STUDY PERFORMANCE REPORT

State: Michigan **Project No.:** F-53-R-13

Study No.: 480 **Title:** Development of decision models for the Great Lake Fisheries

Period Covered: April 1, 1996 to March 31, 1997

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

Summary: We have updated the lakewide salmonine stocking database for Lake Michigan we created last year and reported on and distributed this valuable information source to the Lake Michigan Technical Committee (of the Great Lakes Fishery Commission). We have continued to assemble lakewide information on recreational harvest and effort and continued to participate in a multi-agency design of a lakewide creel survey database and data standardization for Lake Michigan. We also assisted in the ongoing redesign of the Lake Michigan creel survey, and provided oversight during the initial design phase of a project aimed at evaluating the feasibility of using mail surveys to assess harvest and effort on the Great Lakes. We provided written input and attended a workshop leading to a draft design for a lakewide netting survey for lake trout and burbot in Lake Michigan. We have developed a computer program implementing recommended changes in harvest and effort estimates for the Michigan DNR creel survey and have applied this to 1986-95 data. This program also estimates effort targeted at specific species and harvest obtained by this targeted effort. These estimates are essential for modeling of the Lake Michigan system, but compiling them and revisiting estimation methods has been a more involved and time consuming process than was originally expected.

Our analysis of lakewide patterns of harvest, effort and catch rates emphasizes that changes in catch rates have not been uniform lakewide, and that the “collapse” of the chinook salmon fishery during the 1980s was more severe and extended on the east side of Lake Michigan than on the west side. We have implemented a prototype spreadsheet model that predicts chinook harvest and catch-rates in response to stocking locations in Lake Michigan. We have determined a method for resolving numerical problems we encountered in our initial tests of a conceptual spatially explicit model for chinook salmon in Lake Michigan. Progress on this spatial model was limited because we were concentrating on developing the needed data for fitting this and other decision models.

In parallel with our analysis of salmonine data we have also been working cooperatively in the analysis of forage fish data collected by the Great Lakes Science Center (USGS) and this work may shed some light on spatial patterns observed in the salmonine fishery. We are still relatively early in data analysis but now believe that spatial resolution of salmonine data will limit detailed spatial analyses. We continue to work with the forage fish data, but believe it will be most useful in developing spatially aggregated models of the fish community and in describing qualitative spatial patterns.

We also worked to fit a spatially aggregated chinook salmon population model using statistical fitting methods. This model made use of effort data, recreational harvest data and biological data from the recreational fishery and from weir harvests. To our knowledge this (and our work on Lake Huron) represent the first "statistical catch-at-age" analyses of this type for chinook salmon in the Great Lakes. Results confirm that "natural mortality" increased substantially during the late 1980s and that recreational fishing mortality has also been important.

We have expanded our work into other areas by continuing to develop decision models for the Lake Huron piscivore community and detailed population models of lake trout for Lake Huron and Lake Superior, and exploring the possibility of incorporating sea lamprey predation (functional response) models into our lake trout stock assessment models. This expanded scope, as well as increased efforts on Lake Michigan, was possible because of cooperative arrangements with a variety of groups and agencies.

Job 1. Title: Assemble information on salmonine movements.

Findings: A graduate student (under Michigan Sea Grant funding) is in his second year of work on this portion of the Study and is assisting in modeling of chinook salmon movements. Prior to the beginning of this work, there was no reliable lakewide database for salmonine stocking in Lake Michigan that contained specific information on stocking locations. We continue to update the database we created last year and have distributed this database to the Lake Michigan Technical Committee (of the Great Lakes Fishery Commission). The graduate student attended the summer 1996 meeting of the Committee and explained our database and its value to the work of the committee and its state and federal agencies.

We have developed a lakewide database for recreational harvest of salmonines and associated effort. We obtained information on recreational harvest from the states bordering Lake Michigan both from creel survey programs and from charter reporting systems. Some of these data are only available on hard copy, while others were obtained as computer files. We have keypunched and error checked needed data from Illinois, Wisconsin and Indiana. We have included estimates of targeted harvest and effort from when this information was available. Although this kind of information is collected for most of the creel monitored harvest, it has rarely been reported. Integration of the Michigan data is incomplete because we have simultaneously changed the way that estimates and variances are calculated from creel survey data (See Study 667). Currently our updated program for estimating harvest and effort from the Michigan data is operational, but we are still working on methods to expand estimates to unsampled areas. This is necessary because the extent of survey coverage has changed over time. We will continue to work closely with the Lake Michigan Technical Committee on the task of database development, and the PI of this Study (James R. Bence) serves on the Technical Committee's Creel Survey Working Group. Bence was an active participant in the process of documenting existing creel survey methods and making recommendation for changes in these surveys. He took a lead role in designing a lakewide database for creel survey estimates. One recommendation of that working group is that mail surveys should not replace "on-the-ground" creel survey unless they are thoroughly tested first. To this end Bence has overseen the initial design of a pilot mail survey intended to provide estimates that can be compared with Lake Michigan creel survey estimates.

