External Review of Lake Nipissing's Walleye Fishery and Management

Conducted by the Quantitative Fisheries Center, Michigan State University, at the request of the Ontario Ministry of Natural Resources and Forestry (OMNRF).

Panel Membership

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November 2016

Introduction

The Ministry of Natural Resources and Forestry (OMNRF) is responsible for managing fisheries in Ontario. Lake Nipissing is Ontario's third largest inland lake and provides important recreational and commercial fisheries, with the majority of targeted effort focused on Walleye (Sander vitreus). The OMNRF has a Memorandum of Understanding with the Nipissing First Nation regarding the management of its commercial fishery, with the mutual objective of restoring a sustainable walleye population. The Ministry also works in partnership with Dokis First Nation, other local Aboriginal groups and the Anishinabek/Ontario Fisheries Resource Centre to ensure sustainability of the Lake's resources.

Recently, concerns have been raised by OMNRF and First Nations groups about the status of the Lake Nipissing Walleye stock, including the sustainability of current recreational and commercial harvest and the ability of current fishery management approaches to respond to changes in the Walleye population and limit harvest to sustainable levels. A review undertaken by OMNRF (Morgan 2013) summarized several datasets on Walleye abundance and population characteristics, as well as recreational and commercial fishing effort and harvest from 1967 to 2011. The review reached several conclusions, including high levels of Walleye harvest throughout the 1970s and 1980s, a declining Walleye stock in the 1990s, and a current stock size believed to be half of historical abundance. The review also concluded that the current harvest targets of 66,000 $kg \bullet yr^{-1}$ are likely unsustainable given ongoing declines in Walleye abundance. A previous OMNRF review of the Lake Nipissing Walleye fishery (Dunlop 1997) also cited concerns about the potential for overfishing, including the suggestion that the Lake Nipissing Walleye stock was being fished close to its sustainable level during the late 1990s.

The apparent trends of declining Walleye abundance, as well as ongoing concerns about high fishing mortality, have led OMNRF to undertake several changes to Walleye management, including increasingly restrictive bag and slot limits between 1999 and 2014. Nipissing First Nation has also undergone changes to their commercial Walleye fishery in order to reduce their harvest numbers. Changes include conditions set out in their Fisheries Law (i.e. increasing the minimum net mesh size from 3.5 to 3.75 inches), implementing a moratorium once sustainable harvest levels have been reached, and more recently, working with the OMNRF to implement a Memorandum of Understanding to pursue the joint goal of Walleye population recovery in Lake Nipissing. These progressively restrictive management decisions have reflected general concerns about the status of the Walleye stock and the need to prevent overexploitation given the historical and current importance of the fishery.

As a result of ongoing concerns about Walleye abundance and the suitability of current management approaches, OMNRF sought to have a 3rd party independent assessment undertaken in early 2016 of the status of Lake Nipissing's Walleye fishery. OMNRF inquired about the possibility of such a review being conducted by Michigan State University's Quantitative Fisheries Center (QFC), given the center's expertise in stock assessment and management strategy evaluation. After brief discussions about what the review process would entail, an agreement was reached whereby the QFC would undertake the independent review, chaired by Dr. Michael Jones, Co-director of the Quantitative Fisheries Center at MSU.

To initiate the review, a group of 3rd party panel members were invited to participate in the review process by the Chair of the panel (i.e., membership in the panel was not determined or influenced by OMNRF). Panel members were selected by the Chair based on their research and management expertise with Walleye fisheries in north-central North America, as well as expertise pertaining to stock assessment and other aspects of quantitative fisheries science. Panel members were Dr. James Bence, Co-director, Quantitative Fisheries Center, MSU, Dr. Gretchen Hansen, Minnesota Department of Natural Resources[1], Patrick Schmalz, Minnesota Department of Natural Resources, and Dr. Chris Vandergoot, Ohio Department of Natural Resources. Activities to support the review, such as note taking and report writing were undertaken by Dr. Andrew Drake, Post-doctoral Fellow, University of Toronto Scarborough, in collaboration with panel members.

The panel was convened in April 2016 and was guided by a set of Terms of Reference (ToR) developed by OMNRF (see Appendix 1). To support the review process, OMNRF compiled 51 relevant documents and data files, which were accessible to panel members for review in early April 2016 until completion of the review process in June 2016. Documents were shared through a secure Google Drive platform and included: data files (10 items, such as results of the Fall Walleye Index Netting program and supplementary index data used to develop the Dunlop (1997) and Morgan (2013) reports); fisheries management plans (3 items); Lake Nipissing reports (4 items); maps (3 items); model documents (14 items, including the RAMJAM methodology and the Lake Nipissing surplus production model report); newsletters (5 items); water quality documents (2 items), and ten additional items, such as the Nipissing First Nation commercial harvest report, data from Wasi Falls tagging and angling recaptures, and economic analysis of the recreational Walleye fishery, along with other relevant materials.

The panel reviewed the documentation provided by OMNRF during April 2016 and discussed preliminary findings related to the background material during a closed video conference on April 21, 2016. During this discussion, the Chair outlined the review process, which would include (1) review of key documents, (2) face-to-face meeting in North Bay to develop the panel's response to questions raised by the ToR, (3) preparation of a draft report, and (4) preparation of a final report following OMNRF's review of the draft report.

The panel met in person from April 28 to 30, 2016 at the Hampton Inn in North Bay, Ontario. In addition to addressing ToR items, this face-to-face meeting allowed the panel to ask clarifying questions about the data of OMNRF staff familiar with the Lake Nipissing fishery. Attendees from OMNRF during the first half of the meeting included Rob Baker, Mitch Baldwin, Dak de Kerckhove, Larry Ferguson, George Morgan, and Kim Tremblay. The question and answer period with OMNRF staff began at 9 am and concluded shortly after noon on April 29. The remainder of the face-to-face meeting in North Bay was attended only by the panel members.

Objective of 3rd Party Review

The objective of the review was to undertake an independent evaluation of the Lake Nipissing Walleye fishery on behalf of OMNRF. The review was to include:

- Examination of available data;
- A critique of past harvest policies;

[1] At the time of selection to the review panel, Dr. Hansen was a research scientist with the Wisconsin Department of Natural Resources

- Formulation and evaluation of hypotheses to explain the current fishery status, including relative risk to the Walleye population and fishery; and,
- Recommendations of future research, monitoring and assessment.

OMNRF identified four Areas of Interest about the status of the Lake Nipissing Walleye stock and the assessment and management of the Lake Nipissing Walleye fishery. The four Areas of Interest are:

1. Are there detectable trends in Lake Nipissing's Walleye population through the available datasets?
    - o What assumptions need further study (if any) to verify trends?
    - o Are there components within the life history of Lake Nipissing's Walleye that require specific attention?
2. Are there detectable trends in fishing harvest and effort through time from the available data?
    - o What assumptions need further study (if any) to verify trends?
    - o Are there components of the commercial, recreational and subsistence fishery that require special attention?
3. Is the RAMJAM model an appropriate risk assessment methodology for setting quotas?
    - o Is there evidence that the Walleye biological reference points (e.g. B_{msy}) have shifted in the last 20, 10 and 5 years and should be recalculated?
    - o Is the FMSS simulation a reasonable method for calibrating the current fishing mortality into 10 year and 20 year recovery trajectories?
    - o Are there specific components of the model parameters and datasets (population, ecosystem, and harvest) that require additional attention/require more data to be collected? If so, can the data needs be prioritized, and what are the priorities?
4. What are the recommendations for management of a sustainable multi-user Walleye fishery in Lake Nipissing?
    - o Is there evidence that continued exploitation of the Walleye population under the current levels of recreational and commercial harvest will lead to a collapse of the stock? If so, please estimate the degree of risk of collapse, and comment on the possibility of stock recovery to B_{msy} within 20 years.
    - o Is there evidence that continued exploitation of the Walleye population under the current management criteria set forth by the RAMJAM model will lead to a collapse of the stock? If so, please estimate the degree of risk of collapse, and comment on the possibility of stock recovery to B_{msy} within 20 years.

Organization of the Panel Report

The report is organized around the four primary Areas of Interest posed in the ToR. Panel responses are provided for each item, which reflect the collective assessment of the panel. The final section provides a series of concluding statements and considerations for the future assessment and management of the Walleye stock in Lake Nipissing.

