GREAT LAKES FISHERY COMMISSION

2006 Project Completion Report[1]

Review of assessment programs for Great Lake's whitefish

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ABSTRACT:

The Great Lakes Assessment and Model Evaluation Review team was created to provide a basin wide focus to Ontario Ministry of Natural Resources stock assessment. This Coordinated Activities Project brought together members from the Province to one location to summarize and compare assessment and modeling methods used on whitefish and walleye on all Great Lakes. Field assessment programs used for walleye and whitefish are summarized in tabular form and each is discussed for four Great Lakes (excluding Lake Michigan). The use of some of the resulting field data in two models is also described as part of the projects purpose was to bring OMNR "up to speed" with the Upper Great Lakes Technical Committee of modelers. One model is regularly used as part of the quota setting process for lake whitefish found in Lake Huron and Georgian Bay and the other is used for lake whitefish population estimation and quota setting within Lake Ontario. Mathematical differences among the models is described as well as the results generated from using each model to analyze both Lake Ontario and Lake Huron whitefish populations.

Introduction

The Great Lakes Assessment, Modeling and Evaluation Review (GLAMER) Team began meeting in 2003 to discuss common assessment and modeling objectives and issues. One of the first objectives was to acquire a Coordination Activities Program (CAP) grant from the Great Lakes Fishery Commission (GLFC) to assist coordinating the modeling done on the lower Great Lakes whitefish and walleye populations with that being done by the Upper Great Lakes group. GLAMER began by looking at similarities and differences in assessment and modeling techniques currently in use around the Great Lakes.

The following objectives were developed as part of the CAP proposal and were used by the GLAMER team to focus our activities.

<u>Primary objective</u>: to develop and standardize the catch at age modeling used in Ontario's and Ohio's assessment of lake whitefish up to the same working level as that currently employed by Michigan DNR and CORA.

<u>Secondary objective</u>: create a toolbox of assessment modeling techniques specifically aimed at lake whitefish management in Ontario waters of the Great Lakes

This completion report summarizes GLAMER s work and the deliverables of the CAP proposal. Those deliverables were,

1) a report to the GLFC about models and results from the group, and
2) a set of working models specifically targeted to lake whitefish.

Both deliverables were met and are discussed throughout the completion report.

The group was composed of Ontario Ministry of Natural Resources staff from the Lake Ontario Management Unit, Lake Erie Management Unit and the Upper Great Lakes Management Unit. As such, the report will focus on field work done in Ontario waters of the Great Lakes and on international modeling efforts for walleye and whitefish populations in Lakes Erie, Huron and Superior. No U.S. representatives worked directly with GLAMER but members of the Lake Erie walleye task group and Lake Erie Technical Steering Committee are a part of GLAMER. Upper lakes GLAMER members are also members of the Modeling subcommittee of the Michigan-CORA 2000 Consent Decree's Fisheries Technical Committee (referred to in this document as the MSC). As well, the New York State Department of Environmental Conservation provided information on their field programs.

GLAMER held 3 workshops each focused on writing this report or model comparison. It was evident by the end of the third workshop that the most valuable part of this work would be the description of programs and data. More emphasis was placed on the use of models with different data rather than on the technical aspects of the models used to describe fish population status. This last comment will be addressed in the discussion.

Review of Assessment Techniques and Modeling

<u>Program Objectives</u>

Each Great Lakes fisheries management unit deploys a wide range of field programs designed to assess fish populations. Many, of these are exploited by commercial, First Nations, and/or recreational fisheries. These user groups work together, where possible, to ensure that exploitation and fish populations are sustainable for the long term.

There are a wide variety of programs to assess different life stages for a species. For example, trawling programs assess young of the year walleye, whitefish and yellow perch. The relative abundance of forage species such as alewife, herring species, and smelt is also tracked using these programs. Index gillnetting programs are used to assess the current relative abundance of age one and older fish. The remainder of this section describes the programs used on each lake and the objectives of each. This chapter will also discuss how data from each program characterize walleye and whitefish populations.

Characterizing Fish Populations

To best predict the current and future status of fish populations, a basic subset of information about fish populations and their fisheries is needed. At a minimum catch and effort data from a fishery are required. However, when there are high exploitation rates, as there often are for walleye and whitefish on the Great Lakes, agencies require additional information to properly assess these species . Ideally this information can be used to predict the status of year classes that will enter the fishery (pre-recruit and/or recruitment data), and the abundance of the stock which is being (or could be) exploited by fisheries (fishable biomass).

For most stock assessment models, the age structure of fish populations must be determined from harvest tracking programs and fishery independent surveys. This is needed to determine what portion of the population the fishery is targeting and its effect on various age groups in the population. This information can be used to estimate the effect of the fishery on various population parameters such as the spawning (adult) portion of the population, and size at age of fish in the population, in the fishery and not yet recruited to fishery. Also, one usually needs to measure the relative abundance of fish on an annual basis. This is typically based on catch per unit effort relationships from fisheries and surveys, but can also include abundance estimates from tagging programs such as those used for walleye on lakes Ontario and Erie, and for lake whitefish in parts of Lake Huron. Table 1 outlines the types of fish and fishery assessment programs currently in use on the Great Lakes.

Field Assessment: Fishery Independent Methods

In the Great Lakes, there are three types of fishery independent assessments done; these are mid-water trawling, bottom trawling and index gillnetting . Mid water trawls are most often used to assess availability and population demographics for prey fishes. While they do not directly assess whitefish or walleye populations, these programs are important because they describe the nature and abundance of fish that predators such as walleye depend on.

Bottom trawls are deployed to assess the status of young of the year and small benthic fishes. The data from this type of program are typically used to forecast recruitment. This information is not only used to predict the future abundance of fishable biomass, it is very useful for predicting short to medium term sustainability of fish populations under a variety of exploitation options. International trawling programs in western Lake Erie provide recruitment data for walleye and other species. Differences among bottom trawls are shown in Table 2.

Fish tagging programs are used on several lakes for walleye or whitefish. On Lake Ontario, the mark-recapture program is fishery independent and is designed to optimally sample both the non-migratory and migratory components of eastern basin walleye. Genetic research on Lake Ontario walleye suggests eastern Lake Ontario walleye are all from one population which uses a wide variety of spawning locations. In Lake Erie, there are several hypothesized walleye spawning populations with the largest originating from shoals and rivers in the western basin. The Lake Erie tagging program is designed to describe all of these walleye populations, and to provide information to assist in estimating exploitation and natural mortality rates.

Index gillnets are used on all Great Lakes. For lake whitefish and walleye these programs typically focus on age 1 and older fish. There are differences in the index gillnet programs among lakes as shown in Table 3. These differences arise from programs designed to best capture the behavior of all or some species of fish. The Lake Ontario Lake Unit deploys bottom set index gillnets and bottom trawls at the same sites each year to acquire information on walleye and whitefish. On Lake Erie, bottom and canned nets are set at random locations throughout the Canadian waters of Lake Erie to obtain information on the relative abundance of several key species in each area of the lake. Various index gillnet programs are also in use in the U.S. water of Lake Erie. Each program varies depending on its operational jurisdiction. International trawling programs in western Lake Erie provide recruitment data for walleye and other species.

Field Assessment: Fishery Dependent Methods

All provincially licensed commercial fisheries in Ontario must submit Daily Catch Reports (DCRs). These reports show the 'species targeted for harvest, gear type and size, effort duration, location, gross weight of each species harvested. They also show the weight of fish purchased (buyer weight) for each species. The buyer weight does not always reflect the harvested weight for many reasons, and therefore is used for assessment purposes to identify discrepancies is identified.

Often, commercial fisheries are sampled directly by monitoring agencies. Most commercial fishery sampling programs collect biological information such as length, weight, maturity and age of fish in the catch along with information associated with the fishing effort such as location, date, water depth, gear type and fisher name. The intensity of sampling is closely related to the size of the fishery and practicality of sampling (see Table 4. Species of Great Lakes Commercial Fish Sampled for Biological Characteristics). Biological sampling provides approximations of the age distribution of the harvest. The main objective of commercial fish sampling program is to provide detailed information on the harvested fish and where possible those fish discarded or released.

Recreational fisheries are sampled using creels and/or in some instances through voluntary information collection programs such as the angler diary program on Lake Erie. While the latter example does not provide an unbiased assessment of the recreational, it does provide information valuable to assessment of the fishery especially if the unbiased or designed creel occurs infrequently. With the exception of a few regular creel surveys many creels on the Great lakes occur periodically (Table 5. Creel sample programs occurring on the Great Lakes). Regular creels occur annually or on cycles. Where deployed, these programs provide information on angler effort, and species sought, caught and released. Depending on the design, there can be biological sampling of catch, aerial counts boats, trailer counts, on water(frozen or open)/shore/tributary counts with and without interviews of anglers, on water or from shore counts of boats or ice huts on water, and any combination of the above. The main objective of a creel is to provide catch per unit of targeted effort for species sought, caught, released and kept by anglers.

First Nations and Tribal fisheries provide various types of data depending on the arrangement each has with its collaborating agency. For example, the Chippewas of Nawash, and Chippewas of Saugeen First Nations have used a data sharing agreement with OMNR to jointly assess the fish populations sought by these two First Nations and non-native fishers. Several other First Nations in Lake Huron simply report harvest and effort data on modified DCR's, similar to other licensed commercial fisheries. The main objective of assessing First Nation and Tribal fisheries is to incorporate their harvest information into the larger assessment of the 'stocks' fished. Again, this assessment is targeted at reporting the sustainability of fish targeted by one or more fisheries and secondly to use this information to set future harvest levels.

Analytical Assessment: Models

Management agencies around the Great Lakes use different types of models to estimate key fisheries and fish population parameters (Table 6). There are many reasons why models are different including, sophistication or experience of modeling team, availability of data, necessity for more certainty about results and unique characteristics of fish populations and or fisheries.

Stock Assessments

Upper Lakes

For exploited fish populations, all agencies provide at least a rudimentary level of stock assessment. For example, on Lake Superior in Ontario waters, lake herring are not usually subject to a formal modeling exercise however, CUE from fishery and fishery independent methods is plotted over time and the trends are examined.

On Lake Huron, lake whitefish are assessed using data collected from an independent index netting program, an onboard commercial catch sampling program and data provided from the various commercial fisheries Commercial harvest data, and fishery independent data are used in Statistical Catch at Age Analysis (SCAA) in a number of locations.

Assessing the stocks on Lake Huron ranges from the use of simple statistics and biological indicators, to evaluation of trends through time and ultimately to SCAA modeling. All are used to report the status of stocks and to recommend any changes in future harvest (Table 8).

