Achieving a Sustainable Lake Nipissing Walleye Fishery

Final Report May 2017

By Doris Smith, PhD

TABLE OF CONTENTS

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EXECUTIVE SUMMARY

Lake Nipissing is a culturally and environmentally important lake in northeastern Ontario, Canada. For decades the value of Lake Nipissing and its walleye fisheries has helped to drive the economy and shape the local culture for its residents, including First Nations communities. However, this fishery has been declining steadily since the 1980s, a problem that has been seen time and again in other inland, Great Lakes and coastal fisheries in Canada and throughout the world. The once held view of fish stocks as an inexhaustible resource has changed. Although the effects of climate change and other environmental stressors are having profound effects on aquatic ecosystems and fish populations today, overfishing still remains the primary cause for the decline in the Lake Nipissing walleye fish stocks, as it is for most fish stock declines worldwide.

The Ontario Ministry of Natural Resources and Forestry (OMNRF) and Nipissing First Nations (NFN) resource managers have local managing authority over the recreational angling and commercial gill net fishery on Lake Nipissing. They have responded to declines in walleye stocks by imposing progressively harsher controls over the years. These include limits to total annual harvests and daily catch, to protection of vulnerable fish sizes, as well as greater restrictions to gill net fishing through enforcement of the NFN Fisheries Law (e.g. spring moratorium, annual quotas, numbers of nets, and mesh size) and to culturally significant fishing practices (e.g. spear fishing). Despite such intensive management, the walleye stocks have remained stressed.

Compounding these stresses are some serious environmental and social concerns. Persistent anthropogenic influences in Lake Nipissing have affected water quality and have resulted in the proliferation of the aquatic invasive species, the spiny water flea. Temperature effects linked to global climate changes, as well as the piscivorous double-crested cormorant are also having negative impacts. Equally troublesome is the level of frustration and animosity among stakeholders, with tense and combative exchanges over the perceived failure by some to abide by harvest controls. Threats to livelihoods and Treaty protected fishing rights frequently boil over publicly into social media and elsewhere.

Presently, a way forward in addressing the problems surrounding Lake Nipissing is to adopt the “Pillars of Sustainability” approach, one that has been gaining worldwide acceptance as a means to achieve a sustainable fishery. This approach requires that all components, or pillars, of a fishery (i.e. managerial, environmental, economic, and social) must themselves be sustainable before the rewards of a sustainable fishery can be realized (Figure 1). Efforts to recover a fishery are often ineffective if greater importance is given to one pillar over another. If one pillar is weak than the system as a whole is unsustainable. This report will describe the aspects of each pillar, identify the issues within each pillar that are impeding sustainability, and make recommendations to overcome them. In doing so, progress towards a sustainable walleye fishery can be achieved.

Notably absent from this report is a review of NFN commercial fishery data as well as input from NFN in regards to its commercial fishery and commercial fishing practices. Any recommendations or conclusions made herein were based on secondary sources of information.

Management Sustainability

Management sustainability uses assessment methods and tactics to find balance between appropriate harvest levels and the prevention of overfishing of targeted fish stocks. This also includes the promotion of sustainable fishing practices and the active enforcement of policies. Presently, the Lake Nipissing

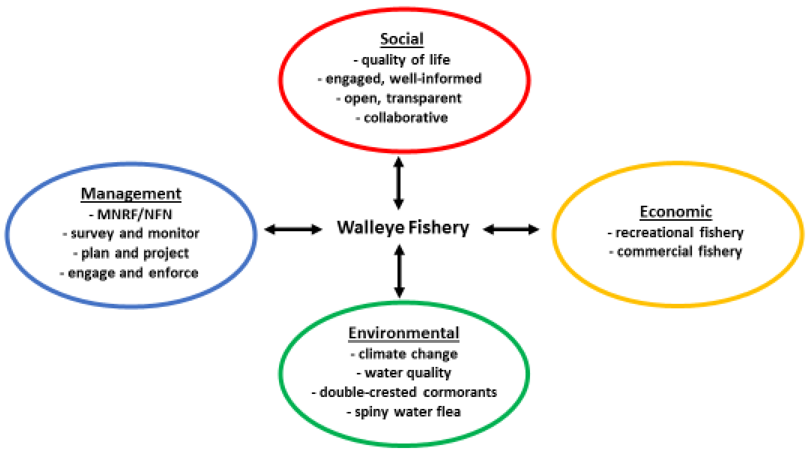

Figure 1. Pillars of Sustainability and the Lake Nipissing Walleye Fishery

ecosystem once dominated by walleye now has yellow perch as the most abundant fish species. While the abundance of juvenile walleye has been increasing steadily for the last several years, adult abundance has remained relatively unchanged.

Current management controls to the recreational fishery include size restrictions (i.e. none kept below 460 mm) in an attempt to protect the juvenile recruits, in the hopes that they will reach maturity and spawn at least once before being harvested. The numbers of male spawners has increased significantly during recent spawning assessments, with a significant increase in female spawners to spawning beds expected in the next few years. Current catch and possession limits (i.e. 2 per day) are attempting to shield the adult walleye spawning stock against further depletion, and divert fishing pressure towards the more abundant yellow perch. The recent Memorandum of Understanding (MOU) between OMNRF and NFN anticipates greater success at implementing the NFN Fisheries Law and thereby curbing illegal and under-reporting of the commercial harvest.

Recommendations:

- The walleye population is rebounding, with a strong cohort of recruits expected to mature in the next few years. Fishery managers and commercial and recreational fishers must resist overexploiting this cohort once they reach regulation size so that the adult population, and the fish population as a whole, can continue on its course to recovery.

- This strong cohort of juveniles have become vulnerable to the recreational fishery and the stresses associated with catch and release. Anglers need to be mindful of all angling stresses and try to minimize their affects. Fisheries managers should develop reliable estimates of hooking mortality to help gauge overall effects on the walleye population.

- The OMNRF should re-evaluate its' strategy of allowing such a high catch and possession limit for yellow perch (i.e. 50 fish/day). Given that yellow perch abundance has been declining and angling preference is shifting to yellow perch, it will be difficult to account for subsequent declines, given the other pressures on this population [e.g. predation from cormorants and other environmental stressors (see section IV)].

- It is not recommended that the Lake Nipissing stocking efforts go beyond what is currently being done. Lake Nipissing does not possess the characteristics that would support a successful stocking effort at this time. Supporting the current abundant natural population of juvenile fish to spawning age provides the best chance of recovering the walleye population in the lake as a whole.

Environmental sustainability

Environmental sustainability aims to maximize ecological health with minimal stressors to support present and future fish populations. Since the effects of environmental stressors to Lake Nipissing are subtle yet broad in scale, some potential impacts to the walleye fishery remain unclear, leaving managers with few options except to monitor effects, anticipate ecosystem changes and incorporate these vulnerabilities into decisions for the lake ecosystem and the fishery. However, some active measures can be taken.

Recommendations:

- An updated analysis of stomach contents of fish populations should be done in order to better gauge the degree to which spiny water flea has been incorporated into the food chain.

- Studies examining the effects of temperature change on walleye life history processes should be carried out to better gauge its impacts to fish populations.

- A more complete analysis of cormorant diets should be done in order to quantify the impact of this predator on the walleye population and its contribution to total fish mortality. This is necessary to determine whether any measures should be taken to control these predatory birds.

- More active measures to control the human influences affecting water quality are necessary to help curb nutrient loading and limit cyanobacterial blooms.

Economic Sustainability

Economic sustainability aims to ensure an efficient harvest that provides lasting economic opportunities to a region, and can attract and maintain a new generation of fishers to the industry for future sustainability. In general, recreational fishing has a several fold greater economic impact than commercial ventures on most waterbodies. However, the commercial fishery is associated with First Nations Treaty rights that pre-date and pre-empt recreational angling. As such, NFN have a right to fish commercially on Lake Nipissing; this should be accepted and respected as a distinct part of the local fishery economy.

Recommendations:

- The NFN community have made many concessions to their Treaty rights for the sake of the Lake Nipissing fishery. However, efforts should be made to reduce bycatch in the commercial fishery by exploring alternative netting techniques. Onboard observer programs or short-term monitoring surveys should be in place on commercial fishing boats to clarify the situation regarding bycatch with gill nets.

- The NFN community should pursue economic opportunities in addition to commercial fishing, such as those which could capitalize on the angling experience together with unique traditional, cultural or historical experiences.

Social Sustainability

Social sustainability aims to ensure that the fishery forms an integral part of the well-being and lifestyle of a community. With open lines of communication, all stakeholders in a community are engaged with a good understanding of the issues and concerns pertaining to the fishery. Such collaborations would also increase the legitimacy of management through enhanced support for regulations and should lead to a reduction in conflict among stakeholders. There are many examples of successful collaborations in support of Lake Nipissing and the walleye fishery. However, additional relationships must be forged in order to achieve social sustainability.

Recommendations:

- Fisheries managers should make annual monitoring and survey data, stock estimates and harvest estimates more easily accessible to any stakeholder that requests it. All stakeholders deserve to be better informed on issues pertaining to the state of the lake and the fishery in order to be part of a walleye recovery plan. This gesture would take a significant step forward in re-establishing good living and working relationships with local stakeholders.

- The NFN community is committed to achieving a sustainable fishery. However, current tensions pertaining to an individual's Treaty protected right to fish, and community rights to impose harvest restrictions for the greater good of the fishery and the community, must be resolved in order to support overall recovery of the walleye fishery.

- A new Lake Nipissing focused website should be created as a way to harness community involvement and promote transparency and open lines of communication on all fronts. This site could draw information presently found on sites operated by local stakeholder groups (e.g. First Nations, LNSA, UFRCA, OMNRF) and act as an educational resource for all to contribute to and access.

I. INTRODUCTION

From the dramatic collapse of the once productive Newfoundland cod fisheries to the decline in commercial Great Lakes fisheries, it appears that a sustainable fishery can be considered the exception rather than the rule. The depletion of many of Canada's important fish stocks is a recent phenomenon that has occurred within the last few generations (Grafton and Kompas 2014). The old perception of fish stocks as an inexhaustible natural resource has changed. Technology in terms of sonar-based "fish-finders" and efficient netting devices have greatly improved our ability to find and catch fish. Also, the effects of climate change and other environmental stressors are having profound effects on aquatic ecosystems and fish populations today. However, overfishing still remains the primary cause for most declines in fish stocks (Isermann and Parsons, 2011).

The "tragedy of the commons" metaphor has often been used to characterize the misuse and overuse by man of natural resources (Hardin, 1968). The idea that shared resources or "common property" such as fisheries, can be used by anyone, yet no one truly owns it, so no one takes responsibility for it. When users of the same common property compete, leading to an unsustainable situation, the tragedy of the commons results. While this characterization may have valid for fishing practices of the past, it is unlikely that many fisheries are being exploited in a "free-for-all" manner today. Most fisheries, especially those actively managed for commercial harvesting or as sport fisheries, are generally limited by quotas or by calculated "open seasons" based on estimates of population size and harvesting intensity (Isermann and Parsons, 2011).

While the concept of sustainability is one supported by most people, agreement on a suitable definition can be difficult. Even one as straightforward as "exploiting species at a level that does not diminish their productivity in the future" (De Alessi 2008), requires consideration of environmental, managerial, economic, and social components of the fishery (Aanesen et al. 2014). Environmental sustainability aims to maximize ecological health with minimal stressors to support present and future fish populations. Management sustainability requires accurate estimation of population size and harvest yields so that overfishing can be prevented and present and future resource use continued. Economic sustainability aims to ensure an efficient harvest with maximum and lasting economic opportunities. Finally, social sustainability aims to ensure that a fishery forms an integral part of the well-being and lifestyle of an open and engaged community (adapted from EU 2002; Leslie and McLeod 2007). Breaking down any sustainability question into its component parts, or pillars, is an approach that has been broadly applied to business models, municipal governments and resource protection (Aanesen et al. 2014; Virapat 2011). Regardless of the application, pillars of sustainability are well integrated, mutually dependent and vital parts of the whole sustainability question (Grafton and Kompas 2014). The pillars must themselves be sustainable before the rewards of a sustainable fishery can be realized (Röckmann et al. 2015; Virapat, 2011). If one pillar is weak than the system as a whole is unsustainable (Grafton and Kompas 2014) (Figure 1).

Lake Nipissing is a culturally and environmentally important lake in northeastern Ontario, Canada. Located in the Great Lakes drainage basin, it is the seventh largest of the estimated 250,000 lakes in Ontario, excluding the Great Lakes (www. ontario.ca/page/about-ontario). Despite its size (822 km^2), the lake is quite shallow, with an average depth of 4.5 meters, but with its deepest point reaching 52 meters (Morgan 2013). The Lake Nipissing watershed drains into Lake Nipissing by 12 major rivers, including the Sturgeon, Amateewakea and South Rivers, with the French River the only outflow into Georgian Bay (Clark et al. 2010). The lake is a valuable natural resource, supporting over forty species of fish, (e.g. walleye, yellow perch, Northern Pike, bass, muskellunge, lake herring and lake whitefish) and many species of birds and wildlife (Morgan 2013).

The Lake has long been an important source of fish for the NFN, while the French River System has been accessed by Dokis First Nation. Following European Settlement, the value of Lake Nipissing as a natural resource has helped to drive the regional economy and shape culture and communities in the area.

Today, the major communities on its shoreline include the city of North Bay (population 52,000) on the Northeast side, Callander (population 4,000) on the Southeast side adjacent to Callander Bay, and the municipality of West Nipissing (population 14,000) on the lake's North side (Statistics Canada Census Profile, 2016). There are approximately 125 tourist enterprises and assorted fisheries related businesses (e.g. hotels, bait shops, boat rentals, ice hut rentals) (Morgan 2013). The Dokis First Nation (population approximately 200) and the Nipissing First Nation (population approximately 1,400) still depend upon the lake and its resources for ceremonial, sustenance and commercial purposes. NFN has a commercial fishery for walleye, and the Dokis manage a modest tourism industry, including cabin rentals, tour operators and a marina to support local cottagers.