Findings of the External Review of Lake Nipissing's Walleye Fishery and Management

1. Are there detectable trends in Lake Nipissing's Walleye population through the available datasets?

The panel began discussing this question by examining the fishery-dependent and independent data that reflect trends in population abundance and biomass, followed by discussions of other demographic attributes of the Walleye population (growth, maturation, mortality). We relied heavily on the Fall Walleye Index Netting (FWIN) data set, a fishery-independent survey widely used in Ontario, which the panel believes is the most informative source of information on population trends. Because this survey has only operated since 1998, evidence for population trends is most convincing for the period 1998-2015. However, the panel also considered data sets with longer time series, particularly the angler catch-per-unit-effort (CPUE) and harvest-per-unit-effort (HPUE) data.

<u>Trends in Abundance and Biomass</u>

Based on FWIN data, we see evidence for generally steady or increasing abundance (age 2 and older) and biomass (300 mm and larger) from 1998 to 2008, followed by a decline in 2009-2010, and then a recovery in abundance and limited recovery in biomass until 2015 (Figures 1 and 2). The recovery in abundance during 2011-2015 was attributable to high recruitment during 2009-2012 as evidenced by a larger increase in abundance than biomass during this time (the changes in abundance and recruitment between 2011 and 2015 have occurred recently enough to not be documented in the Lake Nipissing Data Review 1967 – 2011 (Morgan 2013)). Our interpretation of the trends in abundance and biomass relied on advice from OMNRF that apparent low abundance and biomass during 2002 and 2003 resulted from problems with gillnet fouling during these years, which substantially reduced the nets' catch efficiency. Ignoring data from 2002 and 2003, the index of mean biomass of 300 mm or larger Walleye from 1998 to 2008 was 3.87kg per net, compared to 2.56 kg per net from 2009-2015. We conclude from these FWIN data that population structure changed substantially around 2008, particularly with respect to older, larger fish (Figure 3). We discuss the most plausible mechanism for this change below.

Angler catch rates (CPUE) varied with no obvious trend over most of the period of record (1983-2015: Figure 4), particularly in the winter fishery. In the open water fishery CPUE declined to a lower level during 2003-2010, though catch rates in both fisheries have increased sharply starting in 2011. The high recent catch rates presumably reflect the elevated recruitment during 2009-2012 with the catch dominated by younger, undersized fish. Angler HPUE shows a declining trend (Figure 5) beginning in 1995; however, these trends are affected by changes to the recreational harvest regulations as well as by availability of fish.

Growth

There appear to be persistent trends in the growth of young Walleye from 2005-2015. The FWIN data show increases in growth during 2005-2009, as indicated by increased length and weight at age 3 (Figures 6 and 7), followed by sharp reductions in size at age from 2010-2015 (the 2010 – 2015 reduction has occurred recently enough to not be documented in the Lake Nipissing Data Review 1967 – 2011 (Morgan 2013)). These growth patterns are consistent with a density-dependent growth response due to relatively poor recruitment of Walleye in the early 2000s, followed by large increases in abundance of younger Walleye during the 2010-2015 period.

Maturation

Despite the changes in growth that occurred during 2000-2015, there is no evidence for changes in length or age at maturity during this period (Figures 8 and 9). This apparent paradox may be due to the difficulty of accurately estimating ages at maturity when the sample size for older fish is quite small, as appears to be the case here. The panel concluded that the evidence for a (lack of) response in maturation schedules is at best weak.

Mortality

The panel spent a considerable amount of time discussing the estimates of total mortality rates (Z) for the Lake Nipissing Walleye population, focusing on those derived from catch curve analyses. The estimates from the Fall Walleye Index Netting data include very high total mortality rates for some years (1998, 2003, and 2008, Z above 0.79), with somewhat lower estimates during 2004-2007 and 2010-2014 periods (Figure 10). The average estimate of Z for 1998-2009 was 0.6, dropping to 0.37 during 2010-2015. Given a value for natural mortality (M) of 0.24, as assumed by Morgan (2013), which seems reasonable for Walleye, these total mortality estimates imply high fishing mortality rates during the earlier period (average $F = 0.36$), and more reasonable rates during 2010-2015, though the estimate of Z increased to 0.49 in 2015. A more comprehensive cohort-based analysis of these data would yield more informative estimates of mortality, but this has not been completed to date.

- **What assumptions need further study (if any) to verify trends?**

The assessment of the status of the Walleye population relative to biomass/abundance objectives (reference points) depends on the assumed relationship between index netting (FWIN) and true abundance. Given the importance of this to judging risk (see below), the panel feels this relationship warrants further study. If practical, it would also be useful to evaluate the assumption that M is 0.24 and is constant across ages and years, perhaps via a mark-recapture tagging study similar to those used in other exploited Walleye fisheries (e.g., Lake Erie; Vandergoot and Brenden 2014, Zhao et al. 2011).

- **Are there components within the life history of Lake Nipissing's Walleye that require specific attention?**

The apparent changes in Walleye growth rates during 2000-2015 (increasing, then decreasing) may be reflective of a density-dependent growth response. These changes warrant further consideration in the context of developing a precautionary harvest strategy. If models to evaluate the performance of harvest strategies assume growth is constant when in fact it is greater at low densities and lower at high densities, then models will not properly characterize risks, especially if regulations are size-based and the maturation schedule depends on growth. It is also possible that changes in growth rates are due to changes in the food web resulting from invasive species. For example, spiny water flea are known to alter zooplankton biomass, phenology, and species composition, and these changes can propagate through food webs to affect top predators such as Walleye. However, insufficient data exist to evaluate this possibility.

The panel felt that the data from Lake Nipissing to inform Walleye maturation schedules were not sufficient to accurately characterize this key demographic parameter, due to the small numbers of larger, older fish observed. Because of this limitation, we recommend using age at maturity data from nearby lakes or regional FMZ standards to inform future risk assessments.

The panel also thought that understanding patterns in recruitment in Lake Nipissing was an important part of assessing the risk of different harvest strategies. The stock and fishery appears to have been sustained by strong recruitment during the last few years, likely offsetting the high fishing mortality rates for older fish. Understanding the potential for continued high recruitment is critical to judge the risks of current exploitation rates, as is an assessment of the stock-recruitment relationship for this population (see Summary of Recommendations for additional discussion about recruitment and the stock-recruitment relationship).

2. Are there detectable trends in fishing harvest and effort through time from the available data?

<u>Trends in the Recreational Fishery</u>

The trends in angler effort documented in Morgan (2013) seem reliable, and the panel was confident in the creel program and methods used to estimate angling intensity. The reported trends indicate a general, steady decline in effort since the 1970s (Figure 11). The reported trends in recreational harvest are more variable, though a strong decline has been seen over the period from 1995 to 2015. More specifically, recreational harvest dropped sharply from 1995 to 1999, then rose until 2001-2002, and has declined sharply since then, with the exception of a moderate rise in 2013 relative to the post-2004 baseline (Figure 12).

<u>Trends in the Commercial Fishery</u>

Based on comments in the Supplementary Data tables (Table S4) and discussions during the face-to-face panel meeting, the panel does not have confidence in the data reporting trends in the Lake Nipissing commercial fishery. The records suggest there has been substantial unreported harvest, notably in recent years, and estimates of this harvest are unlikely to be reliable and consistent. Consequently, it is difficult to draw conclusions from these data about trends in commercial harvest and effort. The panel feels this is a critical deficiency in assessment data for this fishery.

- **What assumptions need further study (if any) to verify trends?**
- **Are there components of the commercial, recreational and subsistence fishery that require special attention?**

The absence of reliable commercial harvest data limits the ability to assess past population dynamics, such as with a surplus production or catch-at-age model. However, the FWIN age composition data provide valuable information on mortality rates that could be used to infer historic commercial harvest, assuming that the recreational harvest data and natural mortality estimates are reasonably accurate. The panel strongly encourages OMNRF to use the approach we outline below to gauge the likely magnitude of unreported commercial harvest, as a check on the extrapolated estimates provided in Supplementary Data Table S4. The proposed method is relatively straightforward but would provide increased confidence around estimates of fishing mortality, particularly with respect to the degree of commercial harvest.

