Key Uncertainties Regarding 2003 TAC Determination for the Lake Whitefish Fisheries of the Saugeen Ojibway Nation Territories in Lake Huron

A management brief prepared by:

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Introduction

On 14 October 2003 the Biotechnical Committee of the Saugeen Ojibway/Canada/Ontario Fishing Agreement met at the University of Guelph to exchange and discuss documented analyses associated with the 2003 lake whitefish (*Coregonus clupeaformis*) fisheries of Lake Huron in general, and the fisheries of the Saugeen Ojibway Nation Territories, in particular.

Crawford, S., K. McCann & A. Muir. 2003. 2003 Saugeen Ojibway commercial harvest TACs for lake whitefish (*Coregonus clupeaformis*) in Lake Huron, Report prepared for the Chippewas of Nawash Unceded First Nation R.R. #5, Wiarton, Ontario N0H 2T0. 109pp. http://nawash.ca/Transfer/Crawford/2003_Crawford_etal.pdf.

Mohr, L.C., A. Cottrill, S. Milne & D. McLeish. 2003. Review of Status of Lake Whitefish Populations in the Waters Surrounding the Bruce Peninsula, 2003. Report prepared by Upper Great Lakes Management Unit, Ontario Ministry of Natural Resources, Owen Sound, Ontario.

At that meeting, it was agreed that the parties would take approximately two weeks to review the documented analyses and to prepare a maximum 10-page draft document that would identify the key uncertainties associated with the two sets of analyses, as well as major areas of agreement and disagreement between the parties. The review documents were intended to be written in a manner that would be suitable for presentation and discussion at the non-technical Plenary session of the Saugeen Ojibway/Canada/Ontario Fishing Agreement.

It was also agreed that once the draft documents were prepared by both parties, the Biotechnical Committee would reconvene to present and discuss their key uncertainties, with the objective of identifying those concerns that could be dealt with at the level of the committee, in contrast to those unresolved differences that would have to be addressed at the Plenary.

Objective

The objective of this management brief is to present the Saugeen Ojibway perspective on major issues associated with the OMNR analyses regarding 2003 lake whitefish (*Coregonus clupeaformis*) fisheries of Lake Huron in general, and the fisheries of the Saugeen Ojibway Nation Territories, in particular. A total of six major issues were selected as being most important with regards to 2003 TACs:

1. Congratulations to LHMU for documentation
2. Uncertainties, hypotheses and predictions
3. Distribution of lake whitefish populations in Lake Huron
4. Data scales, parsimony and model fits
5. Relative change versus predicted consequences of TACs
6. Allocation of 2003 TACs

The remainder of this brief will present information and identify key uncertainties associated with each of these major issues.

1. Congratulations to LHMU for documentation

Without being over-the-top, it is important that the OMNR receive recognition for providing reciprocal data exchange and documentation of its analyses for review by the Saugeen Ojibway. This has been a major stumbling block in previous years; one which posed serious problems to the development of a true technical working relationship between the parties. Substantial efforts were made by the OMNR to achieve this reciprocal exchange, and it is genuinely appreciated by the Saugeen Ojibway.

2. Uncertainties, hypotheses and predictions

There is a fundamental difference between the way that the Saugeen Ojibway deals with uncertainties associated with Lake Huron fisheries, and the way that OMNR deals with these uncertainties. This fundamental difference extends into many subsequent differences between the parties and for this reason, requires attention as a major issue.

Since the Saugeen Ojibway's first review of Lake Huron commercial fisheries management (Crawford 1996), it was clear that the OMNR management system was not designed to deal in a scientific manner with ecological uncertainties in the fisheries. Rather, the pre-existing management system was designed to take advantage of available fiscal resources, attempt to sample the fisheries as best they could with those resources, and ultimately make some recommendations to senior OMNR management about whether the supporting population abundance was "Down," "No change" or "Up" - qualitative diagnoses that translated roughly into recommendations of TAC changes relative to the previous year's TAC (-10%, 0%, +10% respectively). This approach of making relative changes to previous TACs is clearly evident in the OMNR's 2003 analyses:

> "*Of importance to note is the fact that historically and currently, the UGLMU have managed fish stocks on a "relative" basis rather than on an absolute basis. This means that quotas have been adjusted relative to a starting point which was considered to be sustainable at the time that it was implemented (OMNR 1985). These quotas have been adjusted according to agreed upon protocol developed with members of the Ontario Commercial Fishermen's Association since 1985 with only rare deviation (Mohr et al 1987).*" (Mohr et al. 2003)

In this respect, there has been no substantial change to the OMNR's method of recommending quota adjustments since the Crawford (1996) review. It is now, pretty much what it was then.

Since 1996, the Saugeen Ojibway have been repeatedly trying to convince the OMNR that in order for the Lake Huron fisheries to be managed in a more scientifically-defensible manner, the OMNR must explicitly recognize and deal with key sources of uncertainty, rather than simply making 'best' assumptions (i.e. hypotheses accepted as being true, without the necessary evidence) about the ecology of the system, and then proceeding with an analysis and decision-making system that is based on unreliable knowledge.

From the perspective of the Saugeen Ojibway, the most fundamental element of a scientifically-defensible management system is the hypothesis (Figure 1). Simply put, an hypothesis (or model as it is sometimes called) is a possible cause-effect explanation of something that happens in the world. In the most desirable situation, we develop alternative hypotheses that could account for the observation, and these hypotheses compete among themselves. The existence of multiple hypotheses reduces our human tendency to ‘jump to conclusions’ about the explanations. In practical terms, we measure the strength of the hypotheses in terms of probabilities that can be determined on the basis of the evidence that we have in hand. The most important characteristic of an hypothesis is that it generates predictions (statements about what will happen in the future) that can be tested through observation of circumstances in the wild, or through experiments. The results of these tests, in turn, provide us with the ability to update the probabilities of hypotheses based on the new evidence - a process which is simply referred to as learning.

This hypothesis-based approach to analysing Lake Huron fisheries was identified in the 2003 Saugeen Ojibway TAC report:

> “*The current report is explicitly based on the principles of DAAM, to the greatest possible extent. In particular, we have intentionally emphasized four of the key technical steps associated with the DAAM process:*
>
> > *1. Identification of key uncertainties as hypotheses,*
> > *2. Examination of evidence for alternative hypotheses,*
> > *3. Development of models to forecast outcomes given different hypotheses, and*
> > *4. Evaluation and ranking of competing hypotheses by likelihood*
>
> *In this way, we hope to continue laying the operational foundation for Decision Analysis and Adaptive Management of Lake Huron fisheries. Our competing hypotheses, predictions and probabilities are intended to provide Nawash Council with a realistic impression of the Lake Huron fisheries populations, in order to develop reasonable and safe harvest limits for the Saugeen Ojibway fisheries.*” (Crawford et al. 2003, p.3)

The Saugeen Ojibway did not invent this technique - it is well established in the primary scientific and management literature.

The biggest problem that the Saugeen Ojibway have with the OMNR approach to analysing Lake Huron fisheries is that the OMNR still works largely on the basis of assumptions, instead of recognizing and dealing directly with their major ecological uncertainties directly. In this sense, the OMNR system is ‘prescriptive’ rather than ‘predictive.’ OMNR does not develop alternative hypotheses that compete with each other to explain the observations. In fact, the OMNR does not use the concept of hypotheses at all - search through the Mohr et al. (2003) report and you will not find a single reference to an ecological hypothesis, any predictions generated by an hypothesis, or the concept that competing hypotheses should be evaluated on the basis of probabilities.

There seems to have been a political reluctance by the OMNR to admit that it’s previous assumptions may have been incorrect. More recently there have been signs that the OMNR is coming to the realization that it is important for them to explicitly recognize and deal with key uncertainties by developing competing hypotheses and testing their predictions. One important example of this shift in attitude is the recent collaboration between the Saugeen Ojibway and OMNR with respect to Decision Analysis-Adaptive Management (Table 1, especially the steps listed under Item 6). Unfortunately, there is no indication of these principles to be found in the OMNR 2003 TAC Report (Mohr et al. 2003).

It would appear that the OMNR has an institutional tendency to think of ‘science’ as being primarily associated with its “Science and Information Resources Division” rather than being used in its “Natural Resource Management Division.” The OMNR will continue to have major problems with the Saugeen Ojibway on this issue, until they realize that hypotheses are as important to their assessment-management units as they are to their research units.

