haphazardly selected locations for 24 hours (the number of nets set in Lake Nipissing varied from 42 to 107 nets·year^{1} between 1998 and 2019). Each net has eight panels (7.6m long by 1.8m deep) with sequentially increasing mesh sizes (25, 38, 51, 64, 76, 102, 127, and 152mm (stretched mesh)). Sets alternate with the large and small mesh ends of the net set closest to shore.

From 1998 to 2003 sampling was both stratified by depth (“shallow” 2-5m and “deep” 5-15m) and area (creel sectors) resulting in annually varying proportions of shallow and deep sets (but good spatial coverage). Beginning in 2004 the minimum lake wide sampling effort target was set at 42 nets with depth stratification determined from lake bathymetry (by assigning one-third of sampling effort to the shallow stratum and two-thirds of sampling effort to the deep stratum) and to further guarantee spatial coverage there were a minimum of 3-4 sets in the West Arm sector, 3 sets in West Bay sector (shallow depth stratum), 3 sets in the Callander Bay sector, 4 sets in the South Bay sector, and 4 sets in the French River sector. Finally, in 2007 the minimum lake wide sampling effort was increased to 48 nets to be set over a two-week period (based on an analysis of sample size requirements for precision and statistical power using data collected from 1998 to 2006).

All fishes captured were identified to species, enumerated, and measured for fork and/or total length to the nearest millimetre. All Smallmouth Bass individuals were measured for fork and total length, weighed to the nearest gram using an electronic balance, and examined internally to determine sex and state of gonad maturation. Age structures were collected for later age interpretation (Note: A fish assigned age x years in the fall had completed x+1 growing-seasons). Scales samples (5 to 10 scales) were collected from behind the left pectoral fin (after wiping away mucus and dirt). As well dorsal spines and/or otoliths were removed, cleaned, and allowed to dry for later age interpretation (Mann 2004).

Data Analysis - This assessment provides measurements of uncertainty (i.e., tables and figures), including calculated relative standard errors, standard deviations and bootstrapped estimates (for averages and 95% confidence limits), to provide sufficient evidence to support the conclusions. The most common strength in the datasets was that many of them had relatively long time-series to observe trends in fisheries performance. The FWIN surveys started in 1998 and continues to the present while the standardized open water creel surveys extend back to 1990. Biological data include information on fish length, weight, sex, maturation state, and collection of ageing structures (scales or otoliths were consistent in the FWIN time series). Unfortunately, the sampling of the harvested Smallmouth Bass (for length and age interpretation) in the open water creel surveys is much more recent, generally extending back only half-a-decade. The two weaknesses of the datasets included in the stock assessment were: 1) most survey and catch data are indices and, alone, cannot be used to estimate true abundances, and 2) many of the surveys were designed to collect data on other species (i.e., Northern Pike or Walleye).

The non-parametric Mann-Kendall test was utilized to detect monotonic trends in the 30-year (1990 to 2019) open water recreational creel survey data and the 22-year (1998 to 2019) FWIN relative abundance time series (Gilbert 1987). The purpose of the Mann-Kendall trend analysis (Mann 1945, Kendall 1975) is to assess whether there is an upward and/or downward trend over time. This is similar to the more familiar linear regression model, generally used to test if the slope is different from zero. The difference between the Mann-Kendall and a linear regression is that the Mann-Kendall test is non-parametric, and therefore not restricted to the assumption of normality like the linear regression. This makes the Mann-Kendall more flexible for estimating these kinds of data. However, it does not mean the Mann-Kendall test is assumption free. The following assumptions underlie the Mann-Kendall test:

a. When no trend is present, the measurements are independent and identically distributed of the underlying population over time, and
b. The measurement observations are unbiased and provide representative samples.

There is potential for violation of both assumptions so the Mann-Kendall tests conducted in this assessment should be viewed as exploratory analyses. The null hypothesis, H_0, is that the data came from a population with independent realizations and were identically distributed. The alternative hypothesis, H_A, is that the data followed a monotonic trend. A monotonic upward (downward) trend means that the variable consistently increases (decreases) over time, but the trend may or may not be linear. In a monotonic relationship, the variables tend to move in the same relative direction, but not necessarily at a constant rate. LOESS (locally weighted smoothing), regression was used to plot temporal trends that were statistically significant (Cleveland 1979). This local regression model creates a smooth line through a time plot or scatter plot to see relationships between variables and foresee trends. Averages and bootstrapped upper and lower 95% confidence intervals were calculated for non-significant time trends. Proportional data (e.g., % kept) was arcsine square-root transformed before analysis (Whitlock and Schluter 2009).

The angler harvested Smallmouth Bass samples (length and age) were tested using the Shapiro-Wilk test to determine if they were taken from a population with a normal distribution (Shapiro and Wilk 1965). Size-at-age 5 was established as a point of reference to describe variability in the temporal patterns of mortality (median age class of Smallmouth Bass caught in the open water angler sampling over the entire range of data available). Smallmouth Bass growth was characterized using the von Bertalanffy growth model. The parameters were calculated from the 2000 (n = 35), 2001 (n = 119), 2007 (n = 95), 2013 (n = 154), 2014 (n = 127), and 2016 (n = 173) IOTN observations as well as the pooled IOTN data (n = 703), and the 1998 to 2019 FWIN observations for males (n = 113), females (n = 148), and all fish (n = 293) using the non-linear least squares estimation function in the R project (R Core Team 2013). The von Bertalanffy growth parameters are:

$$L_t = L_{inf}\left(1 - e^{-k(t-t_o}\right)$$

Where L_t is the size (total length in mm) at age t, L_{inf} is the maximum theoretical length (mm), k is the Brody growth coefficient ($\cdot year^{-1}$), and t_0 is the year when length is zero (Note: For this analysis t_0 was set to -1).

Smallmouth Bass condition (weight-at-length) was estimated from length-weight regressions (an ordinary least-squares regression model fitted to logarithmically transformed (base 10) length and weight data) (Guy and Brown 2007) using the pooled 1998 to 2019 FWIN observations for males (n=142), females (n = 163), and all fish measured (n = 347):

$$W = aL^{B}$$

Where W and L are weight and length respectively, a is the y-intercept, and B is the slope of the line. Length and weight observations from fish with and without sex determination were included in the analysis and only datasets from the FWIN monitoring program that collected at least 100 samples were included in the final dataset. Analysis of covariance was inappropriate for comparing the male and female length-weight regressions because the data violated the assumption that there was homogeneity of within-group regressions (i.e., the regression lines associated with sex have a common slope or parallelism) (Guy and Brown 2007). Instead generated separate regression models were generated from the male and female data to estimate weight-at-length.

Maturity schedules or ogives were calculated from the captured mature and immature fish in the FWIN surveys and determined the proportion of mature and immature fish as a function of length and age for both male and females. Size- and age-at-sexual maturity was estimated by fitting a binary logistic regression model (i.e., the categorical response; maturity, has only two 2 possible outcomes; immature or mature) to the size- and age-at-maturity schedules. The logistic model parameters were used to estimate the proportion mature in a length class or age group for male and female Smallmouth Bass.

Total adult (≥5 years old) Smallmouth Bass mortality rate (designated as Z) estimates were based on the catch-at-age data from the IOTN and FWIN programs, and the angler harvested fish over the entire time series (i.e., each project) using the Robson and Chapman's maximum likelihood estimator (Guy and Brown 2007). For catch curve analyses, two criteria were used to filter data sets for the analysis: a minimum of three age classes greater than or equal to age of full recruitment (i.e., age 5) and at least 30 individuals across these age classes had to be observed (for age). Fishing mortality (designated as F) was estimated from Z and M (i.e., F = Z-M). Exploitation rate (designated as u) was calculated as $u = FA \cdot Z^{-1}$, where $A = 1-e^{-Z}$ (Ricker 1975). To isolate the effects of fishing (i.e., F), natural mortality (designated as M) was estimated from a modification of the Lester et al. 2014 life history model (Cindy Chu, OMNRF, personal communication).

RESULTS

Open Water Creel Surveys - The present study is based on open water angling creel estimates for the period 1990 to 2019, inclusive (Appendices 1 and 7). In this study of the boat-based recreational sport fishing on Lake Nipissing, roving creel surveys were used to quantify angling effort, catch composition, catch, angler success, harvest, and metrics for the Smallmouth Bass harvested.

Angling effort – From 1990 to 2019, total fishing effort (expressed as the number of angler-hours expended by anglers fishing for any species) on Lake Nipissing during the open water season decreased from ≈400,000 angler-hours in the 1990s to less than 150,000 angler-hours in the 2010s (Figure 2; S = -282, p <

0.0001). Fishing pressure from anglers targeting Smallmouth Bass showed no significant trends over the study period (Figure 2; S = -5, P = 0.94; 1990 to 2019 average effort targeted at Smallmouth Bass = 12,944 angler-hours, 95% confidence limits 9,361 to 16,015 angler-hours).

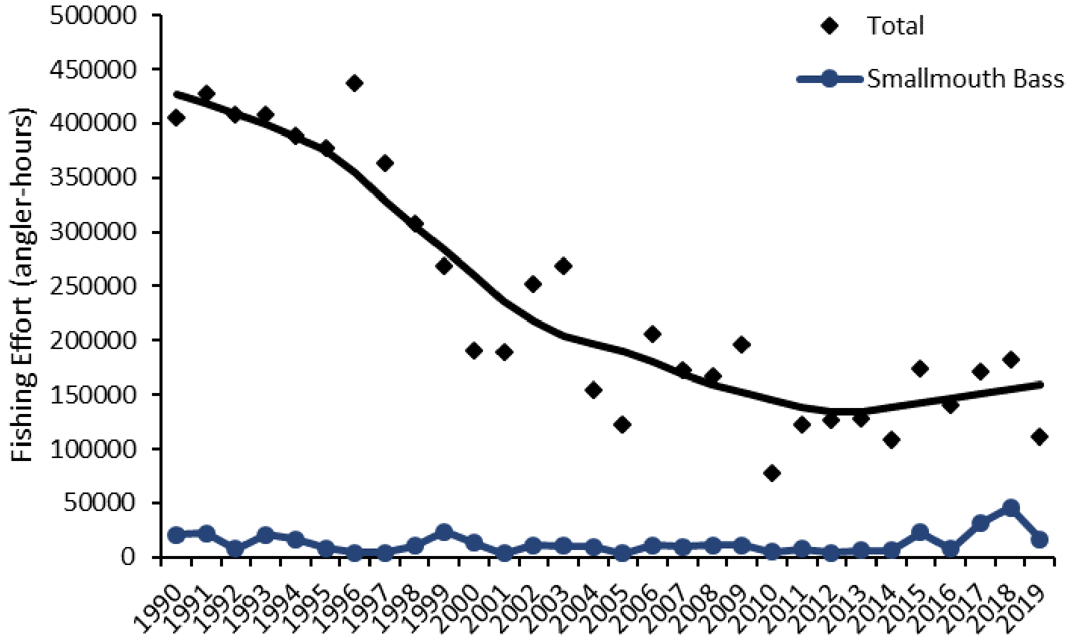


Figure 2. Lake Nipissing 1990 to 2019 open water creel fishing effort (angler-hours) for anglers fishing for any species (total) and only those targeting Smallmouth Bass (Significant trend line (LOESS regression) for total effort time series also plotted).

Although not evident in terms of number, the proportion of the effort contributed by Smallmouth Bass anglers showed a significant increase during the period 1990 to 2019 from 5% of the total effort in the 1990s to early 2010s to 15% in the late 2010s (Figure 3; S = 136, p < 0.05).

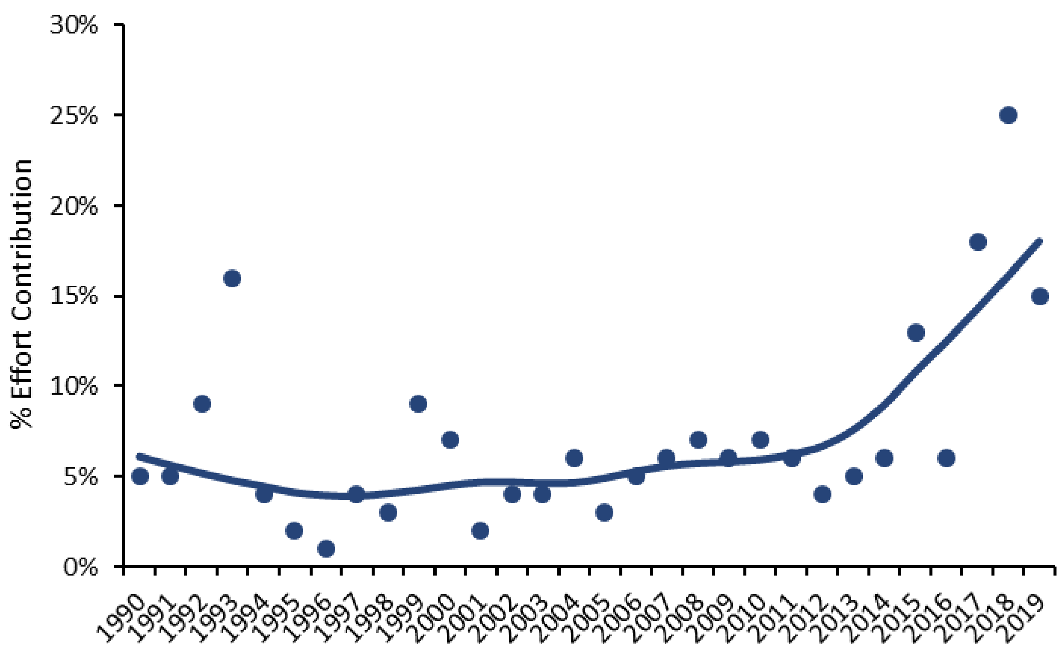


Figure 3. Lake Nipissing open water creel percentage effort contribution (by angler-hours) for anglers targeting Smallmouth Bass for the period 1990 to 2019 (Significant trend lines (LOESS regression) for time series also plotted).

Catch composition – Fourteen species were positively identified in the anglers' catches from 1998 to 2019 [Lake Whitefish, Cisco, Northern Pike, Muskellunge, Common White Sucker, Brown Bullhead (*Ameiurus nebulosis* (Lesueur, 1819)), White Bass (*Morone chrysops* (Rafinesque, 1820)), Rock Bass (*Ambloplites rupestris* (Rafinesque, 18117)), Pumpkinseed (*Lepomis gibbosus* (Linnaeus, 1858)), Smallmouth Bass, Largemouth Bass, Yellow Perch, Walleye, and Freshwater Drum (*Aplodinotus grunniens* (Rafinesque, 1819))]. Although a number of the fish species caught in Lake Nipissing are regarded as extremely important angling species, the anglers' catch was numerically dominated by a limited number of species (Figure 4). Four species, Walleye, Yellow Perch, Northern Pike, and Smallmouth Bass comprised a large proportion of the catch (94% of the total catch by number). Numerically, Walleye (46%) was most commonly caught, followed by Yellow Perch (28%), Northern Pike (13%), and Smallmouth Bass (7%) from 1990 to 2019.