While historically Lake Nipissing had offered a wide variety of angling opportunities, the primary draw has always been for walleye - for the challenge, the taste and the mystique. Even before the tourism explosion of the 1960s and 1970s, people had been coming to Lake Nipissing to fish walleye (LNFMP 2014). Anecdotal recollections by local residents remember a robust fishery and a vibrant local economy that supported it. However, the fishery has been declining steadily since the 1980s, despite close monitoring by fisheries managers. The OMNRF and more recently NFN resource managers have responded to declines by imposing progressively harsher harvest restrictions to prevent further overexploitation. Recent reviews continue to cite concerns regarding overfishing on Lake Nipissing (Morgan 2013; Jones et al. 2016).

Compounding environmental stressors are likely impeding or slowing walleye recovery, with ongoing anthropogenic influences affecting water quality and the proliferation of invasive aquatic species (e.g. spiny water flea), temperature effects linked to global climate changes, and invasion of new top predators (specifically double-crested cormorants) (Morgan 2013; LNFMP 2014). An additional factor in the mix is the high level of animosity and blame among stakeholders, with tense and combative exchanges in terms of threats to livelihoods and Treaty-protected fishing rights.

Presently, the Lake Nipissing ecosystem once dominated by walleye has been shifting to yellow perch. While the abundance of juvenile walleye has been increasing steadily for the last several years, adult abundance has remained relatively unchanged. Current management size restrictions to the angling fishery are attempting to protect these juveniles, in order to allow them to reach maturity and spawn at least once before being harvested. Current catch restrictions to the angling fishery are attempting to shield the walleye spawning stock against further depletion, and divert fishing pressure towards the abundant yellow perch (LNFMP 2014). The recent Memorandum of Understanding (MOU) between OMNRF and the NFN community (March 10, 2016) will hopefully have greater success at implementing the NFN Fisheries Law on its commercial industry and curb fishing that exceeds harvest quotas (NFN Fisheries Update 2016).

Multiple issues confront the Lake Nipissing walleye fisheries which are impeding its ability to achieve sustainability. If the short-term success of the local fish economy were to take precedence over management recommendations or the health of the environment and ecosystem, then sustainability of the fisheries will suffer. Also, the vulnerability of fisheries to ecosystem changes must be taken into account in making management decisions. The social wellbeing of the Lake Nipissing residents, which relies on the resource sector and services, must have bearing on decisions pertaining to the lake in order to garner support and acceptance of fishing restrictions. The key to achieving sustainability for the walleye fishery therefore, requires that all pillars be given equal weight in decision making. Unfortunately, this is currently not the case.

A way forward must address these issues of imbalance. This report will attempt to summarize the issues contributing to the current state of each sustainability pillar in the context of historical and current fishery practices and present management obligations. While many of the issues within each sustainability pillar have been addressed previously (Casselman 2005; Clark et al. 2010; Morgan 2013; LNFMP 2014; NFN Fisheries Update 2016), they have not been adequately integrated.

As an outside observer of the Lake Nipissing fishery, I will present a scientific perspective of the issues that is free of institutional or cultural bias and subjectivity. I will also make recommendations intended to achieve managerial, environmental, economic and social sustainability and in so doing, make progress towards a sustainable fishery and a sustainable and diverse fishing community.

II. Management of Fishery Resources in Ontario

II.a. Provincial Policies Regarding Harvest Practices

For more than 50 years, the Ontario government has held primary responsibility for the management and licensing of the province's fisheries. The OMNRF currently manages Ontario's fisheries under the Fish and Wildlife Conservation Act, 1997 (FWCA), in collaboration with a number of other agencies, including the federal government, the bi-national Great Lakes Fisheries Commission, the Ontario Commercial Fisheries Association (OCFA), the Anishinabek/Ontario Fisheries Resource Centre and Aboriginal fishers (LNFMP 2014). Once the annual harvestable yield is determined for a lake, the province then prioritizes fish, first in terms of conservation objectives, then allocations are made for aboriginal subsistence, ceremonial use and commerce in accordance with Treaty protected rights, followed by recreational harvesting (Fishing Ontario Recreational Fishing Regulations Summary, 2017).

For recreational fishing purposes, Ontario lakes are divided into 20 Fisheries Management Zones (FMZ), most of which have regulations establishing the length of fishing seasons, catch and possession limits and size limits for popular fish species (Fishing Ontario Recreational Fishing Regulations Summary, 2017). Because the recreational fishery in Ontario is not limited by quotas, these harvest restrictions are in place to limit fishing effort. Lake Nipissing, although it is located within FMZ 11, is designated a Provincially Significant Inland Fishery (PSIF), indicating a lake where higher risk exists. In such systems of significant social, economic, or ecological importance, management still occurs on an individual lake level (Ontario's Provincial Fish Strategy, 2015).

Walleye (*Sander vitreus*) is one of the most carefully managed fish species in Ontario. Many lakes, including Lake Nipissing, have areas that are closed to walleye fishing during spawning season (e.g. Shoal Lake FMZ 5, Henderson Lake FMZ6, Chateau Lake FMZ15). Some lakes prohibit walleye fishing year round (e.g. Lake Helen FMZ 6, Jackfish River FMZ 7, Lake Scugog FMZ 17). Only three FMZ (namely zones 1, 13 and 19) have year-round open access to walleye fishing, but all still have catch and possession limits (Fishing Ontario Recreational Fishing Regulations Summary, 2017).

II.b. Indigenous and Treaty Fishing Rights in Ontario

A long history of subsistence fishing by indigenous peoples exists in the region, with net fishing dating back at least to 300-200 BCE in the upper Great Lakes (Bogue 2000). Regional tribes, particularly Ottawa, Ojibwas and Hurons relied historically on fish as a primary source for protein (Turner 1987). Gill nets and hooks and line used by Ojibwa of northwestern Ontario were documented before 1830, as well as writings of witnesses to torchlight spearing in the Fox River of Green Bay in the 1840s (Bogue 2000).

From the time of the earliest meetings between First Nations people and European explorers and colonizers to the Great Lakes region, relationships progressed from infringement, to tolerance, to the formation of agreements with respect to fish and other resource use, trade and settlements. Over time, relationships were formalized into treaties. These Treaties are part of the foundational documents of the history of Canada (Treaties with Aboriginal people in Canada, 2010).

The Royal Proclamation of 1763 officially claimed British territory in North America after Britain won the Seven Years War. It was also the first document to establish guidelines for European settlement of Aboriginal territories and how Nations should co-exist. It was also the first public recognition of First Nations rights to lands and resources based their original occupancy, and how they would be shared (Treaties with Aboriginal people in Canada, 2010).

In total, 36 treaties were negotiated in Ontario between 1763 and 1929 (Treaties with Aboriginal people in Canada, 2010). The Robinson Huron Treaty of 1850 was made between the crown and Ojibwa Chiefs inhabiting the Northeastern shore of Lake Superior, and Ojibwa Chiefs of the eastern and northern shores of Lake Huron and Georgian Bay. The Treaty promised initial sums of money, the creation of reserves, annuities and the continued right to hunt and fish on unoccupied lands in exchange for land cessions (Surtees 1986). The Dokis and Nipissing First Nations settled on lands on the shores of Lake Nipissing, which was part of this Treaty.

Section 35 of the Constitution Act of Canada, 1982 further recognized and affirmed existing aboriginal and treaty rights, including the right to fish for food, community, or ceremonial purposes. The scope of Section 35 has been at the centre of many court battles over land and resource rights in Canada, particularly pertaining to the commercial right to fish. Indeed, fishing rights protected from provincial and federal law have been challenged on several occasions (i.e., R.v. Commanda 1990, R.v. Sparrow 1990, R.v. Smokehouse 1996, R.v. Gladstone 1996, R.v. Shipman et al. 2007). These cases help to guide the relationship between the Crown and NFN and Dokis First Nations pertaining to resource use in the Lake Nipissing region, namely, the priority of the different forms of access to the fish resources: first, conservation of the resource, second, the right to hunt or fish for subsistence purposes, third, harvesting for commerce and finally, recreational harvesting.

In 2014, Chiefs from the Robinson Huron Treaty territory, acting on behalf of approximately 30,000 beneficiaries of the 1850 Treaty, filed an annuities claim regarding the longstanding failure of the Crown to raise the dollar value of annuities agreed to under the Treaty. The annuity hasn't increased since 1874 and remains at $4 for each beneficiary per year. (Chiefs take Ontario, Ottawa to court over breached Robinson-Huron Treaty, 2014). The case is expected to be heard this year (G. Duquette, personal communication).

II.c. Management of the Lake Nipissing Fishery

Since 1967, annual assessments of the health of the Lake Nipissing walleye fishery have relied on the collection of data from netting surveys and information gathered from fishermen (Morgan 2013). Under the management and guidance of the OMNRF (formerly OMNR), other parties, including the Anishinabek /Ontario Fisheries Research Center, Nipissing and Dokis First Nations, Conservation Groups and recreational and commercial fishers have been regular collaborators during these annual programs. Since 1998 fisheries assessments have relied on data collected primarily from open water and winter angler surveys (CREEL), in addition to Fall Walleye Index Netting (FWIN) surveys and assessments of walleye spring spawning at Wasi Falls near Callander Bay.

CREEL Surveys

Roving angler (CREEL) surveys are conducted annually in both open water and winter seasons in order to collect information on recreational angler-hours per group, harvest levels, and angler information (e.g. fishing preference, residency, base of operations and use of ice huts, Lake Nipissing Creel Survey Methodology, 2016). Lake Nipissing is divided into 17 sectors for open water and 13 sectors for winter angler surveying. These sectors, which were defined at least 15 years ago, are based on historical walleye fishing pressure and provide a consistent framework and survey method, allowing year-to-year comparisons. Winter surveys are conducted throughout the ice fishing season, with all angling parties in 2 to 4 sectors being interviewed over the course of each sampling day, such that each sector is sampled at least 4 times during the winter season. Similarly, open water angler interviews begin on the opening day of the season and end the week after Labour Day. Angling parties in 3 sectors are interviewed each sampling day, during one of two time periods (either morning/afternoon, or afternoon/evening), including week days and weekends; each sector is sampled a minimum of 8 times over the open water season Lake Nipissing Creel Survey Methodology, 2016).

FWIN Surveys

FWIN is the annual population assessment survey used for Lake Nipissing to estimate the relative abundance of fish stocks and provide other biological indicators of population health. Adherence to rigorous standardization with respect to gear and protocols ensures that comparable estimates of analyses of trends through time for Lake Nipissing can be obtained (Morgan 2003). Over the course of approximately two weeks, once lake water surface temperatures have cooled to 15^{o}C, 48 nets are set in the water. Monofilament gill nets (60 m long by 1.8 m deep) comprising 8 panels of mesh of increasing size (from 25 mm to 152 mm stretched mesh) are set in randomly selected locations within the lake sectors perpendicular to shore for 24 hours. All fish ensnared in the nets are identified to species, enumerated, and total lengths measured. All sport fish caught are weighed, with a subset being sampled (in terms of scales, dorsal spines, or otoliths) in order to determine population age structure. Walleye are examined to determine sex and state of reproductive maturation. Once examinations and sampling are complete, fish are released for consumption or disposal (Morgan 2003).

Walleye Spawning Assessment

Annual spawning assessment occurs in the spring once the ice is far enough offshore from Wasi Falls, near Callander Bay. Six foot standard trap nets are set and are checked daily until the spawning run is complete. All walleye captured are measured in terms of length and weight, they are examined externally to assign sex (extrusion of milt or eggs), tagged, and age structures (scales or second dorsal spine) are taken for age estimation. All walleye are then released back into the water (K. Tremblay, personal communication).

Risk Assessment Model for Joint Adaptive Management (RAMJAM)

A new approach was adopted by the management agencies for Lake Nipissing (OMNRF and NFN) in 2013-2014 in an ongoing effort to address the chronically stressed state of the fisheries and to prevent the situation from getting worse (LNFMP 2014). The RAMJAM incorporates age-structured computer modeling and universally accepted biological target reference points that are based on the Maximum Sustainable Yield (MSY), or the optimum walleye harvest level the lake can support (Rowe et al. 2014).

This methodology was deemed the best approach by the Lake Nipissing Fisheries Management Plan Advisory Council (LNFMPAC) and OMNRF to determine a recommended safe harvest level for subsequent fishing seasons, while incorporating the least amount of risk to achieve a sustainable population biomass (i.e. approximately 400,000 kg) within a 10 year recovery trajectory (Rowe et al. 2014). Annual harvest data from CREEL and commercial sources as well as data from annual FWIN surveys are applied to the model help to gauge the state of health of the walleye population as well as the risk to the populations with without further management intervention. As the population grows, harvest levels can also grow while remaining on the desired population recovery trajectory. Recovery trajectories would be re-visited each year to monitor progress toward a healthy fishery and make harvest level adjustments when necessary (Rowe et al. 2014). The recommended annual safe harvest level has been approximately 30,000 kg since 2013 (K. Tremblay, personal communication).

II.d. History of Lake Nipissing Recreational Fisheries Management

The recreational fishery of Lake Nipissing has undergone many regulation changes over the last several decades in response to changes in walleye abundance (Figure 2). The walleye fishing season restrictions from 1960 to 1998 were in place solely to protect the spring spawning period, with the opening day being typically before Victoria Day weekend (before May 25th) and closing on March 15th or 31st of the following year (Morgan 2013). No size restrictions were in place, but a daily catch and possession limit of 6 existed.

In response to declining walleye numbers, in 1999, the first Fisheries Management Plan (FMP) was put into practice. The fishing season was shortened by two weeks, the daily catch and possession limit was reduced to 4, and a protected slot size was enforced (walleye between 400-600 mm could not be harvested) to protect the spawning stock during the open water season (LNMP 1999). In 2003, annual harvest target was reduced to 66,000 kg/year (LNFMP 2014). By 2005, the protected slot size was applied all year, as well as a permit requirement for commercial ice huts. The next FMP was implemented in 2007, and included total harvest targets (commercial and recreational) set to 60,000 kg/year, an all season catch and possession limit of 4, but an increase in the winter angling season by one week (Roberts, 2007).

In 2013 the annual harvest yields were estimated for the first time using RAMJAM projections. Total harvest yields (recreational and commercial) were set to 30,000 kg/year and they remained at this level to the present. It was not made clear to the author the process by which allocation of the walleye harvest is determined for Lake Nipissing. It has been set at approximately two thirds commercial harvest and approximately one third for recreational harvest for the last few years (K. Tremblay OMNRF, personal communication).

