STUDY PERFORMANCE REPORT

State: Michigan **Project No.:** F-80-R-1

Study No.: 480 **Title:** Development of Decision Models for the Great Lakes' fisheries

Period Covered: October 1, 1999 - September 30, 2000

Study Objective: Develop decision models for Great Lakes salmonine fisheries that incorporate stocking, harvest, and other management actions as control variables; and predict the likely outcomes such as harvest rates in different locations and other measures of ecosystem performance relevant to achieving a valuable and sustainable fishery.

Summary: Statistical catch-age models were constructed or refined for major predators and harvested species in Lakes Michigan, Huron, and Superior. Similar estimation work has focused on forage fish dynamics in Lake Michigan. Work is now beginning to conduct basic research on the estimation methods and to extend the approach to yellow perch in Lake Michigan. The species-specific stock assessment results are being linked together to estimate consumption of forage fish and to model fish community dynamics in Lake Michigan and Lake Huron.

Job 1. Title: Data review.

Findings: Our work on data review supports our ongoing efforts in the areas of stock assessment and fish community modeling. We continued a number of efforts to update information available for use in fitting and evaluating models.

We analyzed updated information from Biological Resources Division (BRD) of USGS, Michigan Department of Natural Resources, Chippewa Ottawa Treaty Management Authority (COTFMA), and Ontario Ministry of Natural Resources (OMNR) on harvest, age composition, and diets for the major piscivores in Lake Huron for work estimating consumption rates of forage fish (see Job 4 and Study 689, Study Performance Report).

We extended our earlier work (with the Great Lakes Science Center (BRD, USGS)) on forage fish survey data for Lake Michigan to provide age-specific indices of abundance after 1994. This work is based on analysis of a 37 year time-series of trawl survey data and is being done collaboratively with BRD. It was critical to extend these analyses to the most recent years when hydroacoustic data on forage fish were also available. The result of our previous work has been improved indices of abundance based on General Linear Mixed Models, which take into account station and depth effects and account for random year by station interactions. Our methods adjust for changes in survey design, extract more information from the data, and account for multiple sources of uncertainty.

We worked with other investigators to complete the task of bringing together the needed data/information for age-structured stock assessments of lake trout and lake whitefish in much of Michigan's waters of the Great Lakes. These data included harvest and harvest age composition, fishing effort, survey or assessment fishery indices of abundance (and survey age compositions), life history information, weight and length at age, and sea lamprey wounding statistics and effort. We also continued to bring together information on sea lamprey abundance as part of our work on modeling the sea lamprey-lake trout interaction.

Job 3. Title: Spatial model for chinook salmon.

Findings: Our additional explorations of a spatial model for chinook model in Lake Michigan confirmed our tentative conclusion reported last year that available information cannot support such a predictive model. Reasonable spatially explicit predictions are compromised by temporal variations in spatial distributions, coarse resolution of available catch-per-effort information, and lack of information on how catchability and mortality vary spatially. Hence, we have concentrated our efforts on a model for the entire lake. These efforts are reported under Job 4.

Job 4. Title: Tropho-dynamic and predator models.

Findings: We continued to refine existing predator population models for the main basin of Lake Huron and used these in combination with a gross production approach to estimate predator consumption of forage fish. The predators we considered were determined through consultation with the Lake Huron Technical Committee and included, three populations of lake trout (north, central, south), two distinct populations of walleye (Saginaw Bay and southern main basin), chinook salmon (entire main basin), and burbot (entire main basin). Details of model structure were described in previous reports. Our work over the past year has included application of the Wisconsin bioenergetics model to Lake Huron specific information and data to provide improved estimates of gross conversion efficiency, substantial updates to the chinook salmon model, lake trout models, and updated inputs on diets and growth for all predators. The updated chinook salmon model took into account newly available information on changes in chinook salmon size-at-age and associated maturity schedules. The revised model allows for changes in size-at-age and shifts maturity toward younger ages when chinook salmon are larger at age. Lake trout models were updated to make use of data from the past five years and to account for movement within areas of Lake Huron. More detail on this work is reported in the Study 689 Performance Report, and for lake trout models under Job 8.