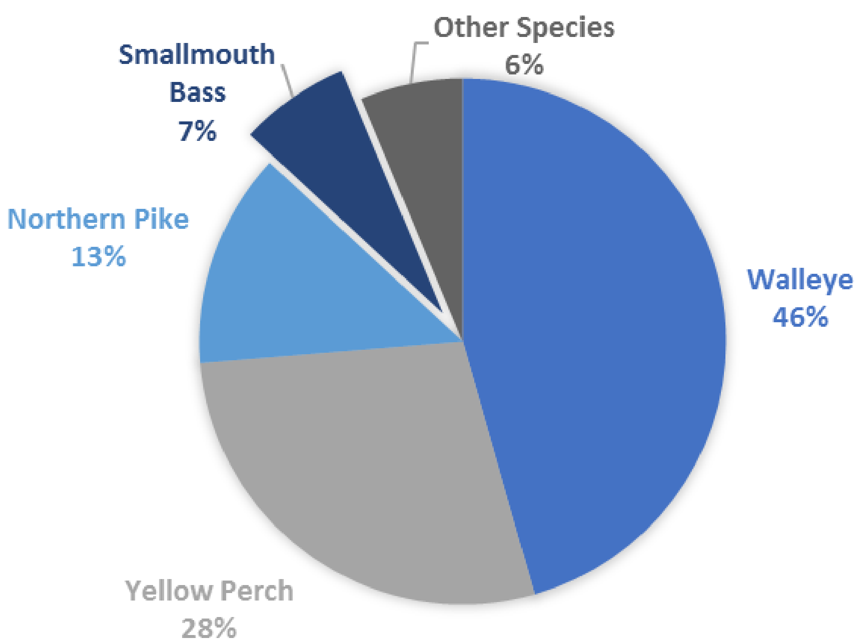


Figure 4. Lake Nipissing open water creel percentage catch composition (by number) of the top four species for the period 1990 to 2019.

Although their annual contributions varied, these species were the most important throughout most of the study period (Figure 5). Walleye, which dominated annual catches throughout most of the period, increased in contribution by number from 1990 to 2019 (Figure 5; S = 121, $p < 0.05$). Yellow Perch, the second most commonly caught fish species, showed a decrease in contribution by number over the same time period (Figure 5; S = -146, $p < 0.01$) while Northern Pike neither increased or decreased (Figure 5; S = -54, p = 0.34; 1990 to 2019 average contribution to the catch = 13%, 95% confidence limits 12% to 15%). Although not evident in terms of number, the proportion of the catch contributed by Smallmouth Bass showed a notable increase during the period 1990 to 2019 from 2% in the late 1990s to 8% in the 2010s (Figure 5; S = 155, $p < 0.01$).

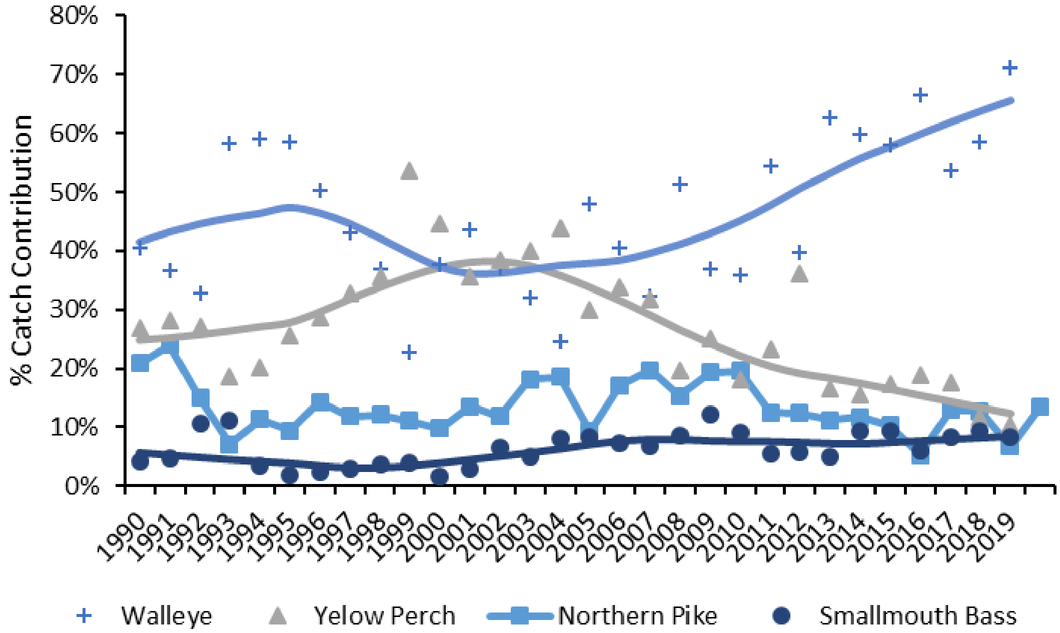


Figure 5. Lake Nipissing 1990 to 2019 open water creel percentage catch composition (by number) of the top four species by year (Significant trend lines (LOESS regression) for Walleye, Yellow Perch, and Smallmouth Bass time series also plotted).

Catch – The total number of Smallmouth Bass caught by anglers varied from a low of 927 in 1997 to a high of 19,418 in 2018 (Figure 6). There was no trend in the number of Smallmouth Bass caught from the 1990s and 2000s (Figure 6; S = -4, p = .92; 1990 to 2009 average number of Smallmouth Bass caught = 7,614, 95% confidence limits 6,220 to 8,975). There was a significant increasing trend in the number of Smallmouth Bass caught from 2010 to 2019 (Figure 6; S = 31, p < 0.01).

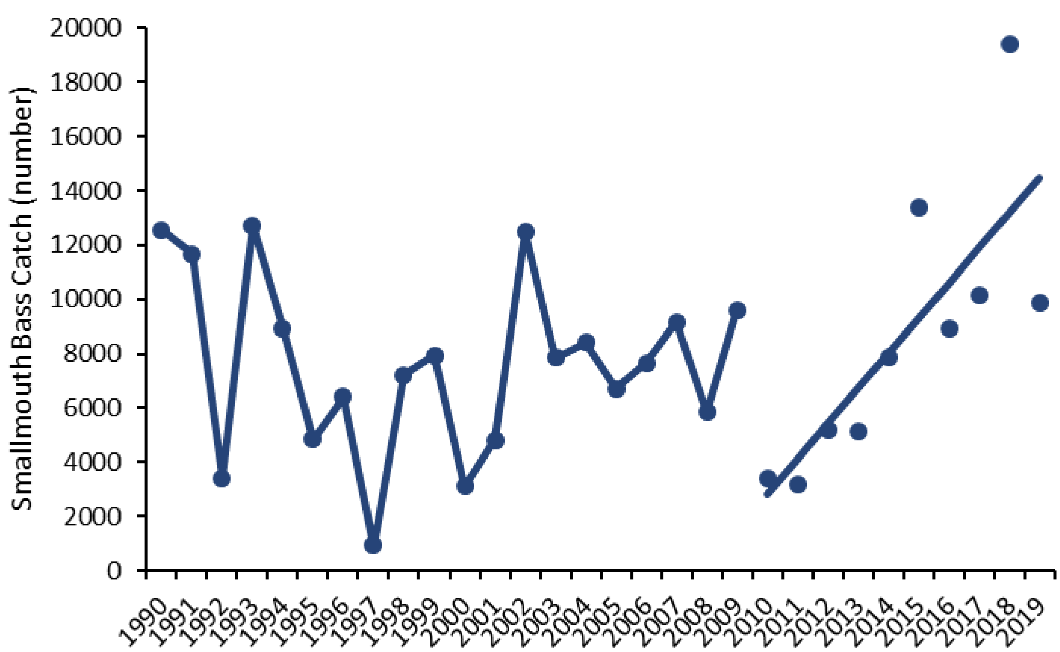


Figure 6. Lake Nipissing 1990 to 2019 open water creel Smallmouth Bass catch (Significant trend line (LOESS regression) for Smallmouth Bass 2010 to 2019 time series also plotted).

Anglers who identified themselves as fishing for Smallmouth Bass (i.e., target anglers) caught ≈50% of the total number estimated in the open water creels (Figure 7; S = -85, p = 0.13; 1990 to 2019 average proportion of the Smallmouth Bass catch by target anglers = 53%, 95% confidence limits 46% to 60%). The proportion caught by target anglers greatly varied from year to year (minimum = 15% in 2016, maximum 88% in 1993).

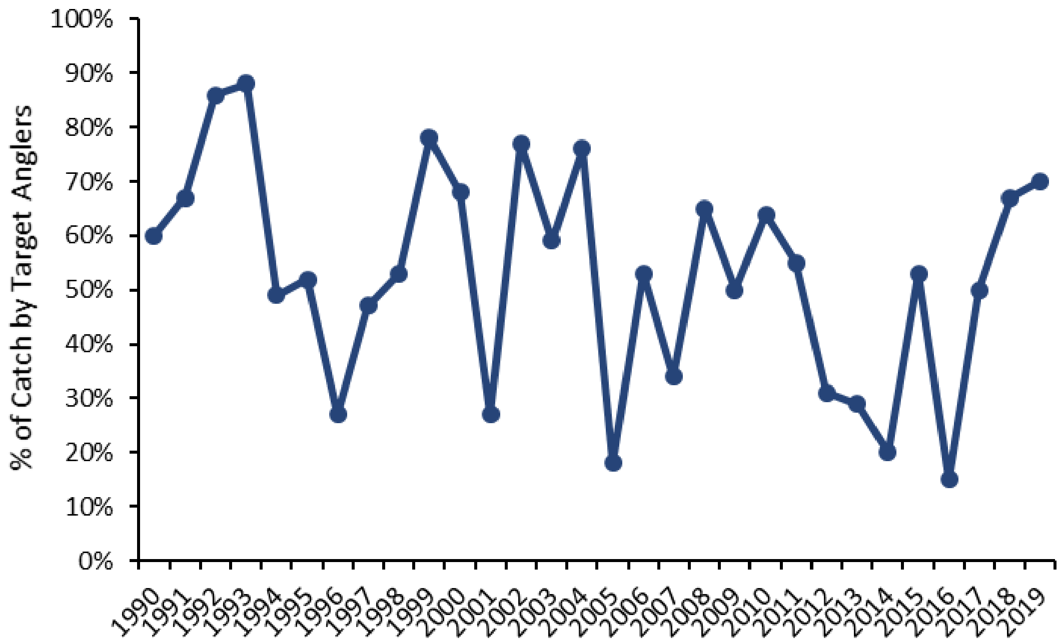


Figure 7. Lake Nipissing 1990 to 2019 open water creel percentage of the Smallmouth Bass catch by anglers who identified themselves as targeting this species.

Angler success (Catch-per-unit-effort) - The Lake Nipissing Smallmouth Bass recreational fishery was characterized by increased overall angler success rates (catch-per-unit-effort or CPUE = number of Smallmouth Bass caught·angler-hour^{-1}) from 1990 to 2019 (Figure 8 – top panel ; S = 202, p < 0.001) but with little variation in targeted angler success rates (Figure 8 – bottom panel: S = -76, p = 0.18; 1990 to 2019 average CPUE = 0.350 Smallmouth Bass·angler-hour^{-1}, 95% confidence limits 0.295 to 0.400 Smallmouth Bass·angler-hour^{-1}). The highest overall target angler CPUE (0.874 Smallmouth Bass·angler-hour^{-1}) occurred in 2002, followed by 2004 (0.655 Smallmouth Bass·angler-hour^{-1}). The lowest overall target angler CPUE took place in 1997 (0.114 Smallmouth Bass·angler-hour^{-1}) followed by 2016 and 2017 (0.171 Smallmouth Bass·angler-hour^{-1} and 0.164 Smallmouth Bass·angler-hour^{-1}, respectively). Targeted Smallmouth Bass angler success rates averaged ≈10 times higher than all angler success rates.

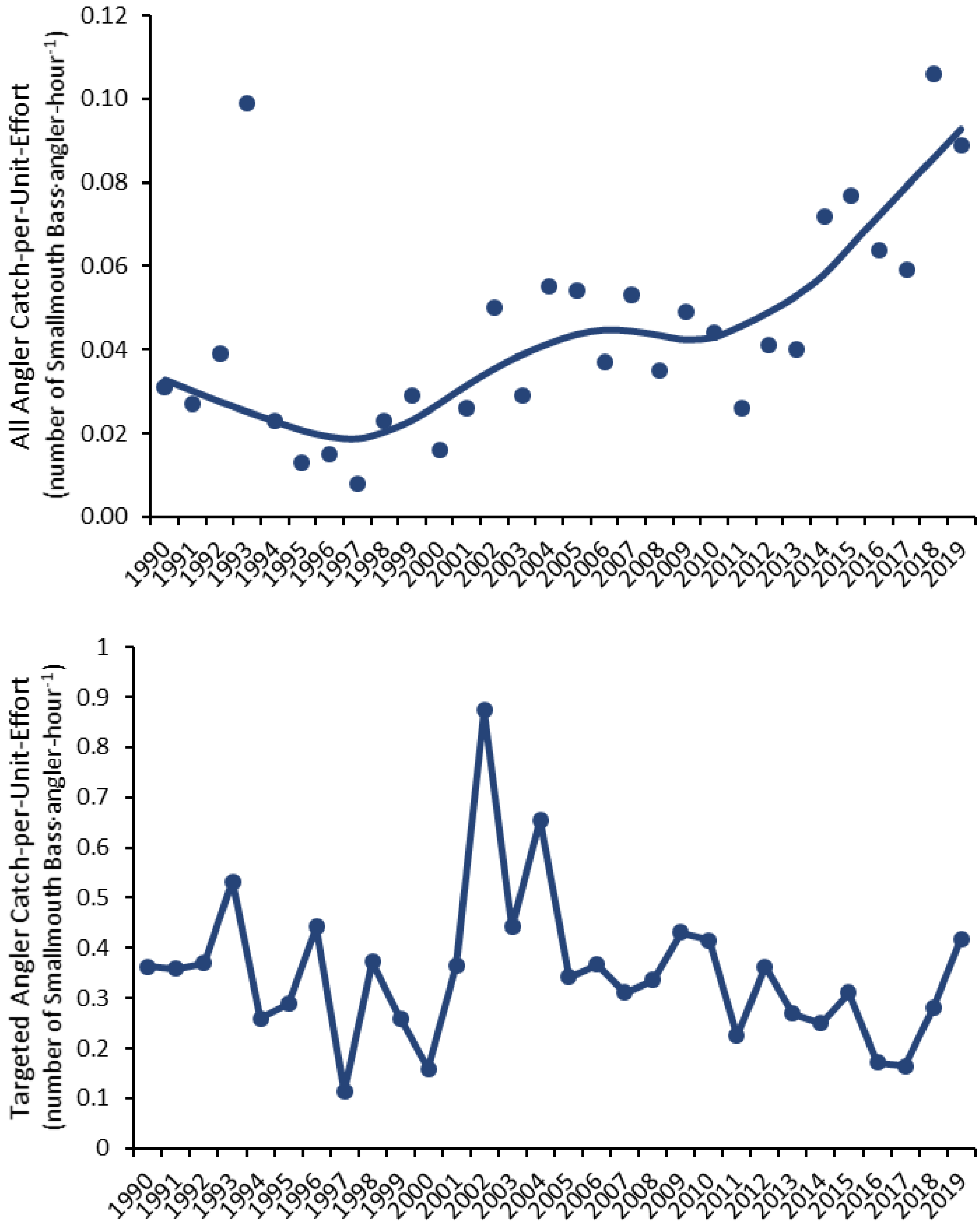


Figure 8. Lake Nipissing 1990 to 2019 open water creel success rate (number of Smallmouth Bass caught·angler-hour^{-1}) for all anglers (top panel) and for anglers targeting Smallmouth Bass (bottom panel) (Significant trend line (LOESS regression) for all angler success rate 1990 to 2019 time series also plotted).

