2006 Saugeen Ojibway Nations commercial harvest TACs for lake whitefish (*Coregonus clupeaformis*) in Lake Huron

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1.0 Introduction

This is the third technical report prepared by Chippewas of Nawash fisheries biologists and colleagues, regarding the biological condition of lake whitefish (*Coregonus clupeaformis*) populations supporting the Saugeen Ojibway Nations fisheries harvests. The first report (Crawford, Muir & McCann 2001) focused on key ecological uncertainties regarding (1) the discrimination of lake whitefish population(s) in Lake Huron, (2) the dynamics of the commercial fishing fleet, and (3) a simple model designed to assess regions of risk in the surplus production space defined by the commercial fishery data. The second report (Crawford, McCann & Muir 2003) introduced the concepts of Decision Analysis-Adaptive Management (DAAM) and extended the biological analyses to include an age-structured model with results presented as a simple decision analysis.

The goal of this technical report is to build on previous technical evaluations by Nawash fisheries biologists to provide Nawash Council with the best available information with which to consider options for 2006 Total Allowable Catches (TACs) for their commercial fisheries. In order to achieve this goal, we identified four specific objectives:

1. Characterize lake whitefish populations in Lake Huron (including recent results of collaborative international mark-recapture program);
2. Describe general trends in commercial effort, harvest and CPUE (catch per unit effort);
3. Compile basic information on trends in biological samples drawn from the commercial harvest; and
4. Present results of recently developed surplus production models and associated risk assessments;
5. Identify key uncertainties related to the dynamics of the lake whitefish populations and the fisheries that they support.

2. Lake whitefish populations in Lake Huron

2.1 Characterizing lake whitefish populations

Population distribution remains a key uncertainty in the ecology of Lake Huron lake whitefish. In a review of published definitions of biological populations, Waples and Gaggiotti (2006) identify two paradigms in how populations are defined:

> "*Ecological Paradigm*: a group of individuals of the same species that co-occur in space and time and have an opportunity to interact with each other.
>
> *Evolutionary Paradigm*: a group of individuals of the same species living in close enough proximity that any member of the group can potentially mate with any other member."

Since we are identifying hypothesized populations for the purpose of managing the sustainability and productivity of a commercially harvested species, the definition we selected is consistent with the evolutionary paradigm. Our definition of a population was proposed by (Futuyma 1998): A group of conspecific organisms that occupy a more or less well-defined geographical region and exhibit reproductive continuity from generation to generation (Futuyma 1998; Waples and Gaggiotti 2006). An holistic (multiple discrimination techniques) approach (Begg and Waldman 1999) was most appropriate for identifying hypothesized whitefish population distributions. The first reason is that the accuracy of any single technique is unknown (Waldman et al. 1997); therefore, considering several techniques allows uncertainty to be expressed as hypotheses. The second reason is that different techniques vary with respect to the degree of spatial resolution they provide for establishing population boundaries (Begg and Waldman 1999; Martien and Taylor 2003). For example, molecular analyses and mark-recapture studies are useful for providing broad-scale patterns of population structure, but may fail to describe locations for hypothesized population boundaries for continuously distributed species (Begg, Cappo et al. 1997; Westlake and O'Corry-Crowe 2002; Martien and Taylor 2003). Meristic and morphometric techniques can provide greater resolution, but may be difficult to interpret due to the combined influence of genetics and environment (Barlow 1961; Casselman, Collins et al. 1981). The third reason is that conflicting evidence about population distribution obtained from different techniques can be represented as competing hypotheses. This approach avoids a common management scenario, where discrepancies among techniques are addressed by over splitting stocks as a precautionary measure (Casselman, Collins et al. 1981; Begg and Waldman 1999). Begg and Waldman (1999) also offer examples where apparent discrepancies in stock identification were subsequently remedied by integrating results from several techniques to infer population structure. This approach is cautioned as well because it implies population structure is certain when additional evidence favours a specific hypothesis. In this case, uncertainty should still be embraced by recognizing the magnitude of evidence in support of each hypothesis in the form of probabilities, allowing all plausible stock identities to be considered quantitatively.

Hypothesized whitefish populations are characterized by their spatial distribution during two temporal periods: spawning and non-spawning. Figure 1 describes a generalized framework for categorizing the spawning and non-spawning distributions of fishes that dwell in lakes throughout their life histories. This approach allows us to characterize both spawning population distribution and the potential contribution of mixed populations to commercial harvests during the non-spawning period.

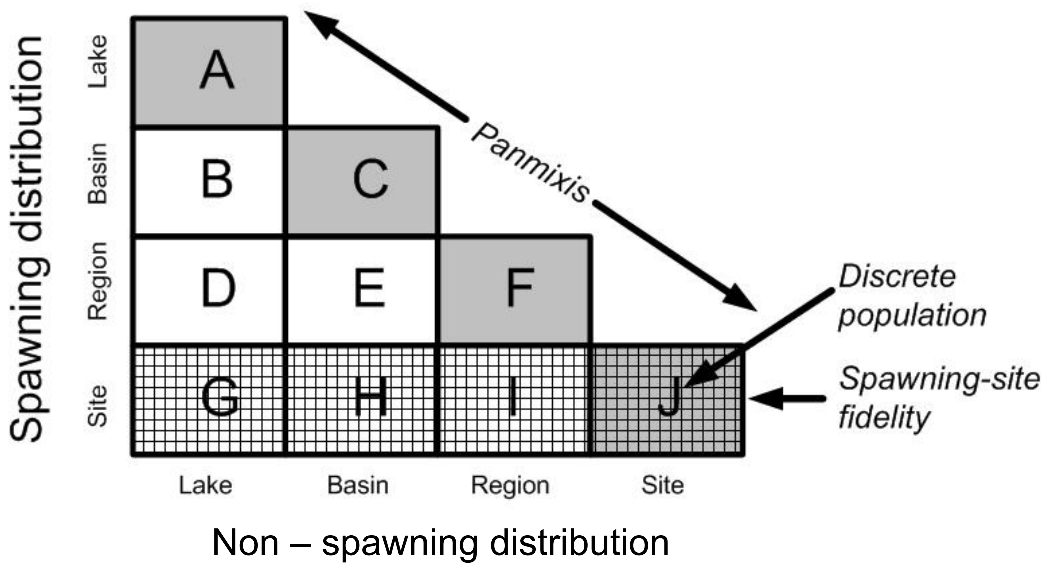

Figure 1. A generalized illustration of the framework used for identifying and categorizing hypothesized population distributions of fish species the dwell in lakes for their entire life history.

2.1.1 Lake white spawning areas

Lake whitefish spawning grounds are generally distributed throughout the North Channel and the Main Basin of Lake Huron and Georgian Bay. Crawford et al. (2001) compiled reported or known spawning locations of lake whitefish reported by Goodyear et al. (1982) with reports from additional sources to generate an updated map of spawning locations (Figure 2). Goodyear et al. (1982) cautioned that the absence of reported spawning areas does not necessarily indicate natural gaps in the spatial distribution of spawning areas. Several areas, including the Southern shore of Manitoulin Island and the Southern shore of Main Basin require additional evidence to verify whether lake whitefish spawning is occurring in these areas. There are indications of lake whitefish spawning activity along the Southern shore of Manitoulin Island but documented reports of this activity are lacking (Loftus 1980). The Southern shore of the Main Basin also lacks reports of lake whitefish spawning; however, this is consistent with evidence that lake whitefish inhabiting this area migrate to Saginaw Bay to spawn due to an hypothesized absence of suitable spawning habitat (Walker 1992).

Figure 2. Reported lake whitefish spawning locations within Lake Huron taken from Goodyear et al. (1982) and additional sources as compiled by Crawford et al. (2001).

2.1.2 Population discrimination studies

We identified plausible hypotheses about the distribution of lake whitefish populations based on a review of stock assessment literature. The most plausible hypotheses of whitefish population distributions located within the traditional waters of the Saugeen Ojibway Nations are summarized in table 1. This summary should not be viewed as a comprehensive list of all patterns of whitefish movement, but is intended to identify the major patterns of population distribution. Other hypotheses to consider include the possibility of long distance migrations by a small number of individuals and the magnitude of gene flow among hypothesized populations Figures 3 – 10 are stylized illustrations of hypothesized populations in Main Basin, Georgian Bay and North Channel. Note that spatial boundaries are highly uncertain and are only intended to provide a generalized spatial characterization of plausible hypothesized population distributions.

Notheastern Main Basin, Georgian Bay and North Channel

Budd (1957) identified three predominant movement patterns of lake whitefish tagged at South Bay between 1949 and 1953. First, Budd (1957) found that half of the recaptures occurring 1 and 2 years following tagging were caught in South Bay, indicating that either many individuals remain in South Bay year round or return annually. Second, the majority of individuals recaptured outside of South Bay were captured along two routes: (i) south along the western shore of the Bruce Peninsula; and, (ii) east through Owen Channel into Georgian Bay. We suggest that these observations support two hypothesized patterns of population distribution, these are: (i) populations that exhibit homing behaviour to major spawning grounds (e.g. South Bay, Britt and the Fishing Islands), with regional mixing of populations during non-spawning periods; and (ii) a population that exhibits a regional spawning distribution encompassing South Bay, western Bruce Peninsula, eastern Manitoulin Island and northeastern Georgian Bay. Third, a small number of individuals traveled extensive distances before recapture, including Grand Bend, Ontario, Oscoda, Michigan, Parry Sound, Ontario, Thunder Beach, Ontario and west of Little Current, Ontario. Cucin and Regier (1966) inferred that lake whitefish in southern Georgian Bay represented a single population from a mark-recapture study. Lake whitefish tagged near Burnt Island were recaptured predominantly along the southern shore of Manitoulin Island with the majority of recaptures corresponding to where they were first tagged (Spangler 1974). Casselman et al (1981) identified several plausible spatial distributions of lake whitefish sampled at 11 locations using mark-recapture and population dynamic studies, morphometric, meristic, osseometrics and genetic analyses. Casselman et al. (1981) recognized varying degrees of discreteness among sampling locations, which we have formally recognized as alternative hypotheses. Tag recapture data suggested that Inner South Bay and Outer South Bay, Burnt Island, Blind River and southern Georgian Bay are discrete populations. However, other techniques indicated that Inner and Outer South Bay, Burnt Island, Blind River and Southampton exhibited varying degrees of discreteness. Uncertainty regarding spatial boundaries between populations was also illustrated between whitefish sampled in northeastern North Channel, and especially between Southampton and Goderich (Casselman et al. 1981).

Western Main Basin

Hill (1982) examined differences in growth rate and genetic discreteness of lake whitefish between Saginaw Bay and Hammond Bay. Differences in growth rates between Saginaw Bay and Hammond Bay samples were identified; however, no genetic differences among these locations were found. Hill (1982) suggested that Saginaw Bay and Hammond Bay lake whitefish may be discrete stocks that experience an unknown degree of gene flow via currents that may transport larval fish away from their natal sites. We further suggest that a single Saginaw Bay – Hammond Bay population be considered a plausible hypothesis based on the strength of the genetic evidence. A mark-recapture study conducted by Walker (1992) concluded that Saginaw Bay whitefish were not isolated from whitefish inhabiting Ontario waters of southern main basin. Walker (1992) also identified two uncertainties about the distribution and migratory behaviour of lake whitefish, these are: (i) the degree of mixing among other hypothesized populations, due to the recovery of one fish near South Bay, Manitoulin Island. This finding conflicts with the contention of other authors that lake whitefish do not migrate great distances (Cucin and Regier 1966; Casselman et al. 1981); and, (ii) the extent of northward movement from Saginaw Bay along western Main Basin, as evidence is limited to that provided by Hill (1982). These uncertainties are thus recognized as alternative hypotheses.

Table 1. Hypothesized lake whitefish populations found in the Saugeen Ojibway Nations Traditional Waters of Lake Huron and Georgian Bay.

Population distribution categories (see fig. 2) Spawning / non-spawning	Hypoth. #	Spawning distribution	Non- spawning distribution
A. Panmixis			
B. Basin / Lake			
C. Basin / Basin	1	Main basin – N. channel	Main basin – N. channel
	2	Main basin	Main basin – N. channel
	3	Main basin	Main basin
	4	Georgian Bay	Georgian Bay
D. Region / Lake			
E. Regional / Basin	5	Eastern main basin – Manitoulin Island	Main Basin – N. Channel
	6	Eastern Main Basin	Main Basin – N. Channel
	7	Eastern Main Basin	Main Basin
	8	Western Bruce Peninsula	Main Basin – N. Channel
	9	Western Bruce Peninsula	Main Basin
	10	Northeastern Main Basin	Main Basin – N. Channel
	11	Northeastern Main Basin	Main Basin
	12	Southern Georgian Bay	Georgian Bay
F. Region / Region	13	Eastern main basin – Maintoulin Island	Eastern main basin – Maintoulin Island
	14	Eastern main basin	Eastern main basin
	15	Western Bruce Peninsula	Western Bruce Peninsula
	16	Northeastern main basin	Northeastern main basin
	17	Southern Georgian Bay	Southern Georgian Bay
G. Site / Lake			
H. Site / Basin	18	Fishing Islands	Main Basin – N. Channel
	19	Fishing Islands	Main Basin
	20	Stokes' Bay	Main Basin – N. Channel
	21	Stokes' Bay	Main Basin
	22	Colpoy's Bay	Georgian Bay
	23	Nottawasaga Bay	Georgian Bay

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Population distribution categories (see fig. 2) Spawning / non-spawning	Hypoth. #	Spawning distribution	Non- spawning distribution
I. Site / Region	24	Fishing Islands	Eastern main basin – Maintoulin Island
	25	Fishing Islands	Eastern main basin
	26	Fishing Islands	Western Bruce Peninsula
	27	Fishing Islands	Northeastern main basin
	28	Stokes Bay	Eastern main basin – Maintoulin Island
	29	Stokes Bay	Eastern main basin
	30	Stokes Bay	Western Bruce Peninsula
	31	Stokes Bay	North Eastern main basin
	32	Colpoy's Bay	Southern Georgian Bay
	33	Nottawasaga Bay	Southern Georgian Bay
J. Site / Site	34	Fishing Islands	Fishing Islands
	35	Stokes' Bay	Stokes' Bay
	36	Colpoy's Bay	Colpoy's Bay
	37	Nottawasaga Bay	Nottawasaga Bay

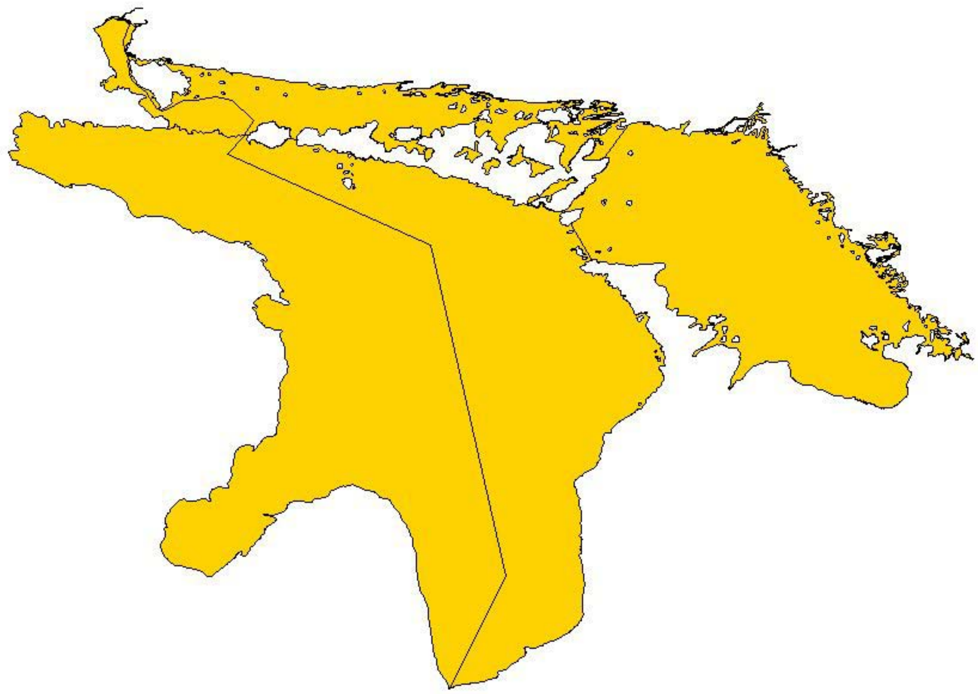


Figure 3. Lake wide panmixis hypothesis.

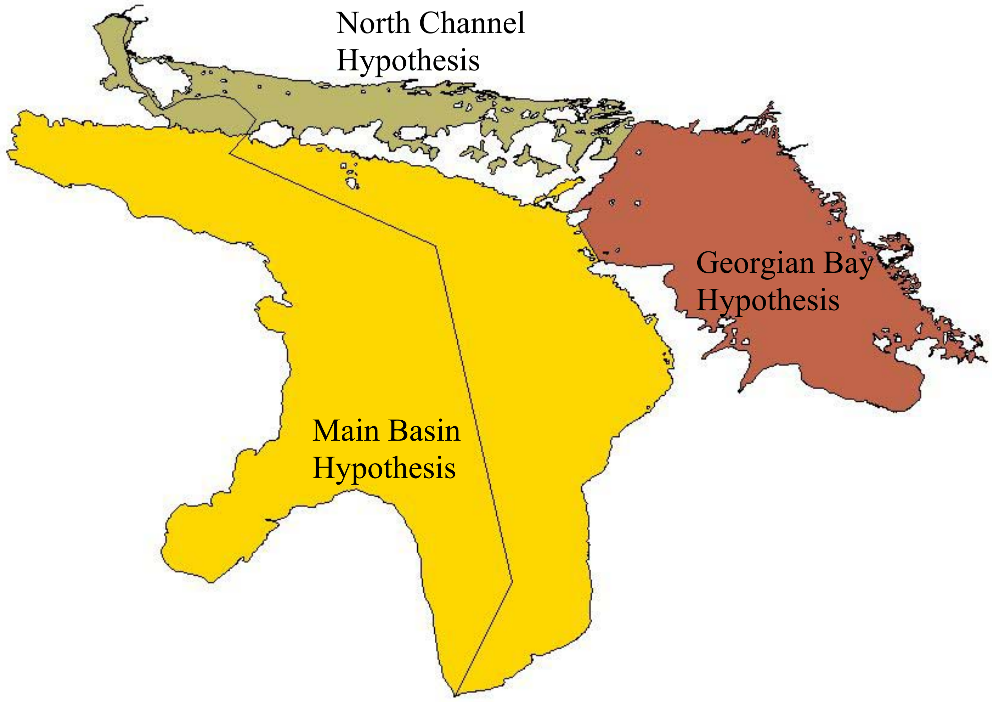


Figure 4. Basin scale hypotheses.

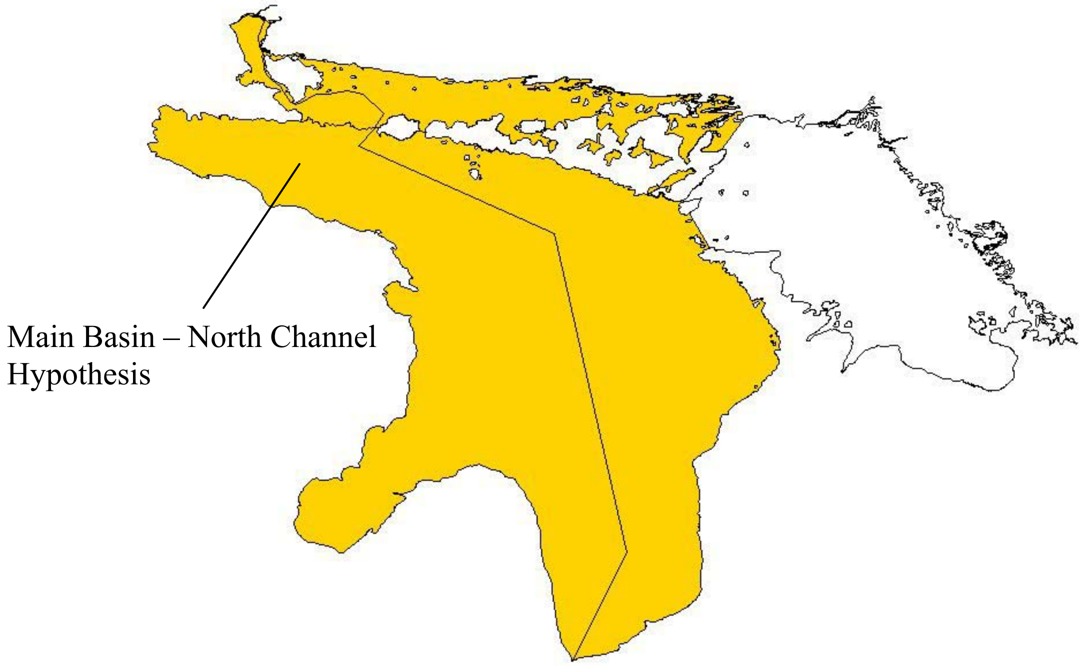


Figure 5. Basin Scale hypotheses.

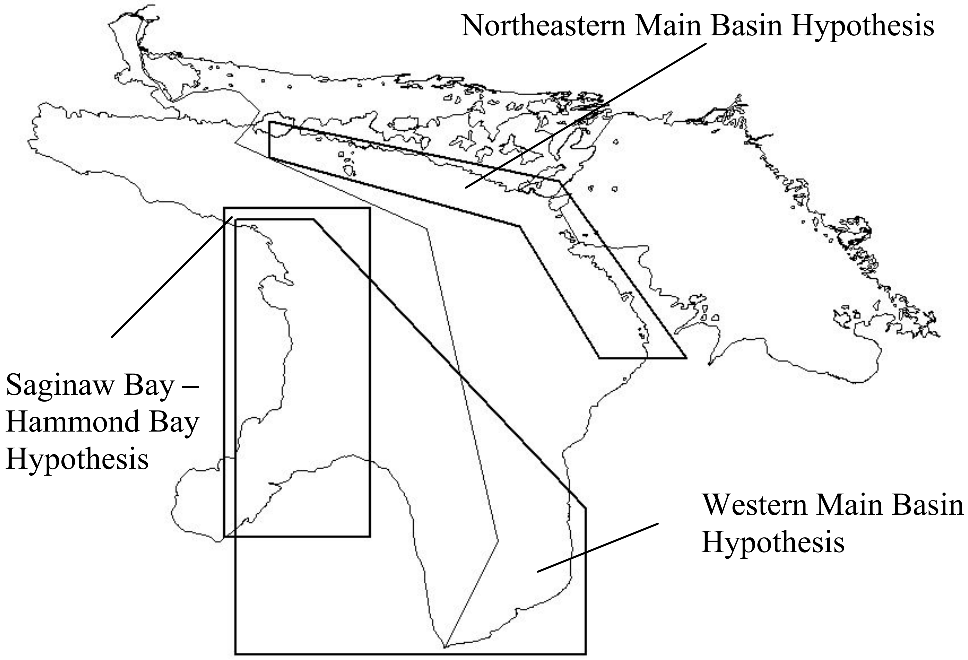


Figure 6 Regional scale hypotheses.

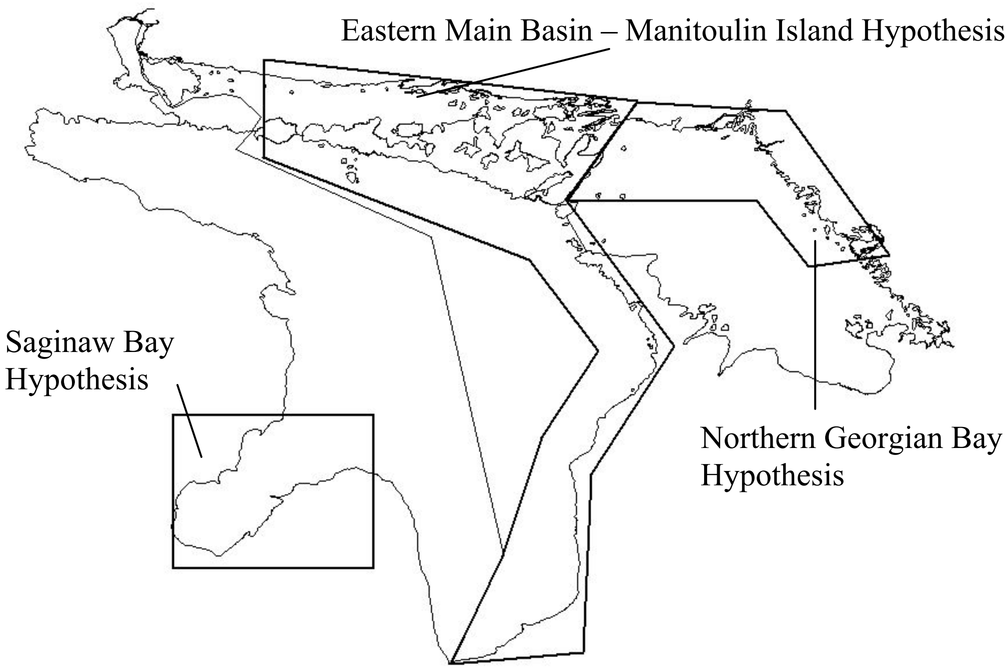


Figure 7. Regional scale hypotheses.

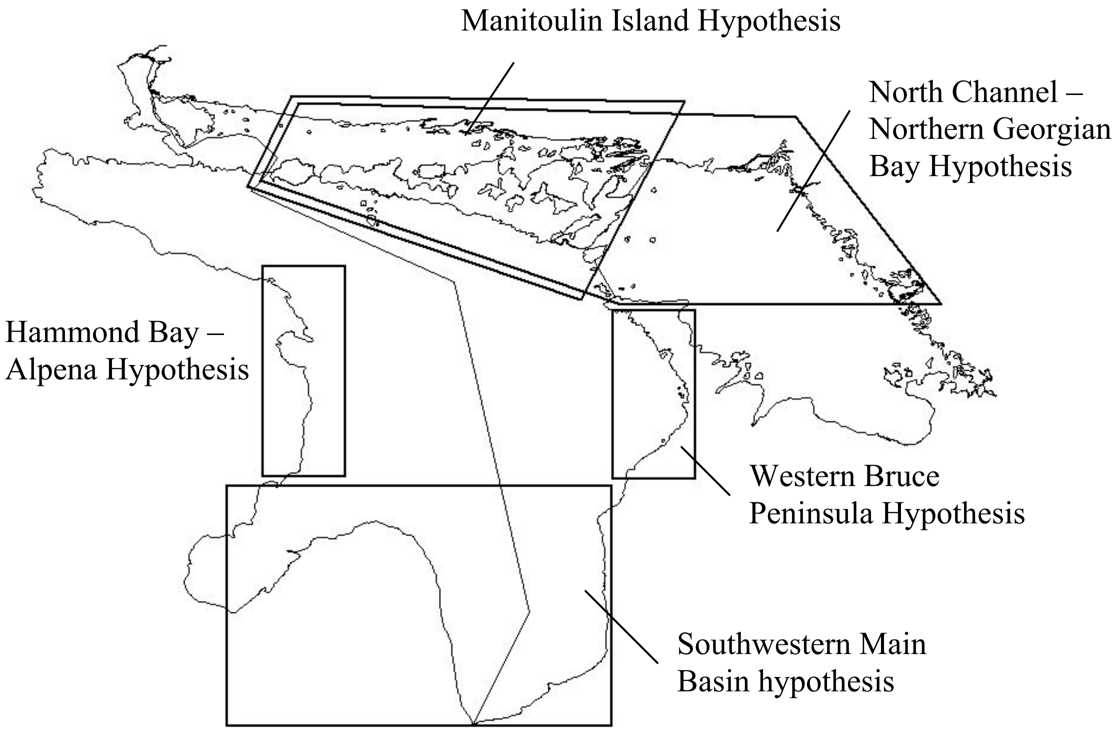


Figure 8. Regional scale hypotheses.

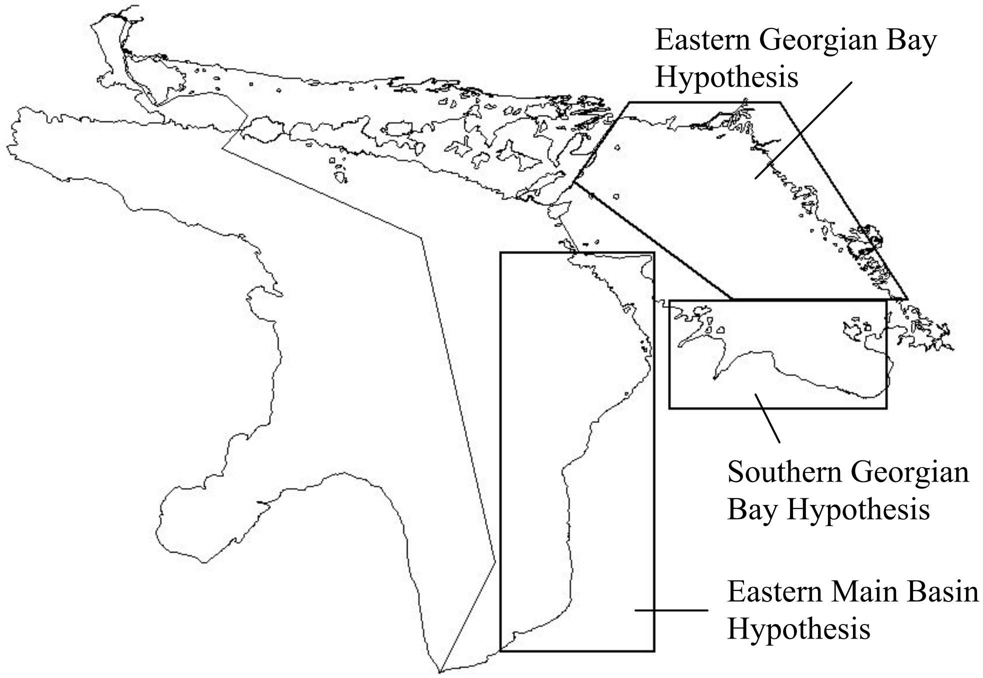


Figure 9. Regional scale hypotheses

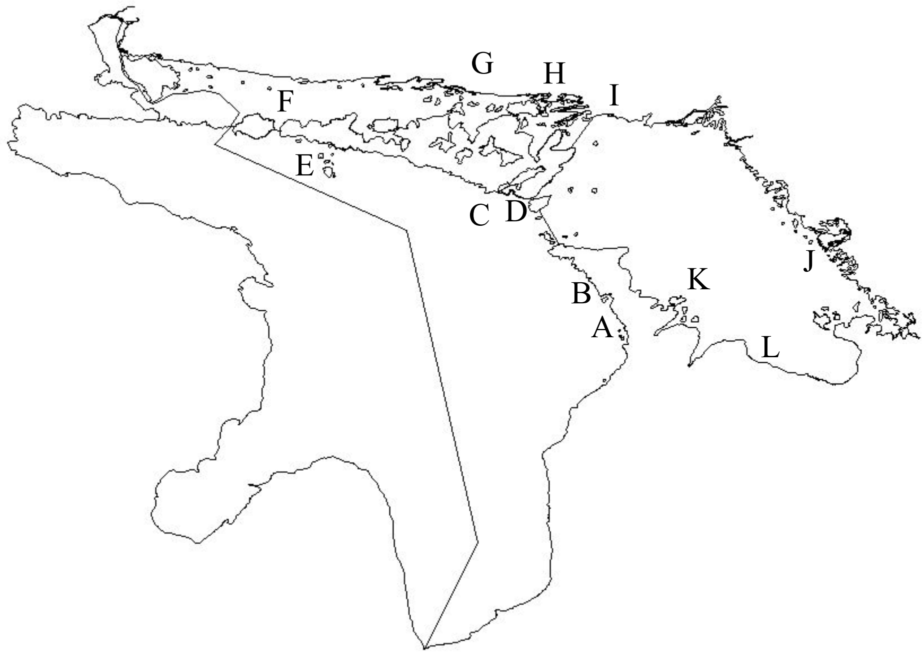


Figure 10. Site scale hypotheses. Fishing Island hypothesis (A), Stokes Bay hypothesis (B), Outer South Bay hypothesis (C), Inner South Bay hypothesis (D), Burnt Island (E), Blind River hypothesis (F), Clapperton Island hypothesis (G), Fraser-Manitowaning Bays hypothesis (H), Eastern Manitoulin Island (I), Parry Island (J), Colpoys Bay hypothesis (K), Nottawasaga Bay (L).

2.2 Whitefish tagging data summary

To date, 24,514 whitefish have been tagged during spawning in the Main Basin of Lake Huron by seven ogranizations: Chippewa/Ottawa Resource Authority, Michigan Dept. of Natural Resources, U.S. Fish and Wildlife Service Alpena Fishery Resource Office, Bruce Power, Chippewas of Nawash, Saugeen First Nation, and Ontario Ministry of Natural Resources. Saugeen Ojibway Nations have tagged 2,084 fish and 939 fish in 2004 and 2005, respectively (Figure 11). The original goal was to tag 3,000 annually between 2004 and 2006 at the Fishing Islands. Due to weather conditions this goal has not been reached; however, we have received two additional trap nets from CORA and anticipate that we will tag 3,000 in 2006, weather permitting.

Recoveries of tagged whitefish are 627 (2.5% of total tagged), with the majority of the recaptures collected from the Detour and Burnt Island regions (Figure 12). Recaptures were summarized by the location where they were originally tagged and were categorized by recapture month into two groups: recaptures collected during future spawning events (October – December in years following tagging) at and non-spawning (January – September). Individuals recaptured during October – December in the year they were tagged, as well as individuals that did not have accurate recapture grid information or date inaccuracies were removed (207 records removed). Further, we recognize that a general spawning period from October – December may not be representative of known spawning periods for each specific location, and that greater precision in this estimate is necessary to make inference about the degree of spatial isolation among populations during spawning. The reader is cautioned about drawing conclusions about the spawning and non-spawning distribution of lake whitefish from this summary due to the small sample size of recaptured fish; however, this summary is intended to illustrate the necessity to continue to develop options for tag recovery. In particular, recaptures should be compared to the spatial deployment and effort of commercial fishing operations to determine if additional effort is necessary to cover areas where commercial fishing is diminished or non existent. Recaptures from Detour-Cheboygan, Burnt Island and Alpena suggest that migration among these locations occurs during non-spawning (Figure 13, 14 and 15). Single individuals tagged at Saginaw Bay have been recaptured during non-spawning near Drummond Island, South Bay, Detour and Sarnia (Figure 16). Three whitefish tagged at the Fishing Islands have been recovered along the south shore of Manitoulin Island during non-spawning (Figure 17). Recaptures during spawning in years following tagging were restricted to whitefish tagged at Detour-Cheboygan and Burnt Island. Three recaptures from Burnt Island returned the following November (Figure 18). Similarly, all but one recapture during spawning from Detour-Cheboygan returned to this region, with a single individual recaptured at Burnt Island in November 2004 (Figure 19).

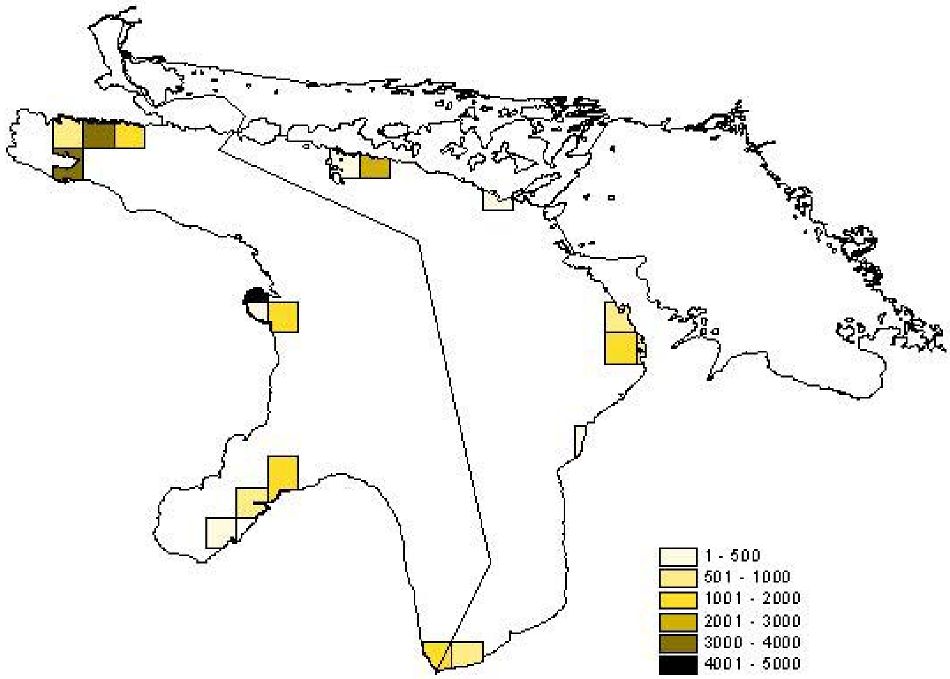


Figure 11. Geographical distribution of tagging effort of lake whitefish in Lake Huron between 2003 and 2005. Individual boxes represent nautical 10 minute grids, while colour and shading indicate number of fish tagged within each grid.

