Status of Lake Nipissing Yellow Perch and Associated Fisheries 1985 to 2019

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Executive Summary

This project aims to improve our understanding and management of the Lake Nipissing Yellow Perch (*Perca flavescens* (Linnaeus, 1758)) population. The status of Yellow Perch in Lake Nipissing was assessed using a combination of fishery-dependent (i.e., recreational winter and open water angling surveys) and fishery-independent data (i.e., Fall Walleye Index Netting (FWIN) surveys). Recreational fishing is an important economic and social driver within the local community, and Lake Nipissing has a variety of fishing opportunities, with Yellow Perch being the second most sought after species in the winter fishery and third in the summer. Creel studies have shown that there has been a decreasing trend in targetted effort for the open water season accross years. Biological indicators from the annual FWIN show a robust Yellow Perch population with an increasing average age; large increase in abundance peaked in late 2000's and coincided with a major decline in Walleye numbers. Ecological interactions are summarized by looking at relationships with other fish species like Walleye (*Sander vitreus* (Mitchill 1818)), predators like Double-crested Cormorants (*Phalacrocorax auratus* (Lesson, 1831)), and shifts in food web dynamics related to the colonization of Lake Nipissing by the Spiny Water Flea (*Bythotrephes longimanus* (Leydig 1860) over the time series. Ecological shifts during the time series has resulted in the Yellow Perch mean trophic position and reliance on pelagic resources to increase. In conclusion, Yellow Perch are an important forage fish species in Lake Nipissing providing an important angling opportunity and play an important ecological role that has changed over time and will likely continue to change into the future. Monitoring Yellow Perch populations helps maintain a holistic view of the health of Lake Nipissing.

Résumé

Ce projet vise à améliorer notre compréhension et la gestion de la population perche jaune (*Perca flavescens* (Linnaeus, 1758)) du lac Nipissing. L'état de la perche jaune dans le lac Nipissing a été évalué à l'aide d'une combinaison d'enquêtes sur les pêches (c.-à-d. les relevés récréatifs de pêche en hiver et en eau libre) et les données indépendantes de la pêche (c.-à-d. les relevés de filets d'index du doré jaune d'automne (FWIN)). La pêche récréative est un important moteur économique et social au sein de la communauté, et le lac Nipissing offre une variété de possibilités de pêche, la perche jaune étant la deuxième espèce la plus recherchée dans la pêche hivernale et la troisième en été. Des études de Creel ont montré qu'il y a eu une tendance à la baisse de l'effort ciblé pour la saison des eaux libre au fil des ans. Les indicateurs biologiques du FWIN montrent une population robuste de perchaudes avec un âge moyen croissant; l'abondance a atteint un sommet à la fin des années 2000 et a coïncidé avec un déclin du nombre de dorés jaune. Les interactions écologiques sont résumées en examinant les relations avec d'autres espèces de poissons comme le doré jaune *(Sander vitreus* (Mitchill 1818)), les prédateurs comme les Cormorans à aigrettes (*Phalacrocorax auratus* (Leçon, 1831)), et les changements dans la dynamique du web alimentaire lié à la colonisation du lac Nipissing Le cladocère épineux (*Bythothtrephes longimanus* (Leydig 1860). Les changements écologiques au cours de la série temporelle ont entraîné une augmentation de la position trophique de la perche jaune et de la dépendance à l'égard des ressources pélagiques. En conclusion, la perche jaune est une importante espèce de poisson fourrage dans le lac Nipissing, ce qui offre une occasion importante de pêche à la ligne et joue un rôle écologique important qui a changé au fil du temps et continuera probablement de changer à l'avenir. La surveillance des populations de la perche jaune aide à maintenir une vision holistique de la santé du lac Nipissing.

Status of Lake Nipissing Yellow Perch and Associated Fisheries 1985 to 2019.

1 – Introduction

Yellow Perch (*Perca flavescens* (Linnaeus 1758)) plays an important role in Lake Nipissing's food web. The primary species of management interest in Lake Nipissing is Walleye (*Sander vitreus* (Mitchill 1818)) but the Lake Nipissing Fisheries Management Plan (2015) recognized the diverse fishery and has taken an ecosystem-based approach with management goals for a variety of fish species including Yellow Perch. Interactions between Walleye and Yellow Perch has been documented in other systems and it is generally understood that there are strong interactions between these two Percid species (Campbell 1998, Nielsen 1980. Post and Rudstam 1992, Rudstrom et al. 1996).

Due to their physiological and ecological similarities these two species may respond similarly to environmental variation, while on the other hand respond antagonistically to being competitors, predators and prey (Lori et al. 2011). Often viewed as a simple predator-prey relationship, the two species typically have a dynamic relationship where at various stages of their life each is a competitor, predator or prey to the other. For example, the abundance of prey can influence the abundance of predators through intraspecific competition (Tonn et al. 1991), and Forney (1974) demonstrated that the abundance of young Perch in a system can indirectly control the size of the Walleye population by regulating Walleye cannibalism. Growth of Yellow Perch and Walleye are related (Rose et al. 1999). However, Perch typically differ from Walleye in that they are a dietary generalist, eating invertebrates early in their life and switching to piscivory around 1 to 4 years (lengths greater than 150 mm) where Walleye switch earlier and are considered specialists (Graeb 2005, Lippert et al. 2007).

In a fisheries management context, it is important to understand the ecological interactions between these two species and how results of management actions may be impacted by these interactions. When considering the decline of the Walleye population in Lake Nipissing in the 2000's, it is important to consider changes in the Yellow Perch population. There have also been other shifts in the food web of Lake Nipissing, for example, the introduction of Spiny Water Flea (Bythotrephes longimanus (Leydig 1860)) in the early 2000's and the increase in Double-crested Cormorant (*Phalacrocorax auratus*, (Lesson 1831)) population in the late 1990's (Lecours 2017).

Until the 1990's, angling harvest of Yellow Perch was virtually unregulated in most areas of the province, with no closed seasons and no daily catch or possession limits (OMNR 2004). A catch limit is defined as the number of fish an angler is allowed to catch and keep in one day, while a possession limit is how many fish you can legally have in cold storage and on hand (OMNRF 2020). In 1994 the North Bay District fishing division that included Lake Nipissing implemented a season for Yellow Perch which aligned with the Walleye season (Table 1). Aligning the two seasons provided simplicity for enforcement and protection of both species. On Lake Nipissing, a daily catch limit of 25 and a possession limit of 50 was implemented in 1999 to control harvest of Yellow Perch because of its popularity in the recreational fishery. Yellow Perch is the second most targeted species in the winter season and the third most targeted in the summer. While a few specific waterbodies, such as Lake Nipissing, introduced catch limits most of the province remained open all season with no limits until 2004 when province-wide catch limits for Yellow Perch were implemented to place a value on the resource and to prevent overexploitation (OMNR 2004). The most recent change for Lake Nipissing occurred in 2014 where the catch limit for Yellow Perch was increased from 25 to 50 for a sports fishing licence, to align with the possession limit and to provide more fishing opportunities and to diversify the fishery (Table 1). This regulation change coincided with the Walleye regulation change to a more restrictive minimum size limit of 46 cm (OMNRF 2015).

Table 1: Recreational fishing regulations for Yellow Perch on Lake Nipissing.

Year	Open Season	Catch Limit	Possession Limit
Before 1994	Open all year	No Limit	No Limit
1994 to 1998	Jan 1 to March 15 Saturday before Victoria Day to Nov 30 Dec 25 to Dec 31	No Limit	No Limit
1999 to 2007 **Specific to Lake Nipissing**	Jan 1 to March 7 Saturday before Victoria Day to Oct 15	25	50
2009 to 2014 **Specific to Lake Nipissing**	Jan 1 to March 15 3rd Saturday in May to Oct 15	25	50
2014 to 2019 **Specific to Lake Nipissing**	Jan 1 to March 15 3rd Saturday in May to Oct 15	Sport: 50 Cons: 25	Sport:50 Cons: 25

The commercial fishery on Lake Nipissing is managed by Nipissing First Nation (NFN). The Natural Resource Department regulates the commercial fishery under the NFN Fisheries Law. The NFN fisheries laws outline fishing area, season species, size, quantities, reporting requirements, assessment requirements, gear specifications and compliance (NFN 2020). Yellow Perch is listed as an incidental species, meaning there are no harvest quantities set. Daily catch records are filled out by fishermen to monitor how many are caught.

Although Yellow Perch are a popular target for recreational anglers, it is a lower priority for fisheries managers in comparison to more intensively managed species such as Walleye. In 2015, the Lake Nipissing Fisheries Management Plan (OMNRF 2015) shifted to more of an ecosystem-based management approach and included goals and objectives for Yellow Perch. The key objectives were:

• To manage the Yellow Perch fishery in order to maintain and sustain the broader Lake Nipissing ecosystem and complex fish community and fisheries; and

• To better understand the relationship of Yellow Perch in a changing ecosystem and more specifically, the relationship between Walleye and Yellow Perch in Lake Nipissing.

This review was undertaken by the Ontario Ministry of Natural Resources and Forestry (MNRF) to assess the status of Yellow Perch in Lake Nipissing. Data has been compiled from existing fishery-dependent and fishery-independent data. Fisheries assessment programs have taken place since the 1970's: open water and winter roving creel surveys (1972 to 2019) and Fall Walleye Index Netting Surveys (1998 to 2019). This review will determine the status of the Yellow Perch population by looking at trends over time and looking at biological indicators to determine its sustainability. The final results will help inform future fisheries management decisions (i.e., regulations) while taking into consideration the changing ecosystem. Consequently, this report will summarize data from 1985 to 2019 Creel surveys and 1989 to 2019 FWIN surveys, because this is when data was consistently collected for Yellow Perch. Main purpose of this report is to: (1) analyses fishery-dependent (e.g., catch, harvest, and effort) and fishery-independent (e.g., growth and mortality) (2) assesses the status of the resource; and (3) identifies future monitoring needs.

2 – Methods

2.1 Study Area

Lake Nipissing (46° 16' 54", 80° 0' 0") is a large (≈87,325 ha) lake located on the Precambrian shield in northeastern Ontario. It is a shallow (mean depth 4.5 m, maximum depth 52 m), mesotrophic (2003-04 total phosphorus 17.5 $\mu \bullet L^{-1}$), slightly basic (2003-04 pH 7.1), productive lake which drains into Georgian Bay via the French River (Dunlop 1997, Clark et al. 2010). The main inflows are the Sturgeon River, Lavase River, Wasi River and South River.

Lake Nipissing has a diverse fish community comprised of forty-two species including Walleye, Yellow Perch, Northern Pike (*Esox lucius* (Linnaeus, 1758)), Muskellunge (*Esox masquinongy* (Mitchill, 1824)), Smallmouth Bass (*Mircopterus dolomieu* (Lacepède, 1802)), Largemouth Bass (*Micropterus salmoides*, (Lacepède, 1802)), White Sucker (*Catostomus commersoni* (Lacepède, 1803)), Cisco (*Coregonus artedi* (Lesueur, 1818)), Lake Whitefish (*Coregonus clupeaformis* (Mitchill, 1818), and Lake Sturgeon (*Acipenser fulvescens* (Rafinesque, 1817)). Yellow Perch are a prolific cool-water species that thrives in warm to cool water habitats and are most abundant in the open water of lakes with moderate vegetation, clear water, and bottoms of muck or sand and gravel (Scott and Crossman 1973).

Lake Nipissing is a popular destination for recreational anglers, easily accessible by two large populations (North Bay, population ≈54,000; West Nipissing, population ≈14,000) and many small communities (Nipissing Township, Callander, Verner). Lake Nipissing is also a popular fishing destination for Ontario residents as it is located approximately 350 km north of the city of Toronto. There are over 125 tourist establishments on Lake Nipissing that depend on the fisheries resource for their livelihood (Morgan 2019). As well, the lake supports Indigenous fishing with two First Nations situated on the shoreline: Dokis First Nation (population ≈200) and Nipissing First Nation (NFN) (population ≈1,400), and nearby Algonquin and Metis communities. Unique to Lake Nipissing, NFN also has a court-recognized treaty right to commercially fish the lake (NFN 2020).

2.2 Fisheries Assessments Methods

Data has been compiled for the Yellow Perch review from fishery-dependent and fishery-independent data. Fishery-independent data comes from statistically-designed standardized Fall Walleye Index Netting surveys (Morgan 2002), while fisheries-dependent data is information that comes from recreational and commercial fishery including, roving angler surveys conducted by MNRF in the winter and open water season, and commercial harvest monitoring data conducted by NFN natural resource department.