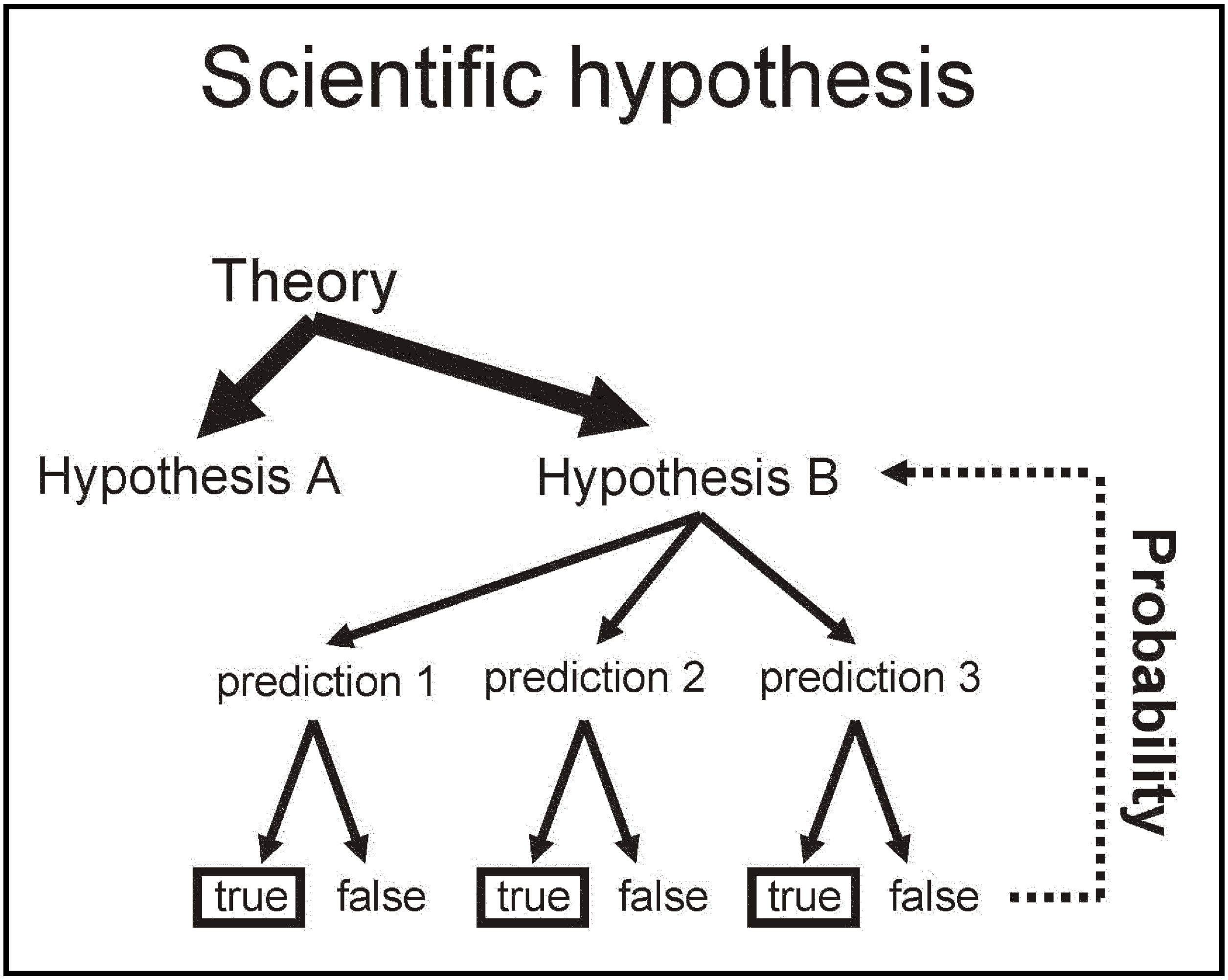

Figure 1. General representation of how key uncertainties are reduced by use of the scientific method. Alternative hypotheses (i.e. models) are developed as logically-possible explanations for an uncertainty about how the world works. Hypotheses generate predictions about what would happen under different circumstances, and these predictions can be put to the test through observation of circumstances in the wild, or through experiments. Results of the tests are used to update the probabilities of the competing hypotheses over time (i.e. learning).

Table 1. Draft principles of Decision Analysis and Adaptive Management (DAAM) prepared for the Saugeen Ojibway/Canada/Ontario Plenary by Prof. Mike Jones (Michigan State University) & Prof. Tom Nudds (University of Guelph), 14 February 2003.

1. Uncertainty is pervasive and has a big effect on ability to make wise decisions.[1]

2. DAAM must be clearly understood.[2]

3. DAAM requires a careful, inclusive specification of the management system.[3]

4. To be effective, DAAM depends on meaningful involvement of all stakeholders.[3]

5. Decision analysis and adaptive management depend on one another to be effective.[4]

6. Successful, inclusive DAAM requires these steps:
   a. All parties involved
   b. Inclusive specification of management objectives and options
   c. Identification of critical uncertainties, as hypotheses
   d. Critical, rigorous examination of evidence for alternative hypotheses
   e. Development of models to forecast outcomes of management, given different hypotheses
   f. Evaluation and ranking of competing hypotheses by likelihood in light of uncertainty (simple DA)
   g. Evaluation of experimental management options (DA - value of information analysis)
   h. Design and implementation of management experiments according to sound principles of experimental design
   i. Monitor key responses.
   j. Update ranking of competing hypotheses by likelihood given monitoring results.

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[1] No management decision is without risk. To be sure, learning about risk occurs as part-and-parcel of DA insofar as DA facilitates risk "assessment", but risk is not necessarily reduced as a result. Uncertainty, and hence risk, remain until tests are performed that explicitly address the key uncertainties that present risk, that is, until risk is actually assessed as a result of applying experimental management.

[2] A clear understanding of DA and AM is essential: combined, they amount to "learning while doing", not "learning, then doing". The latter is referred to now as "muddling through", and is not the preferred option in modern natural resources management. Management agencies often refer to "flexible" management as adaptive management and to "systematic, objective" decision-making as decision analysis. This is wrong. Both are incorrect uses of the terms because they fail to explicitly acknowledge uncertainty and the opportunity to learn.

[3] Unless the management system is fully specified and inclusive, key uncertainties will remain outside the ability of managers to address through DAAM, thus further contributing to risk. The most advanced, large-scale example of AM currently in place (mallard harvest management) has learned from experience that the proper identification of populations and, by extension, stocks within populations, is a key requisite to successful application of DA and AM. This is generally true of any widespread, renewing, biological populations that represent common property resources. Caribou management boards, for example, successfully brought together all of the users throughout the range of particular migratory herds with a view addressing key differences of opinion among the users with respect to the factors that affected the shared resource.

[4] DA and AM are more than simply complementary. Complementarity implies merely existing side-by-side, but not necessarily co-dependent. Experimental management without DA is inefficient, and DA without experimental management is unfinished business.

3. Distribution of lake whitefish populations in Lake Huron

Since the Saugeen Ojibway's review of Lake Huron commercial fisheries management (Crawford 1996), it was clear that the OMNR's quota management areas (Figure 2) were not designed to represent the spatial distribution of lake whitefish populations in Lake Huron. They are administrative areas that attempted to bring together a whole bunch of different variables (e.g. different species, different licence-holders, different ports, different fishing histories), with the aim of having a relatively simple basis for issuing licences, modifying harvest regulations and enforcement. Given these constraints, it would be quite a surprise if any of the OMNR quota management areas actually did correspond to a distinct population of lake whitefish in Lake Huron.

But - for reasons known only to them, and in the face of substantial contradictory evidence - the OMNR has made a decision to stick with its quota management areas. This decision is made very clear in the OMNR 2003 TAC report (Mohr et al. 2003):

Let us consider what the OMNR 2003 TAC report has to say about lake whitefish populations in the Main Basin:

> "*A central main basin stock, roughly coinciding with assessment area LH05 in Quota Management Area 4-4, ... has been identified in earlier studies (Casselman et al., 1981; Budd, 1957) (Figure 1). QMA 4-4, consisting of assessment areas LH05, LH06, and LH07, has been managed as a common stock of whitefish since the inception of the current quota management system in 1984.*" (Mohr et al. 2003)

Ok, let's look at the synthesis map from Casselman et al. (1981) shown in this report as Figure 3. Two out of three data sources that Casselman et al. (1981) examined for the Fishing Islands (J on their map) showed linkages between the Fishing Islands (OMNR's QMA 4-4) and southern Manitoulin Island (OMNR's QMA 4-3). The one data source that appeared to be different for the Fishing Islands was the highly variable age and growth data (so-called 'population dynamics' data) which are expected to exhibit highly variable results in a migratory species. Contrary to claims made by the OMNR, there is no evidence to support the hypothesis of a separate population of lake whitefish in OMNR QMA 4-4.

In fact, it was OMNR biologists who first brought to my attention (several years ago) that they strongly suspected that the lake whitefish from around the Main Basin migrated to use the southern basin as a common feeding ground.

Let's look at a map of the reported spawning areas for lake whitefish in Lake Huron (Figure 4), as compiled and presented to the OMNR in Crawford et al. (2001). The most striking feature about the Main Basin is the virtual absence of spawning areas in the southern end of the basin - it is predominantly sand substrate all the way down along nearshore waters, as opposed to the rocky spawning shoals required by lake whitefish.

> "*The large increase in yield of lake whitefish from Lake Huron after 1981 occurred primarily in the southern main basin (Mohr and Ebener 2003) where few if any spawning stocks of lake whitefish had been identified (Casselman et al. 1981).*" (Ebener et al. 2002)

So, the majority of the lake whitefish harvests in the Main Basin come from OMNR QMA 4-5, which is treated by OMNR as a separate population, even though there is virtually no spawning habitat in the area.

Let's look at the commercial fisheries data for each of the OMNR QMA's from north to south in the Main Basin (Figure 5). Notice the pulse of CPUE (catch-per-unit-effort as an index of relative abundance) for most of the QMA's in month 11 (November) - these data support the hypothesis that lake whitefish aggregate and spawn in the areas where a pulse is observed. Notice that OMNR QMA 4-5 has no apparent CPUE pulse in November at all. These data support the hypothesis (already supported above) that lake whitefish do not spawn in OMNR QMA 4-5. Contrary to claims made by the OMNR, there is no evidence to support the hypothesis of a separate population of lake whitefish data in OMNR QMA 4-4. In fact, the contradictory evidence strongly suggest that it is not a viable hypothesis.