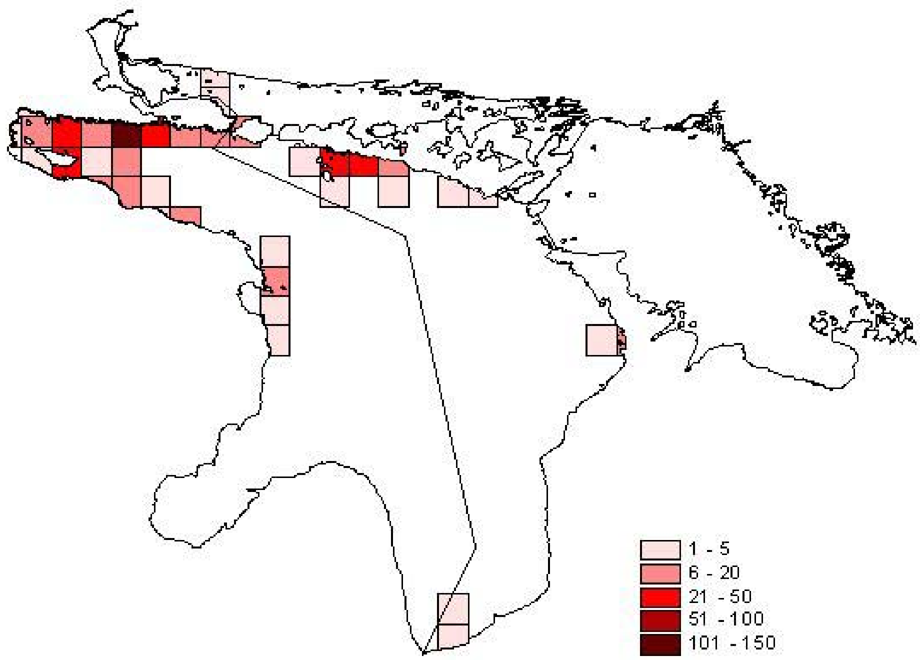


Figure 12. Geographical distribution of recaptured whitefish tagged between 2003 and 2005 in the Main Basin Lake Huron (n=420). . Individual boxes represent nautical 10 minute grids, while colour and shading indicate number of individuals recaptured within each grid.

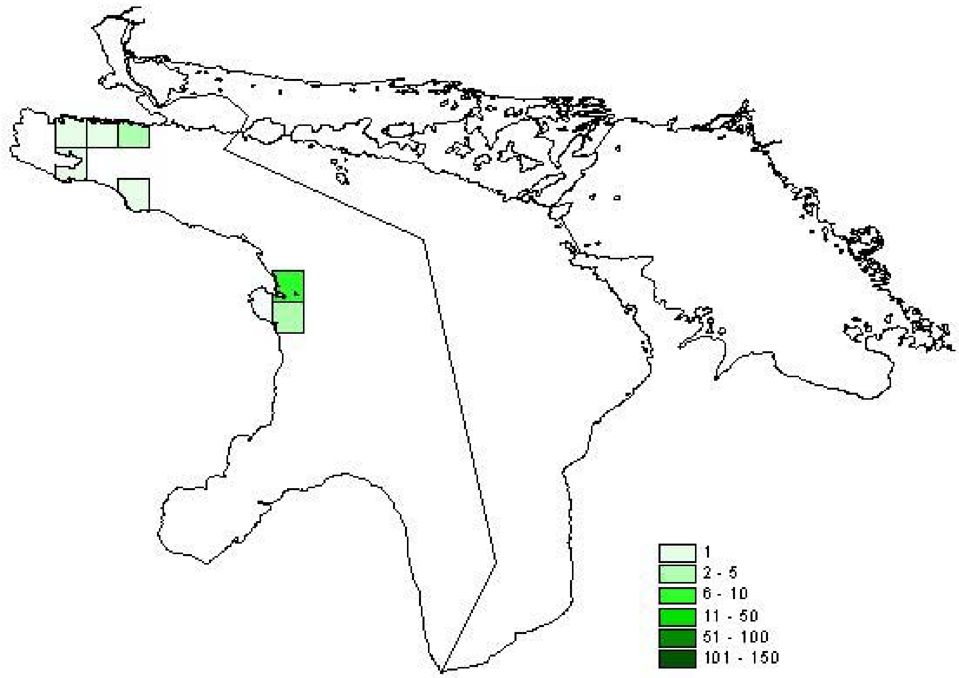


Figure 13. Geographical distribution of recaptures during non-spawning of whitefish tagged at Alpena (n=18). Individual boxes represent nautical 10 minute grids, while colour and shading indicate number of individuals recaptured within each grid.

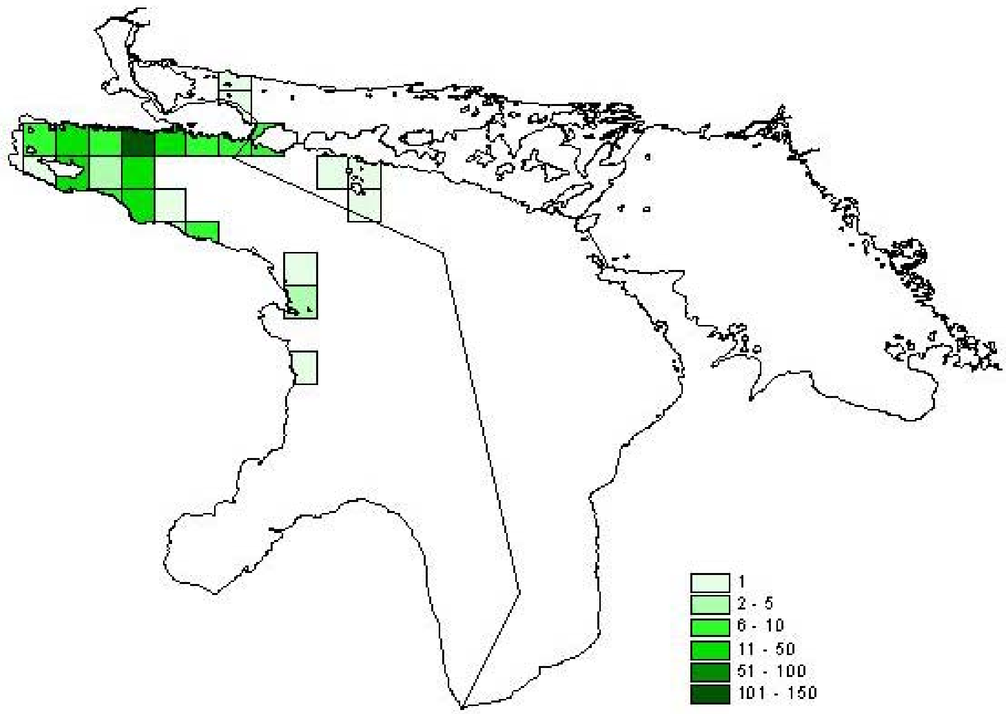


Figure 14. Geographical distribution of recaptures during non-spawning of whitefish tagged at Detour-Cheboygan (n=304). Individual boxes represent nautical 10 minute grids, while colour and shading indicate number of individuals recaptured within each grid.

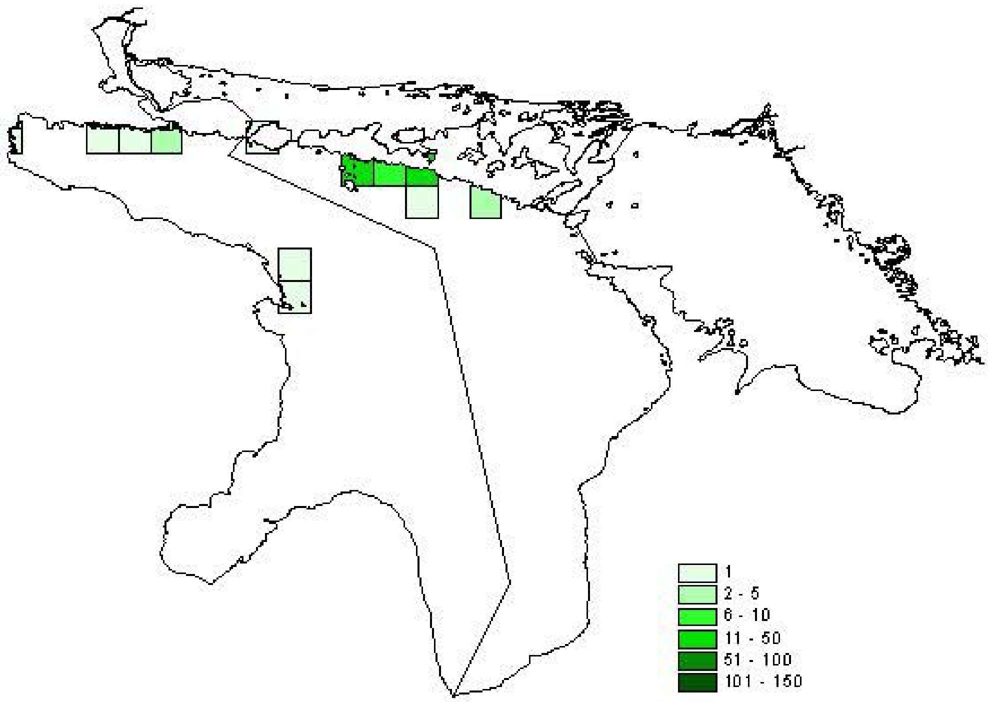


Figure 15. Geographical distribution of recaptures during non-spawning of whitefish tagged at Burnt Island (n=52). Individual boxes represent nautical 10 minute grids, while colour and shading indicate number of individuals recaptured within each grid.

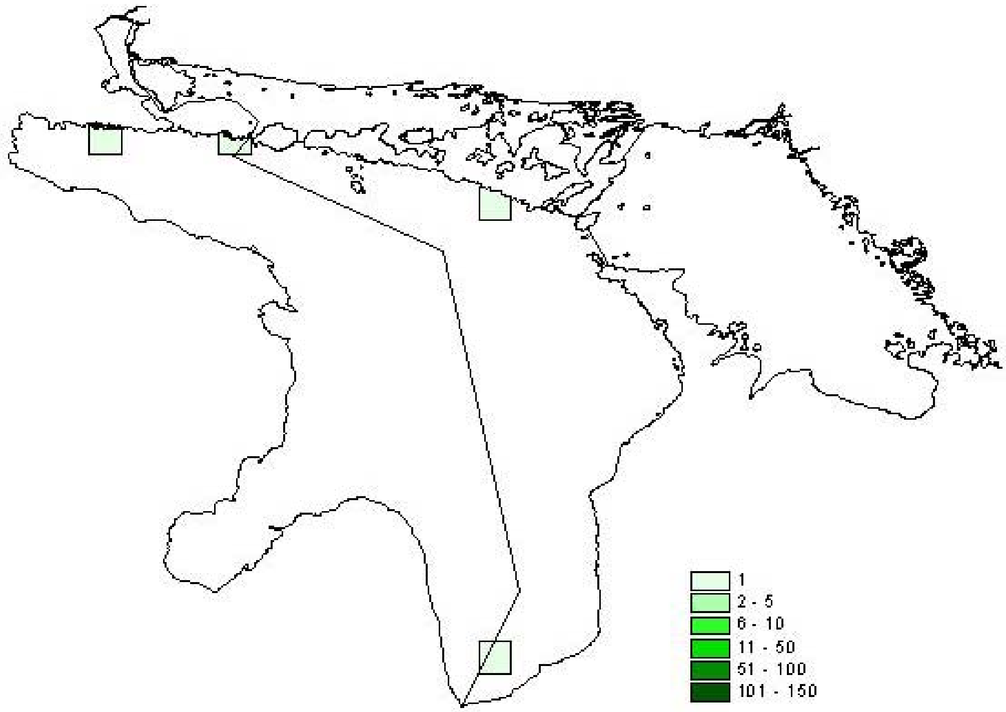


Figure 16. Geographical distribution of recaptures during non-spawning of whitefish tagged at Saginaw Bay (n=4). Individual boxes represent nautical 10 minute grids, while colour and shading indicate number of individuals recaptured within each grid.

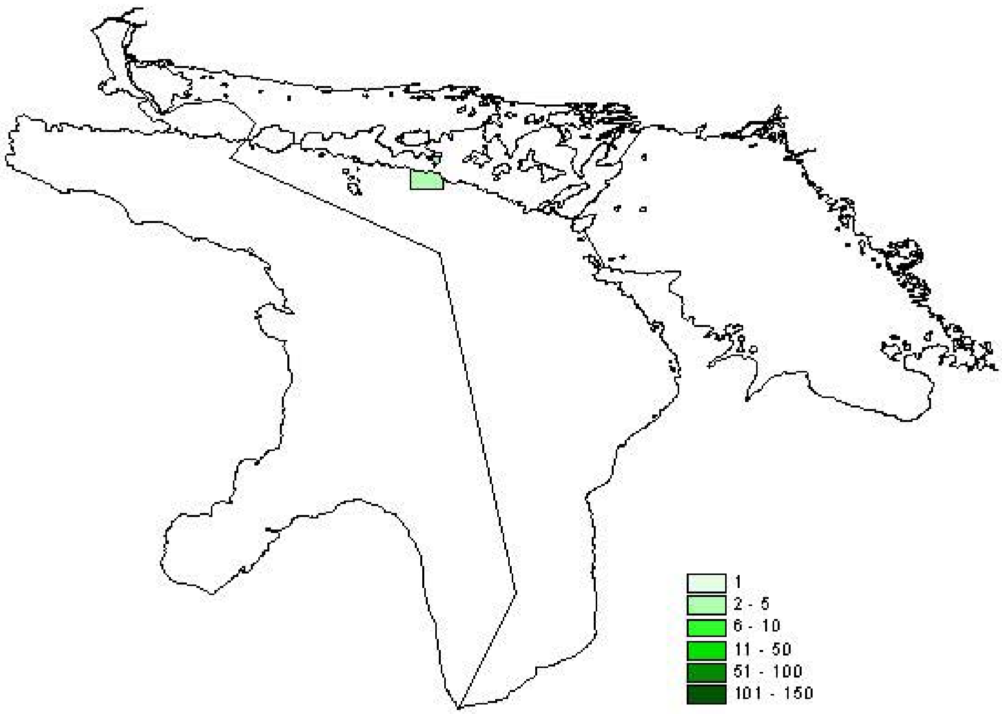


Figure 17. Geographical distribution of recaptures during non-spawning of whitefish tagged at the Fishing Islands (n=3). Individual boxes represent nautical 10 minute grids, while colour and shading indicate number of individuals recaptured within each grid.

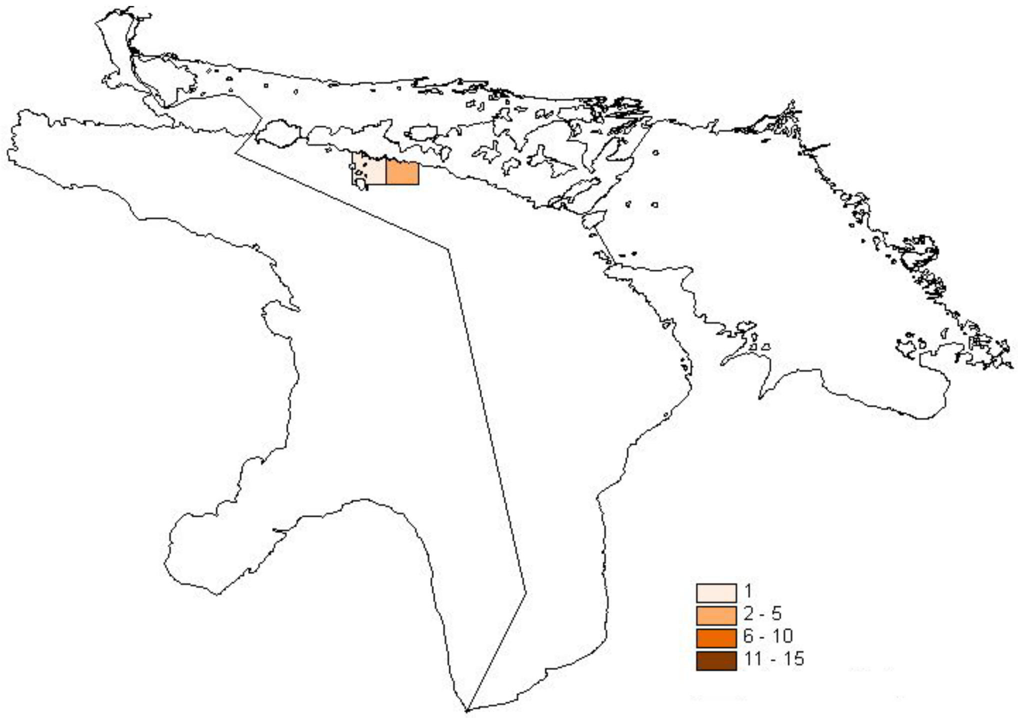


Figure 18. Geographical distribution of whitefish recaptures during spawning in years following tagging at Burnt Island (n=3). Individual boxes represent nautical 10 minute grids, while colour and shading indicate number of individuals recaptured within each grid.

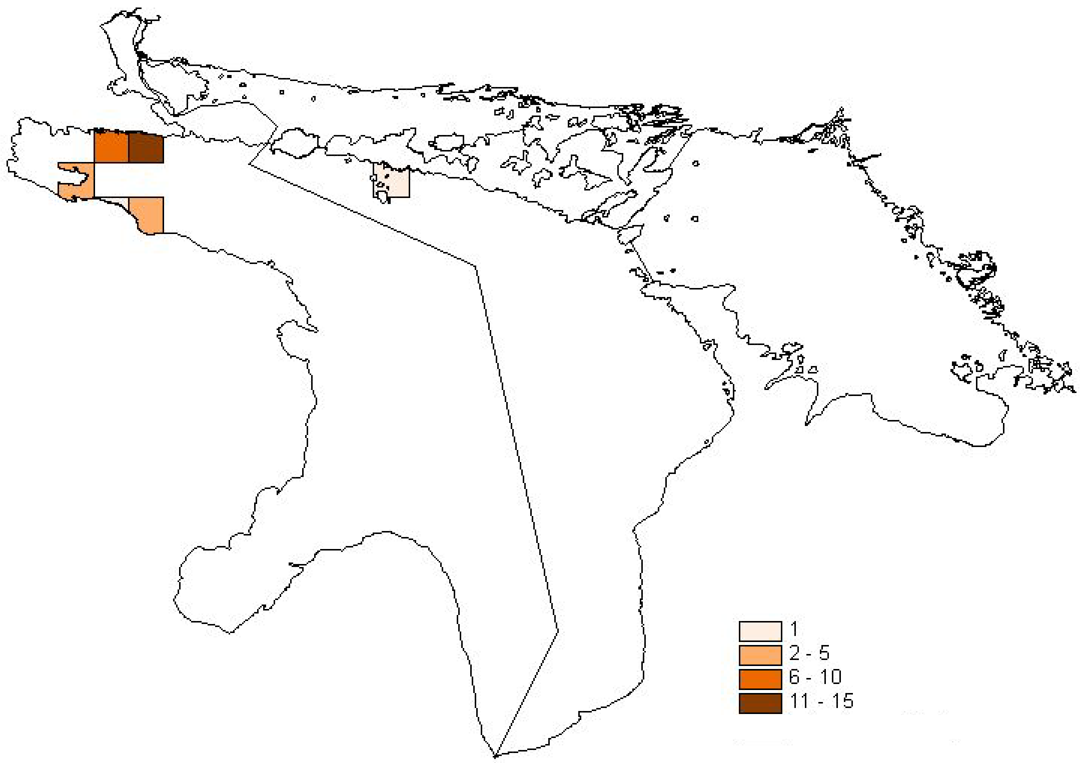


Figure 19. Geographical distribution of whitefish recaptures during spawning in years following tagging at Detour-Cheboygan (n=35). Individual boxes represent nautical 10 minute grids, while colour and shading indicate number of individuals recaptured within each grid.

2.3 Nawash Fisheries Management Regions

The spatio-temporal distribution of whitefish that support the harvests of the Saugeen Ojibway has been recognized as a key uncertainty in previous TAC reports prepared by the Chippewas of Nawash (Crawford et al. 2001; Crawford et al. 2003). Here we reiterate the importance of addressing this uncertainty by employing principles of decision analysis and adaptive management as developed for the Saugeen Ojibway / OMNR Plenary by Prof. Mike Jones (Michigan State University) and Prof. Tom Nudds (University of Guelph) (Crawford et al. 2003). For the purpose of this report we considered hypothesized distribution of whitefish populations at two spatial scales (Figures 20 and 21):

1. Basin
   - **"Main Basin"**, which is spatially equivalent to the Canadian waters of the Main Basin hypothesis
   - **"Georgian Bay",** which is spatially equivalent to the Georgian Bay hypothesis

2. Region
    - **“Main Basin East”,** which is roughly spatially equivalent to the Western Bruce Peninsula hypothesis
    - **“Main Basin South”,** which is roughly equivalent to the Canadian waters of the Southwestern Main Basin hypothesis.
    - **“Main Basin South East”** (sometimes referred to as “Main Basin South + East”).
    - **“Georgian Bay West”,** for which there is considerable uncertainty, and very little empirical evidence, about the spatial extent of this hypothesized population.
    - **“Georgian Bay South”,** which is roughly spatially equivalent to the Southern Georgian Bay hypothesis.

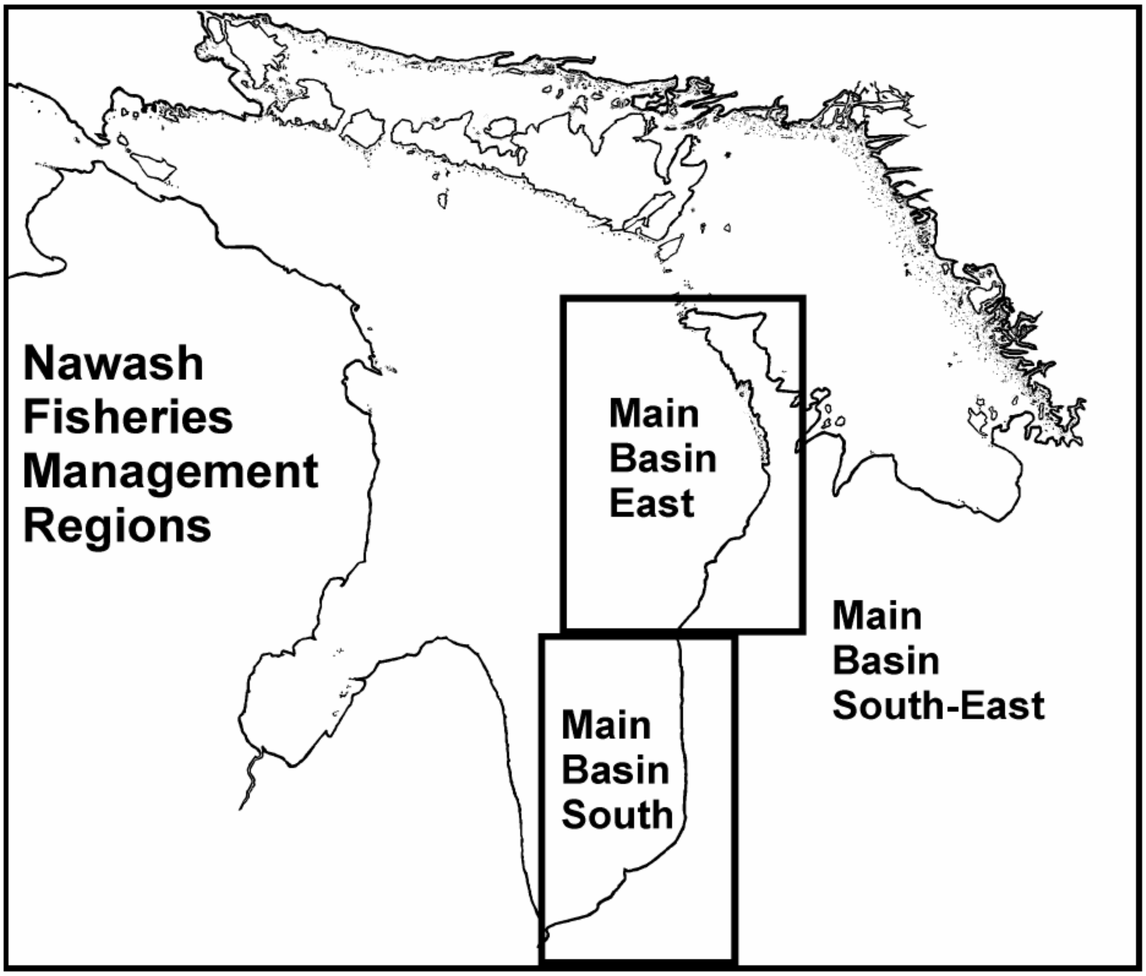


Figure 20. Map of Lake Huron showing the general regions in the Main Basin used by The Chippewas of Nawash Unceded First Nation as hypothesized lake whitefish populations, based on the available evidence. Due to great uncertainties regarding the spatio-temporal behaviour of lake whitefish in southern Main Basin, the region Main Basin South-East will be analysed separately from the two subregions Main Basin East and Main Basin South.

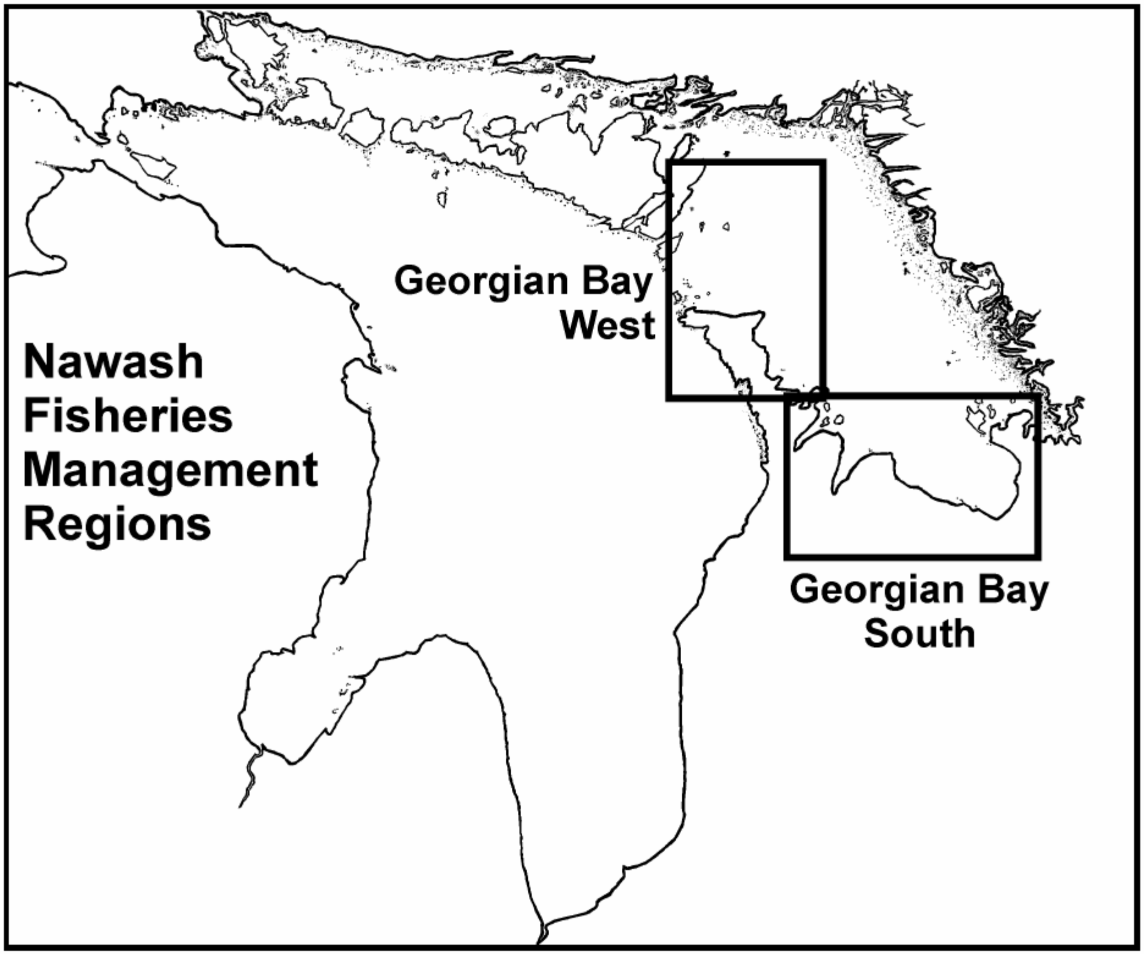


Figure 21. Map of Lake Huron showing the general regions in Georgian Bay used by The Chippewas of Nawash Unceded First Nation as hypothesized lake whitefish populations, based on the available evidence.

3. Commercial Harvest Effort, Catch and CPUE

Harvest and effort of Saugeen Ojibway Nations commercial harvests are recorded by the Saugeen Ojibway Nations Fisheries Harvest Assessment Program according to the procedures developed by Muir (2001). Records from the Saugeen Ojibway commercial harvest and effort databases are amalgamated with the OMNR commercial harvest "ch" database annually. Amalgamation and data management procedures are outlined in Appendix 1.

3.1 Main Basin

Harvest continued to increase in the Main Basin throughout the time series, with some indication of a plateau beginning in the late 1990's (Figure 22). Effort demonstrated no increasing of decreasing long-term trends; however, variation in the level of effort deployed is evident throughout the time series (Figure 23). Trends in CPUE are summarized in figure 24.

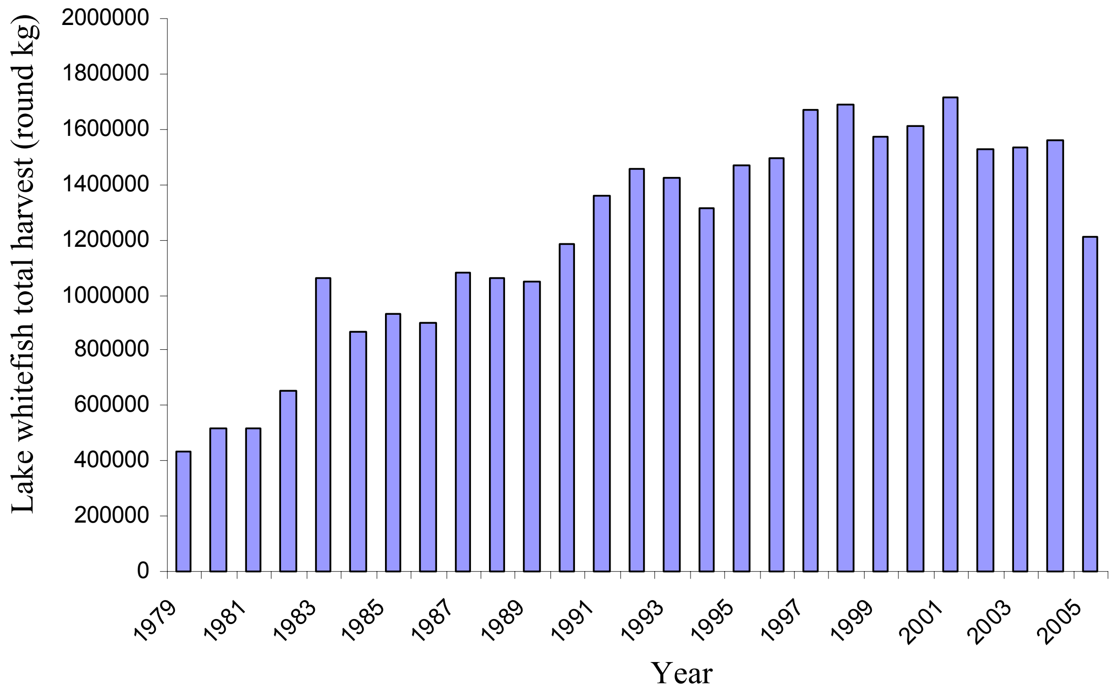


Figure 22. Total annual targeted harvest (round kg) of lake whitefish in Main Basin for the years 1979 until 2005/2006.

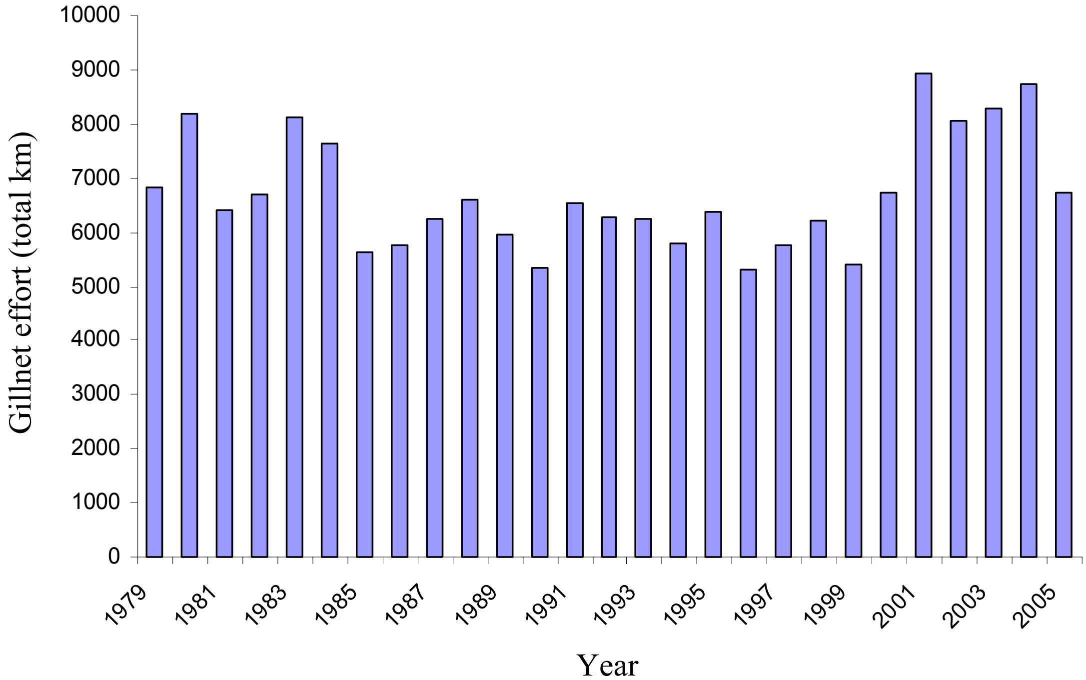


Figure 23. Total annual effort (km of gillnet) targeted at lake whitefish in Main Basin from years 1979 until 2005/2006.

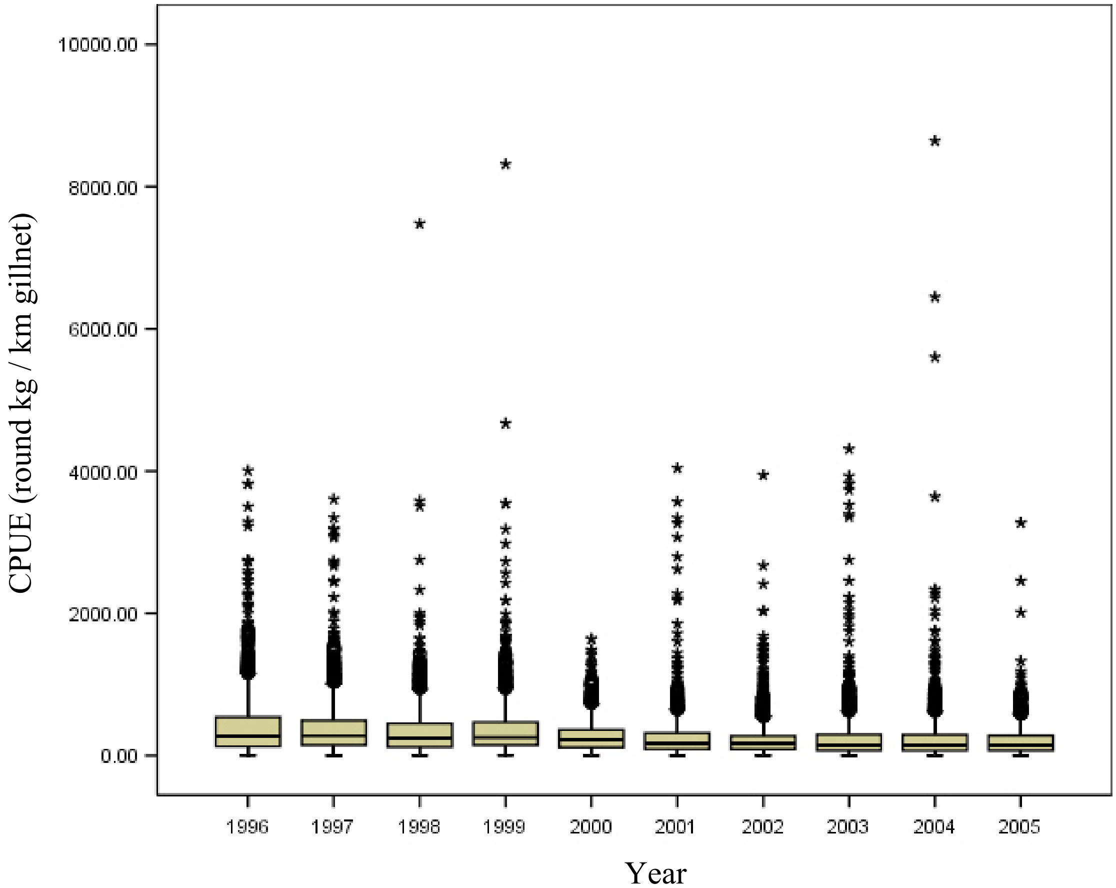


Figure 24. Box plot illustrations of annual CPUE (round kg / km gillnet) of targeted lake whitefish harvests in Main Basin for the years 1996 until 2005.

3.1.1 Main Basin East

Harvest peaked in the early 1990's and again between 2001 and 2004 (Figure 25). Effort remained relatively constant throughout the time series, with the exception of a period of decreased effort between 1996 and 2000 (Figure 26). Trends in CPUE are summarized in figure 27.