The MNRF has been conducting the provincially standardized Fall Walleye Index Netting method (Morgan 2002) annually on Lake Nipissing since 1998. This is the longest, uninterrupted Walleye abundance survey of any inland lake in Ontario. Benthic gill nets (60.8 m long by 1.8 m deep) with multiple mesh sizes (25, 38, 51, 64, 76, 102, 127, and 152 mm) were set for 24 hours when the water temperature was between 10 and 15 ^{o}C. A total of forty-eight index nets are semi-randomly set across the lake, stratified among two depth strata (shallow 2-5 m, and deep 5 – 15 m) with spatial coverage (minimum of 3-4 sets in the West Arm sector, 3 sets in West Bay sector, 3 sets in the Callander Bay sector, 4 sets in the South Bay sector, 4 sets in the French River sector). More details about how sampling effort and spatial allocation changed over the years can be found in Morgan (2019). During processing of the survey catch, all species were enumerated, and measured for total length (mm). Additionally, Walleye, Northern Pike, Bass, and Muskellunge were sampled for age, weight, and internally examined to determine sex and classify the state of gonad maturation. However, only a subset of Yellow Perch had weight, sex, and maturity state determined and aging structures collected: 1998 to 2001, 2007 to 2010, and 2014 to 2019. Aging structures collected were scales and otoliths (Mann 2004).

Roving angler surveys conducted by MNRF in the winter and open water season are the main fisheries-dependent data collected from the recreational fishery. Roving angler surveys have been conducted on Lake Nipissing since 1972 and are used to collect information on recreational fishing effort, catch rates, harvest levels, and types of users. Starting in 1985, data on Yellow Perch was collected in open and winter creels so this is the time series that will be analyzed in this report. Rowe and Seyler (2000) shows that the survey design gives precise estimates of catch and effort for the three most sought-after species: Walleye, Northern Pike, and Yellow Perch. Creels are conducted throughout the entirety of the fishing season, so long as ice conditions or boating circumstances are safe. Lake Nipissing has been divided into seventeen sampling sectors based primarily on historical fishing pressure distribution (Figure 1 and Figure 2) (Jorgensen 1986). On average, three sectors are sampled each day. Creel is stratified by work day or non work day, area, and season. Each sector is sampled a minimum of four times (two work days (Monday to Friday) and two non-work days (Saturday, Sunday, and statutory holiday)) over a season period. Winter has two season periods: 08:00 to 17:00 in January and 09:00 to 18:00 in February and March. Summer has three seasons, divided by two periods: AM shift: 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). The creel crew stays in a sector for two hours in which they interview a proportion of angling parties and records an activity count (i.e., active boats fishing or the number active of commercial ice huts, personal ice huts, and on ice angler groups). Data recorded includes: the total number of angler-hours fished per party, target species, the number of fish caught and harvested, residency of the anglers and their visitor type (e.g., permanent resident or resort guest, use of guide services, etc.). Fish kept by anglers are enumerated and sampled for total length (mm) and scale samples are taken for Walleye, Northern Pike, and a sub-sample of 100 Yellow Perch each month. Yellow Perch were not always biologically sampled for length or age structures during creel surveys, therefore fishing effort was determined from 1985 to 2019. Yellow Perch ages, as determined by interpretation of scale samples, were collected from 1972, 1985, 1988 to 1989, 1990, 1991, 1994, 1995, and 1997. Data was entered into Fishnet 2.0 (Lester & Korver, 1996) and validated for quality control purposes before analysis.

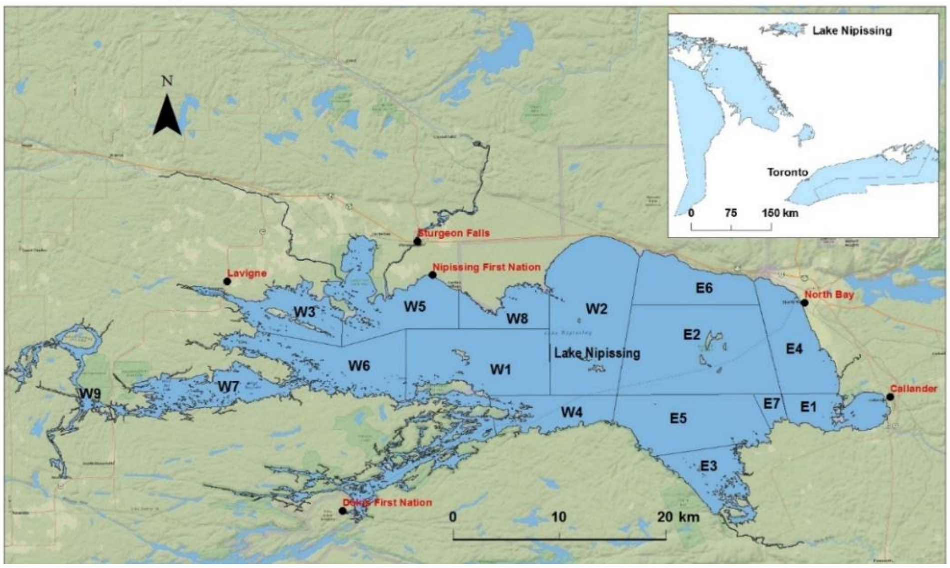

Figure 1. Lake Nipissing winter creel survey sampling sectors.

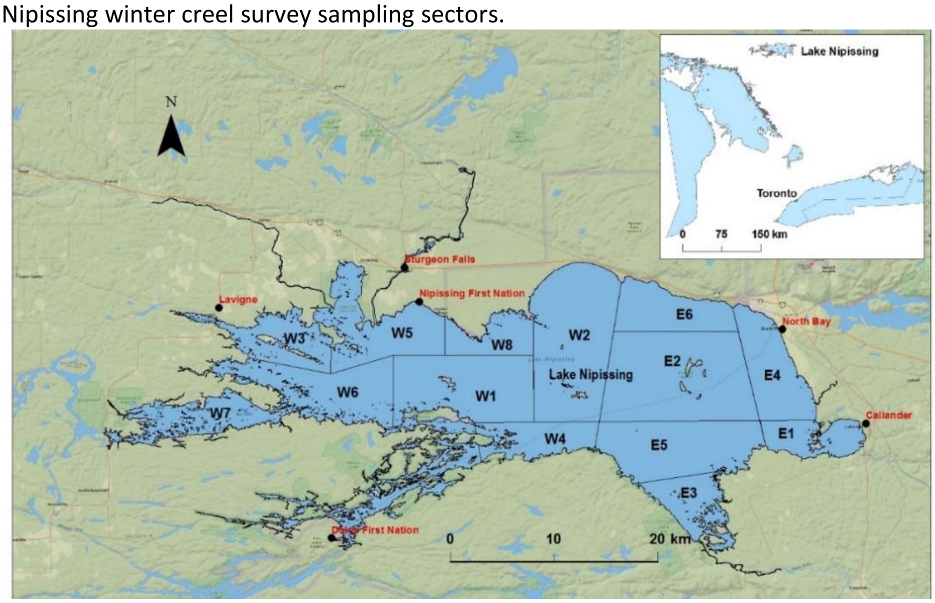

Figure 2. Lake Nipissing open water creel survey sampling sectors.

NFN natural resource department collects the other fisheries-dependent data on the lake with their commercial harvest monitoring program. Commercial fishermen began reporting their commercial Yellow Perch catch and harvest by number from 2009 to 2019. Prior to 2009 there is no recorded information on the nature or extent of this fishery. Perch are mainly considered an incidental catch.

2.3 Data Analyses – Methods

The number of Yellow Perch caught and harvested, angler success (number·angler-hour^{-1}), and fishing effort (angler-hours) was estimated for the recreational fishery using Fishnet 2.0 software (Lester and Korver 1996). Harvest was also expressed in weight (kg) by using the number of fish harvested multiplied by their average weight (g). Commercial harvest is expressed in number caught and number released, and percent catch from 2009 to 2019 (Nikki Commanda, NFN natural resources biologist, personal communication).

Relative abundance of Yellow Perch in the annual FWIN projects was calculated based on the number of fish that were captured per net per day (i.e., catch per unit effort or number of fish·net^{-1}). Length and age frequency distributions for Yellow Perch were calculated based on the fish sampled. Age at maturation (years) and size at maturation (total length, mm) were defined as the age and size when 50% of the population reached sexual maturation. This was primarily estimated using logistic regression.

Yellow Perch adult (≥2 years) instantaneous mortality rate (i.e., $Z_{\geq Age\ 2}$) estimates were based on the catch at age data from the FWIN samples, for the years where aging structures were taken (1998 to 2001, 2007 to 2010, and 2014 to 2019), using the Robson and Chapman's maximum likelihood estimator (Guy and Brown 2007).

Yellow Perch growth was characterized by fitting the "typical" von Bertalanffy growth model, using non-linear least squares estimation in the FSA package in R (Ogle et al. 2020., R Core Team 2013) using the FWIN samples. Additionally, to investigate potential changes in Perch growth rates in response to major changes in abundance of both Perch and Walleye in the lake, the von Bertalanffy growth model was also fit to each year's data and length at age 5 predicted from the model. To facilitate easier interpretation of results across various groups (e.g., years, sexes), t_o was fixed at -1 to keep the analyzes consistent for anyone who wants to compare with lake synopses results (Ontario Ministry of Natural Resources and Forestry, 2016)

for all model fitting. Confidence intervals for parameter estimates were constructed using bootstrap methods in the FSA package.

The typical von Bertalanffy growth model is:

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

Where L_t is the size (total length in mm) at age t, L_∞ is the maximum theoretical length (mm), k is the brody growth coefficient (·year^{-1}), and t_o is the theoretical age when length is zero.

Yellow Perch 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 2015 to 2019 Fall Walleye Index Netting observations for sexes combined, since the data for length and weight were checked for errors throughout the sampling process:

$$W = aL^B$$

Where W and L are weight and length respectively, log a is the coefficient determining y-intercept, and B is the slope of the line.

To represent the changing condition over time condition was measured as Fultons' K (Fulton, 1904), a good descriptor from a single population to show changes from discrete sampling events was estimated as;

$$K = W/(10^{-5}L^3)$$

Where W is the weight (g) and L the total length (mm). The exponent 3 is a typical value representing isometric growth, and the coefficient 10^{-5} is also a typical estimate for a (Guy and Brown 2007).

The non-parametric Mann-Kendall test was utilized to detect monotonic trends in the data series (Gilbert 1987). The null hypothesis, H_0, is that the data come from a population with independent realizations and are identically distributed. The alternative hypothesis, H_A, is that the data follow 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. We assumed a significance level of 0.05. LOESS (locally weighted smoothing), regression was used to plot trends that were statistically significant (Cleveland 1979). This local regression model creates a smooth line (smoothing factor for all LOESS regression models set to 0.4) through a time plot or scatter plot to see relationships between variables and foresee trends.

Stable isotope techniques can provide a measure of trophic position by showing the flow of energy through the different trophic pathways leading to an organism. This technique has been used to show food web interactions, effects of invasions on food web structure or differentiate trophic position between species with a complex diet (Vander Zanden et al. 1999, Post 2002). Consider that in lakes $\delta^{13}C$ is useful for differentiating between two major sources of available energy: littoral (near shore) production from attached algae and detritus that is enriched in $\delta^{13}C$ (less negative $\delta^{13}C$), and pelagic (open water) production from phytoplankton (more negative $\delta^{13}C$) (Post 2002, France 1997). Tunney 2018 also showed that factors like water transparency and/or increased abundance of pelagic prey can also shift offshore derived carbon in predators' diet. Yellow Perch (and other fish species) in Lake Nipissing rely on energy that originates from two different sources; 1) phytoplankton as the pelagic source and fish exploit it by consuming zooplankton, and 2) terrestrial and benthic primary production as the littoral source that finds its way to fish through benthic invertebrates. It is now well known that most north temperate fish species rely to a large degree on benthic invertebrate prey and littoral energy sources, especially for common littoral species, like Yellow Perch, where up to 70% of their food is derived from littoral-benthic sources (Vander Zanden et al. 2011).

Size spectra Analysis looks at the relationship between size (fork length) and $\log_2$ transformed catch per unit effort for all fish species combined and pooled into size bins (20 mm). Size spectra slopes calculated from linear regression of log transformed body size and catch per unit effort measures the energy transfer efficiency by looking at predator-prey ratios (with negative slope as energy shifts to larger and larger organism). Elevation is calculated as total catch per unit effort across all body sizes as separate indicator of community status and measures relative community production (Chu et al. 2016, Sprules and Barth 2016).

A two source $\delta^{13}C$ mixing model (Post 2002) was used to determine the Littoral-Benthic Reliance (BR) of Perch. This mixing model generates unique solutions for the relative importance of littoral food vs pelagic food sources. The calculations are based on average $\delta^{13}C$ values for the decadal Perch scale samples and two diet sources as end-members. For the two end-members, we used Lake Nipissing averages of Unionid clams as the pelagic source and snails as littoral sources (data provided by Dr. Tom Johnston, OMNRF research scientist). Littoral-Benthic Reliance was calculated for each sample and values were averaged over the decades using the formula in Vander Zanden et al. (2011).

$$BR = \frac{(\delta^{13}C_{Perch} - \delta^{13}C_{Pelagic\ End-point})}{(\delta^{13}C_{Littoral\ End-point} - \delta^{13}C_{Pelagic\ End-point})}$$

$\delta^{13}C_{Pelagic\ End\text{-}point}$ and $\delta^{13}C_{Littoral\ End\text{-}point}$ are the end-members for Unionid clams ($\delta^{13}C$ = -28.23 ‰) and snails ($\delta^{13}C$ = -19.00 ‰) , respectively. Note that BR values range from 0 to 1 and that its complement, 1 – BR, represents non-littoral-benthic reliance.