All of these data and interpretations were presented to the OMNR in the 2001 Nawash TAC Report (Crawford et al. 2001). Strangely, when it comes to the 2003 OMNR TAC report, there is absolutely no mention of these data, nor of the clear hypothesis that lake whitefish migrate from feeding grounds in OMNR QMA 4-5 (southern Main Basin) to spawning grounds in OMNR QMA 4-4 (Fishing Islands), and perhaps beyond. In fact, there is no mention of southern Main Basin in the 2003 OMNR TAC Report at all. Something is very wrong with this. Regardless of intention, the 2003 OMNR TAC Report is withholding data and analyses that are likely to be associated with the lake whitefish population(s) supporting the Saugeen Ojibway fisheries. This is a most serious issue that must be addressed.

The situation with OMNR QMA's is very similar in southcentral Georgian Bay.

Consider OMNR QMA 5-6, which has non-ecological landmarks that correspond exactly to the Chippewas of Nawash Unceded First Nation:

> "*Based upon the limited biological or harvest data available, it appears that QMA 5-6 contains two separate lake whitefish stocks. This area extends across Georgian Bay and hence probably incorporates a western nearshore stock in the vicinity of Cape Croker and the islands at the mouth of Colpoys Bay and an eastern offshore stock in the vicinity of the Western Island group. Historical harvest, documented spawning grounds (Goodyear, 1982) and lake morphology tend to support this assumption. The east to west extent of this area was established not as a tool for lake whitefish management but rather as a tool for managing deepwater chub. It also appears that fishery administration and user group separation may have played a role in delineating this area.*" (Mohr et al. 2003)

Thus, it is clear that the OMNR itself has no faith in its QMA 5-6 as an ecologically meaningful tool for understanding the effects of fisheries harvests on supporting populations.

Consider, OMNR QMA 5-8, which the OMNR 2003 TAC Report claims to represent a separate population of lake whitefish:

> "*a southern Georgian Bay stock, roughly coinciding with QMA 5-8, [has] been identified in earlier studies (Cucin and Regier, 1966).*" (Mohr et al. 2003)

Now let's check the Cucin & Regier (1966) distribution map for the recapture of lake whitefish that were tagged at Wiarton in southwestern Georgian Bay (Figure 6). These data clearly show a distribution of lake whitefish along the entire southern Georgian Bay (OMNR QMA's 5-6, 5-8, 5-9).

Not only does the OMNR still assume that QMA 5-8 contains a distinct population of lake whitefish, they now figure that there is some reason that they should subdivide the "single population" in QMA 5-8 into two further QMAs 5-8W (within Fishing Agreement waters) and 5-8E (outside of the Fishing Agreement waters?):

> "*the available data supports the contention that QMA 5-8 contains a single lake whitefish stock. ... The boundaries of this QMA were also adjusted in order to address concerns associated with the separation of commercial and recreational fisheries, including the creation of a restricted non-commercial harvest area [QMA 5-8E, QMA 5-8W].*"(Mohr et al. 2003)

This decision is simply unacceptable from a biological perspective.

So where does this leave us? The Saugeen Ojibway have attempted to represent the ecological uncertainty associated with competing hypotheses about distribution of lake whitefish populations in Lake Huron. The OMNR has made a decision to defend its assumptions about its QMAs in the face of contradictory ecological evidence:

> "*In the meantime, the existing quota management areas are assumed adequate for the purposes of fisheries management and boundary changes will be considered only as new information becomes available.*" (Mohr et al. 2003)

The major question that emerges from this issue is whether or not the OMNR will work with the Saugeen Ojibway to explicitly develop the alternate hypotheses regarding lake whitefish distribution in Lake Huron - hypotheses that will serve as a common foundation upon which to develop and test our models of population dynamics that support TAC decision-making.

It is no small irony that the Saugeen Ojibway are actually working with OMNR in the design and implementation of a basin-wide tagging study for lake whitefish in the Main Basin of Lake Huron. Consider the rationale that was included in the proposal for this project:

> "*Management agencies in both Michigan and Ontario currently use population models to estimate abundance and mortality of lake whitefish stocks in Lake Huron and to set harvest limits from each stock. These population models assume that there is no immigration or emigration between stocks, or at least that immigration and emigration are in equilibrium with each other. In order for these models to function properly, these assumptions have to be met. Unfortunately, we have little faith in the current boundaries of lake whitefish stocks in Lake Huron because most stock boundaries were created with little if any reference to lake whitefish life history information.*" (Ebener et al. 2002)

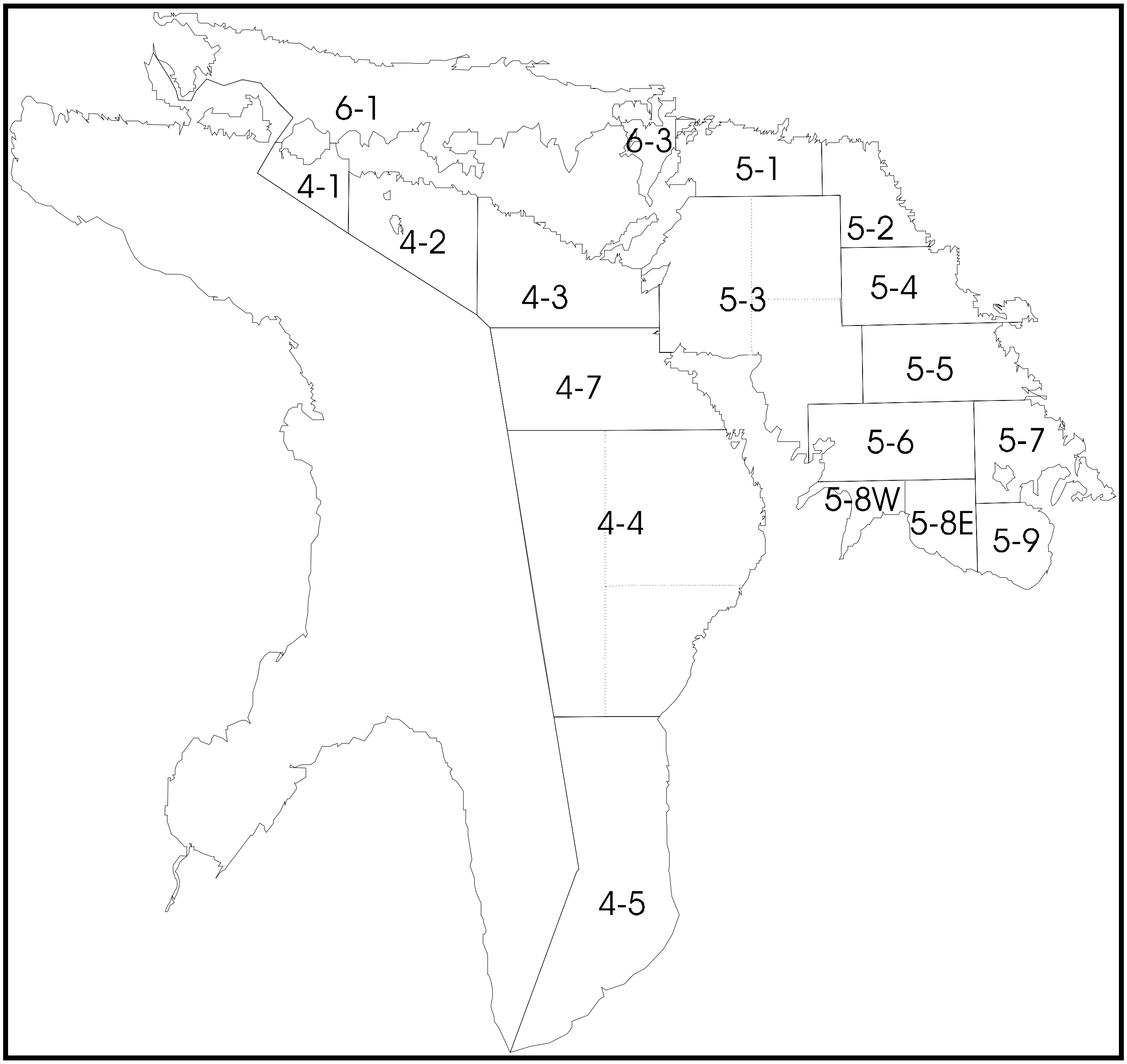

Figure 2. Map of OMNR quota management areas for Lake Huron, used to represent populations of lake whitefish (*Coregonus clupeaformis*) in LHMU 2003 analyses (Mohr et al. 2003).

