STUDY FINAL REPORT

State: Michigan

Project No.: F-80-R-2

Study No.: 496

Title: Develop computer models of lake trout and lake whitefish in 1836 Treaty-ceded waters of lakes Superior, Michigan, and Huron

Period Covered: October 1, 2000 to September 30, 2001

Study Objective: To construct computer models of lake trout and lake whitefish populations and fisheries in 1836 Treaty-ceded waters of lakes Superior, Michigan, and Huron. Then, to utilize those models to assist with negotiating or litigating state/tribal-fishing agreements in the year 2000.

Summary: Lake trout and lake whitefish assessment, commercial and recreational harvest, and stocking data were assembled into relational databases. Geographical boundaries to be used for modeling purposes were defined for lake trout and for lake whitefish. Lake trout and lake whitefish models were constructed and debugged for these geographical areas. Catch-at-age analyses that best described lake trout and lake whitefish population dynamics were completed to the satisfaction of the Modeling Subcommittee. Model simulations were run under various management options using spreadsheet-based software to make short-term projections that were used by the negotiation teams to evaluate settlement options. The spreadsheet software has been used to make short-term harvest and effort projections for the implementation phase of the 2000 Consent Decree. A long-term projection model is in the developmental stage. A summary report describing the statistical catch-at-age modeling approach and generic descriptions of lake trout and lake whitefish models is in press. The status of lake trout and lake whitefish stocks will be described in *Status of lake trout and lake whitefish stocks in 1836 Treaty-ceded waters of the Great Lakes in the Year 2000* written by the members of the Modeling Subcommittee.

Job 1. Title: Inventory and assemble all available assessment data on lake trout and lake whitefish into relational databases by species and lake and correct errors.

Findings: All assessment data on lake trout and lake whitefish dating back to at least 1981 was inventoried and assembled into a common database. This included data collected in collaboration with the tribes, *Federal U.S. Fish and Wildlife Service and U.S. Geological Survey,* and all data available from the Michigan Department of Natural Resources (MDNR).

Job 2. Title: Assemble all sport and commercial harvest data, including age composition, into databases for each lake and correct errors.

Findings: Sport and commercial harvest data were assembled. Estimates of sport harvest prior to 1999 used in the models were those generated using software and algorithms in use at the time those surveys were done. These were deemed the best available estimates of harvest. Initially we considered the possibility of re-estimating harvest for all years using new formulae that provide more robust estimates of variance and potentially more reliable harvest estimates. Difficulties were encountered recovering all data and checking the many special cases. Initial re-estimates were sometimes far from the original values. In checks on a subset of cases this sometimes occurred because of unrecoverable data files needed to re-calculate these estimates. In other cases substantial differences were found that were generally resolvable as they resulted from special aspects of the creel survey at a site that had not been accounted for in the programs being used. However there were some differences in estimated values (generally not large for well-sampled sites) that arose from application of the new algorithm. Because initial checks indicated that re-calculated point estimates (where all data were available and there were no ambiguities) were similar to those calculated in the past, and because a fully verified set of new estimates could not be generated in the time available, the existing estimates were used. This is an area needing further examination. The State of Michigan commercial harvest data have been error checked, are complete, and have been put into a relational database in Lansing, Michigan. Tribal commercial fishery harvest data were also error checked, were also complete, and have been put into a relational database in Lansing, Michigan. Additional data will be requested from the agencies to supplement this database as required for future model development. Data on whitefish not yet recruited to the fisheries will be particularly useful for evaluating uncertainty in projections of fishable stocks.

Job 3. Title: Assemble all stocking data and correct errors.

Findings: Stocking data for lake trout are maintained by USFWS and the MDNR. Verification of data for all three of the upper Great Lakes was completed, and these data were put into a relational database in Lansing, Michigan.

Job 4. Title: Define geographical boundaries for models and migration.

Findings: Lake Michigan areas included a northern area encompassing Statistical Districts MM-1, MM-2, and MM-3 (south to Norwood) combined, MM-4 - Grand Traverse Bay, MM-5 - Leelanau Point to Arcadia, and MM-6 and MM-7 combined - Arcadia to Holland (Table 1, Figure 1). Lake Huron geographic boundaries were a northern area including the MH-1 statistical district and associated Ontario waters - Northern Lake Huron southward to Rogers City, and a north-central area encompassing MH-2 and associated Ontario waters- Rogers City to Sturgeon Point (Table 1, Figure 2). Lake Superior geographic boundaries for models of lake trout populations and fisheries were defined as lake trout management units MI-5 - Marquette, MI-6 - Munising, MI-7 - Grand Marais, and MI-8 - Whitefish Bay (Table 1, Figure 3). Within the northern Lake Michigan and combined MM-7 and MM-8 areas, separate sub-areas encompassing the northern and mid-lake refuges (respectively) were modeled to account for the lack of fishing in those areas and evidence that stocks in those refuges were not well mixed with the more nearshore stocks. Within Lake Superior lake trout were assumed to occur within the management unit they originally recruited to. In Lakes Michigan and Huron transition matrices were developed to account for movement among areas, based on information on movements including results of coded wire-tagging studies. A simple approach was adopted, whereby fish were moved immediately after stocking to a modeled area and were assumed to reside in this area of recruitment thereafter.