Trophic position (TP) was estimated using the equation for two nitrogen sources (Post 2002).

$$TP = \lambda + \frac{(\delta^{15}N_{Perch} - [\delta^{15}N_{Littoral\ End-point} * BR + \delta^{15}N_{Pelagic\ End-point} * (1 - BR)])}{3.4}$$

λ = is the trophic position in the food web (2 for secondary consumers like Perch), $\delta^{15}N_{Pelagic\ End\text{-}point}$ and $\delta^{15}N_{Littoral\ End\text{-}point}$ are the end-members for Unionid clams ($\delta^{13}N$ = 4.34 ‰) and snails ($\delta^{13}C$ = 3.50 ‰), respectively, and 3.4 is the total fractionation index for $\delta^{15}N$ (Post 2002).

However, the $\delta^{13}C$ isotopic signatures need to be corrected for the Suess effect, i.e., the isotopic depletion of the $\delta^{13}C$ signature of atmospheric carbon dioxide (CO_2) due to the admixing of isotopically depleted CO_2 from the burning of fossil fuels. Because the carbon in fossil fuels is isotopically depleted by around 18‰, the CO_2 released when that fuel is burnt is isotopically depleted (e.g., Verburg 2007). This depleted CO_2 results in isotopic depletion of the CO_2 in the air. The effect began in the 1700s at the beginning of the industrial revolution and the rate of isotopic depletion has been gradually increasing since that time. In food-web studies where the lifespan of the organisms studied does not extend beyond a few tens of years, a simpler correction for the Suess effect has been applied as a time-dependent correction of −0.022‰ per year (Chamberlain et al. 2005; Hopkins and Ferguson 2012) to all sample isotope values, except the present-day samples.

3.0 Results

3.1 Fisheries-Dependent Results

Yellow Perch were the second most sought-after species by anglers in winter and the third-most sought-after species in the open water period using pooled targeted effort from 1985-2019 (Figure 3). Since 2014 when catch limits were increased (50 for sport fish license and 25 for a conservation license), the total estimated effort targeting Yellow Perch by the recreational fishery ranged between 52,677 to 308,413 hours per year. As seen in Figure 4, over the whole time series (1985 - 2019) targeted fishing effort averaged 95,164 angling hours in the winter and averaged 27,197 angling hours for open water. There is a significantly decreasing trend in the open water targeted effort (Mann- Kendall's $S = -315$, $p<0.001$) for the whole time series 1985 - 2019. While there was no significant trend for winter targeted fishing effort for the whole time series ($S=-59$, $P=0.41$), there was a slight decreasing trend in fishing effort targeting Yellow Perch from 1985 to 2002 ($S = -61$, $p<0.05$) and an increasing trend from 2004 to 2019 ($S = 98$, $p < 0.001$) (Figure 4).

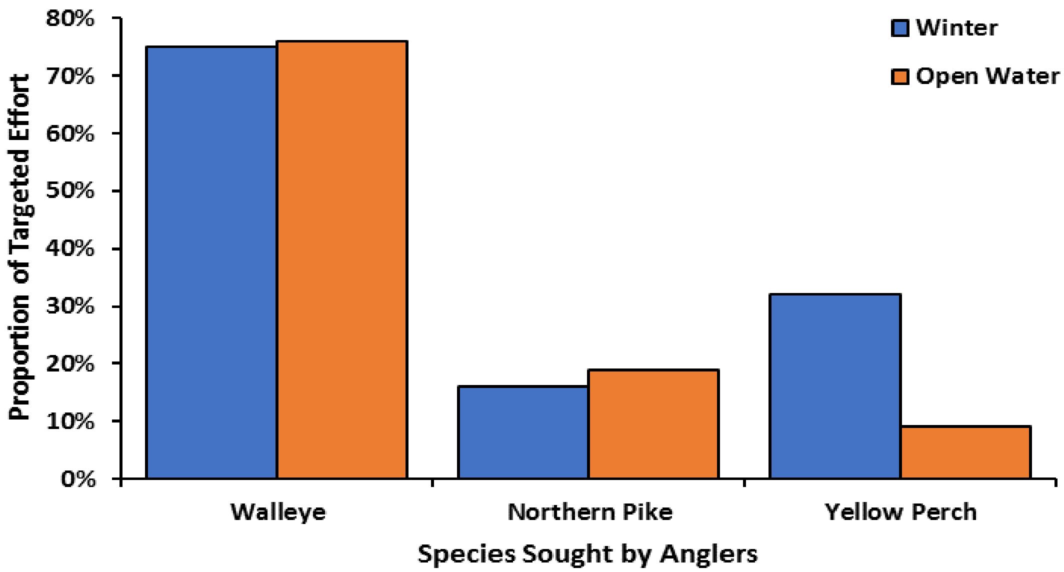

Figure 3. Proportion of fishing effort (angler-hours) targeting pooled effort from 1985-2019 for Walleye, Northern Pike, and Yellow Perch during the winter and open water creel surveys. Targeted angler effort is the amount of time in hours that an angler spends fishing for a specific species.

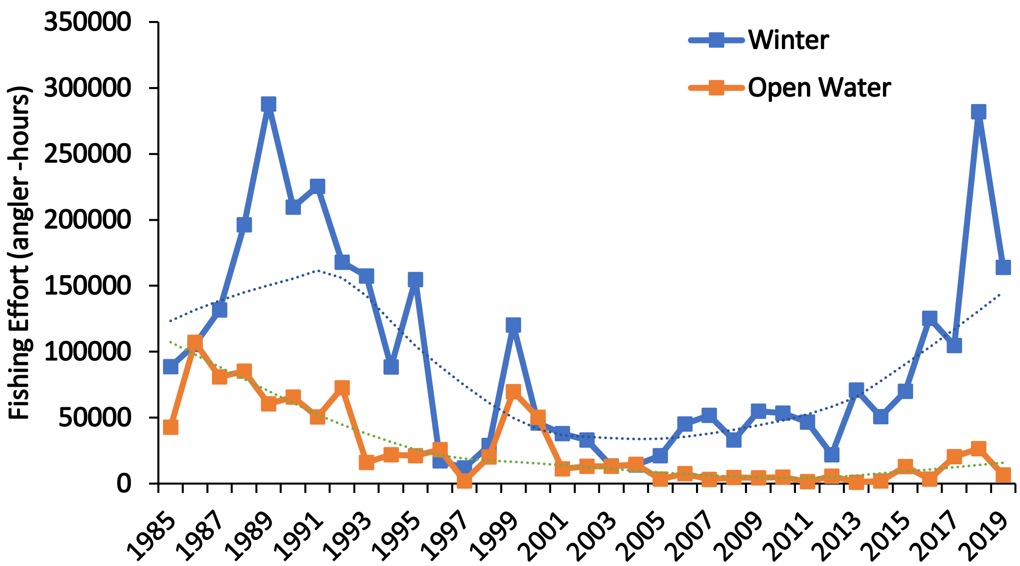

Figure 4. Estimated fishing effort (angler-hours) targeting Yellow Perch in the winter and open water creel surveys 1985 to 2019. Significant trend lines (LOESS regression) for winter and open water time series is also plotted as dashed line.

Over the time series the average annual total catch was 171,827 fish·year^{-1}, with the winter season averaging 122,036 fish·year^{-1} and the open water season catch averaging 49,790 fish·year^{-1} (Figure 5). The average annual harvest was 110,411 fish·year^{-1}, with the winter season averaging 93, 035 fish·year^{-1} and the open water season averaging 17,375 fish·year^{-1} r (Figure 6). Over the time series, the majority (84%) of the annual harvest of Yellow Perch came from the winter fishery. In the open water season, there was a decreasing trend in the reported number of Yellow Perch caught (S = -281, p = <0.001, Figure 5) and harvested (S = -323, p = <0.001, Figure 6), as well as, a significant decreasing trend in the total weight harvested (S = -301, p = <0.001, Figure 7) and harvest per unit effort (S = -139, p = <0.001, Figure 8), with no trends evident in the winter season. However, there has been a slight upward trend in the average size of Yellow Perch harvested in the winter season from 1985 to 2019 (S= 101, p = 0.04, Figure 8), with no significant trend in the open water fishery. Since the new regulation was implemented in 2014, the number of Yellow Perch harvested has ranged from 65,865 to 117,529 fish·year^{-1} or 13,118 to 23,136 kg·year^{-1}. The average size of Yellow Perch harvested since 2014 has ranged from 238g in the summer to 244g in the winter (Figure 8). Fishermen were as successful in the open water as they were in the winter fishing season, catching 1.03 Yellow Perch·angler-hour^{-1} and 0.89 Yellow Perch·angler-hour^{-1} respectively (Figure 10). Yellow Perch made up only 2% of the reported commercial catch, with an average of 723 Yellow Perch·year^{-1} (Table 2). The size of Yellow Perch in Lake Nipissing is too small on average to be marketable and the bycatch is low because of the size (3.75” or 95 mm mesh size) of the commercial nets used.

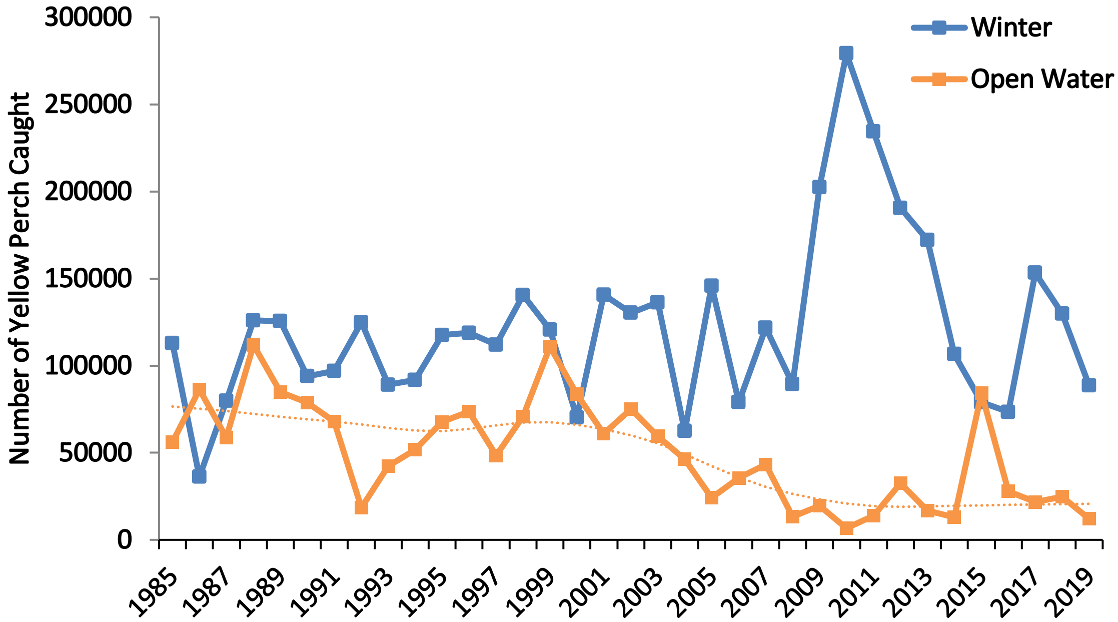

Figure 5. Estimated number of Yellow Perch caught from the winter and open water creel surveys 1985 to 2019. Significant trend lines (LOESS regression) for winter and open water time series is also plotted as dashed line.

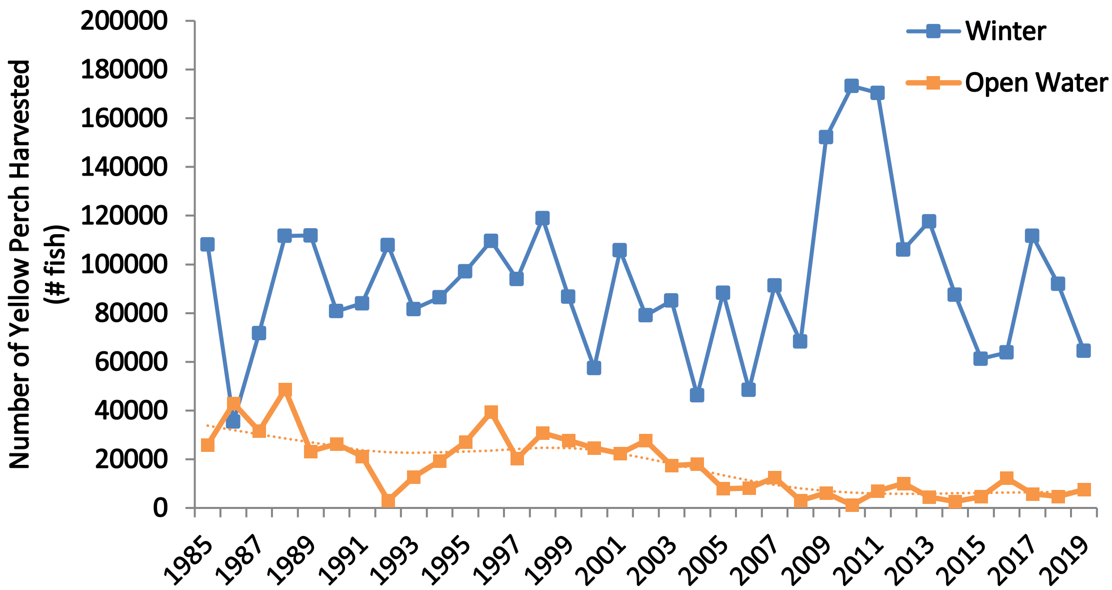

Figure 6. Estimated number of Yellow Perch harvested from the winter and open water creel surveys 1985 to 2019. Significant trend lines (LOESS regression) for winter and open water time series is also plotted as dashed line.

