STUDY FINAL REPORT

State: Michigan **Project No.:** F-80-R-3

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

Period Covered: May 1, 1995 - September 30, 2002

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: Age structured population models were parameterized using statistical catch age methods for lake trout (lakes Michigan, Huron, and Superior), chinook salmon (lakes Michigan and Huron), yellow perch (Lake Michigan), and lake whitefish (lakes Michigan, Huron, and Superior). A similar approach was used to assess the dynamics of sea lamprey in Lake Huron and the dynamics of alewife and bloater in Lake Michigan. The results from these assessment models have been integrated into fish community and tropho-dynamic models. These models have in turn been used to project the consequences of different fishery management strategies. In addition to application of statistical catch-age methods this project has promoted improved stock assessment practices through workshops demonstrating methods. Our assessment and decision modeling depend critically upon the input data, and thus this study included a substantial data review and analysis component. Our work contributed to database standards and the development of lakewide databases for recreational harvest and fish stocking on Lake Michigan. Our work also led to recommendations for changes in creel survey data collection and analysis on Lake Michigan, and the implementation of some of these suggestions in Michigan. Our review of recreational fishery data led to a unique and useful review of the recreational fisheries of the Great Lakes. Based on considerations stemming from environmental assessments, we developed an improved approach for summarizing survey data. We applied this approach to forage fish surveys in Lake Michigan and to lake trout surveys throughout Michigan's waters of the Great Lakes. Results from this study were reported extensively through oral presentations and publications.

Findings: This final report was prepared, including Jobs 4, 6, and 7, which were scheduled for 2001-02. All jobs are reported on below.

Job 1. Title: Data review.–Estimation of vital rate parameters using statistical catch-age and related models, and use of these results in decision models depends critically on the quality of the input data. Our efforts in reviewing and analyzing Great Lakes fishery and survey data were directed toward providing and improving the needed inputs for these models.

Our initial efforts concentrated on Lake Michigan, where we developed lake-wide databases for stocking and recreational harvest (Benjamin and Bence in press a). An outcome of our efforts in this area was a compilation of existing creel survey methods and recommendations for changes in these methods that was presented to the Lake Michigan Committee and its Technical Committee. We helped develop new methods for estimation of fishery effort and harvest from creel surveys in

Michigan which have been reported in the results for other studies (Lockwood et al. 1999), and helped develop the new software implementing these recommendations for the Great Lakes.

Our analysis of sport fishery catch, effort and biological data (Bence and Smith 1999, and Benjamin and Bence in press a) provided the basis for an initial catch-age model for chinook salmon for Lake Michigan. Similar analyses supported statistical catch-age models for lake trout (Lakes Michigan, Huron, and Superior), yellow perch (Lake Michigan), a statistical catch-age chinook salmon model for Lake Huron, and related assessment models for walleye and sea lamprey on Lake Huron. These analyses also allowed us to update assessment models for rainbow trout and brown trout in Lake Michigan. In addition, models for lake trout and lake whitefish depended upon summarizing patterns in catch, effort, and age-composition associated with commercial fisheries, and we collaborated with those involved in collecting these data to ensure appropriate summarizations needed for these models in Lake Michigan, Huron, and Superior. Our assessment models for lake trout relied upon fishery-independent survey data and we developed a novel "mixed model" approach to summarizing these data to better describe the uncertainty in the year specific indices of abundance. A similar approach was extended to deal with the complex survey design of the United States Geological Survey's bottom trawl survey for forage fish and a manuscript on this topic is now being revised based on peer-review. Additional details on the data used for the assessment models and methods of summarizing these data can be found in Sitar et al. (1999), Krause et al. (2002), Bence (2002), Madenjian et al. (2002), Dobiesz (2002, see Project 689), Haeseker et al. (in press), Rutter and Bence (in press), and Szalai et al. (in press).

See Job 7 for full citations.

Job 2. Title: <u>Collect data for lake-wide estimates of chinook movements</u>.–This job was active during 1995 and 1996, but was eliminated when the project was amended in 1997. During 1995 and 1996 we assisted in the collection of coded-wire tagged 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 Michigan DNR, Michigan State University, U.S Fish and Wildlife Service (Green Bay Fishery Resource Office), and Wisconsin Department of Natural Resources. Our partners did not have funding for similar field work in western Lake Michigan in 1996. Data collected during 1995 and 1996 became part of the database for which finding are reported on in Study 464.