Lake Michigan geographic boundaries for models of lake whitefish populations and fisheries were defined as lake whitefish management WFM-01, WFM-02, WFM-03, WFM-04, WFM-05, WFM-06, and WFM-07 (Table 1, Figure 4). In northern Lake Huron geographic boundaries included whitefish management units WFH-01, WFH-02, WFH-04, and WFH-05 (Table 1, Figure 5). Data were inadequate to model the refuge area (WFH-03) in Lake Huron. In Lake Superior geographic boundaries for models of lake whitefish populations and fisheries were defined as lake whitefish management units WFS-04, WFS-05, WFS-06, WFS-07, and WFS-08 (Table 1, Figure 6).

Job 5. Title: Construct age structured lake trout population models and debug.

Findings: Lake trout population models were constructed for management areas as shown in Table 1. Model parameters for use in the construction of the lake trout models are similar to those used by Sitar (1996).

Shawn Sitar (Marquette Fisheries Research Station) and Dr. James Bence (Michigan State University, PERM) developed a comprehensive lake trout model, which took into account sea lamprey induced mortality. Models were developed using the software AD Model Builder (Otter Research Ltd. 1993). AD Model Builder allows the rapid development and fitting of general nonlinear statistical models similar to the catch-at-age models of lake trout and lake whitefish developed here. AD Model Builder achieves its high performance levels by employing the AUTODIF C++ class library. AUTODIF combines an array language with the reverse mode of automatic differentiation supplemented with precompiled code for derivatives of common array and matrix operations. In short, AD Model Builder is able to quickly compute exact solutions to difficult nonlinear problems thus making it state-of-the-art in this type of model development.

Compilation of needed data, and fitting and evaluation of lake trout models for all areas, was completed and has been a team effort including substantial contributions by many Michigan DNR, tribal, and federal biologists.

Job 6. Title: Construct age structured lake whitefish population models and debug.

Findings: A workshop was hosted at Michigan State University on December 29, 1998 to train participants in the use of AD Model Builder and demonstrated the simple lake trout and lake whitefish models described above. Dr. James Bence and Kurt Newman organized the workshop. Participants included biologists and modelers from MDNR, USFWS, and Chippewa Ottawa Tribal Fishery Management Authority (COTFMA).

Lake whitefish models were constructed for management areas as shown in Table 1. Model parameters for use in the construction of the lake whitefish models were similar to those used by Sitar (1996). Recreational fishing intensity is not high enough to include in these models. Data on sea lamprey wounding were only adequate to include in the models for Lake Huron whitefish.

As in Job 5 above, AD Model Builder was used to develop comprehensive models of lake whitefish populations and fisheries. Kurt Newman worked with Dr. James Bence in development of these models. The basic model included two fisheries, trap and gill net. Development of the basic model was done with a time series of the necessary data compiled by Mark Ebener (COTFMA) from whitefish management unit WFM-03. Models have been developed for all whitefish management units. As with lake trout models, the stock assessment and modeling for lake whitefish for all management units was done cooperatively with state and tribal biologists making substantial contributions.

Job 7. Title: Run catch-at-age analysis and estimate the optimum suite of parameters that best describe the population dynamics of lake trout and lake whitefish.

Findings: Fisheries catch-at-age models are used to try and estimate exploitation rate, population size-at-age, and recruitment to the fishery in exploited fish populations. A workshop conducted for the modeling group April 14 and 15, 1999 helped us to focus on model development and data needs. Model and data development were delegated among group members at that meeting. A second meeting on August 19 and 20, 1999 was convened to finalize the status of all stocks being modeled, and the remaining data requirements for model development.

Results from the models described above, which make use of the full time series of data inputs, were compiled and evaluated. Consensus among the modeling group was that the basic results were complete and the development of final reports is underway.

Job 8. Title: <u>Run model simulations according to various management options to estimate future population dynamics</u>.