Lower Lakes

On Lake Erie, walleye and the fisheries they support are subject to intense sampling programs. The programs supporting the walleye stock assessment are the partnership index gillnetting program, bottom trawl index, commercial fishery DCRs, and direct biological sampling of the harvest. Recreational fishery information is sporadic and seldom used for stock assessment in Ontario waters, but the Ohio, Michigan, Pennsylvania, and New York recreational harvests are incorporated (Table 5). This sport fishing data comes from access point creels and trailer counts. U.S. jurisdictions also provide additional index gillnetting results to the stock assessment process.

The data from these programs is used in one of two models that are different primarily by the ‘stocks’ they represent (east vs. west basin stocks). Model results for the west basin stock are used to determine future Total Allowable Catches (TACs) as well as assess survival rates within stocks. A large part of the stock assessment on Lake Erie is focused on biological characteristics within stocks and on trends in CUE from both fishery independent and dependent data. The east basin catch-at-age model is not currently used in stock assessment.

Lake whitefish populations in Lake Erie are sampled primarily through the commercial fishery. Most other programs do not efficiently capture whitefish as these fish tend to exhibit whole lake annual migrations and are unpredictable. Nevertheless, the commercial DCRs and biological sampling of commercial catch provide information about CUE for this species. Trends in CUE are used to establish TAC's and a preliminary SCAA is used to describe trends in the population abundance.

The assessment of walleye and whitefish on Lake Ontario involves a mix of fishery and fishery independent sampling programs. For walleye, most data result from open water and ice fishing sport creels, DCRs, and from fishery independent data, particularly index gillnet and trawls. For lake whitefish, stock assessment is done using fishery independent bottom trawls and gillnets DCRs, and commercial catch sampling. In Lake Ontario, both walleye and whitefish are important to commercial fisheries. However the methods used to describe their status is different among species.

Model Comparison

During GLAMER's workshops it became apparent that "getting up to speed" with the Upper Lakes Technical team and the walleye task group on Lake Erie was not a realistic target for several reasons. The Upper Lakes team needed to provide estimates of abundance, total allowable catch and forecast recruitment with deliverables stated in State of Michigan and/or US legislation.

In the mean time the Lake Erie walleye task group, was moving forward with innovative new modeling techniques that incorporate approaches incorporating Monte Carlo Markov Chains (MCMC) for predicting recruitment estimates and forecasting population abundance and yield. On Lake Ontario, there was no need for a more sophisticated model for lake whitefish but there was clearly a need for a better walleye model. The OMNR Upper Great Lakes team used a tabular approach to assess its Lake Huron whitefish stocks of which model results are only one component and on Lake Superior, the paucity of continuous data did not support complex models and often only trends in CUE were used.

In order to move forward efficiently GLAMER started with the simplest version of models that were most common among agencies. The GLAMER group focused on lake whitefish for the comparison of models. For ease of understanding, the model used on Lake Ontario will be called the Ontario model and that on Huron, the Huron model.

First, the model used by Lake Ontario is virtually identical to that used for walleye and yellow perch on Lake Erie during 2000 (see Appendix A). It is quite simple and uses data from commercial gillnet fisheries, trapnet fisheries, and index gillnetting. One large difference between the models is that the Lake Erie model estimate selectivity whereas the Lake Ontario model requires selectivity for the gillnetting and trapnetting commercial fisheries as input. The assumption is that these selectivity's, although estimated, are known without error. The selectivity matrix for commercial gillnets was created by estimating the overlap in length distributions of whitefish caught in index gillnet with age-specific length distribution from the same survey data. The length distribution of whitefish caught in commercial gear was not used, but was estimated by assuming that all mesh used by the commercial fishery was 4.5 inches (stretched mesh) gillnet. Trapnet selectivity was estimated using a maturity index and LOMU assumed that immature fish would not be harvested by trap nets because this fishery operates almost solely during spawning period.

The Ontario model is closely based on the algorithm for CAGEAN (Deriso et al, 1985) and uses a non-linear sums of squares approach with a penalized likelihood function to find the best solution to minimizing the weighted sums of squares (Akaike's criterion **for least squares; see Burnham and Anderson 2003 page 63**). Whitefish abundance at age (at January 1st), survival, mortalities, and catchabilities are estimated with variances. Natural mortality is input as a constant value, 0.28 in this case. As an aside, a straight forward accounting like process is used to portray different harvest strategies as recruitment is virtually zero on Lake Ontario. Weights (lambdas) are estimated in this model using a variance ratio technique (Quinn and Deriso, 1999).

The model used on Lake Huron is similar to that used by the MSC for modeling lake whitefish in lakes Superior, Michigan, and Huron, but is noticeably different, mathematically, from the Ontario model. A detailed description of the Huron model and it application several Lake Huron whitefish populations can be found in Ebener et al. (2005). The model uses a maximum likelihood estimation (MLE) approach which does not minimize observed to expected deviations as with a least squares approach, but rather minimizes a negative log-likelihood function for each component of the objective function. Depending on the model, and the number of fishing mortality sources (gill nets only, or both gill nets and trap nets) the objective function will have four or seven components; one for a stock recruitment relationship, and one for the catch at age, effort and total harvest for each fishery. The deviations between the observed and expected values are treated as log-normal for each component, except for the catch-at-age values which are assumed to follow a multinomial distribution.

The Lake Huron model also estimates standard deviations associated with all parameters and specified outputs such as abundance at age estimates. Unlike the Ontario model, the Huron model estimates age-specific selectivities by fitting the catch-at-age data to either a logistic (trapnets) or double logistic function. Perhaps the biggest difference is the use of a stock recruitment relationship to estimate number or biomass of fish recruiting to the fishery (or column of the catch at age matrix). These key differences in assumptions and methods were very evident in comparison of model results.

Georgian Bay Whitefish Data (Area 5-8) in Lake Ontario SCAA Model

Inputting Georgian Bay whitefish data into the Lake Ontario model was a relatively simple task. In this case, the Lake Ontario model showed different estimates of abundance than the Huron model for the same population of fish (**Figure 1)**. As noted above, there are several differences in the approach each model employs for estimating catchability, selectivity, recruitment, and in minimizing residuals. The use of a stock recruitment function in the Huron model is probably one of main differentiating factors.

This difference is highlighted by the abundance estimates of age 3 and age 10+ groups, two groups whose selectivities are very different (**Figure 2**). The double logistic function results in very high selectivities >0.8 for the age 10+ group whereas using actual size at age in index net and estimating proportion selected by 4.5 inch stretched mesh gillnet clearly shows that some fish grow out of the gear and are no longer effectively harvested. The result is a twofold difference in expected catch and an obvious decrease in abundance especially for the age 3 and age 10+ groups (Figure 3).

There were other fundamental differences between the models. For example, both models use the same catch equation: F = s q E where s is selectivity is, q is catchability, and E is fishing effort. The catch equation is used to estimate fishing mortality, which in turn, is used to estimate survival of each age class from year to year. While both models had similar estimates for F (0.155 for Ontario and 0.153 for Huron), the assumptions associated with the equation were different. Most notably, the Huron model estimated q, s, and the variance associated with the effort simultaneously, while the Ontario model estimated only q and the variance associated with the effort. Selectivity was calculated outside of the model and included as an input parameter.

Catchability (q) is often interpreted as the proportion of a fish population caught with one unit of fishing effort. The estimated catchability coefficient from the Ontario model (0.0006) was about 40% lower than that from the Huron model (0.0010). As both q and s act as scalars in the model they can influence abundance estimates directly however, it is difficult to separate the effects of q and selectivity (s) because both are used in the catch equation to estimate fishing mortality. This confounding is made more complex when one considers that selectivity is estimated for each age of fish each year whereas a mean catchability is applied for all ages across all years.

Calculating selectivity estimates outside of the model and providing them as model parameters rather than estimating them within the model is another notable difference between the approaches taken by the Ontario and Huron models. This difference is highlighted by examining the selectivities for the age 3 and age 10+ groups (**Figure 2**). The double logistic function of the Huron model results in very high selectivities >0.8 for the age 10+ group whereas using actual size at age from index net and estimating proportion selected by 4.5 inch stretched mesh gillnet clearly shows that some fish grow out of the gear. The Ontario model suggests there are far more age 10+ fish beginning around 1992 and that exploitation is lower on these older fish than estimated by the Huron model.

For age 3 fish, the first year recruited, the models were virtually identical over the long term, but there was a consistent divergence near the end of the time series, 2000-2003 (**Figure 3**). Any differences in estimates of abundance of age 3 fish are reflected in all subsequent population estimates because age 3 is the first column or age in the fishery. The increase in abundance in the Lake Huron model in recent years does not appear in the Ontario model, and is why the Ontario model shows about half as many fish available to the fishery over that time period..

The age classes that are fully selected (or nearly so) by the commercial fishery show the large differences in the exploitation estimates (**Figure 4**). This difference is because model abundance estimates need to balance based on the age class proportions entered into the model. Therefore, if one age class's abundance estimate is increased without an increase in mortality for that age class, the model balances by increasing or decreasing mortality for another age class. This is reflected in the average exploitation estimates for ages 4-9 particularly in more recent years. In fact the last year in the model suggests exploitation of these age classes to be about 48% using the Ontario model and only about 27% using the Huron model (**Figure 4**).

Selectivities for age 4-9 fish are more similar between the Ontario and Huron models than the selectivities for age 3 and age 10+ fish. If you include age 3 and age 10+ fish in the averages plotted in figure 4 a significant drop in average exploitation rates occurs particularly for the Ontario model results (**Figure 4**). Focusing on the last year, there is about a 9% drop in the average rate for the Ontario model and only about 3 % for the Huron model. This clearly demonstrates that the selectivity assumptions used in statistical catch at age modeling for this fish stock are important in determining the performance of a fishery. For example, the Upper Great Lakes Management Unit targets a maximum exploitation rate of 30%, and based on one model they are just under the threshold, while the exploitation rate estimated from the other model (Ontario model) is about 50%, a level that would be considered very high.

Note that the Huron model applies a very low sea lamprey induced mortality rate; however, this mortality rate is far too low to account for the differences shown above. The natural mortality rates applied in each model were approximately the same. So, the largest differences in survival are due mainly to the mathematical assumptions about selectivity used in each model. Interestingly, both models show a general agreement in trends in average survival rate; the Ontario model shows more erratic or large changes in survival than the Huron model. As both model results are potentially equally likely, one must carefully consider periods when one model shows rapid changes that the other does not, such as the trends in the early 1980s and again in the last 3 years modeled (**Figure 5**).