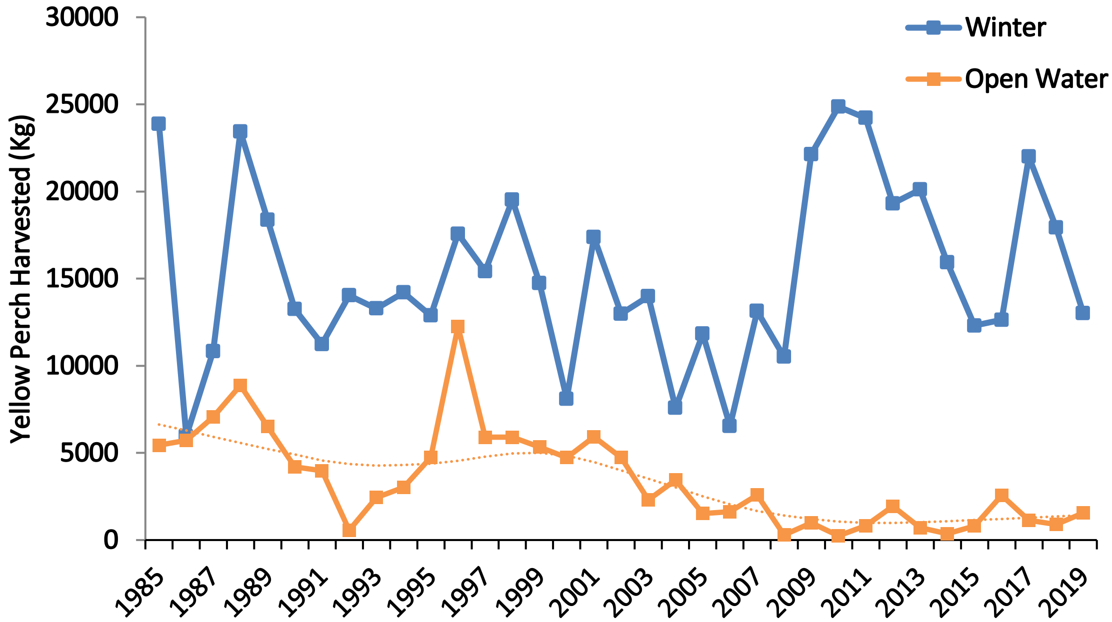

Figure 7. Estimated harvest (kg) of Yellow Perch from the winter and open water creel surveys 1985 to 2019. Significant trend lines (LOESS regression) for winter and open water time series is also plotted as dashed line.

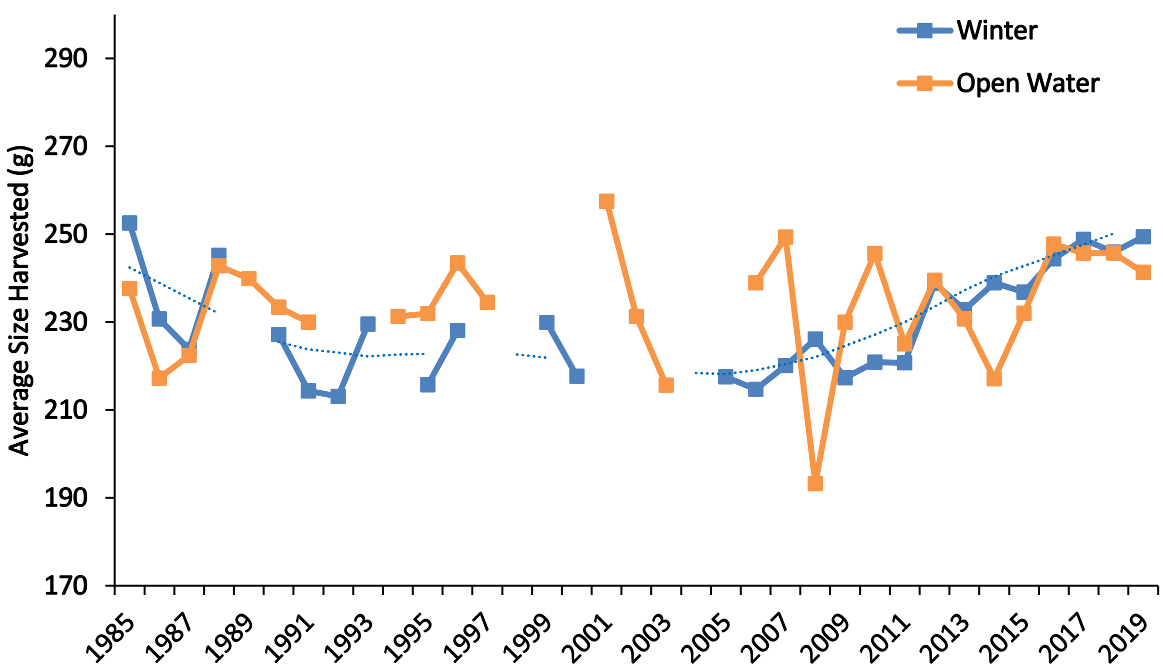

Figure 8. Estimated average weight (g) of Yellow Perch harvested from the winter and open water creel surveys 1985 to 2019. Significant trend lines (LOESS regression) for winter time series is also plotted as dashed line.

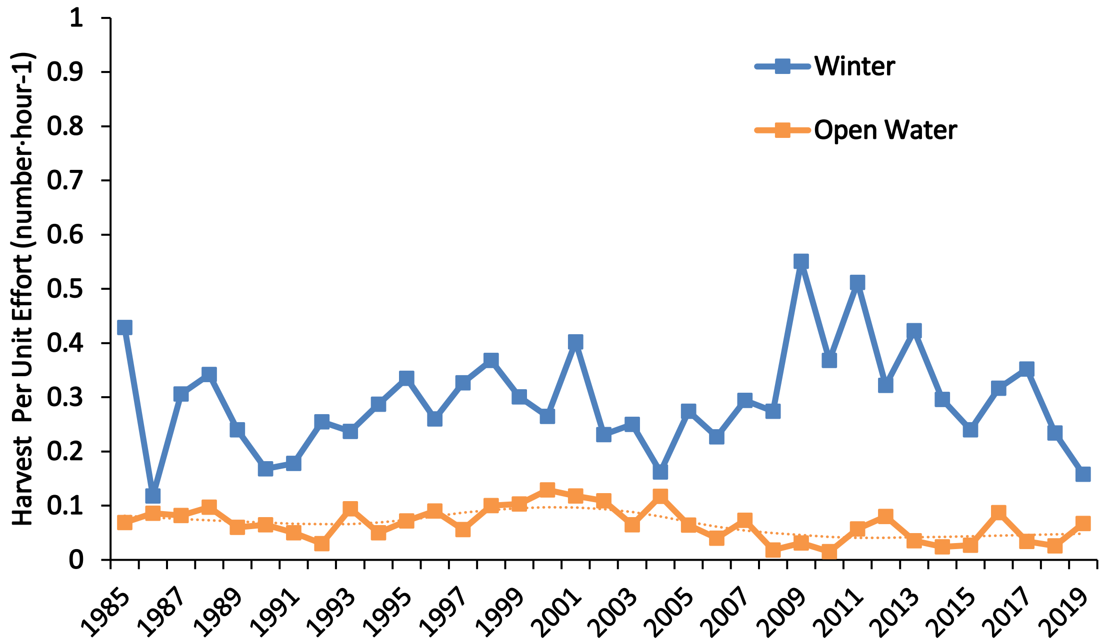

Figure 9. Harvest per unit effort (number·hour-1) for Yellow Perch from the winter and open water creel surveys 1985 to 2019. Significant trend lines (LOESS regression) for open water time series is also plotted as dashed line.

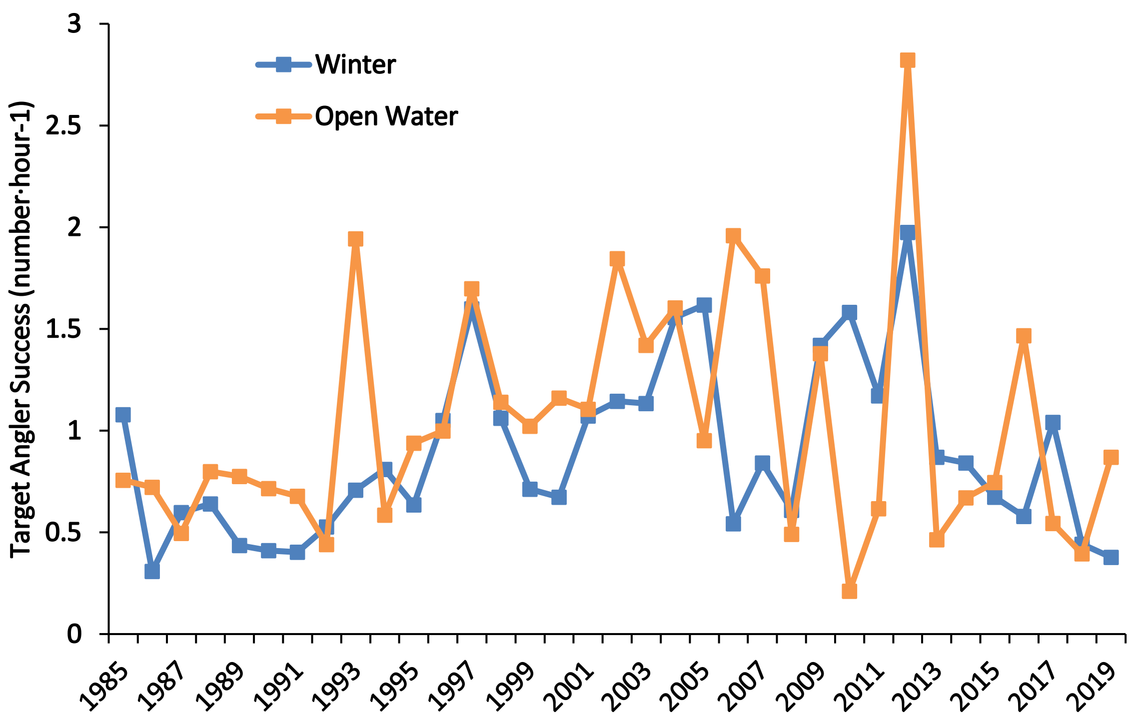

Figure 10. Targeted angler success (number·hour-1) for Yellow Perch from the winter and open water creel surveys 1985 to 2019. No significant trends.

Table 2. Number of Yellow Perch harvested by Nipissing First Nation commercial fishers as reported on their daily catch forms 2009 to 2019.

Year	Number of Yellow Perch Harvested	Percent of Catch (%)
2009	1102	1%
2010	1687	1%
2011	937	2%
2012	986	2%
2013	689	2%
2014	783	2%
2015	645	3%
2016	266	1%
2017	221	1%
2018	412	2%
2019	226	1%
Average	723	2%

3.2 Fisheries-Independent Results

The annual fisheries assessment program FWIN has documented a two- fold increase in Yellow Perch abundance, measured as catch per unit effort for fish of all sizes ($S = 81$, $p = <0.05$, Figure 11)). Additionally, a significant increase in CUE of Yellow Perch ≥200 mm ($S=145$ $P <0.001$) has occurred. However, after 2008, there was a statistically significant decline for all sizes of Yellow Perch ($S = -48$, $p = <0.001$) but not for Yellow Perch ≥200 mm ($S=4$, $p=0.84$) (Figure 11). Figure 12 shows the same trends in biomass per net (WPUE), for fish of all sizes ($S=133$, $P<0.001$), and Yellow Perch ≥200 mm ($S=145$, $P<0.001$) (Figure 12).

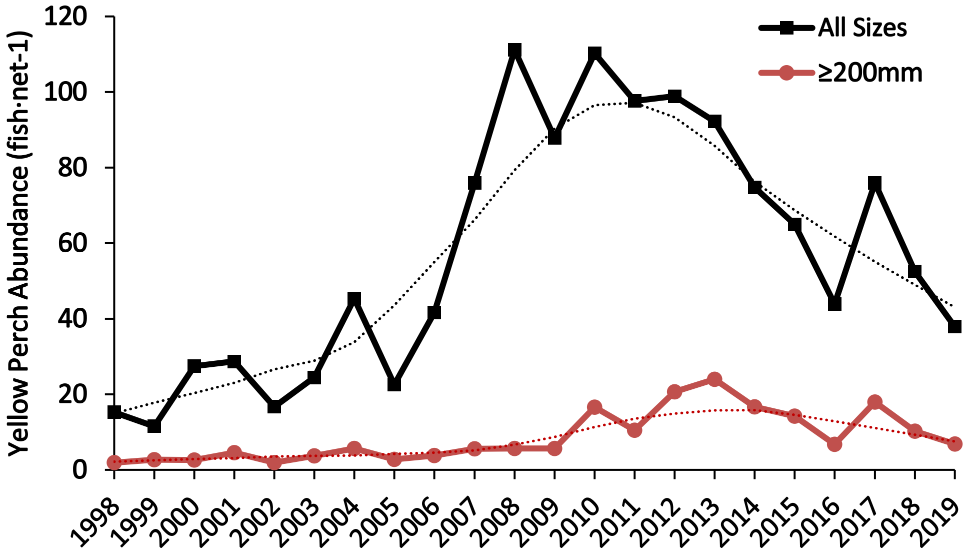

Figure 11. Yellow Perch catch per unit effort (fish·net^{-1}) from the Fall Walleye Index Netting surveys from 1998 to 2019. Significant trend lines (LOESS regression) for open water time series is also plotted as dashed line.