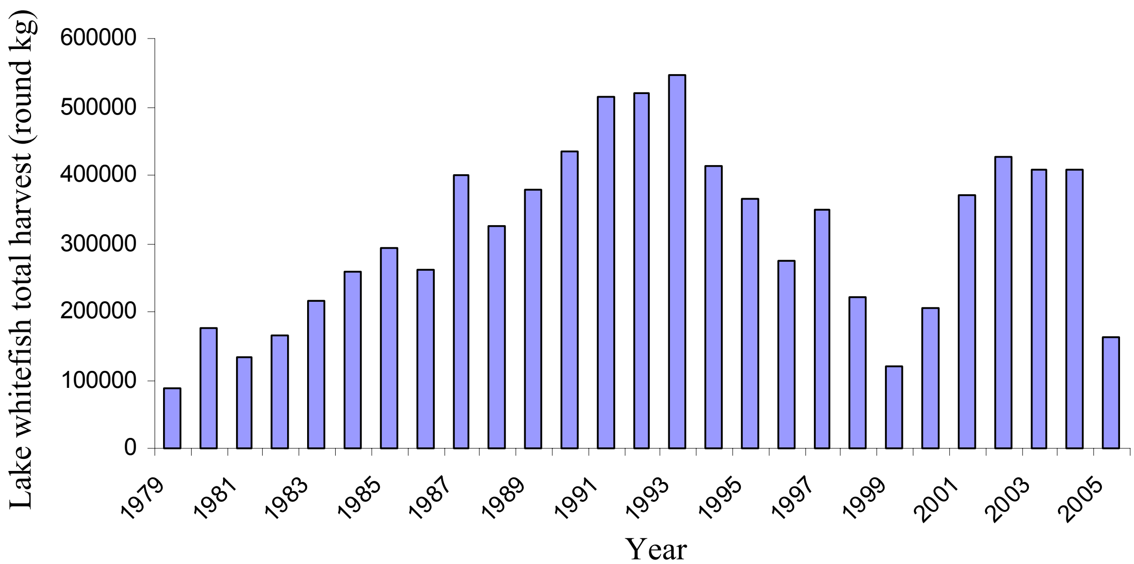


Figure 25. Total annual targeted harvest (round kg) of lake whitefish in region MB-E for years 1979 until 2005/2006.

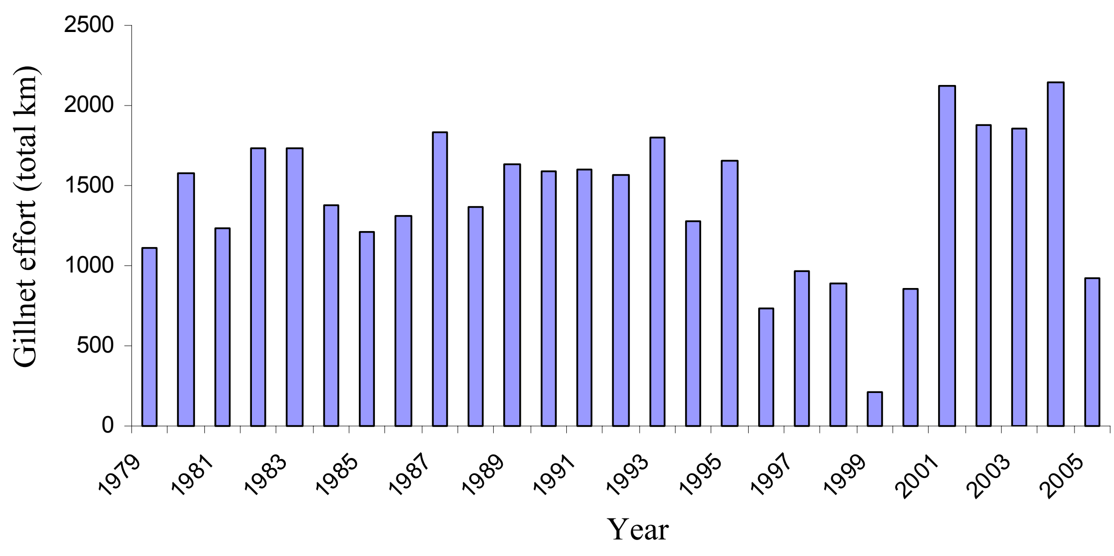


Figure 26. Total annual effort (km of gillnet) targeted at lake whitefish in region MB-E for years 1979 until 2005/2006.

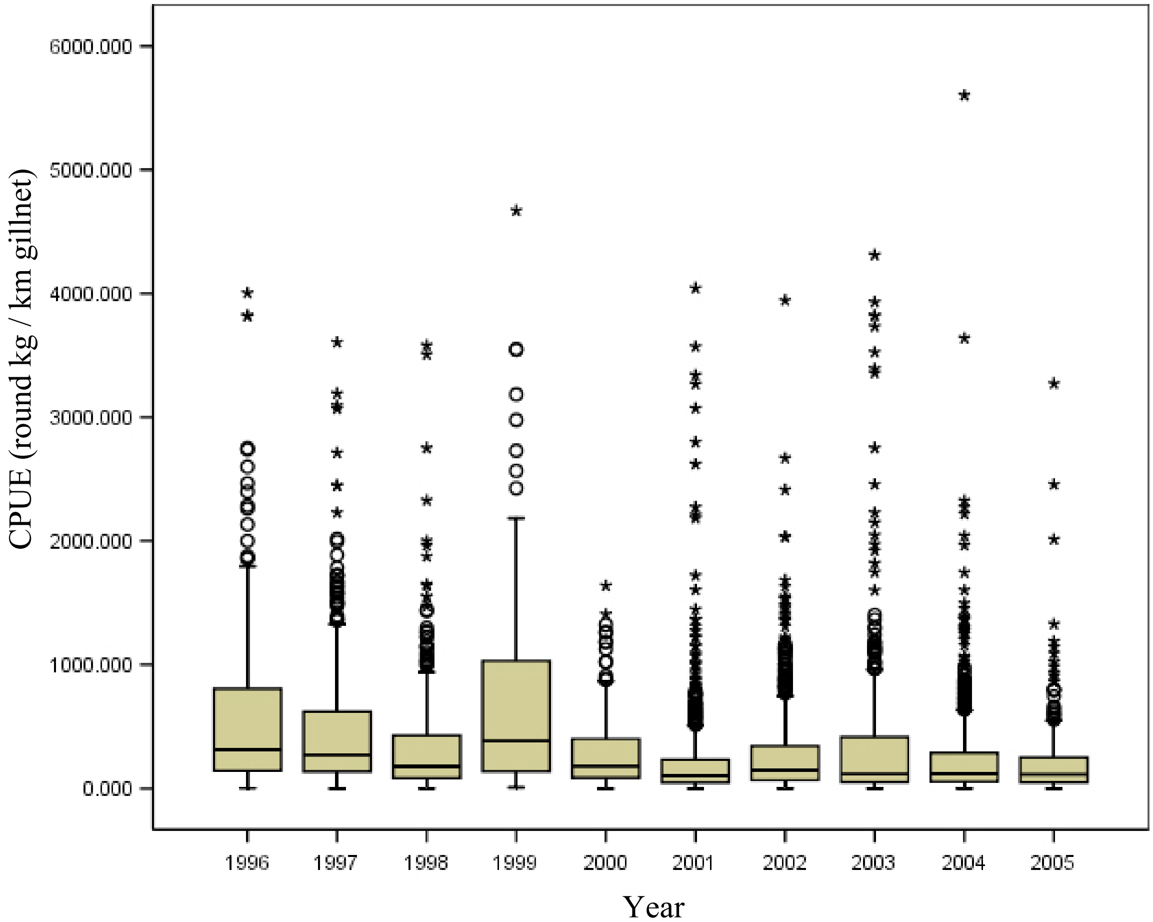


Figure 27. Box plot illustrations of annual CPUE (round kg / km gillnet) of targeted lake whitefish harvests in region MB-E for years 1996 to 2005.

3.1.2 Main Basin South

Total harvest peaked between 1997 and 2001, while effort has been variable over the entire time series (Figure 28 & 29). Trends in CPUE between 1996 and 2005 are represented in figure 30.

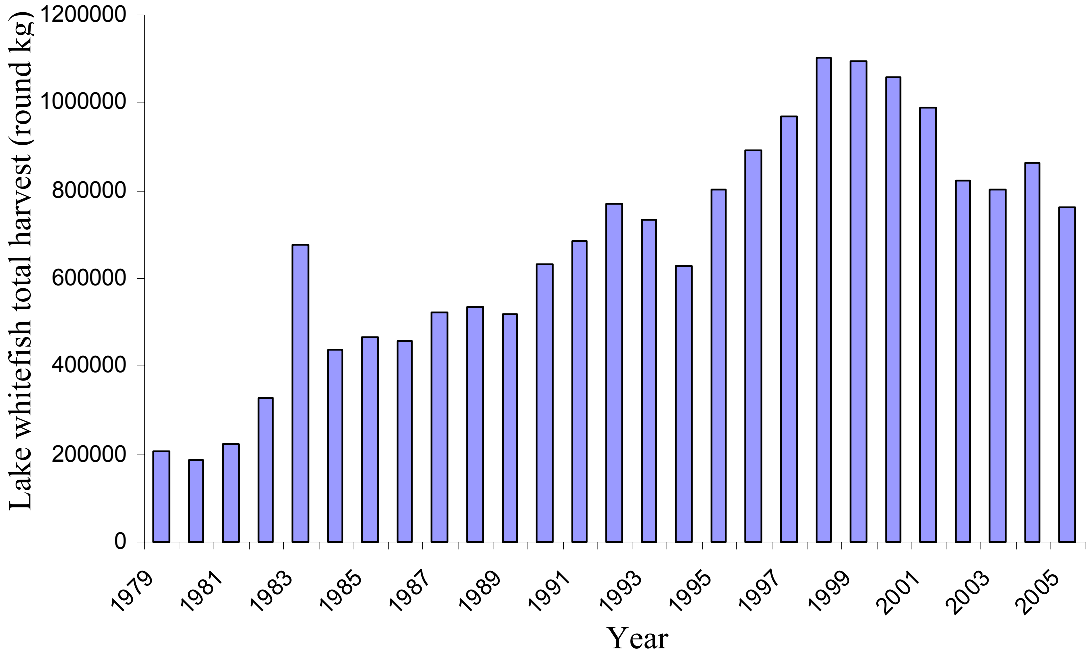


Figure 28. Total annual targeted harvest (round kg) of lake whitefish in Main Basin South for years 1979 until 2005/2006.

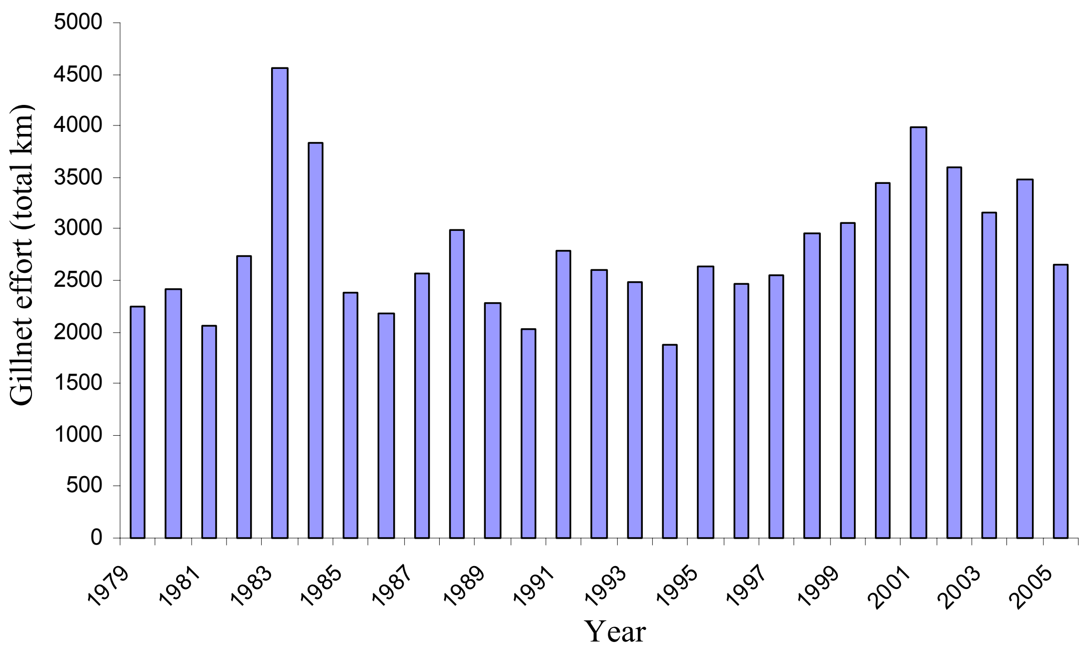


Figure 29. Total annual effort (km of gillnet) targeted at lake whitefish in Main Basin South for years 1979 until 2005/2006.

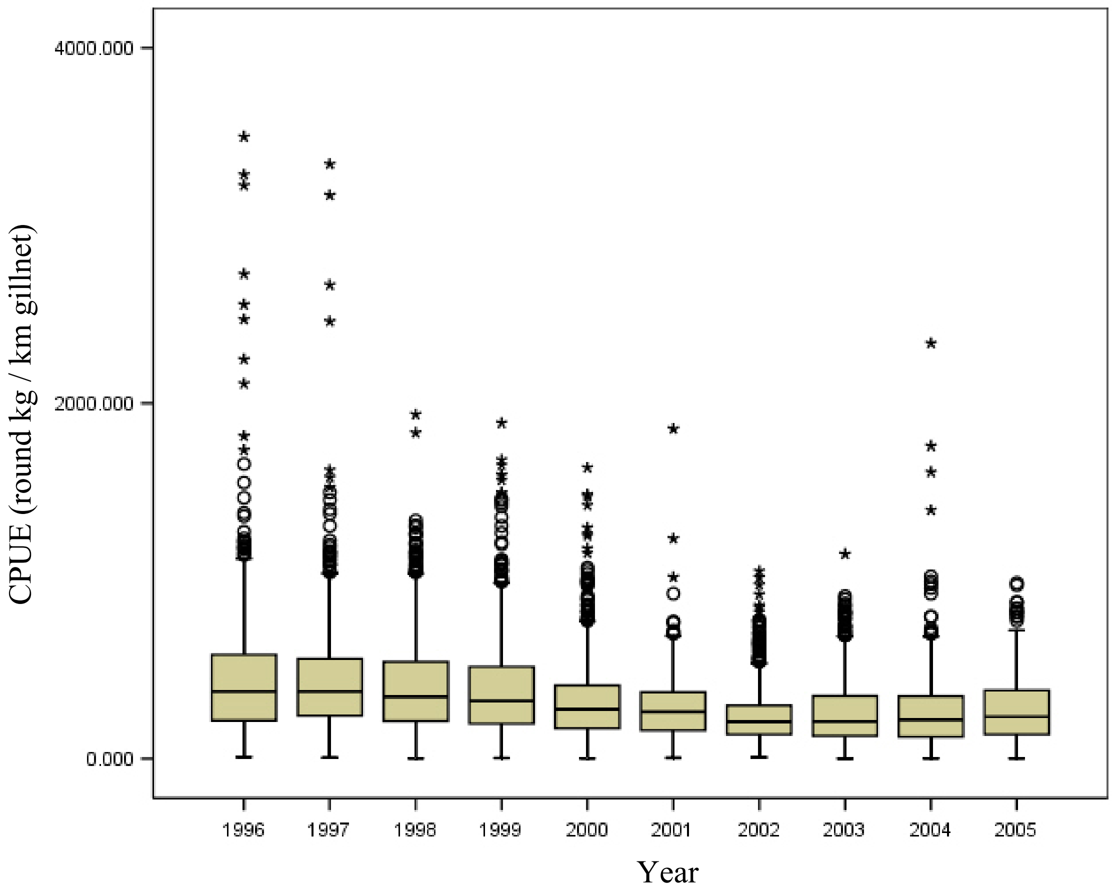


Figure 30. Box plot illustrations of annual CPUE (round kg / km gillnet) of targeted lake whitefish harvests in Main Basin South for years 1996 to 2005.

3.1.3 Main Basin South + East

Total harvest increased from 1979 until its peak in the late 1990's (Figure 31). Gillnet effort increased throughout the 1990's, consistent with historical high effort levels between 1980 and 1984 (Figure 32). Trends in CPUE are represented in figure 33.

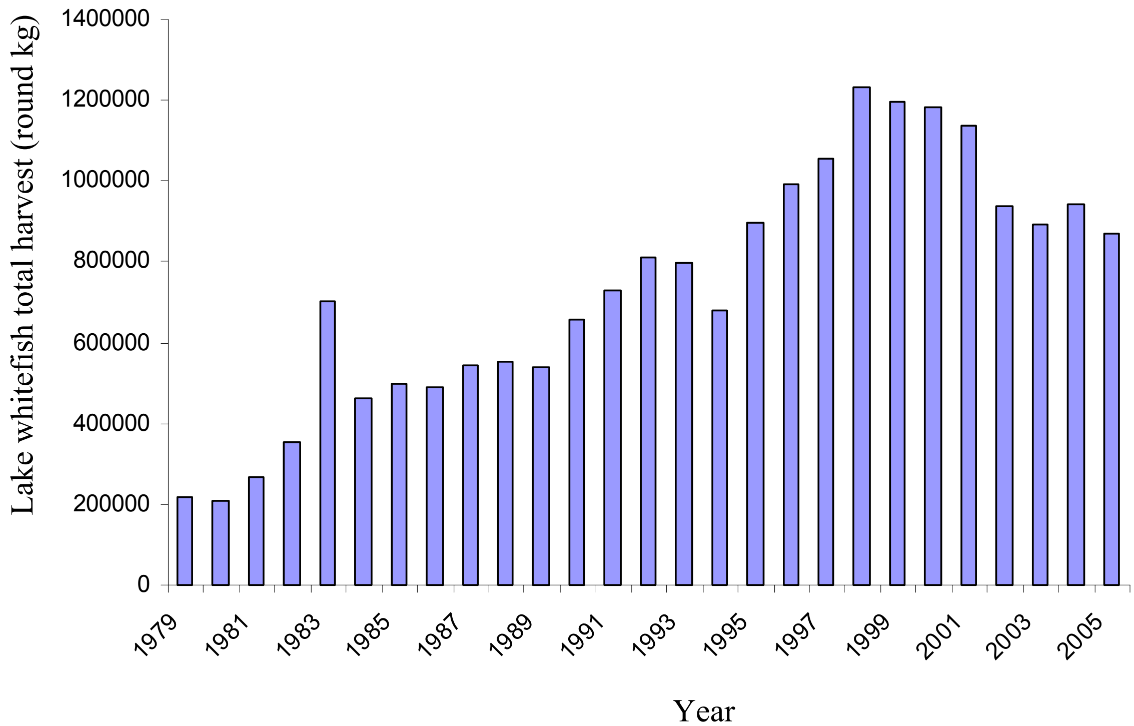


Figure 31. Total annual targeted harvest (round kg) of lake whitefish in Main Basin Southeast for years 1979 until 2005/2006.

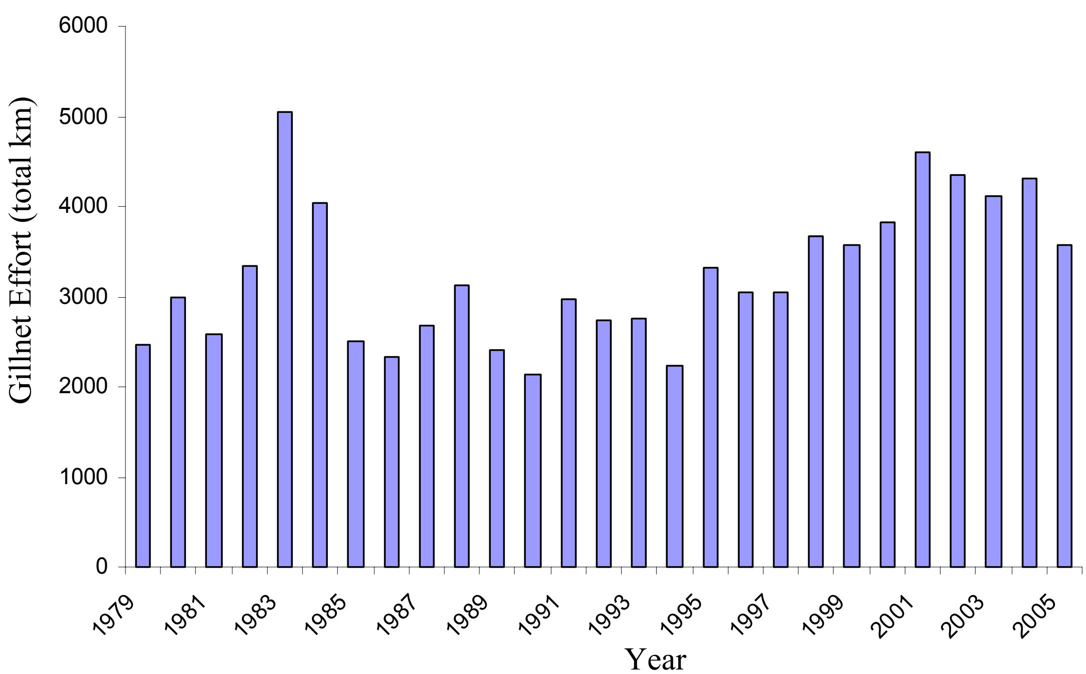


Figure 32. Total annual effort (km of gillnet) targeted at lake whitefish in Main Basin Southeast for years 1979 until 2005/2006.

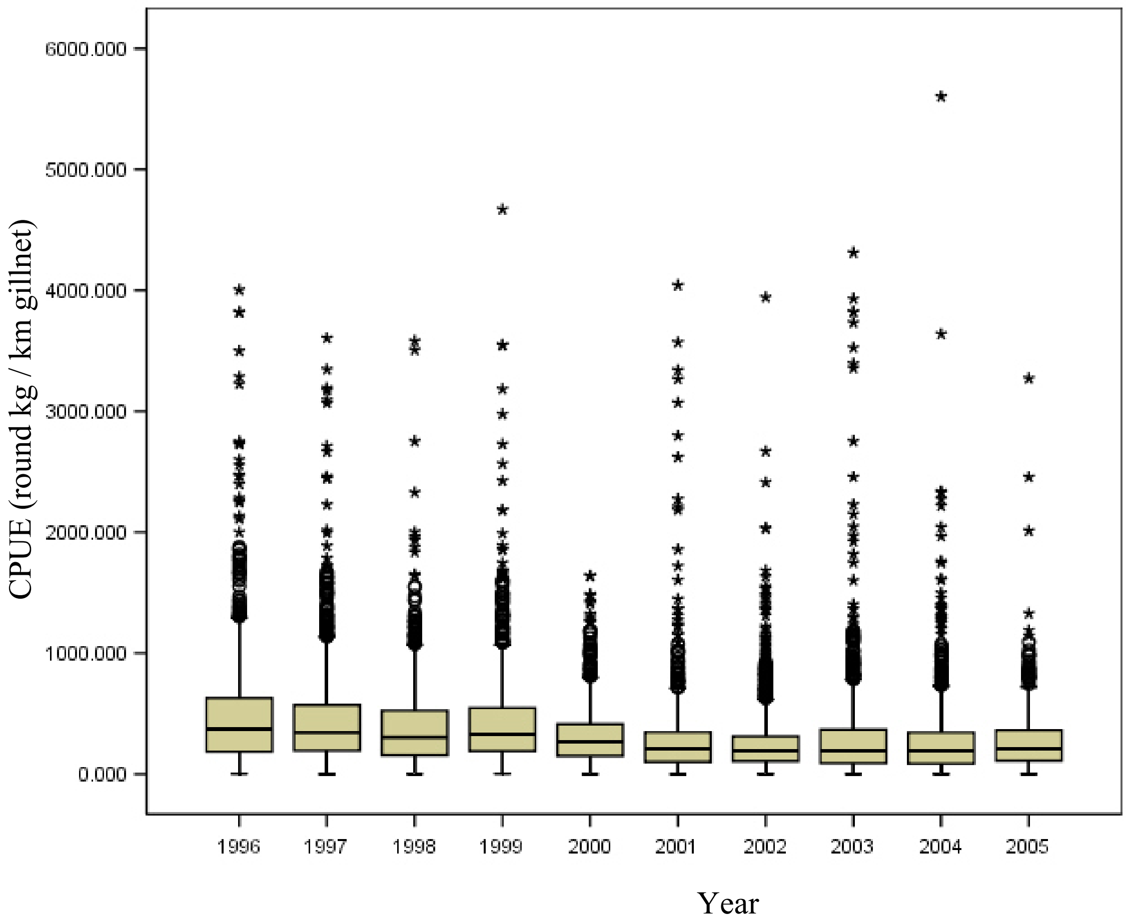


Figure 33. Box plot illustrations of annual CPUE (round kg / km gillnet) of targeted lake whitefish harvests in Main Basin Southeast for years 1996 to 2005.

3.2 Georgian Bay

Harvest increased rapidly, relative to earlier levels of harvest, in the 1990's and has since declined slightly (Figure 34). Total effort also increased throughout the 1990's and currently remains at a high level, relative to historical values (Figure 35). Trends in CPUE are summarized in figure 36.

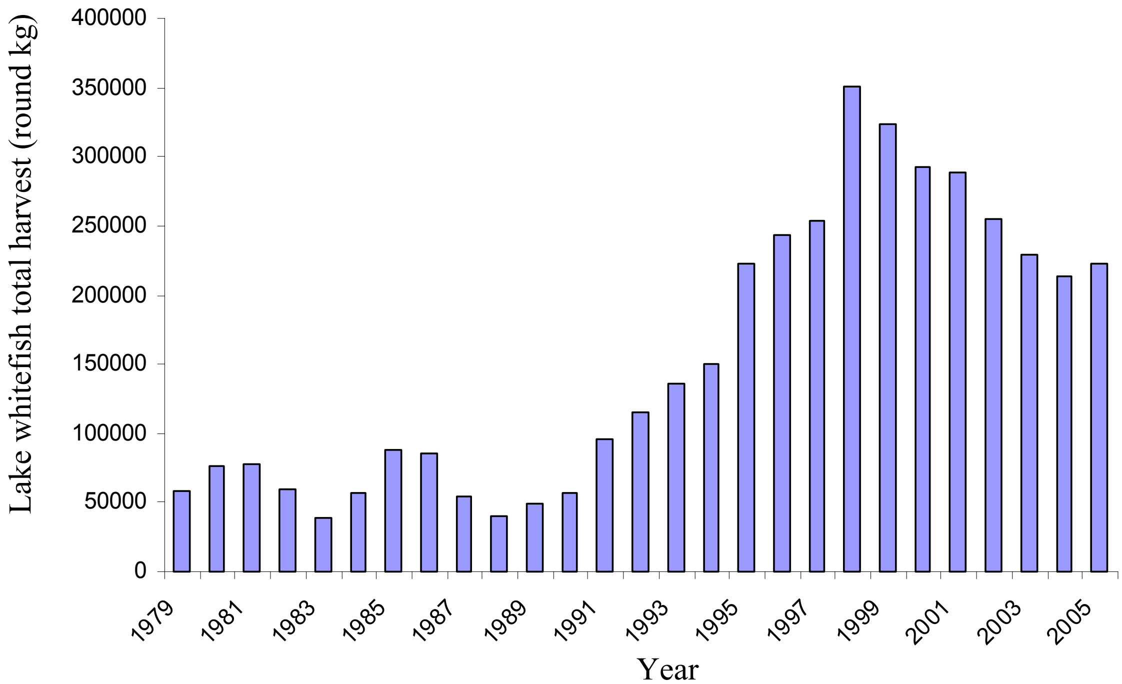


Figure 34. Total annual targeted harvest (round kg) of lake whitefish in Georgian Bay for years 1979 until 2005/2006.

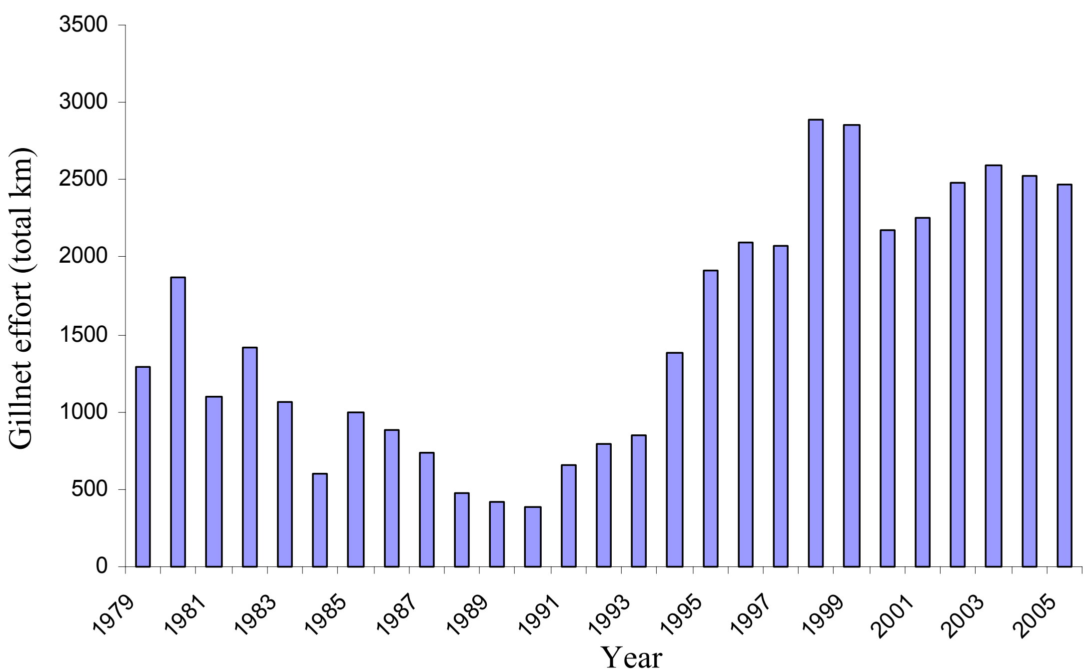


Figure 35. Total annual effort (km of gillnet) targeted at lake whitefish in Georgian Bay for years 1979 until 2005/2006.

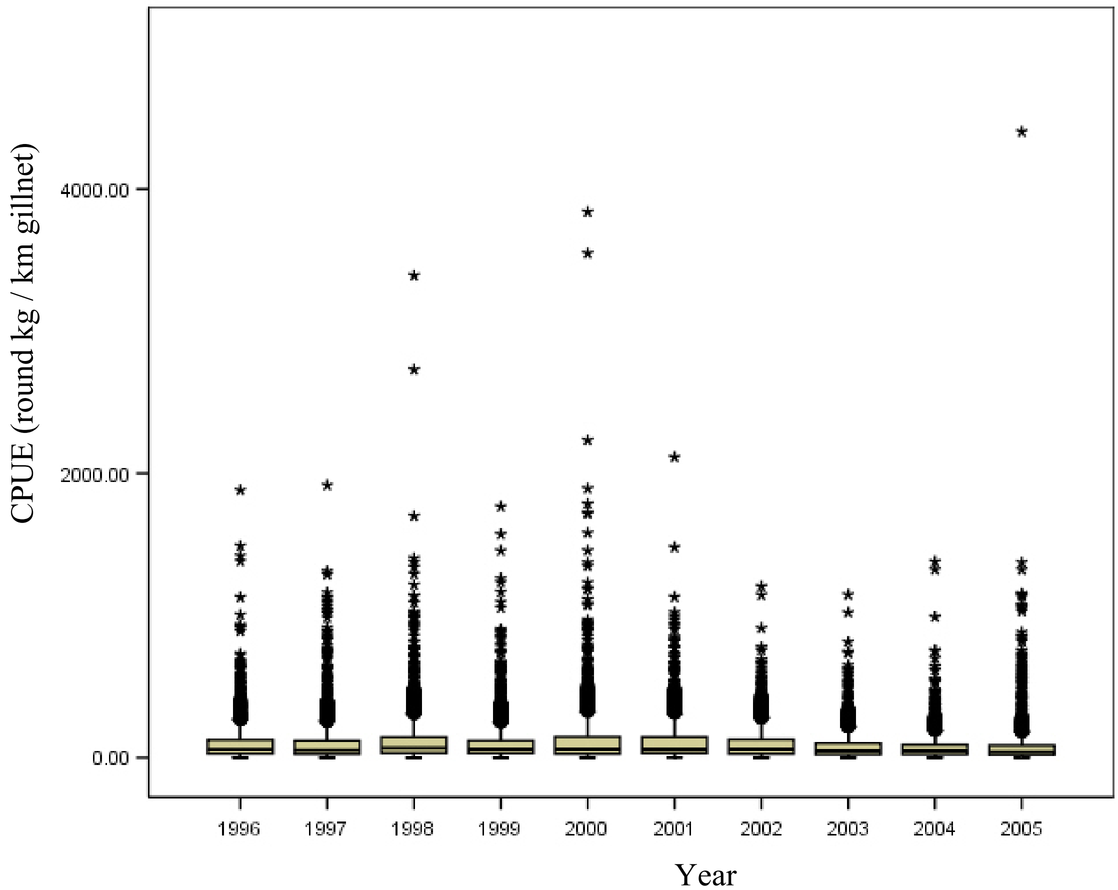


Figure 36. Box plot illustrations of annual CPUE (round kg / km gillnet) of targeted lake whitefish harvests in Georgian Bay for years 1996 to 2005.

3.2.1 Georgian Bay West

Harvest peaked in 1998 and 1999 (Figure 37). Effort increased throughout the 1990's , relative to historical levels of effort, and peaked in 1999 (Figure 38). Trends in CPUE are summarized in figure 39.

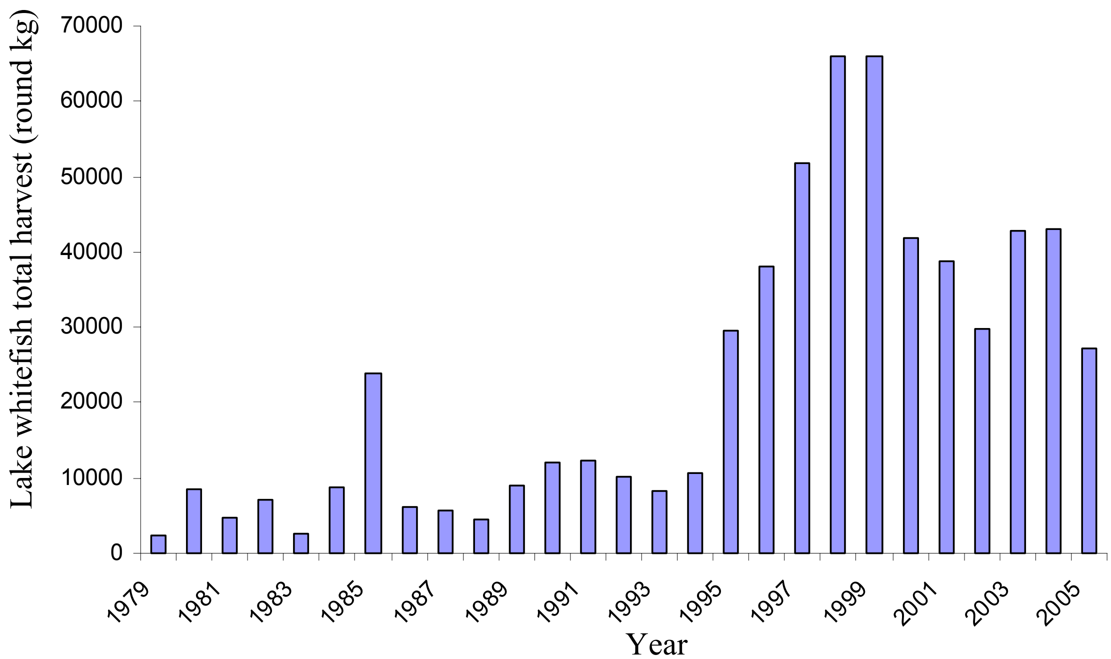


Figure 37. Total annual targeted harvest (round kg) of lake whitefish in region Georgian Bay West for years 1979 until 2005/2006.

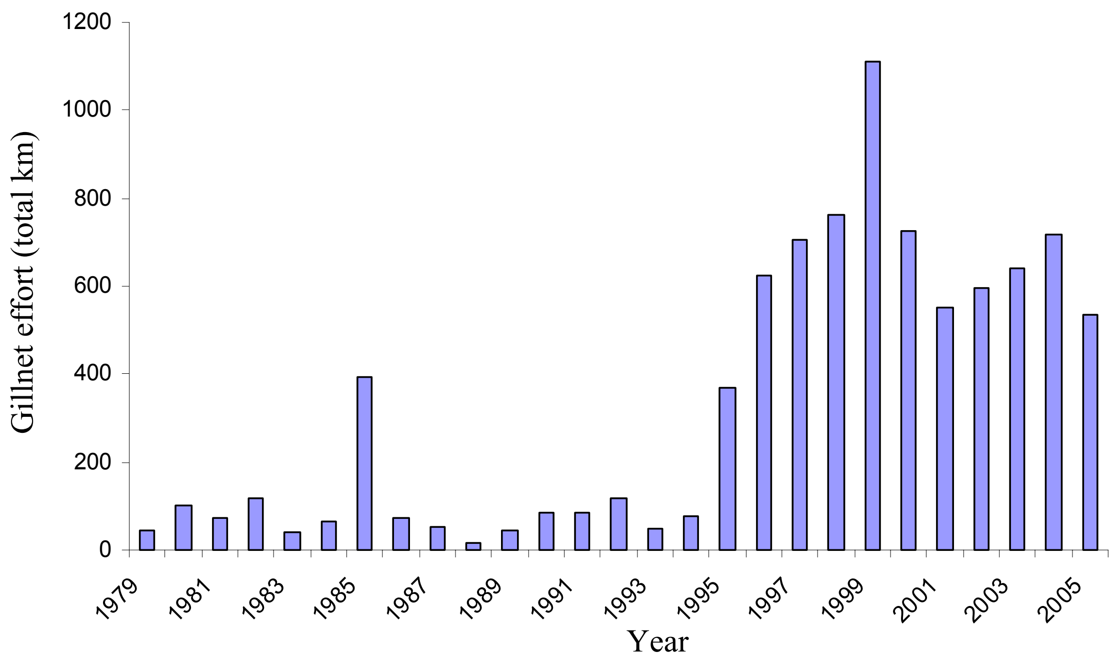


Figure 38. Total annual effort (km of gillnet) targeted at lake whitefish in region Georgian Bay West for years 1979 until 2005/2006.