Harvest – The total number of Smallmouth Bass harvested by anglers varied from a low of 596 in 1997 to a high of 5,775 in 1991 (Figure 9). There was a significant decreasing trend in the number of Smallmouth Bass harvested in the 1990s (Figure 9; S = -25, $p < 0.05$). There was no trend in the number of Smallmouth Bass harvested in the 2000s and 2010s (Figure 9; S = 17, p = 0.60; 2000 to 2019 average number of Smallmouth Bass harvested = 1,750, 95% confidence limits 1,344 to 2,100).

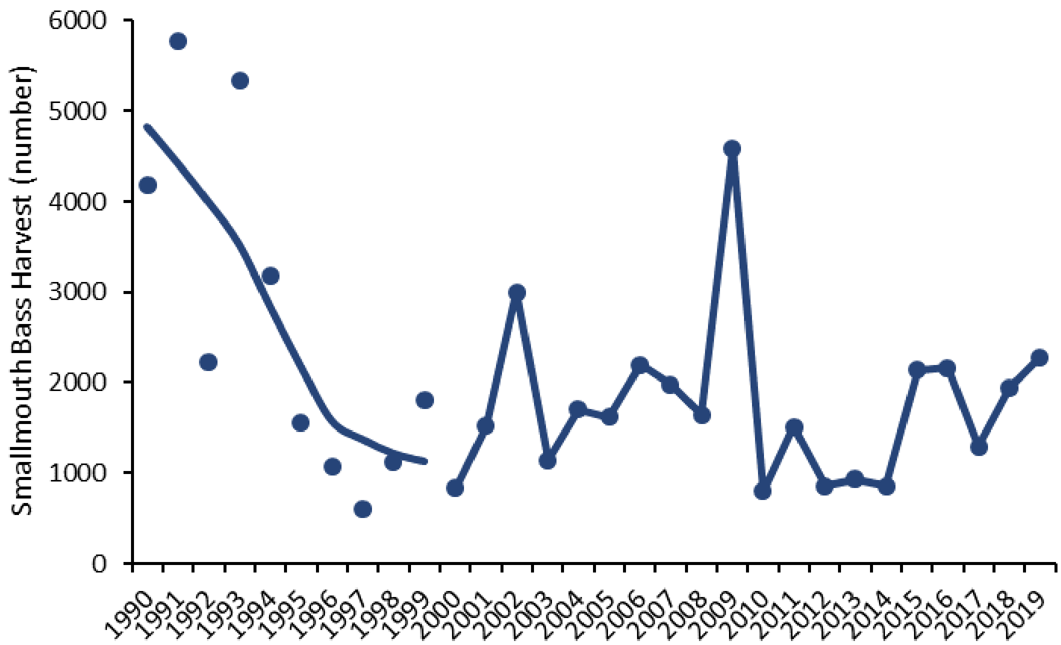


Figure 9. Lake Nipissing 1990 to 2019 open water creel Smallmouth Bass harvest (Significant trend line (LOESS regression) for Smallmouth Bass 1990 to 1999 time series also plotted).

From 1990 to 2019 the proportion of Lake Nipissing Smallmouth Bass caught that were harvested (i.e., % kept by number) during the open water season decreased from ≈50% in the early 1990s to less than 20% in the 2010s (Figure 10; $S = -184$, $p < 0.01$).

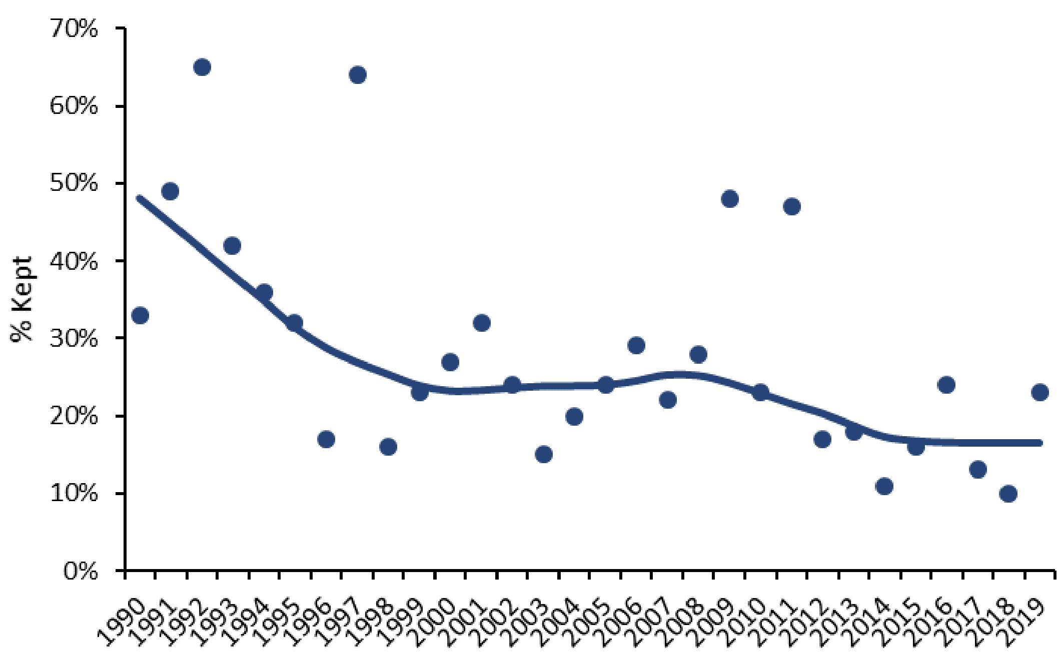


Figure 10. Lake Nipissing 1990 to 2019 open water creel Smallmouth Bass proportion of the number caught that were harvested (kept) by anglers (Significant trend line (LOESS regression) for Smallmouth Bass 1990 to 2019 time series also plotted).

The pooled size distribution of the 2010 to 2019 harvested Smallmouth Bass from Lake Nipissing was normally distributed (Figure 11 – top panel; Shapiro Wilk W = 0.9514, p = 0.55). The average size of Smallmouth Bass harvested from 2010 to 2019 was 374mm total length (95% confidence limits 365mm to 382mm, sample size = 225). The 2014 to 2019 pooled age distribution was not normally distributed (Figure 11 – bottom panel; Shapiro-Wilk W = 0.9352, p < 0.0001). The median age of Smallmouth Bass harvested was 5 years (25% quartile = 4 years and 75% quartile = 7 years, sample size = 165) [*Note: 2014 to 2019 average age of harvested Smallmouth Bass was 5.8 years, 95% confidence limits 5.5 years to 6.1 years*].

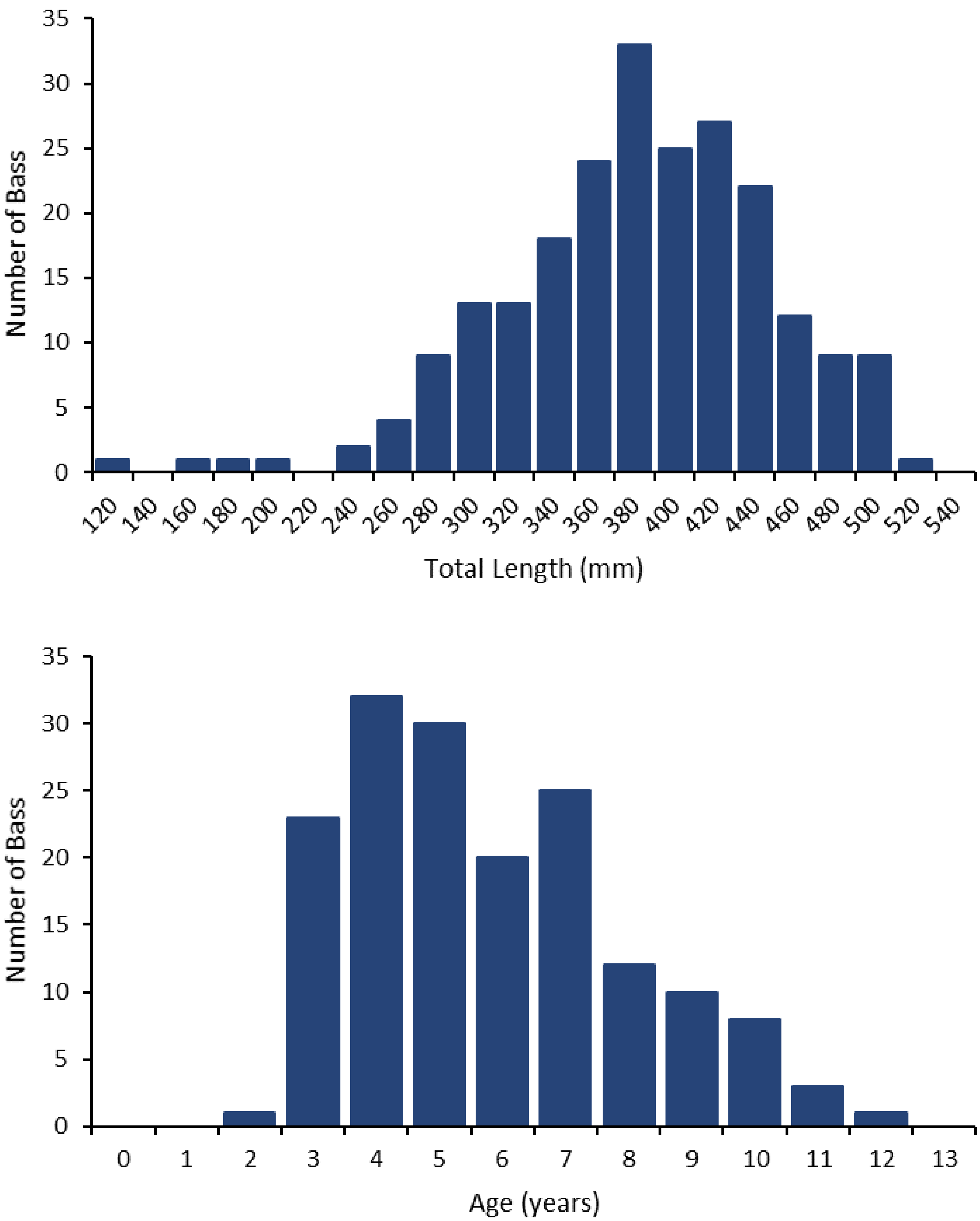


Figure 11. Lake Nipissing size (top panel) and age (bottom panel) distribution of Smallmouth Bass harvested by anglers from 2010 to 2019 for length and 2014 to 2019 for age interpretation.

Index Netting Surveys – Individual observations from the 2000 to 2016 spring (IOTN) and 1998 to 2019 fall (FWIN) index netting surveys were used to estimate various Smallmouth Bass life history parameters (Appendices 3 to 6, 8 and 9). The goal was to provide consistent information (i.e., benchmarks) on key population parameters that will allow future assessment activities to explore temporal trends. The specific aim of the benchmarking was to define population parameters for growth and condition, maturation, and mortality. Changes in abundance were investigated using the 1998 to 2019 FWIN Smallmouth Bass catches.

Abundance – The Smallmouth Bass relative abundance (number of fish·net^{-1}) from the 1998 to 2019 FWIN surveys increased approximately threefold, from ≈0.20 fish·net^{-1} in the early 2000s to ≈0.60 fish·net^{-1} in the early 2010s (Figure 12 — top panel; $S = 121$, $p < 0.001$). The proportion of the FWIN net sets that caught at least one Smallmouth Bass also increased in the early 2010s (Figure 12 — bottom panel: $S = 137$, $p < <0.001$).