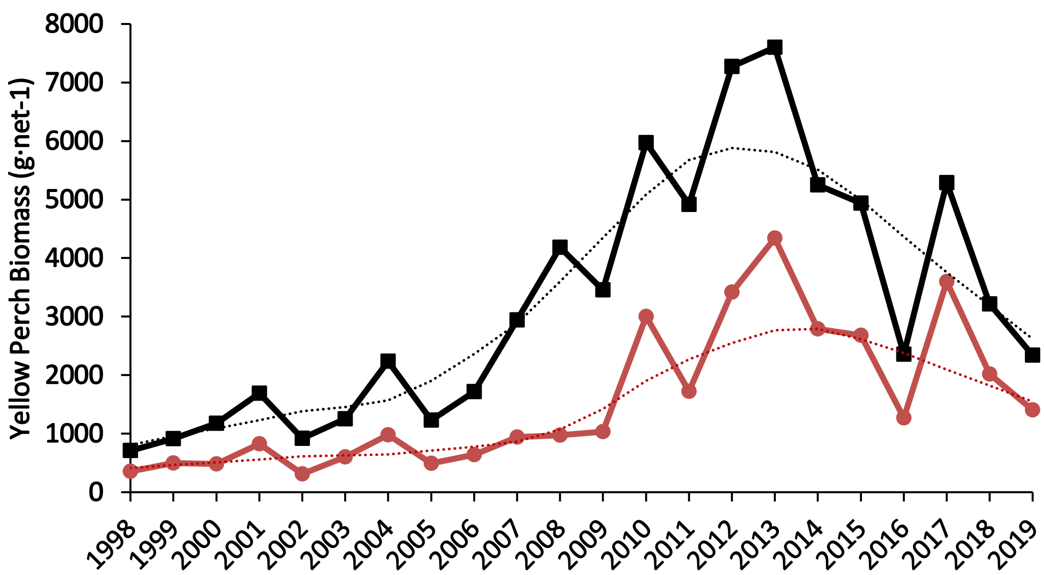

Figure 12. Yellow Perch biomass per unit effort (g/net) from the Fall Walleye Index Netting survey 1998-2019. Significant trend lines (LOESS regression) for open water time series is also plotted as dashed line.

The average age of Yellow Perch showed a slight increase over the whole time series (S=38, $p<0.05$, Figure 13) from 3.3 years to 4.2 years. Currently, the Yellow Perch population in Lake Nipissing is robust with 12 year classes in the 2019 FWIN survey (Figure 14). Age frequency data for the other years of the FWIN program are shown in Appendix 3. On average, male Yellow Perch reach 50% maturity at 101 mm or 0.9 years of age, and Female perch reach 50% maturity at 150 mm or 2 years of age (Appendix 8), with no increasing or decreasing trends over time.

Yellow Perch length relationship for sexes combined was estimated as $W=10^{-5.51}L^{3.25}$, N=1350 R^2 =0.99 and is shown in Figure 15.

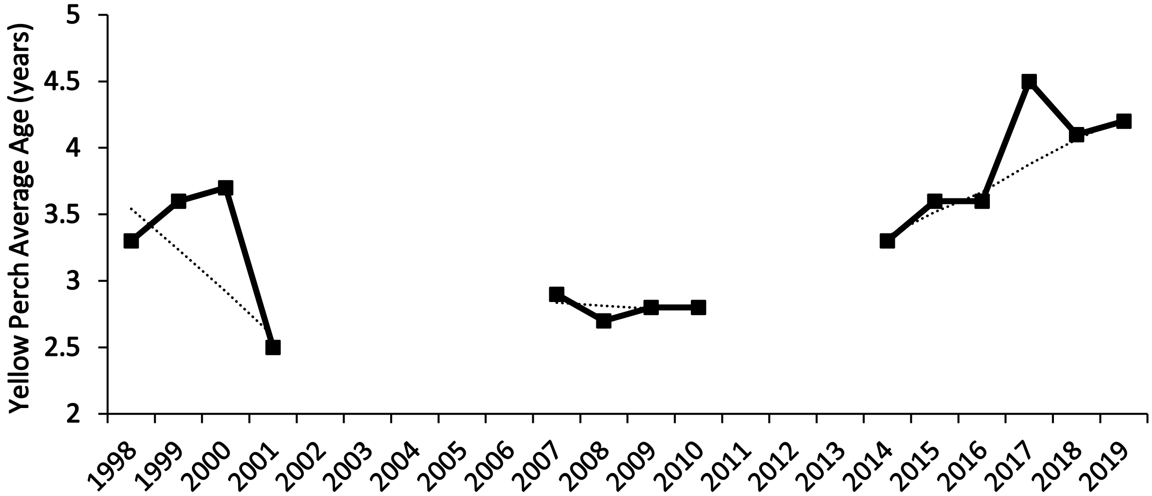

Figure 13. Yellow Perch average age (years) from the Fall Walleye Index Netting survey 1998 to 2019. Significant trend lines (LOESS regression) for open water time series is also plotted as dashed line.

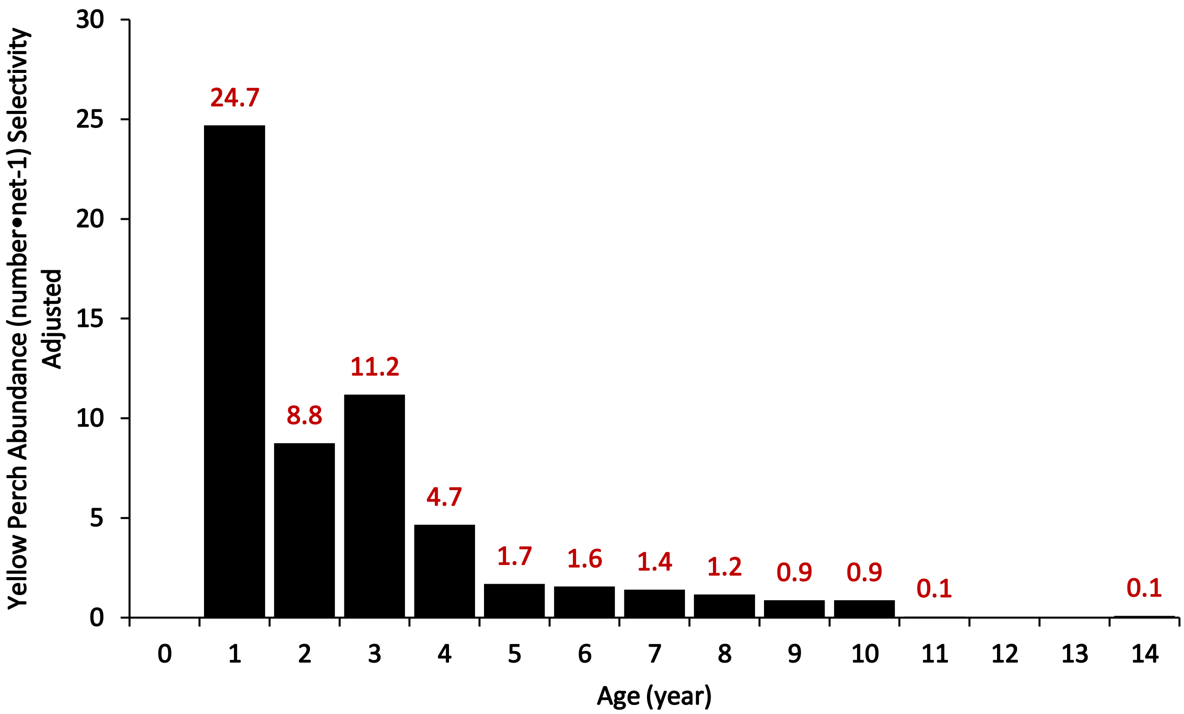

Figure 14. Yellow Perch age frequency distribution (number•net^{-1}, values shown as red numbers on each bar) corrected for net selectivity (Appendix 7 shows correction factors) from the 2019 Fall Walleye Index Netting survey.

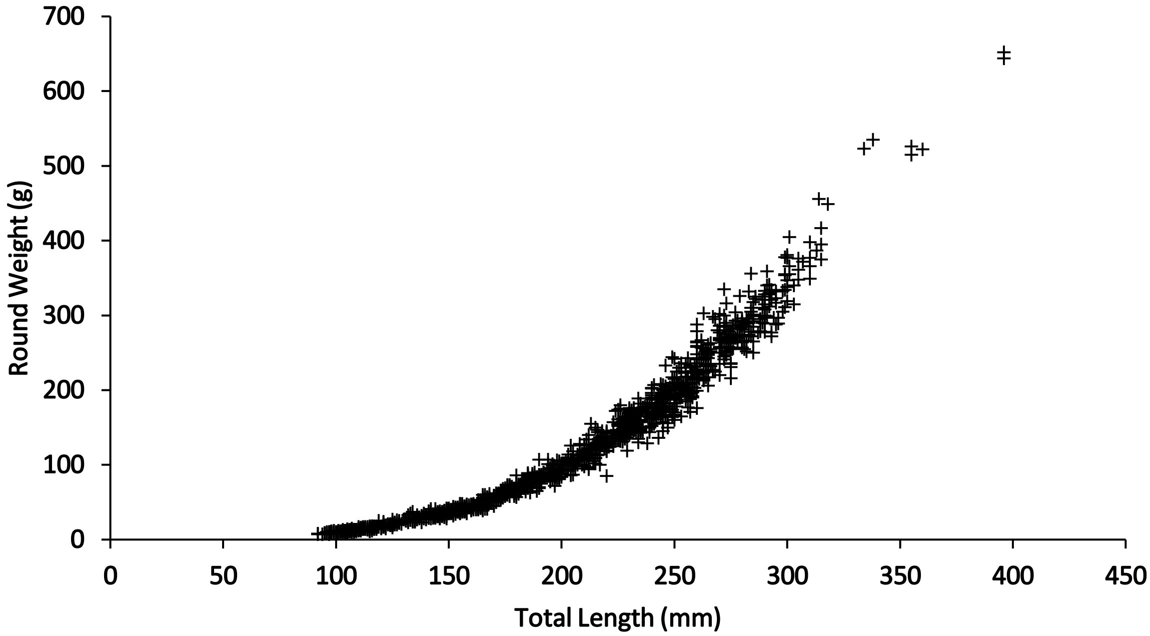

Figure 15. Yellow Perch length-weight relationship, sexes combined, from the Fall Walleye Index Netting surveys 2015 to 2019. Weight=$10^{-5.51}$Total Length $^{3.25}$, N=1350 R^2 =0.99, $p < 0.01$.

There was no significant change in the Fulton's K condition of Yellow Perch over the timeseries (Figure 16).

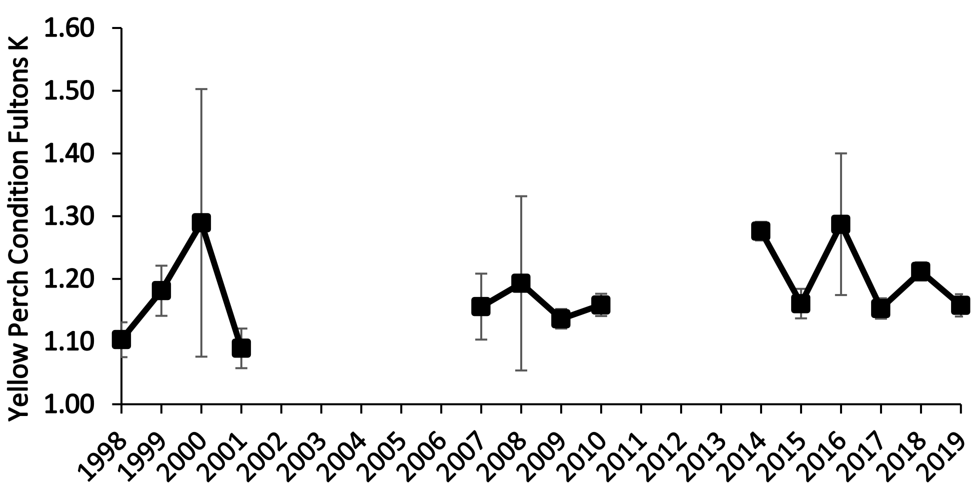

Figure 16. Yellow Perch condition (Fulton's K) from the Fall Walleye Index Netting surveys 1998 to 2019, 95% CI.