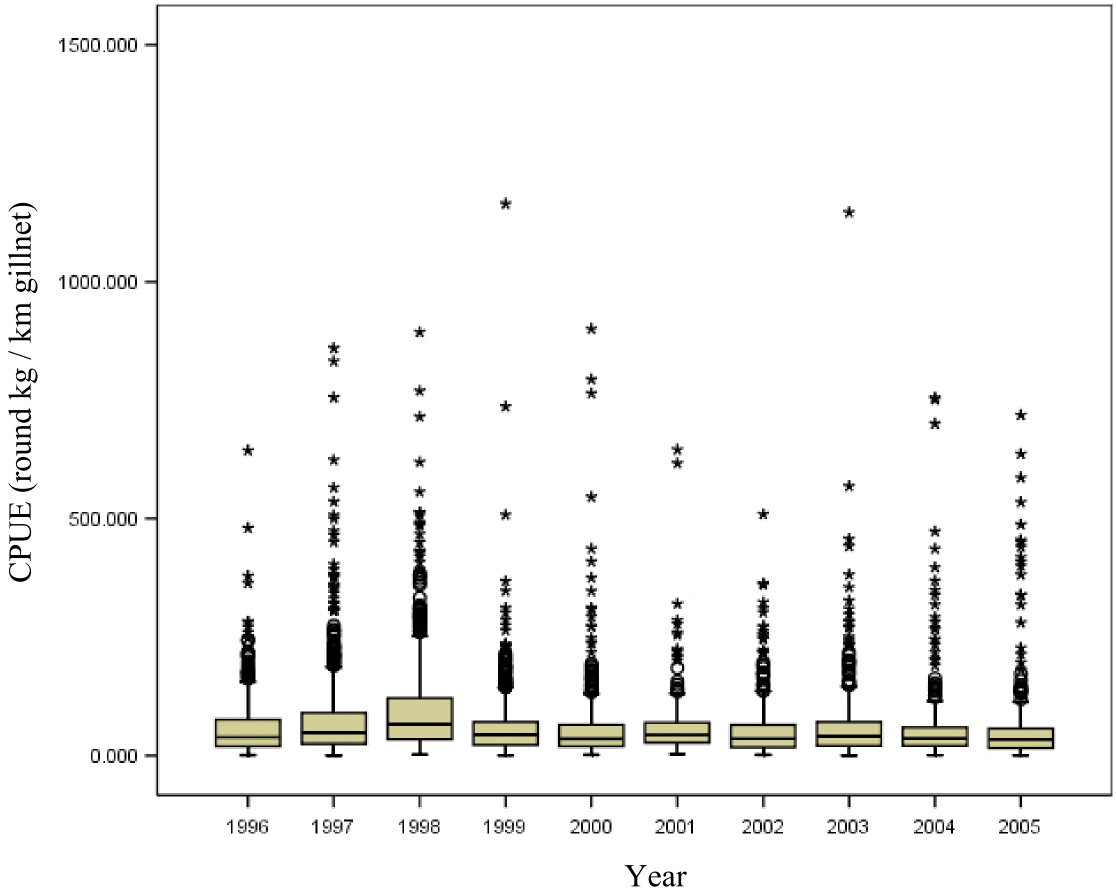


Figure 39. Box plot illustrations of annual CPUE (round kg / km gillnet) of targeted lake whitefish harvests in region Georgian Bay West for years 1996 to 2005.

3.2.2 Georgian Bay South

Harvest increased throughout the 1990's, with a peak harvest of ~150000 rkg in 2001 (Figure 40). Effort has been variable throughout the time series, but generally increased in the 1990's relative to historical values (Figure 41). Trends in CPUE are summarized in figure 42.

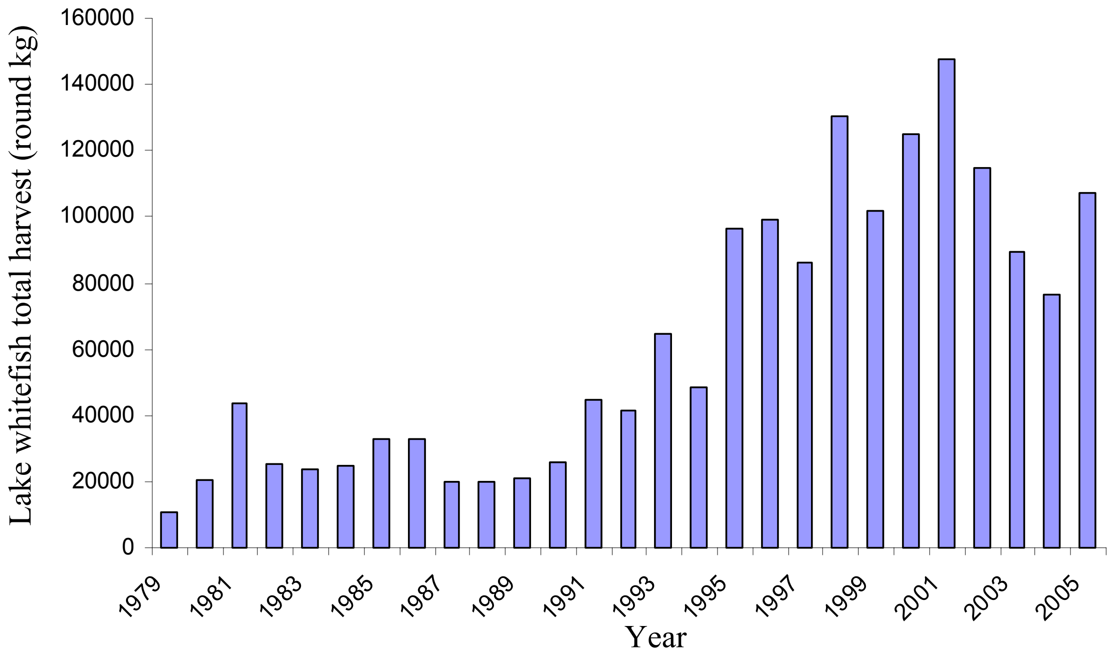


Figure 40. Total annual targeted harvest (round kg) of lake whitefish in region Georgian Bay South for years 1979 until 2005/2006.

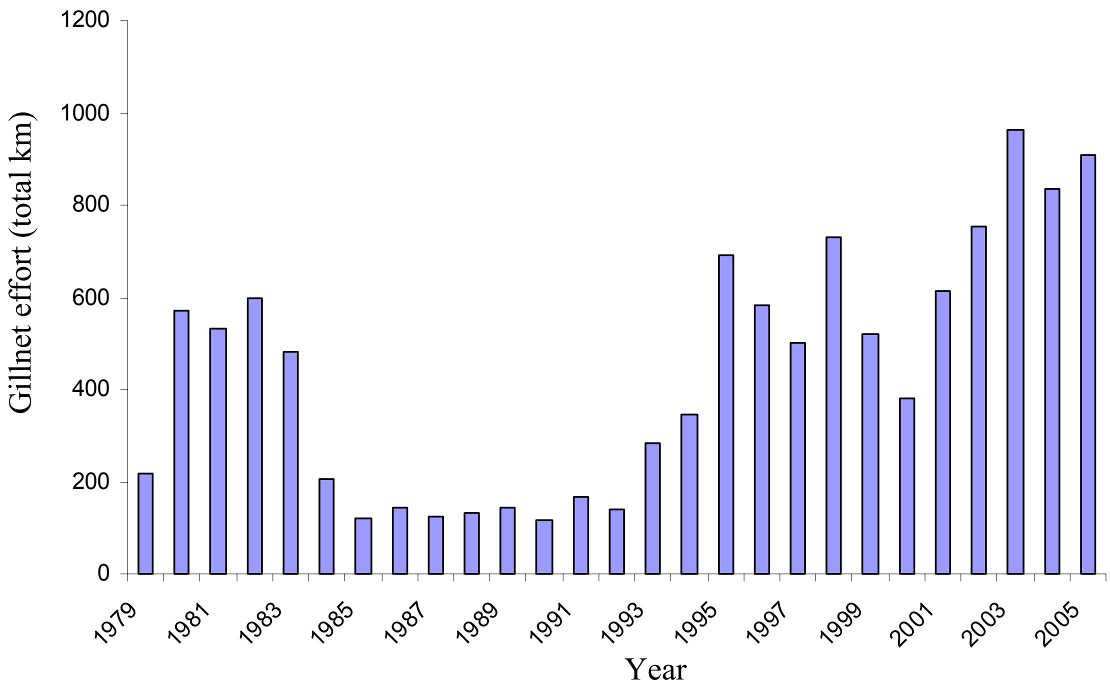


Figure 41. Total annual effort (km of gillnet) targeted at lake whitefish in region Georgian Bay South for years 1979 until 2005/2006.

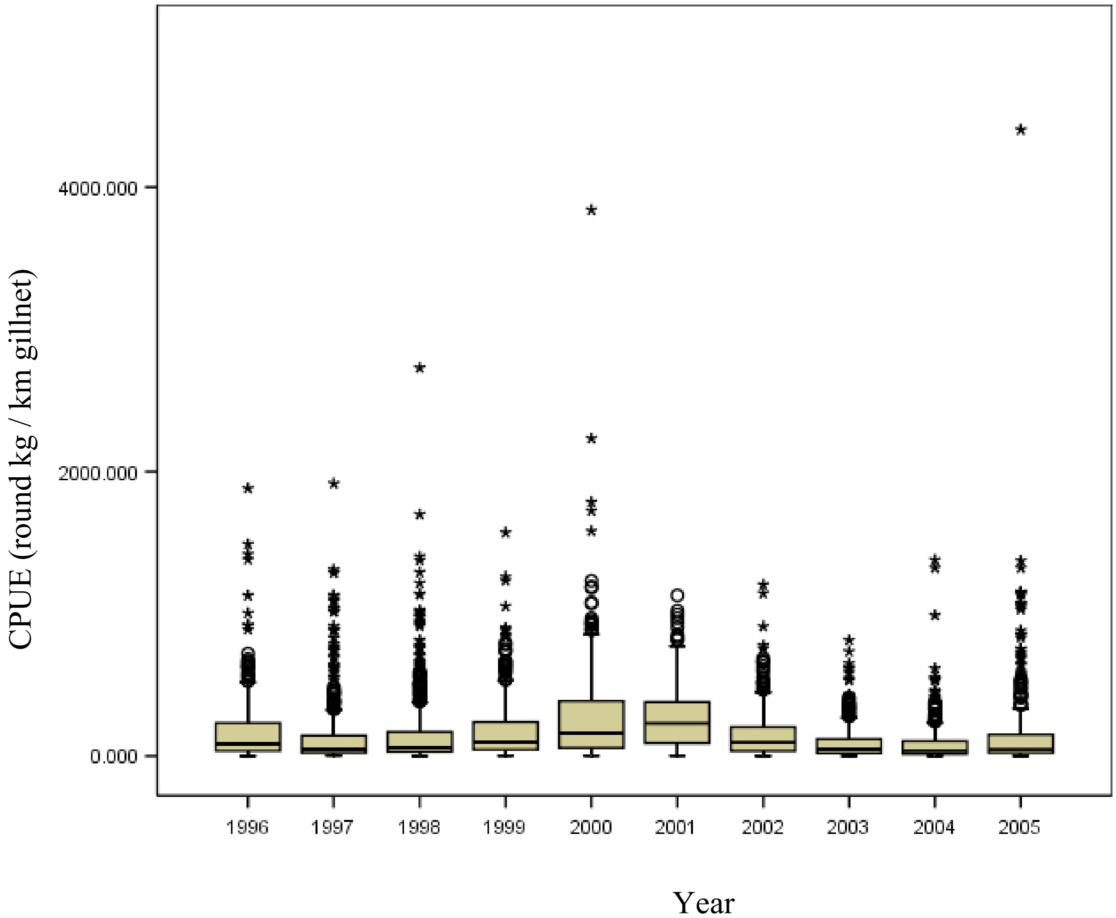


Figure 42. Box plot illustrations of annual CPUE (round kg / km gillnet) of targeted lake whitefish harvests in region Georgian Bay South for years 1996 to 2005.

4. Biological samples from commercial harvests and index assessment surveys

Biological samples are collected from commercial landings of Saugeen Ojibway Nations fishermen by the Saugeen Ojibway Nations Fisheries Harvest Assessment Program according to the procedures developed by Muir (2001). Records from the Saugeen Ojibway "individuals" database are amalgamated annually with the OMNR biological samples "cf" database. Data management procedures are outlined in Appendix 1.

Biological attributes of hypothesized whitefish populations were characterized by three descriptors of age and growth: annual number of age classes in the catch, age distribution of the catch and growth curves for recent cohorts. In general, these descriptors can provide general indicators of the risk of growth over-fishing, which occurs when harvested biomass consists of fish that have not reached an optimum size that maximizes harvested biomass while minimizing the number of individuals taken (Haddon 2001). There are two caveats to assessing a fishery in this manner. First, this approach on its own does not directly address the sustainability of any given harvest level. Second, optimal yield for the Saugeen Ojibway Nations whitefish fishery remains unknown; however, larger fish are more desirable economically and generally more desirable ecologically as a TAC consisting of larger individuals would contain fewer total individuals than if the total biomass consisted of smaller individuals.

Based the biological attributes evaluated here, maintaining harvest levels similar to recent years would be considered risk prone when: (i) consistent declines in the number of age-classes are evident; (ii) fish are not allowed to reach larger sizes (or older ages), as represented in the loss or decline of older age groups; and, (iii) weight-at-age has declined repeatedly between successive cohorts. Further, age and growth attributes provide observations for the development of alternative hypotheses about fishery-induced and environmental effects on whitefish populations and the formulation of predictive models.

Age classes were defined as individuals between age i and $i + 1$. For example, an individual belonging to the 1999 cohort would belong to the 1 year-old age class in 2000, the 2 year old age class in 2001, etc. Sample size of aged fish (scales only) used in following sections (4.2 – 4.4) is listed for each region and basin in table 2. Age and growth summaries were not conducted for GB-W due to a small sample size of aged fish.

Table 2. Sample size of aged whitefish from commercial harvest biological samples and from OMNR index assessment surveys. Summarized are whitefish aged using scales between 1995 and 2005.

Hypothesized whitefish distributions	OMNR	Saugeen Ojibway Nations	Total
Commercial Harvest Samples			
Main Basin	28468	1847	30315
Main Basin East	4158	1847	6005
Main Basin South	14569	n/a	14569
Main Basin South + East	18727	1847	20574
Georgian Bay	22997	1409	24406
Georgian Bay South	14459	507	14966
Georgian Bay West	641	902	1543
Index Assessment Samples			
Main Basin	4796	n/a	4796
Main Basin East	2189	n/a	2189
Main Basin South	2607	n/a	2607
Main Basin South + East	4796	n/a	4796
Georgian Bay	6400	n/a	6400
Georgian Bay South	6357	n/a	6357
Georgian Bay West	43	n/a	43
Total Individuals Aged in Agreement Waters (*MB-E* + *GB-S* + *GB-W*)	27847	3256	31103
Percent of total individuals aged	89%	11%	100%

4.1 Trends in mesh size

Increases in mean mesh size as well as increases in variation in mesh size use occurred beginning between 1993 and 1995 for all regions and Main Basin and Georgian Bay (Figures 43-49). Consequently, we limited our evaluations biological characteristics of the catch to a 10 year period between 1995 and 2005 to limit to the extent possible the influence of mesh size on observed trends.

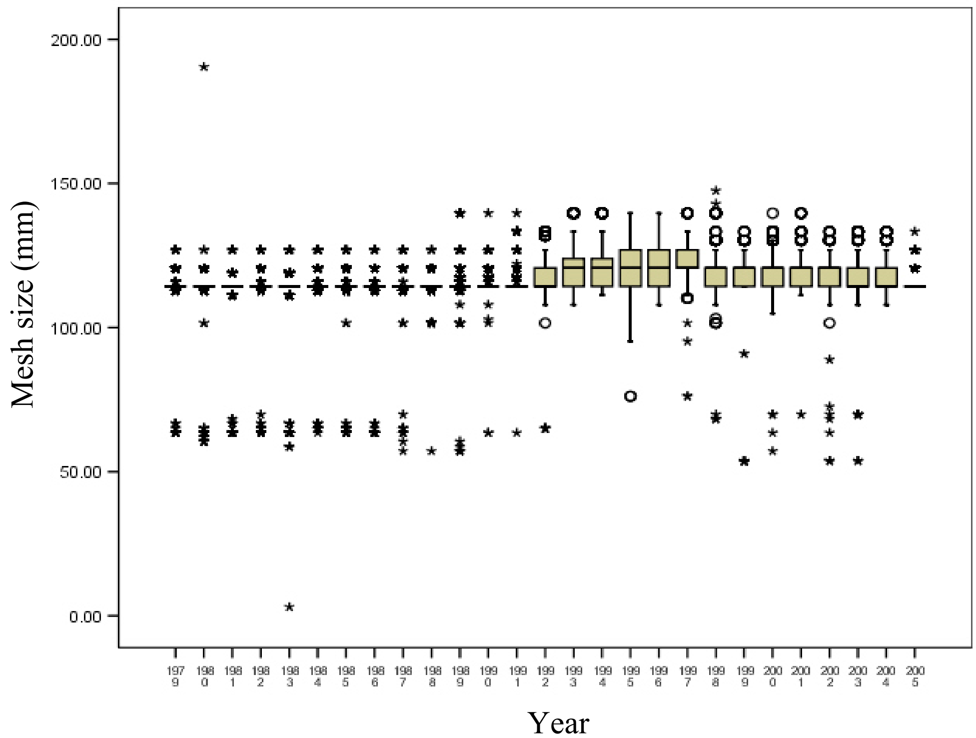


Figure 43. Box plot illustrations of mesh sizes of gillnet targeted at lake whitefish in Main Basin for years 1979 until 2005/2006.

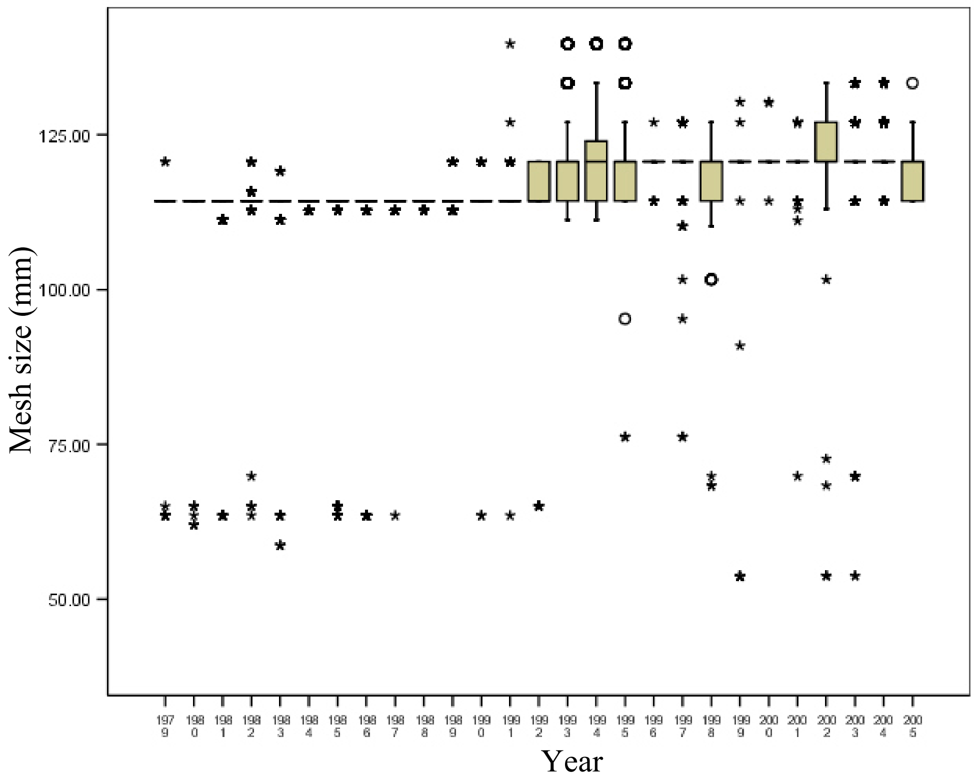


Figure 44. Box plot illustrations of mesh sizes of gillnet targeted at lake whitefish in Main Basin East for years 1979 until 2005/2006.

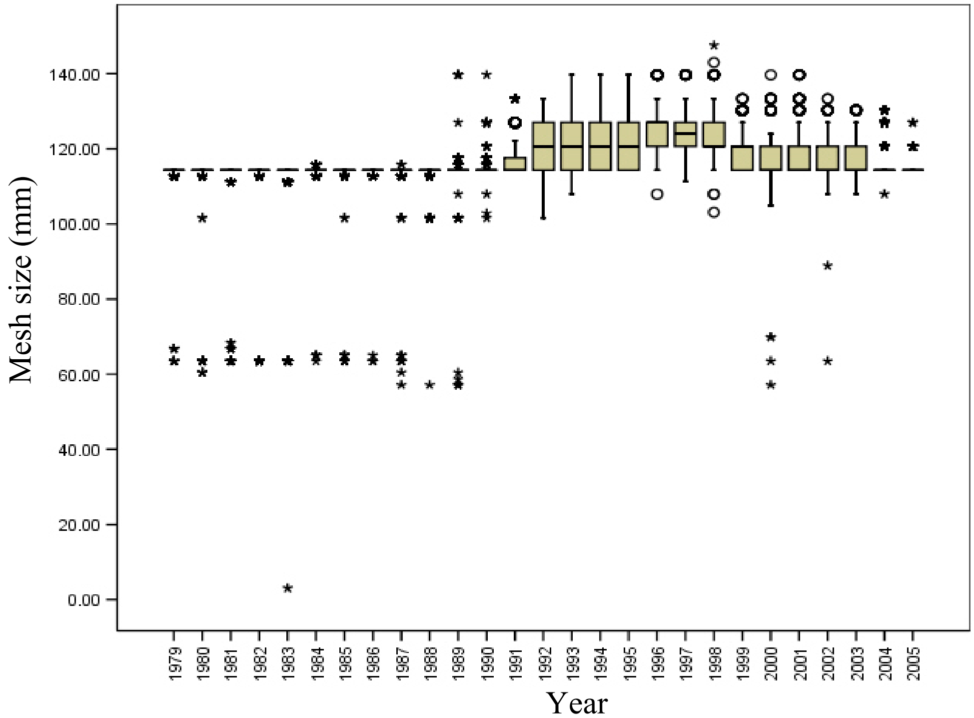


Figure 45. Box plot illustrations of mesh sizes of gillnet targeted at lake whitefish in Main Basin South for years 1979 until 2005/2006.

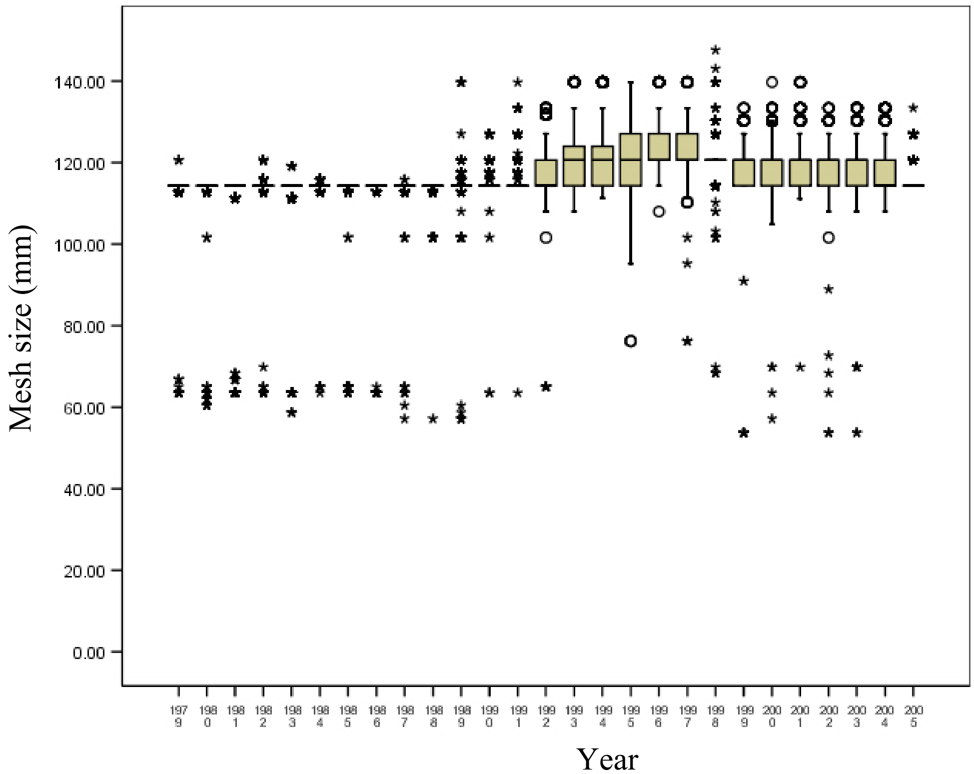


Figure 46. Box plot illustrations of mesh sizes of gillnet targeted at lake whitefish in Main Basin Southeast for years 1979 until 2005/2006.

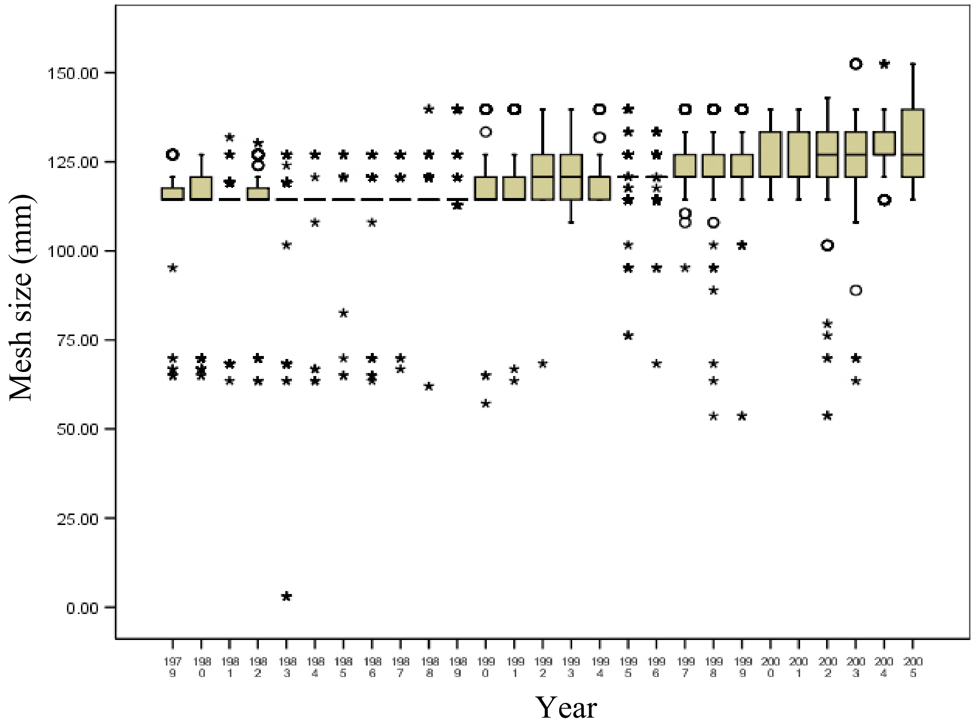


Figure 47. Box plot illustrations of mesh sizes of gillnet targeted at lake whitefish in Georgian Bay for years 1979 until 2005/2006.

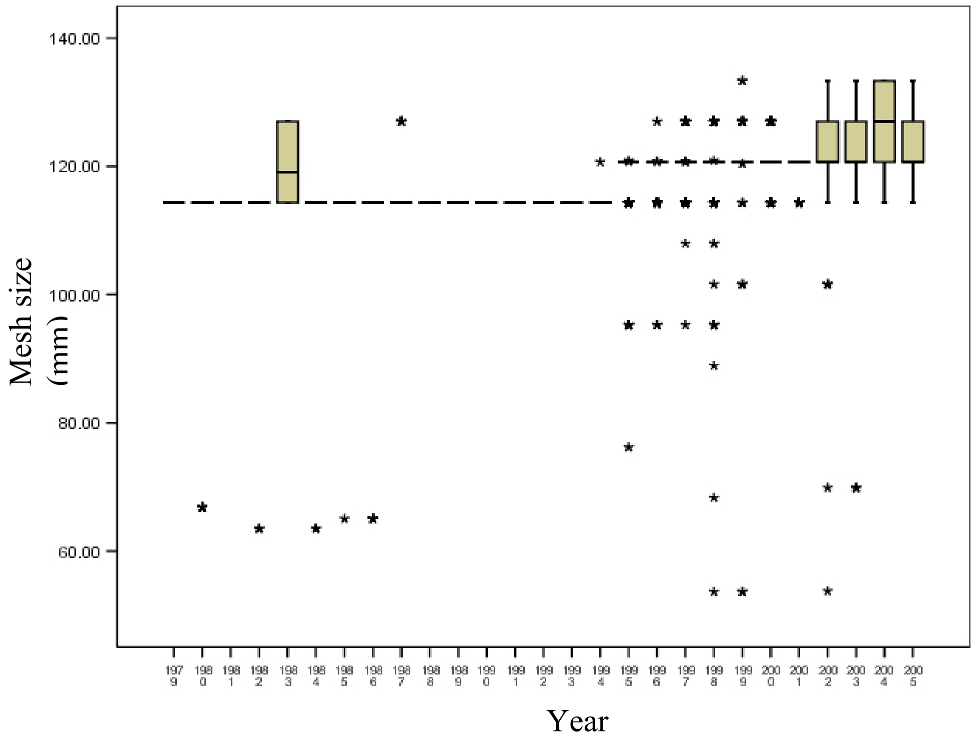


Figure 48. Box plot illustrations of mesh sizes of gillnet targeted at lake whitefish in Georgian Bay West for years 1979 until 2005/2006.

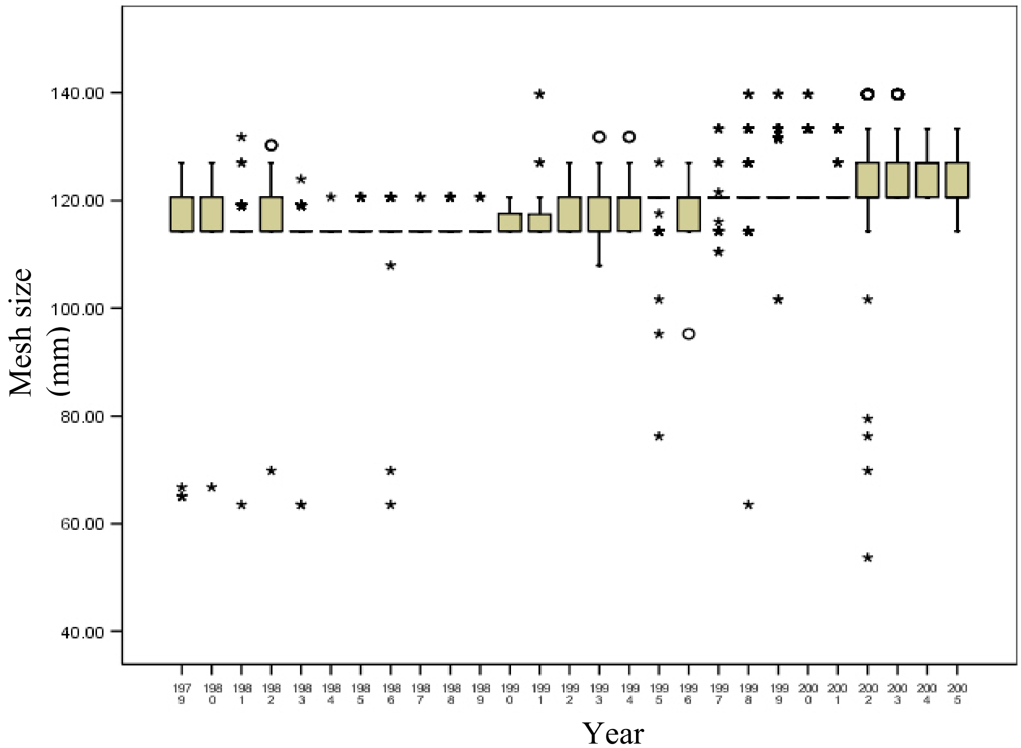


Figure 49. Box plot illustrations of mesh sizes of gillnet targeted at lake whitefish in Georgian Bay South for years 1979 until 2005/2006.

4.2 Age structure of catch

Age structure of catch was summarized as the annual number of age classes in the commercial harvest. Declines in the number of age classes over time should elicit careful consideration of hypothesized explanations of this trend, including environmental effects on recruitment of year classes to the fishery, and fishery-induced effects such as gear selectivity.

Age structure estimates for Main Basin indicate a relatively constant number of age-classes since the shift in mesh size in the early 1990's (Figure 50). Sharp declines in total age classes in Main Basin East occurred in the late 1990's, but have since rebounded (Figure 51). Age structure of catch in Main Basin South remained relatively constant since the early 1990's (Figure 52). No trend in age-structure is evident for Main Basin Southeast (Figure 53). Age structure estimates for Georgian Bay are variable; however, no trend through time is evident (Figure 54). Age structure estimates for Georgian Bay South indicate a relatively constant number of age-classes since the shift in mesh size in the early 1990's (Figure 55).

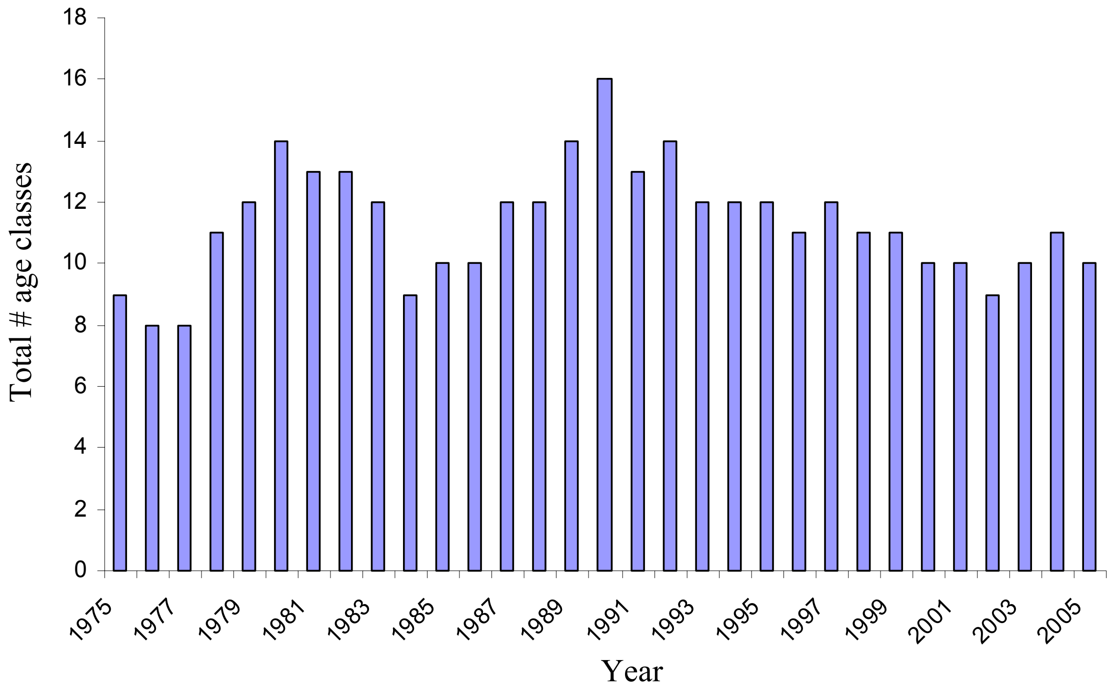


Figure 50. Annual age structure (# of age classes in catch) of commercial harvest in Main Basin for years 1979 until 2005/2006.