We propose a simple modelling exercise that attempts to reconstruct FWIN data based on estimates of recruitment for each cohort and mortality estimates through time. The approach would provide an estimate of implied commercial yield from FWIN data, which could then be compared with reported yield, allowing deviations between the two values to be investigated. Parameters to be estimated in order to fit the FWIN abundance at age data would be (a) initial abundances of each cohort, and (b) annual commercial fishery intensity (*fy*). Commercial selectivity, perhaps as function of mean length at age, would need to be assumed known or potentially estimated if commercial age composition of harvest were available in some years. Recreational harvest at age could be assumed known for each year (more complex alternatives could estimate parameters for the recreational fishery and fit the recreational data). The value of M would be assumed known at 0.24. Once these data are assembled and parameters estimated, inconsistencies could be determined between implied and reported commercial yield. A lack of consistency would imply some degree of bias in commercial estimates of yield, which would be expected if a substantial amount of unreported harvest exits. Another possible explanation for a lack of consistency might be substantial departures from the assumed fixed (and known) catchability assumption of the FWIN data, although the panel could not think of any obvious reason for this to be the case.

3. Is the RAMJAM model an appropriate risk assessment methodology for setting quotas?

The panel spent a considerable amount of time reviewing and discussing the RAMJAM methodology, including reviewing how the surplus production model and FMSS are used within RAMJAM to make a determination for a recommended safe harvest level in a given year. Overall, the panel felt that the methodology was conceptually reasonable and would tend to result in a harvest recommendation with a low risk of overexploitation. However the panel also felt that the approach was unnecessarily complex, relied upon questionable (and sometimes difficult to assess) assumptions about Walleye population dynamics, and may not be implementable as detailed in the RAMJAM report. We provide further details below.

- **Is there evidence that the Walleye biological reference points (e.g. B_{msy}) have shifted in the last 20, 10 and 5 years and should be recalculated?**

The panel did not feel the available data would allow examination of this question in any formal sense. The surplus production analysis as documented does not shed light on changes in B_{MSY} over time. In principal, changes in growth rates, maturation schedules, natural mortality rates and recruitment dynamics would affect B_{MSY}, but the panel feels that the available data do not justify such an analysis at this time.

The RAMJAM methodology uses two reference points to assess risk. The panel agreed that a reference point relative to B_{MSY} is appropriate, and that the limit and target levels (0.5X and 1.3X, respectively) are reasonable and consistent with other fisheries. On the other hand, the panel believes that the harvest reference point should be based on a fishing mortality rate (F), rather than a yield (Y). In many other fisheries, overfishing is defined by comparing the estimated current F to a reference point (such as $0.5F_{MSY}$). If the risk of overfishing (as opposed to being overfished) is to be a criterion for the risk assessment, we recommend using F instead of Y, relative to a chosen reference point.

The biological reference points defined above are key to the RAMJAM methodology. They depend on an accurate estimate of B_{MSY}, which in this case is derived from a surplus production model. The panel reviewed documents by the analysts responsible for the surplus production model, and noted that these analysts acknowledged substantial estimation issues with the model, including the fact that the latest versions of the model (with the most recent data) do not converge. Nevertheless, we do not feel the estimates of B_{MSY} used for the risk assessment are likely to be "way off"; accordingly, we conclude that the biomass target implied by the estimate of 1.3 times the estimate of B_{MSY} is reasonable for management purposes. On the other hand, we would recommend that alternatives to estimating B_{MSY} be considered – in particular a stock-recruitment analysis using the FWIN data. Based on such an analysis and estimates of life history parameters, alternative calculations could be made of both B_{MSY} and F_{MSY}.

- **Is the FMSS simulation a reasonable method for calibrating the current fishing mortality into 10 year and 20 year recovery trajectories?**

The panel attempted to understand the details of the FMSS simulation tool in order to address this question, but concluded that some of these details were not discernable from the RAMJAM document and other materials provided. Specifically, it was not clear (1) exactly how recruitment dynamics are simulated in FMSS, and (2) what assumptions were made about growth rates relative to the observed recent variation in Walleye growth rates, and how this would interact with the size-based regulations in Lake Nipissing. Nevertheless, the panel was able to understand how the model was used to define trajectories of population biomass conditional on a fishing mortality rate, and we concluded – provided the assumptions about recruitment and growth are reasonable – that the procedure is reasonable.

On the other hand, the panel has concerns with how this methodology is implemented in practice. The model-derived trajectories for 10- and 20-year recoveries presume that the actual fishing mortality rates prescribed are implemented, and that recruitment persists at roughly average levels. Under these circumstances the modeled trajectory should be followed, at least approximately. However, if the actual harvest in a given year exceeds the specified quota, and/or recruitment is poor, the biomass in subsequent years will be lower than anticipated, and continued application of the same fishing mortality rate policy (and associated quota) will no longer result in the same 10- or 20-year trajectory. In other words, if the biomass does not increase as forecasted from one year to the next, the quota subsequently specified for a given stock size would be too high and the population would not recover as projected. This scenario would lead to a substantially greater risk of failing to reach targets in the time frame suggested by the risk analysis. In effect the strategy is very vulnerable to uncertainty about actual fishing rates. Of course the converse is also possible (less fishing, or higher recruitment, leading to a more rapid trajectory), but under the circumstances this seems much less likely.

The panel strongly encourages consideration of a simpler harvest control rule. One option, commonly used for other fisheries, is to specify a relationship between the assessed current biomass of the population, relative to a reference point (such as B_{MSY}), and the fishing mortality rate to be used in the current year. These two quantities (biomass and F) can be used to calculate a quota. When the biomass is low, a low F is prescribed; as biomass approaches B_{MSY}, F can increase to a target level judged to balance the risk of overfishing with opportunities to harvest fish.

- **Are there specific components of the model parameters and datasets (population, ecosystem, and harvest) that require additional attention/require more data to be collected? If so, can the data needs be prioritized, and what are the priorities?**

The panel strongly encourages OMNRF to work towards developing a better understanding of the stock-recruitment relationship of Lake Nipissing Walleye. Knowledge of the stock-recruitment relationship could then be used to guide the creation of harvest policies, as described above. Even if recruitment is found to be flat (i.e., no evidence for declines in recruitment at low spawner biomass levels), a hockey-stick type stock-recruitment function would be useful in terms of management, where recruitment declines linearly to zero below the lowest stock size on record; this provides a conservative basis for understanding stock dynamics and the relationship with yield.

4. What are the recommendations for management of a sustainable multi-user Walleye fishery in Lake Nipissing?

- **Is there evidence that continued exploitation of the Walleye population under the current levels of recreational and commercial harvest will lead to a collapse of the stock? If so, please estimate the degree of risk of collapse, and comment on the possibility of stock recovery to *B*msy within 20 years.**

Based on the datasets available to the panel and our understanding of the current levels of harvest (e.g., between 70,000 to 90,000 kg in recent years with majority of harvest attributable to commercial activity, Table S3 and S4 in Supplementary Data), it is our understanding that harvest has far exceeded levels that the RAMJAM risk assessment tool has identified as safe. Given the presumed high levels of fishing mortality currently (e.g., with yield between 70,000 to 90,000kg and a stock around 150,000kg, F is ~ 0.5), we consider the risk of collapse to be very high over a 10- to 20-year period. Continued strong recruitment would offset this risk somewhat, but we consider the likelihood of high recruitment continuing indefinitely to be quite small. On the other hand, if harvest could be held at lower levels of F (~ 0.10), as recommended by the RAMJAM procedure, then we think the risk of collapse is low. If the recent strong recruitment continues and fishing rates are kept low, recovery could happen quite quickly.

- **Is there evidence that continued exploitation of the Walleye population under the current management criteria set forth by the RAMJAM model will lead to a collapse of the stock? If so, please estimate the degree of risk of collapse, and comment on the possibility of stock recovery to *B*msy within 20 years.**

The management criteria set forth by the RAMJAM model sets a conservative harvest level for the Lake Nipissing Walleye population. However, the panel believes that the degree of unreported commercial harvest beyond the levels of harvest recommended by RAMJAM is a key consideration in answering this question. Commercial harvest has likely exceeded a level that RAMJAM has identified as safe for the past three years, likely resulting in fishing mortality rates well in excess of recommended levels. The panel considers it very likely that continued harvest at these levels will lead to population collapse. However, if fishing mortality is held at the lower levels consistent with those recommended by the RAMJAM methodology, and recruitment continues at recent levels, there is a good possibility that a 20-year stock rebuilding goal will be met.

Summary of Recommendations

During the course of panel discussions, several conclusions were reached about additional analyses that could be informative. In this section we outline recommendations for further analyses, and summarize some of our key conclusions from the review.