Yellow Perch total instantaneous adult mortality ($Z_{\geq Age\ 2}$) has declined since 1998 (S = -43, p = <0.5, Figure 17). The average mortality rate for the time series $Z_{\geq Age\ 2}$= 0.59 (or an annual mortality of 44%). Since the new regulations were put in place in 2014, the $Z_{\geq Age\ 2}$ for Yellow Perch averaged 0.47 (or an annual mortality rate of 38%).

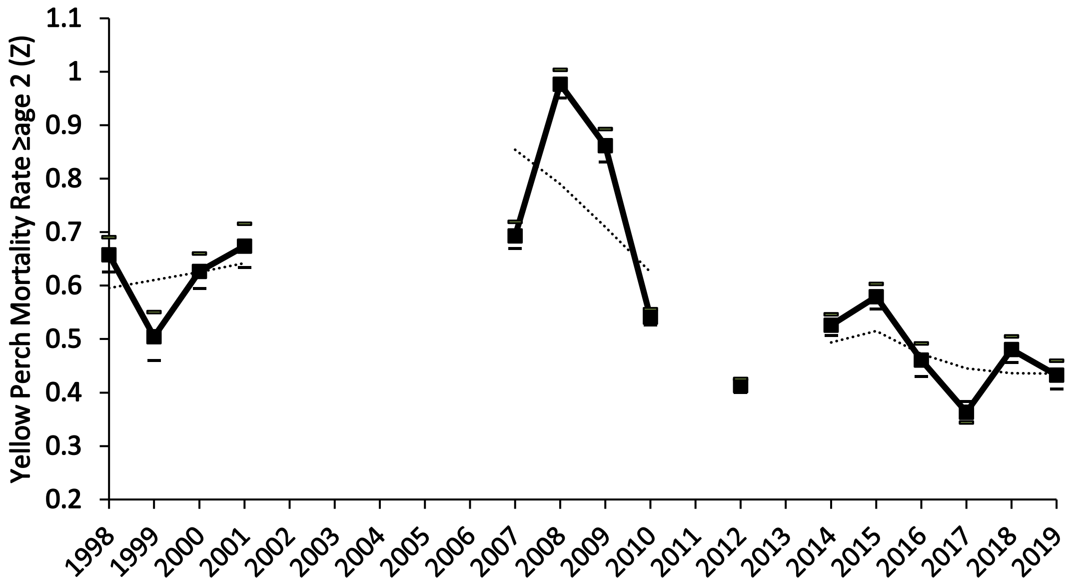

Figure 17. Yellow Perch adult (>2 years old) mortality rates estimated from age distributions Fall Walleye Index Netting surveys from 1998 to 2019. Significant trend lines (LOESS regression) plotted as dashed line, and 95% confidence limits (dashes).

3.3 Ecological Trends

Biomass of Yellow Perch increased from 2007 and peaked in 2013, while the biomass of Walleye ≥350 mm (i.e., exploitable stock size) started declining in 2007 reaching lowest levels in 2010 and has since started to rebuild (Figure 18).

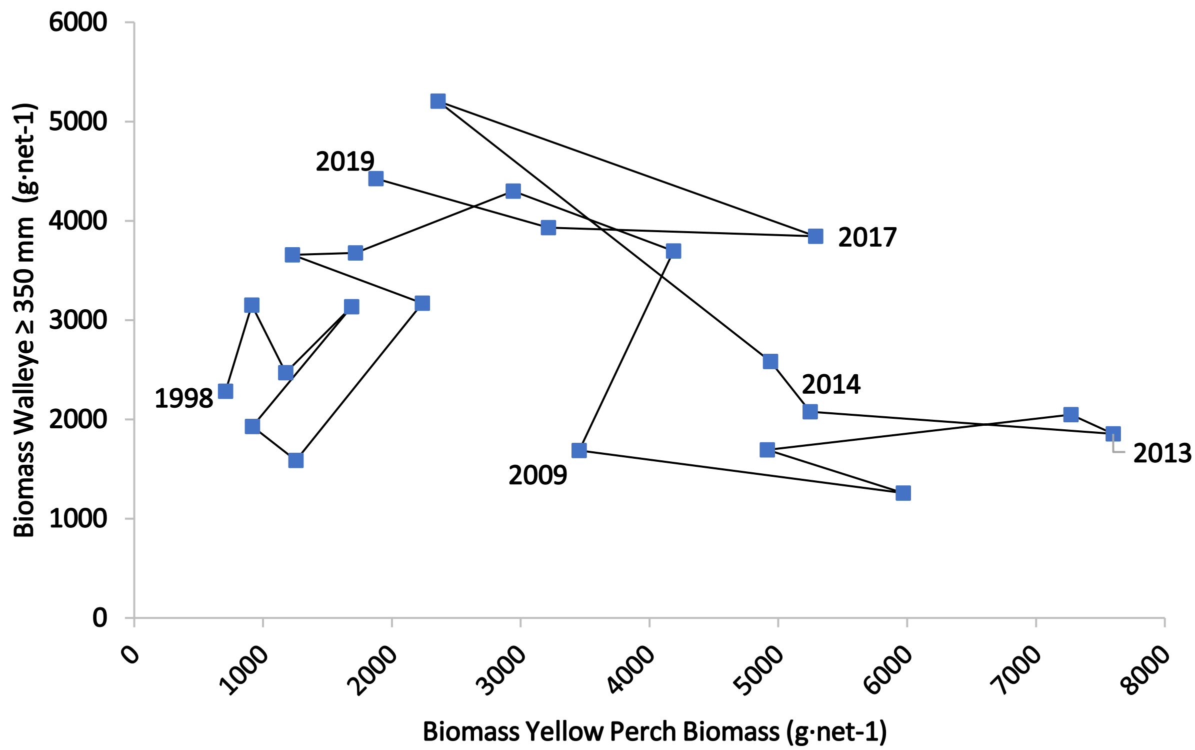

Figure 18. Biomass of Yellow Perch and Walleye ≥350mm over the Fall Walleye Index Netting time series 1998 to 2019.

During the time from 1993 to 2019, that Double-crested Cormorant nests have been counted on Lake Nipissing, there has been an increasing trend in the early 2000's and plateau since 2004 (S =154, p = <0.001, Figure 19). One of the main diet items of the Double-crested Cormorant in Lake Nipissing is the Yellow Perch (Lecours 2017). The increase in number of Cormorants has not appeared to have an impact on the abundance of Yellow Perch in Lake Nipissing. When looking at the size spectra in Lake Nipissing, there was a statistically significant decreasing trend in the slope (S=-87, p= <0.05) and an increasing trend in the elevation (S=-83, p= <0.05) (Figure 20).

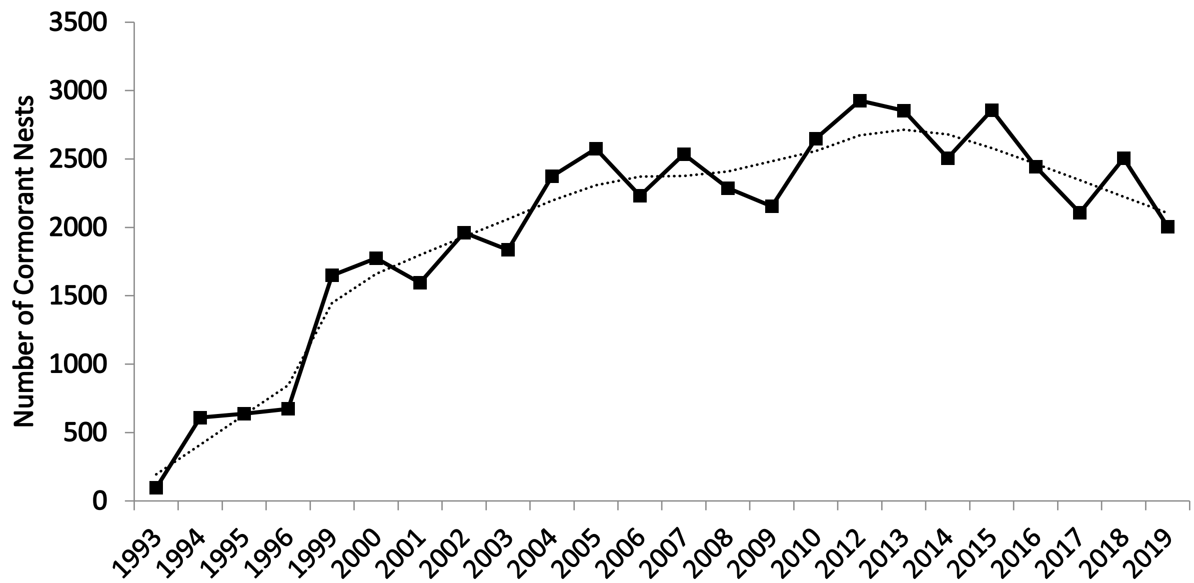

Figure 19. Total number of active cormorant nests on Lake Nipissing. Significant trend lines (LOESS regression) plotted as dashed line.

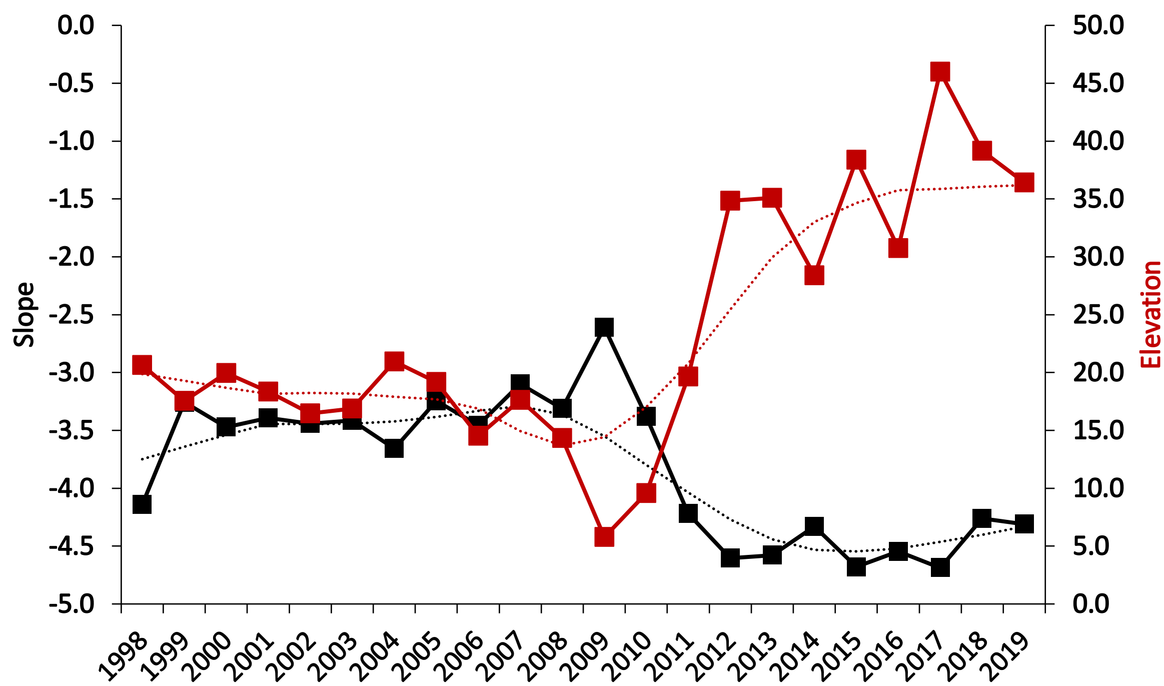

Figure 20. Size Spectra Analysis for Lake Nipissing fish community using 1998 to 2019 Fall Walleye Index Netting data. Significant trend lines (LOESS regression) plotted as dashed line.

In Lake Nipissing Benthic Reliance gradually declined from the 1970's (BR ≈ 0.60) to the 1980's (BR ≈ 0.50), remained relatively stable until the 2000's then further decreased in the 2010's (BR ≈ 0.40) (Figure 21). Yellow Perch trophic position gradually increased from the 1970's to the 2010's by approximately one-half-of-a-trophic-level (Figure 22).

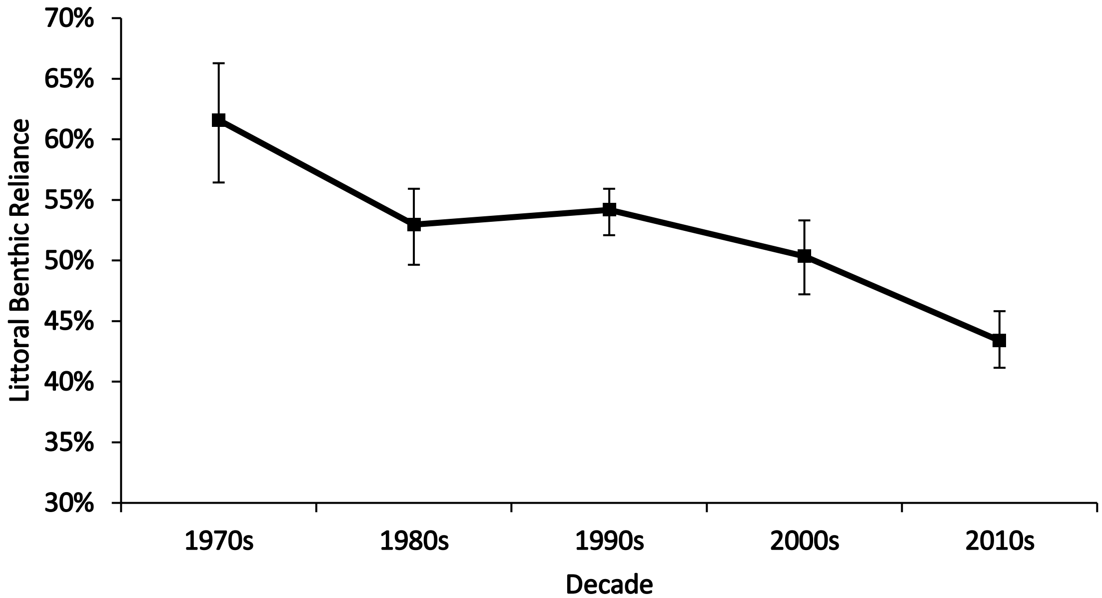

Figure 21: Lake Nipissing Littoral Benthic Reliance illustrated by decade, with bootstrapped CI.