The minimizing function of the Huron model clearly fits observed to expected catch data well and shows no trends in effort residuals (**Figure 6**). Whereas the Ontario model results show a consistent underestimation of harvest for the 7 of the past 10 years (**Figure 6**) as well as a clear trend among deviance residuals for the effort data during the same time period. These latter results suggest that catchability changed over this time period.

Lake Ontario Whitefish Data in Lake Huron SCAA Model

Lake Ontario data was modified to suit the Lake Huron model. When compared with Lake Ontario management unit's modeling results, the Lake Huron model suggested there were many more fish age 3 and older. There is a clear divergence in abundance estimates as shown in Figure 7.LHMU_1 and LOMU_4.

The Lake Huron Model deploys a stock recruitment relationship, while the Lake Ontario example does not. In fact, the model results diverge almost immediately in the time series suggesting that the parameters of the stock recruitment relationship are not correct for the Lake Ontario lake whitefish case. Nevertheless, the plots of the two abundances as shown by Figure 7 clearly show what can happen when a model has no information input about recruitment failure.

All LOMU data sources (e.g. - YOY trawls) clearly show that each year following 1997, there was no observable recruitment. As a consequence, by 2003, fish younger than 9 years of age are virtually absent from the fishery. What is surprising is that the divergence in model predictions appears to occur around 1995, perhaps indicating recruitment to age 3 was declining prior to 1997. This is earlier than when *Dreissena* sp. had fully colonized 1997 or 1998; the start time at which whitefish declines in Lake Ontario are often highlighted.

This highlights the importance of analyses of each dataset outside of the formal model. Plots of the trawl data and commercial catch data are useful representations of the whitefish population. Without looking at trawl data, in this case, one may have erroneously concluded that both model results are equally likely even though they are noticeably different and that the Huron model results are very unlikely for the Lake Ontario fishery. Closer inspection of the catch at age matrix shows, as does the Ontario model, that young fish age 3-6 became less selected by gear due to their smaller size since 1998 or earlier so not only are there fewer young fish, those that are there are smaller than in the past.

Not surprisingly, the Huron model suggests there were 11 million whitefish in Lake Ontario as of Jan 1, 2003 whereas the Ontario model suggests about 1 % of that (about 145,000 fish). Using the Huron model abundance number, an average weight of about 3 lbs, and an exploitation rate of 25 %, the 2003 TAC for Lake Ontario would have been about 8.25 million lbs. The actual TAC in 2003 on Lake Ontario was set at 240,000 lbs, of which only about 50% was harvested.

To further explore the effect of the different selectivity estimation techniques, the Ontario model was employed using selectivities estimated by the Huron model and using the same data. The results are represented by LOMU_6 (**Figure 7**). The resulting abundance of age 3 and older fish is about 20% of what the standard Ontario model, parameterized similarly showed (LOMU_2 on **Figure 7**), suggesting that the population of whitefish on Lake Ontario could be much lower than currently believed or that catchability is too variable to over the time period and a different estimation technique be employed in the model for q.

Comparison of Lake Ontario and Lake Huron Models

In conclusion for comparison of the two models: Although they differ mathematically they show similar results when assumptions are met. When using them, it is critical to consider the history and population dynamics of the fish populations being modeled to look for similarities, assess whether they conform to traditional or classical assumptions, and to consider the types of data input.

Nevertheless, it is quite clear that the Lake Ontario modelers made some sweeping assumptions about the certainty of selectivity data instead of letting the catch at age model incorporate the uncertainty of selectivity associated with a simulation. What is very important and perhaps an improvement is the Ontario modelers' view of growth of whitefish and comparison of mean size at age to selectivity of gillnets. This simple check could be done for the Huron model to adjust any age groups that are partially selected. As it stands now, the double logistic function, because it is a smooth function can not fit the erratic changes in size at age 3 that are apparent in this stock of lake whitefish and adds more parameters to an already parameter rich model.

The Lake Huron modelers make some equally large assumptions about recruitment. These assumptions allow it to make long term predictions under certain conditions, but can result in poor model fits in instances where recruitment has been shown to deviate from the stock recruitment relationship. This is most evident when one puts Lake Ontario whitefish data into the Lake Huron model. When one over estimates the first age recruited to the fishery one runs the risk of overestimating the abundance of whitefish and subsequently promoting the over harvest. This error is compounded in all subsequent age classes due to assumptions about survival. For example, if the catch data and natural mortality are constant, and selectivity is a smooth function that peaks one year after full recruit (e.g. – 5 year olds), then the model must assume that either catchability has changed and/or that there are more fish.

Whether or not the non-linear sums of squares approach is better than the MLE approach is not an important question to answer but rather, one has to associate some degree of belief in the results from the two models. When assumptions are violated such as when a fish population has very poor survival of its young of the year, then the assessment team must have an alternative model in place or a mechanism to switch off the recruitment function. Some alternative parameterizations could include incorporating index netting data into the model and using it to drive a recruitment function or estimate recruitment of the youngest age classes directly. Recruitment functions are notoriously difficult to fit. Intuitively, it is clear that there must be a relationship between the spawning stock and subsequent recruitment (if there are no spawners, there can't be any recruits), but the nature of this relations is frequently unclear.

Recommendations and Summary

All Great Lakes agencies have different State of the Resource reporting requirements particularly for fish species sought by First Nations or commercial and recreational fisheries. The basic annual reporting for stock assessment uses trends through time of catch per unit effort for each fishery and for index type gear. In addition, trends of mean weight at age, age at maturity, number of ages in population, and trends in survival are often presented as well. The methods vary, but the basic outcome or goal is the same: to provide a long term sustainable supply of fish, fishing opportunities and economic benefit.

GLAMER reviewed 4 assessment programs, one from each of OMNRs offices managing Great Lakes fisheries. The work done in Ohio could not be included so we focused on Lake Ontario and Huron whitefish assessments. Each program consists of a suite of field activities, analytical approaches and summaries aimed at providing managers with a set of harvest numbers or ranges to choose from. The strengths and weaknesses of each program was reviewed but the fiscal, personnel and rational limitations to the assessment approaches were not discussed. It it likely that where there are no allocation issues or conflicting resource demands, there is a lessened demand for detailed reporting. Generally, for whitefish and walleye, there is great demand on all Great Lakes from several fisheries and jurisdictions and the associated need for robust, yet transparent assessment methodologies.

With respect to objective 1, GLAMER recommends to those modeling whitefish for the purposes of stock assessment and estimation of total allowable catches, that:

1) Two or more models be deployed and results from each be assessed with respect to simple plots such as those shown in this document and analyses of data from both fishery and fishery independent sources;
2) A tabular summary be produced for each stock assessment. The table should include a common set of biological reference points (BRPs, statistics and population parameters) from the simple (e.g. –mean age, number of age classes in the fishery) to those that are complex (SCAA models) (See table 8. Lake Huron stock assessment table).
3) An action item for agencies is to contact co-managing agencies and/or stakeholders about this summary approach and to try to develop a weighting mechanism for the line items. Again, this standardization of decision making provides a common playing field for multi-jurisdictional fisheries and diverse objectives.
4) Provision of some measure of risk to managers that relates to the two previous points, sustainability of fish populations and fisheries and violations of model assumptions.

All agencies should use the exact same set biological reference points. The methods needed to determine the BRPs do not have to be the same, but they have to address some or all of the same BRPs. This method of stock assessment and estimation of total allowable catch could be used in the absence of a management plan or a pre-established inter-jurisdictional agreement on TAC determination.

In terms of weighting, the weights given to a biological reference point could incorporate information such as data quality, uncertainty and the sensitivity of the species in question. Again, this standardization of decision making provides a common framework for fisheries that span international boundaries or that are likely to migrate over several jurisdictions and be exploited by more than one fishery. Weighting the line items of the list similarly will strengthen the common management approach.

With respect to objective 2, GLAMER recommends the following items be used ;

1) Field programs; bottom trawls for young of the year lake whitefish done in late summer and fall of each year; commercial catch sampling with sub-sampling for age classes present in fishery; record of total harvest of all fisheries; and if possible, fishery independent indices using gear similar to that used by fishery and deployed during time when indices most closely represent that fished by the fishery.
2) Modeling; use output of models particularly to assess trends in its predictive power such as comparing observed to expected harvest, changes in survival over time and not to rely on model output solely for estimating TAC
3) Statistics and Parameters; agencies should use a common set that should include, but is not limited to: plots of CUE per gear type over time (all ages combined, YOY only, strong year classes), mean age of survey overlaid with mean age of harvest over time, number of age classes in fishery representing >10% of harvest, mean size at age of 3 key age classes and of each sex pre-spawning and during spawning, actual exploitation rate, parameters of stock recruitment function(s) over time (if incorporated in model).

Finally, it is recommended that assessment staff provide alternative management scenarios, including consequences and/or risks associated with each alternative strategy. For example, if most of the biological reference points for a stock suggest that harvest could be increased, but one or two strongly suggest that the stock could not withstand increased exploitation (e.g. – recruitment has failed for several consecutive years), what are the consequences of one management strategy over another? What information is required by managers to make appropriate decisions, knowing the risks associated with each? While this process is often followed informally, explicit documentation of the approach is rarely produced.

This completes the requirements of the GLAMER project. This report is deliverable 1. The two models provided are deliverable 2.

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Table 1. Summary of types of fishery independent assessment programs in the Great Lakes.