The third and current FMP implemented in 2014 largely addressed the heavy fishing pressure focused on the abundant juvenile walleyes, that were growing faster than usual and becoming vulnerable to the fishery (due to their size) before being mature enough to spawn (LNFMP 2014). Size restrictions were adjusted to prohibit harvesting of fish less than 460 mm, with a two fish catch and possession limit remaining in place. This was combined with allowing an increased harvest on the now abundant yellow perch population, with the intention of diverting fishing pressure away from the large juvenile walleyes. The open water angling season remained unchanged (Jan. 1 to Mar. 15, 3rd Sat. in May to Oct. 15) (LNFMP 2014).

II.e. History of Lake Nipissing Commercial Fisheries Management and NFN Fisheries Management

The commercial fishery operated by the Nipissing First Nation began reporting its harvests in 1995, by providing data voluntarily to Anishinabek/Ontario Fisheries Research Center. After several years, record keeping was less precise, with harvest estimates compiled based on fish sale records, anecdotal information from NFN and later, estimates provided by MNR Enforcement Officers (Rowe 2007).

Commercial fisheries management on Lake Nipissing has also been responsive to changing walleye stocks (Figure 2). Two important harvest restrictions were imposed on NFN fishermen by Chief and Council in the recent past. In order to protect spawning walleye adults, a spring gill net moratorium was mandated in 2004 from Apr. 1 to May 10, with active enforcement commencing in 2008. In addition, a ban of commercial spearing and a daily limit on recreational spearing (20 walleye per boat) was implemented in 2010 (Morgan 2013).

NFN Fisheries Law

Nipissing First Nation Fisheries Law was implemented in 2006 to govern the commercial harvest on Lake Nipissing, (Morgan 2013). It required that NFN collaborate with OMNRF during the annual FWIN and CREEL surveys. All commercial NFN fishermen were required to register for upcoming fishing seasons and complete daily harvest reports that would be independently audited by fisheries technicians. The commercial season typically runs Jan. 1 to Mar. 31 (winter) and May 10 to Nov. 15-25 (open water). Commercial fishers use bottom set gill nets with a minimum of 89 to 95 mm stretched mesh (3.5 or 3.75 inch, respectively) that are tagged with visible buoys and registered with the NFN Natural Resources Department. Furthermore, each commercial fisher is allowed a maximum of either 5 nets or 500 m of net, with restrictions placed on where nets can be set (e.g. not on Veuve, South and Sturgeon Rivers, within 250 m of Wasi Falls or within 30 m of any dock. Morgan 2013). Since 2009 the NFN Natural

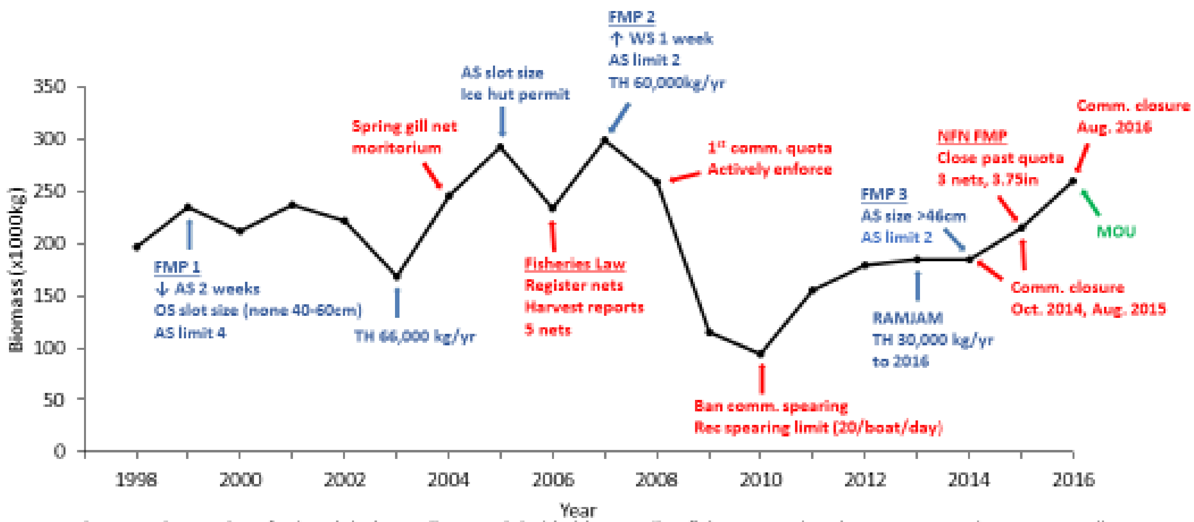

Figure 2. Time series of Lake Nipissing walleye exploitable biomass (i.e. fish >300mm) and management changes to angling and commercial harvests. Data is from annual FWIN surveys. FMP=Fisheries Management Plan, MOU= memorandum of understanding, AS=all season, OS=open water season, TH=target harvest. Blue text=MNRF management changes; Red text=NFN management changes; Green text= combined management efforts

Resources Department has provided the annual commercial walleye harvest estimates to the North Bay OMNRF (Rowe 2007). NFN Chief and Council set a commercial harvest quota for the first time in 2008. Quotas were typically set based on previous years' harvests and stock assessments, and generally fluctuated based on annual stock estimates.

NFN Fisheries Management Plan

New commercial Fisheries Law regulations came into effect in 2015 as part of a NFN Fisheries Management Plan. This included a longer moratorium on spear fishing and gill netting (April 1 to May 15 rather than April 1 to May 10), a reduction in the number of nets per fisherman from 5 to 3 and a mandatory minimum mesh size of 95 mm (3.75 inches). Furthermore, it stated that the season would close when the quota was reached, so as not to exceed safe harvest levels, based on monthly catch reports provided by NFN's Natural Resources Department (Morgan 2013). This did indeed happen in October 2014, August 2015 and August 2016 (New Chief pulls plug on walleye nets, 2015; Nipissing First Nation Council Moves to Close Commercial Walleye Fishery, 2015; Nipissing First Nation calls for closure of recreational winter walleye Fishery, 2016).

Memorandum of Understanding

In March 2016 the OMNRF and NFN signed a Memorandum of Understanding (MOU), forming a new provincially recognized partnership in which OMNRF would support the NFN's Fisheries Management Plan by helping to implement NFN Fisheries Law with respect to Commercial Fishing on Lake Nipissing.

The MOU includes providing financial and technical resources to NFN for costs related to assessment and monitoring of the fish stocks and for compliance and enforcement action. While compliant commercial fishers and community rights to fish for food, subsistence, social and ceremonial purpose will be protected, it also provides for the withdrawal of licenses for any crews using non-members of NFN as part of fishing crews, and actively patrolling and confiscating all unmarked nets (NFN Fisheries Update 2016).

III. Management Sustainability

Management sustainability has a very marked impact on the sustainability of a fishery, as both short-term and long-term effects of decisions affecting the fishery must be addressed. Harvest control restrictions must satisfy the immediate demands of the local fishing community while limiting the long-term effects of fishing practices on maintaining an ecologically balanced, biodiverse aquatic community. One can evaluate the sustainability of the Lake Nipissing walleye fish stocks that are experiencing a heavy fishing pressure environment, by examining some key indicators of population health: relative abundance, age and size distribution and reproductive capacity.

III.a. Lake Nipissing Walleye Population and Fishery

In the 1970s and 1980s, the popularity of walleye among anglers coming to Northern Ontario had made Lake Nipissing a destination of choice. However, the absence of controls resulted in total harvests (recreational and commercial) exceeding 100,000 kilograms per year. The once robust fishery, whose abundance estimates in the 1980s had reached approximately 400,000 kilograms, began to decline steadily (Morgan 2013). Management-imposed harvest reductions and changes in regulations did result in reports of more moderate total harvests in later years; average yields exceeding 35% of the estimated population in the 1990s decreased to approximately 28% in the 2000s. However, walleye populations continued to decline (Morgan 2013). There was overwhelming consensus that the Lake Nipissing walleye population has experienced unsustainably high levels of fishing mortality for too many decades (Rowe 2007; Kaufman 2011; Morgan 2013; Jones et al. 2016).

Current Trends in Walleye Abundance

A closer look at estimates of walleye abundance in the last few decades illustrates the year to year variability seen in the lake, as well as the degree to which the stocks have been carefully managed. With time, angling restrictions imposed by OMNRF became more stringent with respect to length of season and size and quantity of harvests. Additional restrictions and limits on their commercial fishermen were imposed by NFN, notably the spring gill net and spear fishing moratoriums, the establishment of quotas and the pledge to support active enforcement (Figure 2).

During this time the total exploitable biomass (i.e., fish greater than 300 mm total length) rose steadily from approximately 196,000 kg in 1998 to 260,000 in 2008 (Figure 3). The sharp decline in population in 2009 and 2010, with biomass dropping to 94,000 kg, was attributed to high mortality of the spawning stock (Morgan 2013). The population fell into recruitment over-fishing status, a situation in which the proportion of mature fish is so low, that the population does not have the reproductive capacity to produce enough new recruits to replenish itself (Schmalz et al. 2011). This type of overfishing is usually a precursor to stock collapse (Rowe 2013). The NFN-imposed restrictions to spearing contributed to the high levels of recruitment in the years following, allowing the population to rebound and show steady increases since then. Current walleye estimates reached approximately 260,000 kg in 2016.

Please note that the author did not have access to commercial fishery data, nor access to anyone from NFN willing to discuss the commercial fishery and any current fishing practices. As a result, this information is notably absent from the current report.

Current Trends in Recreational Harvest

In response to increasingly stringent OMNRF-imposed angling rules, recreational harvest yields have been trending downward since 1998. During this time the largest recreational harvest was 23% in 2001 (approximately 54,000 kg), with the lowest at 4% in 2015 (approximately 9,500 kg) (Figure 3). The angling effort on Lake Nipissing also shows a gradual decline during the open water season since 1998. The decline in angling effort during the winter season has been more pronounced in the last several years (from 2010 to 2016), but it may be correlated with shortened seasons due to decreasing ice cover over time on the lake (Morgan 2013)(Figure 4).

CREEL data for the last ten years (2006 to 2016) has shown that, on average, winter anglers typically harvest approximately 45% of the annual catch and the open water fishery approximately 55%. The total number of walleye caught by anglers to those fish kept (winter and open water seasons) showed great

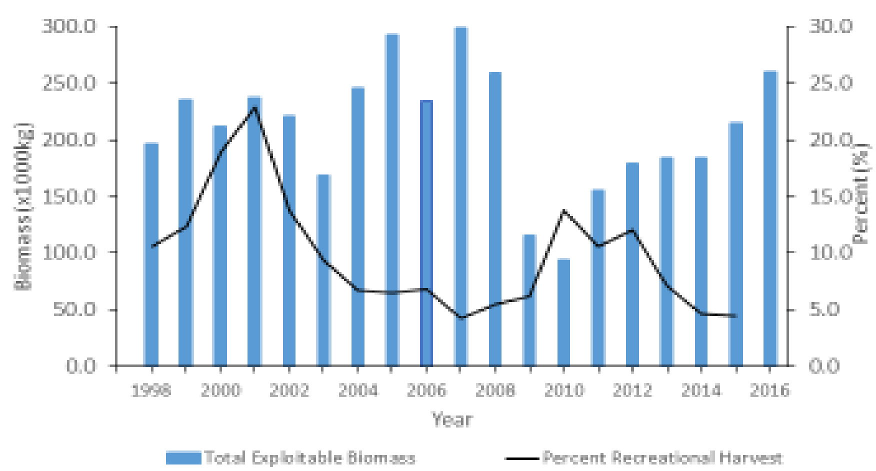

Figure 3. Time series of Lake Nipissing annual walleye biomass (i.e. fish ≥300 mm) and percent recreational harvest. Data is from annual FWIN and CREEL surveys.

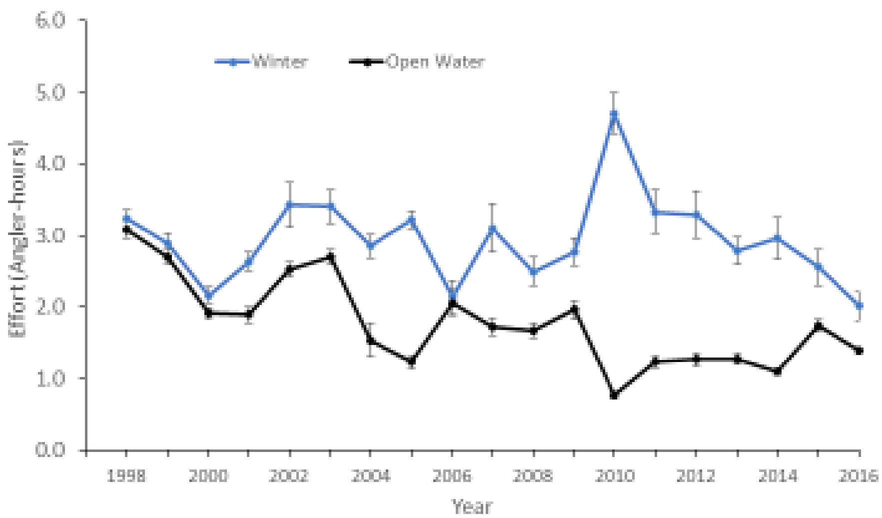

Figure 4. Time series of annual fishing effort on Lake Nipissing (± standard error). Data is from annual CREEL surveys.

fluctuations over time (Figure 5). Prior to 2011, anglers in 2002 caught and kept the greatest numbers of fish (165,000 and 132,000, respectively), whereas anglers reported the lowest numbers of fish caught and kept in 2010 (23,000 and 13,600, respectively). Since the record low harvest year of 2010, there has been a steady increase in the total number of fish caught by anglers, peaking at 139,000 in 2015.

An examination of the percent of the harvest kept reveals a steady downward trend in these values, from approximately 80%, in 1998, to approximately 62% in 2012. Since 2012 there has been a steady rise in the number of fish caught by anglers together with a concomitant decrease in numbers of walleye kept (i.e. 45,000 or 62% kept in 2012, to 12,000 or 9% kept in 2016) (Figure 5). This aptly illustrates the large number of recruits (i.e. >300 mm) that have become vulnerable to the fishery (i.e. exploitable stock), but that fall outside the size restrictions (i.e. 400-600 mm imposed in 2000, above 460 mm imposed in 2014), so must be released back into the water. This was particularly evident in the 2015 and 2016 harvests. This strong cohort of recruits will mature in the next few years, so fishery management and commercial and recreational fishers must resist the urge to overexploit once they reach regulation size. These results also bring to light a serious issue: the high percentage of the exploitable stock (e.g. 91% or 134,000 fish in 2016) that are subjected to the stresses of catch and release during the angling season.