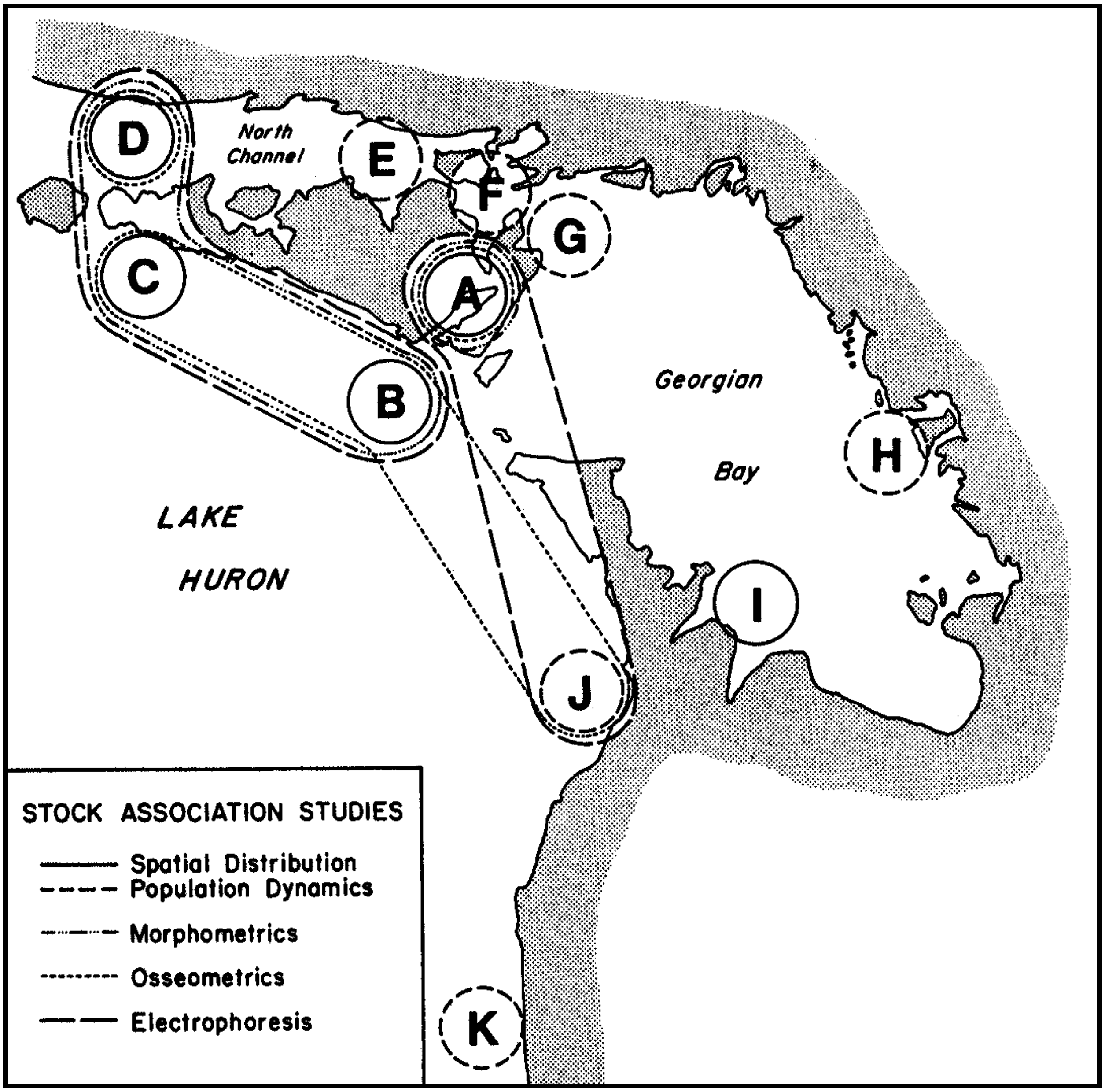

Figure 3. Casselman et al.'s (1981) representation of stock association studies for lake whitefish (*Coregonus clupeaformis*) sampled at 11 locations in Lake Huron. According to the 'association' lines on the map, the variables examined by Casselman et al. (1981) indicate association between lake whitefish sampled from the North Channel and northern and eastern Main Basin. The sample from southcentral Main Basin was characterized solely with age and growth data (so-called 'population dynamics' data). Samples from southern Georgian Bay were based solely on the work of Cucin & Regier (1966), which showed migrations along southern Georgian Bay.

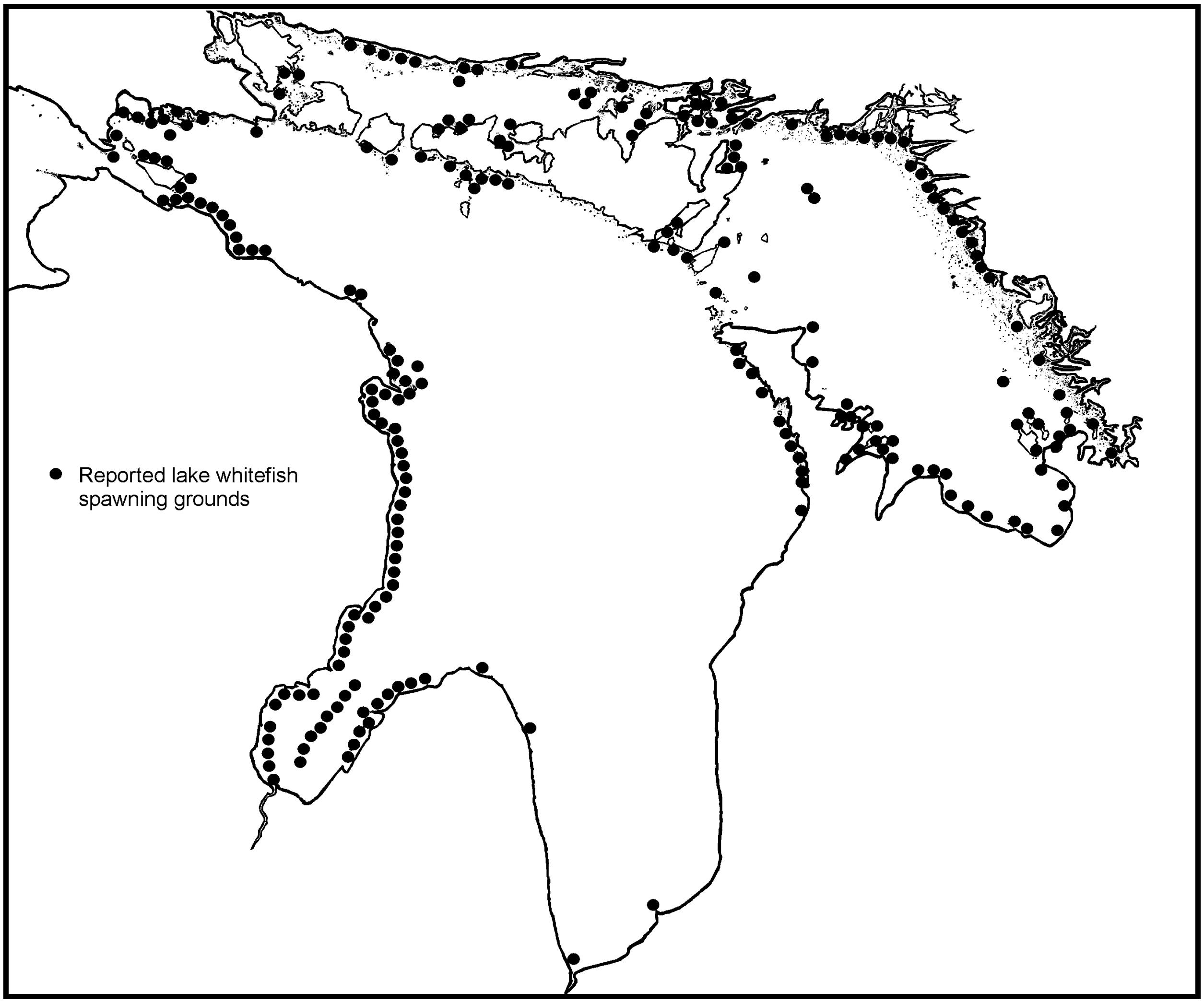

Figure 4. Map of Lake Huron showing locations of reported spawning areas for lake whitefish (*Coregonus clupeaformis*) as compiled by Crawford et al. (2001) from technical and scientific literature. Note the virtual absence of reported spawning grounds in southern Main Basin, strongly suggesting that fish in this region must migrate to other areas of the lake in order to spawn.