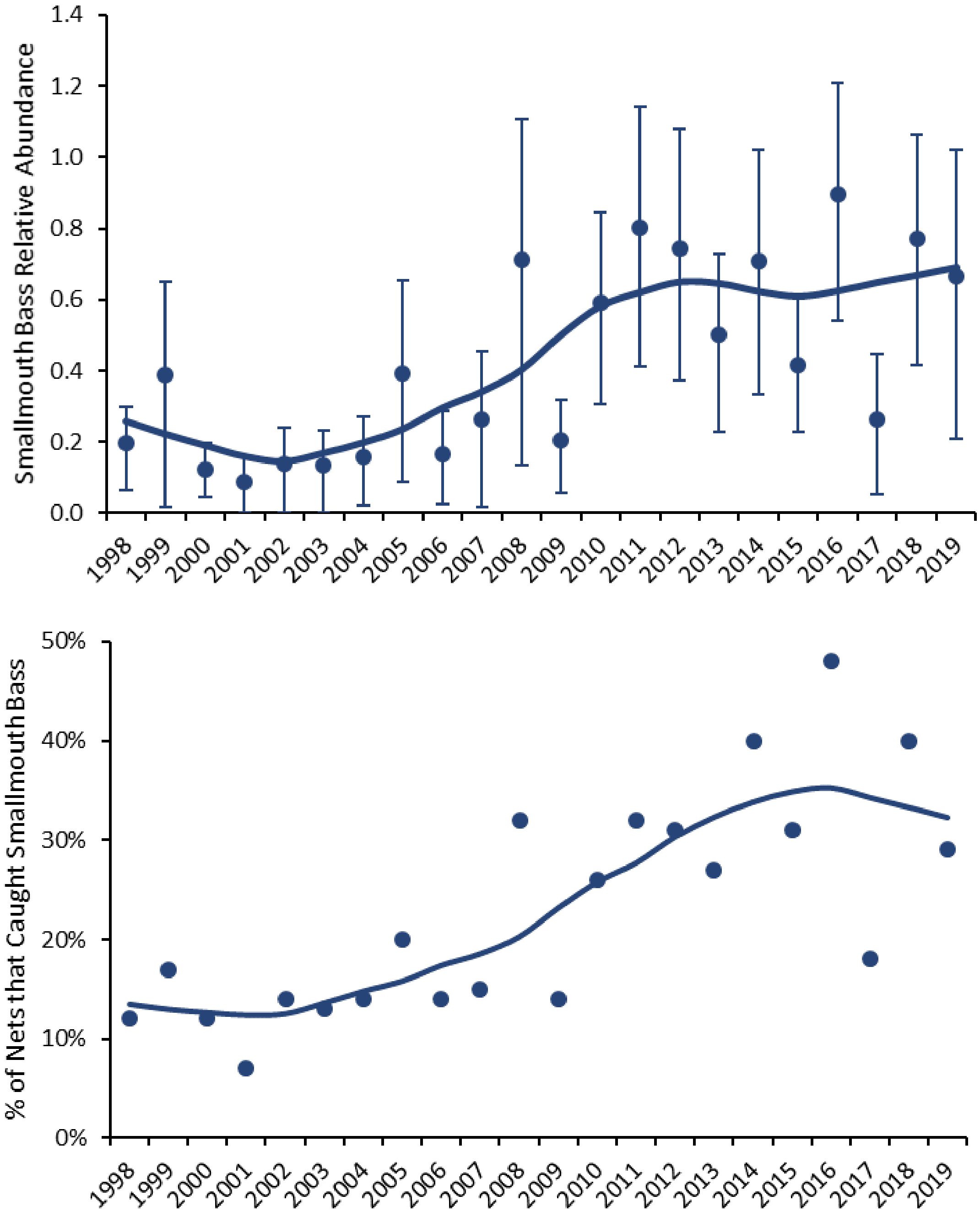


Figure 12. Lake Nipissing Smallmouth Bass relative abundance (top panel — average number of Smallmouth Bass caught·net^{-1} ±95% confidence limits) and proportion of nets that caught at least one Smallmouth Bass (bottom panel) from 1998 to 2019 fall Walleye index netting surveys (Significant trend lines (LOESS regression) for Smallmouth Bass 1998 to 2019 time series also plotted).

Compared to Smallmouth Bass relative abundance (as measured in FWIN catches) from other lakes in Fisheries Management Zone 11 and across Ontario that were sampled using the FWIN protocol from 1996 to 2002 (Malette and Morgan 2005), Lake Nipissing would be considered a low abundance population (Figure 13). [*Note: These FWIN samples are from known Walleye lakes where the nets caught at least one Smallmouth Bass*].

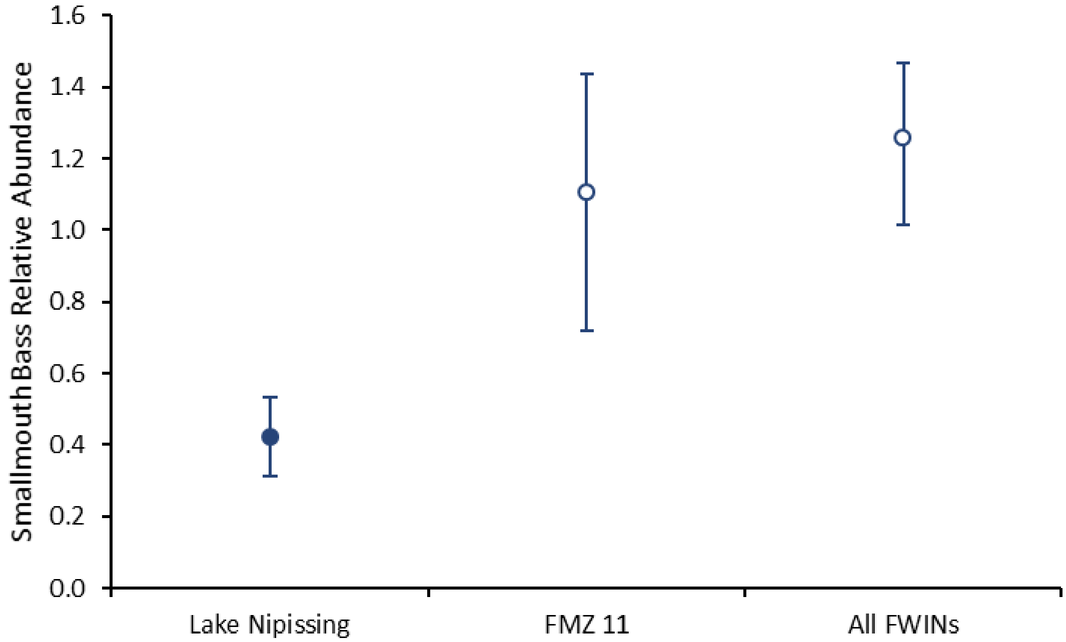


Figure 13. Smallmouth Bass relative abundance (average number of Smallmouth Bass caught·net^{-1} ±95% confidence limits) for Lake Nipissing 1998 to 2019, Fisheries Management Zone 11 (FMZ 11) lakes (excluding Lake Nipissing) 1996 to 2002, and all fall Walleye index netting surveys (All FWINs) conducted in Ontario from 1996 to 2002.

Growth and Condition – Age-specific lengths observations from the IOTN and FWIN programs were used to generate growth models (Table 1). The parameter estimates from the von Bertalanffy standard growth models with nonoverlapping 95% confidence intervals indicated marked differences in the estimated growth rates between the IOTN- and FWIN-based growth models (Table 1). The IOTN-based growth model yielded a higher value for L_{inf} and smaller value for k than the FWIN-based model. Early or pre-maturation growth (defined as the age-at-250mm [Cindy Chu, OMNRF, personal communication]) indicated that FWIN (i.e., gill nets set in the fall) caught faster growing individuals (age-at-250mm = 1.9 years) compared to IOTN (i.e., trap nets set in the spring) (age-at-250mm = 2.2 years).

Table 1. Lake Nipissing Smallmouth Bass von Bertalanffy growth parameters from fish captured during the 2000 to 2016 ice out trap netting projects and 1998 to 2019 fall Walleye index netting projects.

Year	Program[1]	Sex	L_{inf}		k		Sample Size
			Estimate (S.E.)[2]	95% C.L.[3]	Estimate (S.E.)	95% C.L.	
2000	IOTN	Combined	487.5 (16.1)	454.6 to 520.3	0.224 (0.024)	0.195 to 0.293	35
2001	IOTN	Combined	538.8 (16.9)	505.3 to 572.3	0.178 (0.012)	0.153 to 0.203	119
2007	IOTN	Combined	506.3 (8.3)	489.8 to 522.8	0.234 (0.010)	0.214 to 0.252	95
2013	IOTN	Combined	513.4 (8.1)	497.5 to 529.3	0.213 (0.009)	0.195 to 0.231	154
2014	IOTN	Combined	504.9 (8.7)	487.7 to 522.2	0.218 (0.009)	0.201 to 0.236	127
2016	IOTN	Combined	539.8 (11.2)	517.6 to 561.9	0.175 (0.008)	0.160 to 0.190	173
All Years	IOTN	Pooled	515.5 (4.6)	506.5 to 524.5	0.205 (0.004)	0.196 to 0.214	703
1998 to 2019	FWIN	Males	448.0 (14.1)	420.1 to 475.9	0.289 (0.017)	0.255 to 0.323	113
1998 to 2019	FWIN	Females	473.2 (11.5)	450.5 to 495.9	0.267 (0.013)	0.241 to 0.292	148
1998 to 2019	FWIN	All Fish[4]	472.2 (9.1)	454.3 to 490.0	0.263 (0.009)	0.244 to 0.281	293

1. IOTN is an ice out trap netting project and FWIN is a fall Walleye index netting project.
2. S.E. is the standard error of the parameter estimate.
3. 95% C.L. are the lower and upper 95% confidence limits of the parameter estimate.
4. These are all the Smallmouth Bass sampled during the 1998 to 2019 FWIN projects (i.e., males, females, and undetermined sex combined).

The IOTN-based growth model resulted in total length estimates that were shorter for individuals <7 years old but longer for ages >7 when compared with the FWIN-based model (Figure 14; Table 2). Lake Nipissing Smallmouth Bass exhibited faster growth (and larger size-at-age) compared to all other lakes in FMZ 11 where Smallmouth Bass were encountered during the cycle 2 (2008 to 2012) and cycle 3 (2013 to 2017) broad-scale monitoring program (Figure 14; Table 2).

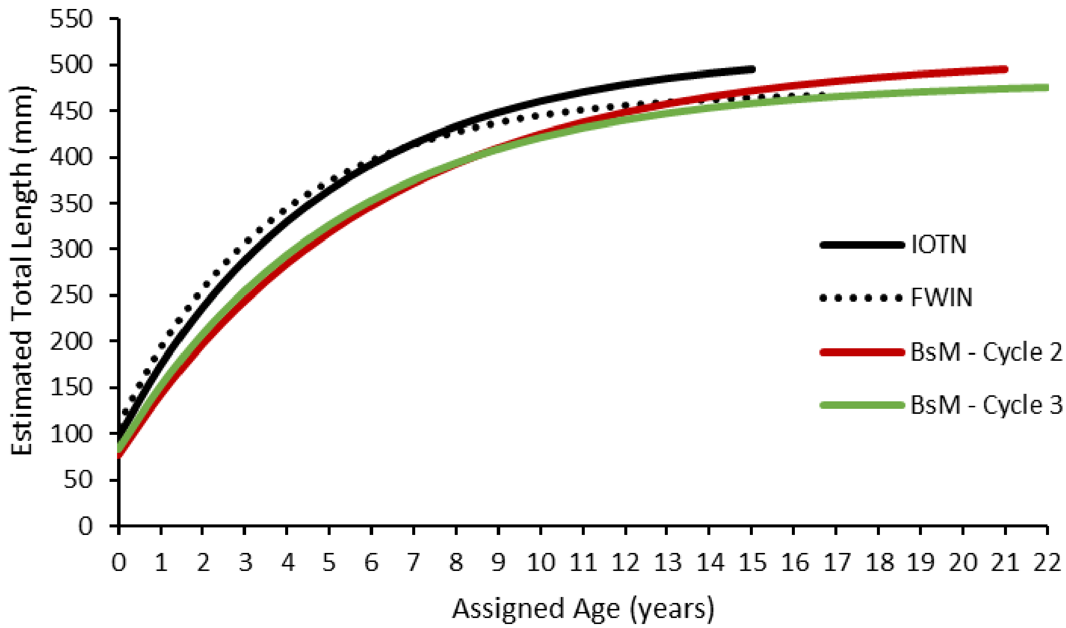


Figure 14. Growth curves for Lake Nipissing Smallmouth Bass from ice out trap netting (IOTN) and fall Walleye index netting (FWIN) programs (all years pooled by program type), and pooled samples from cycle 2 and cycle 3 broad-scale monitoring program (BsM) in Fisheries Management Zone 11 (FMZ 11). The BsM data excluded any sampled Smallmouth Bass from Lake Nipissing. BsM von Bertalanffy growth parameters: Cycle 2 — L_{inf} = 510.0 (9.5, 491.4 to 528.6), k = 0.164 (0.006, 0.152 to 0.176), n = 543; Cycle 3 — L_{inf} = 481.7 (1.2, 473.4 to 489.9), k = 0.188 (0.004, 0.181 to 0.196), n = 949) *[Estimate (Standard Error, Lower and Upper 95% Confidence Limits), Sample Size]*.

Table 2. Predicted Lake Nipissing Smallmouth Bass total length-at-age (mm) estimated from the von Bertalanffy growth models in Table 1 for ice out trap netting, fall Walleye index netting, and broad-scale monitoring programs.

Age	Predicted Total Length-at-Age (mm)			
(years)	IOTN[1]	FWIN[2]	BsM[3] - Cycle 1	BsM - Cycle 2
0	96	109	77	83
1	173	193	142	151
2	237	257	198	208
3	288	307	245	255
4	331	345	285	294
5	365	374	319	326
6	393	397	348	353
7	416	414	372	375
8	434	428	393	393
9	449	438	411	408
10	461	446	426	421
11	471	452	438	431
12	480	457	449	440
13	486	460	458	447
14	492	463	466	453
15	496	465	473	458
16	—	467	478	462
17	—	468	483	465
18	—	—	487	468
19	—	—	491	471
20	—	—	494	472
21	—	—	496	474
22	—	—	—	475

1. IOTN is ice out trap netting.
2. FWIN is fall Walleye index netting
3. BsM is the broad-scale monitoring from cycle 2 (2008 to 2012) and cycle 3 (2013 to 2017) excluding Lake Nipissing samples.

The condition of Smallmouth Bass based on all fall Walleye index netting data are provided in Table 3 and Figure 15. The 95% confidence limits of the condition coefficient (the slope – ‘β’) from the fall Walleye index netting sampling overlapped between males and females. Homogeneity (equality of) of slopes was rejected ($F_{1,303} = 6.66$, $p<0.05$) using analysis of covariance (Whitlock and Schluter 2009). This suggests that condition varied between the sexes as they grew (in length).

Table 3. Condition (total length-weight regression of log_{10} transformed data) of male and female Lake Nipissing Smallmouth Bass captured during the 1998 to 2019 fall Walleye index netting projects.