Lake	Agency	Program Name	Program Type	Multispecies (y/n)	Duration
Erie	OMNR/ ODNR	Interagency Trawl	Trawl	Y	1987 – present
	OMNR / OCFA	Partnership Program	Gill Net	Y	1989 – present
	OMNR	Long Point Bay Gill Net survey	Gill Net	Y	1986-present
		Long Point Bay Trawl Survey	Trawl	Y	1980-present
	ODNR	Ohio Gill Net Assessment	Gill Net	Y	1978 – present
		Ohio West and Central Basin Trawl Surveys	Trawl	Y	1987-present
	MDNR	Michigan Gill Net Assessment	Gill Net	Y	1978 – present
	NYSDEC	New York warm water gill net assessment	Gill Net	Y	1981 – present
		New York cold water gill net assessment	Gill Net	Y	1985-present
		New York Trawl Survey	Trawl	Y	1992-present
	PAFBC	Pennsylvania Gill Net Survey	Gill Net	Y	1979-present
		Pennsylvania Trawl Survey	Trawl	Y	1981-present
	USGS	West Basin Trawl Survey	Trawl	Y	1983-present
Ontario	OMNR	Eastern Lake Ontario Fish Community Index Netting	Gillnet and Bottom Trawl	Y	1958 – present
		Bay of Quinte Nearshore Fish Community Index Netting	Trap Net	Y	1958 – present
		St. Lawrence River Fish Community Index Netting	Gillnet	Y	1984 – present
		Juvenile Salmonid Stream Assessment	Electofishing	Y	1991 – present
		R. H. Saunders Hydroelectric Dam Eel Ladder Monitoring	Fish Ladder Counts	N	1991 – present
		Ganaraska Fishway Rainbow Trout Assessment	Fish Ladder Counts and Biological Sampling	N	1974 – present
		Credit River Chinook Assessment	Biological Sampling	N	1989 – present
	OMNR-	Lake-wide Hydroacoustic	Hydroacoustics	Y	1991 –

Lake	Agency	Program Name	Program Type	Multispecies (y/n)	Duration
	NYSDEC	Assessment of Prey Fish	and Mid-water Trawl		present
	NYSDEC	Eastern Basin Warm Water Assessment	Gillnet	Y	1976 – present
		St. Lawrence River Warm Water Fish Assessment	Gillnet	Y	1977 – present
		Salmon River Hatchery Fish Stocks Assessment	Fish Hatchery	Y	1984 – present
		Black River Fishway Monitoring	Fish Ladder Counts and Biological Sampling	Y	1993-present
		Fall Warm Water Fish Assessment (Yellow Perch)	Bottom Trawl	Y	1993-present
	NYSDEC /USGS	Lake Whitefish Assessment	Trapnet	N	2004-present
	USGS	Major Prey Fish Stock Status - Sculpin	Bottom Trawl	Y	1980-present
	USGS NYSDEC	Major Prey Fish Stock Status (alewife, juvenile smelt)	Bottom Trawl	Y	1978 – present
		Juvenile lake trout assessment	Bottom Trawl	N	1980-present
		Adult Lake Trout Assessment	Gillnet	N	1978-present
Huron	OMNR	Offshore Community Index	Multi mesh gillnet	Y	1979-present
		Nearshore Community Index	Trapnets, Fixed mesh gillnets	Y	1995-present
		Lake sturgeon Assessment	Trapnets, Fixed mesh gillnets	N	1995-present
		Lake trout Rehabilitation Assessment	Trapnets, SLIN, FLIN, multi mesh gillnets	N	1980-present
		Walleye Spawning Assessment	Trapnets	N	1994-present
		Anadromous Species Assessment	Fishway monitoring,	Y	1986 to present
		Muskellunge Popn Assessment	Trapnets	Y	1998 to present
		Nearshore Smallfish Community Index	Fyke nets, Seines, Nordic nets	Y	2003 to present
	OMNR CORA MDNR Saugeen Ojibway Bruce	Whitefish Population Distribution and Movement	Trapnets, Gillnets	N	2004 to present

Lake	Agency	Program Name	Program Type	Multispecies (y/n)	Duration
	Power				
	USGS OMNR	Prey Assessment	Hydroaccoustics, Midwater Trawls, Bottom Trawls	Y	1976-present

Table 2. Differences in trawls deployed by various great lakes government agencies.

Lake	Agency	Program Name	Gear Type	Stratified (depth/ basin)	Random / Fixed Sites	Season	Used in SCAA	Duration	Year design change
Erie	OMNR and Ohio DNR	Interagency Trawl	Two seam, 33' Biloxi bottom trawl (38' ground line) with a ½" cod end liner. 10 minute trawl at 1.6 knots	No - West basin bottom trawl	36 fixed sites in ON waters, & 36 sites in OH waters	August	Estimate YC strength of walleye & yellow perch to predict age 2 recruitment outside of ADMB catch-at-age models	1987 to present (1982-1986 Ontario only trawl)	Fixed sites may be moved if trawling is poor in successive years
	OMNR	Long Point Bay Trawl	6.1 m modified Biloxi bottom trawl	No	Four fixed locations each in Inner and Outer Long Point Bay	Autumn	Estimate YC strength of yellow perch to predict age 2 recruitment outside of ADMB catch-at-age models	1980 – present	
	Ohio DNR	Ohio Central Basin Trawls	Yankee, 2 seam bottom trawl, 10.4m head rope, 25mm bar mesh at cod end, 13mm mesh liner. 10 minute trawls	Four depth strata, sampled before, during and after stratification	16 random sites in the central basin	Monthly – Spring to Autumn	Estimate YC strength of yellow perch to predict age 2 recruitment outside of ADMB catch-at-age models	1990 to present	1995 gear change
	Ohio DNR	Ohio West Basin Trawls	Flat bottom otter trawl 10.7m head rope 13mm bar mesh in cod end	Four depth strata	22 sites	Summer and Autumn	Estimate YC strength of yellow perch to predict age 2 recruitment outside of ADMB catch-at-age models	1980-present	2002 – vessel change
	New York State DEC	New York Autumn Trawl Survey	Four seam bottom trawl, 31.8ft headrope, 38.1ft footrope, 0.4" cod end mesh	No	~ 34 Random sites	October	Estimate YC strength of yellow perch to predict age 2 recruitment outside of ADMB catch-at-age models	1992 - present	Replaced 1986-1991 juvenile Percid assessment
	Pennsylvania FBC	Pennsylvania Autumn Trawl	4 seam otter trawl with 35 ft headrope, 0.25" mesh cod liner, 10 minute tows	3 depth strata	9 fixed sites	October	Estimate YC strength of yellow perch to predict age 2 recruitment outside of ADMB catch-at-age models	1981-present	1980
	USGS	USGS Bottom Trawl	10 minute trawls with 7.9-m (headrope) bottom trawl	West Basin only, depth stratified		Summer and Autumn	Estimate YC strength of yellow perch to predict age 2 recruitment outside of ADMB catch-at-age models	1983-present	
Ontario	OMNR	Eastern Lake Ontario Fish	Bay of Quinte ("Bay Trawl"): 3/4	No	Six fixed sites in Bay of Quinte	Summer	Recruitment Index	1972 – present	1992

Lake	Agency	Program Name	Gear Type	Stratified (depth/ basin)	Random / Fixed Sites	Season	Used in SCAA	Duration	Year design change
		Community Index Netting	Western (poly), 14.24 m head rope, 1/2 in cod end mesh size; Lake Ontario ("Lake Trawl") 3/4 Yankee No. 35, 12 m head rope, 1/2 in cod end mesh size		and 4 fixed sites in Lake Ontario				
	OMNR NYSDEC	Lake-wide Hydroacoustic Assessment of Prey Fish	Midwater						
	NYSDEC	Fall Warm Water Fish Assessment (Yellow Perch)	3-in-1 trawl (18-m headrope) with roller gear along the foot rope and cambered, slotted V-doors	No	16 fixed sites	October		1998 – present	
	USGS NYSDEC	Major Prey Fish Stock Status – Sculpin	3-in-1 trawl (18-m headrope) with roller gear along the foot rope and cambered, slotted V-doors	Stratified by depth	> 100 fixed sites	Autumn		1980 - present	2005 gear change
		Major Prey Fish Stock Status – Alewife	3-in-1 trawl (18-m headrope) with roller gear along the foot rope and cambered, slotted V-doors	Stratified by depth and region	> 100 fixed sites	April		1978 - present	2006 survey design change
		Major Prey Fish Stock Status – Rainbow Smelt	3-in-1 trawl (18-m headrope) with roller gear along the foot rope and cambered, slotted V-doors	Stratified by depth and region	> 100 fixed sites	June		1978 - present	2000 survey design change
		Juvenile Lake Trout Assessment	3-in-1 trawl (18-m headrope, 7.6-m spread) with roller gear along the foot rope and cambered, slotted V-doors	No	14 fixed transects sampled over a range of depths (20-130m)	July		1980 - present	1997 gear change and sampling protocol modification

Lake	Agency	Program Name	Gear Type	Stratified (depth/ basin)	Random / Fixed Sites	Season	Used in SCAA	Duration	Year design change
Superior	USGS	USGS Bottom Trawl	39-ft Yankee bottom trawls, 39-ft roller trawls, and 50-ft midwater trawl. Two sets of 3-ft x 5-ft trawl doors and two sets of midwater trawl doors	30 minute trawls - down-the-bank, cross-contour trawls – daytime vs. night - day and night along-contour trawls	~ 80 fixed sites	Spring		1978 - present (1989 – present (in Ontario waters)	
Huron	USGS/ OMNR	Lake-wide Hydroacoustic Assessment of Prey Fish	Midwater Trawl		22 Semi Fixed sites	Fall	No	1998, 2003-present	
	USGS	USGS Bottom Trawl Prey Assessment	Bottom Trawl 21 metre	Across contours	Fixed sites	Summer	No	1976-present	1992

Table 3. Differences in index gillnet surveys among various great lakes government agencies.

Lake	Agency	Program Name	Gear Type	Stratified (depth/ basin)	Random / Fixed Sites	Season	Used in SCAA	Duration	Year design change
Erie	OMNR and OCFA	Partnership Program	0.38 km panels of graded monofilament gillnet, mesh sizes 32mm to 152mm. Canned and bottom nets Set 24 hours	Stratified by 5 areas in the lake and by depth	144 random sites covering all of ON waters of Lake Erie	August to November	relative abundance (CUE) at age used in ADMB catch-at-age models for walleye and, yellow perch, fish ages 2 and older	1989-present	1995 – depth of canned nets changed from 3m to 7m in central basin
	Ohio DNR	Ohio gill net survey	2 gear types. 1) Historic sites – monofilament canned and bottom nets 12 gangs (15.2m by 1.8m) mesh sizes 32-127. 2) Additional sites - multifilament nylon gillnets, 13 gangs (30.5m long by 1.8 m high) 51mm-127mm, 2m canned at all sites. Set 24 hours	Depth stratified in the western basin	7 fixed historic + additional random (8 additional in 2003, 45 additional in 2004) in OH waters	Autumn	relative abundance (CUE) at age used in ADMB catch-at-age models for walleye ages 2 and older.	1978-present	2004 – additional sites were added to target smallmouth bass
	Michigan DNR	Michigan gill net survey	variable mesh multifilament gillnets	No	2 fixed locations MI waters of Lake Erie	Autumn	relative abundance (CUE) at age used in ADMB catch-at-age models for walleye ages 2 and older.	1978-present	
	Pennsylvania FBC	PA gill net survey	Monofilament 50 ft panels with mesh sizes 1.5 to 6.0" set in 500ft gangs	Depth stratified	4 fixed sites in June, 4 fixed sites in September	June and September	No	1979-present	2002
	New York State DEC	New York coldwater gill net assessment	Multifilament gill net, 50ft panels, mesh sizes 38mm to 152mm, fished at or below 50F isotherm and on the bottom	Depth stratified	3 random transects in each of 2 areas	August	No	1985-present	1996 – replaced monofilament net with multifilament net
	New York State DEC	New York warmwater gill net assessment	14 gill net panels (15.25m by 1.8m) mesh sizes 32mm to 152mm set 24 hours	Depth stratified	40 sites, some fixed, some random in NY nearshore (<11.28m) waters of Lake Erie	September 1 until turnover -	relative abundance (CUE) at age used in ADMB catch-at-age models for walleye ages 2 and older.	1981-present (data used in model begins in 1993)	1993 – changed to accommodate interagency approach. Only bottom habitat sampled since