Job 3. Title: <u>Spatial model for chinook salmon.</u>–We considered a spatially explicit model for chinook salmon in Lake Michigan, whereby populations within each of six geographic regions (representing statistical districts or combinations of statistical districts) were modeled. Within a given area and month time period the rates of change in a resident population were assumed to follow the differential equation

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

Here N is population size, $M_{...BKD}$ is instantaneous per capita mortality due to bacterial kidney disease (which is perhaps better thought of simply as time varying mortality without assigning a cause), M is instantaneous per capita natural mortality that does not vary over time, 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, region emigration or immigration, age, month and year. This equation is presented in a relatively general form, allowing planting site, region, age, month, and year differences; however, even in our initial exploration of this model it was clear that we would need to assume that emigration and immigration rates were constant over years, given generally limited temporal information on spatial locations of chinook salmon from coded wire tagging studies. Further experience indicated that other effects would need to be assumed constant over some of these effects. In particular, given the general difficulties in estimating natural mortality, attempting to estimate temporal variations in natural mortality for specific planting sites and regions was clearly impractical, although differences among planting sites in initial survival seemed possible. Finally, parameterizing such a model requires region specific estimates of abundance. The only potentially lake-wide information on chinook salmon abundance comes from catch rates in the sport fishery. To avoid numerical problems we approximated 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 gathered and organized recreational harvest, weir harvest, and stocking data for use with this spatially explicit model. Analysis of these data (in particular the catch rates) showed that either the basic assumption that the rules that govern chinook salmon movements are static was violated, or that the relationships between catch rates and abundance changed depending upon region and year (Benjamin and Bence in press a). Unfortunately, sufficient data to fully estimate spatial changes in distribution over time are not available. Ultimately a spatially explicit model with believable assumptions has critical parameters that are not estimable from the available data. As a result we have subsequently concentrated our efforts of estimating parameters for spatially aggregated population models (Job 4).

Job 4. Title: Tropho-dynamic and predator models.–On lakes Michigan and Huron we developed or updated assessments for the major predators and developed bioenergetics models to estimate overall consumption by predators. Detailed findings are reported in Madenjian et al. (2002), Dobiesz (2002, see Study 689), Benjamin and Bence (in press b), and are being incorporated into The Great Lakes Fishery Commission's state of the lake reports for lakes Huron and Michigan that are now in preparation. On Lake Huron the assessments formed the basis for projecting how predatory demand would change with changes in sea lamprey management, fishery harvest, or salmonine stocking (see Study 689 for details on findings). On Lake Michigan assessment results were integrated into fish community models. Our first effort in this area was to update the existing SIMPLE model (Jones et al. 1993). We subsequently have developed a simplified stochastic fish community model, which will form the basis for an upcoming decision analysis workshop regarding stocking decisions for Lake Michigan (December 2002). Parameterization of this model relies on the fitting of a functional response model and a stock-recruit model for alewife taking into account our estimates of predator abundances (see Benjamin and Bence in press b, and Madenjian et al. 2002) and indices of prey abundance. To appropriately account for changing size-at-age in bloater populations (a prey fish in Lake Michigan), a growth model that allowed parameters to vary over time was developed and applied (Szalai et al. in press).

See Job 7 and the References section for full citations.

Job 5. Title: **Integration of spatial movement and tropho-dynamics model.**–This job was eliminated through amendment in 1997 and was not active. The integration of spatial movement and tropho-dynamic models was one potential type of decision model considered (and rejected) under Job 4. See discussion under Job 3.

Job 6. Title: **Expand research into other areas.**–Research was extended into a variety of areas. Major areas included:

Detailed findings regarding sea lamprey assessment and decision analysis are reported in Bence et al. (in press), Haesker et al. (in press), and Rutter and Bence (in press).

Dr. Bence expanded his impact on stock assessment in the Great Lakes by assisting in statistical catch-age workshops designed for Great Lakes and other fisheries scientists (see http://www.dnr.cornell.edu/afrp/sawk/) and acting as an external reviewer of statistical catch-age assessments of walleye and yellow perch in Lake Erie during 2001. This review process and workshops were undertaken in partnership with the Great Lakes Fishery Commission and its Lake Committee structure. Application of statistical catch-age methods was further extended to yellow perch on Lake Michigan as part of an ongoing Ph.D. project and to lake whitefish throughout 1836 treaty waters within the state of Michigan (for detailed finding see Bence and Ebener 2002 and Bence 2002).