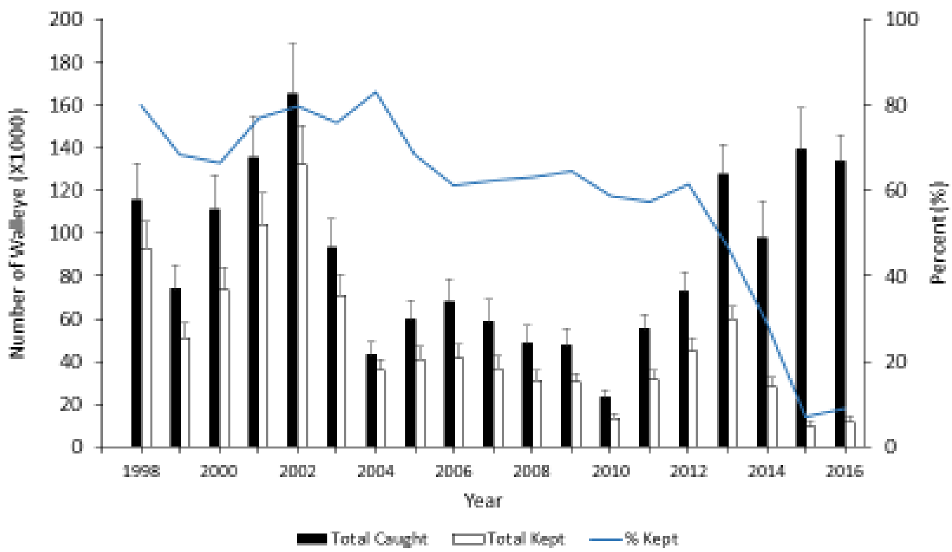

Figure 5: Total number of walleye caught versus kept in the annual recreational fishery (+ standard error). Data is from annual winter and open water CREEL surveys.

III.b. Catch and Release Stresses

Historically, angling stresses experienced by fish were of no concern in a fishery free of regulations and where most walleyes caught, were kept. In the last 15 years, the use of size-based regulations has become a common fisheries management tool to control harvests (Isermann and Parsons 2011). Since a large proportion of protected fish are now being caught and released back into Lake Nipissing, one cannot presume that all fish that are released will survive the ordeal. A review of seven catch-and-release studies involving over 3,800 walleye estimated that in general, hooking mortality falls within the range of 0% to 23% (Casselman 2005). High hooking mortality of fish otherwise protected by regulations could severely undermine the effectiveness of management strategies for Lake Nipissing walleye recovery.

The primary factors influencing hooking mortality include high water temperature (i.e. greater than 24^{o}C for walleye) (Hoffman et al. 1996; Reeves and Bruesewitz 2007), bleeding (Schisler and Bergersen 1996) and internal damage from deep hooking (e.g. in the throat or stomach) (Dextrase and Ball 1991; Dubois et al. 1991). Cutting the line does not significantly improve survival in deeply hooked fish (Schisler and Bergersen 1996; Jenkins 2003). Hooks can also cause physical injury by damaging gills, jaws and eyes, which may impede normal function in terms of movement, feeding or reproduction thereafter (Isermann and Parsons 2011). In addition, fish caught and reeled in quickly from deep water might be too rapidly depressurized, resulting in over-inflation of the gas bladder. Once released and returned to the water, injury or death may follow from an inability to submerge, or internal haemorrhaging (Kerr 2001).

Mortality is also higher for fish that have been exhausted from lengthy angling exercise (Tufts et al. 1991) and by exposure to air (Schisler and Bergersen 1996; Bettoli and Osborne 1998). Once a fish is landed, air exposure causes the gill lamellae to collapse, hindering its ability to take up oxygen, causing asphyxiation (Ferguson and Tufts 1992). This problem is exacerbated with exposure to cold, dry winter air during ice fishing (Dubois et al. 1991). A study examining the effects of both exercise and air exposure on rainbow trout showed that fish chased for approximately 10 minutes had a survival rate of 88%; survival fell to 62% for fish that were then exposed to air for 30 seconds and further to 28% for fish exposed to air for 60 seconds (Ferguson and Tufts, 1992). In a similar study with rock bass, Cooke et al. (2001) showed that fish that were chased for 30 seconds and then had 30 seconds of air exposure required 2 hours for full respiratory recovery, while fish that were exposed to air for 180 seconds required 4 hours to fully recover.

These studies highlight the need for fishermen to be mindful of all angling stresses if the probability of catching a fish outside of the regulation size is high. While catch-and-release practices may not initially cause mortality, it can remove previously healthy fish from the population, with the angler denied the satisfaction of keeping the fish.

Possible mortality of released walleye should be investigated by fisheries managers. Initial efforts could involve additional questions to be posed to anglers during CREEL surveys regarding any hooked fish, including the presence or absence of blood, whether fish were hooked deeply or not, whether the fish swam away, angling time, and whether a picture was taken (i.e. it should be possible to reconstruct the total length of time the fish was out of the water). Correlating this information with approximate water temperature and depth may give a more reliable estimate of hooking mortality, given these stressors. Further, controlled experiments investigating the stress variables described previously would provide further insight on tolerances of hooking stresses in Lake Nipissing walleye, and help to estimate catch-and-release mortality.

III.c. Lake Nipissing Walleye Population Structure

Growth over-fishing occurs when juvenile fish are caught before they have a chance to mature and spawn at least once (Schmalz et al. 2011). Indeed, historical data reveals that juvenile walleye were experiencing increased growth rates without a comparable increase in rate to maturity (Morgan 2013). To illustrate this, a 350 mm walleye caught in the 1980s was approximately 4 years old, whereas a 350 mm fish caught in 2011 was only approximately 1.5 years of age (Morgan 2013; LNFMP 2014). This increase to a size vulnerable to both fisheries (recreational and commercial) before maturity resulted in juvenile mortality rates increasing steadily in the years spanning 1998 to 2011 (Figure 6). Removal of these pre-reproductive fish effectively reduces the numbers of future breeding stock, and subsequent juvenile recruitment. Recent management changes to size and catch limits have had a positive effect on these juvenile mortality rates, which have been declining since 2011. In contrast, adult mortality rates have remained steady (Figure 6).

The current size restrictions imposed on recreational anglers by OMNRF (i.e. above 460 mm in 2014) were intended to protect the large cohort of pre-reproductive recruits and to address the issue of “growth over-fishing” that had become evident in the Lake Nipissing walleye population (LNFMP 2014).

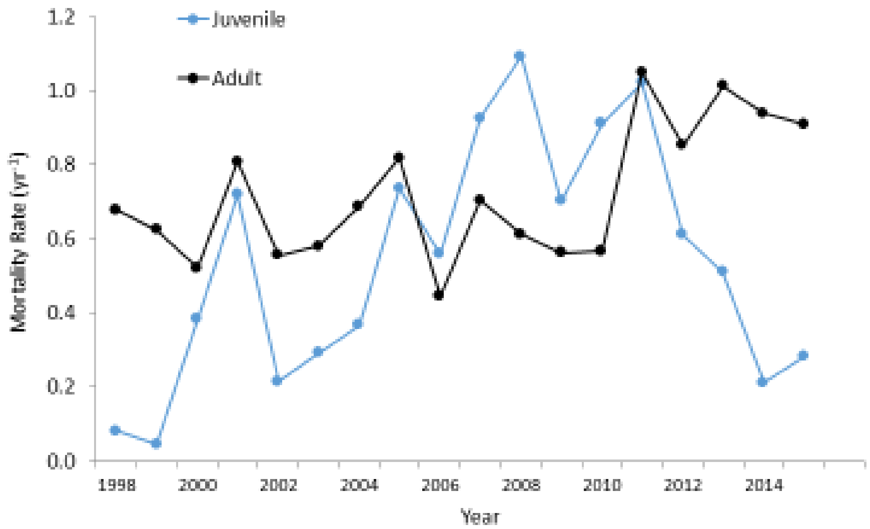

Figure 6: Time series of annual juvenile and adult mortality rates. Data is from annual FWIN surveys.

Abundance estimates of juvenile (i.e. less than 3 years of age) walleye determined from FWIN data also shows that this population has been increasing in the last several years; from 2009 to 2016 numbers have increased from 6 to 16 per net, respectively. However, abundance estimates of adult walleye (i.e. 4 years of age and older) have remained fairly constant at 2 per net since 1998 (Figure 7).

III.d. Lake Nipissing Walleye Spawning Stock Status

Walleye spawning surveys conducted at Wasi Falls showed that more than two times as many males had returned to spawn recently (2013 to 2016) compared to earlier assessments (1968 to 1998), with males aged 4 being the most abundant age class (Figure 8). This is in contrast to the females, in which fewer than half the number had returned to spawn in the years 2013-2016 (Figure 9). Females aged 5 were the most abundant age group in the recent assessment.

These results are in keeping with OMNRF expectations given the current management regulations. Due to the protection of the juvenile walleye the number of first time male spawners (age 4) increased dramatically during the recent spawning assessments. Since female walleye reach sexual maturity approximately 2 years older than males (Morgan 2013; Bozek et al. 2011) a significant increase in female spawners to Wasi Falls is not expected until 2017 or 2018. However, the abundance of older females (aged 10+ years) in the recent assessments has increased under the more restrictive catch limit regulations.

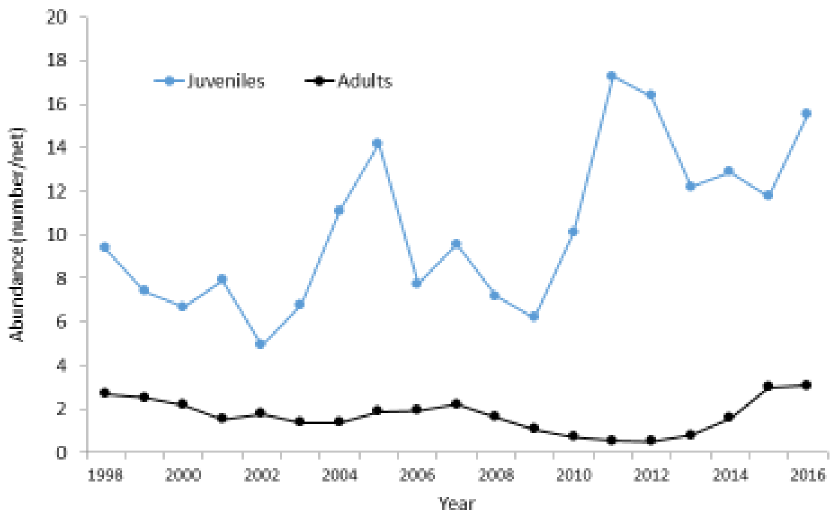

Figure 7: Time series of juvenile (YOY-to-age 3) and adult (≥ age 4) walleye relative abundance versus age. Data is from annual FWIN surveys.

Walleye spawning surveys at Wasi Falls have always detected significantly more males than females. In the earlier assessments (1968 to 1998) approximately 78% were males, whereas in the recent assessments (2013 to 2016) approximately 92% were males. This is not unusual, since male walleye typically comprise a larger proportion of the spawning population on spawning grounds (Priegel 1970). Indeed, a five year study comparing the sex ratios on walleye spawning sites in Lake Winnebago WS, showed that 71 to 98% were males (Priegel 1970). Mature male and female walleye exhibit different spawning behavior. Typically, male walleye become ripe and are ready to spawn at cooler temperatures so arrive at the spawning grounds before females. While females will typically spawn and then leave immediately, males will remain at the spawning grounds for most of the spawning season (Ellis and Giles 1965; Bozek et al. 2011). Thus, the number of males and females counted during the annual walleye spawning surveys at Wasi Falls likely do not represent accurate sex ratios of spawning walleyes.

The current bans on spring gill netting and on spearfishing imposed by NFN Chief and Council are important concessions, given their Treaty rights, but were vital measures necessary to protect spawning adults. Spearfishing is a highly efficient method of selectively targeting larger fish while in a vulnerable state (i.e. when they come in to shallower waters to spawn). The selective removal of spawning individuals can significantly reduce future juvenile recruitment and shift abundance and size structure of species towards fewer and smaller fish (Chapman and Kramer 1999; Matos-Caraballo et al. 2006). Spearfishing typically removes the largest fish, which are those with the highest potential spawning capacity. In terms of ecosystem functioning, the largest fish are also important predators that contribute to maintenance of trophic relationships and a balanced community structure (McClanahan and Muthiga 1988; Dulvy et al. 2002).

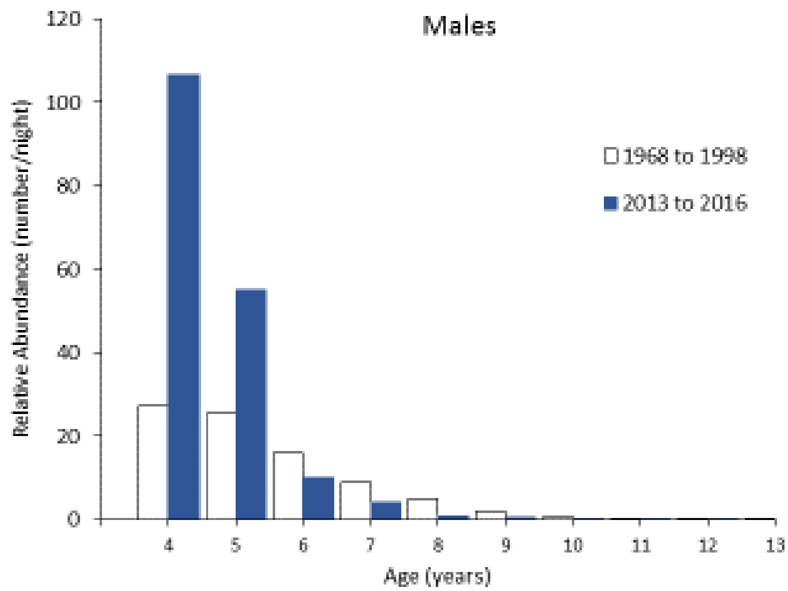

Figure 8: Spawning male walleye abundance at Wasi Falls. Data is from annual spring walleye spawning assessments.