Overall, our results continue to suggest that total consumption may be near the productive capacity of Lake Huron although there is still great uncertainty. Current estimates of consumption are above estimates of historical consumption by lake trout and are substantial relative to estimates of forage abundance. Model projections, however, continue to indicate that large reductions in stocking would be required to substantially reduce predator demand for prey, due to major contributions of self-sustaining native and naturalized predator populations.

We revised our lakewide stock assessment model for chinook salmon in Lake Michigan. This revision was substantial and was needed to account for new information indicating a larger change in growth and maturation than we previously had acknowledged. The change resulted in a less pronounced peak in biomass and consumption during the mid-1980s because of the compensating reductions in growth. The model now predicts an even larger increase in biomass and consumption in the late-1990s due to year classes with higher recruitment (both stocked fish and wild) and an assumed higher survival. We note that this spike in stock size is highly uncertain since it depends upon an unverified assumption that mortality did not increase when stock size reached very high levels.

We continued to work to update the existing SIMPLE model that links predators and prey fish in Lake Michigan, together with Dr. Mike Jones at Michigan State University. During the past year we have focussed on a parameter estimation model to estimate stock-recruitment dynamics of key forage fish species, while accounting for mortality due to predator consumption. This approach treats predator abundances as a forcing function (estimated externally in separate analyses) and parameters are estimated to determine a recruitment time-series and the functional response linking predators to prey. With recruitment and stock sizes of the forage fish then in hand, a stock-recruitment function can be estimated. Because this approach relies on both forage fish survey data and predator abundance estimates, this work is tightly linked to our work on forage fish data and predator stock assessments.

This work was implemented in the AD Model builder environment, and our current model attempts to estimate alewife and bloater recruitment patterns, while treating predators and the abundance of other forage fish as "known". We have encountered two main challenges in this work. First, initially our model (based on the existing SIMPLE model) for bloater assumed constant size-at-age and did not distinguish between the sexes. However, the change in size-at-age over time has been substantial and the sex ratio also has changed over time. It appears that differential mortality rates between the sexes can explain changes in the sex ratio over time, and we have modified the SIMPLE model to allow for this by treating male and female bloater separately. We have addressed changes in bloater size-at-age through a separate estimation model. This model fits observed size-at-age data over time by allowing growth rates to change dynamically. Incremental growth follows a von Bertalanffy model, and the parameters of the model are allowed to change gradually over time. This work is now nearing completion.

The second and larger challenge has to do with the observed patterns in alewife age and length compositions. The prevailing view is that predator consumption of alewife has been substantial and is largely contributory to the observed decline in alewife abundance. However, observed age and length compositions for alewife do not show substantial changes over time. Given the current estimates of size selection by the predators, the model cannot fit the observed age composition without estimating very low levels of predator-induced mortality, and extremely high alewife abundance. Higher predation mortality results in shifts in modeled age- and size-compositions toward younger and smaller fish. We are attempting to explore alternative explanations for this result, including the possibility that consumption by predators on alewife is more heavily concentrated on younger ages than was previously suspected.

Job 6. Title: <u>Expand research into other areas.</u>

Findings: Research was expanded through funding obtained from other agencies and by partnership with other Projects. Additional support was obtained from the Great Lakes Fishery Commission (GLFC) and Michigan Sea Grant (MSG) to sponsor research on salmonine stock assessment and modeling in the Great Lakes. Sea Grant and GLFC supported graduate students and staff who participated in modeling and data analysis of predator and forage fish in Lake Michigan. Currently a Ph.D. student (Emily Smith) is working in this area. Details on this work are described in other Jobs. Additional MSG funding was obtained to support research on stock assessment modeling methods, and funding was arranged through GLFC to support specific stock assessment work on yellow perch in Lake Michigan. A new Ph.D. student was recruited and started in the fall of 2000 (Michael Wilberg) to participate on these projects. GLFC funding has supported work by a Ph.D. student (Mike Rutter) on sea lamprey-lake trout interactions (see Job 8). This sea lamprey work was extended to include active participation in the sea lamprey international symposium (Dr. Bence co-chaired a session) sponsored by the GLFC, and we are working on several review and synthesis manuscripts stemming from that symposium. GLFC funding supported the initial work on predator modeling on Lake Huron (see Job 4), which has now been continued as Study 689 through the work of a Ph.D. student (Norine Dobiesz), and oversight is being provided on this project. GLFC provided funding to support a stock assessment methods workshop Dr. Bence helped coordinate (along with Dr. Patrick Sullivan (Cornell Univ.) and Nigel Lester (OMNR)). As an extension to our work on lake trout stock assessment models (see Job 8) we also developed prototype statistical catch-at-age models for whitefish and provided consultation on extending this approach to a range of whitefish management areas. This work interacts with lake trout work because the two species are caught together.