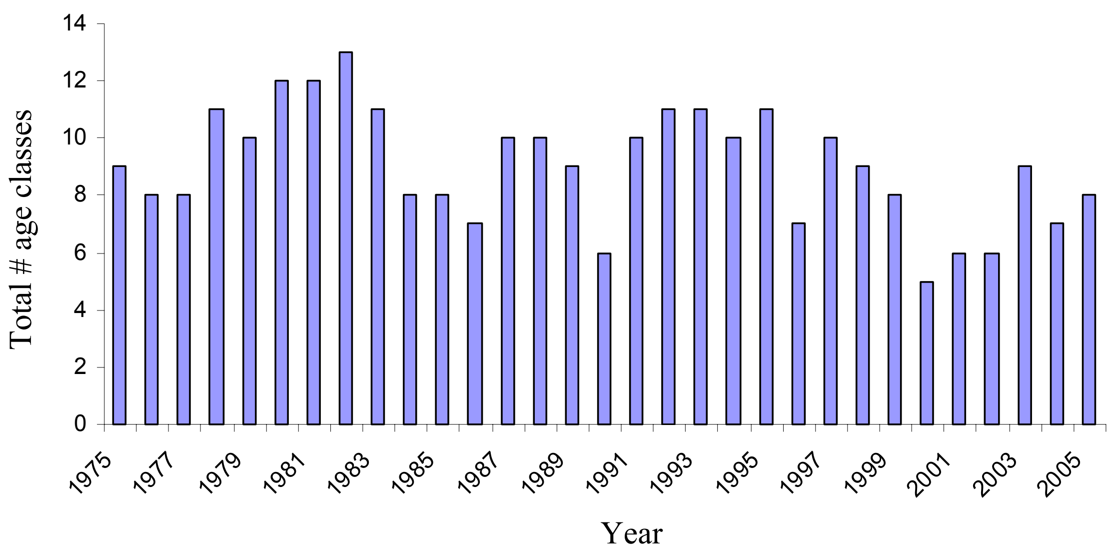


Figure 51. Annual age structure (# of age classes in catch) of commercial harvest in Main Basin East for years 1979 until 2005/2006.

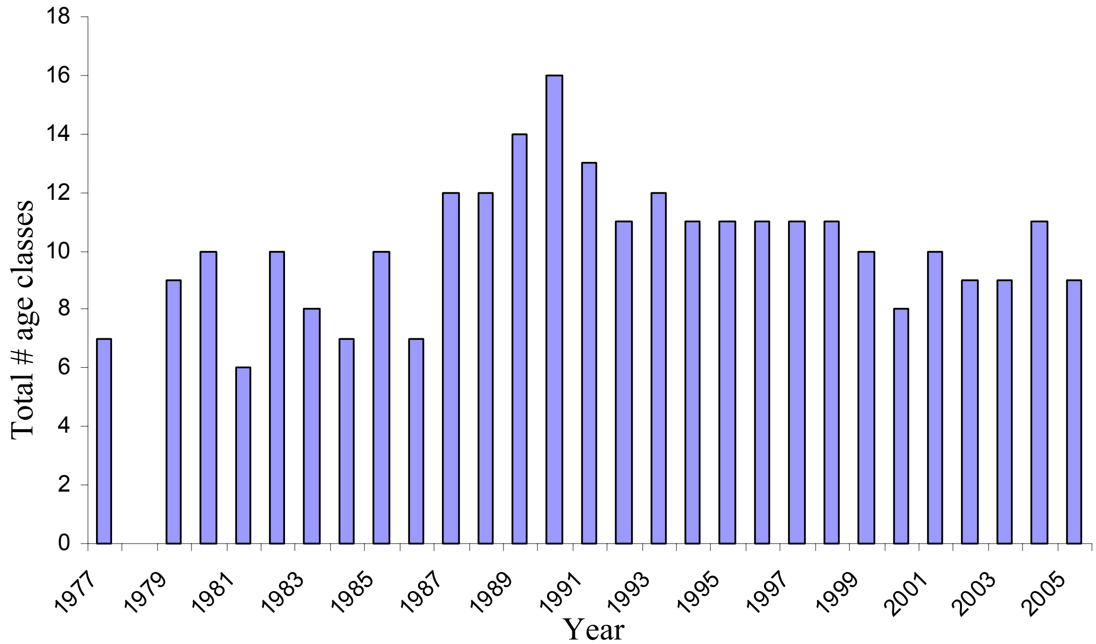


Figure 52. Annual age structure (# of age classes in catch) of commercial harvest in Main Basin South for years 1979 until 2005/2006.

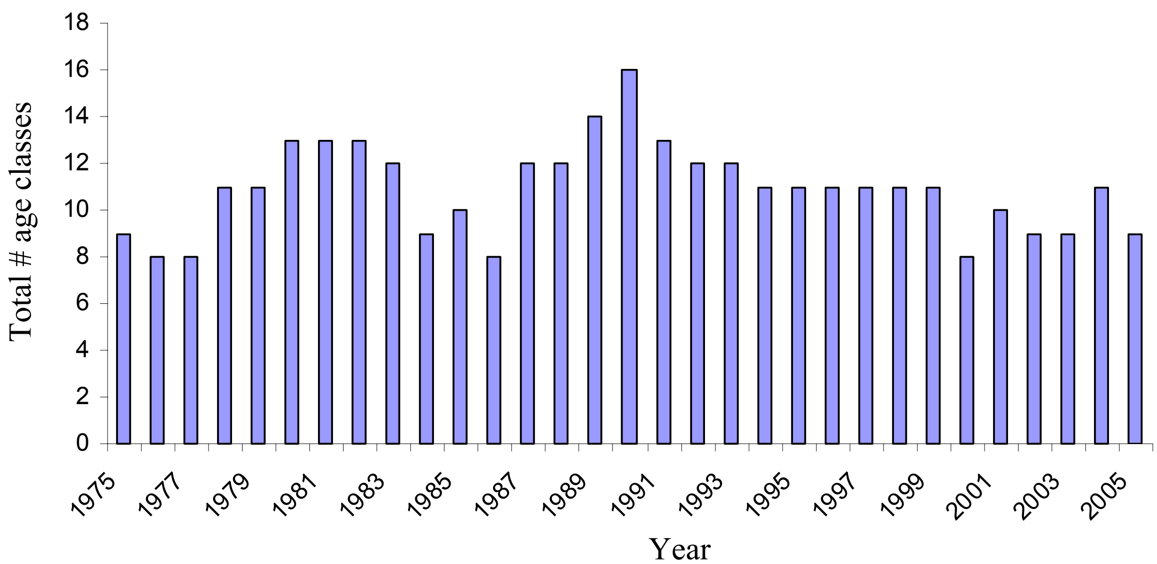


Figure 53. Annual are structure (# of age classes in catch) of commercial harvest in Main Basin Southeast for years 1979 until 2005/2006.

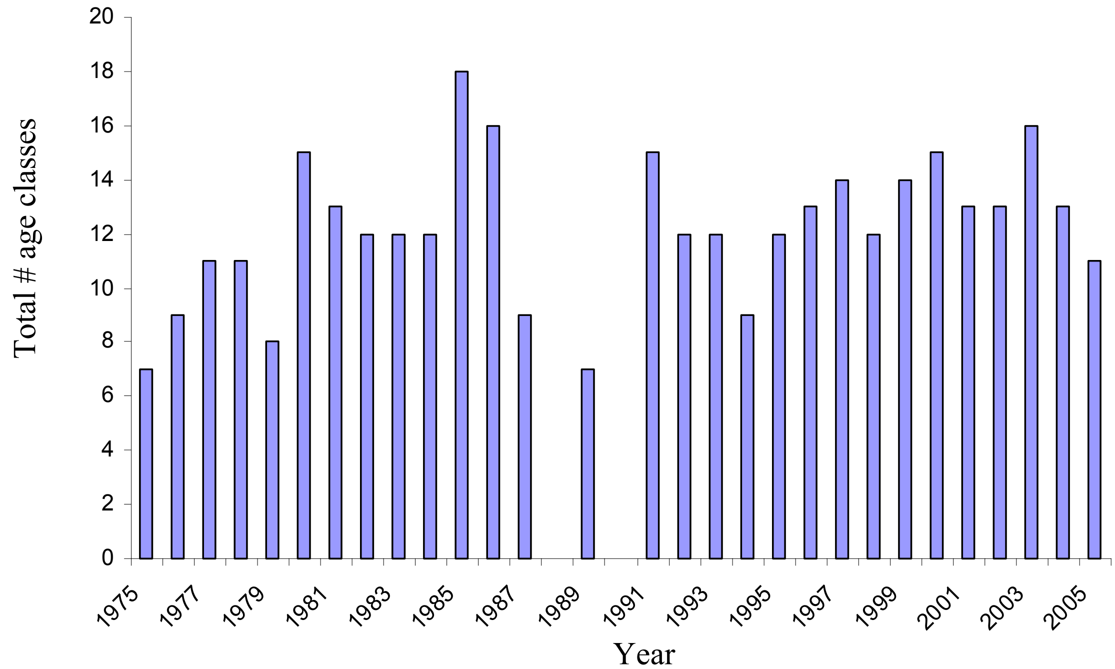


Figure 54. Annual age structure (# of age classes in catch) of commercial harvest in Georgian Bay for years 1979 until 2005/2006.

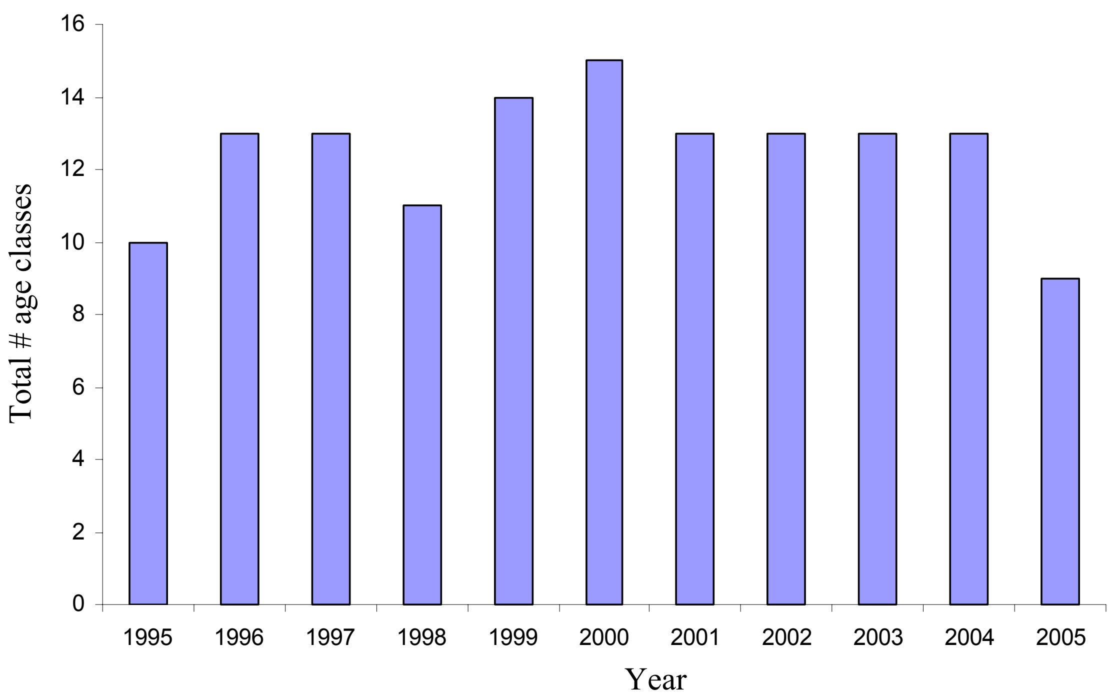


Figure 55. Annual age structure (# of age classes in catch) of commercial harvest in Georgian Bay South for years 1995 until 2005.

4.3 Age distribution of catch

Age distribution of whitefish in the commercial harvest in each basin and region are summarized by year from 1995 – 2005 (Figures 56 - 62). Declining frequency of older age-classes may indicate that continued harvest at current levels is risk prone due to because harvested biomass will consist of continued removal of smaller individuals from the population. Declining frequency of younger age-classes may indicate reduced recruitment and reduction of TAC should be considered.

Age distributions from regions within Main Basin all indicated that a shift, or perhaps a recovery, to older age classes (>8 years) is occurring (Figures 56-59). No trend in age distribution is evident for Georgian Bay and Georgian Bay South; however, greater inter-annual shifts in age distributions are evident relative to Main Basin regions. These trends indicate that harvest strategies consistent with current practices are not risk prone for Main Basin or Georgian Bay.

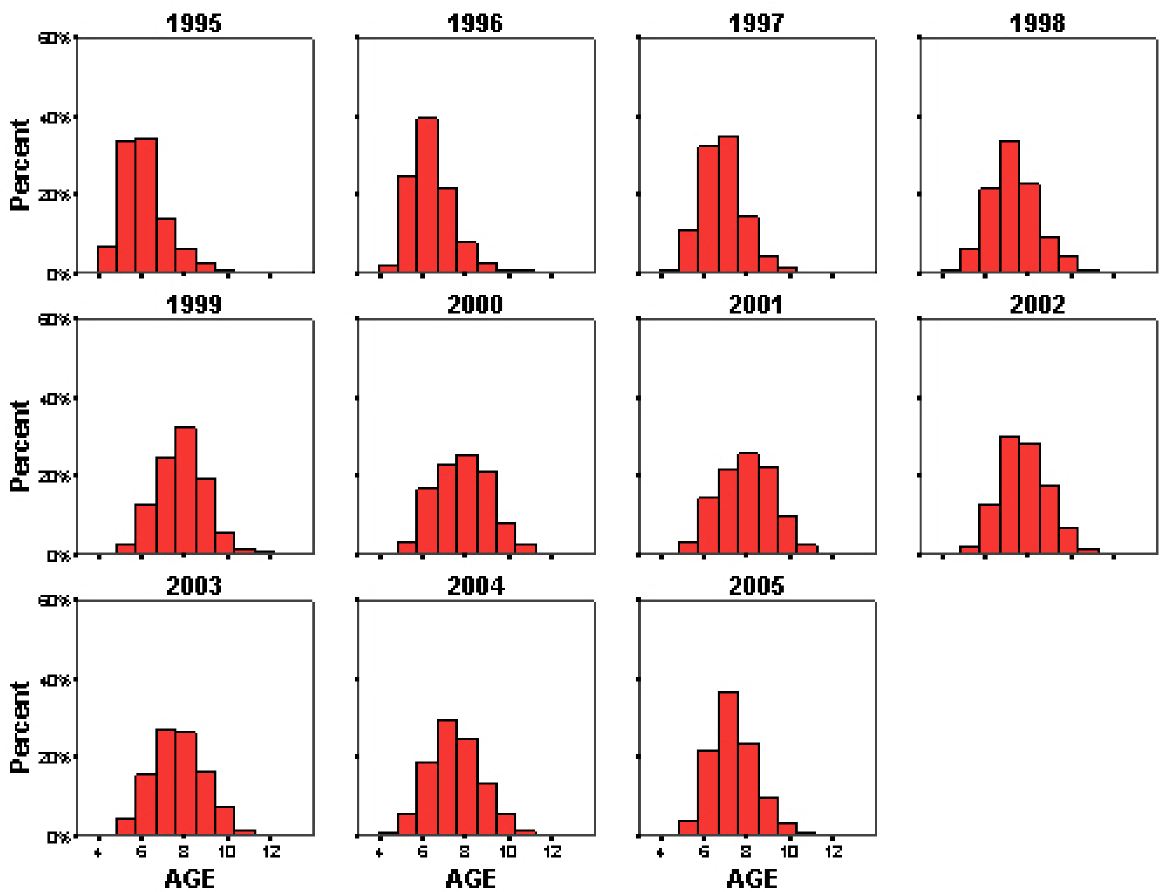


Figure 56. Age distribution of lake whitefish commercial catch in Main Basin for years 1995 to 2005.

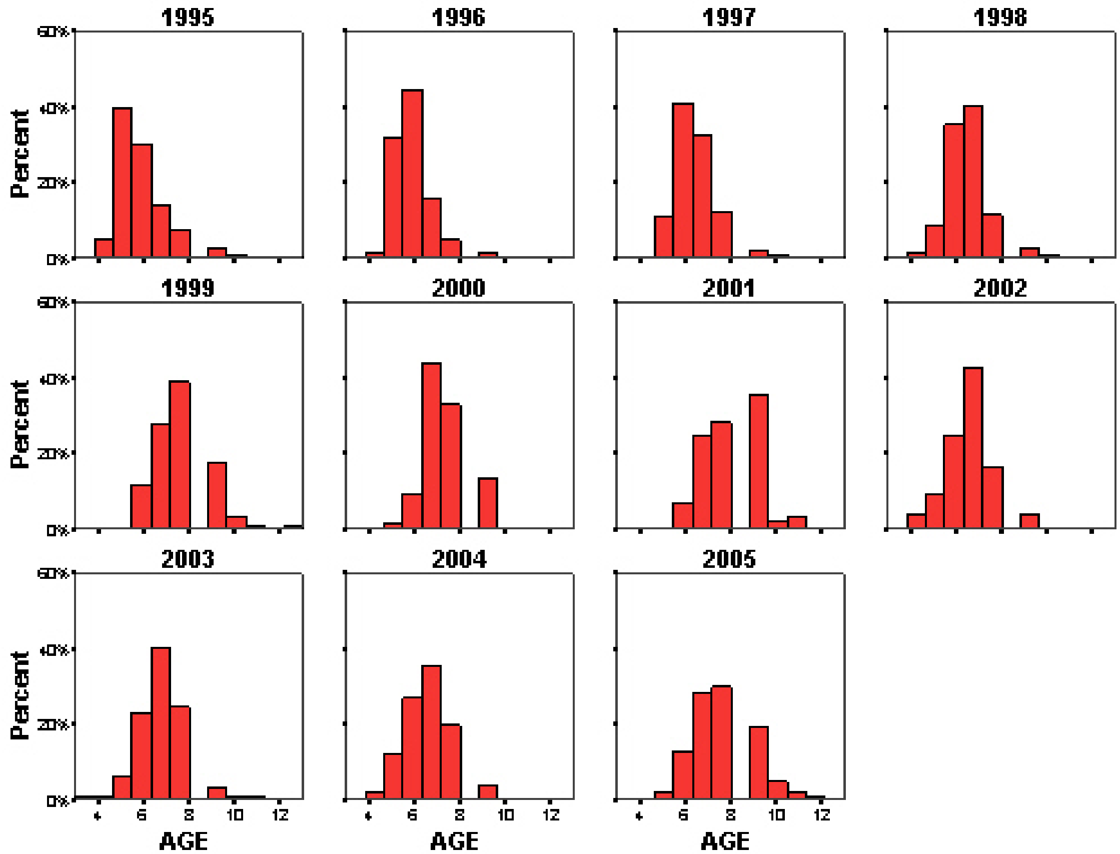


Figure 57. Age distribution of lake whitefish commercial catch in Main Basin East for years 1999 to 2005.

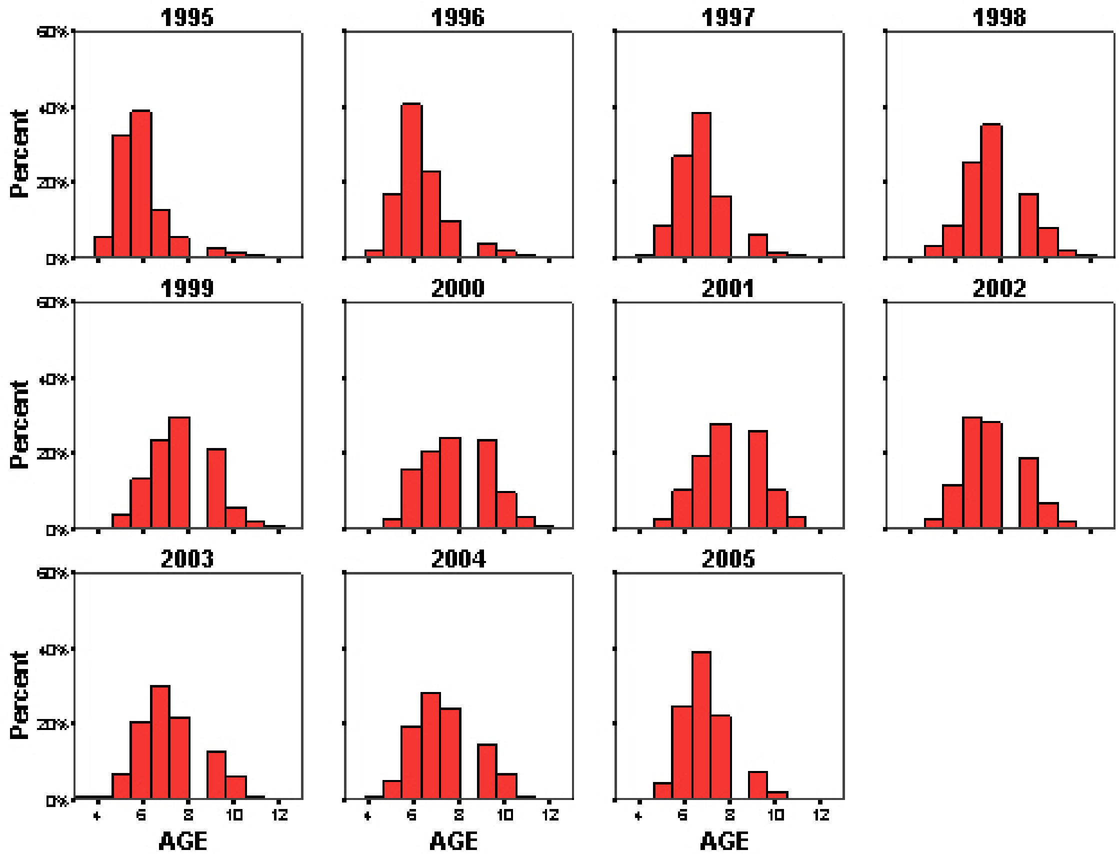


Figure 58. Age distribution of lake whitefish commercial catch in Main Basin South for years 1999 to 2005.

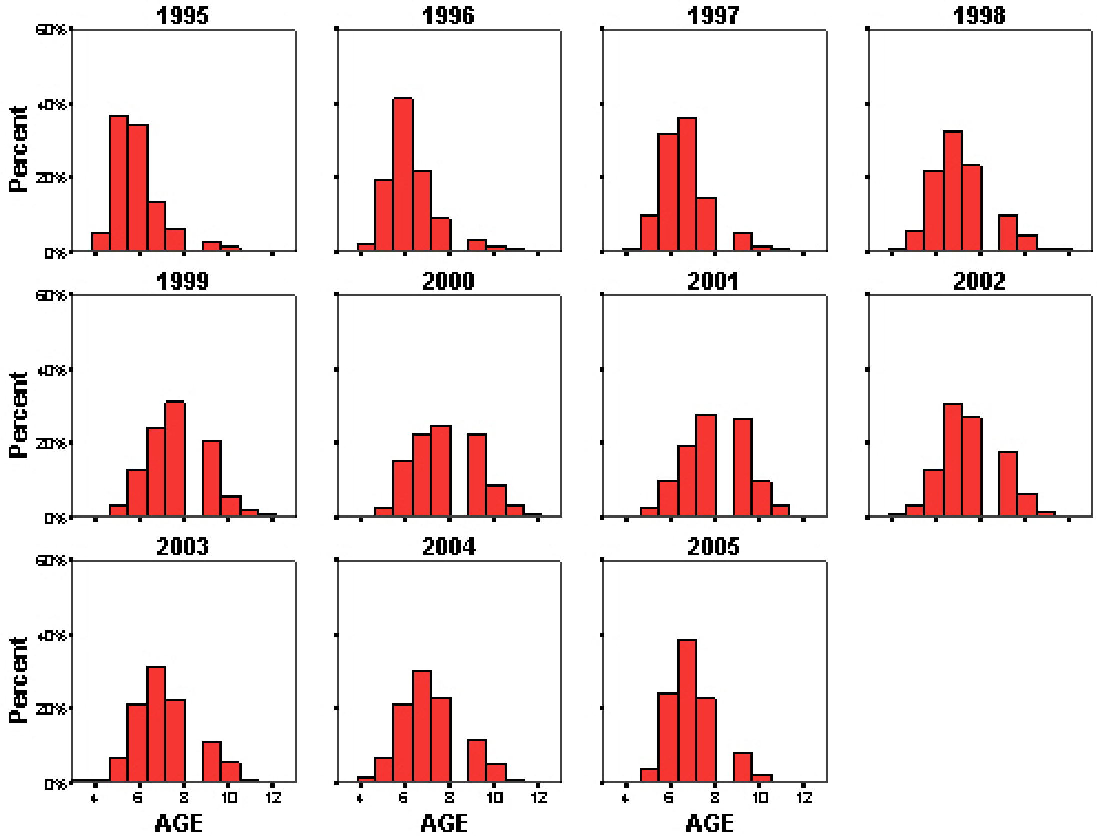


Figure 59. Age distribution of lake whitefish commercial catch in Main Basin Southeast for years 1999 to 2005.

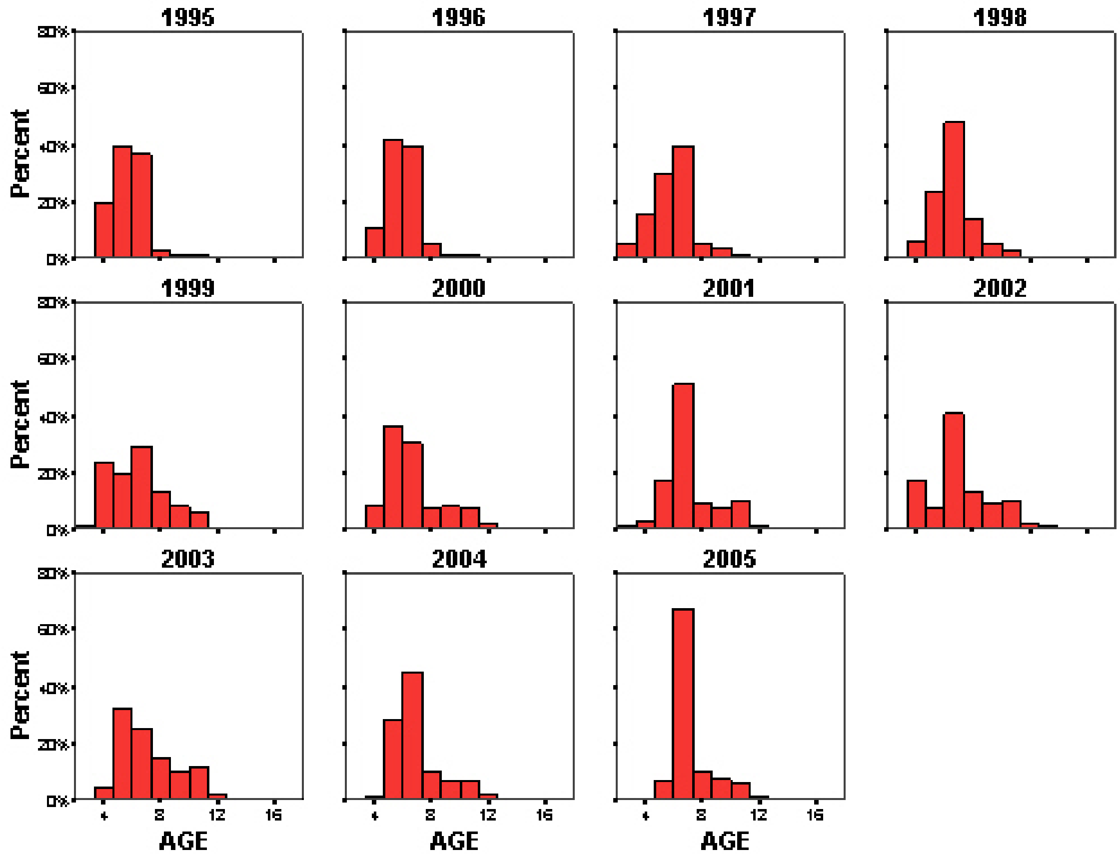


Figure 60. Age distribution of lake whitefish commercial catch in Georgian Bay for years 1999 to 2005.

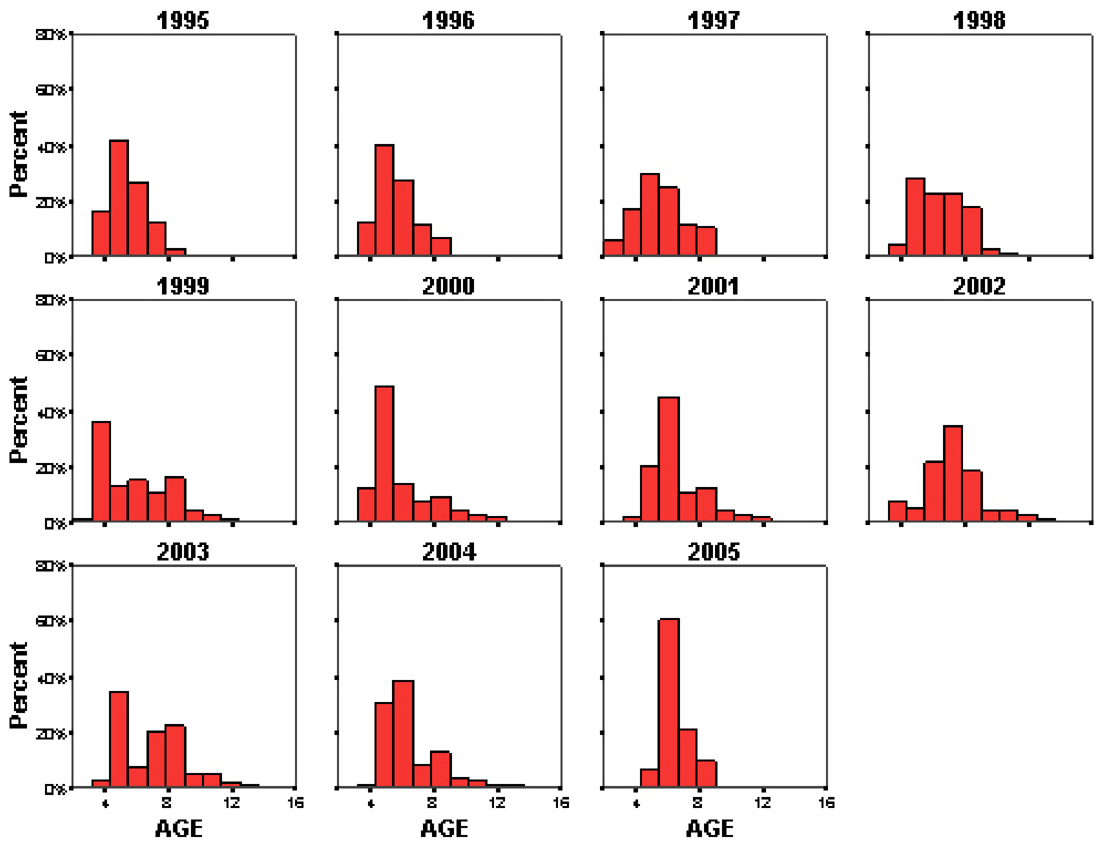


Figure 61. Age distribution of lake whitefish commercial catch in Georgian Bay South for years 1999 to 2005.

4.4 Growth Rate of Catch

Aged individuals from the commercial catch database were pooled with aged individuals from the OMNR index assessment database in an effort to include all available age data in our growth rate analysis. Growth curves were generated for each cohort for ages-classes 4 to 9+. Growth curves were plotted against total harvest (rkg) to examine whether reduced growth rates were evident following higher harvest levels as an indicator that harvest levels may limit individuals from reaching larger sizes. Further, each cohort was characterized as low density dependent or high density dependent to examine whether course trends in density dependent growth was evident. Designation as a low or a high density dependent cohort was based on whether the total CPUE when the cohort reached age 4 was below or above the median CPUE for the entire time series. For example, we began our analysis with the 1991 cohort because these fish recruited to the fishery at age 4 in 1995. If the 1995 total CPUE was less than the median CPUE we would classify the 1991 cohort as a low density dependant cohort, otherwise it would be classified as a high density dependant cohort. The median year is consistently grouped as a low density dependant cohort. Median CPUE is summarized by basin and region in figures 62 – 67. Trends in growth with respect to years of low and high density dependence are characterized for each basin and region in figures 68 – 73.

Declines in weight-at-age for Main Basin are evident, although these trends do not appear to be short term trends (< 5 years) in harvested biomass (Figure 68). Conversely, declines in weight-at-age are not evident when the data are summarized by Main Basin East and Main Basin South, but can be observed when these datasets are pooled as Main Basin Southeast (Figures 69 - 71). Growth rate trends indicate that continued harvests at current levels in Main Basin are not risk prone. Declines in weight-at-age are evident for Georgian Bay and less evident for Georgian Bay South (Figures 72 and 73). The magnitude of the effect of these declines on sustainability is unknown; therefore, growth rate summaries for Georgian Bay suggest that risk adverse strategies would include reducing the TAC for Georgian Bay.

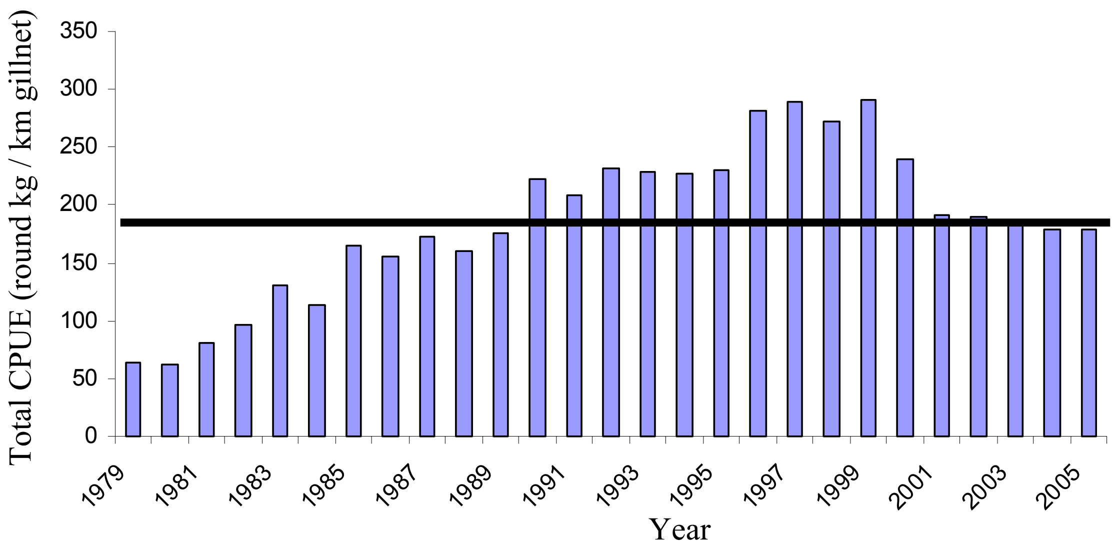


Figure 62. Total CPUE (round kg / km gillnet) for Main Basin. Horizontal line indicates the total CPUE Main Basin median = 185 for years 1979 until 2005/2006.

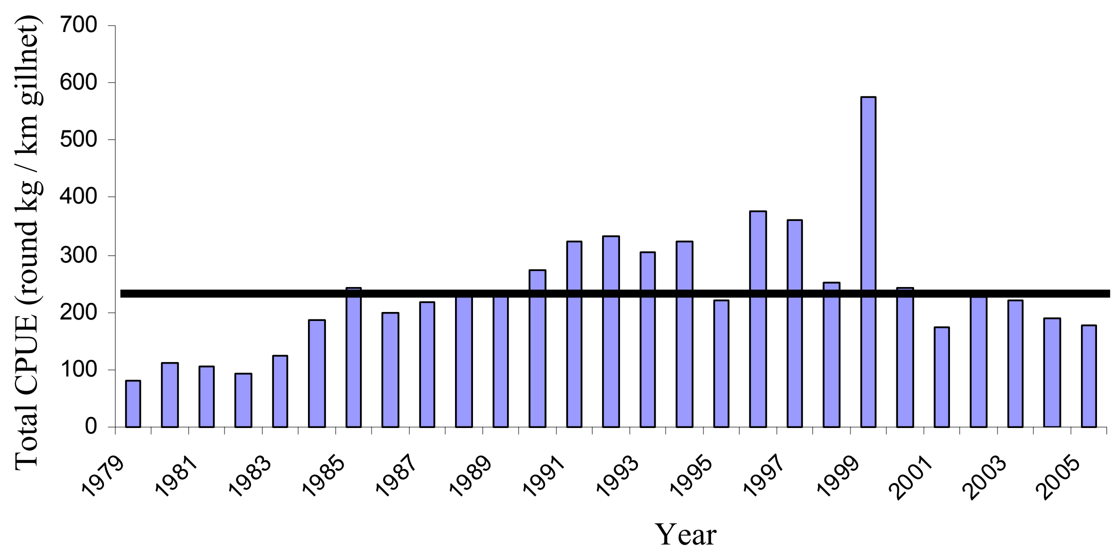


Figure 63. Total CPUE (round kg / km gillnet) for Main Basin East. Horizontal line indicates total CPUE Main Basin East median = 227 for years 1979 until 2005/2006.