Sex	Slope (β)		Intercept (α)		r^2	Sample
	Estimate	95% Confidence Limits	Estimate	95% confidence Limits		Size
Males	3.21	3.16 to 3.27	$4.34X10^{-6}$	$3.21X10^{-6}$ to $5.87X10^{-6}$	0.99	142
Females	3.12	3.07 to 3.18	$7.36X10^{-6}$	$5.37X10^{-6}$ to $1.01X10^{-5}$	0.99	163
All Fish	3.12	3.08 to 3.15	$7.61X10^{-6}$	$6.33X10^{-6}$ to $9.16X10^{-6}$	0.99	347

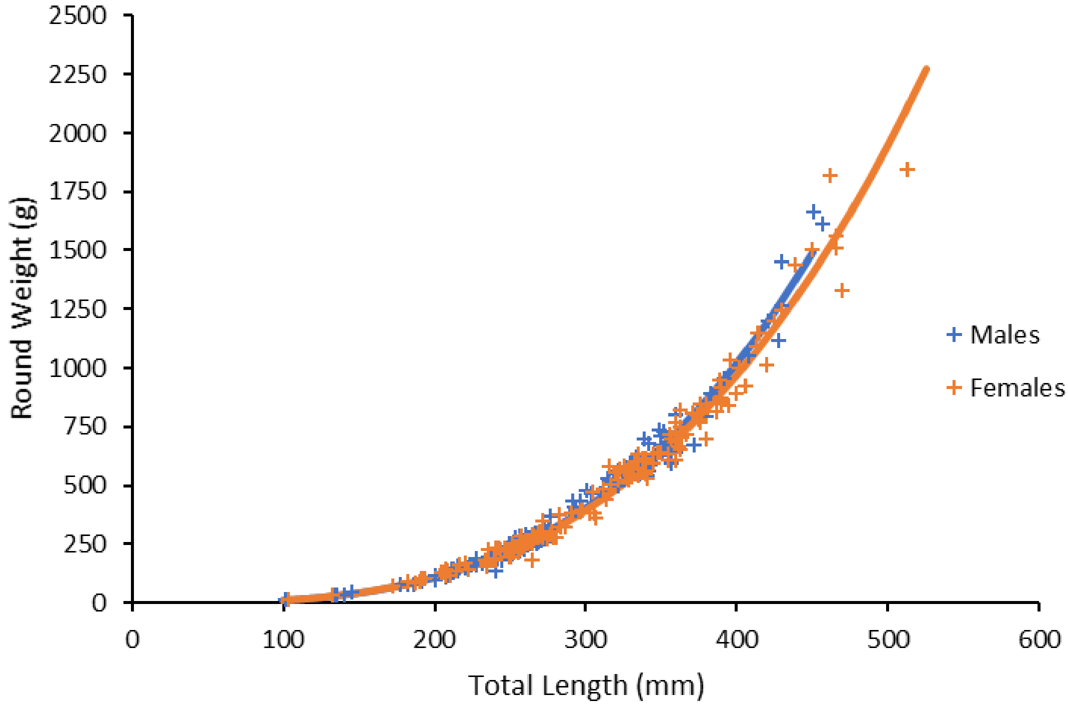


Figure 15. Observed (+) and predicted weight trajectory (line) for total length of Lake Nipissing male and female Smallmouth Bass captured during the fall Walleye index netting projects 1998 to 2019.

The calculated weight of Smallmouth Bass across the observed size range in the FWIN samples varied by sex (Table 4). The calculated weights demonstrated that male Smallmouth Bass weighed approximately the same or just slightly less than females until they reached ≈250mm. Male Smallmouth Bass >250mm weighed consistently more than females (of similar length). Estimates from the length-weight regression model suggest that an average harvested Smallmouth Bass on Lake Nipissing weighed ≈800 grams (i.e., average size of angler-harvested Bass from 2010 to 2019 was 374mm).

Table 4. Weight-at-length (grams and millimetres, respectively) calculated using the Lake Nipissing Smallmouth Bass length-weight regression models in Table 3.

Total Length	Predicted Round Weight (g)		
(mm)	Males	Females	All Fish
100	12	13	13
125	24	26	26
150	44	46	46
175	72	74	74
200	110	112	113
225	161	161	163
250	226	224	226
275	307	302	305
300	406	396	399
325	525	509	513
350	666	641	646
375	832	795	801
400	1024	972	979
425	1244	1175	1183
450	1495	1404	1413
475	—	1662	1673
500	—	1951	1963
525	—	2271	2285

Maturation – Length-based and age-based ogives (i.e., probabilities of being mature) varied between the sexes (Figure 16). Female Smallmouth Bass displayed delayed maturation schedules (i.e., females matured at a larger size and an older age than males). Females had significantly greater length-at-50%-maturity and older age-at-50% maturity than males (Table 5). Female Smallmouth Bass were 100% mature at 351mm while males were 100% mature at 344mm. Bass harvested by anglers appear to be fully sexually mature (i.e., 374mm total length, 95% confidence limits 365mm to 382mm). Female Smallmouth Bass matured approximately one-year later than males (i.e., female age-at-50% maturity = 2.7 years and male age-at-50% maturity = 1.5 years)

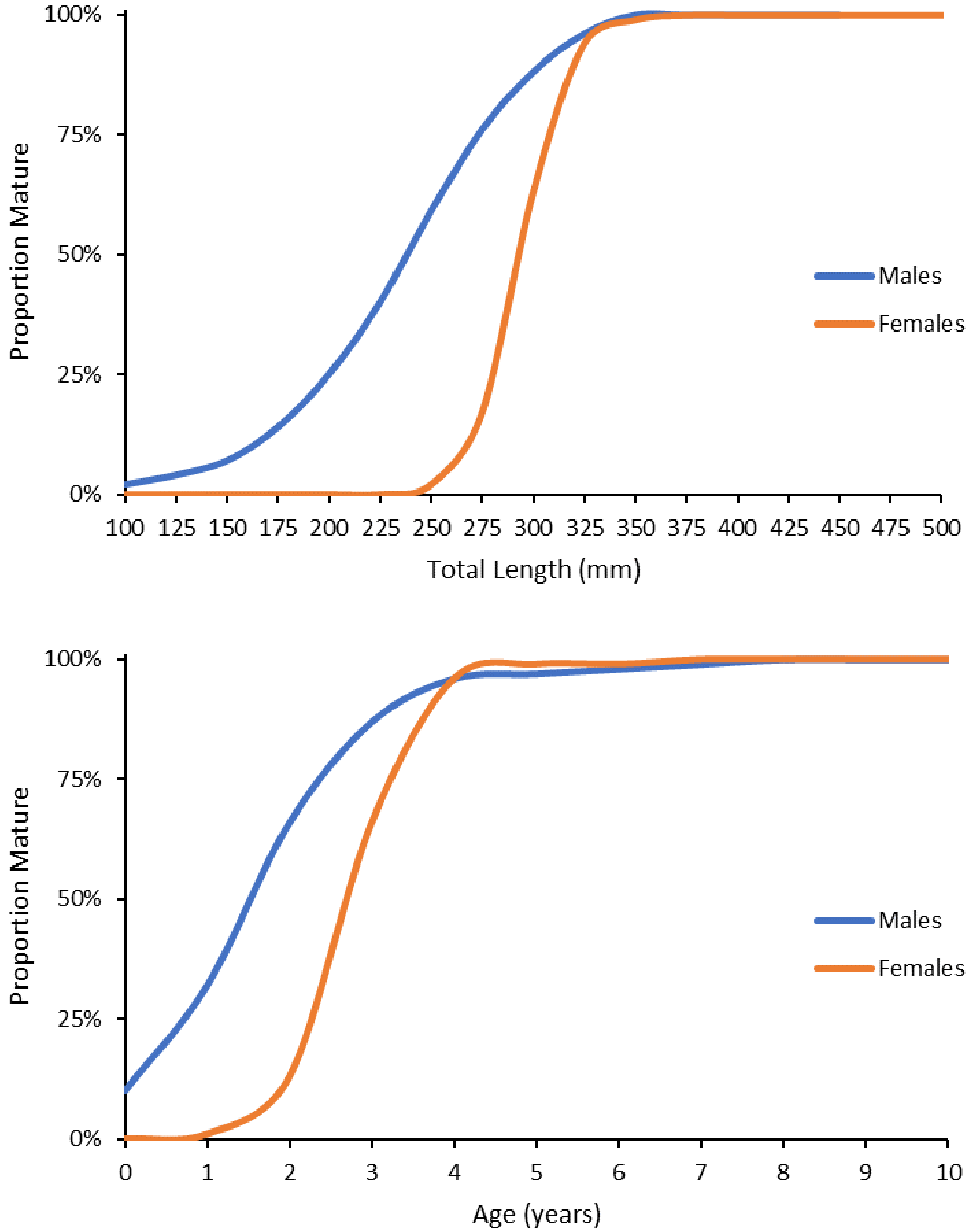


Figure 16. Size (top panel) and age (bottom panel) maturity ogives for Lake Nipissing male and female Smallmouth Bass captured during the fall Walleye index netting projects 1998 to 2019.

Table 5. Lake Nipissing male and female Smallmouth Bass maturity schedules by size (left) and age (right).

Predicted Size-at-Maturity Schedule by Sex

Proportion Mature	Total Length (mm)	
	Males	Females
5%	134	258
10%	162	268
25%	201	280
50%		

Predicted Maturity-at-Age Schedule by Sex

Age (years)	Proportion Mature	
	Males	Females
0	10%	0%
1	32%	1%
2	66%	13%

Mortality – Smallmouth Bass total adult mortality ($Z_{\geq Age\ 5}$) rates varied little between sampling methods or time period (Table 6). The average for all the available index netting data was $Z_{\geq Age\ 5} = 0.40$ (or an annual mortality rate of 33%) and for the open water creel samples was $Z_{\geq Age\ 5} = 0.41$ (or an annual mortality rate of 34%). The natural mortality rate (M) estimated from the modification of the Lester et al. 2014 life history model (using the average growing degree-day ≥5°C from 1967 to 2018) was $M \approx 0.25 \cdot year^{-1}$ (Cindy Chu, Ontario Ministry of Natural Resources and Forestry, personal communication). Smallmouth Bass exploitation rate was estimated at 12-to-13%. Using the reference approach of Lester et al. (2014) a safe fishing rate would be where $F \leq M$ (F = fishing mortality rate and M = natural mortality rate), which equates to an exploitation rate of less than 13%), and fishing rates where $F > 2M$ (exploitation rate of more than 35%) should be avoided. The Smallmouth Bass population in Lake Nipissing has been exploited near the safe recommended fishing level.

Table 6. Estimated Lake Nipissing adult Smallmouth Bass mortality rates ($Z_{\geq Age\ 5}$, $A_{\geq Age\ 5}$, and $u_{\geq Age\ 5}$) from fish captured during the 2000 to 2016 ice out trap netting projects, 1998 to 2019 fall Walleye index netting projects, and 2014 to 2019 open water creel surveys.

Year	Program[1]	Total Mortality Rate ($Z_{\geq Age\ 5}$)			Annual Mortality ($A_{\geq Age\ 5}$)	Exploitation Rate ($u_{\geq Age\ 5}$)
		Estimate	95% C.L.[2]	Sample Size		
2000	IOTN	0.36	0.24 to 0.49	33	30%	9%
2001	IOTN	0.38	0.31 to 0.45	114	31%	11%
2007	IOTN	0.43	0.33 to 0.54	75	35%	15%
2013	IOTN	0.32	0.27 to 0.38	143	28%	6%
2014	IOTN	0.37	0.29 to 0.45	85	31%	10%
2016	IOTN	0.49	0.42 to 0.57	167	39%	19%
All Years	IOTN	0.36	0.42 to 0.47	612	30%	9%
1998 to 2019	FWIN	0.44	0.32 to 0.57	47	35%	15%
IOTN and FWIN Average		0.40	—	—	33%	12%
2014 to 2019	Creel	0.41	0.34 to 0.50	109	34%	13%

1. IOTN is an ice out trap netting project and FWIN is a fall Walleye index netting project.
2. 95% C.L. are the lower and upper 95% confidence limits of the parameter estimate.

DISCUSSION – When tasked with describing particular species abundance trends or implementing regulations, researchers and managers often choose one or a few surveys based on preference or convention. The sampling from the open water creel and the fall Walleye index surveys were the most extensive based on frequencies, locations, and time periods. A number of indicators from the open water creel surveys can be used to assess the status of Smallmouth Bass fishery. These include analyses of changes in targeted angler effort, catch composition, changes in catch, angler success (or CPUE), and harvest. The present data set allowed for the use of all these approaches in assessing the state of the Smallmouth Bass recreational fishery. For over a quarter of a century Smallmouth Bass have been a prominent component of Lake Nipissing's diverse open water recreational fishery. Despite being reasonably abundant, Smallmouth Bass were historically never a focus of Lake Nipissing anglers, whereas Walleye, Yellow Perch, and Northern Pike have been traditional mainstays of the local angling community. During the 2000s however, broad changes in the lake's ecology occurred, including colonization of the lake by predators like Double-crested Cormorants (*Phalacrocorax auratus* (Lesson, 1831)), and shifts in food web dynamics related to the invasion of Lake Nipissing by the Spiny Water Flea (*Bythotrephes longimanus* (Leydig, 1860)). In addition, overexploitation apparently supressed abundance of Lake Nipissing's other top predators, the Walleye and Northern Pike (Morgan 2013, Morgan 2019). The present study indicated that even as the overall fishing effort declined from 1990 to 2019 there was no measurable change in the amount of fishing effort expended by anglers targeting Smallmouth Bass (Figure 2). These two features combined to produce the observation that over the study period the proportion (%) of targeted effort (at Smallmouth Bass) appeared to increase (Figure 3). There is no indication that anglers are shifting fishing effort from the desirable species (i.e., Walleye, Yellow Perch, and Northern Pike) over to a 'less' desirable species (i.e., the Smallmouth Bass or Largemouth Bass – Appendix 10) during the open water season.

Variation in catch composition over time can be interpreted as a sign of decreasing abundance of traditionally-targeted species, but may also reflect changes in targeting and fishing techniques used by anglers. Creel survey results demonstrated that the proportion of Walleye and Smallmouth Bass in the catch increased while Yellow Perch decreased and Northern Pike remained static from 1990 to 2019 (Figure 5). The number of Smallmouth Bass caught has increased in the last decade associated with the increases in population abundance (Figures 6 and 12). Although anglers targeting Smallmouth Bass accounted for <10% of the overall fishing effort on Lake Nipissing they accounted for one-half of the Smallmouth Bass caught in the open water period (Figure 7). Anglers targeting Smallmouth Bass did not show any changes in their success rates while catch rates by all anglers showed increased catch rates as abundance increased (Figure 8). Smallmouth Bass harvest decreased in the 1990s and has remained relatively low and static to the present because anglers have shown an increasing catch-and-release emphasis (i.e., lower % kept) in recent years (Figure 9 and 10). It is apparent that the status of the Smallmouth Bass fishery has changed little over the period 1990 to 2019, other than the increased unintentional catch from anglers not specifically fishing for the species (as the abundance on Smallmouth Bass increased).