Findings: This modeling begins with parameter estimation, which leads to short-term projections of total allowable catches (TAC's), and potentially to long-term projections under different management scenarios (gaming). AD Model Builder also provides simple methods for calculating the profile likelihood and Markov chain simulation estimates of the posterior distribution of parameters of interest. For example, the code for our catch-at-age models could be used to estimate the profile likelihood for the projected biomass of an age class of fish in the fishery. As a typical application of the method, the user of the model could estimate the probability that the biomass of fish for next year will be larger or smaller than a certain value. Estimates like these would obviously be of great interest to negotiating or litigating parties. Parameter estimation for all management units was completed and a short-term projection model was developed utilizing Microsoft Excel software as the platform. A long-term projection model is in the developmental stage.

Job 9. Title: <u>Update models as data become available and recalibrate if necessary</u>.

Findings: Updates to models will continue as new data are collected. At this time the modeling group is in agreement that the parameter estimation phase of this modeling effort has been completed with the best and most appropriate time series data available by management unit. Re-estimation of parameters will be done on a timetable decided upon by the Modeling Subcommittee.

Job 10. Title: <u>Assist the negotiating or litigating parties in predicting how differing settlement scenarios will effect lake trout and whitefish populations</u>.

Findings: On January 25, 1999, Richard Schorfhaar, Dr. James Bence, and Kurt Newman, along with other key MDNR personnel, met with John Wernet, the Assistant in Charge of the Native American Affairs Division of the Attorney General Office to discuss the development of the catch-at-age models. The extent of our collaborative efforts with tribal biologists to date was also discussed. At that meeting, the attorneys became familiar with the ongoing modeling process

A meeting of the Technical Fisheries Review Committee (TFRC) was convened on August 20, 1999. At that meeting, the modeling group discussed the status of the modeling process with members of the TFRC who were also involved in negotiations. The TFRC was satisfied with model development to date. The modeling group provided the litigating parties preliminary results based on model development throughout the latter stages of the negotiations.

A short-term projection model utilizing Microsoft Excel software was used by the negotiators to show how various settlement scenarios would effect lake trout and whitefish populations and the parties.

Assistance to the implementation team and to the Technical Fisheries Committee (TFC) is ongoing. Recommended harvest levels for lake trout and lake whitefish during the 2001 fishing season were provided to the TFC (Tables 2 and 3).

Job 11. Title: Write annual Federal Aid reports and reports documenting construction of the models, how they were used in the negotiation or litigation process, and how well any settlements conformed to the model outputs.

Findings: A summary report describing the statistical catch-at-age modeling approach and generic descriptions of lake trout and lake whitefish models will be authored by Dr. James Bence and Dr. Kurt Newman. It is expected that Richard Schorfhaar and Dr. James Bence will review and edit the manuscript, after which all collaborating parties will have an opportunity to make suggestions and/or additions to the paper.

Final reports/stock assessments are in development. The status of lake trout and lake whitefish stocks will be described in *Status of lake trout and lake whitefish stocks in 1836 Treaty-ceded waters of the Great Lakes in the Year 2000* written by the members of the Modeling Subcommittee.

Literature Cited:

Otter Research Ltd. 1993. AD Model Builder software. Box 265, Station A, Nanaimo, B.C., Canada.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer 39:175-192.

Sitar, S.P. 1996. Estimation of lake trout (Salvelinus namaycush) abundance and mortality due to sea lampreys (Petromyzon marinus) and fishing in the main basin of Lake Huron, 1984-93. Michigan Department of Natural Resources, Fisheries Research Report 2030, Ann Arbor.

Smith, S.H., H.J. Buettner, and R. Hile. 1961. Fishery statistical districts of the Great Lakes. Great Lakes Fishery Commission Technical Report No. 2, Ann Arbor, Michigan.

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Table 1.–Lakes Michigan, Superior, and Huron management units[a] where modeling efforts (x) were done for lake trout, whitefish, or both species.

Management Unit	Michigan		Superior		Huron	
	Lake trout[b]	Whitefish	Lake trout	Whitefish	Lake trout	Whitefish
M-1	x	x			x	x
M-2	x	x			x	x
M-3	x	x				
M-4	x	x	x	x		
M-5	x	x	x	x		
M-6	x	x	x	x		
M-7	x		x	x		
M-8		x	x	x		

[a] Lake Superior management units are subdivisions of statistical districts and lakes Michigan and Huron are statistical districts as described by Smith et al. (1961).
[b] Adequate data were not available for some lake trout management units so MM-1, -2, and –3 were combined into one model as were MM-6 and –7.