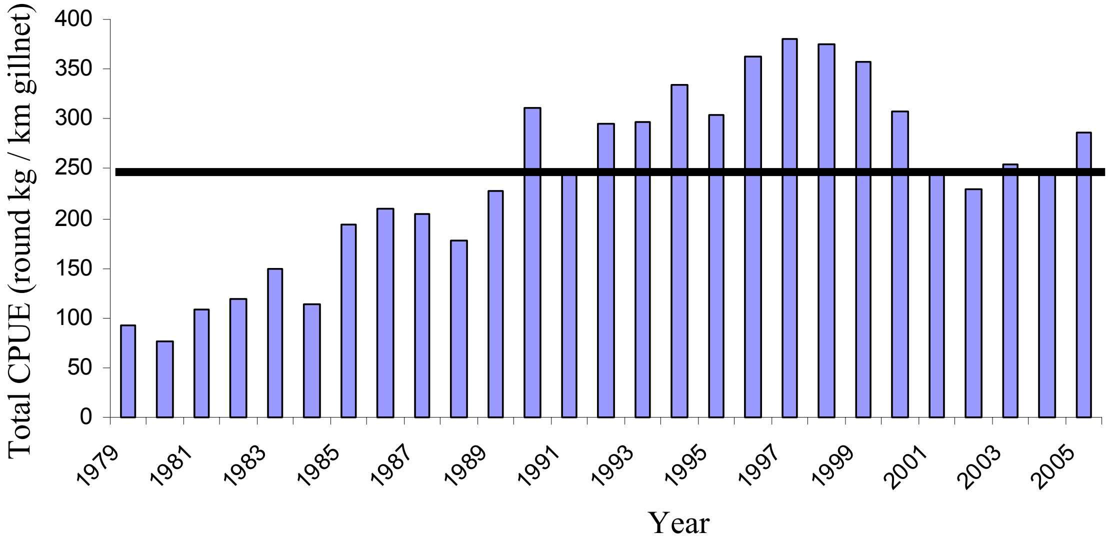


Figure 64. Total CPUE (round kg / km gillnet) for Main Basin South. Horizontal line indicates the total CPUE Main Basin South median = 248 for years 1979 until 2005/2006.

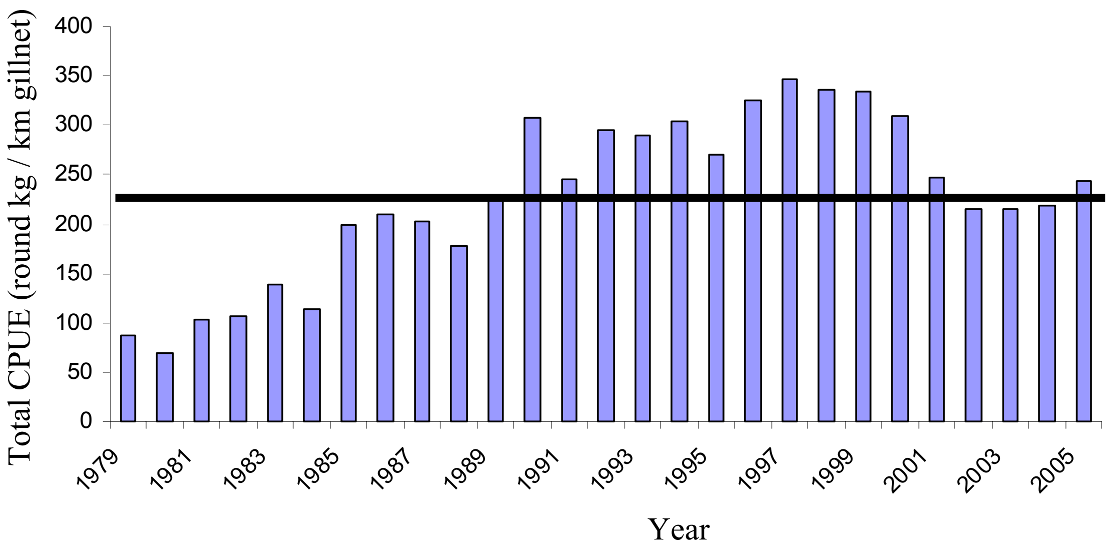


Figure 65. Total CPUE (round kg / km gillnet) for Main Basin Southeast. Horizontal line indicates the total CPUE Main Basin Southeast median = 223 for years 1979 until 2005/2006.

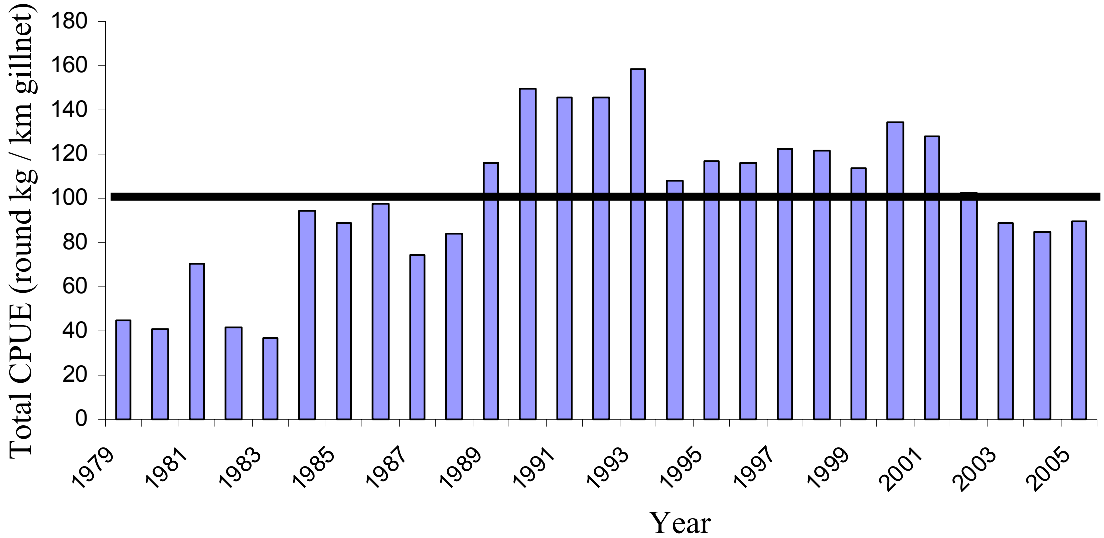


Figure 66. Total CPUE (round kg / km gillnet) for Georgian Bay. Horizontal line indicates the total CPUE Georgian Bay median = 102 for years 1979 until 2005/2006.

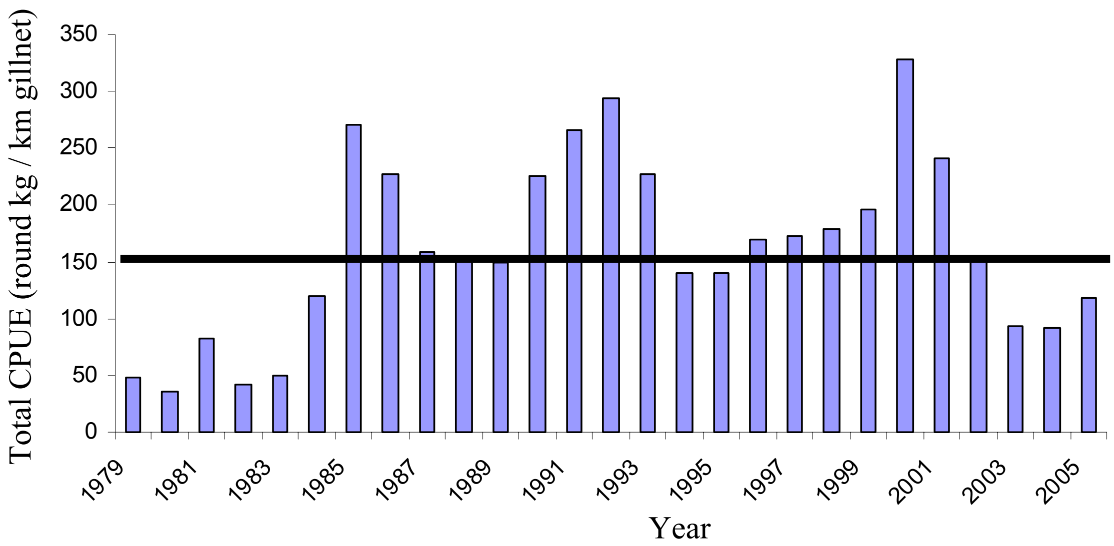


Figure 67. Total CPUE (round kg / km gillnet) for Georgian Bay South. Horizontal line indicates the total CPUE Georgian Bay South median = 153 for years 1979 until 2005/2006.

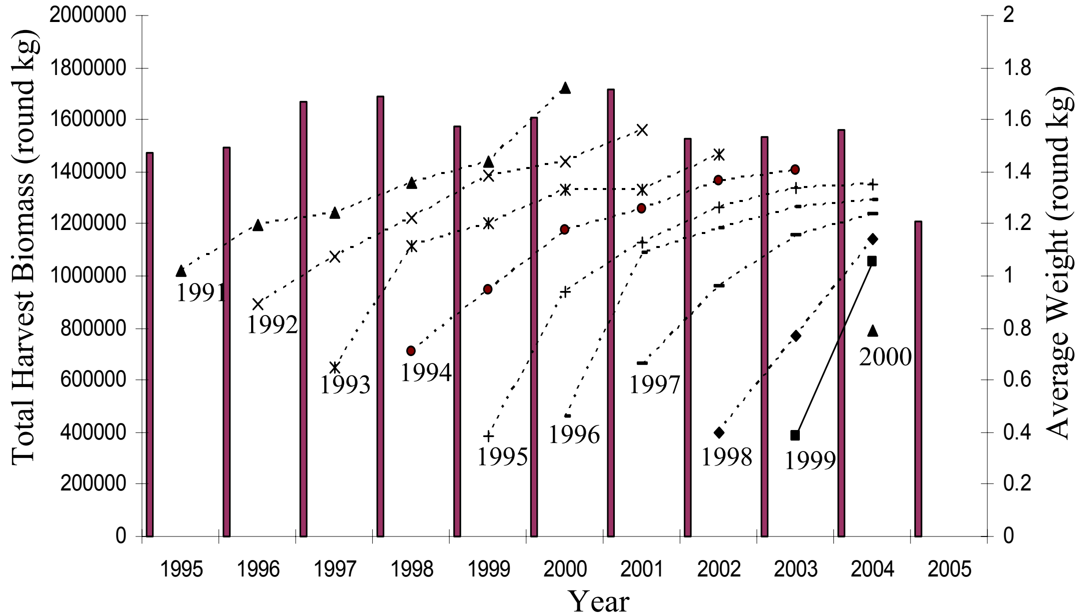


Figure 68. Main Basin total harvest (Bars) and average weight-at-age (rkg) for 1991 – 2000 cohorts (lines). All weight-at-age time series begin at age 4 and increase in 1 year increments. Solid lines indicate a low density dependant cohort and dashed lines indicate a high density dependant cohort.

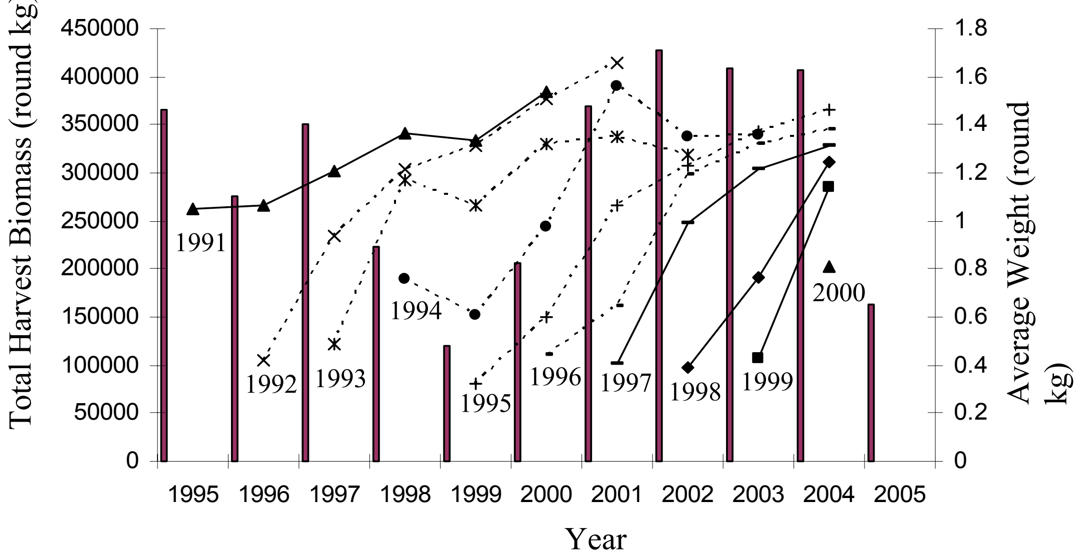


Figure 69. Main Basin East total harvest (Bars) and average weight-at-age (rkg) for 1991 – 2000 cohorts (lines). All weight-at-age time series begin at age 4 and increase in 1 year increments. Solid lines indicate low density dependant cohorts and dashed lines indicate high density dependant cohorts.

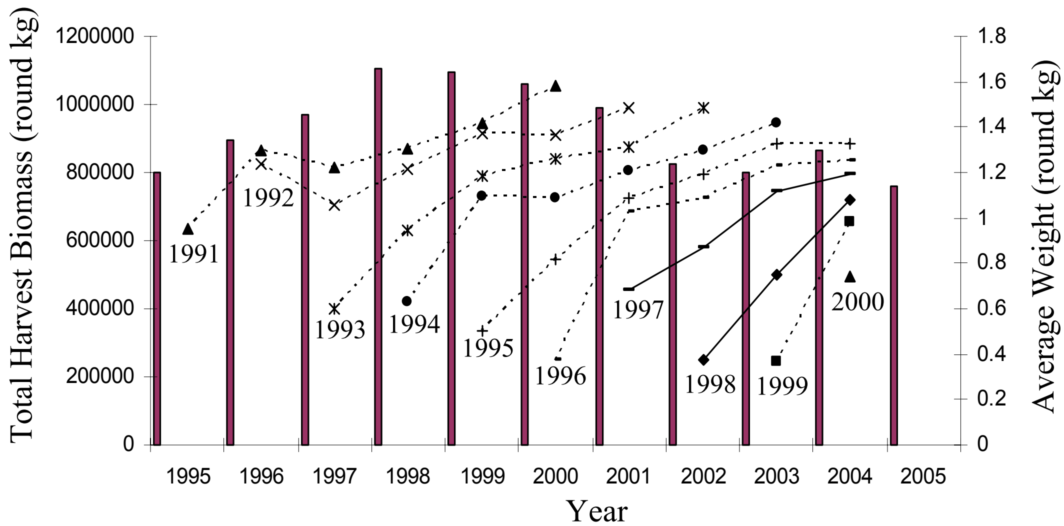


Figure 70. Main Basin South total harvest (Bars) and average weight-at-age (rkg) for 1991 – 2000 cohorts (lines). All weight-at-age time series begin at age 4 and increase in 1 year increments. Solid lines indicate low density dependant cohorts and dashed lines indicate high density dependant cohorts.

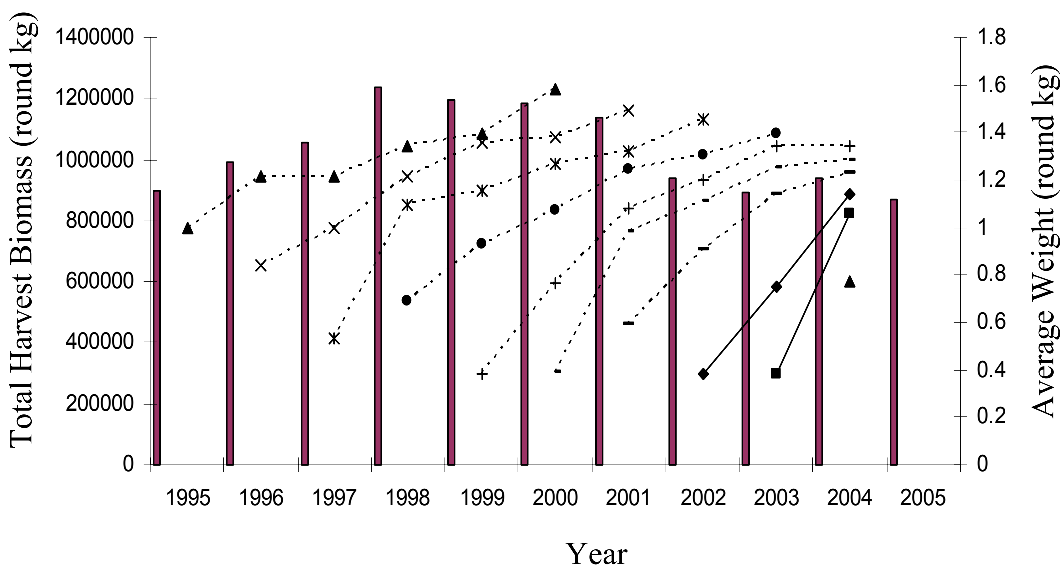


Figure 71. Main Basin Southeast total harvest (Bars) and average weight-at-age (rkg) for 1991 – 2000 cohorts (lines). All weight-at-age time series begin at age 4 and increase in 1 year increments. Solid lines indicate low density dependant cohorts and dashed lines indicate high density dependant cohorts.

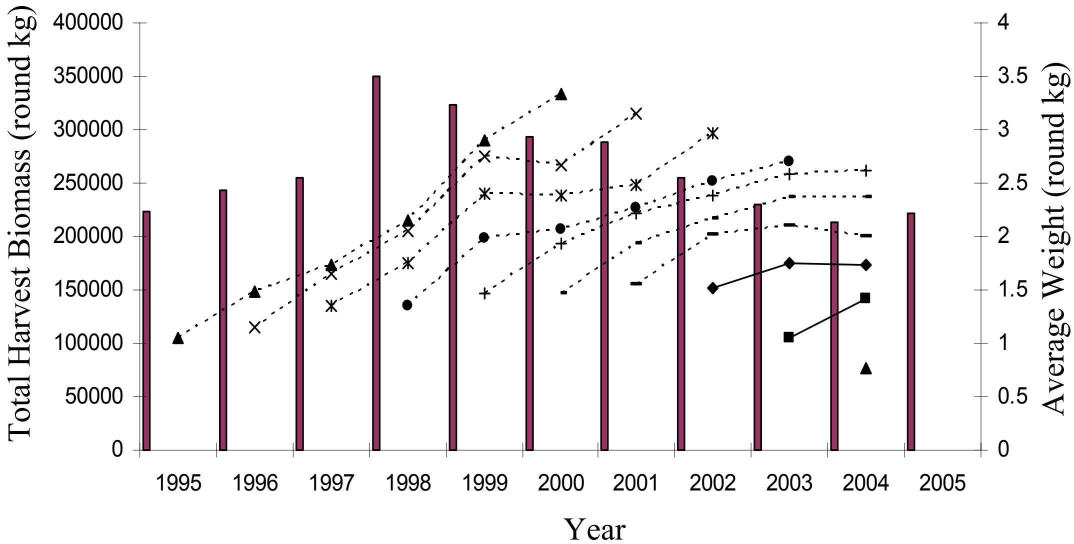


Figure 72. Georgian Bay total harvest (Bars) and average weight-at-age (rkg) for 1991 – 2000 cohorts (lines). All weight-at-age time series begin at age 4 and increase in 1 year increments. Solid lines indicate low density dependant cohorts and dashed lines indicate high density dependant cohorts.

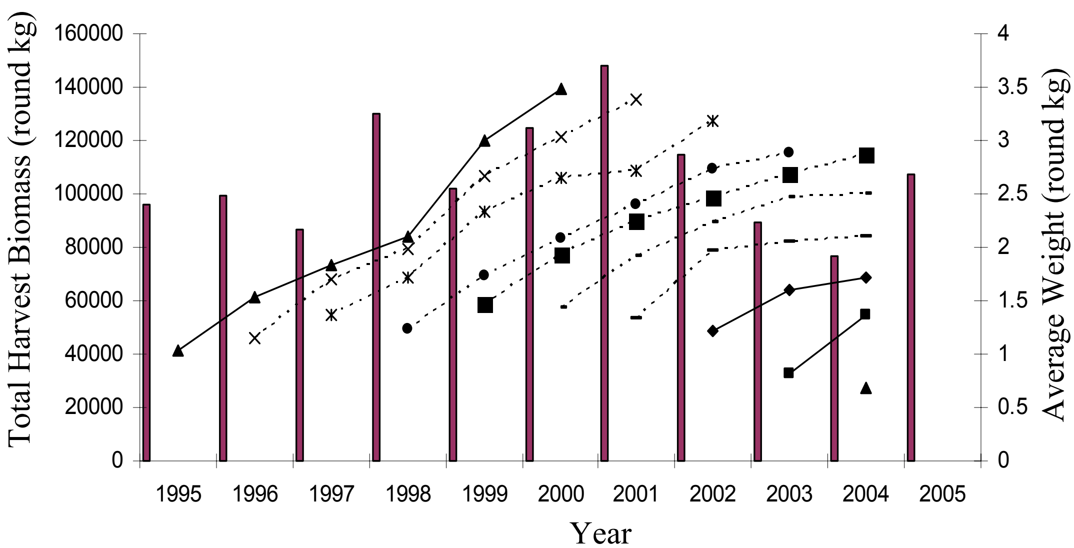


Figure 73. Georgian Bay South total harvest (Bars) and average weight-at-age (rkg) for 1991 – 2000 cohorts (lines). All weight-at-age time series begin at age 4 and increase in 1 year increments. Solid lines indicate low density dependant cohorts and dashed lines indicate high density dependant cohorts.

5. Surplus production modeling

5.1 Surplus production modelling to evaluate risk

The surplus production curve, based on the discrete logistic growth equation, was used as the basis for assessing the status of hypothesized whitefish populations. We used the logistic growth equation presented by Schaefer (1954):

$$B_{t+1} = B_t + \frac{rB_t}{K}(K - B_t) - C_t \qquad (1)$$

where B_t is the predicted biomass at time t, C_t is the observed catch, r is the intrinsic rate of growth and K is the carry capacity. Following the approach of Hatton et al. (2006), we considered a range of hypotheses about the trajectory of population growth through time. Alternative scenarios about the dynamics of the population allow the most likely current state of the population to be identified relative to alternative model fits which may indicate different population growth trajectories (Hatton et al. 2006). This approach allowed us to evaluate the risk of population collapse and our certainty in that assessment.

Risk of population collapse was characterized by a range of alternative scenarios about the state of the fishery, each represented as a hypothesis. Each hypothesized state of the fishery represents a trajectory of population growth, from which risk and sustainability can be inferred. Figure 74 (b) categorizes risk into three levels, which are high, medium and low. High risk scenarios (H3, H5 and H6) are characterized by low population size relative to carrying capacity and high catch levels relative to productivity, which indicates that the trajectory of the population is declining and at high risk of collapse. Medium risk scenarios indicate that the population is small relative to carrying capacity (H1) or that the population is at or above carrying capacity, but harvest levels are above sustainable limits (H6) both indicating a trajectory of population decline. Other risk scenarios indicate that the population is approaching carrying capacity and suggest that the population is at low risk of collapse (H2 and H4). Models were selected from each set of bounding parameters (r, K, q) and seed conditions (B0) that were biologically reasonable and had a good correspondence (negative log likelihood) between predicted biomass and catch per unit effort (see Hatton et al. 2006 for full explanation).

The hypothesized population trajectories and our degree of certainty in these trajectories were determined based on the frequency of hypothesized scenarios in the subset of biologically relevant models. For each Nawash Fisheries Management Region, Main Basin and Georgian Bay we assigned a qualitative indicator of certainty in our assessment of alternative population trajectories, which are: highly unlikely, unlikely, likely, highly likely and indeterminate.

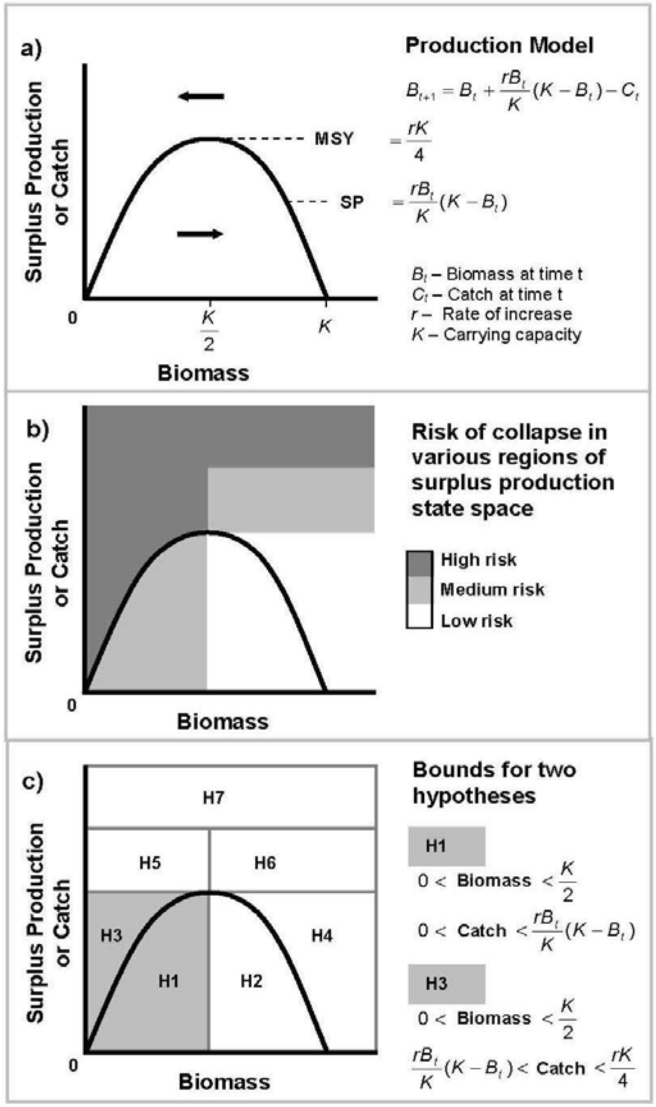


Figure 74. (a) Relationship between surplus production (SP) plotted against biomass (Bt). This curve arises from the production model which includes discrete logistic growth and is extended to include catch (Ct), as shown. Also shown is the carrying capacity (K) and the maximum sustainable yield (MSY), assumed to occur when the population is at a biomass of half of carrying capacity. When fishery catch is above population production, the biomass of the fishery will decline in time, as represented by the upper arrow (and vice versa for the lower arrow). (b) Representation of three general risk levels for the fishery throughout the surplus production state-space. Regions shaded darkest are high risk scenarios, characterized by low population levels relative to carrying capacity (K), and unsustainable harvests relative to productivity. The trajectory of the fishery in these regions is declining and thus at high risk of collapse. Alternatively, regions not shaded portray a fishery approaching virgin levels given current harvest regimes and are thus considered healthy. (c) These various regions in state-space can be formulated into discrete hypotheses about the state of the fishery, encompassing its trajectory, from which risk and sustainability can be inferred. Here are represented seven hypotheses (H1 to H7), the bounds for two of which are shown at right (H1 and H3). By constraining the model to optimally fit the data within the bounds of each hypothesis, we obtain a maximum likelihood estimate for each of our seven scenarios. This allows us the ability to visualize not only the most likely scenario, but how other plausible scenarios are distributed and what risks might be imminent. Source: Hatton et al. (2006)

5.2 Results

Trajectory of Hypothesized Main Basin Population

H1 27% of reasonable model fits
H2 55% of reasonable model fits
H3 18% of reasonable model fits

The frequencies of alternative scenarios about the state of the Main Basin population indicate that there are two likely trajectories. First, the combined frequency of H1 and H3 indicate a population below K/2 and at least a medium risk of population collapse if current harvest rates continue. Second, the frequency of model fits in H3 suggest that the population is between K/2 and K and that current catch levels are not putting the population as risk of collapse.

Trajectory of Hypothesized Main Basin South+East Population

Upon inspection of table 6 we removed the model fit presented in the 10th row (B_t = 1007488, H3) because this model is not biologically meaningful since B_t is roughly equal to the total catch in 2005.

H1 22% of reasonable model fits
H2 67% of reasonable model fits
H3 11% of reasonable model fits

The combined frequencies of H1 and H3 suggest that it is unlikely that the hypothesized Main Basin South+East population is located in these regions of state space; however, emphasis should be placed on reducing uncertainty about the dynamics of this population. It is likely that this hypothesized population is above K/2 with catch levels below production estimates.

Trajectory of Hypothesized Main Basin South Population

Upon inspection of table 9 we removed the model fits presented in the 2nd and 5th rows because these models are not biologically meaningful since B_t is substantially less than the total catch in 2005.

H2 100% of reasonable model fits

It is highly likely that the hypothesized Main Basin South population is above K/2 with catch levels below production estimates inferring that the population is likely to have an increasing trajectory.

Trajectory of Hypothesized Main Basin East Population

Upon inspection of table 12 we removed the model fit presented in the 10th row (B_t = 162900, H1) because this model is not biologically meaningful since B_t is roughly equal to the total catch in 2005.

H1 30% of reasonable model fits,
H2 70% of reasonable model fits,

The frequency of model fits in H2 suggests it is highly likely that the hypothesized Main Basin East population is at a low risk collapse, the population has a trajectory of increasing biomass and current harvest levels are below production estimates. It is unlikely that the population is located in H1; however, the frequency is high enough to warrant caution about potential increases to TAC in this region.

Trajectory of Hypothesized Georgian Bay Population

Upon inspection of table 17 we removed the model fits presented in the 5th and 6th rows because these models are not biologically meaningful since B_t is less than the total catch in 2005.

H2 75% of reasonable model fits,
H4 25% of reasonable model fits,

The frequency of model fits indicates that it is highly likely that the hypothesized Georgian Bay Population is located in H2. It is unlikely that the population is in H4; however, in either case the population biomass is at low risk of collapse only.

Trajectory of Hypothesized Georgian Bay West Population

Upon inspection of table 20 we removed the model fits presented in the 6th and 7th rows because these models are not biologically meaningful since B_t was only slightly larger than the total catch in 2005 and roughly equivalent to the catch in 2004.

H1 20% of reasonable model fits
H2 20% of reasonable model fits
H4 20% of reasonable model fits
H5 20% of reasonable model fits
H6 20% of reasonable model fits

We characterized the status of the Georgian Bay West population as indeterminate due to the uncertainty about its location in state space. Special emphasis should be placed on reducing uncertainty about the dynamics of this population and better resolution of its position with respect to the 6 risk categories.

Trajectory of Hypothesized Georgian Bay South Populations

Upon inspection of table 23 we removed the model fits presented in the 3rd, 5th and 6th rows because these models are not biologically meaningful since B_t was less than the total catch in 2005.

H3 33% of reasonable model fits
H4 67% of reasonable model fits

The hypothesized Georgian Bay South population is likely to be in H4, suggesting that the population is above carrying capacity and at very low risk of collapse. Model fits from H3 and H4 were the only plausible trajectories for this population, further indicating that there is low risk of population collapse.

Table 3. Main Basin (Canadian waters) statistics for effort, catch and CPUE for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005.

	Effort	Catch	CPUE
Year	**total (km gillnet)**	**total (rkg)**	**total (rkg km^{-1})**
1979	6,839	436,626	63.8
1980	8,198	515,533	62.9
1981	6,416	519,479	81.0
1982	6,705	651,846	97.2
1983	8,134	1,060,525	130.4
1984	7,641	866,851	113.5
1985	5,642	930,236	164.9
1986	5,768	899,800	156.0
1987	6,258	1,081,695	172.8
1988	6,597	1,059,080	160.5
1989	5,946	1,046,227	175.9
1990	5,344	1,185,085	221.8
1991	6,531	1,361,877	208.5
1992	6,272	1,457,524	232.4
1993	6,236	1,422,890	228.2
1994	5,777	1,311,442	227.0
1995	6,384	1,469,830	230.2
1996	5,301	1,493,033	281.6
1997	5,776	1,666,716	288.6
1998	6,211	1,686,709	271.6
1999	5,412	1,574,848	291.0
2000	6,724	1,610,728	239.5
2001	8,944	1,716,526	191.9
2002	8,054	1,526,573	189.5
2003	8,275	1,531,016	185.0
2004	8,745	1,561,719	178.6
2005	6,727	1,207,300	179.5

Table 4. Main Basin results of pCNA surplus production models associated with six hypothesized state-space production regions (H1-H6), for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. The minima and maxima for bounding the parameters (r, K, q) and seed conditions (B0) are given as paramRange. The best model fits identified in each of the hypothesized state-space production regions are presented, along with thumbnail graphics showing (i) time series in production state-space, and (ii) predicted (circles, dashed line) versus observed (crosses, solid line) values for the CPUE time series.

paramRange	**Min**	**Strides**	**Max**
B0	1,000,000	3	100,000,000
r	0.00001	3	2.6
K	1,000,000	3	100,000,000
q	0.00000001	3	0.01
sd	0.1	0	1

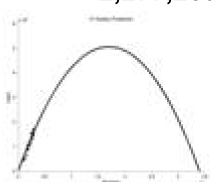
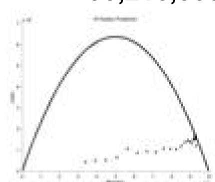
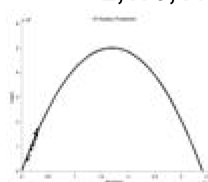
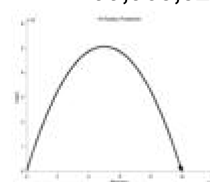
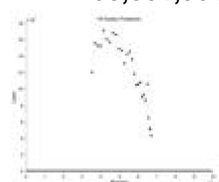
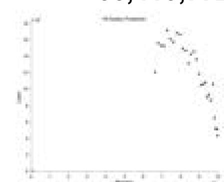
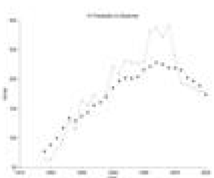
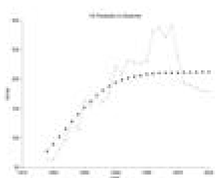
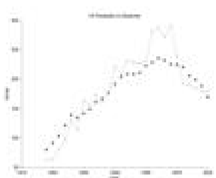
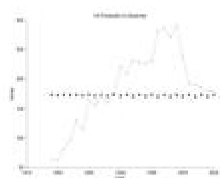
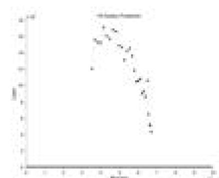
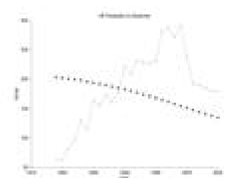
3 Strides	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**
B0	1,012,592	34,041,835	1,026,966	99,992,454	67,000,000	99,999,998
r	1	0	0.589	2	1.01538E-05	0.00001
K	34,000,000	100,000,000	34,000,000	100,000,000	100,000,000	1,000,000
q	7.6077E-05	2.27309E-06	7.77687E-05	1.72939E-06	3.26257E-06	2.02816E-06
sd	0.861	0.925	0.842	1	1	1
NLL	**1.21**	**1.34**	**1.19**	**3.30**	**5.06**	**4.36**
p						
BT	**2,277,260**	**93,216,366**	**2,179,445**	**99,963,322**	**35,361,901**	**66,410,772**
Production						
Prediction						

Table 5. Main Basin results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. Results are ranked in order of increasing negative log likelihood (NLL) which is inversely related to the probability of the surplus production model fit (predicted versus observed CPUE). H indicates which of the six hypothesized state-space production regions (H1-H6) the model fit was associated with.

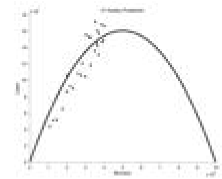
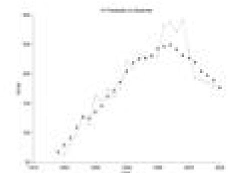
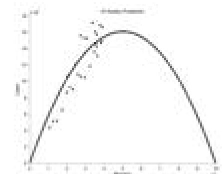
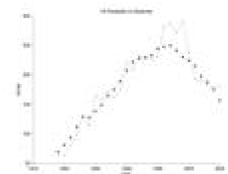
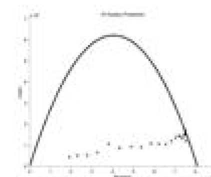
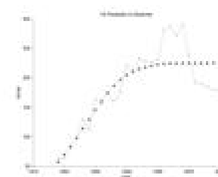
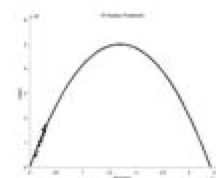
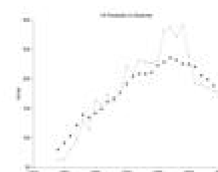
Min	Max	R	K	q	NLL	p	BT	Production	Prediction	H
1,000,000	10,000,000	0.643	9,999,963	6.23E-05	0.82		2,823,236			H 1
1,000,000	10,000,000	0.644	9,999,932	6.39E-05	1.08		2,455,545			H 3
10,000	100,000,000	0.308	80,842,610	2.99E-06	1.12		75,294,335			H 2
1,000,000	100,000,000	0.589	34,000,000	7.78E-05	1.19		2,179,445			H 3

Table 5 con't. Main Basin results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. Results are ranked in order of increasing negative log likelihood (NLL) which is inversely related to the probability of the surplus production model fit (predicted versus observed CPUE). H indicates which of the six hypothesized state-space production regions (H1-H6) the model fit was associated with.