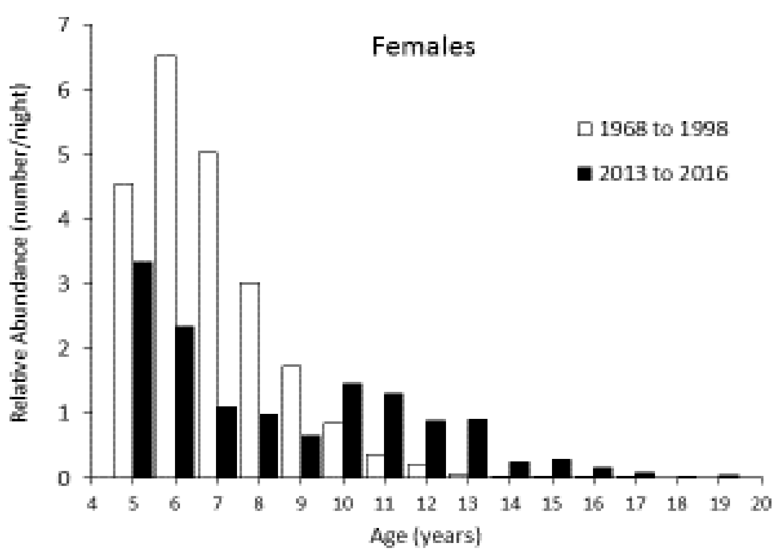

Figure 9: Spawning female walleye abundance at Wasi Falls. Data is from annual spring walleye spawning assessments.

III.e. Lake Nipissing Yellow Perch Population

One of the highlights of the current Lake Nipissing Fisheries Management Plan was to double the permitted daily catch and possession limit of yellow perch from 25 to 50 with the intent of increasing the yellow perch harvest. In an extensive data review of the Lake Nipissing walleye population, Morgan (2013) argued that the decline in walleye as top predator in the lake has resulted in a fish community shift, allowing a dramatic increase in the yellow perch population.

Clearly, yellow perch abundance has increased: it remained relatively stable at 15 per net from 1998 to 2006, then underwent a dramatic increase and has remained more than three times higher than the abundance of walleye ever since (Figure 10). In contrast, the relative abundance of walleye remained consistent at an average of 10 per net throughout the period from 1998 to 2015. To emphasize the difference, in 2012 the average numbers of walleye and yellow perch caught by a FWIN net were 14 and 65, respectively. However, yellow perch abundance has been trending downward since 2012 (Figure 10).

This strategy of allowing more intense harvesting of yellow perch was implemented in an effort to decrease yellow perch abundance and reduce potential competition for lake resources, while facilitating walleye recovery and a re-stabilization of the fish community (LNFMP 2014). A comparison of the annual recreational harvest of walleye and yellow perch shows that anglers have been harvesting an average of 1.5 times more yellow perch than walleye since 2009 (Figure 11). CREEL surveys since 2014 have also shown angler preference trending away from walleye in favour of yellow perch.

The OMNRF should re-evaluate this strategy. Given that yellow perch abundance has been declining and angling preference is shifting to yellow perch, it will be difficult to account for subsequent declines [i.e. fishing effort, predation from cormorants and other environmental stressors (see section IV)].

III.f. Recreational and Commercial Walleye Harvest Estimates

The most difficult aspect of managing a fishery is the uncertainty regarding fishery exploitation. An underestimation of this exploitation, particularly in waterbodies experiencing several types of fishing pressure, may result in harvest levels above fish stock “surpluses”, which will lead to overfishing (Crowder and Murawski 1998; Johnson et al. 2004).

Indeed, fisheries managers have identified overharvesting as the primary cause affecting the recovery of Walleye stocks in Lake Nipissing. Recreational harvest estimates are obtained from seasonal CREEL surveys done by OMNRF biologists, and commercial harvest estimates are obtained by the tracking of daily catches by biologists with the NFN Natural Resources Department. While the bulk of harvest estimates come from true reporting through these methods, accurate accounts of fishing mortality can be undermined by illegal or under-reported harvest (Keledjian et al. 2014), and unreported discard or bycatch (Johnson et al. 2004).

A review of the Lake Nipissing walleye fishery and management by the Quantitative Fisheries Centre at Michigan State University, has suggested that there has been persistent under-reporting of the Lake Nipissing commercial walleye harvest, such that any given estimates are unlikely to be reliable and consistent (Jones et al. 2016). However, this trend in data reporting is expected to improve with

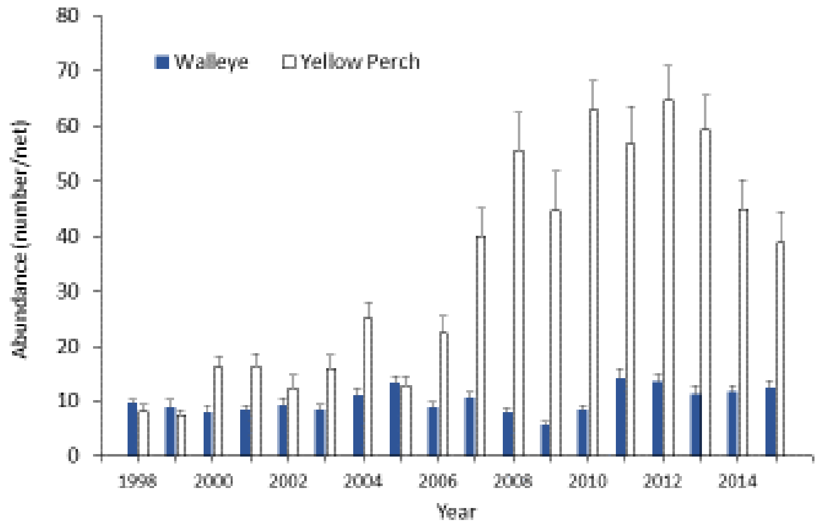

Figure 10. Relative abundance of walleye and yellow perch (+ standard error). Data is from annual FWIN surveys.

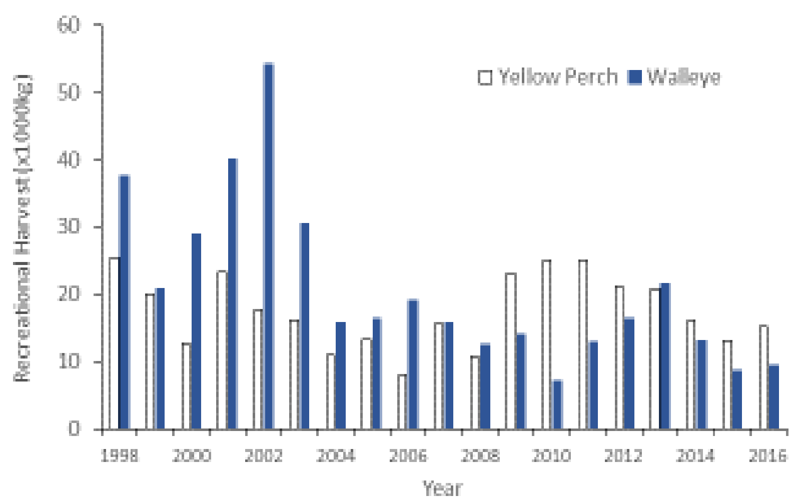

Figure 11: Annual harvest of yellow perch and walleye. Data is from annual CREEL surveys.

financial and technical input from OMNRF for implementing NFN Fisheries Law through the recent Memorandum of Understanding.

The new RAMJAM model for determining safe harvest targets is based on a principle of precaution. It is being applied using management decisions with low risk to the fisheries and following a 10 year walleye recovery plan (Rowe et al. 2013). According to this method, as the walleye population grows, harvest levels should also grow each year while remaining on the desired population recovery trajectory. The authors, who incorporated previous harvest and biomass data into RAMJAM, found that the walleye fishery has been at risk of significant decline or collapse for several years, due to a chronic underestimation of fishing mortality. The first RAMJAM to determine safe harvest targets projecting forward was set in 2013 at 30,000 kg per year; this was half the harvest amount of the previous year. This harvest target remained in place through 2016, even though estimated walleye biomass has been showing steady increases in the last few years. This trend toward recovery is expected to continue.

Given the importance of data from annual FWIN surveys to RAMJAM to help gauge the state of health of the walleye population and to make projections regarding future harvest levels, FWIN abundance estimates should be compared with other reliable estimates of population size to determine the degree of correlation. Mark-recapture tagging studies would give better estimates of total population size and should be carried out.

III.g. The Walleye Stocking Debate

History of Walleye Stocking

Walleye are among the most highly valued fish in North America, found in 32% of all freshwater habitats and targeted as a sport fish in 34 states, 7 provinces, and 1 territory (Fenton et al. 1996). Stocking has become a useful fisheries management tool in order restore depressed fish populations, and to address the increasing demand from both recreational and commercial fisheries. Indeed, the artificial rearing and stocking of walleye has been a management strategy widely used throughout North America for well over a century (Kerr 2011), and continues to play an important role today. Over 995 million hatchery-raised walleyes were released into North American waters in 2006 (Kerr 2011). Walleye stocking of Ontario waters continues today: 1.3 million fry and over 0.3 million fingerlings have been added from 2009 to 2016 by OMNRF (Fish ON-Line).

Lake Nipissing had been stocked with walleye from hatcheries for many decades. Between 1920 and 1954, approximately 25 million yellow walleye (*Sander vitreus*) fry had been introduced in response to depleted native blue walleye (*Sander vitreus glaucus*) stocks (Kaufman 2007). An annual community-based stocking program has been in effect since 1984 with the establishment of a licensed community-run hatchery, in an effort to supplement natural recruitment and enhance angler catch rates on Lake Nipissing. Known records indicate that between 1984 and 1991, 2.2 million fry and almost 0.2 million fingerlings were stocked, and between 2000 and 2006, over 0.3 million walleye fingerlings were released into the lake (Kaufman 2007).

Ontario OMNRF Policies Regarding Stocking

Policies governing fish stocking activities in Ontario were first developed in 1982; stocking is just one of several management tools used by OMNRF to effectively manage aquatic ecosystems and the fisheries they support (OMNR 2002). Concerns regarding the status of a waterbody are first evaluated to identify the nature of the problem, then appropriate management options considered to address the problem in order to achieve the desired outcomes.

Stocking activities are conducted by OMNR, external partners (e.g. Community Fisheries and Wildlife Involvement Program (CFWIP) which is now the Community Hatchery Program (CHP) administered through Ontario Federation of Anglers and Hunters (OFAH)), and private, community based stocking organizations (OMNR 2002). Currently, the OMNRF supports annual volunteer efforts by providing approximately two million eggs from spawning walleye within Lake Nipissing (at Wasi Falls) each spring for local hatchery operations, who then release fry into Lake Nipissing (S. Nelson, personal communication).

Despite public pressure and much debate, increased walleye stocking of Lake Nipissing above current levels is not deemed by OMNRF as the appropriate course of action to address the problem of depleting abundance (LNFMP 2014). Instead management emphasis continues to focus on supporting and enhancing the naturally reproducing walleye population in Lake Nipissing, through harvest regulations and enforcement, monitoring for invasive species, stock surveys and assessments, and public education (LNFMP 2014). The ministry believes that stocking will not address the primary cause of Lake Nipissing's walleye decline, which they identify as overharvesting.

Concerns related to Supplemental Stocking

Stocking waterbodies with a pre-existing viable fish population such as Lake Nipissing (i.e. supplemental stocking), rarely succeeds in enhancing population abundance or year class strength (Fluri 1998). In fact, studies examining the effects of walleye stocking have suggested that lakes with existing viable walleye populations were adversely affected by competition for resources by hatchery fish (Fluri 1998). Comprehensive reviews of numerous walleye stocking projects in North American lakes reported success in only 5% of supplemental stockings (Laarman 1978; Kerr 2007), with fingerling stockings (fish with developed scales and fins, about one finger in length) showing greater success (Fenton et al. 1996; Li et al. 1996; Fluri 1998; Jennings et al. 2005) than fry (tiny fish, lacking scales and fins, about the size of a match head) stockings (Li et al. 1996; Johnson et al. 1996). Kaufman (2007), who assessed the results of walleye fingerling stocking efforts on Lake Nipissing from 2000 to 2006, showed that there was no correlation between the number of walleye stocked and relative abundance of cohorts caught in fall assessment surveys. Furthermore, no relationship existed between stocking level and angler catch rates either 2 or 3 years later when those fish would have been eligible as catch in the angling fishery.

A considerable amount of research exists that may explain the low success rate of supplemental stockings, with specific reference to Lake Nipissing. One of the key factors influencing the success of stocking efforts is the application of the correct stocking density. Lake Nipissing is very large (87,000 ha) with a complex fish community of more than 40 species (Morgan 2013). The recommended walleye stocking intensity for fingerlings in Ontario lakes is between 100 and 125 per hectare, which for Lake Nipissing would amount to 9 and 11 million walleye (OMNR 2002). The required stocking level for fry would be much greater (i.e. 2000 per hectare, or 174 million). It is therefore not surprising that no effect was seen when stocking levels were at about 50,000 fingerlings/year on Lake Nipissing (Kaufman 2007. Indeed, since 2009 only nine Ontario lakes have been stocked by OMRF with the recommended walleye density (Fish ON-Line).

Furthermore, adaptation to complex communities with respect to food availability (Fielder 1992; Peterson et al. 2006), greater susceptibility of stocked fish to predation (Johnson et al. 1996; Kerr 2007), and general adverse effects of stocking, such as handling and transport stress (Kerr 2011) and thermal shock at time of release (Clapp et al. 1997) may also influence survival of stocked fish.

The general concern that stocking programs using hatchery broodstock may, over time, reduce the genetic diversity of the associated wild population is well supported by fisheries scientists (Christie et al. 2012). Captive broodstock are typically a small subset of the population from which they were collected, which implies that their progeny would narrow the genetic diversity of walleyes in the habitat receiving the stock. This may dilute desirable attributes of locally adapted gene complexes, negatively impacting a population's viability or adaptation to environmental changes (Colby and Nepszy 1981; Summerfelt et al. 2011). However, Lake Nipissing walleye are less threatened by such a loss of genetic diversity or undermining of co-adapted gene complexes because annual stocking events use a random subset of the existing (local) wild population as broodstock, with fry being released to the lake several days after hatching.