Table 2.–Lake trout harvest and effort limits recommended by the Technical Fisheries Committee (TFC) for 1836 Treaty waters of lakes Superior, Michigan, and Huron in 2001, as calculated by the Modeling Subcommittee. Harvest limits (lbs) and, where applicable, effort limits (feet of gill net) are provided for each Management Unit. NA means that large mesh gill nets may not be fished in the management unit

Lake and management unit	Harvest limit (lb)		Gill net effort limit (ft)
	State	Tribal	
Lake Superior			
MI-5	137,000	7,000	NA
MI-6	14,000	11,000	612,000
MI-7	42,000	97,000	11,000,000
Lake Michigan			
MM-1,2,3	35,000	486,000	8,500,000
MM-4	57,000	70,000	1,100,000
MM-5	32,000	21,000	720,000
MM-6,7	828,000	92,000	NA
Lake Huron			
MH-1	3,000	69,000	5,900,000
MH-2	11,000	1,000	NA

Table 3.–Lake whitefish harvest limits[a] or Harvest Regulation Guidelines[b] (HRGs) recommended by the Technical Fisheries Committee (TFC) for 1836 Treaty waters of lakes Superior, Michigan, and Huron and their respective Whitefish Management Unit subdivisions (WFS-, WFM-, and WFH-) in 2001, as calculated by the Modeling Subcommittee except as noted.

Lake and management unit	Harvest Limit State (lbs)	Harvest Limit or HRG Tribal (lbs)
Lake Superior		
WFS-04	25,000	415,000
WFS-05	78,000	409,000
WFS-06	0	HRG - 63,000
WFS-07	0	HRG - 409,000
WFS-08	0	HRG - 176,000
Lake Michigan		
WFM-01	80,000	716,000
WFM-02	0	HRG - not provided
WFM-03	0	HRG - 953,000
WFM-04	0	HRG - 590,000
WFM-05	0	HRG - 235,000
WFM-06	45,000	106,000
WFM-08	500,000	2,805,000
Lake Huron		
WFH-01	0	HRG – 327,000
WFH-02	0	HRG – 620,000 – 650,000[c]
WFH-03	0	HRG – 220,000 – 250,000[d]
WFH-04	0	HRG – not provided
WFH-05	0	HRG – not provided

[a] Harvest limit is used in the 2000 Consent Decree as a surrogate of Total Allowable Catch and implies enforcement of the limit.

[b] Harvest Regulation Guidelines consider factors such as fishing effort, catch, fish population characteristics, stocking, sea lamprey impacts, bioenergetics, fish health, and environmental factors in their establishment and enforcement.

[c] Trap net effort increased rapidly making realistic estimates of mortality difficult so the HRG was based largely on recent harvest history.

[d] Only 9 years of data were available making it problematic to use catch-at-age modeling so the HRG was based largely on recent harvest history.