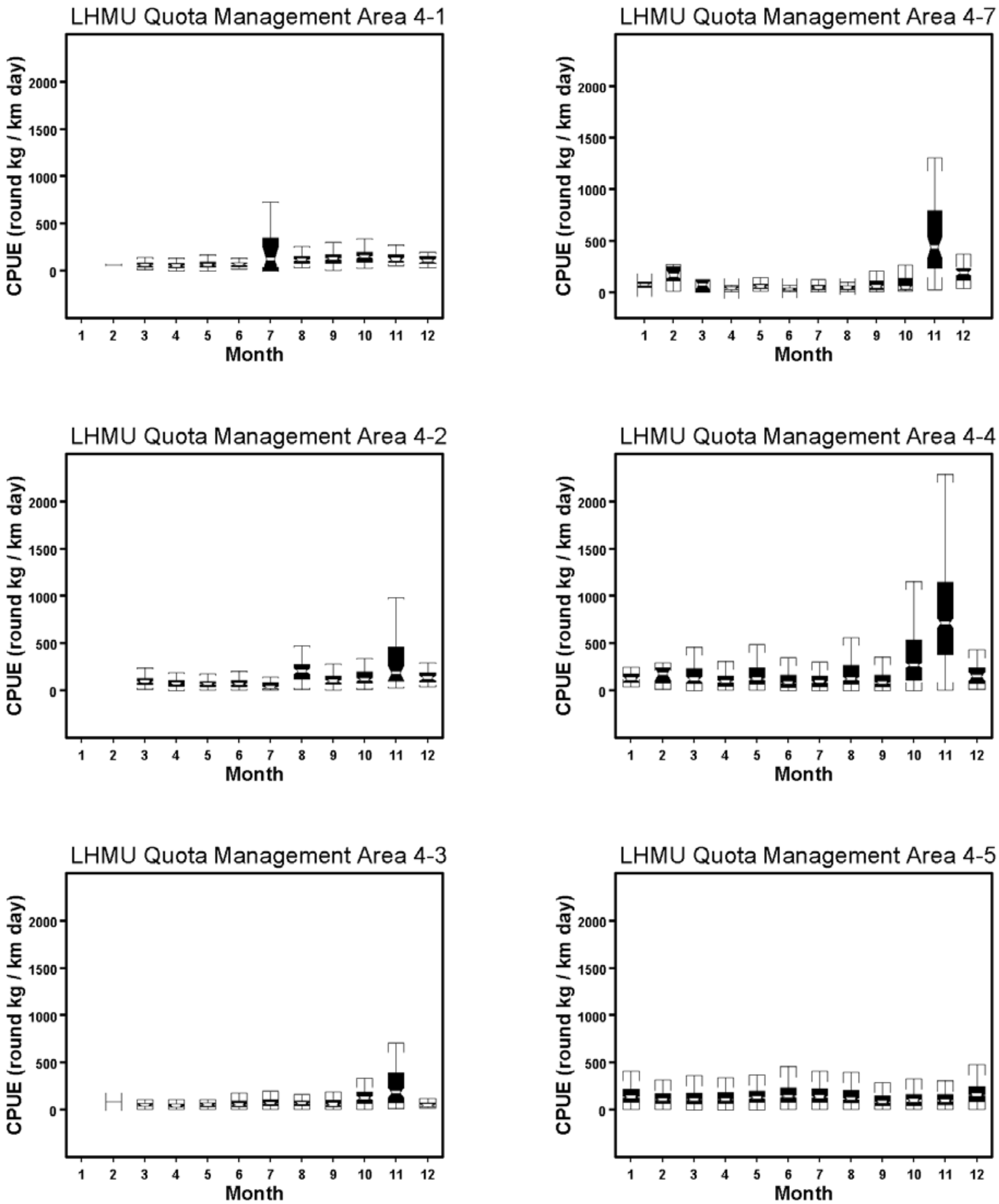

Figure 5. Box plots showing monthly progression of CPUE (rkg / km day) for lake whitefish (*Coregonus clupeaformis*) in the six OMNR management areas in the Main Basin Lake Huron during the period 1994-2000. Bottom right panel shows southern Main Basin (4-5) with no major fall CPUE pulse (Crawford et al. 2001)

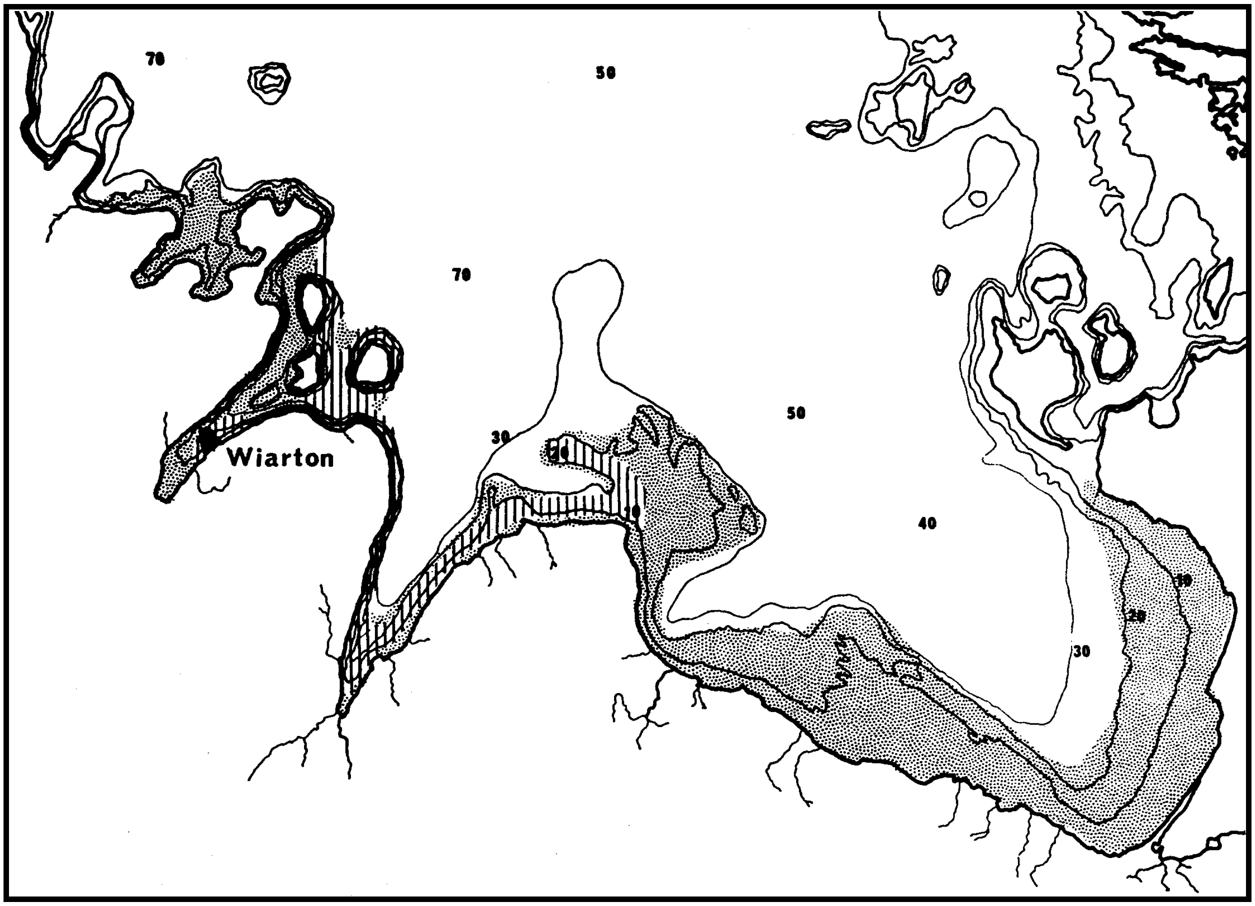

Figure 6. Cucin & Regier's (1966) map of southern Georgian Bay, indicating "*inferred distribution of [lake] whitefish tagged and released at Wiarton pound net in spring 1956, from 4 months after tagging throughout the remainder of their life span. Vertical bars, main concentrations; stippled areas, lower densities.*" The "*main concentration*" of recaptures from fish tagged at this site, extends as a continuum from Hay Island to Wiarton to Big Bay to Owen Sound to Vail's Point to Cape Rich, with "*lower densities*" of recaptures from north of Cape Croker, around southwestern Georgian Bay, and all the way around Nottawasaga Bay in southeastern Georgian Bay.

4. Data scales, parsimony and model fits

There was substantial discussion at the 14 October 2003 meeting of the Biotechnical Committee about the relationship between

1. the spatial scales at which both parties organized their data sets (relative to hypothesized or assumed populations),
2. the number of parameters in the mathematical models used to analyse the pooled data sets, and
3. the measure of how well the mathematical models fit the observed data sets

A few general comments on these relationships are required to identify some key uncertainties in how the parties interpret their analyses.

First, as discussed at length in the previous section, the Saugeen Ojibway analysed the data for hypothesized lake whitefish populations of Lake Huron at three spatial scales: regional, basin-wide, and lake-wide. The Saugeen Ojibway age-structured population models showed that the models consistently gave the best fits to the observed data at the broader spatial scales (lake-wide better than basin-wide better than regional). In our report (Crawford et al. 2003), we interpreted this progression of model fits as supporting the hypothesis that lake whitefish population dynamics are most appropriately understood and predicted at the broader spatial scales, as opposed to the more regional scales (including OMNR QMAs). The OMNR challenged this interpretation, suggesting that model fits would be expected to improve with spatial scale due to a 'pooling effect' of artificially bringing various populations together and thus 'smoothing out the noise' or variance in the signals. We considered this argument and agreed that this would be the case if the 'pooled populations' exhibited data characteristics that were generally similar. However, we would expect that if the hypothesized populations exhibited generally different data characteristics, then the variance of the 'pooled' data set would actually increase with 'pooling,' and this would result in worse model fits for the 'pooled' data compared to the separate hypothesized population data sets. Having said this, we accept the OMNR's identification of model fit comparisons as a key uncertainty in our evaluation of model performance across spatial scales. How do we know if the model is overparametrized? The Saugeen Ojibway are confidant that we can develop effective measures to control for data scale, and we are prepared to work with the OMNR on the research required to implement these measures of model performance.

