STUDY PERFORMANCE REPORT

State: Michigan

Project No.: F-80-R-8

Study No.: 230713

Title: Improving fishery stock assessments in the Great Lakes

Period Covered: October 1, 2006 to September 30, 2007

Study Objective: Work with Michigan DNR researchers and managers, the modeling subcommittee of the Technical Fisheries Committee for 1836 Treaty waters, the Lake Michigan yellow perch task group, and Lake committees and Lake 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 provision of maximum benefits from the resource.

Summary: Study amendments in 2004-2005 and 2005-2006 indicate that the study will apply results broadly including outside the Great Lakes, and encourage the use of state of the art approaches by others. Activities during the past year included: literature review (primarily in support of the research efforts of two graduate students); modeling work aimed at evaluation of fishery policies including harvest of yellow perch in Lake Michigan, harvest of lake whitefish, and sea lamprey control; completion and submission of a general review paper on harvest policies; work toward publishing previous simulations on methods for incorporating time-varying catchability into assessments; simulations evaluating alternative approaches for estimating the relative magnitude of process and observation variance in assessment models; simulations on how to model time-varying selectivity and to choose among the alternatives; and use of statistical models to develop indices of abundance from fishery and survey data for Great Lakes stocks of lake trout and lake whitefish. We also prepared workshop materials and presented them, targeting working fishery professionals, and worked to communicate results through presentations to professional groups and by preparing and submitting written work to peer-reviewed outlets. 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, worked toward model-based decision support, and provided input to improve specific suites of stock assessments.

Findings: Jobs 1, 4, 8, 9, 10, and 12 were scheduled for 2006-07, 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 a fifth (final) year Ph.D. student (Brian Linton) and a third year Ph.D. student (Jon Deroba). In the arena of stock assessment, emphasis has been on articles directly related to manuscripts being prepared or revised. Thus much of the literature we considered dealt with approaches to allowing selectivity and catchability to vary over time, approaches to summarizing fishery or survey catch-per-effort based on ANOVA-like models, and approaches to setting the relative variances of process and observation error when fitting assessment models. We also continued to review harvest policy literature in support of a written review of this topic and to support our harvest policy analyses for yellow perch in Lake Michigan and lake whitefish in 1836 treaty waters.

Job 4. Title: Evaluate policies.–Work on this job included the completion of a manuscript describing the existing literature on harvest policies, some further design work and initial coding for a model to evaluate a harvest policy analysis for lake whitefish in 1836 treaty waters of the Great Lakes, refinement and application of a simulation model for evaluating harvest policies of yellow perch in Lake Michigan, and work to estimate economic injury levels by sea lamprey in the Great Lakes.

Our manuscript reviewing the harvest policy literature, submitted to *Fisheries Research*, clarifies and expands on the basic results we reported in last year's report. These results were also presented at the annual meeting of the American Fisheries Society. Although there is a substantial amount of previous work, the literature is splintered and in some cases apparently contradictory. Our manuscript emphasizes that the major policies of constant catch, constant fishing rate, biomass based fishing rate, and constant escapement involve different tradeoffs between maximizing and stabilizing yield, and that these tradeoffs are altered when uncertainty in stock size or in dynamic processes is acknowledged, or when particular types of temporal correlation in recruitment occur. This review helped us refine the appropriate range of harvest policies to consider in our lake whitefish analysis, emphasized the importance of appropriately incorporating uncertainty, and illustrated that much more can be learned about the relative performance of different types of policies.

The complex life history of lake whitefish, with growth and maturity schedules varying over time and among locations has provided a challenge to developing an appropriate simulation model for this species. We met with the Modeling Subcommittee of the Technical Fisheries Committee for 1836 Treaty waters (MSC), to discuss model structure, critical uncertainties, relevant performance measures, and feasible management strategies. Based on MSC input, we are proceeding with model development by incorporating density-dependent growth as well as a stock-recruitment relationship, stochasticity in recruitment and assessment/implementation (i.e., error in assessing stock size and in achieving a desired fishing mortality rate), and flexibility in the choice of type of harvest policy (choices include constant fishing mortality rates, biomass based fishing mortality rates and conditional constant catch rates). To model the variable life histories we are developing an algorithm to tie maturity schedules to growth through a reactive norm, which presumes that feasible age/length combinations that lead to a given proportion of the population maturing fall along a single curve. We have begun preliminary coding of our model.