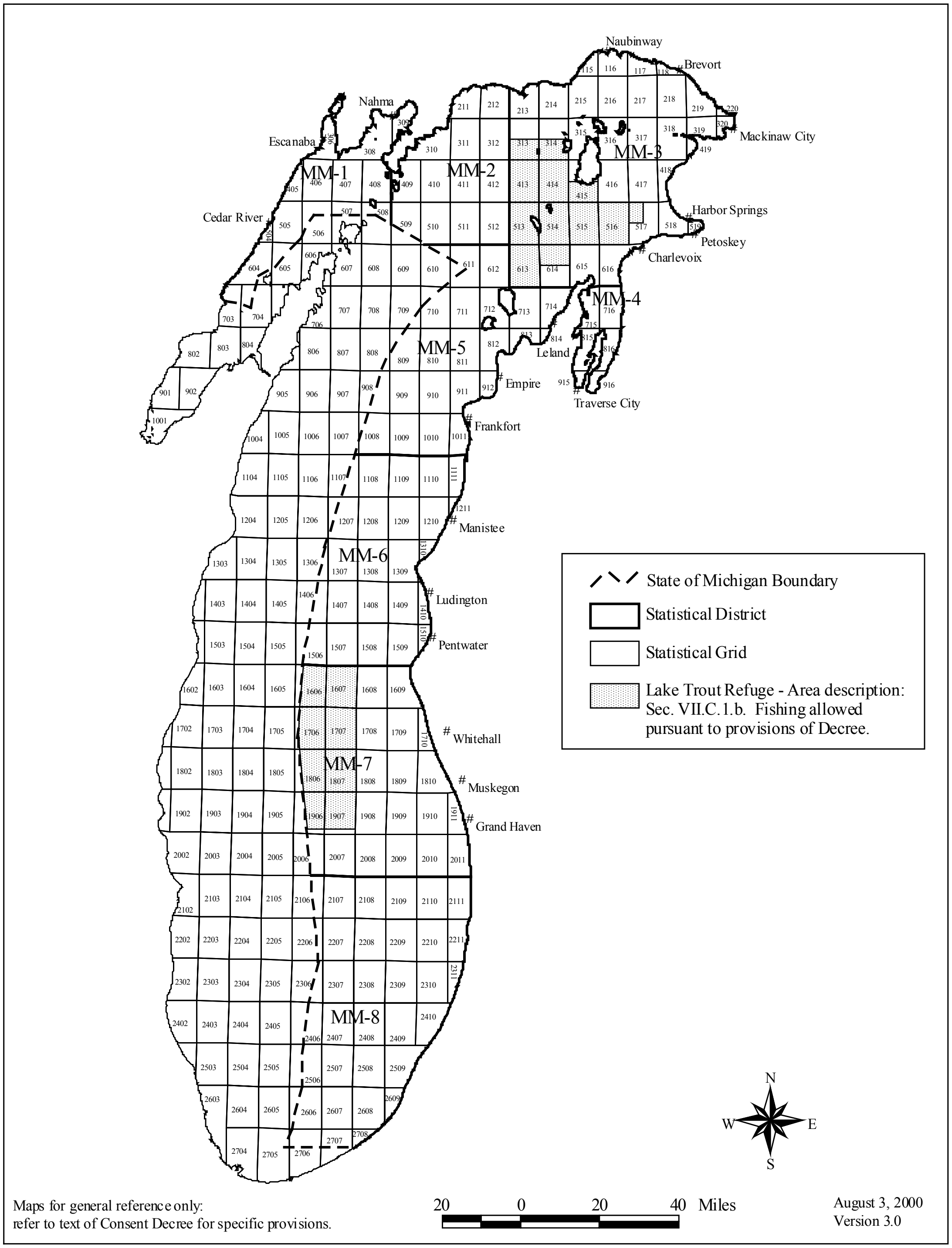

Figure 1.–Lake Michigan Statistical Districts and Lake Trout Refuges (Smith, Buettner and Hile 1961, modified to conform to grid lines) (Sec. VII.A.).

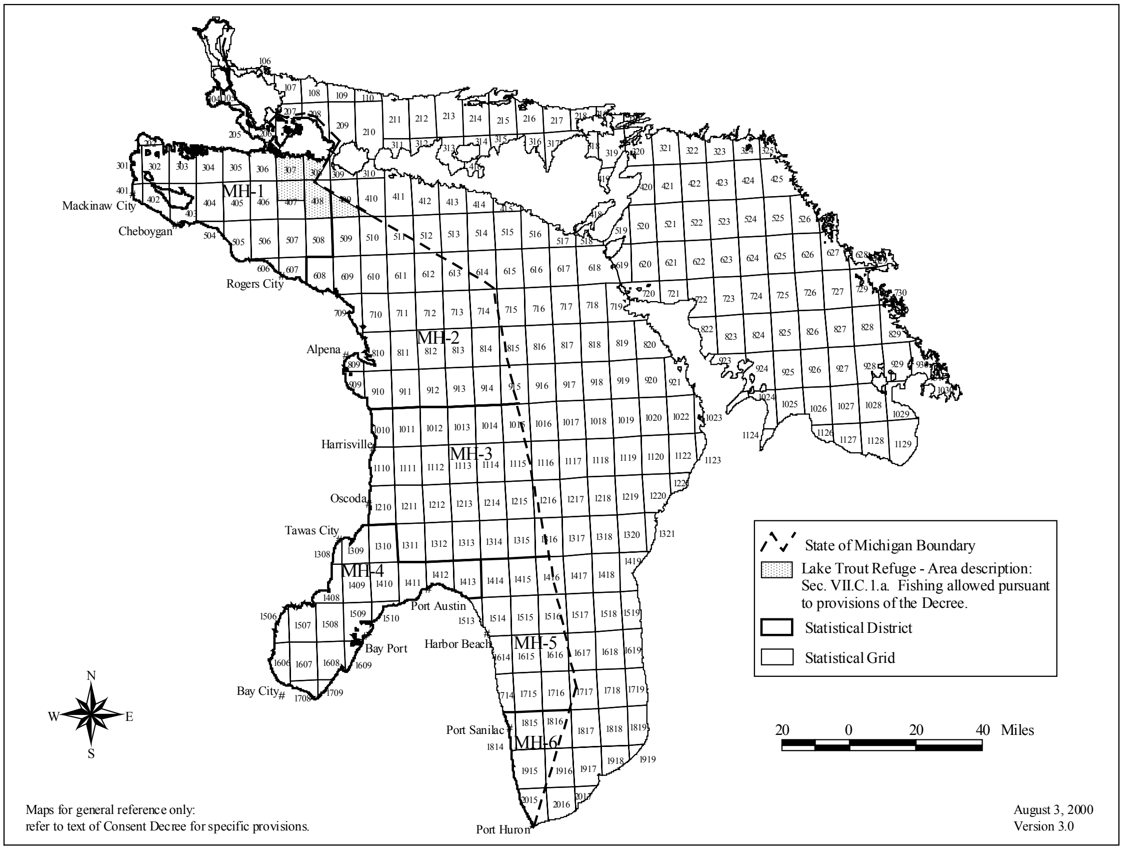

Figure 2.–Lake Huron Statistical Districts and Lake Trout Refuge (Smith, Buettner and Hile 1961, modified to conform to grid lines) (Sec. VII.A.).