Basic research on methods for analyzing spatial and temporal data was finalized in a manuscript accepted for publication (Stewart-Oaten and Bence).

Job 7. Title: Publish results and prepare annual reports.

Findings: This annual report was prepared.

Three manuscripts were accepted for publication:

Stewart-Oaten, A., and J.R. Bence. In press. Temporal and spatial variation in environmental assessment. Ecological Monographs.

Benajmin, D.M., and J.R. Bence. In press. Spatial and temporal changes in the Lake Michigan Chinook Salmon fishery, 1985-1996. Michigan Department of Natural Resources, Fisheries Research Report.

Benajmin, D.M., and J.R. Bence. In press. Statistical catch-at-age assessment of Chinook salmon in Lake Michigan, 1985-1996. Michigan Department of Natural Resources, Fisheries Research Report.

One manuscript was submitted and is now under review:

Ann E. Krause, Daniel B. Hayes, James R. Bence, Charles P. Madenjian, and Ralph M. Stedman. Submitted. Measurement variability in nine Lake Michigan fish species. Journal of Great Lakes Research.

Results were presented in an invited seminar:

Bence, J.R. Fishery stock assessment as inverse population modeling - assessing uncertainty. Invited Seminar. Michigan State University, College of Agriculture and Natural Resources Biometry Group. October 4, 1999.

Job 8. Title: Lake trout model development.

Findings: The development of statistical catch-at-age models for lake trout went from the prototype stage to completed assessments for the most of 1836 treaty ceded waters of lakes Michigan, Huron, and Superior. Assessment models were extended to include the entire main basin of Lake Huron. These models provided a scientific underpinning to negotiations regarding harvest allocation, which ultimately led to a negotiated settlement between the State of Michigan, Tribal groups, and the Federal government. We participated as consultants in the model building process, which included the development of prototype models, in explaining the models to participants in the negotiation process, and as active participants in the construction of some models (notably the models for southern main basin Lake Huron and Lake Michigan).

A related area of lake trout stock assessment modeling has been an attempt to integrate a sea lamprey functional response into the lake trout models. We finalized our methods for summarizing wounding information to support this modeling, and a manuscript is in final stages of preparation. We have applied a novel generalized linear modeling approach to fit a logistic function relating expected wounding and lake trout size using data from individual lake trout. This approach has allowed us to synthesize large databases on marking in the form of year and area-specific asymptotic (with lake trout size) wounding rates. Advantages of this approach include that it allows estimates of marking and mortality even when not all size classes are present and that it avoids biases associated with changes in relative numbers of fish of different sizes within the relatively large size categories used in previous summaries of wounding rates. We have discovered that in Lake Huron the shape parameters of the logistic function, not just the asymptote, appear to vary spatially but not temporally. We found a shift toward higher wounding rates on smaller fish in northern Lake Huron, where larger lake trout are scarce. This potentially suggests flexible behavior by sea lamprey. This result is not consistent with the type 2 functional response in use and complicates the task of modeling the functional response. Efforts to predict observed wounding rates from a functional response that accounts for sea lamprey and lake trout abundance have had limited success. In part, this may reflect this more complex behavioral response, although it may also reflect limitations of available data.

Prepared by: James Bence
Date: September 30, 2000