STUDY PERFORMANCE REPORT

State: Michigan **Project No.:** F-80-R-5

Study No.: 230713 **Title:** Improving fishery stock assessments in the Great Lakes

Period Covered: October 1, 2003 - September 30, 2004

Study Objective: Work with Michigan DNR researchers and managers, the modeling subcommittee (MSC) of the Technical Fisheries Committee for 1836 Treaty waters, the Lake Michigan yellow perch task group, lake committees and technical committees to evaluate the reliability of current and potential alternative approaches to quantitative fish stock assessment, and to evaluate current and alternative harvest or other management policies (e.g., allowable total mortality rates) with regard to their sustainability (e.g., avoiding stock collapses) and providing maximum benefits from the resource.

Summary: Activities during the past year included literature review (primarily in support of the research efforts of two graduate students), evaluation of assumptions underlying and use of resulting indices of abundance from mixed models, development of a general sensitivity analysis for statistical catch-at-age models with specific application to yellow perch in Lake Michigan, simulations evaluating different approaches to modeling selectivity and temporal changes in selectivity in statistical catch-at-age models, material preparation and design work for work shops for fishery professionals and managers, and preparation and submission of written work to peer-reviewed journals (one paper accepted for publication and another nearly ready for submission). All these activities achieved their primary goals and led to improved capacity for stock assessment in the Great Lakes and more broadly. These activities improved the science of statistical catch at age assessments, helped develop greater capacity among fishery professionals to use these methods, provided tools to improve specific suites of stock assessments, and directly led to improved stock assessments for yellow perch in Lake Michigan.

Findings: Jobs 1, 2, 5, 6, 7, 9, 10, 11, and 12 were scheduled for 2003-04, and progress is reported below.

Job 1. Title: **Literature review.**–The literature search begun last year has been continued to find articles pertaining to the Great Lakes, harvest policies and assessment approaches. This ongoing work reflects the need to stay abreast of ongoing developments and for training of graduate students participating in this project. This included one second-year student (Brian Linton) and a graduate student who started in August 2004 (Jon Deroba). Many of the articles examined this year have dealt with stock assessment approaches, sensitivity analyses used to evaluate stock assessment models, methods for estimating gear selectivity in stock assessment models, and harvest policies.

Job 2. Title: **Sensitivity analysis.**–A general evaluation of sensitivity of assumptions of existing stock assessment models is continuing. We built upon preliminary sensitivity analysis on lake whitefish during the previous year to emphasize sensitivity analysis of other assessment models, particularly yellow perch in Lake Michigan. The analysis evaluates sensitivity of the stock assessment models to variations in model inputs, such as statistical weights put on different data sources, as well as to variation in model structure, such as details of how selectivity is modeled. Sensitivity of the stock assessment models is evaluated by measuring changes in selected model outputs, which include: the predicted fully selected fishing mortalities for the active fisheries, predicted population biomass, predicted current spawning stock biomass per recruit (SSBR),

predicted SSBR of the unfished population, predicted SSBR at target mortality levels, and the estimated yield calculated for target mortality rates for the projected population. Results suggest that the yellow perch assessment model we have developed for Lake Michigan is relatively robust to different weightings for different data sources. For example, most outputs changed less than 10% when the weight put on a particular source of input data was changed five fold. We also provided input to Ji He (Michigan DNR Alpena) on approaches to evaluating sensitivity of lake trout and lake whitefish assessment models on Lake Huron outside the 1836 treaty water boundaries.

Job 5 Title: Mixed models.–Our work suggests that in some cases the "random effects" of existing mixed models are correlated either spatially or temporally suggesting we may need to change estimation models. We have also explored the possibility of using model averaging across different descriptions of random effects. Finally, we have developed an alternative approach to using abundance indices generated from these mixed models in analysis. The current approach is to weight each observation by its standard error. This approach does not account for the built in correlations among parameter estimates from mixed models. We are suggesting an alternative that takes into account the estimated correlation structure (asymptotic variance-covariance matrix) for the log-scale abundance indices.