Our work on harvest policy analysis for yellow perch and determining economic injury levels for sea lamprey control was done collaboratively with postdoctoral research associates supported through other funding sources at the Quantitative Fisheries Center at Michigan State University. In part, this study allowed for my participation in these important policy analyses. Historically, yellow perch have been economically important throughout most of the Great Lakes region by supporting both recreational and commercial fisheries, yet there is no established harvest policy for their management. Using a decision analysis framework, we constructed a stochastic forecasting model to evaluate harvest scenarios for yellow perch in Lake Michigan. We met with the Lake Michigan Yellow Perch task group in January 2007, and based on this input revised the model to allow for additional potential decision options (harvest policies) and track additional relevant performance measures. Our simulations track the age, sex, and size structure of the yellow perch population through time in four management areas of southern Lake Michigan. The model we developed allows for simulations with different decision options, which represent alternative management actions. We made repeated simulations for each decision option because the model is stochastic, incorporating both process errors and uncertainty about parameter values (or states of nature). Thus, each individual simulation uses different parameter values and has different process errors that influence system dynamics. This approach and the structure of our model allows us to explicitly incorporate uncertainty about population processes (e.g., stock-recruitment relationships, maximum recruitment potential, migration among areas) and propagate this through to produce a distribution of outcomes associated with any given harvest policy. Our model framework allows us to evaluate selected management policies to based on the distribution of outcomes and pre-determined measures of performance (e.g., annual catch, size composition of population). We have now run a wide range of simulations for the case where there is only a recreational fishery for yellow perch on Lake Michigan, as well as more limited simulation where there is mixed recreational and commercial fishery. We also conducted simulations using a variant of the model where fishing mortality rate was defined in terms of how much spawning stock biomass per recruit (SSBR) was reduced by fishing (i.e., spawning potential ratio (SPR) which is equal to SSBR as a proportion of SSBR without fishing). We reported results of the base model simulations for the recreational fishery and for the variant model in two presentations at the annual meeting of the American Fisheries Society. The results so far are very encouraging with regard to potential benefits of a biomass-based harvest policy, wherein fishing mortality rate is scaled back at lower stock sizes. We found that the best biomass-based policy could produce nearly the same average yield, while substantially reducing the probability of reaching low stock sizes, compared with the best constant fishing mortality rate policy. We plan to evaluate how assessment and implementation error might influence this result. We applied our variant model for the case of constant fishing mortality rate. Conceptual ambiguity in how to calculate SPR arises because size at age and maturity at age change over time in the yellow perch model application. We showed that when SPR is calculated using the current life history values for the no fishing case, spawning biomass distributions are essentially a function of SPR and not of fishery selectivity patterns. Furthermore, the SPR that maximizes fishery yield was quite robust to changes in fishery selectivity, although fishery selectivity did influence the amount of that yield.

Economic injury levels (EILs) are defined as the pest population size associated with a justifiable budget for pest control. The basic idea is that there are diminishing returns so that at some point the increased benefits from increased control exactly balance the increased costs. This forms the EIL and EIL budget. We adapted a preexisting stochastic simulation model for sea lamprey (the pest) and populated the model with relevant inputs for each of the five Great Lakes. During the past year, we made a number of changes to model structure primarily to better capture the nature of potential control efforts that were not directed at larval populations in streams. In essence, the model tracks larval populations in stream reaches, the resulting parasite population in the lake, and the returning spawners that repopulate streams. Control strategies consist of ranking streams (e.g., based on kill of late stage larvae per dollar) and treating the highest ranked streams. The modifications acknowledge that important larval populations may exist in treatable lentic areas, and we have now included a mechanism by which portions of these lentic areas can be ranked and treated like the streams are. We are in the process of finishing simulations and preparing a report describing EILs by lake and their sensitivity to inputs such as the assumed fishery value of their host (e.g., lake trout).

Job 8. Title: <u>Evaluate alternative stock assessment approaches.</u>–We previously reported on results of two simulation experiments evaluating the performance of assessments when fishery catchability is varying over time. Results from one of the experiments were published in the *Canadian Journal of Fisheries and Aquatic Sciences.* We submitted a manuscript to the same journal on the second experiment. Although the editors gave us the option of resubmitting a revised manuscript based on reviews, we have decided to proceed with a revision to be sent to another journal. Our opinion is that the useful comments from the reviews do not substantively change the message of this work. The essence of our results has not changed since we summarized them in last year's report, and thus we do not repeat that summary.