The panel concluded that OMNRF has made good use of available data; however, three sets of additional analyses could be performed relatively easily to reduce uncertainties in current stock status and provide greater confidence in the outcome of management strategy decisions. In order of priority, the panel believes the most pressing task is to create an age-structured stock assessment using FWIN data to compare reported commercial yield to estimated commercial yield, as outlined in the response to item 2. Undertaking this modeling exercise would lead to a better assessment of fishing mortality, especially the degree of unreported harvest, which appears to be an important driver of current stock status. It would also begin the process of constructing an age-based assessment methodology for this fishery, which the panel believes would be very useful if reliable fishery-dependent data can be obtained.

Second, the panel felt that an independent analysis of reference points using a stock-recruit approach would be beneficial. A stock-recruit analysis could be done fairly quickly and would increase confidence in current reference points. Even if recruitment is flat, implementing a hockey stick type stock-recruit function would provide support for conservative harvest decisions when spawning stock biomass is low.

Third, the panel felt that calibration of FWIN data specific to Lake Nipissing would be extremely valuable given the importance of the fall Walleye survey to our understanding of population dynamics. Calibration could be based on a tagging study, which would also provide additional benefits including a better understanding of natural mortality. While a tagging study would require a high degree of cooperation between harvesters and agencies to ensure reasonable tag recovery rates, in our experience a reward system can help to achieve high tag returns. Overall, the panel felt that FWIN survey data were critical to many of our conclusions and are therefore vital to ongoing assessment and management of the Lake Nipissing Walleye fishery.

Several other conclusions were reached by the panel. First, it is important to point out that large changes in growth appear to have occurred between 2005–2015, especially with respect to younger fish. As mentioned previously in this document, there have been large decreases in the growth of younger fish that have been unacknowledged since the Lake Nipissing Data Review 1967-2011 (Morgan 2013) was produced. The potential for a density-dependent growth response and its effect on recommended harvest strategies warrants future consideration.

Second, the panel cautioned that recent strong recruitment is a very encouraging sign regarding the future trajectory of the Walleye stock, but there is a concurrent decline in size at age coupled with changes in fish condition. In terms of recruitment, the panel suggested that OMNRF should be wary of the potential effects of *Bythotrephes* sp., given that Walleye recruitment failures have been observed in other systems (e.g., Milles Lacs, MN) when *Bythotrephes* sp. colonize the plankton community. Recruitment failures have also been associated with the invasion of Rainbow Smelt in inland Walleye lakes, most of which are smaller in size than Lake Nipissing.

The panel also felt it was important to provide context around the fishing mortality rates likely occurring in the Lake Nipissing Walleye fishery relative to other North American Walleye fisheries. Given a natural mortality rate of 0.24 and the total mortality rates estimated using FWIN data (mean of 0.52, range 0.26-0.92: Figure 13), fishing mortality rates in Lake Nipissing are high in the context of Walleye fisheries across central North America. For comparison, Lester et al. (2014) conducted a model-based review of safe fishing mortality rates (F_{safe}) for Walleye, focusing on the relationship between climate, minimum harvested size limits, and compensatory growth. The value of F_{safe} corresponds to the value of MSY in a classic surplus production model (Lester et al. 2014). A fishery fitting the characteristics of Lake Nipissing would have a safe fishing mortality rate (F_{safe}) of around 0.18 based on natural morality estimates of 0.24 ($F_{safe} \approx 0.75M$); however, F_{safe} could be lower than 0.18 if fish below the minimum recreational size limit are being harvested by recreational or commercial components of the Lake Nipissing fishery. Estimates of fishing mortality from the Lake Nipissing fishery have exceeded F_{safe} for 11 of the past 18 years in the period from 1998 to 2015, based on FWIN data (Figure 13).

Lastly, during the review of the draft report, OMNRF asked the panel to comment on the suitability of stocking, as well as the appropriateness of the minimum size limit in the recreational fishery, for addressing the current challenges of stock sustainability. The panel felt that stocking was unlikely to lead to any benefits, and could potentially lead to substantial risk by interfering with recent strong recruitment (i.e., stocking could lead to even lower growth in young fish if their density is increased). The panel felt that the current size limit is very likely to be effective at reducing the harvest and kill of younger walleye in the recreational fishery, but cannot reach a conclusion about its suitability relative to alternative size-based limits on exploitation without further analysis. A useful approach to addressing this question would be to develop a model to evaluate the spawning stock produced per recruit as a function of different size regulations (e.g., SPR analysis). This analysis could evaluate how different size regulations would influence the production of future spawning stock, potentially even modeling a greater contribution of older, larger females to spawning stock. This approach could also consider tradeoffs between spawning stock production and the sizes and numbers of fish harvested relative to angler preferences.

Acknowledgements

The panel wishes to thank OMNRF liaison Larry Ferguson for supporting the review process, as well as OMNRF staff who attended the panel's Q&A session of April 29th, 2016.

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Figures

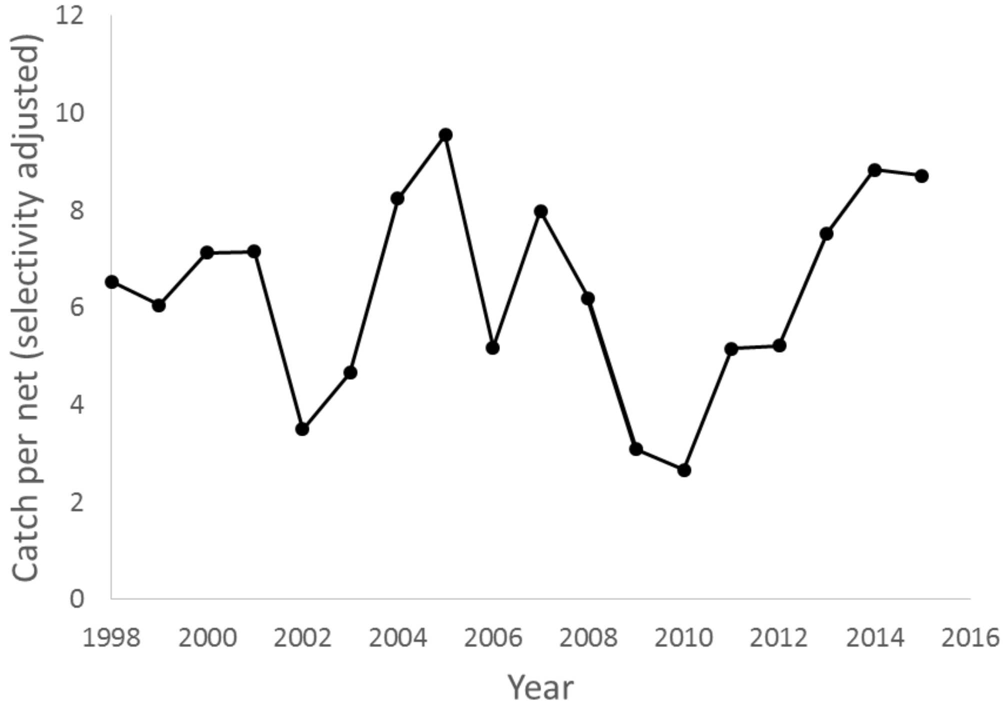

Figure 1. Catch per net (selectivity adjusted) of age 2 and older Walleye, 1998-2015, based on Fall Walleye Index Netting. Data from Table S12.4 in Supplementary Data, Morgan (2013).

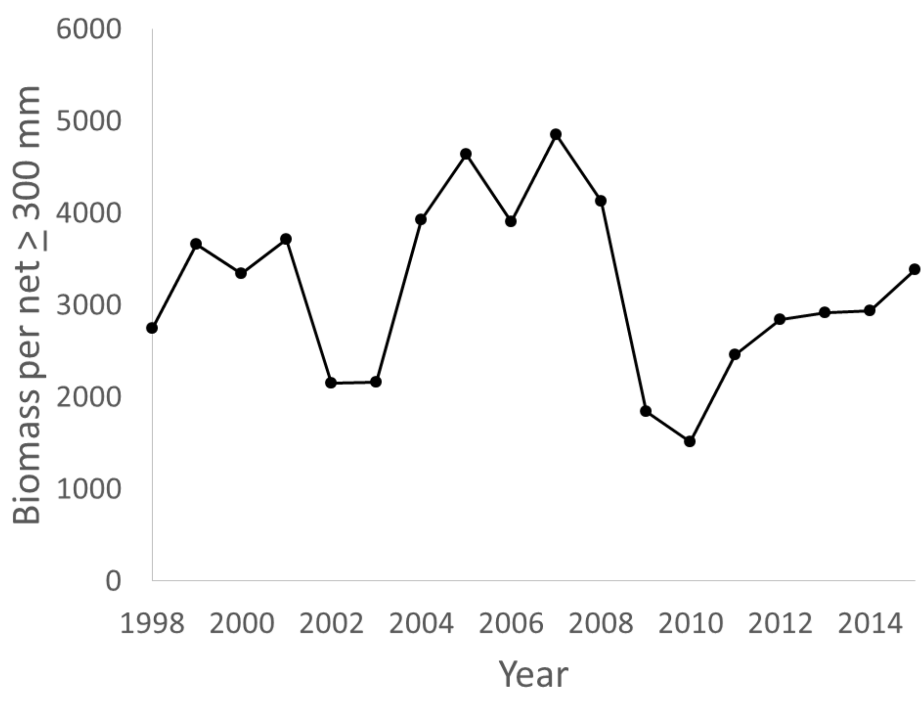

Figure 2. Biomass per net of Walleye (grams•net^{-1}) ≥ 300 mm total length, 1998-2015, based on Fall Walleye Index Netting. Data from Table S13.2 in Supplementary Data, Morgan (2013).