Lake	Agency	Program Name	Gear Type	Stratified (depth/ basin)	Random / Fixed Sites	Season	Used in SCAA	Duration	Year design change
									1996
Ontario	OMNR	Eastern Lake Ontario Fish Communit y Index Netting	Ten mesh sizes 1 1/2 in to 6 in stretch monofilament mesh at 1.2 in increments; 15 or 50 ft 1/2 mesh and 50 ft and all other mesh sizes; total gang length 465 or 500 ft; 24 hour bottom sets	Stratified by Bay of Quinte and 3 eastern Lake Ontario regions 3 to 5 areas sampled in each region; some areas are depth stratified	All sites fixed; 45 sites sampled in 2005	Summer	Age-specific abundance used in catch-age models for lake whitefish and walleye	1958 - present	Major re-design in 1992 including multi to monofilament twine
		St. Lawrence River Fish Communit y Index Netting				Fall			
Ontario	NYSDEC	Eastern Basin Warmwate r gillnet assessme nt	Nine 50' x 8' panels of 2-6" mesh in 0.5" increments	Stratified by depth	29 random gillnet sets stratified among 3 depth strata	Late July to mid August		1976 – present	1993 – multi-to monofilament
	USGS, NYSDEC	Fall adult lake trout gillnet survey	Nine 15.2- x 2.4-m panels of 51- to 151-mm mesh in 12.5-mm increments.	Stratified by depth	Main basin: 12 locations along the U.S. shore, 4 nets fished along random transects within each location. Eastern Basin: 2 locations, 4 nets fished along fixed sites within each location.	Fall		1978 - present	1996 - only U.S. sites sampled
Huron	OMNR	Offshore Communit y Index	Standard net is 375m, monofilament web, 25m of 38mm (1.5") plus 50m of each 51, 64, 76, 89, 102, 114, and 127mm. Overnight bottom sets	Yes	Fixed and random sites	Spring, summer, Fall	Yes	1979-present	1993
		Lake trout	Numerous different net configurations	Yes	Both	Spring, Fall	No	1992-present	2005
Superior	OMNR, Michigan DNR,	Spring lake trout index	2 gear types 1) 4.5" multifilament, 18 meshes deep, 500 yds long,	Nets set down the bank between 15	Total of 20 random sites within a	Spring (April – May)		1997 – present (Ontario)	2003 - originally 3

Lake	Agency	Program Name	Gear Type	Stratified (depth/ basin)	Random / Fixed Sites	Season	Used in SCAA	Duration	Year design change
	CORA, Wisconsin DNR, Minnesota DNR	gillnet survey	bottom sets. 2) Multi-mesh 5x100 yds of the following mesh sizes :76 mm, 89mm, 102 mm, 114 mm, 127 mm.	and 70 fathoms	management zone				night set were used, now most agencies are using overnight sets

Table 4. Species of Great Lakes commercial fish sampled from Commercial Fishery Harvest

Lake	Agency	Trawl/ Gillnet/ Other	Species
Erie	OMNR	Gillnet	Walleye
			Yellow perch
			Whitefish
			White Bass
			White Perch
		Trawl	Smelt
	Ohio DNR	Trap net	Yellow perch
			White Bass
			White Perch
			Whitefish
	New York State DEC	Trap net	Yellow perch
	Pennsylvania FBC	Trap net	Yellow perch
Huron	OMNR	Gillnet	Lake Trout
			Walleye
			Whitefish
			Yellow Perch
			Lake Herring
			Lake Sturgeon
		Trap net	Whitefish
			Walleye
			Yellow Perch
			Lake Sturgeon
	MDNR		
Ontario	OMNR	Gillnet	Whitefish
		Trap and Hoop Nets	Whitefish, Herring
Superior	OMNR	Gillnet	Whitefish
			Herring
			Lake Trout
			Yellow perch
			Chub

Table 5. Creel Surveys on the Great Lakes

Lake	Agency	Design	Years	Data Used in Decision Making
Erie	OMNR	Access Point	2003 East Basin 2004 Central Basin 2005 West Basin (first creels since a comprehensive creel in 1998)	Yes, estimates of walleye harvest are included in Ontario TAC but not in SCAA
		Access Point – Long Point Bay	1984 – present	No
		Angler Diaries	1983 – present	No
	Ohio DNR	Access Point	1978 – present	Yes, catch at age data used in SCAA
	Michigan DNR	Access Point Charter operators are required to report harvest	1978 – present	Yes, catch at age data used in SCAA
	Pennsylvania FBC	Access Point	1996 – present	Yes, catch at age data used in SCAA
	New York State DEC	Access Point	1988 – present	Yes, catch at age data used in SCAA
Ontario	OMNR	Bay of Quinte open-water and ice fisheries (walleye); roving, random-stratified	1979 – present	Yes, for example, to assess effectiveness of walleye size limit restrictions

Lake	Agency	Design	Years	Data Used in Decision Making
		Western Lake Ontrario Salmon and Trout Fishery (boats); Access Point	1977 – present	Yes, for example to assess stocking returns
	New York State DEC	Eastern Basin; Access Point and Aircraft - Counts	1998 and 2003 (Plan on conducting every 5 years)	Yes, for example to assess stocking returns and to estimate harvest and catch rates and effort
		Comprehensive Lake Ontario Tributary; Instantaneous Roving and direct contact	1984, 2005 – present	Yes, for example to estimate harvest and catch rates, effort, residency, and regulation satisfaction
		Salmon River Creel Survey; Instantaneous Access/Roving and direct contact	1984, 89, 92, 1997 – present	Yes, for example to estimate harvest and catch rates, effort, residency, and regulation satisfaction
		Access Point – Direct Contact Fishing Boat Census	1984 – present	Yes, for example to estimate harvest and catch rates and effort
Superior	OMNR	Winter – Batchewana Bay	1989,1994	No
		Open Water – Batchewana Bay	2000	Yes, angler success rate info to support lake trout harvest restrictions
		Winter – Inner Thunder Bay	1983-1988, 1993	Yes, info. used to determine lake trout stocking levels
		Open Water – Goulais Bay	1997	No
		Angler Diaries	1987 - present	Yes, monitor

Lake	Agency	Design	Years	Data Used in Decision Making
				rainbow trout production to set sport harvest limits
Huron	OMNR	Index Access Creels (several sites visited annually or in rotation)	1988-present	Yes
		On water Roving Lake Trout Parry Sound, Iroquois Bay		Yes
		ON water Roving Severn Sound		Yes

Table 6. Models used to assess key fisheries and fishery parameters by the Great Lakes units.

Lake	Agency or Lake Committee	Species	Life Stage	Number of models	Type of Model	Peer Reviewed
Erie	Walleye Task Group	Walleye	Exploitable biomass (ages 2 and older)	2 models – west/ central and east basin	Catch-at-age analysis using ADMB	Yes
	Yellow Perch Task Group	Yellow perch	Exploitable biomass (ages 2 and older)	4 models – west, west-central, east-central and east basin	Catch-at-age analysis using ADMB	Yes
Ontario	OMNR	Lake whitefish	Exploitable biomass (age 3 and older)	1 single-stock model	Catch-at-age analysis using ADMB	Originates from peer reviewed model but has not been formally peer reviewed
Huron	Upper Lakes Modeling Team	Whitefish/Lake Trout	Exploitable biomass (age 3 and older)	Unique models for each species and one model per geographic area	Catch-at-age analysis using ADMB	Originates from peer reviewed model but has not been formally peer reviewed
		Whitefish/Walleye	Exploitable biomass (age 3 and older)	Unique models for each species and one model per geographic area	Catch-at-age Cohort Model (Pope 1973) EXCEL	No
Superior	Upper Lakes Modeling Team	Whitefish/Lake trout	Exploitable biomass (age 3 and older)	Unique models for each species and one model per geographic area	Catch-at-age analysis using ADMB	Originates from peer reviewed model but has not been formally peer reviewed

Table 7. Information used for fish stock assessment by each lake unit.

Lake	Agency	Species	Information	Gear Type
Ontario	OMNR	Smallmouth Bass, Largemouth Bass, Northern Pike, Walleye, Yellow perch, Sunfishes, Crappie, Drum, Carp,	CUE, Age Structure, Mortality, Growth, Condition, Age-at-maturity	Gill Net, Trawl, Trap Net, Sport Creel, Commercial Catch Sampling
	NYSDEC			
Superior	OMNR	Lake trout Whitefish Herring Chub	CPUE Age Distribution Mortality Rate Growth Rate	Index gillnet Commercial catch & sampling
Huron	OMNR	Non-modeled species	CPUE, Age Structure, Mortality, Growth, Maturation rate	Index gillnet, Commercial Catch Sampling, Index Trapnet
	OMNR	Lake Whitefish	See attachment	Index gillnet, Commercial Catch Sampling, Index Trapnet

Table 8. Upper Great Lakes Management Unit, Lake Huron Stock Status Evaluation Protocol (SSEP)