In general, walleye stocking shows greater success in relatively small lakes (< 350 ha), of suitable water quality and habitat (OMNR 2002), with relatively simple fish communities (Fluri 1998; Fayram et al. 2005), with few predators or competitor species (Kerr 2011), few "natural" walleyes (Fluri 1998), in lakes with little angling pressure (Seip 1995), and where fingerlings rather than fry are stocked at the correct stocking density (Heidinger et al. 1985; Fielder 1992; Li et al. 1996; Brooks et al. 2002). This complex set of requirements may explain the generally poor success rate of supplemental stockings.

It is not recommended that the Lake Nipissing stocking efforts go beyond what is currently being done. Most of the characteristics of a lake suitable for supplemental stocking described in the previous paragraph do not apply to Lake Nipissing. In addition, the abundant juvenile population currently in Lake Nipissing may be adversely affected by competition from stocked fish. Currently, supporting this natural population of young fish to spawning age provides the best chance of recovering the walleye population in the lake as a whole. One must also consider the logistics of a stocking program of this magnitude. Although estimates are currently not known, one could speculate as to the costs, including operational, infrastructure and labour costs, for stocking Lake Nipissing with the appropriate density of walleyes (i.e. 9 to 11 million walleye fingerlings). Current stocking efforts serves as a useful means for collaborating with stakeholders to promoting stewardship of the lake and should continue in this capacity.

IV. Environmental Sustainability

Environmental sustainability is at the heart of a sustainable fisheries resource. In order for Lake Nipissing to support a productive walleye fishery, it must have the capacity to support a healthy food web, sustain a variety of fish populations and a diverse age and size structure of each species. Several environmental stressors currently affecting Lake Nipissing are unduly affecting ecosystem balance, including anthropogenically-induced changes in water quality, climate change effects, notably temperature, predation pressure from double-crested cormorants and the presence of the invasive spiny water flea.

Because the effects of these stressors are broad in scale, subtle, and difficult to rectify, some potential impacts and vulnerabilities remain unclear. Ongoing scientific studies and monitoring programs by OMNRF and local researchers are establishing baselines of environmental indicators that will help track changes in biochemical and biophysical properties that in the future may be indicators of adaptation to new sustainability levels.

Ontario's Broad-scale Fisheries Monitoring program monitors Lake Nipissing fish for contaminants (e.g. mercury, PCBs, insecticides), water temperature, dissolved oxygen levels, invasive species (e.g., rainbow smelt, zooplankton) and fish disease (i.e., viral hemorrhagic septicemia (VHS)) (www .sse.gov.on. ca/sites/ MNR-PublicDocs/EN/Policy/LakeBulletinReport-EN-Lake_Nipissing-Zone11-Cycle01-17-5770-51258/LakeBulletinReport-EN-Lake_Nipissing-Zone11-Cycle01-17-5770-51258.html).

IV.a. Climate change

Anthropogenic greenhouse gas emissions have, over many decades, caused lasting changes to our world. The 2014 Intergovernmental Panel on Climate Change (IPCC) Report estimates global average temperatures to increase by 1.1 to 6.4 C^{o} by the end of the 21st century and ocean levels to rise by 180 to 590 mm. While the specific impacts of these changes will vary by location, climate change is already bringing more variable weather patterns, temperature extremes and heavy precipitation events (IPCC 2014).

The complexity of the climate change issue makes it difficult to predict how any specific aquatic environment will respond. There will be changes to air and water temperatures, evaporation rates, ice cover, seasonal precipitation and water levels, and this may have significant consequences for flora and fauna within an ecosystem (IPCC 2014). Climate change effects have been noted locally. It is expected that the average air temperature will increase by 2^{o}C over the next 60 years (cccma.ec.gc.ca/diagnostics /gcm2/gcm2.shtml). Also, since the 1970s the number of days of ice cover on Lake Nipissing has been getting progressively shorter (Morgan 2013).

Given that Lake Nipissing is a relatively shallow lake, climate change is expected to have a more marked impact on fish species (LNFMP 2014). Temperature is one of the most important abiotic factors influencing fish survival and performance (Hasnain et al. 2010). Species have defined temperature preferences for the maintenance of key biochemical, physiological, and life history processes, namely, growth and reproduction (Wood and McDonald 1997; Beitinger et al. 2000). As water temperatures rise, species such as bass, with warmer water preferences, may proliferate at the expense of walleye (Hasnain et al. 2010). A trend toward earlier spawning of walleye has been linked to climate change. An analysis of the peak of spawning runs from walleyes in Minnesota lakes plotted against the date of "ice-out" showed that walleye spawning begins 0.5–1.0 days earlier for each 1 day decrease in ice-out date (Schneider et al. 2010). It is recommended that studies examining the effects of temperature change on life history processes be carried out for the Lake Nipissing fish community, especially for walleye, to better gauge environmental impacts on fish stocks.

IV.b. Double–Crested Cormorants (*Phalocroccrax auritus*)

The double-crested cormorant is a relatively large migratory water bird widespread throughout North America. Cormorants are opportunistic fish-eaters, and will dive to depths of 1.5 to 7.6 m, and travel 8 to 16 km from their colony in search of easy, abundant prey. Adults consume an average of 500 g of fish per day, and prefer prey of a size approximately 150 mm (Weseloh and Collier 1995; Weseloh et al. 2002). Their numbers have increased dramatically in the Great Lakes during the 1990s, in part due to reduced use of organochlorines (particularly PCBs) in the environment and protection from human persecution (Weseloh et al. 2002). The growing role of the cormorant as a new top predator in many lakes has been a concern for management agencies for decades. Piscivorous birds are not typically regulated by predation in these ecosystems; when they become abundant they have the potential to alter fish community structures (Rudstam et al. 2004). Cormorants are also a source of concern for anglers, many of whom view the birds as principle stressors to fish stocks.

While some studies have concluded that cormorants have marginal or no effect on fish populations (Suter 1995, Trapp et al. 1995), others have demonstrated significant influences. Van DeValk et al. (2002), compared angler harvest and cormorant consumption of yellow perch and walleye in Oneida Lake NY, and showed that each group removed approximately 13% of the spring population during the 1997-1998 angling season. Rudstam et al. (2004) attributed the increase in mortality of sub-adult (age 1-3 years) walleye and yellow perch to the 360 nesting pairs of cormorants on Oneida Lake. The 5-year study concluded that walleye and yellow perch comprised 40-82% of the cormorant diet, with cormorants consuming 24,000 to 49,000 kg of these fish annually. It was concluded that a decline observed in both the walleye and the yellow perch populations was caused by cormorant predation. Cormorant predation has also been implicated in the decline of smallmouth bass and yellow perch in Lake Ontario (Burnett et al. 2002, Lantry et al. 2002).

In general, society's tolerance of control programs to deal with wildlife conflicts varies considerably, depending on the situation. While culling to prevent the spread of disease is overwhelmingly supported (e.g. control of bats in relation to limiting the spread of rabies), it is harder to justify intervention for "nuisance" animals (e.g. Canada geese producing droppings in public spaces), human commensals (e.g. the growing number of raccoons in urban areas) or even controls carried out for "humane" reasons (e.g. to curb starvation of overpopulated deer). Intervention to counteract ecosystem impacts (e.g. the question of controlling mute swans) is equally divisive. Some wildlife managers view culls or harvests of overpopulated wildlife as a legitimate means to restore the balance of an ecosystem in order to maintain healthy, biodiverse habitats.

Cormorant management, including egg and nest removal, egg oiling and non-lethal hazing, became part of the overall management strategy for Oneida Lake NY, and was effective at reducing the number of resident and transient cormorants (Rudstam et al. 2004). With cormorant controls, the mortality of sub-adult walleye and yellow perch declined to levels observed in the pre-cormorant period (Coleman et al. 2016). A joint Department of Environmental Conservation (DEC) and volunteer cormorant "hazing" program was implemented on Oneida Lake in 2013 (http://www.dec.ny.gov/outdoor/ 72333.html.) Culling of more than 25,000 cormorants has also occurred on Leech Lake MN since 2004 in order to help restore walleye populations (http://www.dnr.state.mn.us/birds/doublecrestedcormorant.html).

Policies Governing Management of Double-crested Cormorants in Ontario

Under the Fish and Wildlife Conservation Act (FWCA 1997) cormorants and their nests and eggs are protected as a “species wild by nature”. In response to concerns regarding increasing populations of cormorants in Ontario, a provincial policy was implemented in 1998 which stated that “*…control of cormorant numbers should only be considered in specific local areas if the birds are found to be having significant negative ecological impacts on specific habitats or on other species*”. Any cormorant control measures would be assessed on a site-by-site basis, with public consultation prior to any control program.

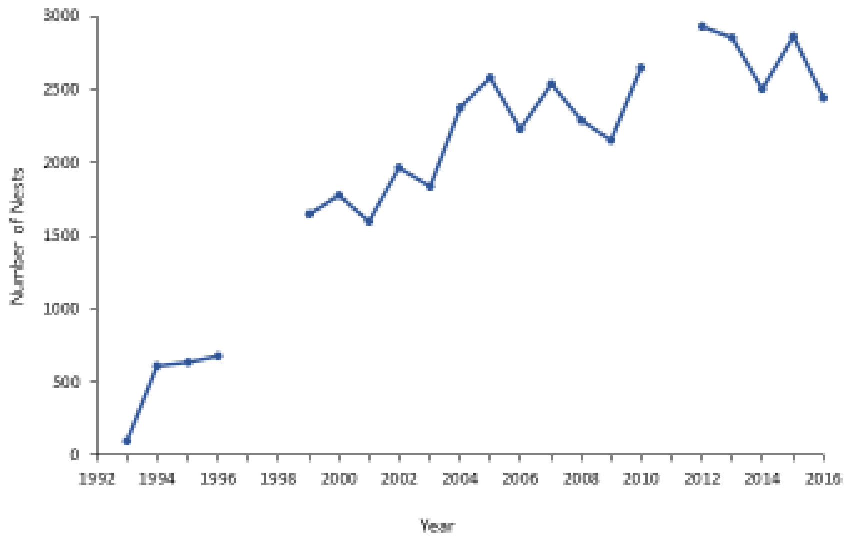

Figure 12: Number of cormorant nests on Lake Nipissing. Nest counts are from Jorgensen, Stronks and Preston 1996 unpublished Lake Nipissing data file report, Jean-Marc Fillion, Lake Nipissing Partners in Conservation, and MNR. Data was not available for 1997, 1998 and 2011.

East Sister Island, in the Pelee Archipelago in Lake Erie, is currently being monitored by OMNRF for cormorant impacts on the island's ecosystem. This 15 hectare Provincial Nature Reserve, which is home to over 20 rare plant species and several bird species, including a major breeding colony of great blue herons, is being threatened by a large colony of cormorants (over 5,100 nests). Specific management activities (i.e., nest removal, egg oiling, culling) may be deemed necessary in the future to control the colony (www. ontario.ca/page/east-sister-island-provincial-park-management-plan).

Lake Nipissing Double-Crested Cormorant Population

Lake Nipissing has the largest inland breeding population of cormorants in northeastern Ontario (OMNR 2006). Cormorants were first observed nesting on Lake Nipissing in 1981. Annual Cormorant Nest Count Surveys conducted by OMNRF since 1993 indicated that the number of active nests had increased to approximately 3,000 by 2012, and have remained relatively stable since (Figure 12). Dietary analysis has shown that cormorants on Lake Nipissing consume approximately 7 perch to 1 walleye (LNFMP 2014). Given the relative abundance of yellow perch in the lake, such results are expected as cormorants are opportunistic predators. Cormorant predation may be a factor contributing to the recent decline in yellow perch abundance (Figure 10). Also, since they are currently preferentially predating upon yellow perch, cormorants cannot be the sole factor driving the decline of walleye in the lake. Fisheries management staff will continue to monitor the cormorant population and they intend to prevent and/or mitigate any significant negative impacts cormorants may have on the Lake Nipissing ecosystem or fishery (LNFMP 2014).

Given that the cormorant population has stabilized, a more complete analysis of cormorant diets is needed to quantify in greater detail the impact of this predator on the walleye population. The predictive value of this analysis will help to gauge future effects of predation on fish populations if further changes occur in the relative abundance of walleye and yellow perch.

IV.c. Spiny water flea (*Bythotrephes longimanus*)

In this age of globalization and the concomitant increase in trade and travel, the threat posed by biological invasions, and aquatic invasive species in particular, has become a serious issue (Olden et al. 2008). Invasive species are a major threat to native species and biodiversity and can fundamentally change the structure and function of food webs (Vander Zanden et al. 1999; Yan 2001; Rogers et al., 2014).

The invasion and proliferation of the spiny water flea is one of more than 180 cases where non-indigenous species have been reported in North American waters, and are having profound impacts and causing significant environmental change (www. glerl.noaa.gov//res/Programs/glansis/ glansis.html). Spiny water flea is a zooplankter, one of the small heterotrophs or detritivores present in the water column that are important in most aquatic food webs (OMNR 2010). With a diet of smaller zooplankton, coupled with the ability to proliferate quickly and easily, introduced spiny water flea can cause an average of 30 to 40% decline in native populations of zooplankton (dnr.state.mn.us/invasives/ aquaticanimals/spinywaterflea/ index.html). Zooplankton biomass has been positively correlated to fingerling walleye survival (Fielder 1992a; Donovan et al. 1997; Peterson et al. 2006).

With total body lengths reaching 10-15 mm and barbed tail spines making up approximately 60% of body length, its palatability as an alternative prey species for smaller fish is limited (Barnhisel 1995). These organisms can be transported long distances on boats or equipment and are easily spread between waterbodies on angling equipment, in bait buckets, and in live wells and bilge waters (ON 2012). Since the first reports of this species in North America in the early 1980s, spiny water flea has since been found in all the Great Lakes and in more than 100 inland lakes in Ontario and in the American states that border the Great Lakes (OMNR 2012).