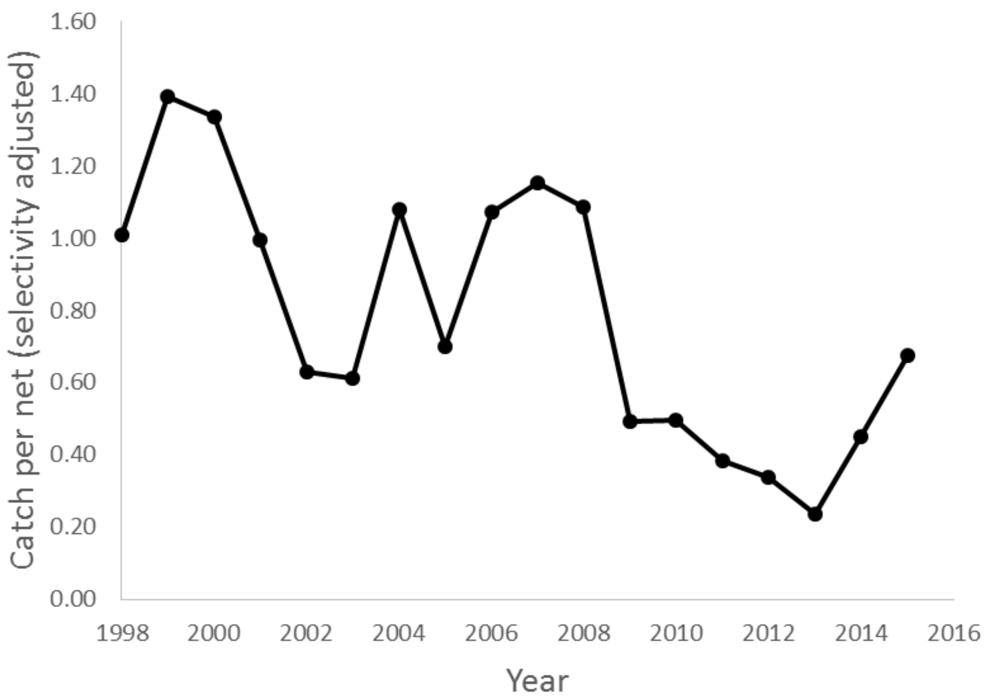

Figure 3. Catch per net (selectivity adjusted) of age 5 and older Walleye, 1998 - 2015, based on Fall Walleye Index Netting. Data from Table S12.4 in Supplementary Data, Morgan (2013).

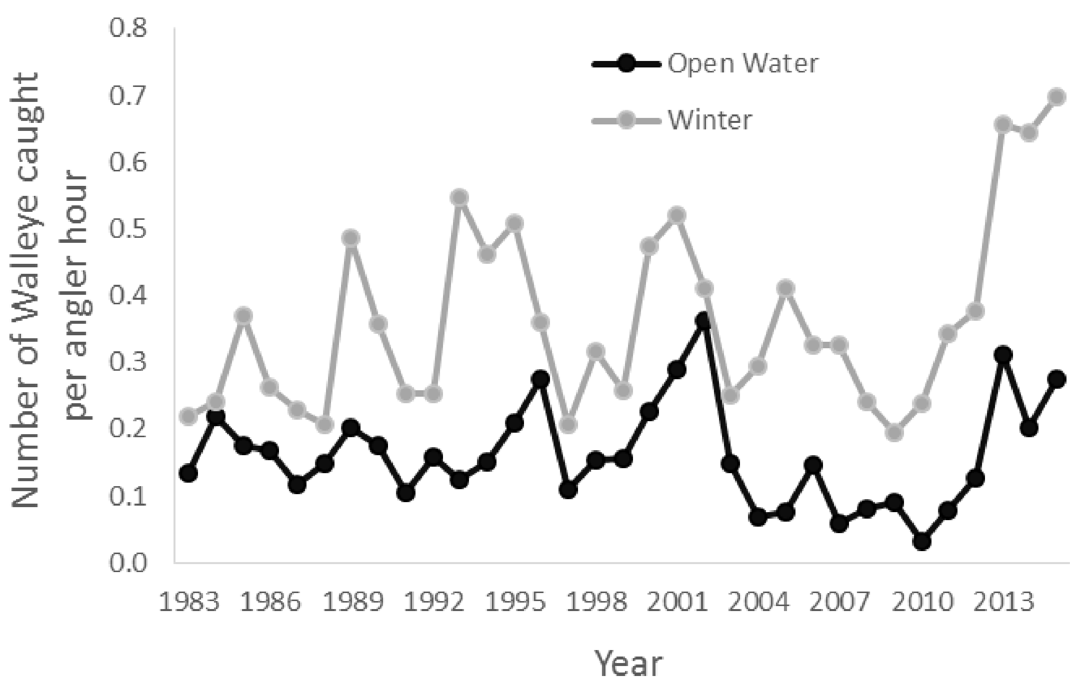

Figure 4. Estimate of the number of Walleye caught•angler hr^{-1} in open water and winter fisheries in Lake Nipissing, 1976-2015, based on the relationship between fishing effort and catch rates obtained through creel surveys. Data from Table S.3 in Supplementary Data, Morgan (2013).

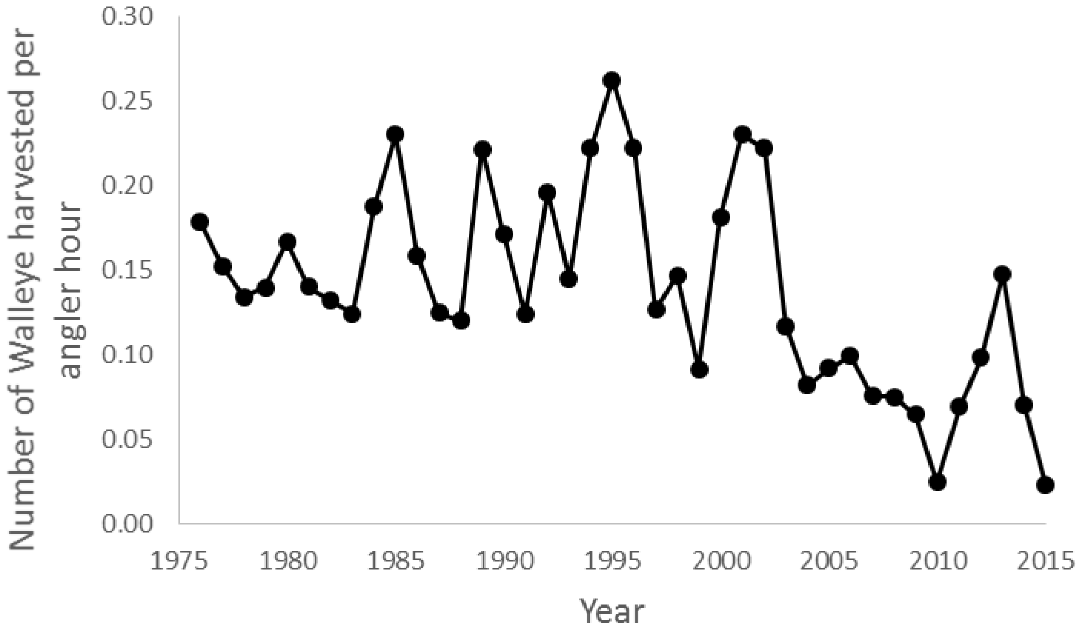

Figure 5. Number of Walleye harvested•angler hr^{-1} in the open water and winter fishery combined, 1976-2015, based on the relationship between fishing effort, catch rates, and proportion retained. Data from Table S3 in Supplementary Data, Morgan (2013).