Second, with respect to model complexity (i.e. number of parameters in the models), we have already identified this as a key uncertainty in the comparison of Saugeen Ojibway and OMNR models of lake whitefish population dynamics:

> "*It is important to realize that in the 2001 Nawash TAC Report (Crawford et al. 2001) we also explicitly stated our basic philosophy of progressing from robust, simple mathematical models of the Lake Huron whitefish fisheries (i.e. models that provide general evaluations in which we have a high degree of confidence) to more detailed, complex mathematical models (i.e. models that provide more specific evaluations at a greater risk of being untrue). As a general rule, simple models are more robust than complex models of the same phenomenon (Bellman 1957, Ludwig & Walters 1985, Hilborn & Walters 1992). This trade-off between model complexity and model confidence has often been ignored by analysts who have exhibited a tendency to jump right into complex models with a high number of parameters that must be fit to the observed data. Yodzis & Innes (1992) referred to this tendency as the "plague of parameters" or "overparameterization," and they strongly suggested that mathematical models should*

> *be developed in a progression from simple to complex, with specific parameters brought into the modeling process to reflect key uncertainties addressed by competing ecological hypotheses of cause-and-effect.*" (Crawford et al. 2003, p.14)

The fact that the Saugeen Ojibway intentionally chose to begin with simple models (e.g. 3-5 parameters) before proceeding with moderately complex model (8-12 parameters) reflects our need to make sure that we do not jump to a model that necessarily gives better fits, at the risk of getting model fits that are not ecologically realistic. We have concerns that the OMNR may have jumped to a readily available mathematical model (developed by the Michigan DNR and CORA) that incorporates an excess of parameters that could obscure or miss the underlying ecological process we wish to understand.

The basic point here is that while model fits are a necessary tool in evaluating model performance, a good model fit to the observed data does not mean the model is 'right' or that we should accept a particular model at face value. It is extremely important to remember that models (hypotheses) are only as good as their predictions. Good models will generate predictions about future consequences of management actions that will be verified by empirical data collected from that system. This is the fundamental link between the hypotheses discussed in Section 2, and the use of mathematical models discussed in this section.

With these caveats in mind, it is important to compare and contrast the ADMB mathematical models used by the Saugeen Ojibway and the OMNR in their 2003 TAC analyses. One thing we really liked about the OMNR model is their use of empirical data, recognizing and using patterns in the data (e.g. mortality estimated by using Pauly's equations with empirical data; incorporating selectivity in their effects of harvesting). However, what we really don't have in the OMNR model is an analysis on how to make a decision; no hypotheses; no attempt to explicitly distinguish between density-dependence and density-independence (e.g. gamma function in recruitment). In some senses the OMNR does much more than the Saugeen Ojibway model, but in some senses it has not done as much.

Perhaps most importantly, there is very little theoretical basis for the manner in which the OMNR took the results of their mathematical population modelling and applied it to their decision-making with respect to TAC recommendations. OMNR proceeds from objective and quantitative estimates of hypothesized population parameters to a 'decision-making protocol' that is extremely subjective and qualitative. Effectively, the vast majority of value in the OMNR's population modelling process is needlessly lost in this transition, while several sources of bias and misinterpretation are brought in to the process. This specific concern is addressed in more detail in the next section.

5. Relative change versus predicted consequences of TACs

In the 2003 OMNR TAC Report (Mohr et al. 2003), the ultimate synthesis of information is presented as the "Lake whitefish stock status evaluation protocols." Consider the example of the protocol for OMNR QMA 4-4 presented in this report as Table 2. There are numerous problems with the specific application of the OMNR protocol in this case:

1. The vague terminology leads to the need for very arbitrary decision-making about variables like CUE (what distinguishes "increase" from "no trend" from "decline"; how significant were these changes) and Predicted Recruitment (how do you know when a year class is truly "strong" or "average" or "weak") and Mean Age of Catch (how do you discriminate between "significant change" and "minor change" and "no significant change" without any statistical tests).
2. Choosing between multiple occurrences of identical conditions. For example, Mean Age at Catch has two cells for "No Significant Change" and two cells for "Minor Change." A more extreme example would be Growth Rate which has "No Significant Change" in three different cells, and "Significant Change" in two different cells. How could an analyst possibly pick between them in any meaningful and unbiased manner?
3. Conditions which do not make ecological sense. For example, in Growth Rate both of the possible "Significant Changes" are interpreted as indicators of "increased risk" to the population, despite the fact that an increased growth rate could indicate a broadening of forage base, and a decreased growth rate could indicate an increase in population abundance (e.g. density-dependence compensation in growth).
4. In one of the examples where some text description is provided with the protocol, the QMA 4-4 protocol evaluation indicates:

   > "*NOTES: Total annual mortality was quite different from both models. 38% from SCAA and 65% from Cohort Analysis. The average of the two was used to select the appropriate category in the whitefish protocol.*"

   If the two mathematical models used by OMNR were giving mortality estimates that were as drastically different as this, then the analysts should have been exploring the reasons why. Splitting the difference is not acceptable in this case.
5. Even using the shaded cells as provided by the OMNR (I was tempted to reshade cells according to some different interpretations, but I resisted), we see that the OMNR evaluation of "Health/Sustainability" (whatever that is) for QMA 4-4 is as follows:

   1 (Real Good) = 0 cells
   2.(Good) = 4 cells
   3 (Neutral) = 3 cells
   4 (Bad) = 1 cell
   5 (Real Bad) = 0 cells

   Thus, by the OMNR's own ranking scheme, the overall "Health/Sustainability" for the lake whitefish "population" in QMA 4-4 would be closer to "Good" than anything else. Yet, when you check the OMNR 2003 TAC recommendation it clearly states "NO CHANGE IN QUOTA IS RECOMMENDED FOR 2003." This recommendation is not even consistent with the OMNR's own protocol.

We could consider all of the various other “lake whitefish stock status evaluation protocols” presented in the 2003 OMNR TAC Report (Mohr et al. 2003), but we would typically just see more of the same kinds of arbitrary and subjective decision-making. However, there are two other observations of significance.

First, it is important to note that for the remainder of the OMNR QMAs surrounding the Saugeen Peninsula (4-7, 5-3, 5-6, and 5-8W) the OMNR examined at most 2 of the 8 variables (CUE, Predicted Recruitment) in their “lake whitefish stock status evaluation protocols.” For reasons, known only to them, they did not attempt to characterize the remaining non-model factors in the protocol (e.g. Age Structure of Catch, Mean Age of Catch, Growth Rate). According to the OMNR system, such a lack of information is necessarily interpreted as supporting the conclusion that “NO CHANGE IN QUOTA IS RECOMMENDED FOR 2003."

Second, it is also important to clearly indicate how illogical the OMNR application of its “lake whitefish stock status evaluation protocols” can be. Consider the example of the protocols for OMNR QMA 5-8W and 5-8E presented in this report as Tables 3 and 4, respectively. Recall that, by the OMNR’s own statement “*the available data supports the contention that QMA 5-8 contains a single lake whitefish stock.*”(Mohr et al. 2003). Yet for reasons known only to the OMNR, they decided to evaluate data and make TAC recommendations on the artificially subdivided QMAs on a separate basis. The result is truly insightful. The “lake whitefish stock status evaluation protocol” for QMA 5-8W (inside Fishing Agreement waters) shows only 1 of 8 factors was considered (i.e. CUE) which is necessarily interpreted as supporting the conclusion that “NO CHANGE IN QUOTA IS RECOMMENDED FOR 2003." In contrast, the “lake whitefish stock status evaluation protocol” for QMA 5-8E (outside the Fishing Agreement waters?) shows all 8 of 8 factors were considered, interpreted as supporting the conclusion that “AN INCREASE OF 10% IN QUOTA IS RECOMMENDED FOR 2003." This is simply wrong, even by the OMNR’s methods.

So where does this discussion of the 2003 LHMU lake whitefish stock status evaluation protocols leave us?

I believe there are two important conclusions.

First, there is more than sufficient evidence for the OMNR to finally abandon its LHMU lake whitefish stock status evaluation protocol and the “relative decision-making system” that goes with it. Plain and simple.

Second, we should return to the basic strengths associated with modelling our ecological hypotheses associated with lake whitefish population dynamics in Lake Huron. This was the approach that we took in the 2003 Saugeen Ojibway TAC Report when we predicted the consequences of alternative management actions (TACs) over hypothesized distributions of lake whitefish populations in Lake Huron (Crawford et al. 2003). Each of these decision tables showed a range of TAC options in the first column, followed by the consequent (predicted) population biomass-at-age for the population if that TAC had been taken in 2003:

> “*The projected data for the Main Basin hypotheses are summarized (without the age-structured information) in [Table 5 this report]. Considering the 4yr_Huron_A hypothesis, it can be seen that the model predicts that a lakewide harvest of 3.1 million round kilograms would extract an amount of biomass equivalent to the predicted production of new biomass by the population (= surplus production). This scenario is repeated for the*

Main Basin hypothesis (surplus production=1.8 million round kilograms), and for the Main Basin South+East region (surplus production=1.5 million round kilograms)." (Crawford et al. 2003)

We are confident in the ability of the Saugeen Ojibway model to reliably capture the general trends of the observed data at these different spatial scales of hypothesized population distribution.

At this point in the report, we thought it would be useful to undertake a comparison between the Saugeen Ojibway model with the more complex model that was employed by the OMNR solely for the OMNR QMAs. To this end, we closely examined the ADMB code provided to us by the OMNR, formatted our lakewide data to match the file specifications for the OMNR model and fit the observed data. The results were very interesting.

First, the observed versus predicted harvest (rkg) of lakewide harvest using OMNR ADMB model with Nawash data (Figure 7) gave very good model fits. This is very similar to the results obtained by the OMNR when using their model with their QMA data, as expected.