We have conducted two additional simulation experiments evaluating stock assessment methodology. Detailed results of both were reported in a completed Ph.D. dissertation by Brian Linton. We have begun work on a manuscript for journal submission based on the first of these experiments. The first experiment addresses approaches to estimating the relative magnitude of process and observation error in assessments. We reported preliminary results from the first experiment last year. During the past year we repeated simulations after discovering an error in the simulation code. The change did lead to a different estimation method performing best, but the summary result we previously reported was unchanged i.e. information on the relative magnitude of process and measurement error can be obtained through the process of fitting a statistical catch at age model although prior information on the magnitude of observation error is required. The second of the simulation experiments included in Brian Linton's dissertation work evaluated different methods of modeling time-varying fishery selectivity and on how to choose among the alternative models. In this work we evaluate four methods for handling time varying selectivity. We used double logistic with one, two, or all four function parameters varying over time according to a random walk, as well as selectivity at each age varying according to a random walk combined with a smoothness penalty for too sharp a change in selectivity from one age to the next. None of these estimation methods outperformed the others in all cases. Model selection methods we considered included information criteria, and degree of retrospectivity. Degree of retrospectivity, the best selection method, is based on a retrospective analysis of bias in model parameter estimates as the data time series for estimation is sequentially shortened. We recommend this method of model selection together with consideration of a broad array of potential time-varying selectivity models.

Although some changes in catchability can be handled through appropriate modeling, assessments perform better with a reliable index of abundance, either based on surveys or fishery catch and effort data. In 1836 treaty waters, lake trout models rely on gill-net survey indices of abundance derived from fitting general linear mixed models that adjust for site and depth effects. We previously evaluated alternative approaches to building these models and found that approaches already in place were satisfactory. We submitted this work as a Michigan DNR research report, and are in the final stages of revision of this report based on reviews. While we still believe the status quo models are reasonable, our subsequent analyses have suggested that there may sometimes be benefits to dropping some fixed effects from the models or from allowing for temporal correlations in random year by site interactions. The 1836 treaty waters lake whitefish models used fishery catch and effort in a way that presumes that the ratio of aggregate catch to aggregate effort can index abundance. We previously reported on this work to develop abundance indices for lake whitefish from fishery data using statistical models. In the past year we prepared a rough draft manuscript on this work, and are in the process of revising this for submission to a journal for publication.

Job 9. Title: <u>Develop workshop materials.</u>–I provided guidance to Travis Brenden (associate director of the Quantitative Fisheries Center at Michigan State University) who finalized the content for an online course on approaches to estimation of parameters of nonlinear models. This course will become available for enrollment October 16, 2007. I provided guidance to Brian Linton who revised materials for two short courses on the use of AD Model builder, a software package widely used in fishery stock assessment work. I provided feedback on course design and online materials for an introduction for fishery scientists and natural resource professionals to the R statistical programming language.

Job 10. Title: <u>Conduct workshops.</u>–In August 2007, Brian Linton taught two short courses on the use of AD Model Builder software, which is a powerful tool for estimating model parameters and is widely used in the fitting of fishery stock assessment models. I provided some guidance on the delivery of the course. The first short course (AD Model Builder Basics) was an introduction to

AD Model Builder, and the second short course (AD Model Builder Advanced Fishery Applications) introduced concepts that are more advanced. Nine fishery professionals attended these short courses. A postdoctoral scientist at the Quantitative Fisheries Center presented a short course on using the R statistical programming language, with some input from me on logistics.

Job 12. Title: **Prepare annual performance report.**–This performance report was completed as scheduled. In addition, project personnel have worked toward publication of work in the primary literature as described in other jobs with completed/published documents listed below. Furthermore, three presentations based on work reported here were given at the American Fisheries Society Annual Meeting in San Francisco in September 2007.

Documents completed during performance period:

[1]He, J. X., and J. R. Bence. 2007. Modeling annual growth variation using a hierarchical Bayesian approach and the von Bertalanffy growth function, with application to lake trout in southern Lake Huron. Transactions of the American Fisheries Society 136:318–330.

Linton, B. C. 2007. Model selection and data weighting methods for statistical catch-at-age analysis: application to 1836 treaty water stock assessments. Doctoral dissertation. Michigan State University, East Lansing.

Wilberg, M. J., and J. R. Bence. 2006. Performance of time-varying catchability estimators in statistical catch-at-age analysis. Canadian Journal of Fisheries and Aquatic Sciences 63:2275-2285.

Prepared by: James R. Bence
Date: September 30, 2007

[1] He and Bence (2007) is provided with the annual performance report for Study 230522 of Project F-81-R-8.