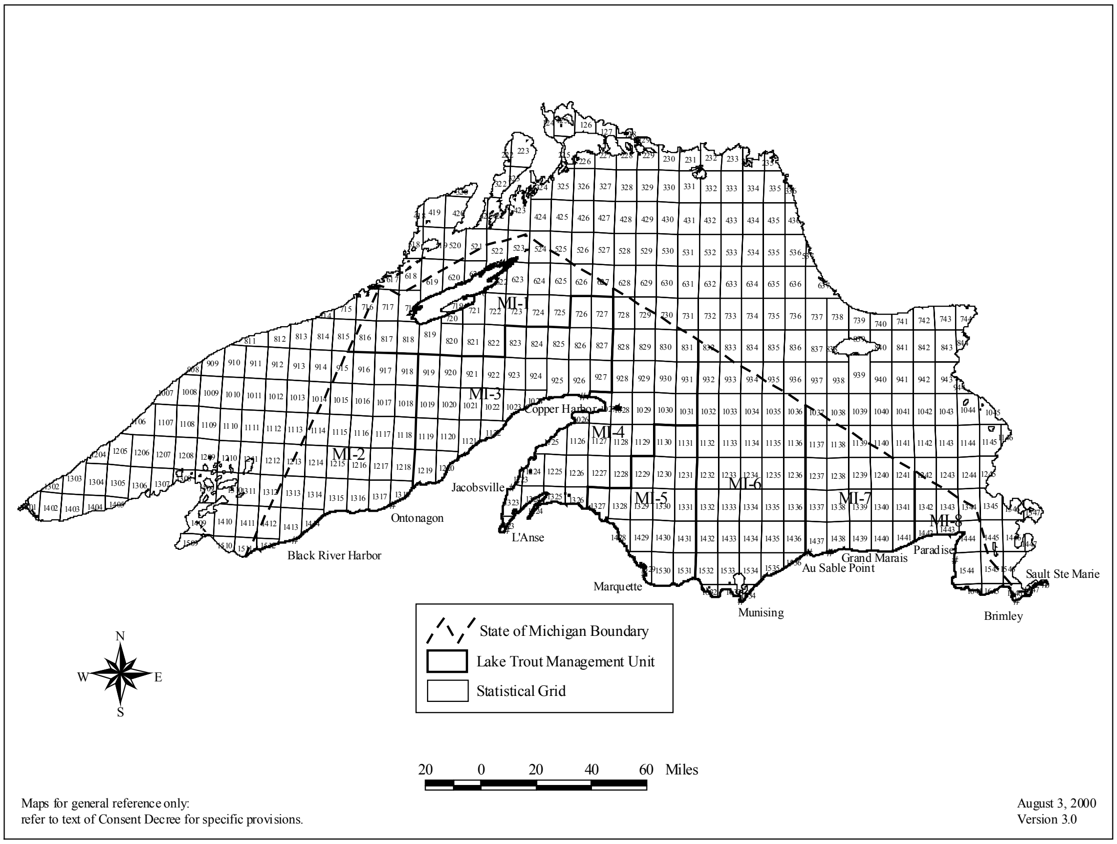

Figure 3.–Lake Superior Lake Trout Management Units (Hansen [ED.] 1996) (Sec. VII.A.).