Second, the predicted biomass (rkg) of the hypothesized lakewide population of lake whitefish using OMNR ADMB model with Nawash data (Figure 8) shows two distinct periods of population abundance. The period 1979-1991 is characterized by predicted biomass levels between 5,000,000 and 15,000,000 rkg, while the period 1992-2003 is characterized by much higher predicted biomass levels between 15,000,000 and 30,000,000 rkg. This general observation is consistent with the 2001 and 2003 Saugeen Ojibway TAC Reports (Crawford et al. 2001, 2003).

Third, and most important is the predicted consequences of alternate TACs for the hypothesized population, as shown in Table 6. If we take a 24-year average biomass of approximately 17,000,000 rkg, find the projected 2003 TAC that would result in survival of this biomass, it can be seen that the threshold TAC predicted by the OMNR model for the lakewide population hypothesis is 3,000,000 rkg (highlighted row) - almost exactly the same TAC that the Saugeen Ojibway predicted as representing the threshold for surplus production in their lakewide model (Crawford et al. 2003).

This convergence between the Saugeen Ojibway and OMNR models lends support to the interpretations that:

1. The hypothesized lakewide population of lake whitefish in Lake Huron is still at high levels of abundance, compared to 24-year average historic levels.
2. The current rates of harvest are low, relative to hypothesized lakewide population production, and
3. The hypothesized lakewide population of lake whitefish in Lake Huron can sustain a 2003 harvest of approximately 3,000,000 rkg.

As a final note in this subsection, we found it peculiar that the OMNR did not undertake the kind of predictions of TAC consequences as we presented in the 2003 Saugeen Ojibway TAC Report and in this report. Examination of their model code reveals that their ADMB model generates all of the required population parameter estimates to be incorporated in a simple spreadsheet for calculation. In fact, the American modellers from whom the OMNR recieved their code do exactly these kinds of calculations to construct the kind of TAC decision tables that are presented in this report.

6. Allocation of 2003 TACs

There is one simple yet fundamental issue that must be identified as it relates to TAC determination for lake whitefish fisheries in Lake Huron generally, and the Saugeen Ojibway fisheries in particular. The biologists involved in the interpretation of the Lake Huron fisheries data and analyses should be focused exclusively on the ecological aspects of the supporting populations, and the predicted consequences of alternate harvest strategies. Allocation of TACs is a matter for political negotiation, and it should not have any bearing on how the hypotheses are developed, how the analyses are performed, or how the results of modelling efforts are interpreted. In the case of the Saugeen Ojibway/Canada/Ontario Fishing Agreement, it is the responsibility of the Biotechnical Committee to describe the dynamics of the hypothesized populations supporting the harvests, and to generate the best possible predictions about the most probable effects of harvesting options.

Table 2. LHMU lake whitefish stock status evaluation protocol for Year 2002 for OMNR QMA 4-4. (Mohr et al. 2003)

Parameter	Status of Stock				
	← -		Risk		+ →
		+	Health/Sustainability	-	
	1	2	3	4	5
CUE	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	3 or more strong year classes predicted	1 or 2 strong year classes predicted	Average or below average year classes predicted	1 or 2 weak year classes predicted	3 or more 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 $\leq$ 8 year classes	Multi-aged with $\leq$ 6 year classes
Mean Age of Catch	No Significant Change	No Significant Change	Minor Change	Minor Change	Significant Change
Total Annual Mortality	<0.45	0.45 to 0.6	0.6 to 0.65	0.65 to 0.70	>0.70
Modelled Abundance Estimate 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
Growth rate	No significant change	No significant change	No significant change	Significant change	Significant change
Ratio of Harvest:Exploitable Biomass Estimate	<20%	20% to 30%	30% to 40%	40% to 50%	>50%

NOTES: Total annual mortality was quite different from both models. 38% from SCAA and 65% from Cohort Analysis. The average of the two was used to select the appropriate category in the whitefish protocol.

LHMU lake whitefish stock status evaluation protocolYear___2002 QMA____58-W__

Parameter	Status of Stock				
	← - Risk + →				
	+ Health/Sustainability -				
	1	2	3	4	5
CUE	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	3 or more strong year classes predicted	1 or 2 strong year classes predicted	Average or below average year classes predicted	1 or 2 weak year classes predicted	3 or more 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	No Significant Change	No Significant Change	Minor Change	Minor Change	Significant Change
Total Annual Mortality	<0.45	0.45 to 0.6	0.6 to 0.65	0.65 to 0.70	>0.70
Modelled Abundance Estimate 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
Growth rate	No significant change	No significant change	No significant change	Significant change	Significant change
Ratio of Harvest:Exploitable Biomass Estimate	<20%	20% to 30%	30% to 40%	40% to 50%	>50%

NOTES:

Further analysis of available data is recommended

LHMU lake whitefish stock status evaluation protocolYear___2002__   QMA__5-8E__

Parameter	Status of Stock				
	← - Risk + →				
	+ Health/Sustainability -				
	1	2	3	4	5
CUE	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	3 or more strong year classes predicted	1 or 2 strong year classes predicted	Average or below average year classes predicted	1 or 2 weak year classes predicted	3 or more 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	No Significant Change	No Significant Change	Minor Change	Minor Change	Significant Change
Total Annual Mortality	<0.45	0.45 to 0.6	0.6 to 0.65	0.65 to 0.70	>0.70
Modelled Abundance Estimate 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
Growth rate	No significant change	No significant change	No significant change	Significant change	Significant change
Ratio of Harvest:Exploitable Biomass Estimate	<20%	20% to 30%	30% to 40%	40% to 50%	>50%

NOTES:

Table 5. Summary of projected biomass (rkg) consequences of alternative 2003 TAC levels, for hypothesized lake whitefish populations described by ADMB models 4yr_Huron_A (Lake Huron, Canadian waters), 4yr_MB_A (Main Basin, Canadian waters) and 4yr_MB_SE (Main Basin South+East, Canadian waters). Baseline biomass values in the first data line represent 2002 model conditions with which to compare alternative management actions. (Source: Crawford et al. 2003).

	4yr_Huron_A			4yr_MB_A			4yr_MBSE_A		
TAC (rkg)	135,335,450	Δ	%	4,665,831	Δ	%	3,341,488	Δ	%
0	138,473,126	3,137,676	2.32	6,554,911	1,889,081	40.5	4,917,690	1,576,202	47.2
500,000	137,973,126	2,637,676	1.95	6,054,911	1,389,081	29.8	4,417,690	1,076,202	32.2
1,000,000	137,473,126	2,137,676	1.58	5,554,911	889,081	19.1	3,917,690	576,202	17.2
1,500,000	136,973,126	1,637,676	1.21	5,054,911	389,081	8.3	3,417,690	76,202	2.3
1,600,000				4,954,911	289,081	6.20	3,317,690	-23,798	-0.71
1,700,000				4,854,911	189,081	4.05	3,217,690	-123,798	-3.70
1,800,000				4,754,911	89,081	1.91	3,117,690	-223,798	-6.70
1,900,000				4,654,911	-10,919	-0.23	3,017,690	-323,798	-9.69
2,000,000	136,473,126	1,137,676	0.84	4,554,911	-110,919	-2.4	2,917,690	-423,798	-12.7
2,500,000	135,973,126	637,676	0.47	4,054,911	-610,919	-13.1	2,417,690	-923,798	-27.6
3,000,000	135,473,126	137,676	0.10	3,554,915	-1,110,916	-23.8	1,917,690	-1,423,798	-42.6
3,100,000	135,373,126	37,676	0.03						
3,200,000	135,273,126	-62,324	-0.05						
3,300,000	135,173,126	-162,324	-0.12						
3,400,000	135,073,126	-262,324	-0.19						
3,500,000	134,973,126	-362,324	-0.27						
4,000,000	134,473,126	-862,324	-0.64						

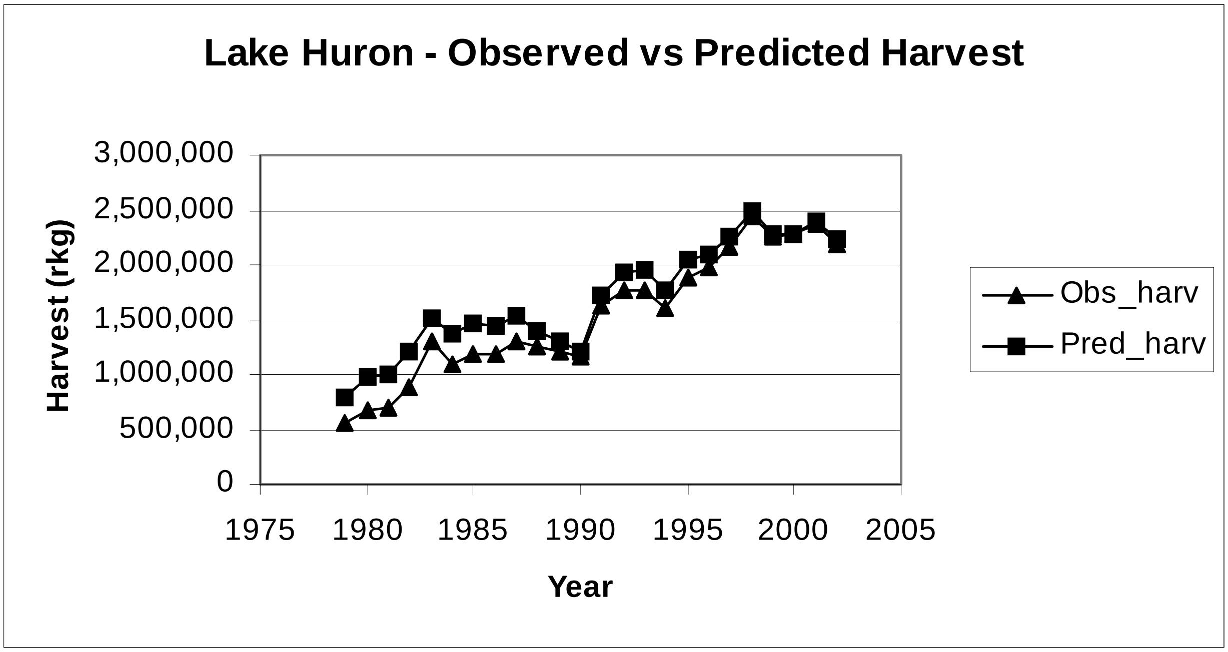

Figure 7. Observed versus predicted harvest (rkg) of lakewide harvest of lake whitefish using OMNR ADMB model with Nawash data.