Results of predator consumption in lakes Michigan and Huron were compared with each other and with similar estimates for Lake Ontario and Lake Superior to better understand top-down trophic influences in the Great Lakes. Comparable estimates were obtained for Lake Ontario by developing a first-generation statistical catch-age model for chinook salmon in that lake, in collaboration with the Ontario Ministry of Natural Resources and their partners. These comparisons suggested that consumption of prey fish per unit area is highest in Lake Michigan, but reaches comparable levels in Lake Ontario. Somewhat lower consumption of prey fish occurs in Lake Huron. Much lower prey fish standing stocks and predator consumption of prey fish occurs in Lake Superior, although the top down effect may be large there. Lake Ontario appears to stand out in having much higher standing stocks of alewife. This appears to be a long-standing difference stemming from higher recruitment of alewife in that lake. The smaller average zooplankton size in that lake is consistent with the higher alewife abundance. Similarly, chinook salmon have generally grown faster in Lake Ontario, as might be expected if the dominant prey is more available there. Results from this comparison were presented at a special GLFC workshop, as the second phase of the Salmonid Communities of Oligotrophic Lakes-2 process.

Expertise and understanding of appropriate methods for assessing fish population dynamics was organized in the form of a book chapter that is in preparation for an AFS publication. The chapter is now being revised based on comments from the book editor.

Statistical methods for environmental assessment were developed further and the connection between these methods, the analysis of fishery survey data, and the process of stock assessment was explored. Detailed findings are reported in Sitar et al. (1999), Krause (in revision), and Stewart-Oaten and Bence (2001). Dr. Bence's expertise in the area of statistical analysis of fisheries and survey data was further harnessed through his participation in reviews of the Lake Michigan lakewide assessment plan, the parasitic sea lamprey assessment program for the Great Lakes (coordinated by the Great Lakes Fishery Commission), and through less formal consultation by fishery scientists working on the Great Lakes regarding sampling designs and appropriate sampling levels.

The overview of recreational fishery data (Job 1) led to a broad review of recreational fisheries of the Great Lakes (Bence and Smith 1999) and to suggested modifications to the processing of creel survey data which were implemented as part of another study (Lockwood et al. 1999).

Expansion of work in the area of lake trout assessment and for tropho-dynamics in Lake Huron are reported under Jobs 8 and Jobs 4. Job 8 was added and Job 4 expanded when this study was amended in 1997.

See Job 7 and Reference section for full citations.

Job 7. Title: Publish results and prepare annual reports.–This final report was prepared. Results have been communicated through published journal papers, book chapters, Michigan DNR Fisheries Division Research Reports, and through oral presentations.

Publications:

Bence, J. R. 2002. Stock assessment models. In Bence J.R. and Ebener, M.P. (eds.). Summary Status of Lake Trout and Lake Whitefish Populations in the 1836 Treaty-Ceded Waters of Lakes Superior, Huron and Michigan in 2000, with recommended yield and effort levels for 2001. Technical Fisheries Committee, 1836 Treaty-Ceded Waters of Lakes Superior, Huron and Michigan.

Bence, J. R. and M. P. Ebener, M.P. 2002. Executive Summary in Bence J.R. and Ebener, M.P. (eds.). Summary Status of Lake Trout and Lake Whitefish Populations in the 1836 Treaty-Ceded Waters of Lakes Superior, Huron and Michigan in 2000, with recommended yield and effort levels for 2001. Technical Fisheries Committee, 1836 Treaty-Ceded Waters of Lakes Superior, Huron and Michigan.

Bence, J. R, M. A. Rutter, R. A. Bergstedt, W. Swink, G. Christie, P. Cochran, M Ebener, and J. Koonce. In press. Sea lamprey parasite-host Interactions in the Great Lakes. Journal of Great Lakes Research.

Bence, J. R., and K. D. Smith. 1999. An overview of recreational fisheries of the Great Lakes. *In* W.W. Taylor and P. Fererri editors, Great Lakes Fisheries Policy and Management: a Binational Perspective. Michigan State University Press. East Lansing, Michigan.

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

Benjamin, D. M. and J. R. Bence. In press (b). Statistical catch-at-age assessment of Chinook salmon in Lake Michigan, 1985-1996. Michigan Department of Natural Resources, Fisheries Division, Fisheries Research Report. Ann Arbor, Michigan.

Haeseker, S., M. Jones and J. Bence. In press. Estimating uncertainty in the stock-recruit relationship for St. Marys River sea lamprey. Journal of Great Lakes Research.

Krause, A. E., D. B. Hayes, J. R. Bence, C. P. Madenjian, and R. M. Stedman. In revision (based on peer-reviews). Estimates of age-specific abundance indices for bloater and alewife in Lake Michigan, 1962-1996. North American Journal of Fisheries Management.