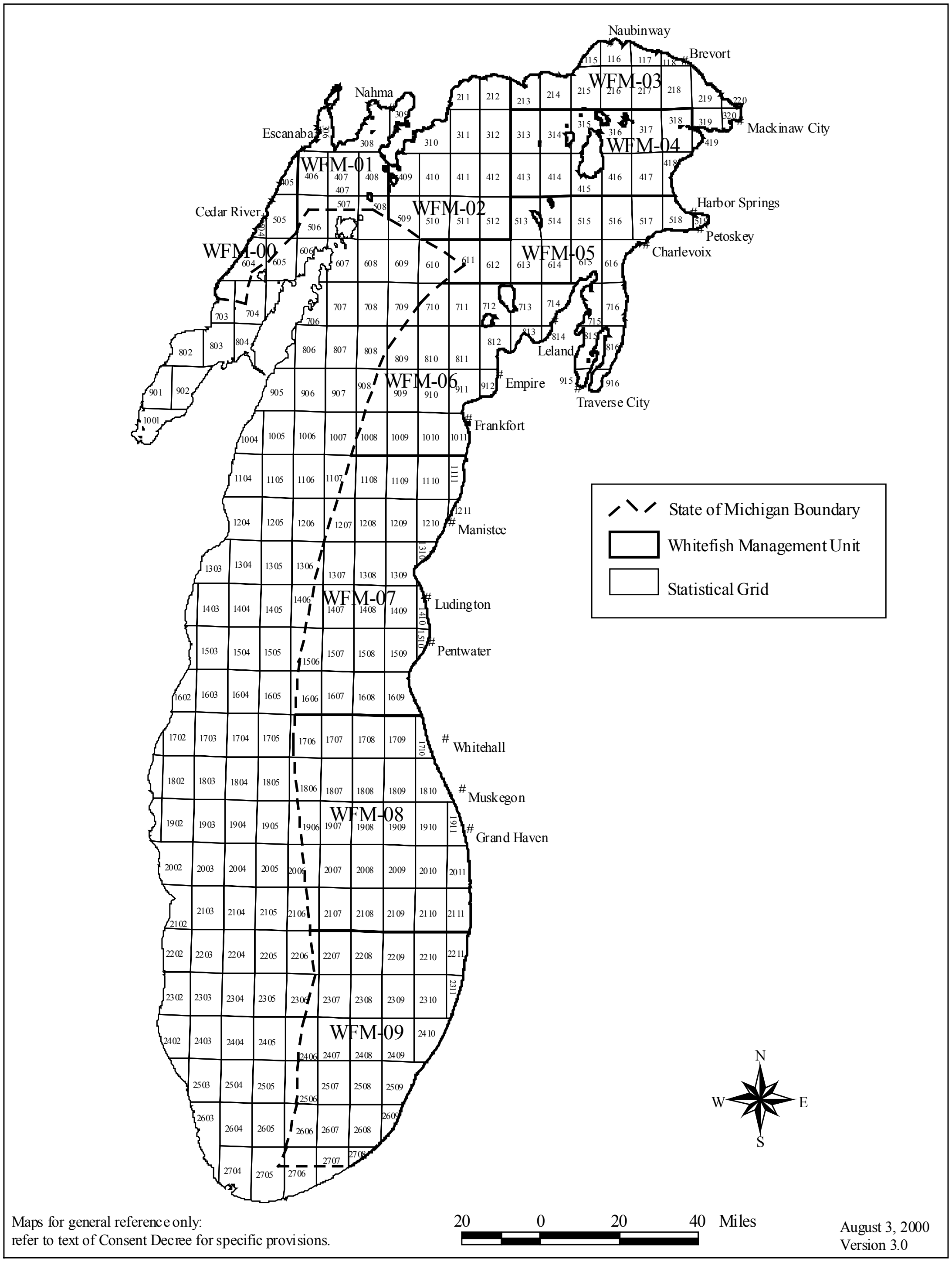

Figure 4.–Lake Michigan Whitefish Management Units (Sec. VII.A.).