The spiny water flea was first collected and confirmed in the lake in 1998 by Lake Nipissing Partners in Conservation (Filion 2011). By 2009, the spiny water flea was well established in the lake. In 2010, an extensive survey of zooplankton abundance and diversity showed that the spiny water flea nearly eliminated all the small zooplankton species in the Lake Nipissing by the end of June, followed by the near-collapse of its own population due to a lack of food resources. This severely limited the feeding options for juveniles and other small fish, affecting survival, growth rates and recruitment potential

(Barnhisel 1995). Further, a large percentage of the bio-energy accumulated in the spiny water flea population was lost to the sediments when it collapsed. This scenario has critical implications for the food web, as these energy reserves are lost to predators higher up the food chain. Analysis of gut contents has shown that walleye have had to adapt and access other food sources, including spiny water flea (Fillion, 2011).

The Ontario Federation of Anglers and Hunters (OFAH), in partnership with OMNRF established the Invading Species Awareness Program in 1992 to address such threats. The primary goals are education, awareness and monitoring and tracking initiatives to help prevent the introduction of additional invasive species (www.ontario.ca/page/stop-spread-invasive-species).

Unfortunately, once a new invasive species becomes established, it is usually impossible to eradicate or prevent its inevitable spread. However, an updated analysis of stomach contents of fish harvested during peak periods of spiny water flea abundance is warranted. Such prey analysis would better gauge the degree to which the spiny water flea has been incorporated in the food chain, and would explain whether fish species differ in their ability to consume this invasive zooplankter.

IV.d. Water Quality

The Inland Lakes Group (Ministry of the Environment, Dorset Environmental Science Centre (DESC)), assesses the water quality of the large inland lakes in Ontario including Lake Nipissing, approximately every 15 years, with the next report expected to be released later this year as part of the Lake Nipissing State of the Basin Report (A. James, personal communication). Assisting the DESC in monitoring is the "Lake Partner Program", in which volunteers collect lake water samples for analysis of phosphorus and water clarity by the DESC Water Chemistry Laboratory. The most recent report concluded that the water chemistry of the main body of Lake Nipissing has not changed appreciably from 1988-1990 to 2003-2004, and was similar to those reported for many other lakes throughout Ontario (Clark et al. 2010). However, the water quality of Cache Bay and Callander Bay within Lake Nipissing is suboptimal and has been characterized by persistently elevated nutrient levels, primarily of phosphate and nitrate. Because of their proximity to major local inflows, sources of phosphate and nitrate are likely to be due to nearby anthropogenic activities (e.g. use of phosphate-containing detergents, agricultural land use, sewage, and industrial discharge). Callander Bay is the water supply for the Municipality of Callander but it is also the discharge location for the Municipality's Sewage Treatment Lagoon Systems (Ontario Clean Water Agency 2012). The risk that the discharge poses to the municipal supply and recreational use of Callander Bay's water is significant (HESL 2010). Because of this high risk, Callander Bay is closely monitored as part of a source water protection plan governed by the North Bay Mattawa Conservation Authority (NBMCA), which monitors for threats to drinking water. In addition, researchers at Nipissing University are currently carrying out high frequency monitoring of Callander Bay for a spectrum of indicators of water quality, including temperature, dissolved oxygen, total phosphate and precipitation (A. James, personal communication).

High levels of nutrients can be problematic for they can lead to nuisance algal blooms and the loss of water clarity (Clark et al. 2010). Freshwater algae (i.e. phytoplankton), are a natural and essential part of any ecosystem, as the base of much of the aquatic food chain (Huynh and Serediak, 2006). However, natural sources of phosphorus or nitrogen compounds supplemented by human activities can often trigger explosive growth or algal blooms, primarily in summer months under sunny, calm conditions.

Algal blooms are of concern for ecological, aesthetic, and human health impacts (Clark et al. 2010). Dissolved oxygen can become depleted in the water as large numbers of dead algae decay, which may lead to anoxia and fish kills. Some of the bloom-forming organisms are cyanobacteria (formerly termed blue-green algae), some of which can potentially produce toxins that may have harmful effects on aquatic and terrestrial life (Huynh and Serediak, 2006).

The Sudbury and District Health Unit has confirmed cyanobacterial blooms in Lake Nipissing and the watershed, including Callander Bay, and the West Arm of Lake Nipissing, in the last several years (www.sdhu.com/health-topics-programs/water/blue-green-algae-cyanobacteria). These recurring problems demand more active measures to control agricultural, urban, and storm-water runoff, and to properly maintain and inspect waterfront septic systems.

Furthermore, researchers have determined that areas of high localized phosphorous within the sediment in Callander Bay (accumulated from anthropogenic sources) can be re-released into the water following sediment disturbances or under low oxygen (anoxic) conditions (HESL 2010; Chase and Lovett-Doust 2017a). Indeed, heavy metals have also been found in these sediments, likely fallout from years of mining practices in the greater area of Sudbury (Chase and Lovett-Doust 2017b). The Ontario fish consumption advisory recommends restricting intake of Lake Nipissing fish primarily for mercury contamination only (www.ontario.ca/environment-and-energy/sport-fish-consumption-advisory?id=46178000). Concern regarding such contaminant effects on food webs, fish behavior and development, in particular given the close proximity to the spawning beds at Wasi Falls, have been expressed and warrant further study (L. Lovett-Doust, personal communication).

V. Economic Sustainability

V.a. History of Commercial Fishing in the Great Lakes Region

An economy based on fisheries has been a mainstay for many communities for centuries. The Great Lakes region has historically supported some of the most productive commercial walleye fisheries in North America. Net fisheries were established throughout the 1800s, with gill nets becoming the most commonly used gear (Nielsen 1999; Schmalz et al. 2011). By the early 1900s, inland water fisheries were well established and productive (Schmalz et al. 2011). In Ontario, most of the commercial walleye fishing occurred on the larger lakes, including Lake of the Woods, Lake Seul, Rainy Lake and Lake Nipigon. These fisheries relied primarily on gill nets over other fishing methods (Schupp and Macins, 1977).

The historical collapses of Great Lakes fisheries in general mirror those that have occurred in major fishing regions of the world's oceans. The seemingly limitless freshwater resources fell to the combined effects of overfishing, pollution, habitat destruction and invasive species (Schneider and Leech 1977). Lake Erie, the warmest and most productive of the Great Lakes, had a peak annual walleye harvest of 7 million kilograms in 1956, but by 1971 that had declined to 38,000 kilograms (Baldwin et al. 2002). In Lake Ontario, the annual walleye yield peaked in 1958 at 76,000 kilograms, but declined to zero by 1985 (Schneider and Leech, 1977; Baldwin et al. 2002). Overall, the total annual walleye yield of Ontario's inland lakes had peaked at 1 million kilograms in 1960, declining to 0.4 million kilograms in 1972 (Baldwin et al. 2002).

Commercial fishing operations continue today on all the Great Lakes, but the operations are smaller and well-regulated, with strict limits on the number of commercial licenses that specify species and fishing location, and amount and type of gear used. Currently, commercial walleye fishing is largely limited to the Ontario waters of Lake Erie, and fishers predominantly use gill nets to catch walleye, yellow perch and lake whitefish. The 2015 Ontario Lake Erie commercial walleye harvest was 1.4 million (Wills et al. 2016). Currently, the most successful commercial walleye fishery on an inland lake in North America is on Red Lakes MN and is operated by the local Red Lake Band of Chippewa fishermen (www. seafoodwatch.org/seafood-recommendations/groups/walleye?q=Walleye&o=454107191).

V.b. Economic Value of Commercial and Recreational Fisheries

Walleye quotas for Great Lakes fishing allotted to the U.S. states have eliminated or tightly restricted commercial fishing, choosing instead to reserve depleting stocks for recreational fisheries (Schmaltz et al. 2011). In general, recreational sport fishing has a greater economic impact than commercial fishing. For example, in 2011, revenue generated per pound of finfish harvested from recreational and commercial fishing in the U.S. was $330.32 and $3.02, respectively. Included in these values are "multiplier effects" (e.g. fishing tackle, equipment and trip-related goods and services for recreational fishing; harvesters to processors to final consumers for commercial fishing, SA Fish and Wildlife Economics and Statistics, 2013). In 1999, the overall economic contribution of recreational and commercial fishing to New York State was $3.6 billion and $0.15 billion, respectively (multiplier effects included) (NYSGI, 2000). In 2005, the Ontario commercial harvest (Lake Erie and inland lakes) was valued at $200 million, relatively small compared to the province's recreational fisheries, in which anglers spent over $1.8 billion on direct recreational fishing expenditures (multiplier effects included) (www. statcan.gc.ca/pub/16-002-x/2008002/t/5212689-eng.htm; www. ontario.ca/page/commercial-fishing0).

Anglers in Northern Ontario make a substantial contribution to the economic wellbeing of the region and the province as a whole. The importance of the fishery to the local economy of the area cannot be underestimated. Every sector of the tourism economy benefits from the regions' recreational fishery, in terms of sales of fuel, gear, food and retail purchases, rentals (e.g. ice huts, guides, boats) and accommodation (Research Resolutions & Consulting Ltd. 2015).

Recent CREEL surveys covering the past five years (2012 to 2016) show that while 63% were local, a large proportion of the winter recreational fishers were visitors to the area (36% Ontario residents, 1% from outside Ontario), with an even larger proportion of visitors during the open water seasons (45% Ontario residents, 15% outside Ontario) (Figure 13). A greater proportion of visitors stayed in commercial lodging and/or used ice huts (26% in winter, 49% in open water season) compared with those staying in non-commercial lodging, such as cottagers, day trippers or campers (3% in winter, 12% in open water season) (Figure 14).

In total, recreational fishermen accounted for $407 million of the $1.1 billion spent by all overnight tourists in Northern Ontario. In 2012, this activity generated approximately 4,745 jobs and $189 million in wages across the province, with more than 90% of the economic benefits generated being retained within the region (Ministry of Tourism, Culture and Sport 2014).

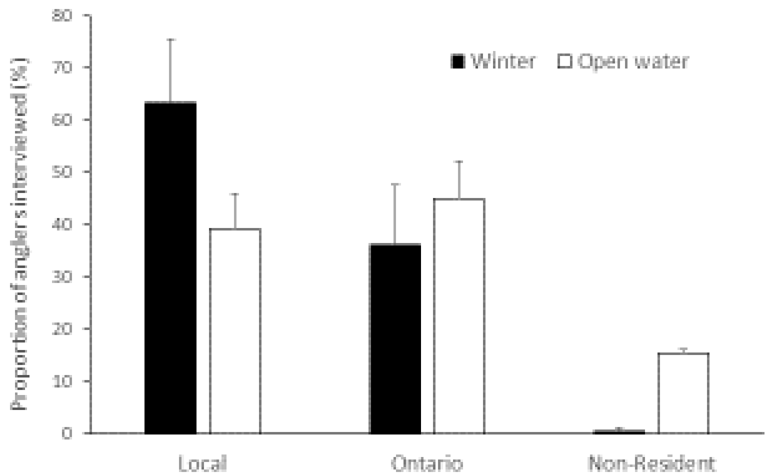

Figure 13. Residency of anglers interviewed during 2012 to 2016 winter and open water CREEL surveys (+ standard error).

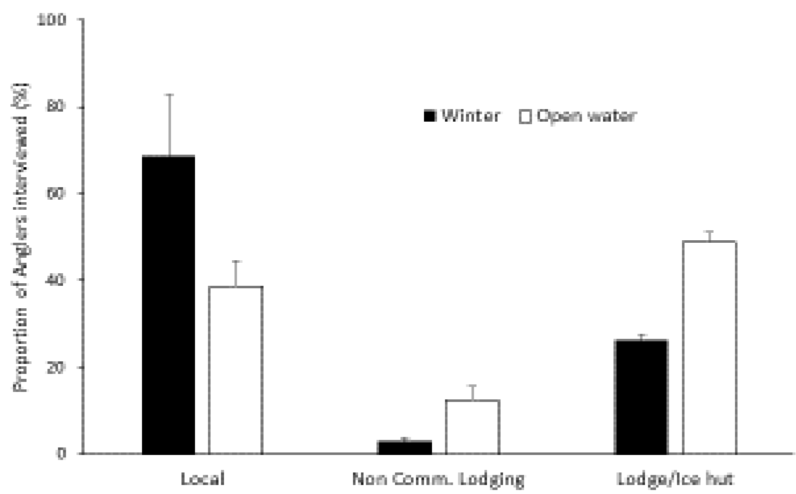

Figure 14. Lodging of anglers interviewed during 2012 to 2016 winter and open water CREEL surveys (+ standard error).

V.c. Gill Nets: Commercial Fishing and Population Assessment Surveys

The commercial fishery on Lake Nipissing currently use gill nets with 95 mm (3¾ inch) mesh in order to selectively target “plate sized fish” (i.e., approximately 420 to 430 mm) (Scott Kaufman, personal communication); this larger mesh size (up from 89 mm or 3½ inches) was implemented only last year under recently updated NFN Fishery Management Laws. Although the exact figure is unknown, the commercial fishery is believed to be allotted approximately 66% of the current total harvest level, or approximately 20,000 kg (K. Tremblay, OMNRF, personal communication).

The use of gill nets in commercial fisheries, while historically the simplest, cheapest and most efficient means for catching fish, is met with widespread disdain among fishermen, conservationists and other stakeholders. Ontario and most North American tribal fishing communities are among the few remaining that sanction gill nets in their commercial fisheries. In 1972 the Department of Natural Resources banned the use of small-mesh gill nets throughout the Great Lakes, followed by a ban in 1974 on large-mesh gill nets in all Michigan waters of the Great Lakes (Goniea, 2017). New York, Ohio and Indiana banned the use of gill nets in 1994 (www. michigan.gov/dnr/ 0,4570,7-153-10364_52259 10951_11244-69487--00.html Fisheries Research Report No.1960, 1990).

Gill nets are panels of monofilament netting normally set horizontally in the water and attached to float and lead lines that allow the netting to remain suspended in the water column (Morgan 2003). Mortality rates are high for fish that become entangled in the netting, as it is virtually impossible to escape. Fish caught by the gills may suffocate or sustain irreversible physical damage to the gill arches and elsewhere (Hubert et al. 2012). Gill nets are especially effective in the capture of fish species that are active and move substantial distances during their daily routines, so it is the gear of choice for commercial walleye fisheries (MCWS 2012; Wills et al. 2016). The efficiency of walleye trapping using gill nets was aptly demonstrated by Hubert et al. (2012), who showed that autumn overnight gill net sets caught 35 fold more walleye than trap nets (a common form of live capture-see below).