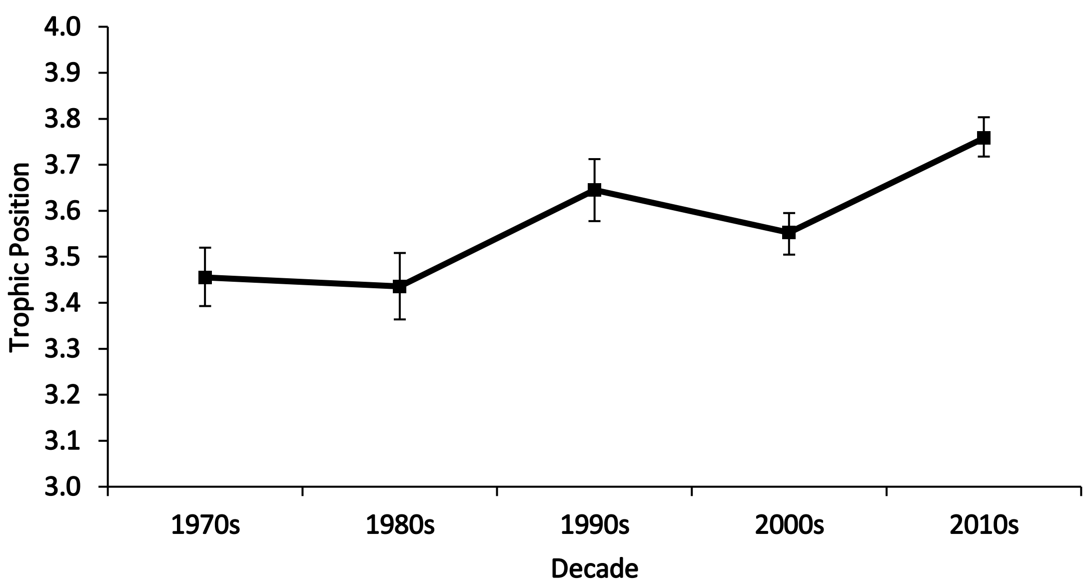

Figure 22: Trophic position of Yellow Perch in Lake Nipissing illustrated by decade with bootstrapped CI.

4.0 Discussion

Yellow Perch play a growing role in the Lake Nipissing fishery and are a significant contributor to the local economy. Lake Nipissing has been a premier fishing destination in northeastern Ontario for decades. On average anglers spend 123,028 hours per year (ranging 52,677 - 308,413 hours per year hours) targeting Yellow Perch. In 2014, new regulations increased the catch limits (Sports License 50) and encouraged anglers to switch their effort towards Yellow Perch (MNRF 2015). The management plan recognised the importance of the annual index netting to monitor fisheries trends, evaluate sustainable harvest levels, and to determine if regulations are appropriate. Fisheries indices suggest that the current catch limits are sustainable, and that Yellow Perch is not presently being overexploited. Although there has been a decrease in Yellow Perch abundance since 2013, there is no indication this decrease is due to an increase in fishing pressure as there were no marked increase in harvest. Yellow Perch are especially popular fish to target in the winter fishery with effort increasing in recent years. The open water recreational Yellow Perch fishery has seen a decrease in fishing effort, catch, and harvest rate but with diverse fishing opportunities present in Lake Nipissing – Walleye, Northern Pike, Muskellunge, Small and Largemouth Bass, this trend is less concerning.

The plan's goal is to manage the Yellow Perch population at appropriate levels to maintain and sustain the broader Lake Nipissing ecosystem. As well, to rebuild the Walleye population efforts were made to attempt to redirect fishing pressure onto Yellow Perch (MNRF 2015). The current Yellow Perch population is healthy, with relative abundance being doubled that of the beginning of the time series, with 37.83 yellow perch·net^{-1} caught in 2019, compared to 14.94 yellow perch·net^{-1} in 1998. As well the catch per unit effort of large (>200 mm) Yellow Perch are increasing in the population, with 7.55 yellow perch·net^{-1} in 2019 compared to 2.17 yellow perch·net^{-1} in 1998. Other indicators of a heathy Yellow Perch population include; multiple age classes present in the population, increasing average age, decreasing mortality, and increasing size of Yellow Perch caught in the winter. Lake Nipissing Female age at maturity for Yellow Perch of 2 years of age is similar to other female Yellow Perch populations in the French River, Lake Manitou, Bay of Quinte, and Rice Lake (Purchase et al 2015).

Over a 35-year period (1985-2019), the relative abundance of Walleye and Yellow Perch diverged in Lake Nipissing. This trend was like that in Sagninaw Bay where Yellow Perch and Walleye Populations in 1980-2008, where they noted Walleye abundance increased, while relative abundance of older (age 1-2) Yellow Perch declined (Ivan et al 2011). As well, when the mean size at age of Walleye decreased in Saginaw Bay, the size at age of Yellow Perch increased. When considering a forage fish like Yellow Perch, it is informative to look at ecological interactions (Rudstam 1996). In aquatic ecosystems, one way to model trophic cascades involves size spectrum, where the community is composed of traits (asymptotic body size) rather than species, and each trait is represented by a separate spectrum of body size (Sprules and Barth 2016). Progression between size classes represents growth, recruitment, and mortality. The key process in the model is prey selection, which is assumed to be solely on the basis of the size difference between predator and prey rather than on traits (Rossberg 2012). In Lake Nipissing, the increase of small-sized fish like Yellow Perch might be a consequence of the predation release from large-bodied predators, for instance when Walleye biomass was at it's lowest in 2009 and the Yellow Perch abundance peaked in 2008, this switch from relatively large to small-sized fish is indicated by the decrease in size spectrum slope. On a similar note, higher size spectrum intercept may be an indicator of productivity provided you control for variation in slopes (Chu 2016). This is probably not the case as you can see from Figure 20, which shows a strong negative association between slope and intercept. This might indicate more potential competition between smaller Walleye and other fish species like Yellow Perch (Fulhart 2002). However, in the future if Walleye abundance continues to recover and increase it is likely that these trends will reverse and Yellow Perch abundance may be affected. Another notable trend that has occurred around the same time period is the increase in Yellow Perch size at age five since 2010, which is also the time where Yellow Perch shows a decrease in mortality and an increasing average age.

Another predator of Yellow Perch is the Double-crested Cormorant which re-established a population on Lake Nipissing in the 1990's to early 2000's. The population of Double-crested Cormorants on the lake appears to have reached an equilibrium. A masters study completed by Matt Lecours (2017) showed that Yellow Perch made up 42% of the diet of Double-crested Cormorants on Lake Nipissing. This predator-prey interaction could benefit the recovery of the Walleye population as juvenile Walleye compete with Yellow Perch.

In Lake Nipissing Littoral Benthic Reliance gradually declined from the 1970's (BR ≈ 0.60) to the 1980's (BR ≈ 0.50), remained relatively stable until the 2000's then further decreased in the 2010's (BR ≈ 0.40) (Figure 21). As the Walleye population declined (Morgan 2012) Yellow Perch appear to have obtained greater access to pelagic resources (and possibly occupied more offshore habitats) once released from the predation pressure exerted by the Walleye (and other predators). With the establishment of Spiny Water Flea in the lake 2000's, Yellow Perch appeared to increase their use of pelagic food resources.

Yellow Perch reliance on pelagic food has increased from the 1970's to the 2010's (Figure 22). Three potential explanations exist for greater pelagic feeding by Perch in Lake Nipissing. As the Yellow Perch abundance increased in the mid-2000's (coincident with the decline of the Walleye population in the lake) competition limited the availability of large-bodied benthic invertebrates and likely made littoral food either less available to Yellow Perch or less efficient to feed on. Another possibility is that the Perch abundance might have been so high that strong intraspecific competition resulted in niche broadening and hence a stronger reliance on pelagic food sources by most individuals. Finally, the colonization and increased abundance of the Spiny Water Flea in the 2000's may have provided a readily available (and large) alternate food source in the pelagic habitat.

Further work to tease out the Walleye and Yellow Perch food web positions using stable isotope analysis and food web modelling is still in progress by Dr. Tom Johnston's lab (research scientist, Aquatic Research and Monitoring Section, MNRF) with his work on using stable isotopes to build a contemporary food web for Lake Nipissing. (Tom Johnston, pers. comm.).

5 Summary

The status of Yellow Perch in Lake Nipissing was assessed using a combination of fishery-dependent (i.e., recreational winter and open water angling surveys) and fishery-independent data (i.e., Fall Walleye Index Netting surveys). Yellow Perch play an important role as a forage fish species, as well as a recreational fish species that is targeted by anglers. The population fluctuates, with many contributing ecological factors, but biological indicators show that the population is healthy and is not being overexploited. Yellow Perch remain to be a much sought-after species in the winter fishery and provide diversity for recreational anglers on Lake Nipissing. Research being conducted on Lake Nipissing regarding food web structure and shifts in energy dynamics will highlight the importance of Yellow Perch in the system. The annual fisheries assessments, creel and Fall Walleye Index Netting surveys, are important tools for monitoring a variety of fish species in the lake, as well as understanding other ecological interactions and should be continued into the future.

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Appendix 1: Lake Nipissing recreational fishing effort and Yellow Perch catch, harvest, and angler success data 1985 to 2019.

Year	Effort (angler-hours)		% Effort Targeting Yellow Perch		Number of Yellow Perch Caught		Number of Yellow Perch Harvested		Weight of Yellow Perch Harvested (kg)		Angler Success (number•hour^{-1})	
	Winter	Open Water	Winter	Open Water	Winter	Open Water	Winter	Open Water	Winter	Open Water	Winter	Open Water
1985	88538	42707	35%	11%	112815	56194	108150	25853	23867	5450	1.078	0.757
1986	105304	107173	35%	21%	36196	86236	35487	43051	5973	5719	0.308	0.722
1987	131747	80959	56%	21%	79697	58799	71744	31607	10834	7067	0.598	0.495
1988	196120	85189	60%	17%	125986	111867	111688	48634	23434	8879	0.64	0.799
1989	287906	60543	62%	15%	125496	84804	111896	23270	18376	6501	0.435	0.776
1990	209485	65489	44%	16%	93923	78816	80801	26333	13243	4194	0.411	0.716
1991	225478	50524	48%	12%	96886	67935	84004	21190	11239	3971	0.403	0.678
1992	167735	72595	40%	12%	124863	18473	107880	2989	14036	574	0.527	0.441
1993	157374	16052	46%	12%	89048	42292	81617	12743	13283	2445	0.707	1.943
1994	88395	21986	29%	6%	91793	51799	86449	19334	14197	3031	0.81	0.585
1995	154754	21184	53%	6%	117552	67681	97145	27151	12883	4751	0.636	0.938
1996	17265	25702	48%	6%	118835	73534	109665	39362	17566	12253	1.051	0.998
1997	11830	25433	45%	7%	111991	48370	93916	20213	15423	5899	1.599	1.6975
1998	29020	20058	43%	7%	140500	70898	118894	30755	19525	5901	1.061	1.14
1999	120146	69634	42%	6%	120606	110880	86720	27778	14734	5330	0.713	1.022
2000	45947	50199	21%	6%	70257	83523	57433	24605	8104	4721	0.673	1.16
2001	37924	11230	14%	6%	140641	60860	105780	22332	17372	5917	1.072	1.106
2002	32978	13114	10%	5%	130275	75056	79045	27563	12981	4732	1.144	1.846
2003	13283	13235	4%	5%	136243	59470	85118	17422	13978	2315	1.133	1.42
2004	14184	14503	5%	9%	62449	46144	46166	17963	7582	3447	1.556	1.603
2005	21106	3413	7%	3%	145794	24157	88306	7949	11834	1525	1.617	0.951
2006	45281	7577	21%	4%	79035	35491	48491	8185	6540	1627	0.543	1.959
2007	51639	3054	17%	2%	121756	43197	91353	12540	13136	2588	0.842	1.761
2008	32997	4549	13%	3%	89413	13364	68312	3049	10509	291	0.608	0.491
2009	54917	4447	20%	2%	202440	19639	152157	6150	22138	980	1.42	1.379
2010	53353	4886	11%	6%	279187	6676	173212	1159	24867	243	1.582	0.211
2011	46642	1578	14%	1%	234385	13811	170398	7008	24222	823	1.171	0.616
2012	21770	5637	7%	4%	190507	32497	106084	10085	19306	1940	1.975	2.822
2013	70843	1076	25%	1%	172095	16835	117682	4436	20110	719	0.869	0.464
2014	50686	1991	17%	2%	106604	12861	87518	2599	15928	364	0.842	0.67
2015	70039	12902	27%	7%	78936	84314	61223	4642	12306	812	0.673	0.745
2016	125424	3397	62%	2%	73373	27753	63803	12198	12633	2574	0.579	1.467
2017	104803	20301	33%	12%	153275	21708	111681	5848	22001	1135	1.041	0.544
2018	282006	26407	72%	15%	129860	24674	91959	4679	17932	903	0.442	0.395
2019	163830	6537	40%	6%	88569	12060	64466	7468	13022	1554	0.377	0.869

Appendix 2: Summary of Yellow Perch total length-at-age data from fall Walleye index netting 1998 to 2019.