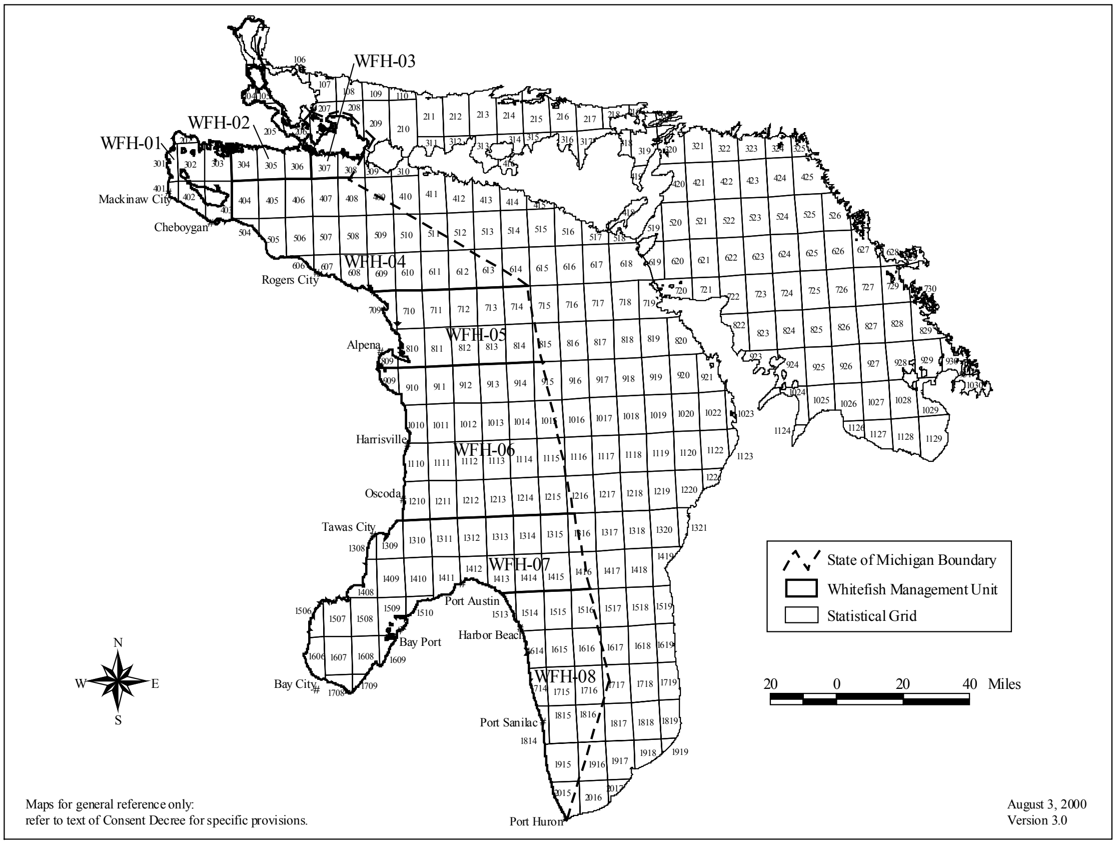

Figure 5.–Lake Huron Whitefish Management Units (Sec. VII.A.).

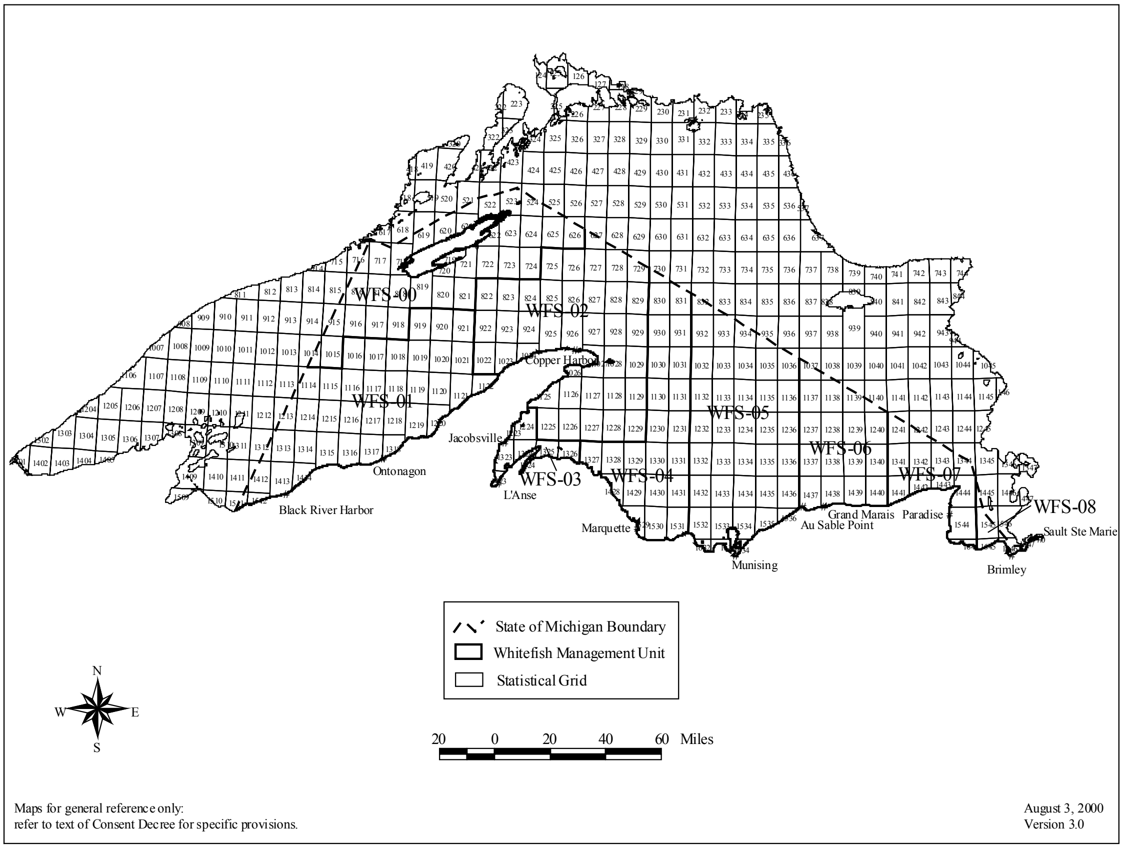

Figure 6.–Lake Michigan Whitefish Management Units (Sec. VII.A.).