Gill nets are routinely used by fisheries managers in monitoring programs as a means to assess the relative abundance and age of fish stocks (i.e., Fall Walleye Index Netting) (Morgan, 2003; Isermann and Parsons, 2011). While gill nets used in FWIN surveys consist of several panels of different mesh sizes to capture samples of all age classes of fish, commercial gill nets are typically of one mesh size, allowing the operator to selectively target a particular size of fish (i.e. within the permitted size range, and with high commercial value). While the greatest proportion of fish caught will reflect the targeted fish size, an incidental group of non-target fish (i.e. bycatch) will always become entangled (Portt et al. 2006). Bycatch could include other species of the target size or non-legal target species. Bycatch can represent a significant mortality source that is often unknown or unaccounted for (McMillan 2012).

V.d. Gill Nets and Bycatch

It has been reported that 17–22 percent of marine fish caught in U.S. fisheries are discarded as bycatch before ever reaching port, likely amounting to 2 billion pounds per year (Harrington et al. 2005; National Marine Fisheries Service, 2011). While reports are rarer, freshwater commercial fisheries have shown comparable results. The commercial gill net fishery for gizzard shad had an estimated annual 15 percent bycatch of Black Crappie (Dotson et al. 2009). A commercial gill net fishery targeting lake whitefish showed lake trout bycatch levels that ranged seasonally from 4 to 44% (Johnson et al. 2004).

While the level of fish mortality associated with gill netting is deemed acceptable when part of a management assessment program, public consensus is generally that bycatch should be minimized and alternative commercial fish harvesting techniques should be pursued. While some non-target species may have market value, any discarded portions of fishery catches, at a minimum, represent an unacceptable waste of natural resources (Crowder and Murawski 1998).

V.e. Entrapment Methods as Alternatives to Gill Nets

Entrapment methods provide an alternative means for commercial fishing and have been used in coastal-marine and large-lake fisheries (www. seafoodwatch.org/seafood-recommendations/ groups/walleye?q=Walleye). Hoop, trap and pound nets are all variations of entrapment methods by which fish are coerced into entering an enclosed netted area through one or more funnel-shaped openings that hinder escape after entry (Hubert et al. 2012). Corralled fish can be removed with a dip net or released with little or no injury to the fish, allowing fish to be harvested in an unstressed state, at their freshest, which should sell for more than gill net caught fish (Hubert et al. 2012).

Trap nets are generally used in shallow areas of lakes and reservoirs and are designed to take advantage of fish migration routes and spawning movements (Hubert et al. 2012). For this reason, trap nets are widely used as a sampling method for monitoring purposes in the assessment of spawning stocks and catch and release programs. Trap nets are used in the commercial harvest of lake whitefish, channel catfish and yellow perch in Lake Huron's commercial fishery (MacMillan, 2012). Sustainable small trap net fisheries for walleye exist in the Canadian waters of the Great Lakes (except Lake Erie). Although no supporting data were provided, walleye are typically caught with lake trout and lake whitefish (Goniea, 2017).

Recommendations

For the Lake Nipissing walleye fishery to be sustainable, the outcome of any fishing effort must be optimized. It could be argued that because recreational sport fishing offers a several fold greater economic impact than commercial ventures, a commercial fishery on Lake Nipissing should be phased out. It is true that greater emphasis on a recreational fishery might ensure a greater level of economic stability, better able to weather unpredictable catch opportunities that come with exploiting an already stressed resource and better able to adapt to market changes. The NFN commercial fishers should be encouraged to explore opportunities which could capitalize on the angling experience together with unique traditional, cultural or historical experiences (e.g. http://www.spiriteagle.ca/).

However, the commercial fishery is associated with First Nations Treaty rights that pre-date and pre-empt recreational angling. As such, NFN a right to fish commercially; this should be accepted and respected as a distinct part of the local fishery economy. In exercising these Treaty rights, however, NFN fishers have the responsibility to use sustainable fishing practices. The current bans on spring gill netting and on spearfishing were constructive measures necessary to protect spawning adults that will contribute to reproduction in future years. In addition, restrictions to the commercial fishery including reductions in quotas and improved enforcement of NFN Fisheries Law with the recent Memorandum of Understanding, is confirmation of a community committed to a sustainable fishery.

However, efforts should be made to change current netting techniques in order to minimize bycatch.

The use of moving gill nets (i.e. strung between two boats) with regular inspections that would allow for the release of non-target species, should reduce the level of bycatch compared with the more traditional stationary nets that are in place for 24 hours. Also, setting gill nets for shorter periods of time, but placed to coincide with locations and periods of active walleye movement (e.g. dusk) should also minimize bycatch. The use of trap nets or another form of nonlethal entrapment as an alternative harvesting technique should also be considered.

At a minimum, if not currently being done, onboard observer programs or short-term monitoring surveys should be in place on commercial fishing boats to clarify the situation regarding bycatch with the gill nets. This would help to increase the accuracy of stock assessments and improve harvest estimates.

VI. Social Sustainability

Social sustainability has very broad requirements and is believed to be the most difficult of all pillars to achieve. On the surface, indicators of a socially sustainable community include a satisfying quality of life and, in the case of the Lake Nipissing region, the ability to live and work within a fishing culture, including the fulfillment of food, ceremonial and social needs. Fishing has always been about more than just catching fish. It is also about the sounds and smells of nature and just unwinding and spending time with family and friends (Research Resolutions & Consulting Ltd. 2015).

At its core, social sustainability demands an engaged fishing community that, through open lines of communication and transparency, is well informed of the issues and concerns. Social sustainability invites, with respect and without judgement, participation from all stakeholders in an open and honest exchange of ideas in order to create positive and lasting change towards a sustainable fishery. The community stakeholders supporting Lake Nipissing include: policy (i.e. national, provincial, First Nations), scientists and resource managers, industry (e.g. tour operators, commercial fisheries, bait shops), community organizations and recreational anglers.

Many examples of successful collaborations between stakeholders exist in support of Lake Nipissing:

- between the Lake Nipissing Fisheries Management Plan Advisory Council (LNFMPAC) and OMNRF to move forward on the current walleye recovery plan
- the Memorandum of Understanding between OMNRF and NFN to help promote NFN Fisheries Law and collaborative management
- between Nipissing University's Integrative Watershed Research Centre and its citizen scientists collecting water samples for monitoring purposes
- between North Bay Mattawa Conservation Authority (NBMCA) and communities within the Lake Nipissing watershed for water quality monitoring and improvement efforts
- between OMNRF and LNSA during the annual walleye stocking efforts
- between members of the Upper French River Cottagers Association (UFRCA) for spawning bed improvement projects
- between this author and OMNRF for requests for information pertaining to the recreational fishery and for participation in CREEL and FWIN surveys

One of the best examples of collaboration was The Lake Nipissing Summit, a forum for open discussion of Lake Nipissing walleye fishery and environmental issues, with participating stakeholders including municipal, NFN, scientists and OMNRF. This well-intentioned conference, recently held for 2 or 3 years, lost its focus and shared goals, and then stopped meeting on a regular basis (S. Kaufman, personal communication).

Transparency

There is a notable lack of transparency and open discourse between fisheries management (OMNRF, NFN) and local stakeholders, no doubt stemming from the sensitive issue of Provincial versus Federal jurisdictions regarding fisheries and Treaty rights. However, all stakeholders deserve to be better informed in issues pertaining to the state of the lake and the fishery in order to be part of a walleye recovery plan. The OMNRF should make annual monitoring and survey data, stock and angling harvest levels and fish allocation more easily accessible to any stakeholder who is interested. Ideally, this would include information regarding the commercial fishery as well. In addition, despite repeated attempts by this author to connect with NFN community members to seek input to this report, these requests were denied.

This lack of transparency and ease of access in regards to fishery information has been an ongoing source of frustration for many, and only serves to promote speculation, misunderstanding, poor relations and fuel hostile exchanges. The commitment to better access and the release of clear comprehensive annual assessments is the right of all citizens of their provincial agencies (www. ontario.ca/page/ published-plans-and-annual-reports-2015-2016-ministry-natural-resources-and-forestry). Access to fisheries information through other provincial and neighbouring state natural resource departments (www. dnr.wi.gov/topic/fishing/reports/; www. michigan.gov/dnr /0,4570,7-153-10364_52259_47568-91516--,00.html; Wills et al. 2016) is, in contrast, straightforward and transparent. This current gap in accessibility to information must be bridged.

Positive interactions, particularly between groups that may often have competing interests, would be a great step towards achieving social sustainability. This could be the reality for Lake Nipissing residents: living and working together to protect and reap the benefits of this shared resource.

Education and Compliance

Open dialogue and respect also ties in closely with resource users having a good understanding of and being compliant with harvest restrictions. This would act to counter under-reporting and end destructive fishing practices by recreational and commercial fishers, resulting in good mortality estimates, and an enhanced ability to maintain harvests below target yields. Building compliance can take time, either because some may be unaware of the regulations, or because some may express a blatant disregard for those regulations. Indeed, much media attention has been directed at noncompliant fishermen over the last several years. In one such occasion, there was a heated confrontation between enforcement officers (OMNRF and NFN Natural Resource representatives) and rogue NFN fishermen using gill nets on Lake Nipissing after NFN had closed its commercial fishery for the season in August 2016. The closure was made in order to remain within the NFN recommended safe harvest level. This issue brought to light the conflict between an individual's Treaty protected right to fish, and community rights to impose harvest restrictions for the greater good of the fishery and the community. This division between core social values, and how the rights of individuals are affected if not aligned with the collective, is a complex issue that must be resolved within the NFN community in order to support the overall recovery of the walleye fishery.

Community involvement

The management of fisheries resources needs to expand to include broad involvement of stakeholders at all stages, from conception to implementation (EU 2002). Resident resource users provide local ecological knowledge and information that can complement the scientific information of regional managers (Linke et al. 2011, Röckmann et al. 2012, Haapasaari et al. 2013). This inclusion would also increase the legitimacy of management through enhanced understanding and support for management regulations, a likely reduction in conflict among the stakeholders (Haapasaari et al. 2013), and increased public awareness of environmental issues. Community involvement provides logistical support and enthusiasm, resulting in more successful outcomes. However, along with support and a diverse knowledge base, stakeholders may also bring different values or expectations in relation to resource use. Conservation of sustainable natural resources should always have the highest priority in management decisions (Aanesen et al., 2014).

A way to harness community involvement and progress towards a more socially sustainable fishery would be to create a community website for posting information pertaining to Lake Nipissing and its fishery. This would include, most importantly, annual walleye survey data and harvests provided by OMNRF/NFN, but also reports pertaining to water quality, invasive species and cormorant predation, information on local collaborative projects and information on possible funding sources for research or community projects. This centralized site would draw information presently found on sites operated by local stakeholder groups (e.g. UFRCA, NBMCA, NFN, Dokis FN, LNSA) and would be readily accessible to all under one site. Equally important would be educational resource sections, not only providing scientific information to help promote fisheries sustainability and understanding of harvest restrictions and compliance issues, but information to promote understanding and acceptance of First Nations communities and their inherent and Treaty Rights.

VII. Conclusion

Lake Nipissing and the walleye fishery it supports is vital to the local economy and way of life of the surrounding communities. Several recognized factors are contributing to an unsustainable fishery, making local stakeholders, including First Nations communities, vulnerable both socially and economically.

- The effects of environmental stressors are subtle yet broad in scale, so some potential impacts to the fishery remain unclear. The effects of climate change and the introduction of invasive alien species leave managers with few options except to monitor effects, anticipate ecosystem changes and incorporate these vulnerabilities into recommendations for fishery management. At a minimum, more active measures to control the human influences affecting water quality are necessary to help curb nutrient loading and limit cyanobacterial blooms. Also, a better understanding of the contribution of cormorant predation to total fish mortality is necessary to determine whether any measures should be taken to control these predatory birds.

- Fisheries managers should make annual monitoring and survey data, stock estimates and harvest estimates more easily accessible to any stakeholder that requests it. All stakeholders deserve to be better informed on issues pertaining to the state of the lake and the fishery in order to be part of a walleye recovery plan. This gesture would take a significant step forward in re-establishing good living and working relationships with local stakeholders.

- Transparency and open communication on all fronts, through the implementation of a new Lake Nipissing focused community website, should enhance understanding of management policies, improve compliance with harvest restrictions and, most importantly, stem the flow of antagonistic outbursts between those who share Lake Nipissing's resources.

- Compliance with management regulations and goals is important to a sustainable fishery, for it leads to good estimates of total fishing mortality and an enhanced ability to maintain harvests below target yields. Such success depends upon active participation and the knowledge that everyone has a role to play in achieving a sustainable fishery.

- The commercial fishery is associated with First Nations Treaty rights that pre-date and pre-empt recreational angling. As such, NFN have a right to fish commercially; this should be accepted and respected as a distinct part of the local fishery economy. The NFN community have made great strides as stewards of the lake and fishery, including bans on spring gill netting, spearfishing, and improvements to the enforcement of NFN Fisheries Law with the recent Memorandum of Understanding. However, efforts should be made to reduce bycatch in the commercial fishery by exploring alternative netting techniques. Also, onboard observer programs or short-term monitoring surveys should be in place on commercial fishing boats to clarify the situation regarding bycatch with the gill nets. This would help to increase the accuracy of stock assessments and improve harvest estimates.

- The walleye population is rebounding, with a strong cohort of recruits that have become vulnerable to the recreational fishery and the stresses associated with catch and release. Anglers need to be mindful of all angling stresses and try to minimize their affects. It is also important for management to develop reliable estimates of hooking mortality to gauge its effects on fish populations. Fishery management and anglers must resist the urge to overexploit this strong cohort of recruits in the coming years once they reach 460 mm.

- The OMNRF strategy of allowing more intense harvesting of yellow perch in an effort to decrease yellow perch abundance should be re-evaluated. Given that yellow perch abundance was already trending downwards and the relative fishing pressure on yellow perch, it will be difficult to account for subsequent declines (i.e. fishing effort vs predation vs environmental).

- It is not recommended that the Lake Nipissing stocking efforts go beyond what is currently being done. Lake Nipissing does not possess the characteristics that would support a successful stocking effort. Supporting the abundant natural population of juvenile fish to spawning age provides the best chance of recovering the walleye population in the lake as a whole.

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