We continue to review and synthesize information relevant to chinook salmon abundance and movements. Our results indicate that appropriately defined subsets of total effort should be used when using catch-per-unit-effort as an index of abundance for salmonines. This is so because of changes in targets sought by anglers over time, and different catch rates for anglers depending upon their claimed angling target. We have found that the decline in chinook harvest and catch per unit effort as well as effort was more severe on the east shore of Lake Michigan than on the west shore. CWT data indicate substantial movements of fish across the lake and our investigation of size distributions of chinook salmon found them to be similar in Wisconsin and Michigan fisheries and to have changed similarly over time. These results argue against the different temporal patterns simply reflecting spatially segregated stocks that experienced different mortality regimes. A hypothesis consistent with the observed patterns and reports of "alewife hot spots" on the Wisconsin (west) shore is that chinook salmon tended to aggregate in areas of relatively high prey abundance when overall prey abundance was low. We hope to follow up on this as we further investigate data on alewife abundance.

Job 2. Title: Collect data for lake wide estimates of chinook salmon movements.

Findings: We assisted in the collection of CWT fish near Ludington Michigan through supervision of one collector located at the Michigan State University field station there. During the 1995 fishing season data were collected from the western Lake Michigan as part of a cooperative arrangement among MDNR, MSU, USFWS, and WDNR. Funding was not available for the similar field work in 1996.

Job 3. Title: Develop spatial movement models.

Findings: A conceptual spatially explicit model for chinook salmon in Lake Michigan was previously proposed and examined, whereby populations within specific areas were modeled in monthly time steps. Within a given area and month time period the rates of change in a resident population were assumed to follow the differential equation:

$$\frac{dN_{s,r,a,m,y}}{dt} = -\left(M_{s,r,a,m,y-BKD} + M_{s,r,a,m} + F_{r,a,m,y} + MAT_{s,r,a,m} + \sum_{l\neq r} E_{s,r,l,a,m}\right) \times N_{s,r,a,m,y} + \sum_{l\neq r} I_{s,r,l,a,m}$$

Here N is population size, $M_{...BKD}$ is instantaneous per capita mortality due to bacterial kidney disease, M is instantaneous per capita natural mortality from other sources, F is the instantaneous per capita mortality due to fishing, MAT represents the per capita instantaneous maturation rate, and E represents the per capita instantaneous emigration rate to adjacent areas. The instantaneous total immigration rate from an adjacent area is represented by I. The subscripts s,r,l,a,m, and y refer to planting site, region being modeled, adjacent region emigration or immigration refers to, age, month and year. This equation is presented in a general form allowing planting site, region, age, month and year differences; however, we will need to assume that rates are constant over some of these effects due to limited information. Numerical problems we described previously have been solved by using monthly time steps and approximating migration by having it occur at the end of the monthly time step, after all mortality had occurred. The approximation is computationally more efficient than numerical integration of the differential equation and has little influence on predictions.

We have not made substantial progress in model fitting because we are still working on collating needed data (see job 1). We will be fitting the spatial model for chinook salmon to recreational harvest, weir harvest, and stocking data. A Master's student (under Michigan Sea Grant funding (same student as for Task 1)) is assisting in this work. A limitation of this model is that it assumes that the rules that govern chinook salmon movements are static, whereas our analysis of historical trends in catch rates for chinook salmon in the recreational fishery suggests that this may not be the case. We hope to explore potential ways to incorporate these patterns into models. As a preliminary step we fit a spatially aggregated model with annual time steps to available data on harvest, targeted effort, age compositions of all and mature fish in the recreational harvest and age compositions of fish at harvest weirs. This model was built upon existing models we had developed for Lake Huron (see below) and which had been developed for Lake Michigan (see Study 650). This model generally fit available data quite well and suggested a substantial increase in "natural" mortality for ages 2 and above starting in 1987, consistent with observations on bacterial kidney disease. The model also indicated that fishing mortality was considerable, with harvest taking on average 20-25% of the surviving age 3-4 fish from 1986-95.

