STUDY PERFORMANCE REPORT

State: Michigan

Project No.: F-80-R-6

Study No.: 230713

Title: Improving fishery stock assessments in the Great Lakes

Period Covered: October 1, 2004 - September 30, 2005

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, completion of a sensitivity analysis for statistical catch-at-age models for lake whitefish in Lake Huron and a tool for automating this for lake whitefish assessments in other areas and for lake trout, developing an approach for additional simulations to evaluate how to address time-varying selectivity in age-structured assessment models, material preparation and presentations for workshops for fishery professionals and managers, and preparation and submission of written work to peer-reviewed journals (two papers published, one submitted, two nearing 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, and provided tools to improve specific suites of stock assessments.

Findings: Jobs 1, 2, 3, 5, 6, 7, 9, 10, and 12 were scheduled for 2004-05 and progress is reported below.

Job 1. Title: Literature review.–We have continued the literature search and review of 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 third year student (Brian Linton) and a graduate student who started in August 2004 (Jon Deroba). In the arena of stock assessment, articles examined this year have dealt primarily with estimating time-varying gear selectivity in assessment models, and methods for conducting simulation studies to evaluate stock assessment models. Jon Deroba has undertaken and largely completed a comprehensive review of the harvest policy and reference point literature. We expect this review to form the basis of a dissertation chapter and subsequent publication.

Job 2. Title: Sensitivity analysis.–We completed development of a general approach for evaluation of how sensitive lake trout and lake whitefish stock assessments are to the assessment model assumptions. The analysis determines how much stock assessment results change (sensitivity) in response to changes in model inputs. We evaluated changes such as starting values and bounds for model parameters, as well as to variation in model structure, such as the method used to estimate recruitment and the likelihood function used to fit model predictions to observed data.

The results evaluated for sensitivity included: the predicted fully selected fishing mortalities for the active fisheries, predicted population biomass, predicted spawning stock biomass per recruit (SSBR) of the unfished population, predicted SSBR at target mortality levels, predicted spawning potential reduction SSBR(target)/SSBR(unfished), and the estimated yield calculated for target mortality rates for the projected population. We applied this sensitivity analysis to whitefish stock assessments for four management units on Lake Huron. The fifth lake whitefish management unit on Lake Huron was not included because the stock assessment model failed to converge to a satisfactory solution. Results suggest that these stock assessment models are most sensitive to changes in recruitment parameters, gear selectivity parameters, and the likelihood function. One of the lake whitefish stock assessment models was found to be unstable since it converged to the same, suboptimal solution in one-third of the model variations tested. New programs for automating the sensitivity analysis of lake whitefish and lake trout stock assessment models were presented to the Modeling Subcommittee of the Technical Fisheries Committee for 1836 treaty waters.

Job 3. Title: <u>**Stock-Recruit Analysis.**</u>–Estimates of stock and recruitment for existing whitefish models were examined. Results indicated that significant variation could be explained by stock size following a Ricker model. However, there was also evidence that deviations from the Ricker models tended to be correlated among areas, especially within the same lake. Model-based characterization of these results will form an important basis for simulating harvest policies; however, it is likely that the stock-recruitment analysis will need to be considered further as part of future harvest policy analysis.

Job 5. Title: <u>**Mixed Models.**</u>–Existing mixed model applications have been used to summarize lake trout survey catch per effort data for use in stock assessments applied in lakes Michigan, Superior, and Huron. We have explored the sensitivity of the estimates from these mixed models to their assumptions, and evaluated assumptions by examination of residual patterns. We have also examined corrected Akaike's Information Criterion (AIC_C) for alternative models, as a basis for selecting the model that best explains patterns in observed data. We found that point estimates of the annual average CPE (least squares mean on log-scale) were not sensitive to the constant used prior to log transformation. However, there were modest changes in the estimated standard errors, with these becoming larger for smaller constant values. Generally there were relatively few zeros in the data, which is why the constant had modest influence on results. The base model included effects of location (grid) and year, a depth effect (for Lakes Huron and Superior but not Lake Michigan) and a random grid by year interaction. The deletion of the random interaction or the addition of additional random interactions involving depth caused little change in the point estimates for average annual CPE, but did influence the estimated standard errors. In general, estimated standard errors were larger as more random effects were included in the models. An important issue to keep in mind is that the goal is not to produce the smallest estimated standard errors, but rather to estimate a standard error that appropriately describes uncertainty in the log average abundance for each year. To this end we compared AIC_C values for models including different random effects or no random effects at all. In general the currently used or status quo mixed models were selected as "best". The one exception was a single management area on Lake Superior, where a model that also included all possible interactions with depth had the lowest (best) AIC_C. In this case the best model produced estimated standard errors as well as point estimates that were similar to the status quo model. Contrary to our initial impressions, further examination of residual and best linear unbiased predictors for random effects (BLUPs) suggests that temporal and spatial correlations are weak and thus the independence assumptions made by the mixed models are plausible. Our overall conclusion is that the status quo lake trout mixed models represent a reasonable approach and are generally robust to alternative assumptions. We have also developed mixed models for fishery catch per effort (CPE) for lake whitefish assessment models. The existing assessment models are fit to aggregated total catch for the management area and treat fully selected fishing mortality for a gear (trap net or gill net) as being proportional to fishery effort for that gear, up to a multiplicative error. This approach is equivalent to assuming that expected C/E based on annual totals is proportional to the average abundance of fish in the management area. A number of known or measured factors can cause this raw CPE (C/E) to vary from what would be expected given abundance. These include when during the year fishing took place, where fishing took place, and who fished. Less aggregated data were obtained from Mark Ebener of the Chippewa-Ottawa Resource Authority, in the form of grid by month total catch biomass and effort for each operator and gear type. We developed mixed models for each gear type and management area that incorporated effects due to operator, grid, and month and their interactions. We selected among alternative models based on AIC_C. We discovered that trends in the resulting mixed model estimates differed substantially from the trends in raw CPE in some areas, because of changes from year to year in who fished and the months and locations where fishing took place. These results suggest that assessments could be improved by using model-based CPE estimates that account for these "nuisance" factors.