Fall Walleye Index Netting 1998-2019

Age (years)	Yellow Perch Total Length-at-Age (mm)								
	Average	Minimum	Maximum	Standard Error	Coefficient of Variation	25% Quartile	Median	75% Quartile	Sample Size
0	105	91	142	5.25	17%	94	91	106	11
1	113	92	165	0.50	11%	105	110	117	588
2	135	89	210	0.79	19%	109	141	155	1060
3	178	102	258	0.93	14%	159	176	196	759
4	211	107	277	1.35	14%	191	215	234	500
5	231	147	292	1.29	11%	215	230	247	381
6	253	176	318	1.55	10%	236	255	269	245
7	262	210	305	1.91	9%	248	265	278	144
8	268	205	316	1.97	9%	252	266	284	134
9	272	235	318	3.18	8%	258	267	290	47
10	272	221	305	3.51	8%	257	274	288	38
11	274	245	298	4.49	7%	271	282	288	16
12	281	245	314	4.82	7%	271	282	293	15
13	283	270	305	11.06	7%	287	291	290	3
14	290	283	295	3.53	2%	283	291	298	3

Appendix 3. Age frequency data and estimated adult Yellow Perch mortality rates ($Z_{\geq Age2}$) from winter and open water creel surveys fall Walleye index netting 1967 to 2018.

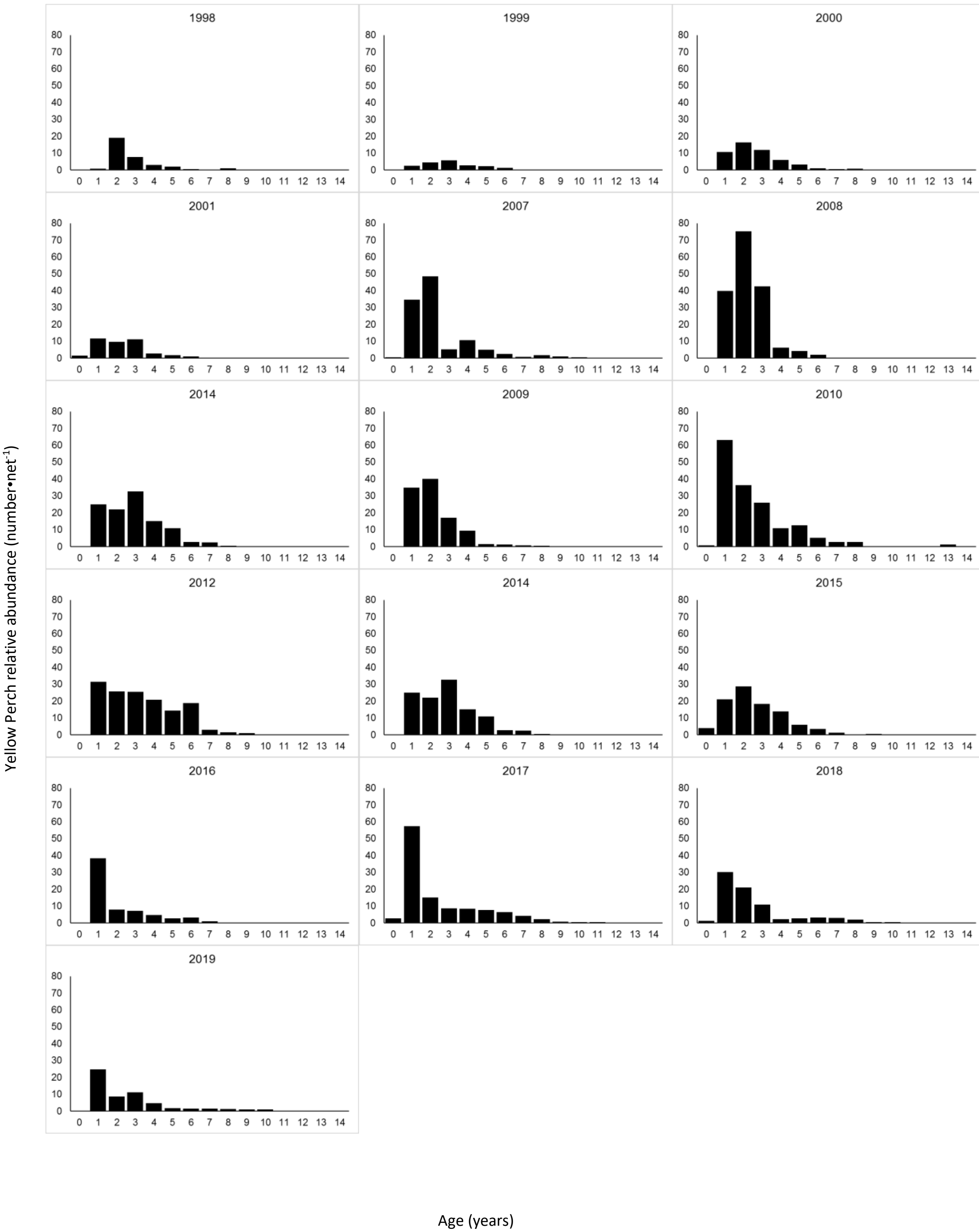
Fall Walleye Index Netting 1998-2019

	Number of Yellow Perch with Age Interpretation by Year													
Age (Years)	1998	1999	2000	2001	2007	2008	2009	2010	2014	2015	2016	2017	2018	2019
0	1	0	0	1	1	0	0	3	0	3	0	1	1	0
1	13	6	37	33	73	31	61	99	19	21	65	43	34	53
2	415	33	74	28	98	47	66	52	16	47	35	59	52	38
3	185	46	94	27	14	47	48	44	30	41	35	34	52	62
4	98	29	72	11	33	11	40	25	19	36	35	41	13	37
5	73	23	55	7	27	10	11	33	13	20	28	42	19	20
6	18	12	18	5	10	6	11	12	5	21	39	43	25	20
7	8	4	12	0	4	0	5	7	3	6	13	33	26	23
8	34	1	15	0	10	2	4	6	1	3	0	19	20	19
9	7	1	2	1	4	1	0	0	0	2	3	7	4	15
10	8	0	4	0	3	0	0	0	1	3	0	4	5	10
11	7	0	0	0	0	0	0	0	0	0	1	6	1	1
12	8	0	0	0	0	0	0	0	0	1	1	3	2	0
Total	875	155	383	113	277	155	246	281	107	204	255	335	254	298
Average Age	3.3	3.6	3.7	2.5	2.9	2.7	2.8	2.8	3.3	3.6	3.6	4.5	4.1	4.2

Appendix 4. Age frequency data and estimated adult Yellow Perch mortality rates ($Z_{\geq Age2}$) from fall Walleye index netting 1998 to 2019.

Fall Walleye Index Netting 1998 - 2019				
Year	$Z_{\geq Age\ 2}$	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Number of Yellow Perch ≥Age 2 (corrected for net Selectivity)
1998	0.6577	0.626	0.6905	1659
1999	0.5044	0.4603	0.5505	493
2000	0.6268	0.5943	0.6603	1433
2001	0.674	0.634	0.7156	1091
2007	0.6928	0.669	0.7194	2794
2008	0.977	0.9507	1.0039	5621
2009	0.8616	0.8311	0.893	3168
2010	0.5409	0.5261	0.5559	5193
2012	0.4126	0.3996	0.4257	3885
2014	0.5263	0.5067	0.5462	2786
2015	0.5793	0.5557	0.6034	2323
2016	0.4606	0.4302	0.4919	873
2017	0.3633	0.3828	0.3441	1372
2018	0.4803	0.456	0.5052	1495
2019	0.4326	0.4063	0.4596	1031

Appendix 5. Yellow Perch age frequency distributions from 1998 to 2019 fall Walleye index netting surveys (selectivity adjusted relative abundance; number•net^{-1}).



Appendix 6: Von Bertalanffy growth model parameter estimates for each year where aging samples were collected.

Year	N	t0	Linf	Linf_Lower	Linf_Upper	K	K_Lower	K_Upper
1998	811	-1	359.42	342.8	379.9	0.14	0.13	0.15
1999	147	-1	306.4	286.41	330.79	0.25	0.22	0.29
2000	264	-1	320.56	300.78	348.74	0.21	0.18	0.23
2001	16	-1	447.45	239.04	2071.38	0.14	0.02	0.42
2007	257	-1	272.48	261.59	285.77	0.26	0.24	0.28
2008	149	-1	350.91	315.21	395.48	0.18	0.15	0.21
2009	237	-1	345.39	318.52	377.28	0.19	0.17	0.22
2010	276	-1	297.33	283.21	312.01	0.24	0.22	0.26
2014	95	-1	337.6	301.52	383.69	0.21	0.17	0.26
2015	177	-1	321.95	303.85	341.38	0.23	0.2	0.26
2016	224	-1	298.77	287.15	313.18	0.26	0.24	0.29
2017	318	-1	302.29	294.95	310.11	0.25	0.23	0.26
2018	235	-1	315.59	303.38	331.03	0.23	0.21	0.24
2019	287	-1	323.51	311.84	336.8	0.21	0.2	0.23

Appendix 7. Gill net relative selectivity correction factors for Yellow Perch caught in standard FWIN gill nets.

Fork Length (mm)	Size Bin	Relative Selectivity
		Yellow Perch
10	1 to 19	3.30E-13
30	20 to 39	1.24E-08
50	40 to 59	4.51E-05
70	60 to 79	0.013208138
90	80 to 99	0.308801054
110	100 to 119	0.599005897
130	120 to 139	0.30605209
150	140 to 159	0.631753407
170	160 to 179	0.700780107
190	180 to 199	0.65974789
210	200 to 219	0.826989064
230	220 to 239	0.903989256
250	240 to 259	0.930355649
270	260 to 279	0.990000118
290	280 to 299	1
310	300 to 319	0.92698749
330	320 to 339	0.820318892

Appendix 8. Length (mm) and Age at 50% maturity for Yellow Perch sampled from FWIN Surveys

	A50%Male	a	b	n	A50%Female	a	b	n
1998	1.7	5.9646	-10.937	372	1.8	2.1515	-6.8503	439
1999	1.7	10.606	-19.219	55	1.7	1.8846	-4.2458	90
2000	1.4	18.868	-26.812	54	1.8	4.6004	-8.9245	163
2007	1.8	0.56	-1.93	104	4.5	20.465	93.74	153
2008	0	1.8565	-0.85243	64	2	2.239	-5.4351	85
2010	0.6	5.3522	-4.2647	129	2.1	4.0594	-9.2193	147
2014	0.7	36.779	-27.938	35	1.7	1.7799	-4.0778	57
2015	0.5	17.648	-8.9717	70	2.4	3.0096	-8.1621	107
2016	0.7	3.1758	-2.9678	91	1.5	1.5044	-3.2029	133
2017	0.5	3.9248	-3.0288	140	1.7	2.2564	-4.6879	178
2018	0.6	1.4568	-1.7906	97	1.8	2.2696	5.1154	166
2019	0.6	2.5531	-2.3352	102	1.2	0.6616	-1.7471	157
Average	0.90				2.02			
SE	0.17				2.02			
SD	0.59				0.84			

	L50%Male	a	b	n	L50%Female	a	b	n
1998	88	0.056289	-5.9212	372	165	0.13232	-22.835	425
1999	133	1.732	-232.14	57	158	0.056069	-9.8296	86
2000	103	1.583	-163.86	101	131	0.02528	-4.2662	86
2007	84	1.7554	-149.36	104	150	0.071624	-11.693	152
2008	104	0.56972	-60.379	64	157	0.069318	-11.822	85
2010	104	0.22699	-24.66	129	142	0.047906	-7.7722	143
2014	93	1.95	-182.41	35	147	0.039501	-6.7543	57
2015	103	1.6119	-166.79	70	187	0.95505	-181.89	95
2016	110	0.085421	-10.319	91	165	0.08272	-14.647	123
2017	99	0.066948	-7.5637	140	149	0.06316	-10.364	153
2018	101	0.040171	-4.997	96	131	0.05882	-8.6778	138
2019	88	0.068054	-6.9432	100	119	0.021805	-3.544	128
Average	100.83				150.08			
SE	3.71				5.28			
SD	12.88				18.31			