The nearest large lake to Lake Nipissing is Lake Simcoe, which is one of the most intensively fished lakes in Ontario (Sutton and Lennox 2020). Lake Nipissing exhibited similar total and targeted fishing effort, Smallmouth Bass catches, and angler success rates (for anglers targeting Bass) compared to Lake Simcoe from 2014 to 2018 (Table 7). However, Lake Nipissing Smallmouth Bass harvest was two-thirds lower than Lake Simcoe because Lake Simcoe anglers kept almost twice as much (Lake Nipissing 2014 to 2018 average % kept = 15%; Lake Simcoe 2014 to 2018 average % kept = 27%). Significantly more of the estimated catch on Lake Simcoe was by anglers specifically targeting Smallmouth Bass (Lake Nipissing 2014 to 2018 average % of catch by target anglers = 41%; Lake Simcoe 2014 to 2018 average % of catch by target anglers = 80%) but the majority of the Smallmouth Bass harvest in each lake was by anglers targeting this species.

Table 7: Comparison of Smallmouth Bass fishery performance metrics from the Lake Simcoe and Lake Nipissing 2014 to 2018 open water creel surveys.

Fishery Performance Metric	Average (±95% Confidence Limits)		Significance[1]
	Lake Nipissing 2014-2018	Lake Simcoe 2014-2018	
Total Fishing Effort (angler-hours)	155330 (117590 to 193180)	176060 (150970 to 201150)	NS
Smallmouth Bass Target Effort (angler-hours)	22830 (2090 to 43569)	44939 (14301 to 75576)	NS
Proportion (%) of Total Effort by Target Anglers	14% (3% to 24%)	25% (10% to 39%)	NS
Number of Smallmouth Bass Caught	11946 (6149 to 17744)	18690 (11110 to 26270)	P<0.10
Number of Smallmouth Bass Harvested	1680 (963 to 2397)	5007 (2558 to 7455)	p<0.01
Proportion (%) of Smallmouth Bass Kept	15% (8% to 22%)	27% (19% to 34%)	p<0.05
Proportion (%) of Smallmouth Bass Caught by Target Anglers	41% (13% to 69%)	80% (56% to 100%)	p<0.05
Proportion (%) of Smallmouth Bass Harvested by Target Anglers	65% (16% to 100%)	85% (48% to 100%)	NS
All Angler Success Rate (number of Smallmouth Bass caught·angler-hour^{-1})	0.076 (0.053 to 0.098)	0.104 (0.076 to 0.132)	P<0.10
Target Angler Success Rate (number of Smallmouth Bass caught·angler-hour^{-1})	0.235 (0.154 to 0.316)	0.551 (0.067 to 1.036)	NS

1. Comparison of means using t-test. NS is non-significant (p≥0.10).

In 2014 the Bass fishing season on Lake Nipissing was lengthened by one-week to provide additional angling opportunities (i.e., by moving the opening day from the fourth Saturday in June to the third Saturday in June) and communication materials were distributed that promoted angling for Bass focussing on their sporting qualities (OMNRF 2014). Beginning In 2020 the surrounding Fisheries Management Zone 11 (FMZ 11), amended the Bass fishing season to open earlier on the third Saturday in May (to align with the spring opening of the fishing season for Walleye and Northern Pike). The fishery management objectives of the FMZ 11 regulations were intended to permit additional harvest opportunities and simplify the current regulations. Could Lake Nipissing adopt a consistent spring opening date to align with the rest of FMZ 11?

The Lake Nipissing May-June (i.e., 36% of the open water creel survey period) fishery performance metrics from the 2009 to 2013 (i.e., 4th Saturday in June Bass season opener) were compared to those from 2015 to 2019 (i.e., 3rd Saturday in June Bass season opener – one week earlier) (Table 8). [*Note: The 2014 Lake Nipissing creel data was not used because of the change in the Walleye regulations which occurred that spring. The size limit changed from a 400-to-600mm protected slot size to a 460mm minimum size limit.*] There were observed significant increases in:

a. the amount of effort expended by anglers searching for Smallmouth Bass,
b. the proportion of effort being exerted on Smallmouth Bass,
c. the number of Smallmouth Bass caught,
d. the number of Smallmouth Bass harvested, and
e. the success rates for anglers seeking Smallmouth Bass

Changing the opening date to the third Saturday in May would add an additional 4 to 5 weeks of angling opportunity to target Smallmouth Bass. It is likely there would be an increase in targeted effort early in the season when Bass are spawning. Establishment of a springtime season may result in anglers having even higher success rates. The current fishing regulations on Lake Nipissing protect the large concentrations of shore-spawning Smallmouth Bass which are providing a high-quality fishery. However, there is a need to keep the regulations simple and easy to understand (within FMZ 11) while still maintaining or improving the Bass fishing on Lake Nipissing. There are also difficulties enforcing the current regulations because Bass are caught in the spring once the season opens for Walleye and Northern Pike (open on the long weekend in May). Anglers may be targeting these fish even though they are not allowed to harvest them. If the season is changed the open water creel survey should provide long-term surveillance for assessing the potential impacts of increased angling activity for the foreseeable future.

Table 8: Comparison of Smallmouth Bass fishery performance metrics from before (2009 to 2013) and after (2015 to 2019) changing the opening date of the Bass season (i.e., one week earlier) on Lake Nipissing.

Fishery Performance Metric	Average (±95% Confidence Limits)		Significance[1]
	Last Saturday in June (2009 to 2013)	Third Saturday in June (2015 to 2019)	
Smallmouth Bass Target Effort (angler-hours)	755 (311 to 1190)	5238 (2438 to 7719)	P<0.05
% of Total Effort Targeting Smallmouth Bass	1% (1% to 2%)	8% (4% to 12%)	P<0.05
Number of Smallmouth Bass Caught	1281 (778 to 1784)	4426 (2932 to 5428)	P<0.01
Number of Smallmouth Bass Harvested	149 (35 to 263)	549 (127 to 870)	P<0.01
Target Angler Success Rate (number caught·angler-hour^{-1})	0.140 (0 to 0.280)	0.332 (0.188 to 0.467)	P<0.10

1. Comparison of means using t-test. NS is non-significant (p≥0.10).

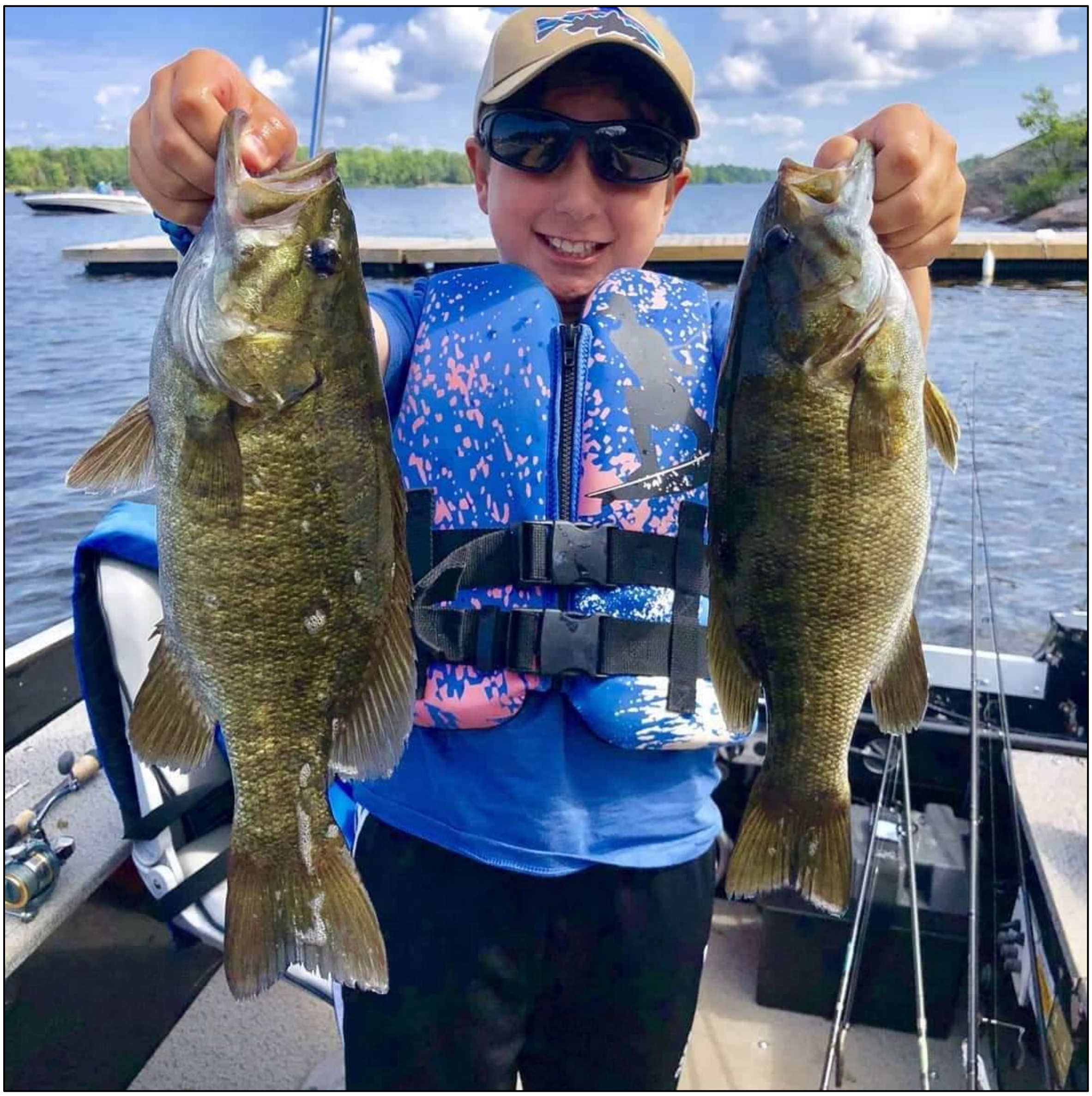
Analyses of temporal changes in the fall Walleye index netting relative abundance indicated that Smallmouth Bass experienced a significant increase over the period 1998 to 2019 (Figure 12) and may indicate that exploitation levels are not having an effect on the status of this species. This increase in relative abundance was accompanied by an increase in the number of nets that caught at least one Smallmouth Bass (Figure 12). This suggests that as the abundance of Smallmouth Bass increases in Lake Nipissing they will occupy more suitable habitats throughout the lake and become available to more anglers (i.e., anglers fishing for species other than Smallmouth Bass). Comparing the size and age composition of harvested Smallmouth Bass (Figure 11) to the maturity ogives (Figure 15; Table 5) showed that the majority of fish harvested were sexually mature. If there had been a large proportion of immature specimens in the harvest this would be a cause for concern, since, if such fish are retained by anglers, they are not given the opportunity to breed before been removed.

Lake Nipissing Smallmouth Bass exhibited good growth rates (Figure 14; Table 1 and 2) compared to nearby populations in FMZ 11. One of the growth metrics used by the MNRF broad-scale monitoring program is $Lmax_{2,5}$ which is the average total length (mm) of the largest 5% of the fish sampled after removing the top 2% of lengths (OMNRF 2016). Smallmouth bass $Lmax_{2,5}$ was 420mm during Cycle 2 sampling and 450mm during Cycle 3 sampling from the three extra large lakes (i.e.>5,000 ha) where they were caught in Fisheries Management Zone 11. Lake Nipissing Smallmouth Bass $Lmax_{2,5}$ was 481mm and 431mm for fish sampled in the ice out trap netting and fall Walleye index netting surveys, respectively. The estimated time to produce a large Smallmouth Bass (defined as fish weighing 3 pounds (1361g) or more) ranged from 9 to 11 years (these fish would be >18 inches (450mm) in length).

Although Lake Nipissing supports an important recreational fishery, as well as an expanding tournament fishery (currently there are 10 to 15 organized tournaments annually), there appears little indication that these activities are impacting the Smallmouth population. Total annual mortality was low (<35%) and angler exploitation rates (*u*) ranged from 6% to 19% with an average of 12% for Smallmouth Bass age 5 and older (Table 6) suggesting that angling does not represent a major source of mortality on the Lake Nipissing population.

Because of their; increasing abundance, good growth rates, large maximum size, low mortality, and low harvest, there is an opportunity to explore increasing angling activity for Smallmouth Bass on Lake Nipissing.

SUMMARY – The results from this study indicates that Smallmouth Bass in Lake Nipissing have experience increased abundance, good growth, and low mortality (and angler exploitation) over the last thirty years. Though confounded by other changes in the ecosystem, the most likely explanation for these trends has been an increase in catch-and-release angling for Smallmouth Bass. In the 1990s anglers kept one-out-of-every-two-fish caught. By the 2010s this had dramatically decreased to one-out-of-every-five-fish caught. The possibility of adjusting the current protective season to provide consistency of regulation across the Fisheries Management Zone should be explored. Implementation of a long-term monitoring strategy, working with recreational fishers (to determine the size of fish that are being released) as well as addressing research priorities (including understanding movement patterns, habitat use, species interactions, and trophic ecology) will be critical to the ongoing sustainability of the Lake Nipissing Smallmouth Bass recreational fishery into the future.



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Appendix 1: Lake Nipissing recreational fishing effort and Smallmouth Bass catch, harvest, and angler success data from 1990 to 2019 open water creel surveys.