Parameter	Status of Stock				
	← - Risk + → + Health/Sustainability -				
CPUE Commercial Harvest	Increase over 2 or more consecutive years	No Trend over 2 consecutive years	Decline over 2 consecutive years	Decline over 3 consecutive years	Decline over >3 consecutive years
Predicted Recruitment from Independent Index	3 or more strong year classes predicted	1 or 2 strong year classes predicted	average year classes predicted	1 or 2 weak year classes predicted	3 + weak year classes predicted
Age Structure of Catch	Multi aged with > 12 year classes	Multi aged with > 10 year classes	Multi aged with > 8 year classes	Multi aged with ≤ 8 year classes	Multi aged with ≤ 6 year classes
Mean Age of Catch	Major Positive Change	Minor Positive Change	No Change	Minor Negative Change	Major Negative Change
Size at Age	Major Positive Change	Minor Positive Change	No Change	Minor Negative Change	Major Negative Change
Age Mature : Mean Age	>=0.6	>=0.7	>=0.8	>=0.9	>=1.0
COHORT ANALYSIS					
Total Annual Mortality	<0.45	0.45 to 0.6	0.6 to 0.65	0.65 to 0.70	>0.70
Estimated Exploitable Biomass	Significant increase over 2 consecutive years	No significant change over 2 consecutive years	Significant decrease over 2 consecutive years	Significant decrease over 3 consecutive years	Significant decrease over 5 consecutive years
Ratio of Harvest : Exploitable Biomass Estimate 2004 / 2005	<20%	20% to 30%	30% to 40%	40% to 50%	>50%
	<20%	20% to 30%	30% to 40%	40% to 50%	>50%
SCAA					
Total Annual Mortality	<0.45	0.45 to 0.6	0.6 to 0.65	0.65 to 0.70	>0.70
Estimated Exploitable Biomass	Significant increase over 2 consecutive years	No significant change over 2 consecutive years	Significant decrease over 2 consecutive years	Significant decrease over 3 consecutive years	Significant decrease over 5 consecutive years
SSBM	Increasing	Increasing	Unchanged	Decreasing	Decreasing
Ratio of F:M	<0.5	<0.8	< 1.0	>1	>1.5
SPR	>.45	>.35	> .20	<.20	<.15
Predicted 3 yr Old Recruitment	Increase over 3 or more years	Increase over 2 years	No Trend	Decrease over 3 years	Decrease over 5 or more years
Ratio Harvest : Est. Exploitable Biomass 2004 / 2005	<20%	20% to 30%	30% to 40%	40% to 50%	>50%
	<20%	20% to 30%	30% to 40%	40% to 50%	>50%

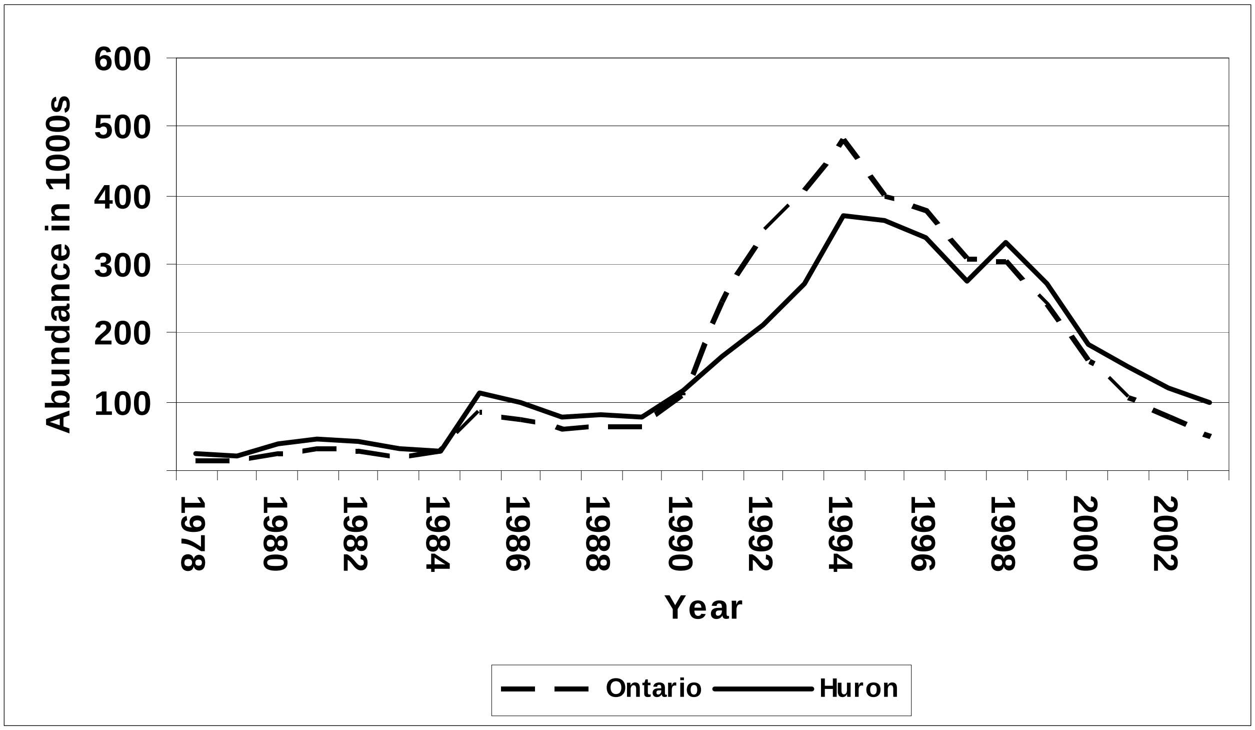
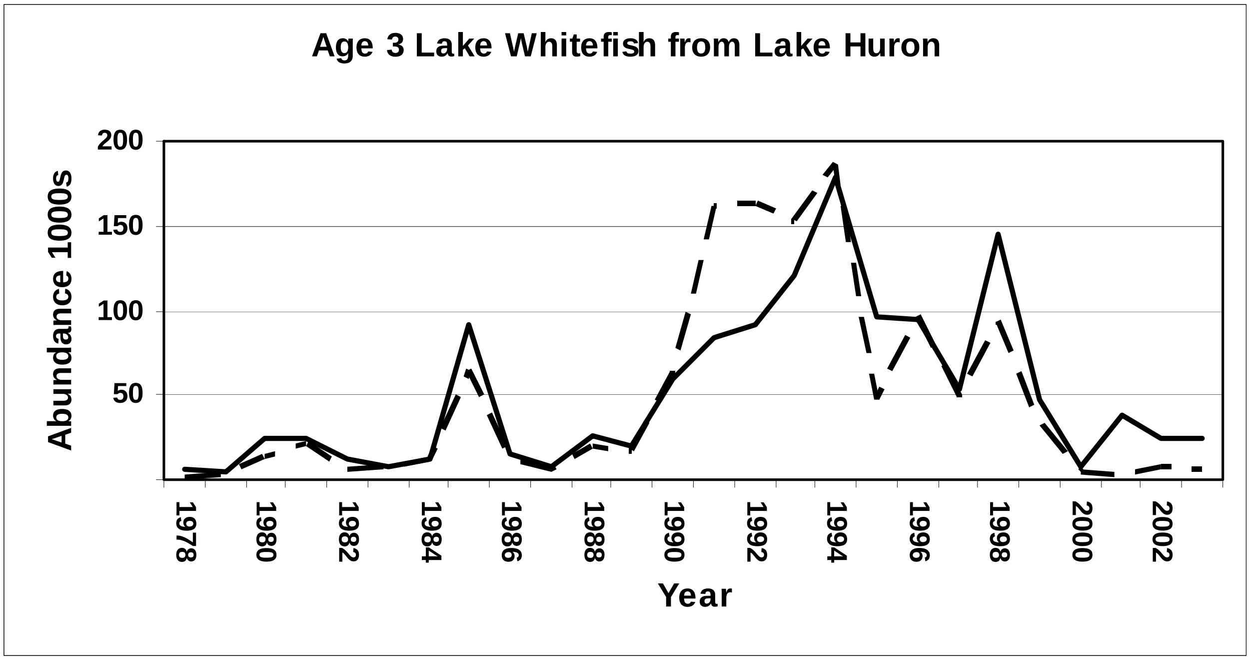


Figure 1. Model results for abundance of Lake Huron lake whitefish (*Coregonus clupeaformis*) using two statistical catch at age models. The Ontario model is that used for Lake Ontario lake whitefish and the Huron Model is that used for the same fish caught in AA19, Georgian Bay.



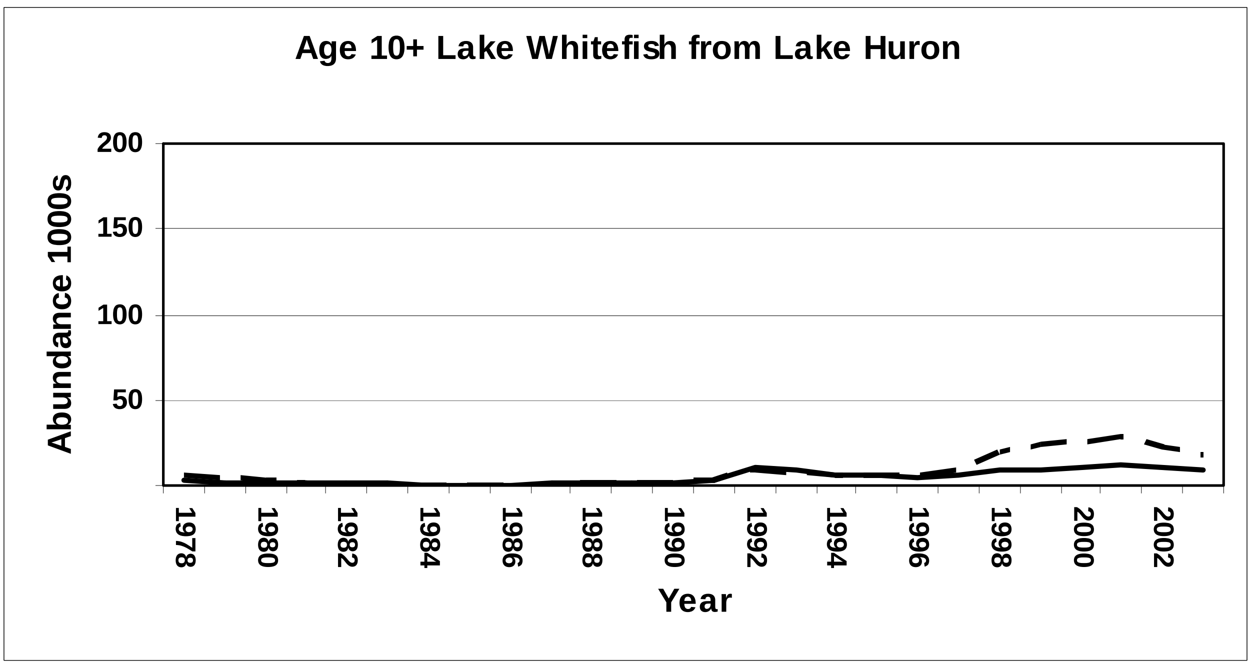
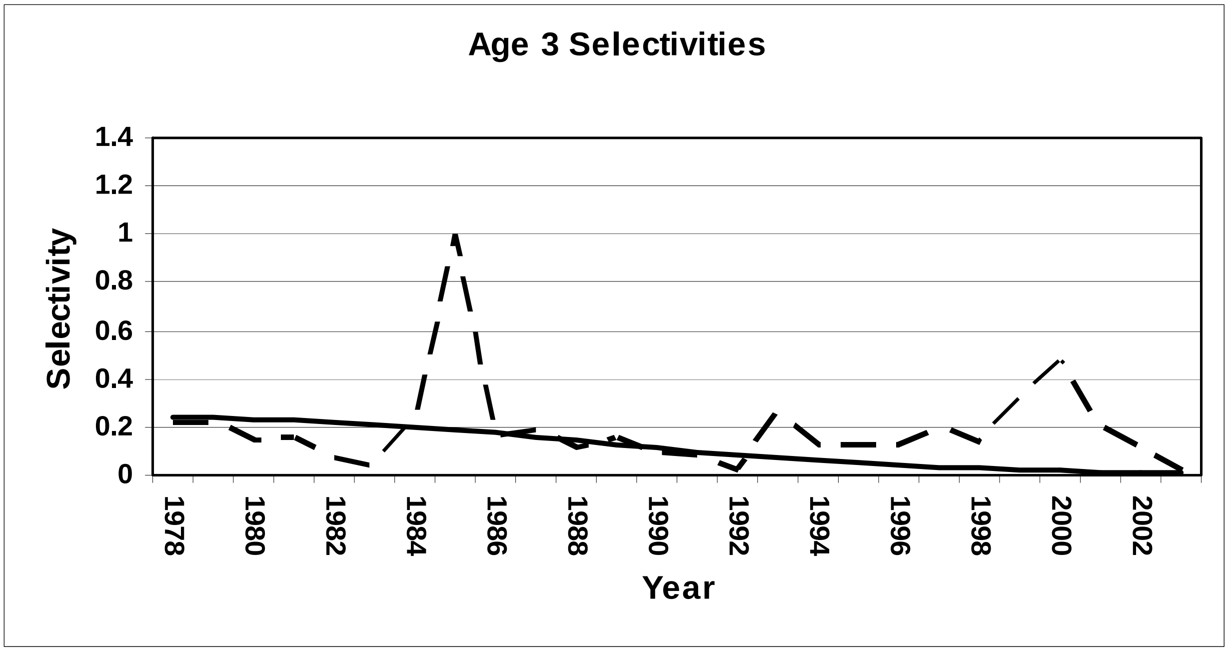