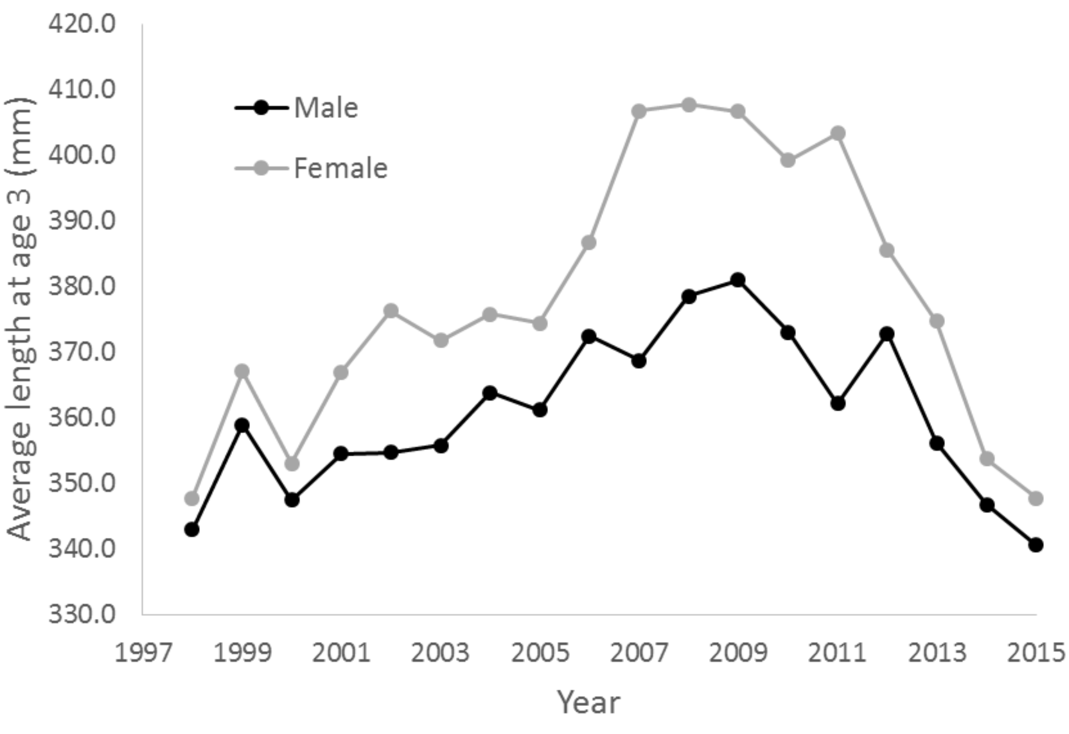

Figure 6. Average total length at age 3 of Walleye (mm), based on Fall Walleye Index Netting, 1998-2015. Data from Table S16 in Supplementary Data, Morgan (2013).

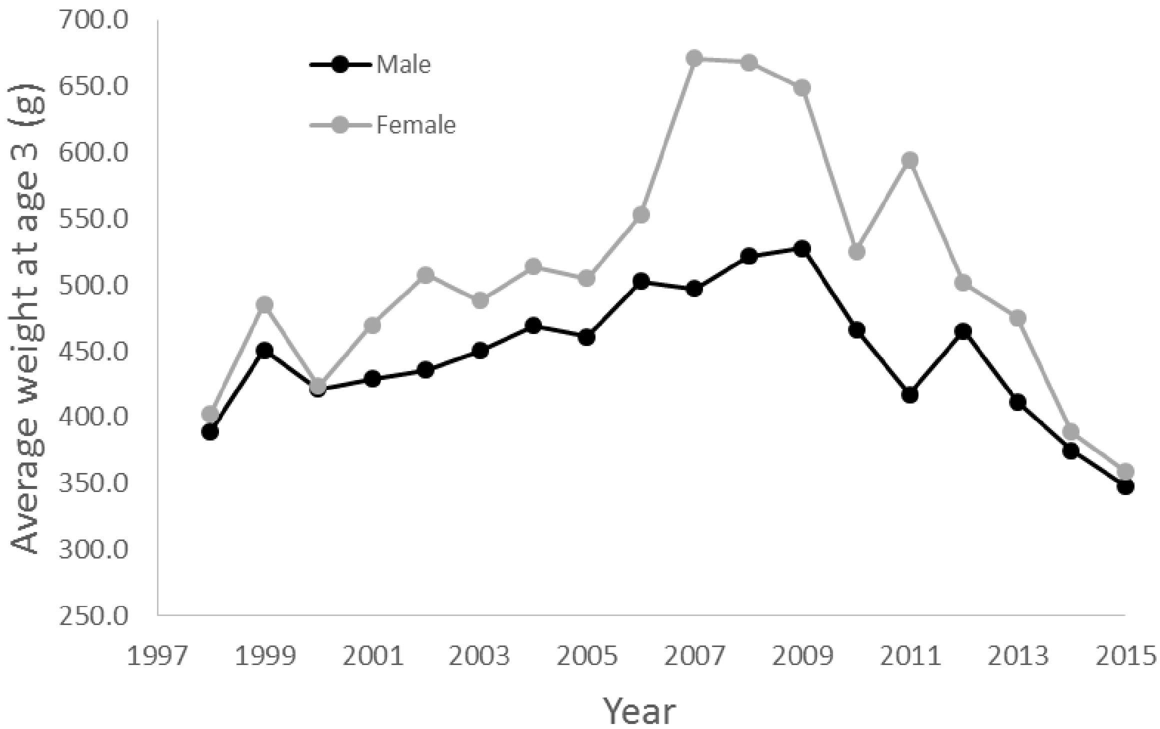

Figure 7. Average weight at age 3 of Walleye (g), based on Fall Walleye Index Netting, 1998-2015. Data from Table S16 in Supplementary Data, Morgan (2013).

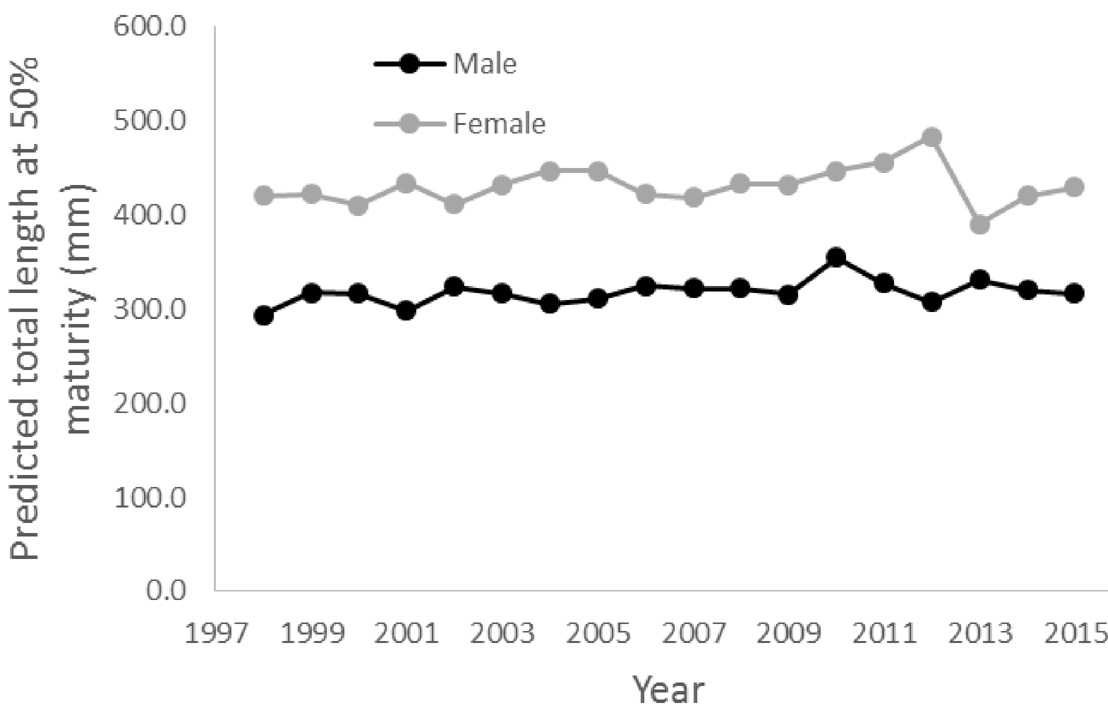

Figure 8. Predicted total length at 50% maturity (mm) based on a logistic function, 1998-2015. Data from Tables S21.1 and S21.2 in Supplementary Data, Morgan (2013).