Year	Effort (angler-hours)		% Effort Targeting Bass	Number of Bass Caught	% of Catch by Target Anglers	Number of Bass Harvested	% Kept	Angler Success (number·hour^{-1})	
	Total	Targeting Bass						Target Anglers	All Anglers
1990	405818 (5%)[1]	20843 (13%)	5%	12565 (17%)	60%	4191 (20%)	33%	0.363	0.031
1991	427578 (5%)	21987 (11%)	5%	11684 (11%)	67%	5775 (15%)	49%	0.358	0.027
1992	408214 (5%)	7908 (24%)	9%	3416 (29%)	86%	2220 (31%)	65%	0.370	0.039
1993	408214 (7%)	20951 (27%)	16%	12742 (26%)	88%	5334 (26%)	42%	0.532	0.099
1994	388850 (5%)	16844 (15%)	4%	8927 (13%)	49%	3182 (18%)	36%	0.260	0.023
1995	377061 (5%)	8708 (17%)	2%	4827 (18%)	52%	1554 (20%)	32%	0.288	0.013
1996	437011 (5%)	3868 (45%)	1%	6390 (17%)	27%	1075 (28%)	17%	0.442	0.015
1997	363335 (6%)	3851 (17%)	4%	927 (53%)	47%	596 (53%)	64%	0.114	0.008
1998	308433 (4%)	10354 (12%)	3%	7220 (9%)	53%	1122 (14%)	16%	0.372	0.023
1999	269360 (4%)	23632 (11%)	9%	7934 (18%)	78%	1812 (25%)	23%	0.260	0.029
2000	190621 (4%)	13304 (12%)	7%	3111 (18%)	68%	836 (21%)	27%	0.159	0.016
2001	189072 (6%)	3614 (12%)	2%	4822 (23%)	27%	1521 (27%)	32%	0.364	0.026
2002	252121 (4%)	11054 (6%)	4%	12489 (10%)	77%	3002 (9%)	24%	0.874	0.050
2003	269146 (4%)	10484 (10%)	4%	7858 (6%)	59%	1140 (22%)	15%	0.442	0.029
2004	153668 (15%)	9782 (12%)	6%	8421 (23%)	76%	1699 (20%)	20%	0.655	0.055
2005	123285 (8%)	3466 (32%)	3%	6704 (28%)	18%	1619 (22%)	24%	0.342	0.054
2006	205571 (9%)	10953 (12%)	5%	7650 (10%)	53%	2199 (5%)	29%	0.367	0.037
2007	172574 (7%)	10008 (11%)	6%	9151 (13%)	34%	1975 (53%)	22%	0.311	0.053
2008	167038 (6%)	11309 (13%)	7%	5848 (10%)	65%	1641 (17%)	28%	0.336	0.035
2009	195841 (7%)	11162 (19%)	6%	9595 (16%)	50%	4591 (19%)	48%	0.431	0.049
2010	77238 (7%)	5200 (12%)	7%	3392 (15%)	64%	795 (15%)	23%	0.415	0.044

Appendix 1: Lake Nipissing recreational fishing effort and Smallmouth Bass catch, harvest, and angler success data from 1990 to 2019 open water creel surveys. (continued)

Year	Effort (angler-hours)		% Effort Targeting Bass	Number of Bass Caught	% of Catch by Target Anglers	Number of Bass Harvested	% Kept	Angler Success (number·hour^{-1})	
	Total	Targeting Bass						Target Anglers	All Anglers
2011	123490 (7%)	7814 (16%)	6%	3206 (34%)	55%	1509 (35%)	47%	0.225	0.026
2012	126218 (7%)	4416 (30%)	4%	5196 (17%)	31%	861 (35%)	17%	0.362	0.041
2013	127797 (6%)	6169 (23%)	5%	5140 (6%)	29%	934 (15%)	18%	0.269	0.040
2014	109290 (4%)	6146 (13%)	6%	7842 (12%)	20%	861 (26%)	11%	0.250	0.072
2015	174255 (5%)	22756 (7%)	13%	13404 (9%)	53%	2141 (12%)	16%	0.311	0.077
2016	139554 (4%)	7942 (15%)	6%	8912 (12%)	15%	2161 (17%)	24%	0.171	0.064
2017	170932 (3%)	31060 (6%)	18%	10156 (8%)	50%	1293 (18%)	13%	0.164	0.059
2018	182643 (3%)	46244 (4%)	25%	19418 (6%)	67%	1945 (18%)	10%	0.280	0.106
2019	110923 (4%)	16477 (12%)	15%	9870 (15%)	70%	2279 (31%)	23%	0.418	0.089

1. Relative standard error of the estimate expressed as a percentage.

Appendix 2: Lake Nipissing recreational fishing effort and Smallmouth Bass catch, harvest, and angler success data from 2009 to 2019 open water creel surveys by seasonal stratum (May opening weekend to the end of June, July, and August to the first Friday after Labour Day in September). Season opener changed in 2014.

Year	Period	Effort Targeting Bass (angler-hours)	% Effort Targeting Bass	Number of Bass Caught	% of Catch by Target Anglers	Number of Bass Harvested	% Kept	Angler Success ($number\cdot hour^{-1}$)	
								All Angler	Target Angler
2009	May-June (35 days)	1449	2%	1959	20%	322	16%	0.022	0.266
	July	47	0%	1109	0%	322	29%	0.045	0.000
	August	1572	4%	5430	52%	2345	58%	0.089	0.478
2010	May-June (36 days)	381	1%	829	0%	174	21%	0.018	0.000
	July	1260	11%	1258	76%	370	30%	0.108	0.760
	August	3559	18%	1305	92%	250	19%	0.065	0.338
2011	May-June (37 days)	315	1%	552	0%	0	0%	0.010	0.000
	July	3624	17%	1196	86%	687	57%	0.056	0.283
	August	541	2%	546	28%	140	26%	0.021	0.283
2012	May-June (39 days)	1335	2%	1937	30%	249	13%	0.024	0.433
	July	1029	4%	2160	18%	413	19%	0.084	0.370
	August	2051	11%	1099	58%	199	18%	0.059	0.312
2013	May-June (40 days)	296	0%	1129	0%	0	0%	0.016	0.000
	July	2691	11%	1441	42%	413	29%	0.061	0.227
	August	3182	10%	2570	34%	521	20%	0.077	0.273
2014	May-June (41 days)	1286	3%	2816	24%	407	14%	0.058	0.535
	July	1026	5%	1265	0%	91	7%	0.062	0.000
	August	3864	9%	3761	23%	363	10%	0.092	0.221
2015	May-June (42 days)	2379	4%	3150	46%	143	5%	0.054	0.605
	July	6421	16%	4840	80%	641	13%	0.121	0.604
	August	13957	19%	5415	33%	1357	25%	0.072	0.126
2016	May-June (44 days)	2298	3%	3881	4%	588	15%	0.058	0.070
	July	1722	6%	2075	28%	405	20%	0.068	0.334
	August	3921	9%	2956	21%	1168	40%	0.07	0.159
2017	May-June (45 days)	4435	7%	3470	36%	217	6%	0.052	0.282
	July	11987	29%	2396	70%	490	20%	0.058	0.140
	August	14639	24%	4290	50%	586	14%	0.069	0.147
2018	May-June (46 days)	10407	13%	7251	70%	423	6%	0.091	0.489
	July	9100	24%	2382	68%	87	4%	0.062	0.177
	August	26737	42%	9785	49%	1436	15%	0.152	0.234
2019	May-June (47 days)	6672	14%	4378	82%	1376	31%	0.089	0.536
	July	5332	19%	2954	50%	634	21%	0.105	0.274
	August	4474	13%	2538	73%	269	11%	0.076	0.415

Appendix 3: Lake Nipissing Smallmouth Bass relative abundance (number·net^{-1}) from ice out trap netting index netting surveys 1999 to 2016.

Ice Out Trap Netting Surveys 1999 to 2016

Year	Number of Smallmouth Bass·Net^{-1}						Number of Nets	Number of Nets with Zero Catch (%)
	Average	Minimum	Maximum	Standard Deviation	95% LCL[1]	95% UCL[1]		
1999	6.62	0	64	12.343	3.09	9.55	55	19 (35%)
2000	1.60	0	22	4.051	0.35	2.58	48	29 (60%)
2001	2.93	0	14	3.732	1.78	3.93	46	13 (28%)
2007	2.30	0	13	2.651	1.46	3.00	43	11 (26%)
2013	11.09	0	3	24.957	0	18.68	22	4 (18%)
2014	5.30	0	37	8.9684	1.80	8.10	30	12 (40%)
2016	6.85	0	119	22.813	0	12.30	27	10 (37%)

1. 95% LCL is the lower 95% confidence limit and 95% UCL is the upper 95% confidence limit of the parameter estimate

Appendix 4: Lake Nipissing Smallmouth Bass relative abundance (number·net^{-1}) from fall Walleye index netting surveys 1998 to 2019.

Fall Walleye Index Netting Surveys 1998 to 2019

Year	Number of Smallmouth Bass·Net^{-1}						Number of Nets	Number of Nets with Zero Catch (%)
	Average	Minimum	Maximum	Standard Deviation	95% LCL[1]	95% UCL[1]		
1998	0.20	0	4	0.621	0.07	0.30	107	94 (88%)
1999	0.39	0	8	1.235	0	0.65	54	45 (83%)
2000	0.12	0	1	0.329	0	0.20	66	58 (88%)
2001	0.09	0	2	0.342	0	0.16	57	53 (93%)
2002	0.14	0	1	0.351	0	0.24	29	25 (86%)
2003	0.13	0	1	0.346	0	0.23	30	26 (87%)
2004	0.16	0	2	0.428	0	0.27	44	38 (86%)
2005	0.39	0	4	0.977	0.09	0.65	46	37 (80%)
2006	0.17	0	2	0.437	0	0.29	42	36 (86%)
2007	0.26	0	5	0.836	0	0.45	53	45 (85%)
2008	0.71	0	16	2.096	0.14	1.11	66	45 (68%)
2009	0.20	0	3	0.558	0.06	0.32	69	59 (86%)
2010	0.59	0	6	1.232	0.31	0.85	78	58 (74%)
2011	0.80	0	5	1.420	0.41	1.14	56	38 (68%)
2012	0.75	0	4	1.324	0.37	1.08	51	35 (69%)
2013	0.50	0	3	0.923	0.23	0.73	48	35 (73%)
2014	0.71	0	6	1.254	0.33	1.02	48	29 (60%)
2015	0.42	0	2	0.679	0.23	0.60	48	33 (69%)
2016	0.90	0	5	1.207	0.54	1.21	48	25 (52%)
2017	0.26	0	2	0.601	0.05	0.45	38	31 (82%)
2018	0.77	0	4	1.171	0.42	1.06	48	29 (60%)
2019	0.67	0	7	1.449	0.21	1.02	48	34 (71%)

1. 95% LCL is the lower 95% confidence limit and 95% UCL is the upper 95% confidence limit of the parameter estimate

Appendix 5: Smallmouth Bass relative abundance (number·net^{-1}) by Fisheries Management Zone from fall Walleye index netting surveys conducted in Ontario from 1996 to 2003.

Fisheries Management Zone	Number of Smallmouth Bass·Net^{-1}						Number of Lakes (or years) Sampled
	Average	Minimum	Maximum	Standard Deviation	95% LCL[1]	95% UCL[1]	
4	0.51	0.06	2.56	0.550	0.26	0.70	22
5	1.31	0.02	11.06	1.756	0.84	1.70	63
6	1.52	0.03	11.60	3.225	0	2.67	12
7	0.76	0.08	1.81	0.739	0.03	1.30	4
8	0.72	0.04	2.33	0.673	0.42	1.00	20
9	0.01	0.01	0.01	—	—	—	1
10	1.78	0.06	10.17	2.132	1.10	2.36	43
11[2]	1.11	0.08	4.50	0.977	0.72	1.44	28
Lake Nipissing	0.42	0.09	0.90	0.268	0.31	0.53	22
12	0.28	0.13	0.82	0.238	0.12	0.40	10
15	1.23	0.03	7.42	1.594	0.71	1.67	40
16	3.76	0.50	15.50	5.811	0	6.60	6
17	0.60	0.04	2.14	0.550	0.32	0.83	16
18	1.60	0.08	15.29	2.659	0.57	2.28	33
Combined	1.26	0.01	15.50	1.951	1.01	1.47	298

1. 95% LCL is the lower 95% confidence limit and 95% UCL is the upper 95% confidence limit of the parameter estimate.

2. Excluding Lake Nipissing.

Appendix 6: Lake Nipissing Smallmouth Bass total length-at-age (mm) from ice out trap net surveys (2000 to 2016 pooled), fall Walleye index netting surveys (1998 to 2019 pooled); and cycle 2 (2008 to 2012) and cycle 3 (2013 to 2017) broad-scale monitoring surveys in fisheries management zone 11[1].

Ice Out Trap Net Surveys 2000 to 2016 pooled

Age (years)	Smallmouth Bass Total Length-at-Age (mm)				
	Average	Minimum	Maximum	Standard Deviation	Sample Size
0	—	—	—	—	—
1	—	—	—	—	—
2	—	—	—	—	—
3	297.6	261	345	22.91	14
4	338.8	300	377	18.54	77
5	360.0	290	451	25.83	156
6	390.5	315	466	24.65	90
7	415.3	362	480	20.82	121
8	433.5	380	498	20.79	132
9	453.8	392	501	22.06	59
10	464.7	400	488	17.47	29
11	467.5	426	498	23.72	15
12	485.8	437	522	28.66	6
13	485	475	495	14.14	2
14	—	—	—	—	—
15	486.5	485	488	2.12	2

Fall Walleye Index Netting Surveys 1998 to 2019 pooled – Males

Age (years)	Male Smallmouth Bass Total Length-at-Age (mm)				
	Average	Minimum	Maximum	Standard Deviation	Sample Size
0	126.2	101	145	19.19	6
1	209.0	177	227	13.58	16
2	260.5	186	347	26.09	35
3	299.4	207	353	36.55	33
4	335.8	275	360	23.26	13
5	372	372	372		1
6	397.7	380	421	21.08	3
7	430	430	430		1
8	429.5	408	451	30.41	2
9	428	428	428		1
10	430	430	430		1
11	457	457	457		1

Appendix 6: Lake Nipissing Smallmouth Bass total length-at-age (mm) from ice out trap net surveys (2000 to 2016 pooled), fall Walleye index netting surveys (1998 to 2019 pooled); and cycle 2 (2008 to 2012) and cycle 3 (2013 to 2017) broad-scale monitoring surveys in fisheries management zone 11[1]. (continued)

Fall Walleye Index Netting Surveys 1998 to 2019 pooled - Females

Age (years)	Female Smallmouth Bass Total Length-at-Age (mm)				
	Average	Minimum	Maximum	Standard Deviation	Sample Size
0	117.5	103	132	20.51	2
1	209.9	172	242	21.24	18
2	259.9	207	340	23.90	38
3	305.5	247	364	33.72	39
4	347.4	316	376	17.42	15
5	380.8	303	485	40.72	18
6	393.8	341	439	37.85	5
7	405.2	362	462	33.25	6
8	436.5	405	468	44.55	2
9	425	425	425	—	1
10	468.0	466	470	2.83	2
11	—	—	—	—	—
12	—	—	—	—	—
13	466	466	466	—	1
14	—	—	—	—	—
15	—	—	—	—	—
16	—	—	—	—	—
17	513	513	513	—	1

Fall Walleye Index Netting Surveys 1998 to 2019 pooled

Age (years)	Smallmouth Bass Total Length-at-Age (mm)				
	Average	Minimum	Maximum	Standard Deviation	Sample Size
0	114.1	82	145	21.25	18
1	203.7	131	242	23.29	43
2	256.1	186	347	26.85	83
3	302.3	207	364	34.67	74
4	342.0	275	376	20.80	28
5	380.4	303	485	39.63	19
6	398.6	341	439	30.48	9
7	408.7	362	462	31.77	7
8	433.0	405	468	31.40	4
9	426.5	425	428	2.12	2
10	455.3	430	470	22.03	3
11	457	457	457	—	1
12	—	—	—	—	—
13	466	466	466	—	1
14	—	—	—	—	—
15	—	—	—	—	—
16	—	—	—	—	—
17	513	513	513	—	1