Figure 3. Comparison of abundance estimates using different statistical catch at age models for age 3 (upper plot) and age 10+ (lower plot) lake whitefish from Lake Huron. The Huron model is represented by a solid line and the Ontario model, a dashed line.



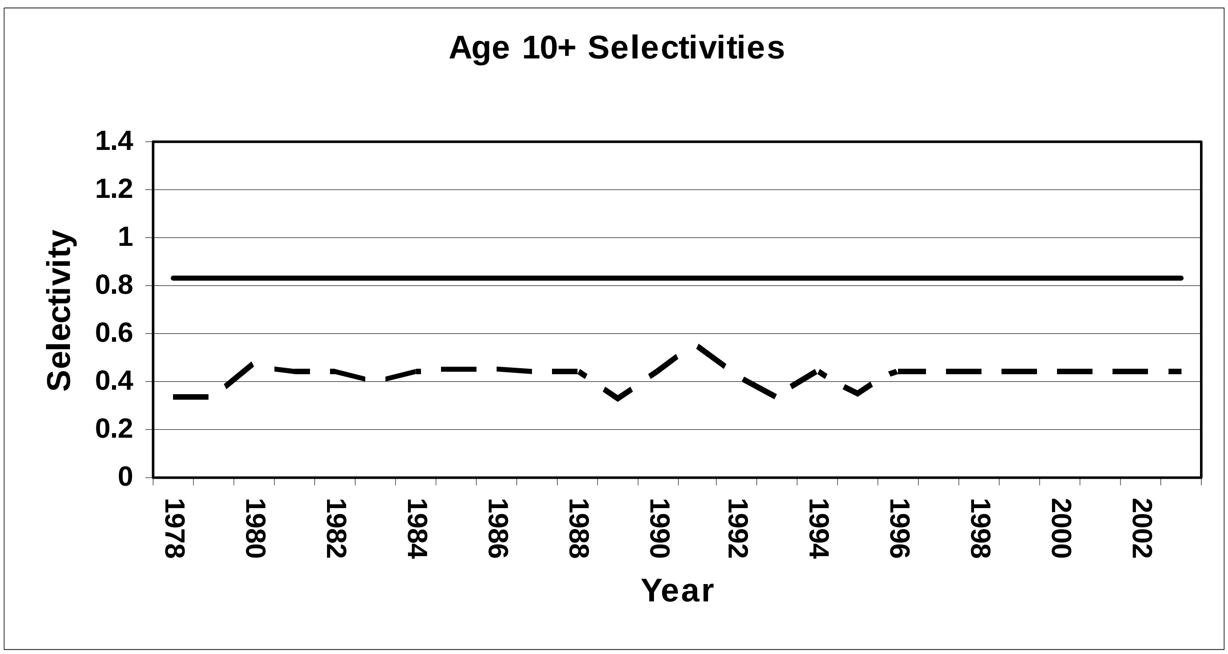


Figure 2. Comparison of selectivities among age 3 (upper plot) and age 10+ (lower plot) lake whitefish from Lake Huron. The Huron model (solid line) selectivities result from double logistic function whereas those from Ontario model (dashed line) are input and based on percent caught in index gillnets, mesh size and assuming log normal distributions.

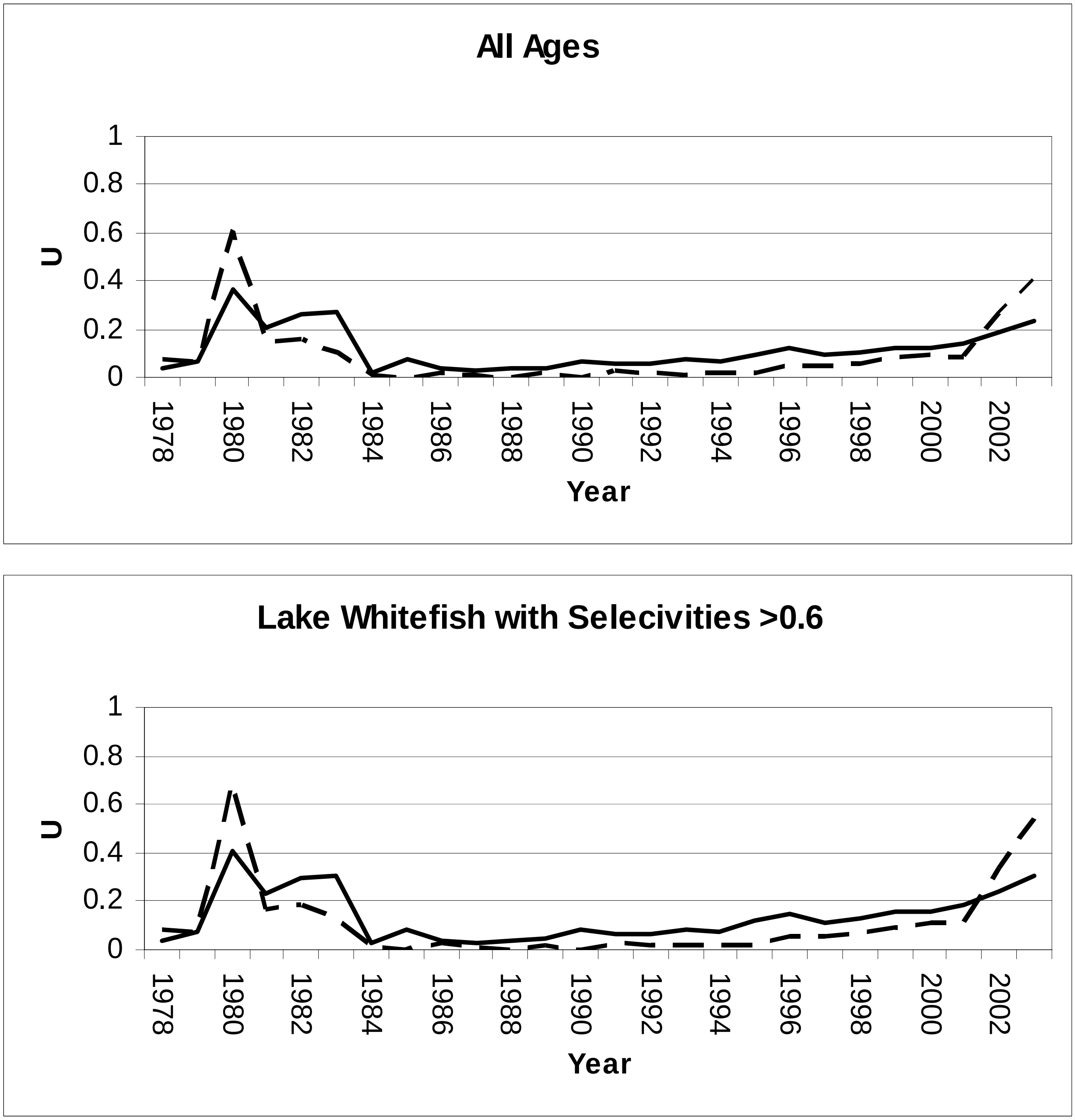


Figure 4. Comparison of average exploitation for lake whitefish from Lake Huron using the Huron model (solid line) and the Ontario model (dashed line). The upper plot is for ages 3-10+ and the lower for ages 4-9 or that which are almost fully selected by commercial gillnet.