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

Findings: Work was expanded into developing appropriate decision models for the Lake Huron piscivore community (assisted by Great Lakes Fishery Commission funding), developing detailed population models of lake trout for Lake Huron (by collaborating with Shawn Sitar, a former Master's student at Michigan State University now with USFWS), developing lake trout population models for Lake Superior (assisted by funding from the Red Cliff Band of Lake Superior Chippewas), and integrating sea lamprey functional response and population estimates into lake trout stock assessment models (assisted by GLFC funding).

Population models for the major piscivores in Lake Huron's main basin have been developed. Chinook salmon appears to be the most abundant predator and is probably the dominant predator in the current fish community of the main basin outside of Saginaw Bay. Examination of recreational age composition data used in model fitting indicate that age 4 chinook salmon have become scarce in the past four years. This pattern could not be fit with a constant mortality rate and is of concern. It might reflect a change in maturation schedule or a change in fishery selectivity. Also of concern was a decline in chinook salmon size-at-age harvested by the recreational fishery during the 1990s. This decline appears to reflect a decline in size at age-2 rather than a decline in growth rate after that point. For walleye, population models were developed for Saginaw Bay and for the southern main basin and extrapolated to other areas. Results suggest that a large portion of the walleye in the main basin of Lake Huron (including Saginaw Bay) come from sources other than stocking. Abundance of burbot was estimated by assuming equal catchability as lake trout and expanding CPUE based on abundance estimates for lake trout. This suggests that burbot may be a significant predator in the Lake Huron system although this is a very uncertain result. We have also reviewed information available for implementing bioenergetics models in Lake Huron. Lake Huron specific data are generally lacking. We have worked with the Lake Huron Technical Committee to promote collection of needed diet data. We are also working with the Lake Huron Technical Committee to obtain samples we will analyze to obtain energy density data for major prey and predator species.

Our collaborative work on lake trout modeling in Lake Huron with Shawn Sitar continued and we used models developed as part of his Master's thesis to evaluate consequences of sea lamprey control options on the St. Mary's river to lake trout population trajectories and equilibrium yield per recruit (stocked lake trout) and spawning stock of lake trout per recruit. These results indicate that control of sea lamprey produces substantial benefits, which are substantially larger if fishing mortality is also reduced.

We have now finished an example lake trout statistical catch-at-age model for the MI-4 area of Lake Superior for the 1973-94 period. The model we developed dealt with wild and hatchery fish independently, modeled fishery and survey selectivity as a function of size and allowed growth to vary over time. Recruitment each year was estimated as a "free parameter" rather than being assumed known based on numbers stocked. Model predictions matched observed data quite well. This model indicates that a substantial decline in survival of hatchery-reared fish to ages observed in surveys and the fishery, in agreement with published (and quite different) analyses. Current total mortality rates are similar for wild and hatchery fish and appear to be higher than recommended levels, largely due to increases in fishing mortality. Preliminary analyses suggest that conclusions regarding mortality rates and recommended harvest are not critically dependent upon the allowance of time-varying growth. Thus, simpler age (rather than age and size) structured models may be suitable for providing management advice. However, there are substantial differences in historical peak recruitment and mortality rates, and these differences could be important when generating stock-recruitment functions and using the functions to evaluate policies.

Initial steps have begun to evaluate the possibility of integrating sea lamprey abundance and functional response information into the lake trout population models we have been working with. Our initial approach is to assess whether an existing functional response model combined with estimates of sea lamprey abundance can predict observed patterns of wounding seen in lake trout caught in spring surveys in Lake Huron and Lake Superior. Preliminary results suggest there may be some lack of fit.

Job 7. Title: Prepare annual report and publications.

Findings: This report was prepared on time. Progress has been reported to the Lake Huron and Lake Superior Technical Committee's at their semi-annual meetings. Patterns in the lakewide recreational fishery in Lake Michigan were presented to a Michigan Sea Grant regional fishery workshop and in a presented paper to the Michigan Academy of Science, Arts, & Letters at its 1997 annual meeting. Analyses of measurement error in forage fish data were also presented at that meeting. Descriptive information on the sea lamprey-lake trout interaction in Lake Huron was published in the Michigan Academician.

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