Appendix 6: Lake Nipissing Smallmouth Bass total length-at-age (mm) from ice out trap net surveys (2000 to 2016 pooled), fall Walleye index netting surveys (1998 to 2019 pooled); and cycle 2 (2008 to 2012) and cycle 3 (2013 to 2017) broad-scale monitoring surveys in fisheries management zone 11[1]. (continued)

Broad-scale Monitoring Surveys – Cycle 2 (2008 to 2012)

Age (years)	Smallmouth Bass Total Length-at-Age (mm)				
	Average	Minimum	Maximum	Standard Deviation	Sample Size
0	—	—	—	—	—
1	136.0	90	241	70.46	4
2	181.5	130	503	60.23	47
3	234.8	146	374	46.99	93
4	284.9	189	456	55.78	124
5	352.2	195	429	53.14	32
6	364.5	277	418	32.77	22
7	389.3	271	456	40.58	31
8	385.8	283	533	48.66	27
9	412.7	276	463	32.73	88
10	419.7	365	453	31.19	7
11	435.8	400	472	23.24	10
12	442.2	396	492	24.37	25
13	449.6	410	499	25.55	12
14	389.7	210	518	160.29	3
15	479.5	428	581	39.98	11
16	472.7	468	480	6.43	3
17	503	503	503	—	1
18	—	—	—	—	—
19	494	494	494	—	1
20	—	—	—	—	—
21	464.5	433	496	44.55	2

1. Excluding samples from Lake Nipissing,

Appendix 6: Lake Nipissing Smallmouth Bass total length-at-age (mm) from ice out trap net surveys (2000 to 2016 pooled), fall Walleye index netting surveys (1998 to 2019 pooled); and cycle 2 (2008 to 2012) and cycle 3 (2013 to 2017) broad-scale monitoring surveys in fisheries management zone 11[1]. (continued)

Broad-scale Monitoring Surveys – Cycle 3 (2013 to 2017)

Age (years)	Smallmouth Bass Total Length-at-Age (mm)				
	Average	Minimum	Maximum	Standard Deviation	Sample Size
0	—	—	—	—	—
1	237.5	135	340	144.96	2
2	180.7	136	226	22.74	23
3	259.9	130	378	33.36	135
4	295.8	237	417	34.89	81
5	331.7	239	376	31.92	31
6	349.5	242	461	33.82	124
7	374.1	267	450	34.79	167
8	392.3	295	474	35.28	164
9	407.1	273	475	39.17	72
10	416.9	374	444	23.20	13
11	434.4	382	475	21.58	22
12	435.2	403	468	18.91	17
13	455.4	376	520	29.57	35
14	453.4	376	533	33.96	24
15	469.1	410	510	33.23	7
16	451.8	431	470	11.14	9
17	462.0	422	508	32.46	7
18	473.3	452	487	18.72	3
19	472.0	413	500	29.11	7
20	469.8	457	493	16.32	4
21	471	471	471	—	1
22	500	500	500	—	1

1. Excluding samples from Lake Nipissing,

Appendix 7: Lake Nipissing Smallmouth Bass total length-at-age (mm) from recreational angler harvested fish (2014 to 2019 pooled).

Recreational Creel Surveys (2014 to 2019)

Age (years)	Smallmouth Bass Total Length-at-Age (mm)				
	Average	Minimum	Maximum	Standard Deviation	Sample Size
0	—	—	—	—	—
1	—	—	—	—	—
2	266	266	266	—	1
3	298.6	31.5	251	360	23
4	333.4	36.8	225	387	32
5	367.6	28.1	300	426	30
6	395.3	25.3	336	460	20
7	413.4	21.0	350	472	25
8	434.9	21.5	400	479	12
9	445.8	23.0	417	496	10
10	481.6	16.0	450	498	8
11	473.0	19.1	462	495	3
12	485	—	485	485	1

Appendix 8: Lake Nipissing Smallmouth Bass round weight-at-age (g) fall Walleye index netting surveys (1998 to 2019 pooled).

Fall Walleye Index Netting Surveys 1998 to 2019 pooled – Males

Age (years)	Male Smallmouth Bass Round Weight-at-Age (g)				
	Average	Minimum	Maximum	Standard Deviation	Sample Size
0	28.5	11	46	14.14	6
1	131.1	79	160	25.96	16
2	257.2	75	527	74.98	35
3	434.9	112	735	170.29	33
4	571.5	269	800	117.71	13
5	671	671	671	—	1
6	984.3	795	1200	203.78	3
7	1266	1266	1266	—	1
8	1359.0	1053	1665	432.75	2
9	1114	1114	1114	—	1
10	1450	1450	1450	—	1
11	1610	1610	1610	—	1

Fall Walleye Index Netting Surveys 1998 to 2019 pooled - Females

Age (years)	Female Smallmouth Bass Round Weight-at-Age (g)				
	Average	Minimum	Maximum	Standard Deviation	Sample Size
0	21.2	11	31.4	14.42	2
1	163.7	72	515	101.19	18
2	259.4	117	552	84.20	38
3	435.3	192	751	160.36	39
4	636.9	540	810	80.88	15
5	842.1	382	1246	226.65	18
6	925.4	528	1436	345.68	5
7	1043.3	662	1821	412.68	6
8	556	402	710	217.79	2
9	1197	1197	1197	—	1
10	1446.0	1331	1561	162.63	2
11	—	—	—	—	—
12	—	—	—	—	—
13	1510	1510	1510	—	1
14	—	—	—	—	—
15	—	—	—	—	—
16	—	—	—	—	—
17	1845	1845	1845	—	1

Appendix 8: Lake Nipissing Smallmouth Bass round weight-at-age (g) fall Walleye index netting surveys (1998 to 2019 pooled). (continued)

Fall Walleye Index Netting Surveys 1998 to 2019 pooled

Age (years)	Smallmouth Bass Total Length-at-Age (mm)				
	Average	Minimum	Maximum	Standard Deviation	Sample Size
0	22.1	9	46	12.41	18
1	136.5	29	515	74.22	43
2	247.9	75	552	83.03	83
3	432.1	112	751	163.06	74
4	606.5	269	810	103.22	28
5	833.1	382	1246	223.74	19
6	988.2	528	1436	293.03	9
7	1075.1	662	1821	386.01	7
8	957.5	402	1665	541.45	4
9	1155.5	1114	1197	58.69	2
10	1447.3	1331	1561	115.02	3
11	1610	1610	1610	—	1
12	—	—	—	—	—
13	1510	1510	1510	—	1
14	—	—	—	—	—
15	—	—	—	—	—
16	—	—	—	—	—
17	1845	1845	1845	—	1

Appendix 9: Lake Nipissing Smallmouth age frequency distributions from open water creel surveys 2014 to 2019, ice out trap netting surveys 2000 to 2016 and fall Walleye index netting surveys 1998 to 2019.

Open Water Angler Creel Samples 2014 to 2019

Age	Number of Smallmouth Bass with Age Interpretation by Year						
(years)	2014	2015	2016	2017	2018	2019	Total
2	—	—	—	—	1	—	1
3	8	1	1	—	5	8	23
4	3	6	10	3	3	7	32
5	1	3	9	10	5	2	30
6	1	1	2	11	2	3	20
7	3	3	1	3	2	13	25
8	—	2	3	2	0	5	12
9	2	1	4	1	1	1	10
10	1	—	2	3	0	2	8
11	1	—	—	—	—	2	3
12	—	1	—	—	—	—	1

Ice Out Trap Netting Surveys 2000 to 2016

Age	Number of Smallmouth Bass with Age Interpretation by Year						
(years)	2000	2001	2007	2013	2014	2016	Total
0	—	—	—	—	—	—	—
1	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—
3	—	3	1	5	5	—	14
4	2	2	24	6	37	6	77
5	8	17	26	12	17	76	156
6	7	25	10	9	14	25	90
7	8	31	6	42	16	18	121
8	3	17	15	59	21	17	132
9	1	15	9	8	10	16	59
10	2	5	2	9	3	8	29
11	2	3	1	2	3	4	15
12	—	1	—	2	1	2	6
13	2	—	—	—	—	—	2
14	—	—	—	—	—	—	—
15	—	—	1	—	—	1	2
Total	35	119	95	154	127	173	703

Appendix 9: Lake Nipissing Smallmouth age frequency distributions from open water creel surveys 2014 to 2019, ice out trap netting surveys 2000 to 2016 and fall Walleye index netting surveys 1998 to 2019. (continued)

Fall Walleye Index Netting Surveys 1998 to 2019

Age	Number of Smallmouth Bass with Age Interpretation											
(years)	1998	2008	2009	2010	2012	2014	2015	2016	2017	2018	2019	Total
0	2	—	—	—	5	—	2	3	—	5	1	18
1	1	1	—	4	16	1	2	9	2	3	4	43
2	4	10	3	5	11	13	4	3	5	19	6	84
3	6	18	2	4	2	14	7	4	1	4	12	74
4	3	1	3	10	1	—	1	4	—	2	3	28
5	2	—	2	5	—	—	2	5	2	1	—	19
6	—	—	1	1	1	—	2	3	—	1	—	9
7	—	—	—	—	2	—	—	1	—	—	4	7
8	—	—	—	1	—	1	1	—	—	—	1	4
9	—	—	—	—	—	—	—	1	—	—	1	2
10	1	—	—	—	—	—	—	1	—	1	—	3
11	—	—	—	1	—	—	—	—	—	—	—	1
12	—	—	—	—	—	—	—	—	—	—	—	—
13	—	—	—	—	—	—	—	1	—	—	—	1
14	—	—	—	—	—	—	—	—	—	—	—	—
15	—	—	—	—	—	—	—	—	—	—	—	—
16	—	—	—	—	—	—	—	—	—	—	—	—
17	—	—	—	—	—	—	—	1	—	—	—	1
Total	19	30	11	31	38	29	21	36	10	36	32	294

Appendix 10: Lake Nipissing recreational fishing effort and Largemouth Bass catch, harvest, and angler success data from 1990 to 2019 open water creel surveys.

Year	Effort (angler-hours)		% Effort Targeting Bass	Number of Bass Caught	% of Catch by Target Anglers	Number of Bass Harvested	% Kept	Angler Success (number·hour^{-1})	
	Total	Targeting Bass						Target Anglers	All Anglers
1990	405818 (5%)[1]	1000 (43%)	<1%	736 (35%)	52%	142 (47%)	19%	0.383	0.002
1991	427578 (5%)	1780 (29%)	<1%	478 (34%)	77%	325 (46%)	68%	0.206	0.001
1992	408214 (5%)	0 (—)	—	0 (—)	—	0 (—)	—	—	—
1993	408214 (7%)	0 (—)	—	0 (—)	—	0 (—)	—	—	—
1994	388850 (5%)	415 (59%)	<1%	875 (89%)	91%	23 (100%)	3%	1.929	0.002
1995	377061 (5%)	0 (—)	—	0 (—)	—	0 (—)	—	—	—
1996	437011 (5%)	8 (100%)	<1%	129 (75%)	21%	119 (80%)	93%	3.337	<0.001
1997	363335 (6%)	0 (—)	—	0 (—)	—	0 (—)	—	—	—
1998	308433 (4%)	0 (—)	—	0 (—)	—	0 (—)	—	—	—
1999	269360 (4%)	660 (59%)	<1%	281 (63%)	11%	0 (—)	0%	0.048	0.001
2000	190621 (4%)	2184 (0%)	1%	642 (0%)	90%	575 (0%)	90%	0.263	0.003
2001	189072 (6%)	0 (—)	—	176 (81%)	0%	0 (—)	0%	—	0.001
2002	252121 (4%)	0 (—)	0%	156 (16%)	0%	104 (22%)	66%	—	0.001
2003	269146 (4%)	1605 (18%)	1%	924 (3%)	33%	55 (0%)	6%	0.189	0.003
2004	153668 (15%)	918 (39%)	1%	956 (50%)	44%	373 (55%)	39%	0.453	0.006
2005	123285 (8%)	0 (—)	0%	95 (100%)	0%	0 (—)	0%	—	0.001
2006	205571 (9%)	2460 (7%)	1%	432 (0%)	40%	0 (—)	0%	0.070	0.002
2007	172574 (7%)	1043 (0%)	1%	228 (0%)	38%	0 (—)	0%	0.082	0.001
2008	167038 (6%)	2249 (10%)	1%	981 (14%)	84%	322 (51%)	33%	0.365	0.006
2009	195841 (7%)	0 (—)	0%	364 (67%)	0%	0 (—)	0%	—	0.002
2010	77238 (7%)	165 (0%)	<1%	106 (0%)	100%	106 (0%)	100%	0.642	0.001

Appendix 10: Lake Nipissing recreational fishing effort and Largemouth Bass catch, harvest, and angler success data from 1990 to 2019 open water creel surveys. (continued)

Year	Effort (angler-hours)		% Effort Targeting Bass	Number of Bass Caught	% of Catch by Target Anglers	Number of Bass Harvested	% Kept	Angler Success (number·hour^{-1})	
	Total	Targeting Bass						Target Anglers	All Anglers
2011	123490 (7%)	196 (100%)	<1%	50 (100%)	0%	50 (100%)	100%	<0.001	<0.001
2012	126218 (7%)	1090 (0%)	1%	385 (27%)	0%	0 (—)	0%	0.003	<0.001
2013	127797 (6%)	0 (—)	0%	385 (46%)	0%	0 (—)	0%	—	0.003
2014	109290 (4%)	491 (59%)	<1%	904 (77%)	73%	179 (89%)	20%	1.337	0.008
2015	174255 (5%)	792 (0%)	1%	501 (69%)	0%	0 (—)	0%	<0.001	0.003
2016	139554 (4%)	302 (33%)	<1%	421 (12%)	7%	99 (24%)	24%	0.102	0.003
2017	170932 (3%)	15461 (6%)	9%	2775 (28%)	83%	343 (0%)	12%	0.148	0.016
2018	182643 (3%)	19523 (6%)	11%	2357 (17%)	69%	0 (—)	0%	0.083	0.013
2019	110923 (4%)	3077 (11%)	3%	1632 (9%)	79%	308 (0%)	19%	0.418	0.015

1. Relative standard error of the estimate expressed as a percentage.