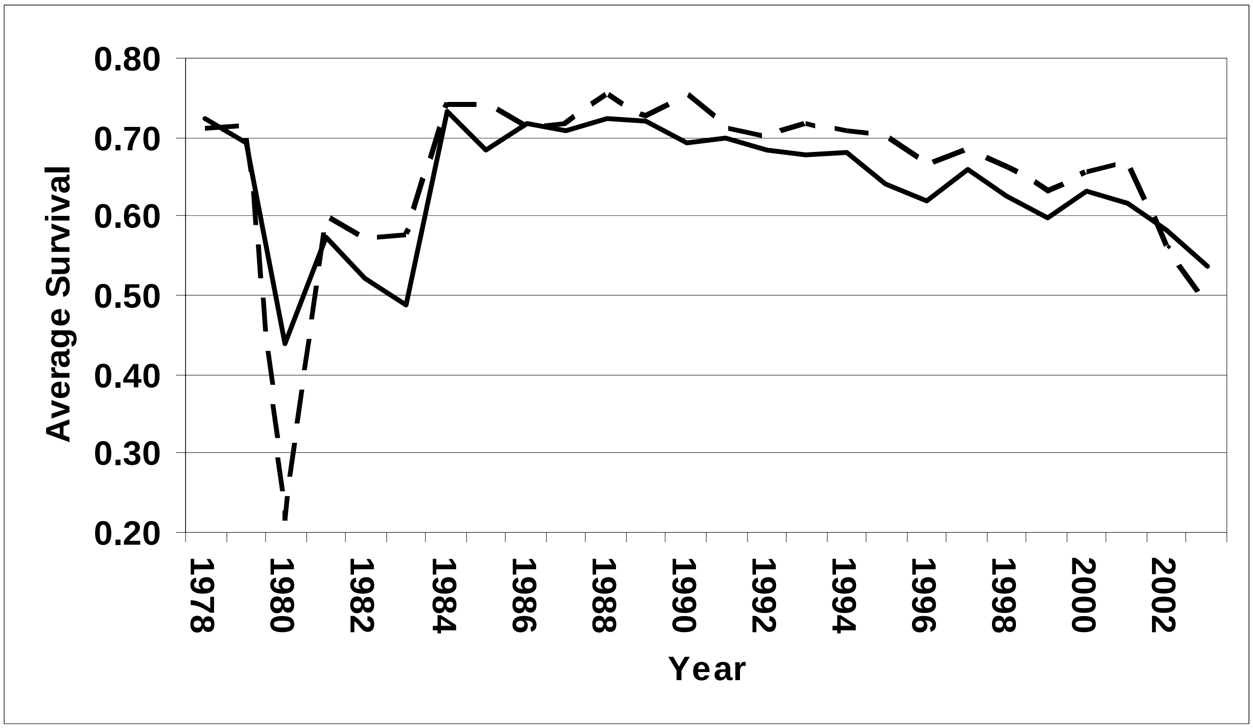
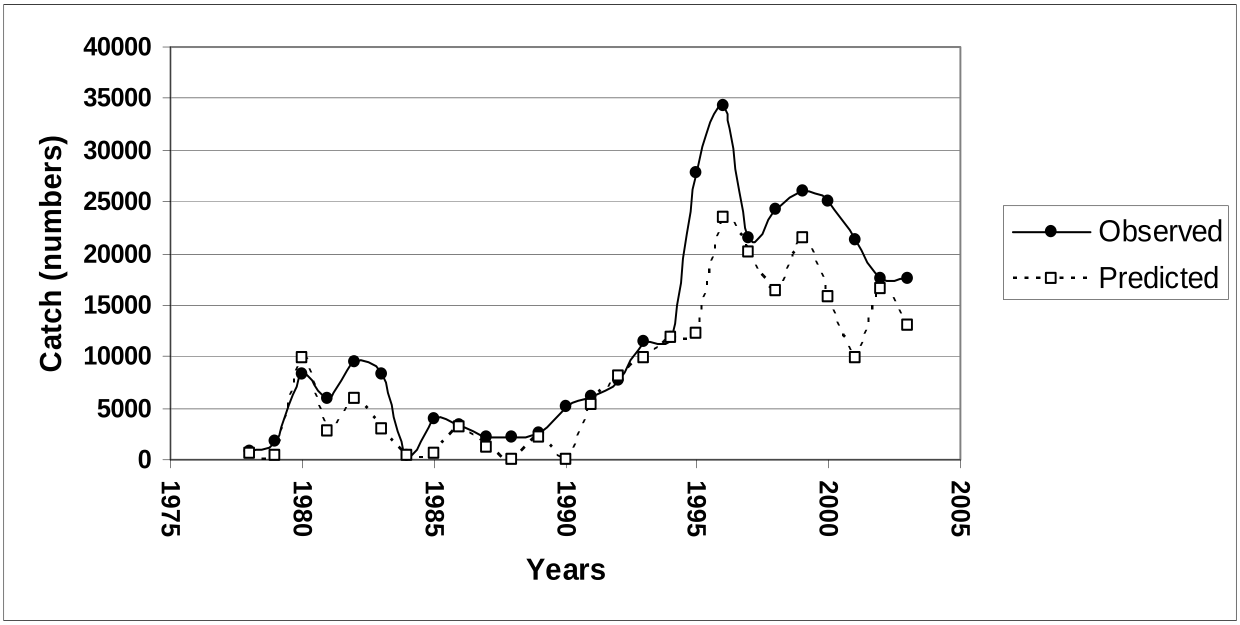


Figure 5. Average survival of Lake Huron lake whitefish age 3-10+ estimated using the Huron model (solid line) and the Ontario model (dashed line).



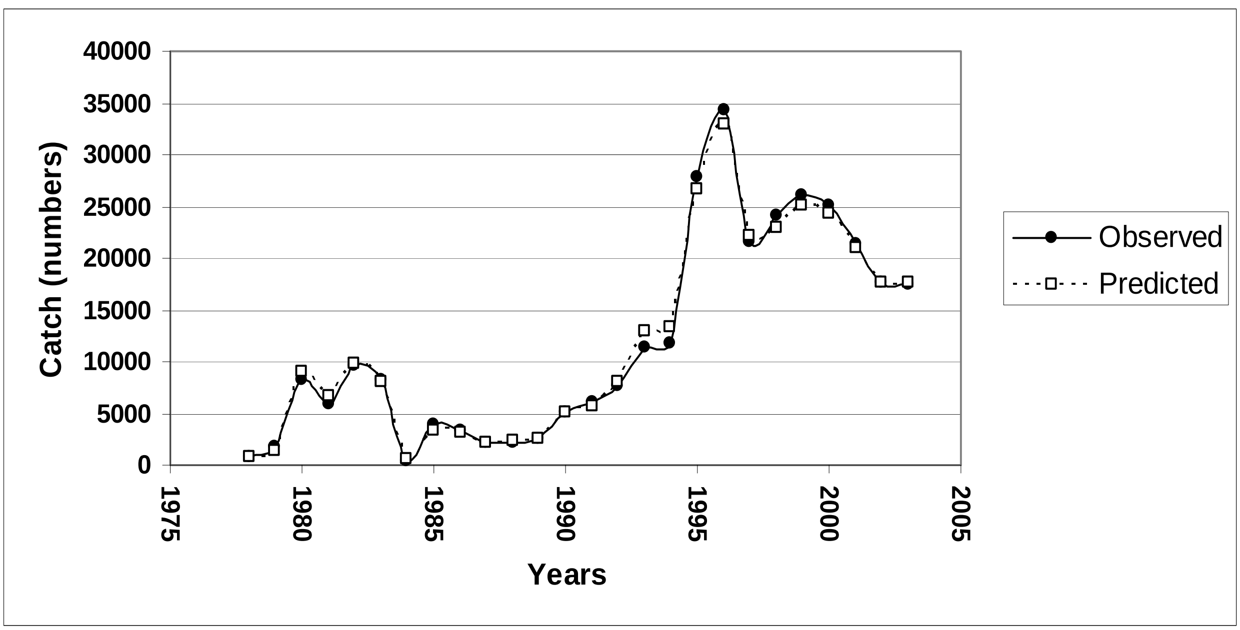


Figure 6. Observed and predicted Lake whitefish commercial catch data for Georgian Bay lake whitefish using two models. The upper plot represents the Ontario model and lower plot, the Huron model.

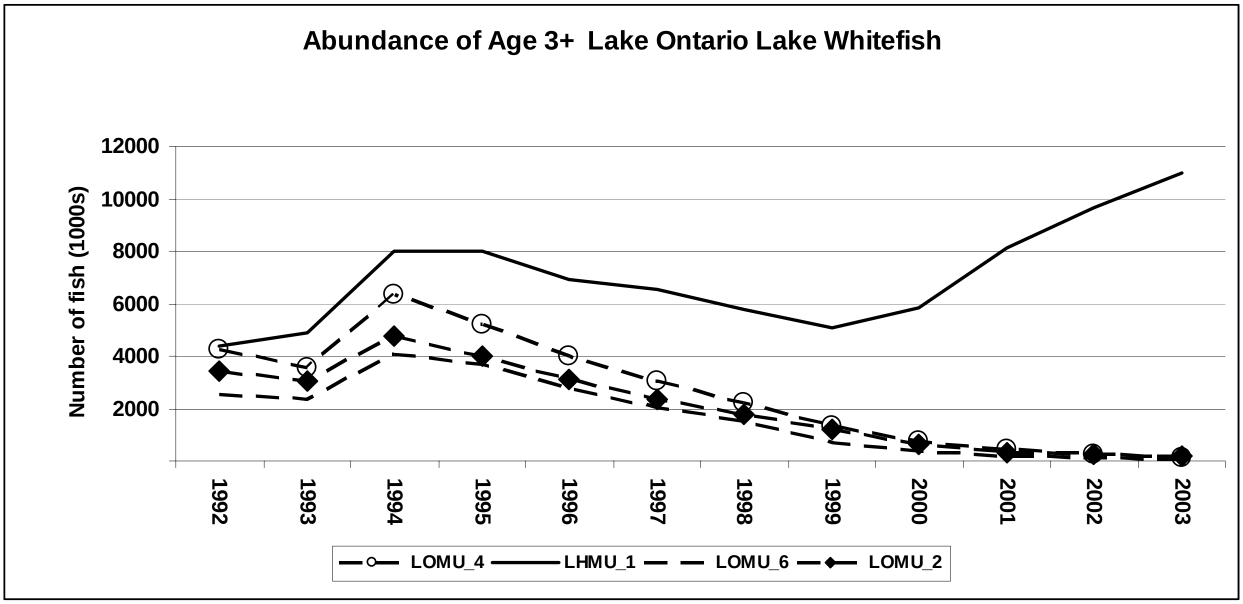


Figure 7. Comparison of abundance estimates of age 3+ Lake Ontario lake whitefish using two different statistical catch at age models. The solid line represents the results of the Huron model (LHMU_1) with a stock recruitment assumption, the dashed line with circles is the fully optimized Ontario model (LOMU_4), dashed line with diamonds is the Ontario model with a very low weight attributed to fishery independent data (LOMU_2) and the dashed line without symbols is the Ontario model using selectivities output from the Huron model and a very low weight attributed to fishery independent data (LOMU_6).