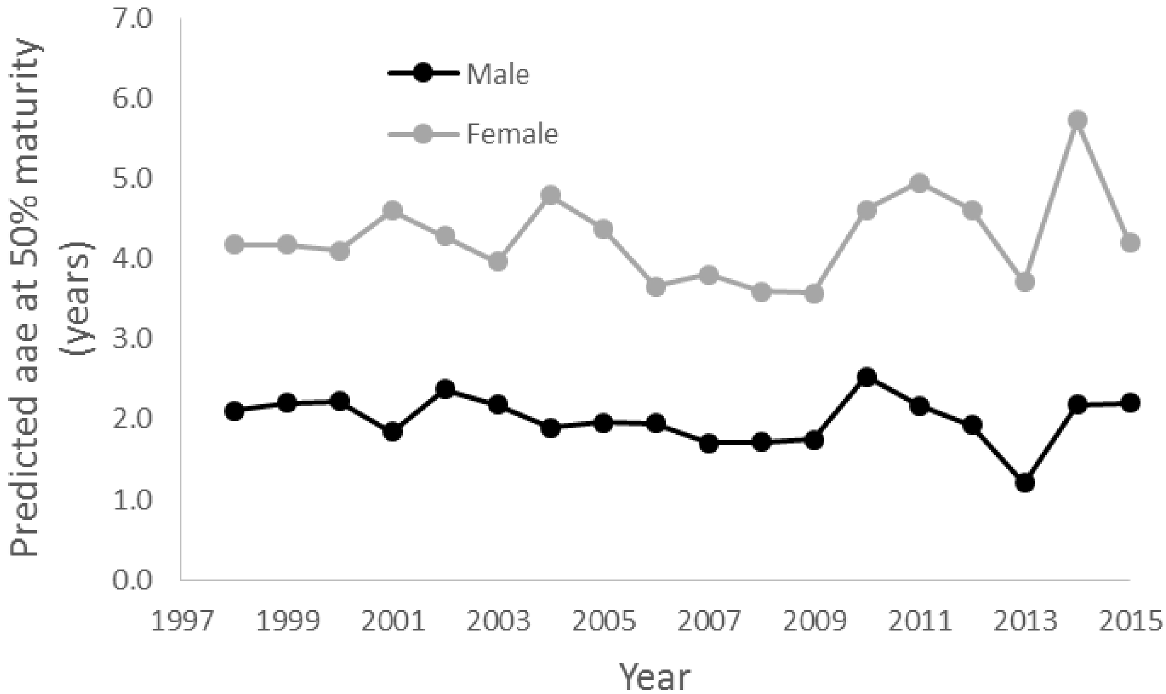

Figure 9. Predicted age at 50% maturity (years) based on a logistic function, 1998-2015. Data from Tables S21.3 and S21.4 in Supplementary Data, Morgan (2013).

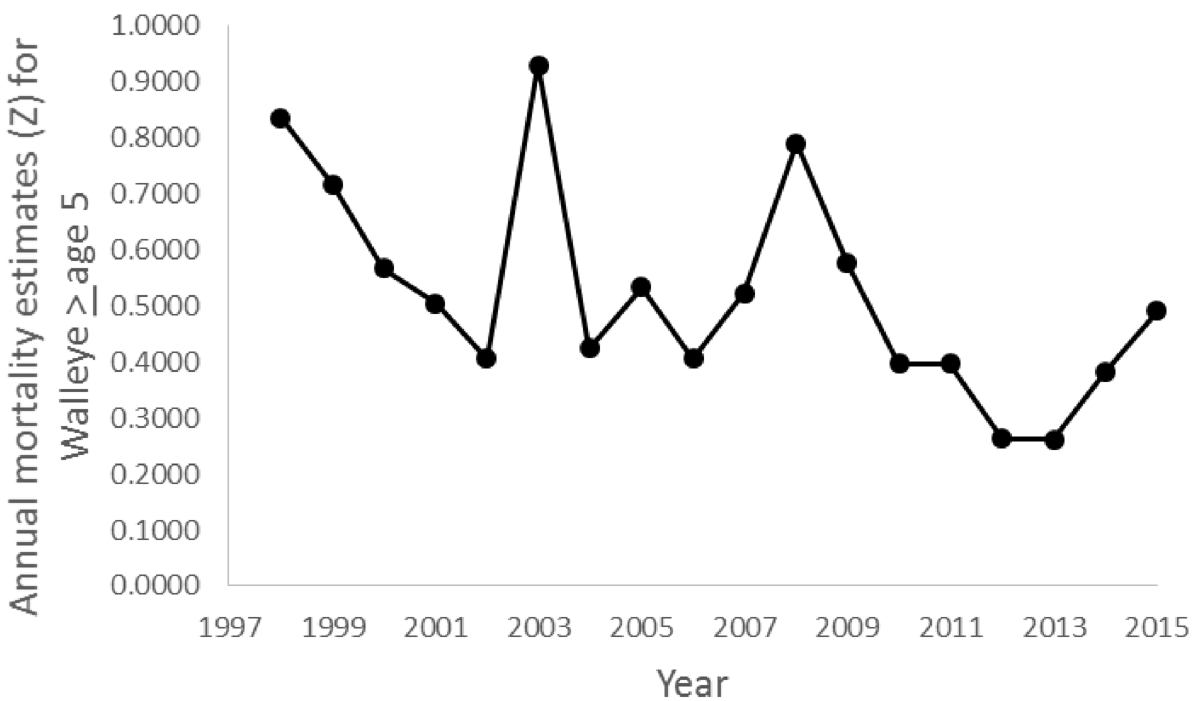

Figure 10. Selectivity-adjusted total mortality rates derived using the Robson and Chapman method for ages 5 and older, 1998-2015, based on Fall Walleye Index Netting. Data from Table S9.1 in Supplementary Data, Morgan (2013).

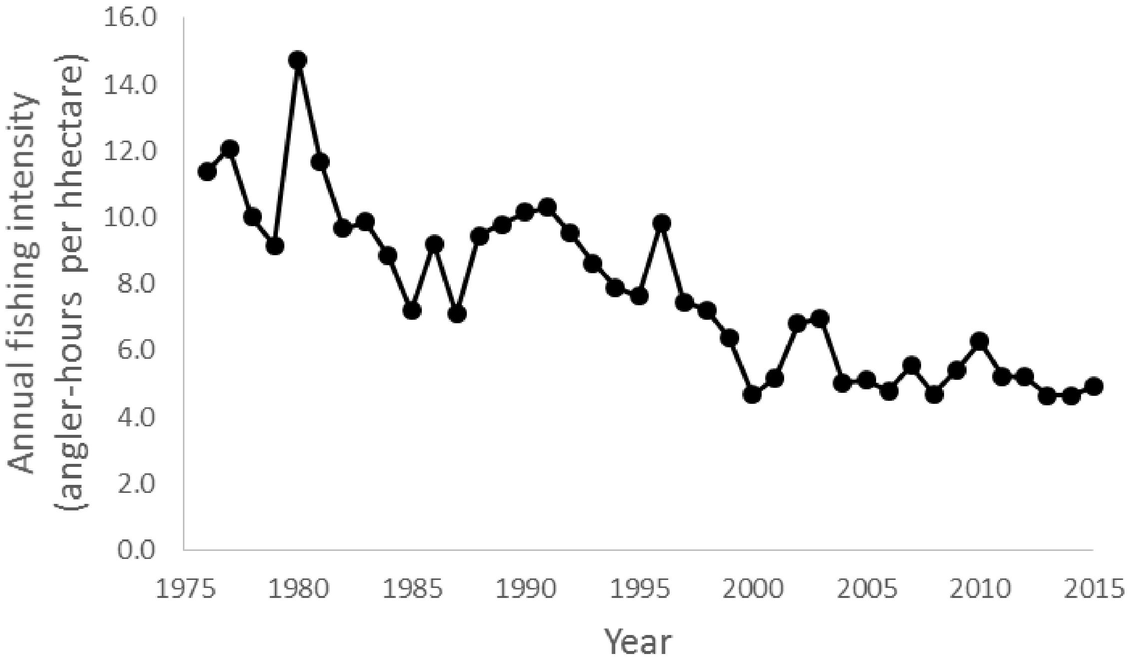

Figure 11. Estimate of total annual fishing intensity (angler-hours•ha^{-1}, open water and winter angling combined) based on creel surveys. Data from Table S3, Supplementary Data, Morgan (2013).