Job 6 Title: Sensitivity to Selectivity Approach.–We participated in a collaborative research effort with Terry Quinn (University of Alaska) and Paul Radomski (Minnesota Department of Natural Resources) that has come to completion. A manuscript based on this work has been accepted for publication, and in the past year, we conducted simulations at Michigan State University to check simulations done by Paul Radomski using a different computing environment and performed additional analyses in response to reviewer concerns. In our final simulations, we evaluated the relative performance of statistical catch at age models (SCAA) making different assumptions about selectivity and Virtual Population Analysis (VPA). Generally, models that correctly modeled selectivity performed best, and VPA performed poorly when there was substantial measurement error in the fishery catch data. In this situation statistical models were preferred, especially if they were able to allow for the general kinds of temporal changes in selectivity that actually took place in the simulations. We have completed the experimental design for a new experiment to further evaluate alternative approaches to modeling time-varying selectivity in age-structured stock assessment models. In many of the assessment models used in the Great Lakes, selectivity is described by a double logistic function of age, with parameters that vary with time according to a quadratic function. Alternative methods for modeling selectivity in this study will include the use of different functions (e.g. using a gamma function in the place of a double logistic function) to model selectivity, and different ways of allowing selectivity to change with time (e.g. varying selectivity with time according to a random walk function instead of using a quadratic function). In the simulations, we will fit a stock assessment model using each of the selectivity sub-models to a series of simulated data sets. The simulated data sets will describe a hypothetical lake whitefish population. The goal of the study differs from our previous collaborative study in that we are not primarily seeking to identify a single best method for modeling selectivity. Rather, we seek to develop a method by which stock assessment biologists can determine how well a given method of modeling selectivity works in a specific stock assessment model. Methods for evaluating the selectivity sub-models include model selection criteria (e.g. Akaike's information criterion), examination of residuals for patterns, and various summations of the residuals (e.g. mean residual square error).

Job 7. Title: Evaluate catchability approaches.–We extended a series of simulations that evaluated different approaches to estimating catchability in a "generic" statistical catch-at-age assessment model based on comments we received at the 2003 Annual Meeting of the American Fisheries Society. A set of assumptions were made in the form of a generating model to produce simulated data and for each simulated dataset a suite of different estimating models was applied. The estimating models were evaluated on the basis of how well they reproduced known quantities

of interest (e.g., overall exploitation). The basic age-structured model used in both the generating and estimating models started from an initial age-structured population and accounted for recruitment and mortality each year. Total mortality rate (Z) was a sum of a constant natural mortality rate (M) and a fishing mortality rate (F) that varied by age and year using a separability assumption. Fishing mortality (on fully selected ages) was then was assumed to be in some sense "proportional" to effort (i.e., $F = q \bullet$ Effort). Generating and estimating models differed in how they allowed "q" (catchability) to vary over time. Generating models included ones that modeled catchability as white noise, as an autoregressive process, as changing abruptly in the middle of the modeled period, as trending over time, and as being density dependent (a power function of density). Estimating models included modeling catchability as white noise, random walk, or density dependent. The primary changes in our simulations involve how we included both fishery independent survey indices of abundance and fishery data. We now are generating simulated assessments that only use the survey data and only use the fishery data, as well as the type of simulated assessments we had done previously (that included both types of data). These new simulations are intended to determine whether the inclusion of fishery effort data helps or hurts an assessment when the assumption of direct proportionality between fishing mortality and fishing effort is violated. They are also intended to determine whether reasonable assessment results can be achieved when the direct proportionality assumption is violated and no fishery independent data are available. Our new simulation code has been developed and tested but results have not yet been compiled.

Job 9. Title: Develop workshop materials.–Dr. Bence has been working on text associated with past short courses. The intent here is to develop a monograph or manual for use with the short courses.

Job 10. Title: Hold workshops.–No workshops were held but planning was begun for more regular holding of workshops starting in 2005. Planning was begun for participation in two Council of Lake Committee's special workshops on stock assessment and harvest policies. Dr. Bence is directing a graduate student who will be presenting at one of these workshops in October and will be giving a presentation at the second workshop in 2005.

Job 11. Title: Lake Michigan yellow perch assessments.–Some refinements were done on the yellow perch assessment models developed in previous years. These represent separate assessments for Wisconsin and Illinois waters of Lake Michigan. The results following revisions remain unchanged and appear robust (see Job 2). Results indicate that total mortality rates were quite high (sometimes $Z>2.0$ on the most highly selected categories) during the period of less restricted fishing (prior to the 1990s). Available evidence strongly suggests these high mortality rates were largely due to commercial (Wisconsin) and recreational (Illinois) fishing, and in general fishing mortality rates were higher in Wisconsin than in Illinois. After closures of commercial fisheries and greater restrictions on recreational fishing, mortality rates declined. Under current conditions (recreational) fishing mortality rates on highly selected ages are on the order of $F=0.1$. Efforts to construct similar assessment models and obtain reliable estimates of mortality and stock size for Indiana and Michigan waters were less successful. This is primarily a consequence of data limitations. A manuscript is nearing completion on this work (see Job 12).

Job 12. Title: Prepare publications/reports.–This report was prepared on time. A manuscript describing the yellow perch assessment is nearing completion and submission to a peer-reviewed journal. A manuscript describing our collaborative simulations evaluating selectivity patterns was accepted for publication at the *Canadian Journal of Fisheries and Aquatic Sciences*.

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