Job 6. Title: Sensitivity to Selectivity Approach–We developed a simulation-based approach to evaluate current and alternative techniques for modeling time-varying selectivity in the stock assessment models. The current method for modeling selectivity uses a double logistic function which varies with time, according to either a quadratic function or a random walk process. Variation in selectivity is assumed to be known in the current stock assessment models. One goal of our current (in progress) simulation study is to determine how well temporal variation in selectivity can be estimated within a stock assessment model. The simulation study will fit a stock assessment model to simulated data sets describing a hypothetical lake whitefish population with different levels of variation in selectivity. Future simulations will evaluate the estimation of selectivity variation using different selectivity functions (e.g., using a gamma function in place of the double logistic) and under different conditions (e.g., as fish growth changes over time). This study is qualitatively distinct from our previous work on this topic because its goal is not just to find a single submodel for time varying selectivity that works best on average. Rather, the goal of the study is to develop a method by which stock assessment biologists can determine how well a given method of modeling selectivity works for a specific stock assessment. Methods for evaluating the selectivity submodels include: model selection criteria (e.g., Akaike's information criterion), examination of residuals for patterns, retrospective analysis, and various summations of the residuals (e.g., mean residual square error).

Job 7. Title: Evaluate catchability approaches.–Jim Bence collaborated with a graduate student who was funded by other means. We completed a series of simulations that evaluated different approaches to estimating catchability in a "generic" statistical catch-at-age assessment. 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 were 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. During this year we analyzed results of our simulations, and re-ran the simulations based on "friendly" reviews. We also completed a second set of simulations and evaluated whether Bayesian model selection methods could select the correct models and whether the selection procedure outperformed a single best omnibus approach. Results showed that the model selection procedures could identify the correct model, but only slightly improved estimates of key quantities. We believe the latter result partly reflects the details of our simulations.

Job 9. Title: Develop workshop materials.–Dr. Bence continued working on text associated with past short courses. The intent here is to develop a monograph or manual for use with the short courses. In addition he supervised efforts of a Visiting Assistant Professor funded from other sources, as part of the new Quantitative Fisheries Center at Michigan State University. This effort is developing online materials for approaches to estimation of parameters of nonlinear models. He also developed and oversaw development of materials for two Council of Lake Committee's workshops.

Job 10. Title: Hold workshops.–Dr. Bence provided guidance to a graduate student (funded by other sources) who gave a presentation at a Council of Lake Committees' workshop on stock assessment methods. Dr. Bence gave a presentation and helped plan a second Council of Lake Committees' workshop on harvest policies.

Job 12. Title: Prepare publications/reports.–This report was prepared. The sensitivity analysis of the lake whitefish stock assessment models for Lake Huron is being prepared for publication as a DNR report. A draft of the report has been presented to the MSC. Descriptions of the lake whitefish and lake trout projection models have been completed and were presented to the MSC for inclusion in the short report on the status of lake trout and lake whitefish populations in the 1836 treaty-ceded waters of lakes Superior, Huron, and Michigan. Two manuscripts describing our simulations comparing alternative approaches to modeling time-varying catchability were prepared for submission to the Canadian Journal of Fisheries and Aquatic Sciences.

The yellow perch assessment (Job 11 reported on in previous years) was submitted and published:

Wilberg, M.J., J.R. Bence, B.T. Eggold, D. Makauskas, and D.F. Clapp. 2005. Yellow Perch Dynamics in Southwestern Lake Michigan during 1986-2002. North American Journal of Fisheries Management 25: 1130-1152.

Collaborative work on evaluating approaches to addressing time-varying catchability is published:

Radomski, P., J.R. Bence, and T.J. Quinn II. 2005. Comparison of virtual population analysis and statistical kill-at-age analysis for a recreational, kill-dominated fishery. Canadian Journal of Fisheries and Aquatic Sciences 62: 436-452.

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