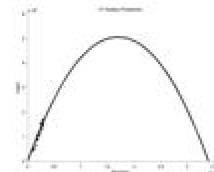
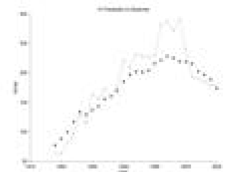
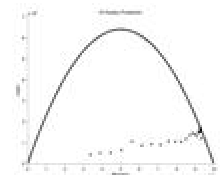
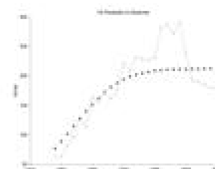
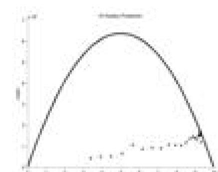
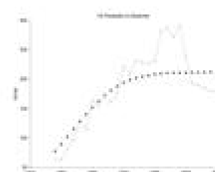
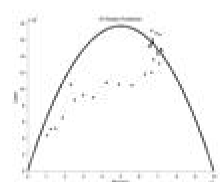
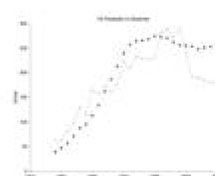
Min	***Max***	***R***	***K***	***q***	***NLL***	***p***	***BT***	***Production***	***Prediction***	***H***
1,000,000	100,000,000	0.595	34,000,000	7.61E-05	1.21		2,277,260			H 1
100,000	100,000,000	0.256	100,000,000	2.28E-06	1.33		93,250,990			H 2
1,000,000	100,000,000	0.255	100,000,000	2.27E-06	1.34		93,216,366			H 2
1,000,000	10,000,000	0.709	9,999,866	3.80E-05	1.73		6,677,255			H 2

Table 5 con't. Main Basin results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. Results are ranked in order of increasing negative log likelihood (NLL) which is inversely related to the probability of the surplus production model fit (predicted versus observed CPUE). H indicates which of the six hypothesized state-space production regions (H1-H6) the model fit was associated with.

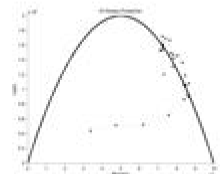
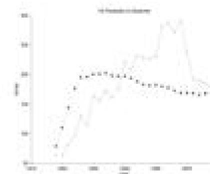
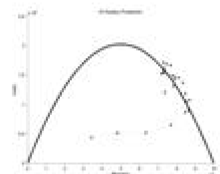
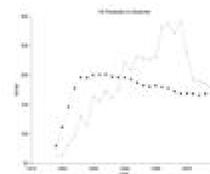
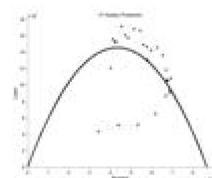
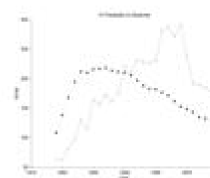
Min	***Max***	***R***	***K***	***q***	***NLL***	***p***	***BT***	***Production***	***Prediction***	***H***
10,000	10,000,000	0.799	9,999,999	2.33E-05	2.43		7,313,166			H 2
100,000	10,000,000	0.810	9,999,999	2.31E-05	2.46		7,371,857			H 2
10,000	10,000,000	0.672	8,672,065	3.15E-05	3.41		4,027,851			H 1

Table 6. Main Basin South+East (Canadian waters) statistics for effort, catch and CPUE for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005.

	Effort	**Catch**	**CPUE**
Year	**total (km gillnet)**	**total (rkg)**	**total (rkg km^{-1})**
1979	3,354	293,905	87.6
1980	3,994	360,637	90.3
1981	3,287	354,968	108.0
1982	4,479	492,932	110.1
1983	6,299	894,354	142.0
1984	5,217	697,645	133.7
1985	3,598	759,115	211.0
1986	3,496	718,875	205.6
1987	4,394	926,189	210.8
1988	4,356	857,955	196.9
1989	3,909	896,042	229.2
1990	3,606	1,066,675	295.8
1991	4,391	1,200,485	273.4
1992	4,171	1,289,373	309.2
1993	4,281	1,281,142	299.3
1994	3,160	1,043,060	330.1
1995	4,287	1,166,858	272.2
1996	3,192	1,168,994	366.2
1997	3,523	1,320,627	374.8
1998	3,835	1,326,804	346.0
1999	3,268	1,214,403	371.6
2000	4,295	1,265,128	294.6
2001	6,109	1,357,690	222.3
2002	5,471	1,249,511	228.4
2003	5,010	1,209,725	241.5
2004	5,629	1,271,240	225.9
2005	3,577	924,516	258.5

Table 7. Main Basin South+East results of pCNA surplus production models associated with six hypothesized state-space production regions (H1-H6), for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

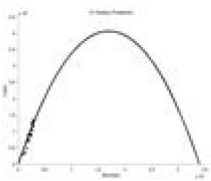
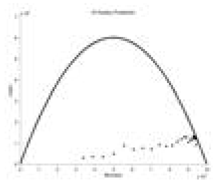
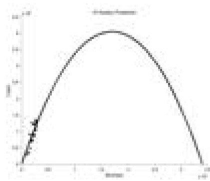
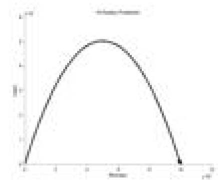
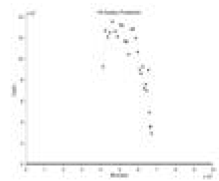
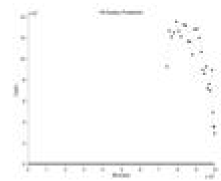
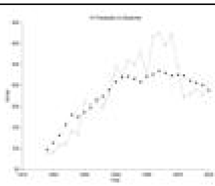
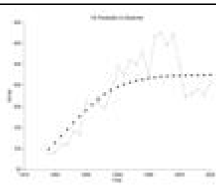
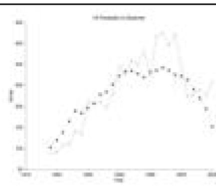
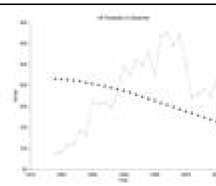
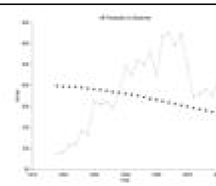
paramRange	**Min**	**Strides**	**Max**			
B0	1,000,000	3	100,000,000			
r	0.00001	3	2.6			
K	1,000,000	3	100,000,000			
q	0.00000001	3	0.01			
sd	0.1	0	1			
3 Strides	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**
B0	1,000,374	34,008,704	1,005,344	99,997,958	67,000,231	99,997,958
r	0	0	0.477	2	1.00121E-05	1.3283E-05
K	34,000,000	100,000,000	33,999,628	99,999,994	99,999,999	100,000,000
q	9.68617E-05	2.91089E-06	0.000101692	2.21334E-06	3.96032E-06	2.47919E-06
sd	0.916	0.978	1.000	1	1	1
NLL	**1.36**	**1.40**	**1.53**	**3.33**	**4.65**	**4.08**
p						
BT	**2,452,075**	**94,163,570**	**1,500,780**	**99,904,690**	**41,322,131**	**74,316,577**
Production						
Prediction						

Table 8. Main Basin South+East results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

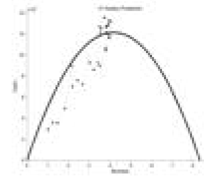
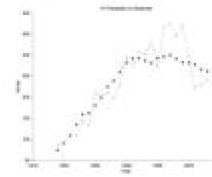
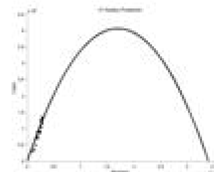
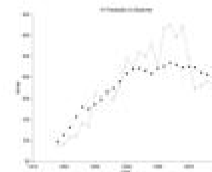
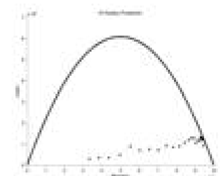
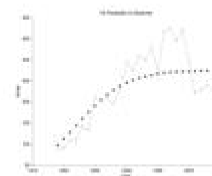
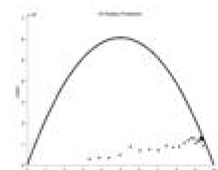
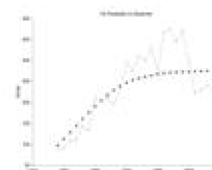
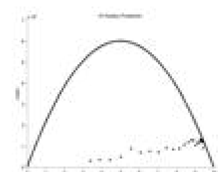
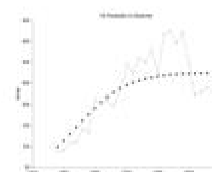
Min	*Max*	*r*	*K*	*q*	*NLL*	*p*	*BT*	*Production*	*Prediction*	*H*
1,000,000	10,000,000	1	8,329,044	7.3967E-05	1.12		3,416,529			H1
1,000,000	100,000,000	0.478	34,000,000	0.0000969	1.36		2,452,075			H1
10,000	100,000,000	0	100,000,000	2.914E-06	1.38		94,248,619			H2
100,000	100,000,000	0.243	100,000,000	2.9156E-06	1.38		94,234,785			H2
1,000,000	100,000,000	0	100,000,000	2.9109E-06	1.40		94,163,570			H2

Table 8 con't. Main Basin South+East results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

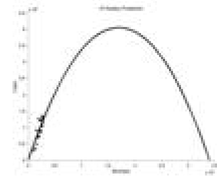
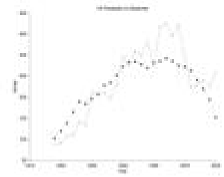
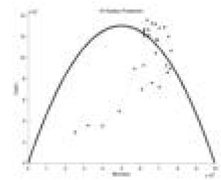
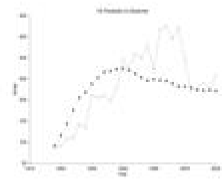
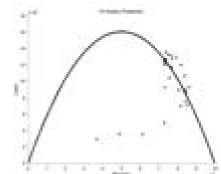
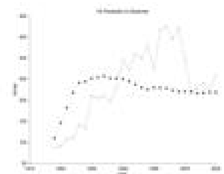
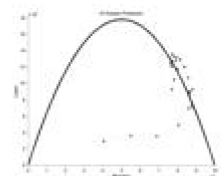
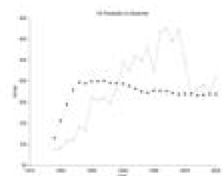
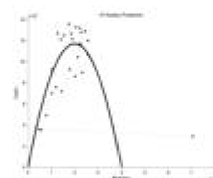
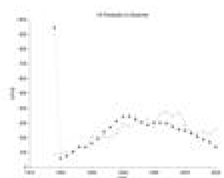
Min	***Max***	***r***	***K***	***q***	***NLL***	***p***	***BT***	***Production***	***Prediction***	***H***
1,000,000	100,000,000	0.477	33,999,628	0.00010169	1.53		1,500,780			H3
100,000	10,000,000	1	9,999,999	3.5945E-05	1.88		6,164,845			H2
10,000	10,000,000	0.6427	9,999,997	2.9792E-05	2.551		7,329,854			H2
1,000,000	10,000,000	1	9,999,999	2.839E-05	2.71		7,707,781			H2
1,000,000	10,000,000	1.170	4,000,000	0.0001341	4.53		1,007,488			H3

Table 9. Main Basin South (Canadian waters) statistics for effort, catch and CPUE for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005.

	Effort	**Catch**	**CPUE**
Year	**total (km gillnet)**	**total (rkg)**	**total (rkg km^{-1})**
1979	2,243	205,415	91.6
1980	2,415	185,817	76.9
1981	2,056	222,875	108.4
1982	2,745	328,802	119.8
1983	4,561	677,142	148.5
1984	3,839	439,214	114.4
1985	2,389	464,813	194.6
1986	2,180	456,567	209.4
1987	2,559	524,882	205.1
1988	2,990	533,131	178.3
1989	2,273	518,314	228.0
1990	2,022	630,739	311.9
1991	2,794	684,554	245.0
1992	2,604	769,220	295.4
1993	2,476	733,365	296.2
1994	1,883	629,966	334.5
1995	2,636	800,697	303.8
1996	2,462	893,810	363.0
1997	2,554	970,641	380.1
1998	2,950	1,104,141	374.3
1999	3,060	1,094,759	357.8
2000	3,444	1,059,774	307.7
2001	3,981	987,931	248.1
2002	3,596	822,547	228.8
2003	3,160	801,172	253.5
2004	3,481	864,254	248.3
2005	2,658	761,326	286.4

Table 10. Main Basin South results of pCNA surplus production models associated with six hypothesized state-space production regions (H1-H6), for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

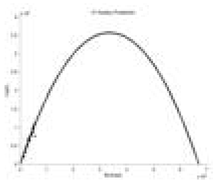
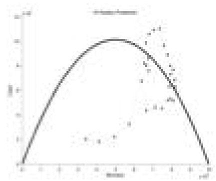
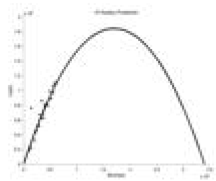
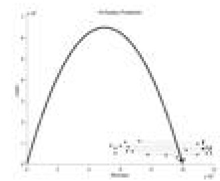
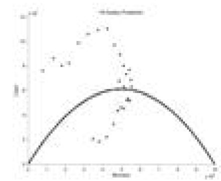
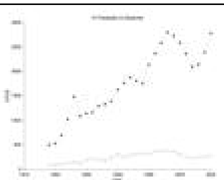
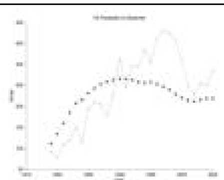
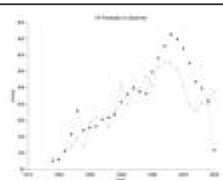
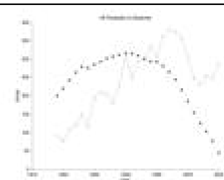
paramRange	**Min**	**Strides**	**Max**			
B0	100,000	3	10,000,000			
r	0.00001	3	2.6			
K	100,000	3	10,000,000			
q	0.00000001	3	0.01			
sd	0.1	0	1			
3 Strides	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**
B0	100,000	3,430,038	100,000	9,983,208	3,481,700	0
r	2	0	2	3	0	0
K	6,700,000	10,000,000	3,400,000	10,000,000	9,995,741	0
q	0.005012632	3.24165E-05	0.00076094	2.49454E-05	5.72701E-05	0
sd	0.999992221	1	0.99670821	1	1	0
NLL	**54.07**	**2.22**	**1.96**	**5.25**	**6.96**	**Inf**
p						
BT	**555,073**	**6,770,997**	**142,501**	**11,375,737**	**782,181**	**NaN**
Production						
Prediction						

Table 11. Main Basin South results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

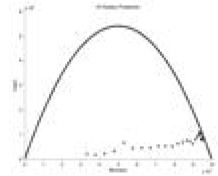
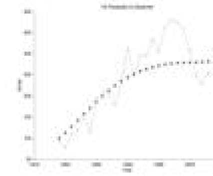
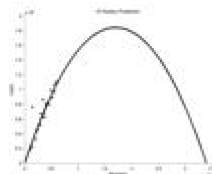
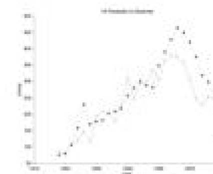
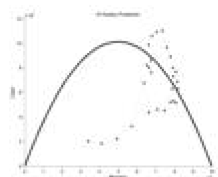
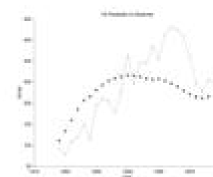
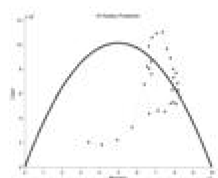
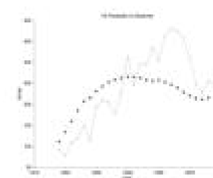
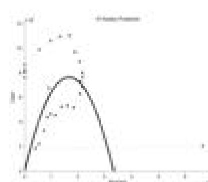
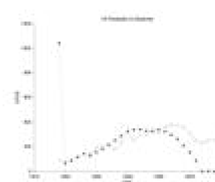
Min	***Max***	***r***	***K***	***q***	***NLL***	***p***	***BT***	***Production***	***Prediction***	***H***
10,000	100,000,000	0	99,999,907	2.9752E-06	1.43		95,058,994			H2
100,000	10,000,000	2	3,400,000	0.00076094	1.96		142,501			H3
10,000	10,000,000	0.4053	10,000,000	3.2462E-05	2.209		6,762,984			H2
100,000	10,000,000	0.406	10,000,000	3.2416E-05	2.22		6,770,997			H2
10,000	10,000,000	1	3,340,000	0.00015626	1,636.67		0			H3

Table 12. Main Basin East (Canadian waters) statistics for effort, catch and CPUE for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005.

	Effort	**Catch**	**CPUE**
Year	**total (km gillnet)**	**total (rkg)**	**total (rkg km^{-1})**
1979	1,111	88,490	79.7
1980	1,579	174,820	110.7
1981	1,231	132,093	107.3
1982	1,734	164,130	94.6
1983	1,738	217,212	125.0
1984	1,378	258,430	187.6
1985	1,210	294,302	243.3
1986	1,316	262,308	199.3
1987	1,835	401,306	218.7
1988	1,366	324,823	237.7
1989	1,636	377,728	230.8
1990	1,584	435,936	275.2
1991	1,597	515,930	323.1
1992	1,566	520,153	332.1
1993	1,805	547,777	303.5
1994	1,277	413,095	323.5
1995	1,651	366,161	221.7
1996	730	275,184	377.0
1997	969	349,986	361.1
1998	885	222,663	251.7
1999	208	119,643	575.2
2000	851	205,354	241.4
2001	2,127	369,759	173.8
2002	1,875	426,963	227.7
2003	1,850	408,553	220.8
2004	2,148	406,986	189.5
2005	919	163,190	177.6

Table 13. Main Basin East results of pCNA surplus production models associated with six hypothesized state-space production regions (H1-H6), for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

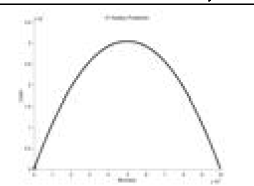
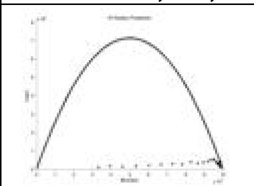
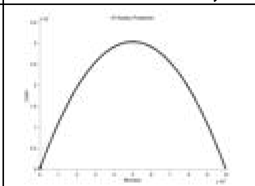
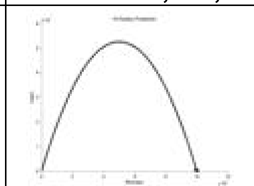
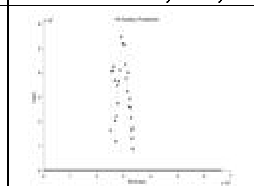
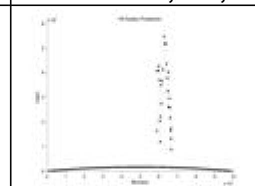
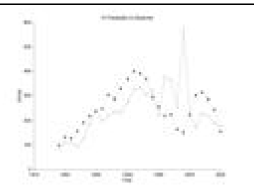
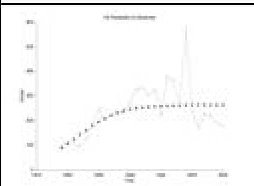
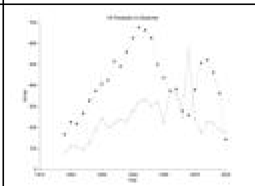
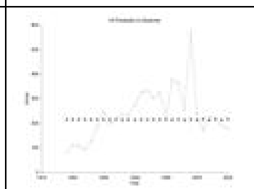
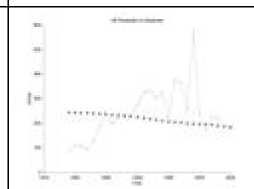
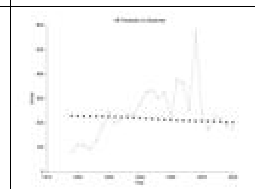
paramRange	**Min**	**Strides**	**Max**			
B0	100,000	3	100,000,000			
r	0.00001	3	2.6			
K	100,000	3	100,000,000			
q	0.00000001	3	0.01			
sd	0.1	0	1			
3 Strides	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**
B0	102,775	33,393,897	103,078	99,999,816	33,400,203	66,700,027
r	1	0	1	2	0	0
K	100,000,000	100,000,000	100,000,000	100,000,000	66,700,000	100,000,000
q	0.000951295	2.67605E-06	0.001614656	2.1574E-06	7.32E-06	3.42329E-06
sd	0.999998645	1	0.999963082	1	1	1
NLL	**2.98**	**1.89**	**7.64**	**3.59**	**4.23**	**3.85**
p						
BT	**162,900**	**98,646,902**	**88,618**	**100,801,484**	**25,124,699**	**58,823,508**
Production						
Prediction						

Table 14. Main Basin East results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

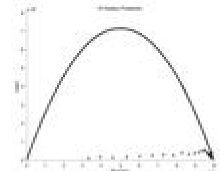
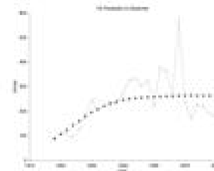
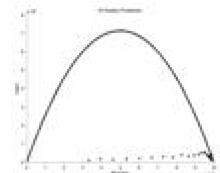
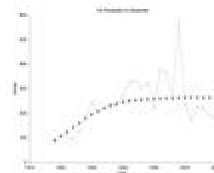
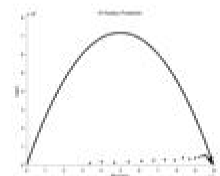
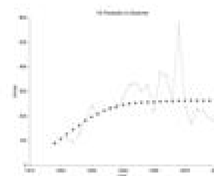
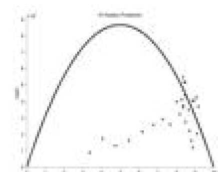
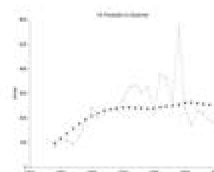
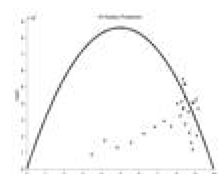
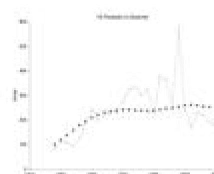
Min	***Max***	***r***	***K***	***q***	***NLL***	***p***	***BT***	***Production***	***Prediction***	***H***
10,000	100,000,000	0.286	100,000,000	2.6744E-06	1.89		98,651,766			H2
100,000	100,000,000	0.286	100,000,000	0.0000027	1.89		98,646,902			H2
1,000,000	100,000,000	0.287	100,000,000	2.6654E-06	1.90		98,658,185			H2
10,000	10,000,000	0.347	9,999,994	2.8695E-05	2.07		8,802,285			H2
100,000	10,000,000	0.345	9,999,933	2.8552E-05	2.09		8,794,567			H2

Table 14 con't. Main Basin East results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

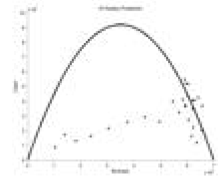
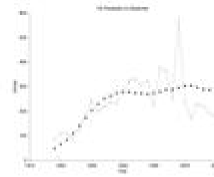
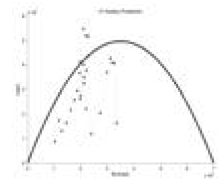
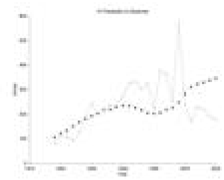
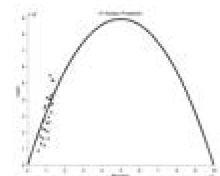
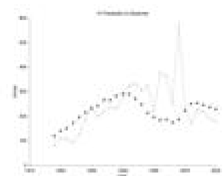
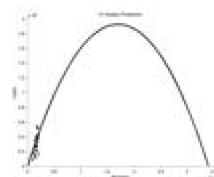
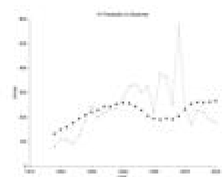
Min	***Max***	***r***	***K***	***q***	***NLL***	***p***	***BT***	***Production***	***Prediction***	***H***
1,000,000	10,000,000	0.526	6,999,982	4.619E-05	2.13		6,167,478			H2
1,000,000	10,000,000	0.284	7,000,000	0.0001033	2.84		3,352,435			H1
100,000	10,000,000	0.358	9,999,999	0.00020722	2.90		1,108,967			H1
1,000,000	100,000,000	0.227	34,000,000	0.00013116	2.97		2,029,551			H1

Table 14 con't. Main Basin East results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

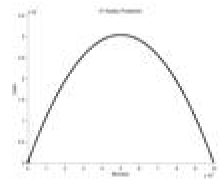
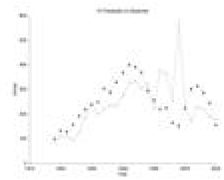
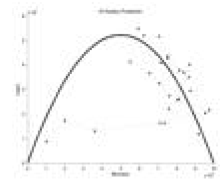
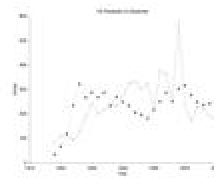
Min	*Max*	*r*	*K*	*q*	*NLL*	*p*	*BT*	*Production*	*Prediction*	*H*
100,000	100,000,000	1.218	100,000,000	0.00095129	2.98		162,900			H1
100,000	1,000,000	2.090	1,000,000	0.00033009	3.45		734,983			H2

Table 15. Georgian Bay statistics for effort, catch and CPUE for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005.

	Effort	**Catch**
Year	**total (km gillnet)**	**total (rkg)**
1979	1,297	58,604
1980	1,866	75,805
1981	1,100	77,270
1982	1,415	59,147
1983	1,069	39,175
1984	597	56,497
1985	998	88,234
1986	885	86,020
1987	734	54,357
1988	473	39,791
1989	424	49,068
1990	384	57,533
1991	660	96,234
1992	797	115,730
1993	854	135,516
1994	1,387	149,594
1995	1,911	223,204
1996	2,095	243,549
1997	2,075	254,344
1998	2,891	350,449
1999	2,853	323,175
2000	2,171	292,541
2001	2,250	288,677
2002	2,486	254,847
2003	2,590	229,465
2004	2,522	213,346
2005	2,475	222,351

Table 16. Georgian Bay results of pCNA surplus production models associated with six hypothesized state-space production regions (H1-H6), for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

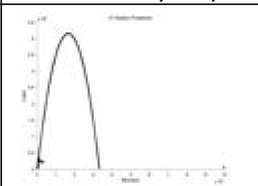
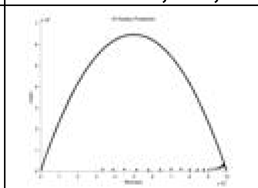
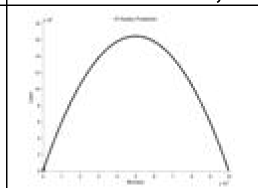
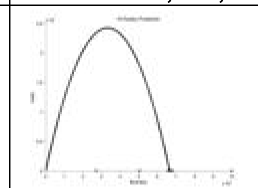
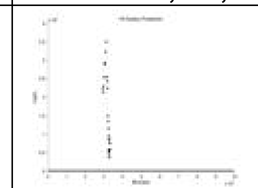
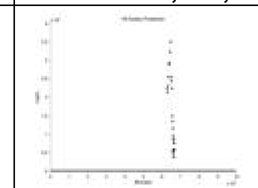
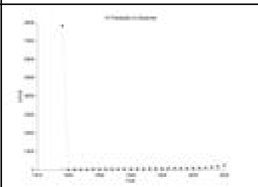
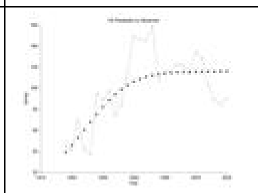
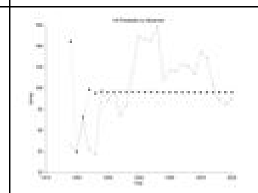
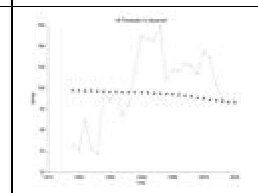
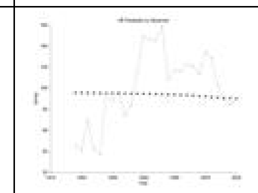
paramRange	**Min**	**Strides**	**Max**			
B0	1,000	3	100,000,000			
r	0.00001	3	2.6			
K	1,000	3	100,000,000			
q	0.00000001	3	0.01			
sd	0.1	0	1			
3 Strides	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**
B0	100,000,000	33,333,999	99,219	99,999,357	33,334,013	66,667,006
r	0	0	0.659	1	0.000	0.000
K	33,334,000	100,000,000	100,000,000	66,667,014	100,000,000	100,000,000
q	7.82883E-05	1.17168E-06	0.000453001	1.44237E-06	2.92356E-06	1.43101E-06
sd	1	1	1.000	1	1	1
NLL	**40.53**	**1.67**	**3.64**	**3.11**	**3.27**	**3.19**
p						
BT	**3,221,392**	**98,914,837**	**157,244**	**66,523,635**	**29,428,641**	**62,761,689**
Production						
Prediction						

Table 17. Georgian Bay results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

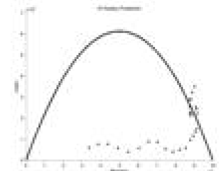
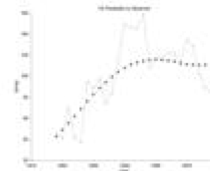
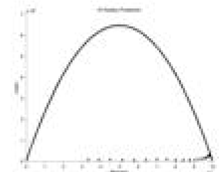
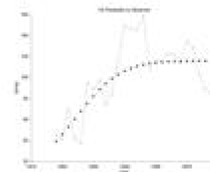
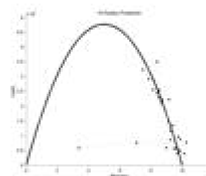
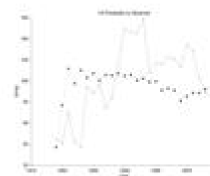
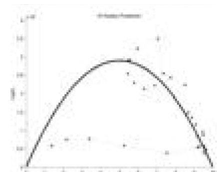
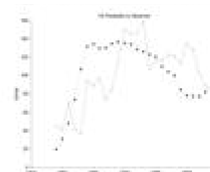
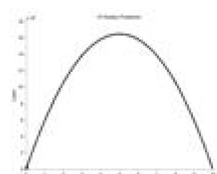
Min	***Max***	***r***	***K***	***q***	***NLL***	***p***	***BT***	***Production***	***Prediction***	***H***
1,000	10,000,000	0	9,999,979	1.2599E-05	1.62		8,847,363			H2
1,000	100,000,000	0	100,000,000	1.1717E-06	1.67		98,914,837			H2
1,000	1,000,000	2	1,000,000	0.00010861	2.98		874,719			H4
1,000	1,000,000	1.160	999,966	0.0001414	3.03		688,345			H2
1,000	100,000,000	1	100,000,000	0.000453	3.64		157,244			H3

Table 17 con't. Georgian Bay results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

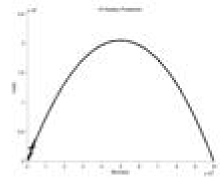
Min	*Max*	*r*	*K*	*q*	*NLL*	*p*	*BT*	*Production*	*Prediction*	*H*
1,000	10,000,000	1	10,000,000	0.0006068	3.99		121,239			H3

Table 18. Georgian Bay West statistics for effort, catch and CPUE for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005.

	Effort	**Catch**
Year	**total (km gillnet)**	**total (rkg)**
1979	47	2,441
1980	101	8,493
1981	74	4,672
1982	116	6,989
1983	39	2,503
1984	65	8,736
1985	395	23,884
1986	71	6,135
1987	51	5,583
1988	16	4,469
1989	44	8,880
1990	84	12,041
1991	87	12,296
1992	117	10,156
1993	47	8,363
1994	76	10,583
1995	370	29,620
1996	622	38,019
1997	705	51,864
1998	761	66,063
1999	1,110	65,950
2000	726	41,795
2001	551	38,710
2002	598	29,868
2003	639	42,690
2004	717	43,155
2005	536	27,292

Table 19. Georgian Bay West results of pCNA surplus production models associated with six hypothesized state-space production regions (H1-H6), for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

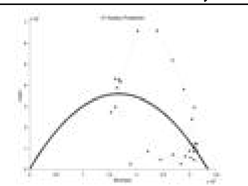
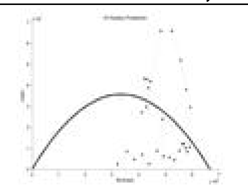
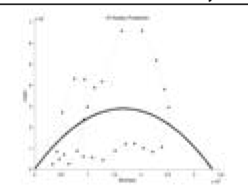
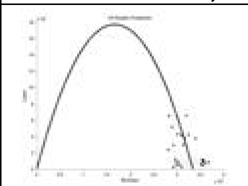
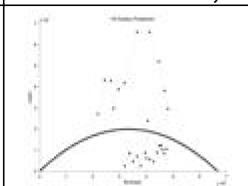
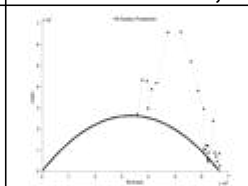
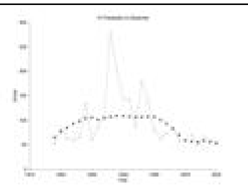
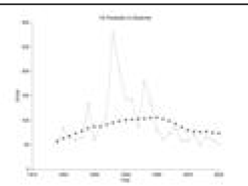
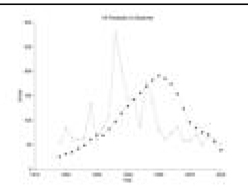
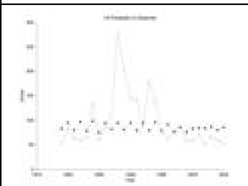
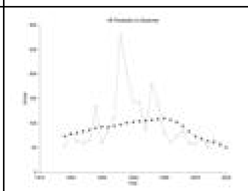
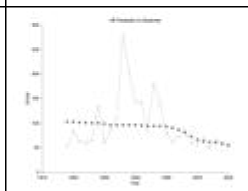
paramRange	**Min**	**Strides**	**Max**			
B0	1,000	3	1,000,000			
r	0.00001	3	2.6			
K	1,000	3	1,000,000			
q	0.00000001	3	0.01			
sd	0.1	0	1			
3 Strides	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**
B0	188,796	321,584	33,786	309,871	320,339	668,228
r	0.429	0.213	0.347	2.125	0.120	0.158
K	334,000	667,000	334,014	333,997	667,030	667,001
q	0.000348603	0.0001787	0.0007591	0.0002688	0.000229159	0.00015447
sd	1	1.000	1.000	1.000	1	1
NLL	**2.56**	**2.91**	**5.32**	**3.52**	**2.77**	**3.16**
p						
BT	**153,091**	**410,800**	**51,709**	**320,913**	**219,238**	**359,552**
Production						
Prediction						

Table 20. Georgian Bay West results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

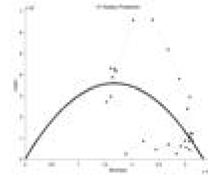
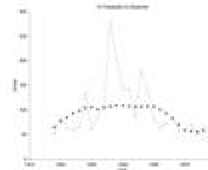
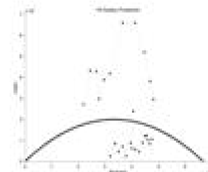
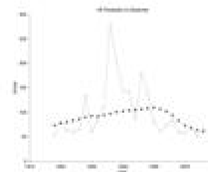
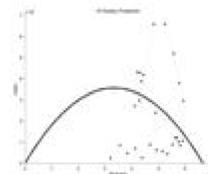
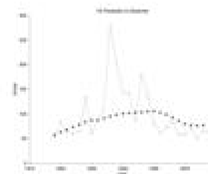
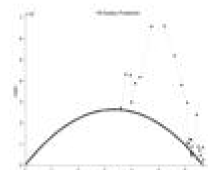
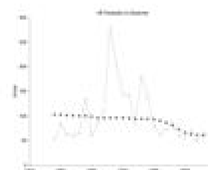
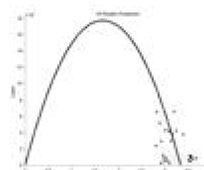
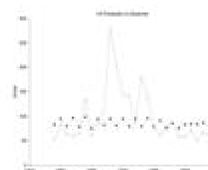
Min	*Max*	*r*	*K*	*q*	*NLL*	*p*	*BT*	*Production*	*Prediction*	*H*
1,000	1,000,000	0.4293	334,000	0.0003486	2.555		153,091			H1
1,000	1,000,000	0	667,030	0.00022916	2.77		219,238			H5
1,000	1,000,000	0	667,000	0.00017867	2.91		410,800			H2
1,000	1,000,000	0.158	667,001	0.00015447	3.16		359,552			H6
1,000	1,000,000	2	333,997	0.00026884	3.52		320,913			H4

Table 21 con't. Georgian Bay West results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

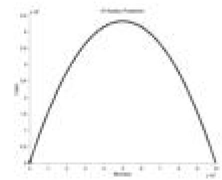
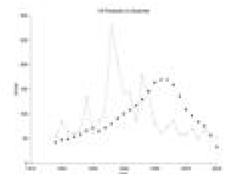
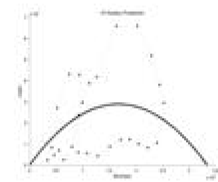
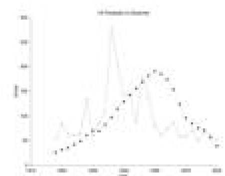
Min	***Max***	***r***	***K***	***q***	***NLL***	***p***	***BT***	***Production***	***Prediction***	***H***
1,000	10,000,000	0	100,000,000	0.00076202	4.98		43,425			H3
1,000	1,000,000	0.347	334,014	0.0007591	5.32		51,709			H3

Table 21. Georgian Bay South statistics for effort, catch and CPUE for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005.