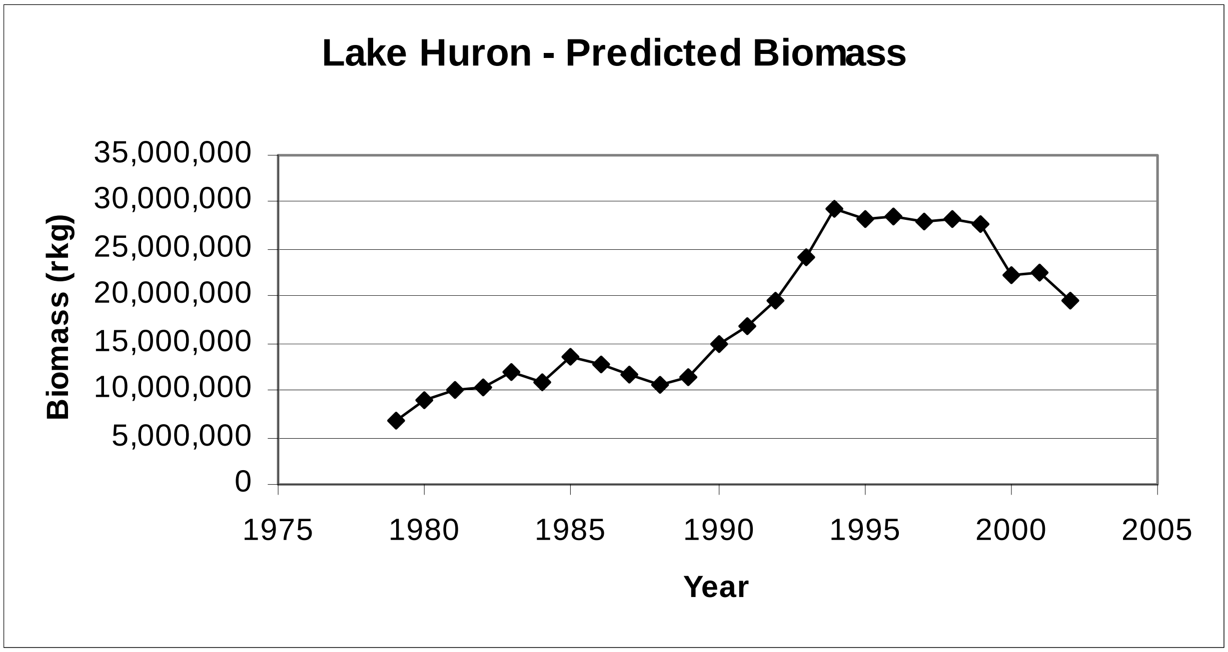

Figure 8. Predicted biomass (rkg) of the hypothesized lakewide population of lake whitefish using OMNR ADMB model with Nawash data.

Table 6. Nawash run of OMNR ADMB model using lakewide data for Lake Huron (Canadian waters).

TAC (rkg)	Year	Biomass (rkg)									
		3	4	5	6	7	8	9	10+	Total	Average
	1979	1,065,232	1,745,391	1,404,603	904,326	709,107	245,095	258,056	505,494	6,837,305	
	1980	3,843,950	790,043	1,283,067	1,045,387	677,630	570,358	176,384	633,776	9,020,595	
	1981	2,561,483	3,317,097	707,941	1,154,078	774,739	518,709	437,562	489,376	9,960,985	
	1982	2,701,767	2,426,237	2,548,183	423,372	765,333	477,335	363,086	605,430	10,310,741	
	1983	3,892,556	2,239,978	1,876,802	1,894,023	328,282	729,753	358,282	640,169	11,959,844	
	1984	3,195,093	3,472,248	1,508,118	1,097,389	902,318	153,122	187,561	348,770	10,864,619	
	1985	5,695,438	2,625,144	2,585,544	1,066,444	685,823	562,169	81,065	345,672	13,647,299	
	1986	3,074,332	4,834,159	1,807,701	1,433,310	560,564	394,377	305,976	211,667	12,622,086	
	1987	2,300,008	2,526,435	3,544,939	1,176,885	984,683	420,168	293,157	456,191	11,702,465	
	1988	2,240,729	1,908,978	1,882,629	2,365,688	783,468	658,454	288,687	424,042	10,552,676	
	1989	4,039,621	2,047,343	1,448,194	1,295,986	1,440,389	456,597	352,631	371,051	11,451,813	
	1990	6,566,635	3,662,912	1,518,293	877,025	739,499	806,326	253,552	382,108	14,806,349	11,144,731
	1991	5,431,782	5,439,099	2,785,885	1,074,332	611,690	533,770	566,380	416,665	16,859,603	
	1992	6,783,064	5,049,703	4,176,775	1,758,074	627,164	353,784	285,659	520,139	19,554,361	
	1993	9,817,063	5,895,386	3,824,212	2,529,844	987,799	338,462	194,471	428,501	24,015,738	
	1994	11,265,813	8,174,781	4,746,131	2,453,066	1,513,711	572,129	196,681	333,358	29,255,670	
	1995	6,503,685	9,187,211	6,138,209	3,157,643	1,534,844	954,253	343,049	304,442	28,123,336	
	1996	6,846,644	6,278,561	7,240,898	4,157,711	1,906,190	936,018	572,029	420,523	28,358,574	
	1997	6,993,467	6,447,669	4,937,341	4,730,621	2,440,791	1,140,171	553,293	586,166	27,829,519	
	1998	7,922,970	5,569,640	5,107,808	3,360,119	3,077,392	1,633,198	751,676	721,880	28,144,684	
	1999	4,166,345	7,904,041	5,429,589	4,003,120	2,280,695	1,943,973	1,038,843	1,031,522	27,798,129	
	2000	3,336,379	3,814,819	6,515,588	3,377,988	2,054,927	1,076,836	940,536	1,139,195	22,256,269	
	2001	7,071,295	3,008,500	3,163,835	4,574,530	1,931,440	1,092,146	595,719	1,203,638	22,641,103	
	2002	2,364,400	6,745,455	2,587,922	2,262,599	2,656,204	1,080,525	643,434	1,146,966	19,487,504	24,527,041
2003 TAC											17,835,886
0	2003	4,943,938	2,173,798	5,531,311	1,870,381	1,562,683	1,773,971	806,409	1,377,497	20,039,990	
500000	2003	4,943,234	2,170,164	5,511,656	1,805,782	1,464,699	1,669,175	702,096	1,273,185	19,539,990	

1000000	2003	4,942,529	2,166,529	5,492,000	1,741,183	1,366,714	1,564,379	597,784	1,168,872	19,039,990	
1500000	2003	4,941,825	2,162,894	5,472,344	1,676,584	1,268,730	1,459,582	493,471	1,064,559	18,539,990	
2000000	2003	4,941,120	2,159,260	5,452,689	1,611,985	1,170,745	1,354,786	389,158	960,247	18,039,990	
2500000	2003	4,940,416	2,155,625	5,433,033	1,547,386	1,072,761	1,249,990	284,846	855,934	17,539,990	
3000000	2003	4,939,711	2,151,990	5,413,378	1,482,787	974,776	1,145,193	180,533	751,621	17,039,990	
3500000	2003	4,939,007	2,148,355	5,393,722	1,418,188	876,791	1,040,397	76,220	647,308	16,539,990	
4000000	2003	4,938,303	2,144,721	5,374,067	1,353,589	778,807	935,601	(28,093)	542,996	16,039,990	
4500000	2003	4,937,598	2,141,086	5,354,411	1,288,990	680,822	830,805	(132,405)	438,683	15,539,990	
5000000	2003	4,936,894	2,137,451	5,334,755	1,224,391	582,838	726,008	(236,718)	334,370	15,039,990	
5500000	2003	4,936,189	2,133,817	5,315,100	1,159,793	484,853	621,212	(341,031)	230,058	14,539,990	
6000000	2003	4,935,485	2,130,182	5,295,444	1,095,194	386,869	516,416	(445,343)	125,745	14,039,990	
6500000	2003	4,934,780	2,126,547	5,275,789	1,030,595	288,884	411,619	(549,656)	21,432	13,539,990	