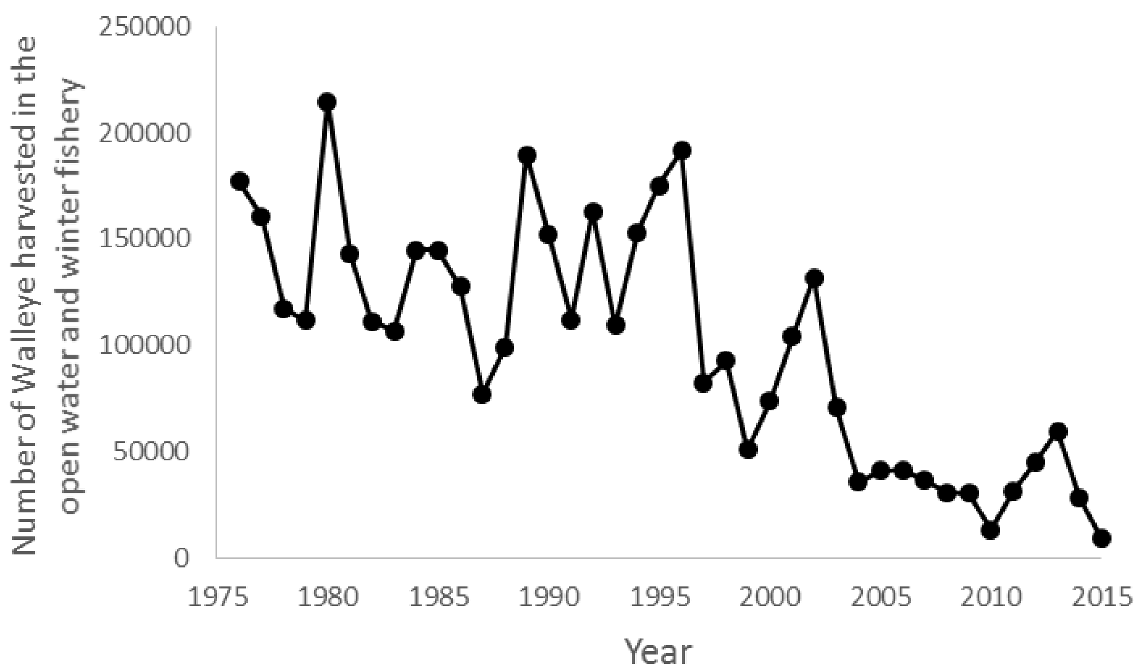

Figure 12. Number of Walleye harvested (open water and winter angling combined) based on creel surveys. Data from Table S3, Supplementary Data, Morgan (2013).

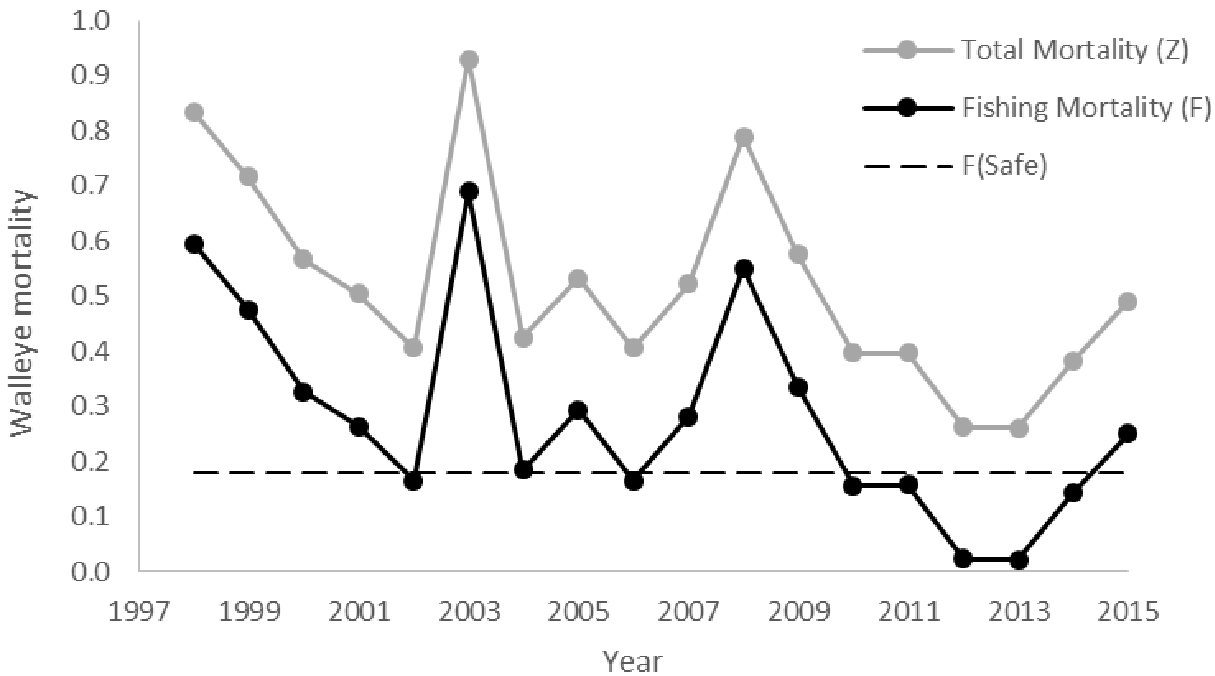

Figure 13. Comparison of total mortality (*Z*, derived using Robson and Chapman method and the FWIN data) and fishing mortality (*F*, where $F = Z\text{-}M$), given an assumed natural mortality rate (*M*) of 0.24. Based on Table S9.1 from Supplementary Data used in Morgan (2013). The dashed horizontal line is the approximate F_{safe} value for Lake Nipissing based on the equation $F_{safe} \approx 0.75*M$, following Lester et al. (2014).

Appendix 1

TERMS OF REFERENCE FOR THE EXPERT REVIEW OF LAKE NIPISSING'S WALLEYE FISHERY

TITLE

External Panel Review of Lake Nipissing's Walleye Fishery and Management

OBJECTIVES

The panel of scientists will undertake the independent review of the Lake Nipissing Walleye fishery on behalf of the Ontario Ministry of Natural Resources and Forestry (MNRF).

The review will include:

- Examination of available data;
- A critique of past harvest policies;
- Formulation and evaluation of hypotheses to explain the current fishery status, including relative risk to the Walleye population and fishery;
- Recommendations of future research, monitoring and assessment.

Areas of interest to MNRF:

1. Are there detectable trends in Lake Nipissing's Walleye population through the available datasets?
    - What assumptions need further study (if any) to verify trends?
    - Are there components within the life history of Lake Nipissing's Walleye that require specific attention?

2. Are there detectable trends in fishing harvest and effort through time from the available data?
    - What assumptions need further study (if any) to verify trends?
    - Are there components of the commercial, recreational and subsistence fishery that require special attention?

3. Is the RAMJAM model an appropriate risk assessment methodology for setting quotas?
    - Is there evidence that the Walleye biological reference points (e.g. Bmsy) have shifted in the last 20, 10 and 5 years and should be recalculated?
    - Is the FMSS simulation a reasonable method for calibrating the current fishing mortality into 10 year and 20 year recovery trajectories?

- Are there specific components of the model parameters and datasets (population, ecosystem, and harvest) that require additional attention/require more data to be collected? If so, can the data needs be prioritized, and what are the priorities?

4. What are the recommendations for management of a sustainable multi-user Walleye fishery in Lake Nipissing?
    - Is there evidence that continued exploitation of the Walleye population under the current levels of recreational and commercial harvest will lead to a collapse of the stock? If so, please estimate the degree of risk of collapse, and comment on the possibility of stock recovery to Bmsy within 20 years.
    - Is there evidence that continued exploitation of the Walleye population under the current management criteria set forth by the RAMJAM model will lead to a collapse of the stock? If so, please estimate the degree of risk of collapse, and comment on the possibility of stock recovery to Bmsy within 20 years.