	Effort	Catch
Year	**total (km gillnet)**	**total (rkg)**
1979	219	10,691
1980	570	20,477
1981	532	43,641
1982	597	25,293
1983	480	23,718
1984	207	24,683
1985	121	32,737
1986	144	32,747
1987	125	19,884
1988	131	20,071
1989	143	21,217
1990	115	25,853
1991	168	44,703
1992	141	41,291
1993	284	64,504
1994	346	48,512
1995	690	96,274
1996	583	99,024
1997	502	86,366
1998	730	130,125
1999	520	102,005
2000	380	124,745
2001	613	147,784
2002	753	114,588
2003	964	89,260
2004	836	76,462
2005	907	107,309

Table 22. Georgian Bay South results of pCNA surplus production models associated with six hypothesized state-space production regions (H1-H6), for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

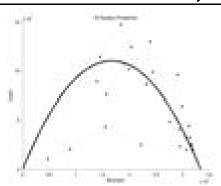
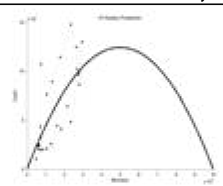
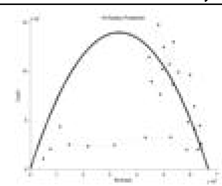
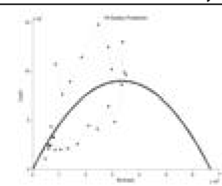
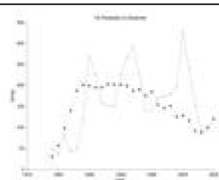
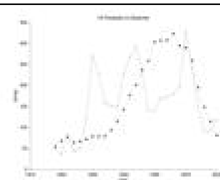
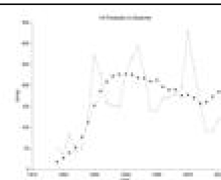
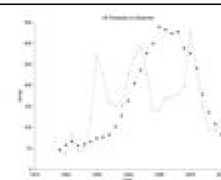
paramRange	**Min**	**Strides**	**Max**			
B0	1,000	3	1,000,000			
r	0.00001	3	2.6			
K	1,000	3	1,000,000			
q	0.00000001	3	0.01			
sd	0.1	0	1			
3 Strides	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**
B0	0	46,789	49,088	49,189	46,903	0
r	0	1.324	0.498	0.836	0.539	0
K	0	333,821	1,000,000	668,399	667,000	0
q	0	0.0006337	0.0010977	0.0003530	0.00096982	0
sd	0	1.000	1.000	1.000	1	0
NLL	**Inf**	**4.26**	**4.71**	**3.20**	**4.71**	**Inf**
p						
BT	**NaN**	**191,161**	**74,366**	**521,214**	**85,534**	**NaN**
Production						
Prediction						

Table 23. Georgian Bay South results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

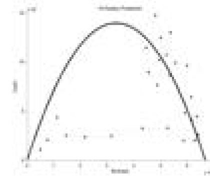
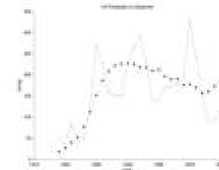
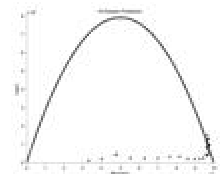
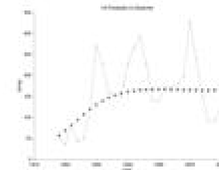
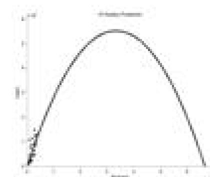
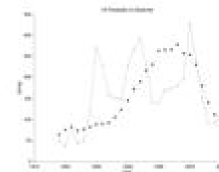
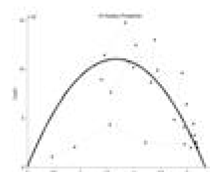
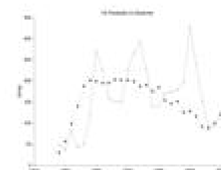
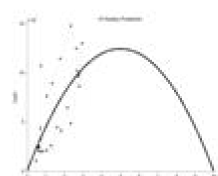
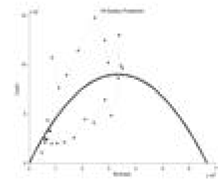
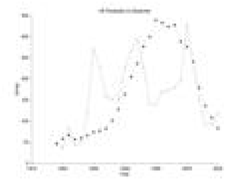
Min	***Max***	***r***	***K***	***q***	***NLL***	***p***	***BT***	***Production***	***Prediction***	***H***
1,000	1,000,000	0.836	668,399	0.0003530	3.20		521,214			H4
1,000	10,000,000	0.317	10,000,000	1.7073E-05	3.29		9,674,831			H4
1,000	10,000,000	0	6,667,000	0.00083184	3.99		102,291			H3
1,000	1,000,000	1.3236	333,821	0.0006337	4.26		191,161			H2
1,000	1,000,000	0	1,000,000	0.00109775	4.71		74,366			H3

Table 23 con't. Georgian Bay South results of pCNA surplus production models over different parameter bounds of both B0 and K (Min, Max) for targeted lake whitefish (*Coregonus clupeaformis*) commercial fisheries of Lake Huron for the period 1979-2005. See Main Basin table for explanation of presentation format.

Min	***Max***	***r***	***K***	***q***	***NLL***	***p***	***BT***	***Production***	***Prediction***	***H***
1,000	1,000,000	1	667,000	0.00096982	4.71		85,534			H5

6. Key uncertainties and future work

6.1 Age – structured models

Evaluation of the consequences using statistical catch-at-age modelling for assessing whitefish population dynamics is a priority for the Nawash Fisheries Assessment program. Two key uncertainties persist with respect to population modelling. First, the 2003 TAC report (Crawford et al. 2003) identified "the validation of age estimates for harvested lake whitefish populations, both ongoing and retroactively from the historical database" as a key uncertainty that limits the applicability of using existing age data for age-structured models. Using non-validated age estimates may lead to highly spurious age-structured models. Since the 2003 report, the Nawash Fisheries Assessment Program has implemented a standard methodology to generate age estimates for whitefish using scales and otoliths (Muir and Den Haas 2003). Further, a research paper for publication in the primary literature is being prepared on validation of annulus formation in Georgian Bay whitefish. Our current focus for age validation is to generate a correction factor between scales and otoliths, as well as quantify the effects of ageing errors (precision) on population modelling.

The second research question related to implementing age structured models is the development of models and the evaluation of their value, with respect to model complexity, for predicting population response to alternate harvest strategies. This question will be addressed by examining the tradeoff between model complexity (number and parameters) and model fit. Developing models in a progression from simple to complex will allow the most informative models to be identified, without model over parameterization. Further, models representing alternative ecological hypotheses can be distinguished based on complexity and fit using Akaike's Information Criterion (AIC) or Bayesian methods.

6.2 Georgian Bay whitefish genetics

Currently, the Nawash Fisheries Assessment program and the University of Guelph are conducting a genetic analysis of Georgian Bay whitefish population distribution. Our objective is to develop and demonstrate the applicability of a framework for quantitatively considering uncertainty in the population distribution of lake whitefish in Georgian Bay. This approach will allow harvest levels to be established in a way that considers ecological uncertainties in the decision making process. The project concentrates on identifying plausible states of nature for lake whitefish distributions in Georgian Bay and assigning and updating probabilities to each hypothesis. Competing hypotheses regarding lake whitefish distributions can be developed from primary and technical literature, commercial harvest and fishery independent survey data, expert opinion and traditional ecological knowledge. Degree of belief in each hypothesis can be established based on what is already known. Identifying plausible hypotheses *a priori* allows predictions to be generated that can then be tested in order to update prior probabilities and to reduce key uncertainties. The basis for this approach to generating and updating probabilities through research is Bayesian statistical inference. Bayesian statistics differ from traditional (or frequentist) statistics in the way that probability is interpreted. The Bayesian definition of probability is the degree of belief in a hypothesis, conditional on the available data or $P\langle H|x\rangle$, where H is a hypothesis and x is the observed data. The frequentist definition of probability is the likelihood ("truth") of the outcome if the data were collected under identical conditions an infinite number of times or $P\langle x|H\rangle$, which is interpreted as *the probability of the data, given the hypothesis* (Ellison 1996).

Bayesian statistics allow the process of science to iteratively update what is already known, while recognizing uncertainty and utilizing probability as a measure of uncertainty (Gelman et al. 1995). Bayes' theorem is the product of what is already known (*prior probability*) and the probability of the (new) data (*likelihood function*) to produce the *posterior probability* for a given hypothesis. Generally, the equation takes the form:

Posterior probability = likelihood x prior probability

Bayesian statistical inference not only provides probabilities necessary to quantify uncertainty, as required to conduct a decision analysis, but allows several complex and potentially conflicting sources of information to be integrated effectively.

We identify the difficulty in integrating existing and new information into a decision making framework, even when the presence of considerable uncertainty is acknowledged, as the manager's dilemma. Our proposed solution to this dilemma, named Sequential Bayesian Analysis of Mixed Data, as the name implies, relies on Bayesian statistical inference to iteratively update probabilities. Specifically, we are proposing to conduct a genetic analysis of lake whitefish in Georgian Bay to test predictions generated from competing hypotheses. Probabilities generated from this analysis will be used to update prior probabilities generated from previous knowledge.

Our genetic analysis, for the purpose of population discrimination, takes on the role of testing predictions generated from competing hypotheses, quantifying uncertainty about population boundaries and further organizing and refining hypothesized states of nature. The difference between our approach to testing predictions versus allowing a software application that employs Bayesian analyses to identify discrete stocks is subtle, but important, in that our approach forces probabilities to be assigned to biologically meaningful stock boundaries instead of assigning probabilities to statistically meaningful stock boundaries. Further, our approach will address a contentious topic in population genetics, which is how to determine where boundaries should be placed when no obvious distributional gaps exist (Martien and Taylor 2003). By assigning probabilities to alternative states of nature the analyst is not forced to decide for certain where boundaries should be placed, only to decide for each hypothesis '*what degree of belief would I put in this hypothesized distribution of populations?*' Further, the economic risk of over-splitting stocks and ecological risk of under-splitting stocks is explicitly incorporated into the decision making process (DA) in the form of probabilities assigned to putative stocks from panmixis to discrete units. Finally, genetic analyses may be used to refine hypotheses by identifying putative stocks that may not have been previously recognized.

It is important to note that hypotheses that are not considered are by default assigned a probability of zero (Gelman et al. 1995). Conversely, managing fish stocks under only a single state of nature implies a degree of belief (probability) of 1 in that state of nature. Failure to incorporate ecological uncertainty is failure to fully consider the full range of ecological consequences of management decisions.

6.3 Western Science / Traditional Ecological Knowledge for fisheries Management

At the University of Guelph, Chantel LaRiviere and Caitlin Meanwell are beginning a paired Master of Science program, advised by Dr. Steve Crawford. At the general level, the goal of the research program is to improve communication between Aboriginal traditional knowledge and western science, in the context of resource management decision-making. To achieve this goal, a case study approach is being developed to evaluate reciprocal communication between the Chippewas of Nawash Unceded First Nation (Nawash) and the College of Biological Sciences (CBS) at the University of Guelph, with specific respect to fisheries management planning. Chantel LaRiviere will be evaluating the translation of fisheries science from CBS to Nawash, while Caitlin Meanwell will be evaluating the translation of traditional practice from Nawash to CBS. By understanding the mechanisms that cause problems in communication, the researchers hope to propose practical guidelines to improve communication and more effectively incorporate Aboriginal traditional knowledge in resource management planning.

7. 2006 TAC options for Nawash Council

TAC Options for Main Basin East

2005 SO TAC = 509 045 rkg
2005 total harvest = 163 190 rkg

Increase

- Plausible model fits in H2 indicate that it is likely that the population is being harvested near sustainable limits
- The potential for the population to be in H1 illustrates that some uncertainty about the trajectory of the population is in question.
- Based on these trajectories we do not recommend an increase in TAC

No Change

- The most likely trajectories of the population indicate that current harvest levels are sustainable in recent years.
- Based on the most plausible trajectories maintaining the 2005 TAC level would place the population at low risk of collapse

Decrease

- The biological evaluation of Main Basin East suggests that current harvest levels are at low risk of population collapse
- Decision makers should consider that trajectories are based on actual catch, not TAC. Between 2000 – 2005 the total harvest was between 163,190 and 426,963 rkg.

TAC Options for Georgian Bay West

2005 SO TAC = 27 359 rkg
2005 total harvest = 27 292 rkg

Increase

- Due to the indeterminate trajectory of this population, we do not recommend an increase at this time.

No Change

- The level of risk associated with continuing harvest at the current TAC level is unknown and may vary from high to low risk of population collapse.
- Continued harvest at this level may facilitate further learning about the dynamics of this population and lead to greater resolution in state space about the trajectory of this population in future years; however, there is greater risk of population collapse associated with this strategy than with a decrease in TAC

Decrease

- Decreasing the TAC may be considered more risk adverse than maintaining current harvest levels; however, this may lower the risk of population collapse.

TAC Options for Georgian Bay South

2005 SO TAC	=	69 800 rkg
2005 total harvest	=	107 309 rkg

Increase

- The Georgian Bay South population is likely near or above carrying capacity, with only low risk of collapse.
- Our analyses indicate that a moderate increase to the TAC is unlikely to increase the risk of population collapse.
- Based on quota recommendation tables provided by OMNR Lake Huron Management Unit staff (in Appendix 2) moderate (10%) increases were made to 5-8 and 5-9 in 2005 and again to 5-9 in 2006. In total, LHMU recommended the following for 2006:

5-6	32,198 rkg
5-8	53, 326 rkg
5-9	121,510 rkg
GB-S	**207,034 rkg**

- Decision makers should consider the amount of TAC for GB-S to be allocated to the Saugeen Ojibway. In general, the Saugeen Ojibway waters (as outlined in the 2005 fishing agreement) found in GB-S consist of all of 5-8 and the western half of 5-6.

No Change

- Since the population is likely in either H3 or H4 and consequently at low risk of collapse, it would be of very low risk to maintain the current TAC.

Decrease

- The most likely trajectories of the population indicate that the population is at low risk of collapse, and may be near or above carrying capacity
- A decrease in TAC is not necessary for the sustainability of the population

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Appendix 1. Data Exchange and Data Management

Formatting OMNR commercial harvest and effort data

The OMNR databases, received from LHMU on May 1, that are used in this report:
LHMU_CF_07MAR06.mdb
LHMU_CH_07MAR06.mdb

CH Database

1. Creation of a unique identifier for effort information in table LHMU_New_131
   - A make table query created a new *COMB_CODE* using *[YEAR] + [-OMNR-] +[PRJ_CD] + [CHSAM]* from table LHMU_New_131.
   - The formatted table is named LHMU_New_131_coded.

2. Creation of a unique identifier for effort information in table LHMU_New_132
   - A make table query created a new *COMB_CODE* using *[YEAR] + [-OMNR-] +[PRJ_CD] + [CHSAM]*, and created a new *COMB_EFF_CODE* for each commercial harvest using *[YEAR] + [-OMNR-] + [PRJ_CD] + [CHSAM] + [EFF]* from table LHMU_New_132.
   - Six criteria were used in the creation of the formatted table:

Field	Criteria
SPCTRG	"091"
GRID	>""
GRTP	"GL"
MESH5	>0
EFFDST (converted to km)	>0
EFFDUR (converted to days)	>0

   - The formatted table is named LHMU_New_132_coded_091_GL.
   - A find duplicates query identified no records with duplicate *COMB_EFF_CODE.*

3. Creation of a unique identifier for effort information in table LHMU_New_133
   - A make table query created a new *COMB_EFF_CODE* for each commercial harvest using *[YEAR] + [-OMNR-] + [PRJ_CD] + [CHSAM] + [EFF]* from table LHMU_New_133.
   - One criteria was used in the creation of the formatted table:

Field	Criteria
SPC	"091"

   - The formatted table is named LHMU_New_133_coded_91.

4. Creation of a targeted lake whitefish harvest table
   - A find unmatched query identified unmatched harvest records between LHMU_New_132_coded_091_GL and LHMU_New_133_coded_91 using the field *COMB_EFF_CODE*. 324 unmatched records were removed.

- A make table query was used to combine targeted gillnet effort for lake whitefish (LHMU_New_131_coded and LHMU_New_132_coded_091_GL) with harvest of lake whitefish (LHMU_New_133_coded_91).
- A field named *SumOfHVSWT* was created to sum *HVSWT* (round kg) across dublicate *COMB_EFF_CODE* records. *SumOfHVSWT* provides the total weight of lake whitefish for each unique harvest event (*COMB_EFF_CODE*).
- The formatted table is named LHMU_overall_091_GL_091.mdb

5. Creation of a targeted lake whitefish CPUE table
   - A make table query was used to add two additional fields to the LHMU_overall_091_GL_091.mdb table, these are:

Field	Description
CPUE_RKGKM	Round kg / km gillnet
CPUE_RKGKMDAYS	Round kg / km gillnet / days set

   - The formatted table is named LHMU_overall_091_GL_091_CPUE.

CF Database

The Effort information in the OMNR CF database (Biological Samples) does not link to the Effort information in the CH database (Commercial Harvest). Both are given *COMB_CODE* fields; however, at no time in the data formatting or analysis process are these tables linked.

1. Creation of a unique identified for effort information in table cf_121
   - A make table query created *COMB_CODE* using *[YEAR] + [-OMNR-] +[PRJ_CD] + [SAM]* from cf_121.
   - Three criteria were used in the creation of the formatted table:

Field	Criteria
SPCTRG	"091"
MESH5	>0
GRTP	"GL"

   - The formatted table is named cf_121_coded_091_GL

2. Creation of a unique identified for biological sample information in cf_125
   - A make table query created *COMB_CODE* using *[YEAR] + [-OMNR-] +[PRJ_CD] + [SAM]*, and *INDIV_CODE* using *IIf([EFF] Is Null,[YEAR]+'-OMNR-'+[PRJ_CD]+'-'+[SAM]+'-'+[FISH],[YEAR]+'-OMNR-'+[PRJ_CD]+'-'+[SAM]+'-'+[EFF]+'-'+[FISH])* from table cf_125.
   - Six criteria were used in the creation of the formatted table:

Field	Criteria
SPC	"091"
FLEN	>0
RTW (converted to kg)	>0

   - Formatted table is named cf_125_coded_091

3. Creation of a targeted lake whitefish biological samples database

- A make table query was used to combine targeted gillnet effort for lake whitefish (cf_121_coded_091_GL) with individual biological sample data (cf_125_coded_091).
- The formatted table is named cf_overall_GL_091 (Several records contain ages with missing AGEM or contain unknown AGEM codes; these were removed before using this database for age analyses).
- A find duplicates query was used to identify and remove 1 record (both entries removed as they contained different values) with duplicate *INDIV_CODE*

<u>Formatting Saugeen Ojibway commercial harvest and effort data</u>

Databases used in this report:
2006_07_26 SO Master.mdb

General Audit and Update of Saugeen Ojibway Master database

1. Update Harvest and Effort table
   - Harvest Table:
     - Deleted 7 records with WFT = 0
     - Deleted 119 records with HVSWT9 not >0
     - Deleted 1 record with WUT = 0
     - Deleted 6 records where SPC = 910, 810, 750
     - Replaced WUT = null, with 2 (pounds) via Update query
     - Removed Fields: RHVSWT9
   - Effort Table:
     - Deleted 1 record where SPCTRG=910

Modify Saugeen Ojibway Nations Master database to mirror "CH" and "CF" format

1. Creation of targeted lake whitefish harvest (CPUE) table
   - A make table query was used to combine targeted gillnet effort for lake whitefish (Effort) with harvest of lake whitefish (Harvest)
     Three criteria were used in the creation of the formatted table:

Field	Criteria
SPCTRG	"091"
GRTP	"GL"
SPC	"091"

   - A field named *SumOfHVSWT* was created to covert harvest weights to round kg, based on fields *HVSWT9*, *WUT* and *WFT*.
   - Two additional fields were added, these are:

Field	Description
CPUE_RKGKM	Round kg / km gillnet
CPUE_RKGKMDAYS	Round kg / km gillnet / days set

   - The formatted table is named SO_overall_GL_091_CPUE.mdb

2. Creation of targeted lake whitefish individuals table in "CF" format

- A make table query was used to combine targeted gillnet effort for lake whitefish (Effort) with individual biological sample data for lake whitefish (Individuals)

  Five criteria were used in the creation of the formatted table:

Field	Criteria
SPCTRG	"091"
GRTP	"GL"
SPC	"091"
FLEN	>0
RWT (converted to kg)	>0

- Formatted table is named SO_overall_coded_GL_091_scale (only scale ages were included for consistency with cf_overall_GL_091)

Lake Huron lake whitefish Master Database

Database name: 2006_07_26 Lake Huron Master_091

1. Merging OMNR and Saugeen Ojibway targeted lake whitefish harvest databases
   - Append table query was used to append table SO_oveall_GL_091_CPUE to LHMU_overall_091_GL_091_CPUE.
   - The formatted table is named Harvest_Lake Huron Mater_091.

2. Merging OMNR and Saugeen Ojibway targeted lake whitefish individual biological sample databases
   - Append table query was used to append table SO_overall_GL_091_scale to cf_oveall_GL_091.
   - Formatted table is named Individuals_Lake Huron Master_091.

3. Creation of a merged Individuals database containing only individuals with scale ages
   - A make table query was used to create a subset of records from Individuals_Lake Huron Master_091 that contain scale ages.

     The following criteria were used in the creation of the formatted table:

Field	Criteria
AGE	>0

   - Seven records were deleted that contained non-scale or unknown ageing structures (field generated from XAGEM). Null entries were retained under the assumption that these fish were aged using scales.
   - Formatted table is named Individuals with ages_Lake Huron Master

<u>Formatting OMNR index assessment data</u>
Database name: LHMU_IA_07MAR06.mdb

1. Creation of a unique identifier for table Offshore_FN121
   - A make table query created a new *COMB_CODE* using *[YEAR]+'-OMNR-'+[PRJ_CD]+'-'+[SAM]* from table Offshore_FN121
   - One criteria was used in the creation of the formatted table:

<u>Field</u>	<u>Criteria</u>
EFFST	"1" Or Is Null

   (This eliminated sampling events identified as problematic)
   - Formatted table is named Offshore_FN122_coded

2. Creation of a unique identifier for Offshore_FN122
   - A make table query created a new *COMB_CODE* using *[YEAR]+'-OMNR-'+[PRJ_CD]+'-'+[SAM]* from table Offshore_FN122
   - A new *EFF_CODE* using *[YEAR]+'-OMNR-'+[PRJ_CD]+'-'+[SAM]+'-'+[EFF]* was created from table Offshore_FN122
   - Formatted table is named Offshore_FN122_coded

3. Creation of a unique identifier for Offshore_FN123
   - A make table query created a new *COMB_CODE* using *[YEAR]+'-OMNR-'+[PRJ_CD]+'-'+[SAM]* from table Offshore_FN123
   - A new *EFF_CODE* using *[YEAR]+'-OMNR-'+[PRJ_CD]+'-'+[SAM]+'-'+[EFF]* was created from table Offshore_FN123
   - Two criteria was used in the creation of the formatted table:

<u>Field</u>	<u>Criteria</u>
SPC	"091"
CATCNT	>0

   - Formatted table is named Offshore_FN123_091_coded

4. Creation of a unique identifier for Offshore_FN125
   - A make table query created a new *COMB_CODE* using *[YEAR]+'-OMNR-'+[PRJ_CD]+'-'+[SAM]* from table Offshore_FN125
   - A new *EFF_CODE* using *[YEAR]+'-OMNR-'+[PRJ_CD]+'-'+[SAM]+'-'+[EFF]* was created from table Offshore_FN125
   - A new *FISH_CODE* using *[YEAR]+'-OMNR-'+[PRJ_CD]+'-'+[SAM]+'-'+[EFF]+'-'+[FISH]* was created from table Offshore_FN125
   - One criteria were used in the creation of the formatted table:

<u>Field</u>	<u>Criteria</u>
SPC	"091"

   - 43 records were deleted that contained non-scale or unknown ageing structures (field generated from XAGEM). Null entries were retained under the assumption that these fish were aged using scales.
   - Formatted table is named Offshore_FN125_091_coded

5. Find duplicates queries were used to identify duplicate identifier codes (*COMB_CODE, EFF_CODE, FISH_CODE*) in Offshore_FN121_coded, Offshore_FN122_coded, Offshore_FN123_091_coded and Offshore_FN125_091_coded. No duplicates were found.

6. A find unmatched query was used to identify records in Offshore_FN125_091_coded that did not have matching effort data (via *COMB_CODE*) in Offshore_FN121_coded. 952 unmatched records were removed.

7. A find unmatched query was used to identify records in Offshore_FN125_091_coded that did not have matching effort data (via *EFF_CODE*) in Offshore_FN122_coded. No records were unmatched.

8. A find unmatched query was used to identify records in Offshore_FN123_091_coded that did not have matching effort data (via *COMB_CODE*) in Offshore_FN121_coded. 189 unmatched records were removed.

9. A find unmatched query was used to identify records in Offshore_FN123_091_coded that did not have matching effort data (via *EFF_CODE*) in Offshore_FN122_coded. 80 unmatched records were removed.

10. Creation of a lake whitefish individual sample index assessment table
    - A make table query combined fields (according to relationships between tables using *COMB_CODE* and *EFF_CODE*) from Offshore_FN121_coded, Offshore_FN122_coded and Offshore_FN125_091_coded.
    - One criteria were used in the creation of the formatted table:

<u>Field</u>	<u>Criteria</u>
AGE	>0

    - Formatted table is named IA_overall_091 Individuals

11. Creation of a lake whitefish abundance index assessment table
    - A make table query combined fields (according to relationships between tables using *COMB_CODE* and *EFF_CODE*) from Offshore_FN121_coded, Offshore_FN122_coded and Offshore_FN123_091_coded.
    - Formatted table is named IA_overall_091 Abundance

12. Creation of index assessment effort table
    - A cross tab query calculated average *EFFDST_KM* for each *YEAR* by *EFF_CODE* by QMA combination.
    - Query named IA_overall individuals Effort

Appendix 2. Email exchange between LHMU and Nawash Biologists regarding TAC recommendations

September 6th, 2006

Lloyd (Mohr),

I am requesting a biotech meeting on September 20th, 06 (morning or afternoon is fine for me).
Here is the first agenda item: 1. Review Nawash and LHMU reports/evaluations (including the 'binder report') for TAC determination for lake whitefish.

Please let me know if the date is suitable and if you will be adding any other agenda items.

Bill (Harford)

September 11, 2006

Bill/David (Latremouille):

In terms of our meeting, it appears that the only agenda item at this time is the review of TAC's. At this point in time the OMNR has not completed stock assessment for any of the whitefish stocks in QMAs 4-4, 4-7, 5-3, 5-6, or 5-8. Due to a number of reasons (mainly a lack of age data to feed the catch at age dependent models) we have been unable to conduct our normal analyses. A change in staffing in our office as well as the timing of the data has meant that I have had to move on to other tasks. Bottom line is that we have nothing to offer in terms of our TAC assessment for whitefish in S/O waters at this time. If you on the other hand would like to discuss your analysis and recommendations/interpretations I would be more than willing to meet and discuss them with you.

In terms of other agenda items, we may want to discuss the data exchange process. I think the last database we received still was different from the previous one we received in 2004. Maybe we need to re-define what each of us is looking for in each others data. Also, I had a request to include lake trout data in the monthly harvest updates so we may want to discuss that issue as well.

Anyway, the 29th is still good for me. Let me know what you think.

Cheers,
Lloyd

September 22, 2006

Bill:

I have a couple of requests with respect to some S/O data.
As I indicated in my last email, we are lacking age data for our popn modeling. If the ages aren't currently available, I was wondering if we could request a random subsample of scale samples. We would age them and return them as quickly as possible, likely by the end of the year. I would be interested in samples from 2004, 2005 and if possible, 2006 (the latter could be sent later, say December or January). I have not sat down and figured out how many but likely somewhere in the neighborhood of 750. Is this possible?

I have also been asked if we could get lake trout data included in the harvest summaries that you are providing. We do get the lake trout data in the final data exchange, but we would like to see it inlcuded in the year end summaries if possible.

I assume we are still on for the 29th? I have booked our boardroom if that is acceptable. Is there a preferred time?

Cheers,
Lloyd

September 27, 2006

Lloyd

In response to your most recent email:

1. Biotech Meeting: In the absence of OMNR analyses related to 2006 TACs, I have been advised that there is no need for a Biotech meeting at this time.

2. Lake trout: My understanding is that the Saugeen Ojibway do not associate Lake Huron lake trout harvests with TACs, since they consider the lake trout to be part of an ongoing OMNR put-grow-take hatchery stocking program that has not addressed basic scientific and ecological issues previously identified by First Nations. I have been advised that the in-season data exchange with the OMNR refers only to species associated with TACs, and that if the OMNR wishes to discuss this issue it should be raised at the Plenary rather than Biotech.

3. Whitefish scale samples: I will provide you with whitefish scale samples for 2004, 2005 and 2006 - please describe the specific
distribution of requested samples (years, regions). Further, I am requesting that when these fish are aged that the data be shared with the Saugeen Ojibway fisheries programs.

Bill

November 1, 2006

Lloyd

I have been directed by the Saugeen Ojibway Joint Fisheries Committee to make the following information request based on your September 11th email.

On Sept 11, 2006 you wrote:

"In terms of our meeting, it appears that the only agenda item at this time is the review of TAC's. At this point in time the OMNR has not completed stock assessment for any of the whitefish stocks in QMAs 4-4, 4-7, 5-3, 5-6, or 5-8. Due to a number of reasons (mainly a lack of age data to feed the catch at age dependent models) we have been unable to conduct our normal analyses. A change in staffing in our office as well as the timing of the data has meant that I have had to move on to other tasks. Bottom line is that we have nothing to offer in terms of our TAC assessment for whitefish in S/O waters at this time."

If any analyses or stock assessments for whitefish have been completed by LHMU since september 11, 2006 can you please forward them to David Latremouille and myself prior to Plenary (I have suggested a nov. 24 meeting date to Mark)

Bill

November 3, 2006

Bill:

First thanks for the scale samples. Much appreciated.

As to your request, I think I need to clarify my original response. The UGLMU would very much like to convene a meeting of the Bio Tech Committee to review the status of stocks around the Bruce Peninsula along with the Saugeen Ojibway commercial fishery. Although our Unit has yet to complete catch at age modeling for the area, we have looked at the information for whitefish stocks around the lake and have taken a quick look at the data provided by the Saugeen Ojibway. We are very interested in hearing the results of any stock assessment your group has completed and in sharing our perspective based on our interpretation of the data to date. Once we have a chance to interpret the age structures from the Saugeen Ojibway, then we will proceed with more detailed analysis and would hope to convene another meeting at that time.

I think with a Plenary meeting scheduled, we are obligated to have something to offer to that group. Please let me know your thoughts.

Thanks,
Lloyd

November 20, 2006

Bill:
The following is my perspective on TAC for 2006 for lake whitefish in the waters surrounding the Bruce Peninsula.

Catch at age analysis and statistical catch at age modeling where last done for these waters in 2005, based upon harvest data up to and including 2004. However age data was not available for the 2004 catch and therefore we assumed an age distribution in the 2004 catch similar to that in 2003. The results suggest that whitefish biomass declined slightly in 2004 and given current mortality and recruitment, would likely continue to decline. However, spawning stock biomass is still relatively high and it is not anticipated that this decline in overall biomass would have a significant impact on the commercial quotas. Our stock status evaluation protocol (SSEP) is slightly positive suggesting that harvest is sustainable. The recommendation for 2005 was no change to TAC.

In terms of 2006, our analysis lakewide was completed in April of this year. At that time we did not have the Nawash data to evaluate. We did not model any of the lake whitefish populations in the lake at that time. Our overall assessment of lake whitefish populations in Lake Huron for 2006 was that the populations continue to do well, there are indications that biomass is generally stable in most areas (i.e. QMA 4-5), while others show slight increases (i.e. QMA 5-9). In the end only 2 QMA's saw changes to whitefish quotas in 2006, QMA 5-1 in north eastern G. Bay, and QMA 5-9 in south eastern G. Bay; both saw increases of 10%. All other areas remained unchanged.

In terms of the waters around the Bruce, we are currently working on the scale samples provided. Complete analysis will likely not occur until the new year. Our evaluation of the data is very coarse at this time. Preliminary review of CPUE (all effort) suggests that relative abundance is down very slightly in the main basin or unchanged in south western G. Bay. Of interest to us is the fact that a large amount of quota was not fished in 2005. According to the records you supplied us with, only about 32% of the quota was harvested in the main basin and only about 60% was harvested in Georgian Bay. While we tend not use % quota harvested as a direct measure of population status, when dramatic changes in harvest do occur, we look for some reason for the change. Can you offer any insight in these changes?

My feeling at this point is that no change in TAC is warranted for 2006. Hopefully SCAA modeling and other analysis will confirm this recommendation and give us some insight into possible TAC for 2007.

I am available to meet with you and David Latremouille the morning of the 21st or the afternoon of the 22nd to discuss TAC recommendations. Please let me know which works for you two.

Cheers,
Lloyd

November 20, 2006

Lloyd,

I am willing to meet with you on wednesday afternoon to qualify and discuss your analyses.
How about 2:30 pm?

Bill

November 21, 2006

Bill:

Sounds good. Is there someplace you prefer to meet? Our boardroom is available.

Lloyd

November 21, 2006

Lloyd,

LHMU would be best, that way it's not far for Dave if he is finished tagging and can meet.
Also, after talking to Mark he indicated that MNR had concerns with data exchange and ageing data, perhaps if this is a simple miscommunication or an oversight on my part we can correct this problem on wed, rather than draging it into Plenary.
Bill

November 24, 2006

Steve (Crawford) /Bill (Harford) /David (Latremouille),

Here is the requested information. Let me know if there are questions.

Dave (Reid)

Table 1. Changes to the Lake Huron commercial lake whitefish quotas for the year .

QMA	Current Base Quota (kg)	Recommended Change (%)		Revised Change (%)	Final Change (%)	Final Issued Quota (kg)	Final Base Quota (kg)
4-1	94,785	0		0	0	94,785	94,785
4-2	246,667	0		0	0	246,667	246,667
4-3	174,545	0		0	0	166,701	174,545
4-4	423,216	0	**P**	0	0	423,216	423,216
4-5	1,075,516	0		0	0	1,075,516	1,075,516
4-7	84,677	0	**P**	0	0	84,677	84,677
5-1	82,231	0		+10	+10	90,454	90,454
5-2	55,334	+10		+10	+10	60,868	60,868
5-3	55,722	0	**P**	0	0	55,722	55,722
5-4	8,511	0		0	0	2,134	8,511
5-5	18,000	0		0	0	0	18,000
5-6	32,198	0	**P**	0	0	29,930	32,198
5-7	68,657	0		0	+10	75,522	75,522
5-8W	10,000	+10	**P**	+10	+10	11,000	11,000
5-8E	38,478	+10	**P**	+10	+10	42,326	42,326
5-9	110,463	+10		+10	+10	121,510	121,510
6-1	381,102	0		0	0	381,102	381,102
6-3	4,888	0		0	0	4,774	4,888
TOTAL	2,964,990					2,966,904	3,001,507

Pending final discussions/negotiations with First Nations 20-May-05

Quotas in 2005 were based upon stock assessment using the UGLMU's lake whitefish SSEP. All normal analysis was completed. Where 2004 age data was lacking, age distribution was assumed to be identical to the previous year (2003).
Quotas in 2006 were based upon minimal stock assessment using only 1-4 elements of the UGLMU's lake whitefish SSEP. No modeling occurred for any lake whitefish populations.
Note that standard practice by the UGLMU is to maintain status quo for quotas when data is not available to suggest otherwise. This was applied to Pending recommendations in 2006.

November 25, 2006

Dave (Reid),

Thank you for sending:
(a) 2005 and 2006 OMNR quota changes for all Lake Huron quota management areas
(b) 2004 LHMU Stock Status Evaluation Protocol (Lake Whitefish) for OMNR quota management areas 4-4, 4-7, 5-3, 5-6 and 5-8E

Please send:
(c) 2004 LHMU Stock Status Evaluation Protocol (Lake Whitefish) for OMNR quota management areas 5-8W and 5-9

(c) 2005 LHMU Stock Status Evaluation Protocol (Lake Whitefish) for OMNR quota management areas 4-4, 4-7, 5-3, 5-6, 5-8W, 5-8E and 5-9

Steve Crawford

Table 1. Changes to the Lake Huron commercial lake whitefish quotas for the year .

QMA	Current Base Quota (kg)	Recommended Change (%)		Revised Change (%)	Final Change (%)	Issued Quota (kg)	Final Base Quota (kg)
4-1	94,785	0		0	0	94,785	94,785
4-2	246,667	0		0	0	246,667	246,667
4-3	174,545	0		0	0	174,545	174,545
4-4	423,216	0	**P**	0	0	423,216	423,216
4-5	1,075,516	0		0	0	1,075,516	1,075,516
4-7	84,677	0	**P**	0	0	84,677	84,677
5-1	90,454	0		0	+10	90,454	90,454
5-2	60,868	0		0	0	60,868	60,868
5-3	55,722	0	**P**	0	0	55,722	55,722
5-4	8,511	0		0	0	8,511	8,511
5-5	18,000	0		0	0	18,000	18,000
5-6	32,198	0	**P**	0	0	32,198	32,198
5-7	75,522	0		0	0	75,522	75,522
5-8	53,326	0	**P**	0	0	53,326	53,326
5-9	121,510	+10		+10	+10	121,510	121,510
6-1	381,102	0		0	0	381,102	381,102
6-3	4,888	0		0	0	4,888	4,888
TOTAL	3,001,507					3,001,507	3,001,507

Pending final discussions/negotiations with First Nations 19-May-06
5-8 E and W combined again