Krause, A. E., D. B. Hayes, J. R. Bence, C. P. Madenjian, and R. M. Stedman. 2002. Measurement error associated with surveys of fish abundance in Lake Michigan. Journal of Great Lakes Research 28: 44-51.

Madenjian, C. P., G. L. Fahnenstiel, T. H. Johengen, T. F. Nalepa, H. A. Vanderploeg, G. W. Fleischer, P. J.Schneeberger, D. M. Benjamin, E. B. Smith, J. R. Bence, E. S. Rutherford, D. S. Lavis, D. M. Robertson, D. J. Jude, and M. P. Ebener. 2002. Dynamics of the Lake Michigan food web, 1970-2000. Canadian Journal of Fisheries and Aquatic Sciences 59: 736-753.

Rutter, M. A., and J. R. Bence. In press. An improved method to estimate sea lamprey wounding rate on hosts with application to lake trout in Lake Huron. Journal of Great Lakes Research.

Sitar, S. P., J. R. Bence, J. Johnson, M. P. Ebener, and W. W. Taylor. 1999. Lake trout mortality and abundance in Southern Lake Huron. North American Journal of Fisheries Management 19:881-900.

Stewart-Oaten, A., and J. R. Bence. 2001. Temporal and spatial variation in environmental assessment. Ecological Monographs 71:305-339

Szalai, E. B., G. W. Fleischer, and J. R. Bence. In press. Modeling time-varying growth using a generalized von Bertalanffy model with application to the growth dynamics of bloater in Lake Michigan. Canadian Journal of Fisheries and Aquatic Sciences.

Oral or poster presentations:

During 2002:

Bence, J. R. An overview of assessment methods for whitefish used in 1836 treaty ceded waters of the Great Lakes. Great Lakes Fishery Commission sponsored Great Lakes Whitefish-Diporeia workshop, Ann Arbor, Michigan. February 26-27, 2002.

Bence, J. R. Assessing fishery dynamics: recent advances with applications to the Great Lakes. Invited seminar, Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan. April 3, 2002.

Sitar, S. P., J. R. Bence, M. P. Ebener, J. Jonas, and A. P. Woldt. Stock assessment of lake trout in 1836 treaty waters of the upper Great Lakes. Symposium on the Ecology, Habitat and Management of Lake Trout in North America, August 14-16, 2002. Sponsored by the Yukon Department of Renewable Resources. Abstracts published by Yukon Department of Renewable Resources, Box 31471, Whitehorse, Yukon Territory Y1A 6K8. Canada.

Woldt, A. P., S. P. Sitar, J. R. Bence, and M. P. Ebener. Status of lake trout in northern Lake Huron: an example of inter-agency assessment and management using statistical catch at age modeling. Symposium on the ecology, habitat and management of lake trout in North America, August 14-16, 2002. Sponsored by the Yukon Department of Renewable Resources. Abstracts published by Yukon Department of Renewable Resources, Box 31471, Whitehorse, Yukon Territory Y1A 6K8. Canada.

During 2001:

Dobiesz, N. E., and J. R. Bence, Consumption by key predators in the Lake Huron main basin. Poster presented at Michigan DNR Fisheries Division In Service meeting, March 1, 2001.

Dobiesz, N. E., and J. R. Bence. Predator-prey interactions: prey consumption by key predators in Lake Huron. State of Lake Huron Symposium, Upper Lakes Meetings, Sault Ste. Marie, Canada. March 22, 2001.

Dobiesz, N. E., and J. R. Bence, Prey fish biomass eaten by predators in the main basin of Lake Huron. International Association for Great Lakes Research. June 10-14, 2001. University of Wisconsin - Green Bay. Abstract published by IAGLR, 2205 Commonwealth Blvd, Ann Arbor, Michigan 48105.

Ebener, M. P., J. R. Bence, R. Bergstedt, and K. Mullet. Sea lamprey marking assessment. Common Session, Upper Lake Meetings, Sault Ste. Marie, Canada. March 22, 2001.

Madenjian, C. P., G. L. Fahnenstiel, T. H. Johengen, T. F. Nalepa, H. A. Vanderploeg, G. W. Fleischer, P. J. Schneeberger, D. M. Benjamin, E. B. Smith, J. R. Bence, E. S. Rutherford, D. S. Lavis, D. M. Robertson, D. J. Jude, and M. P. Ebener. Dynamics of the Lake Michigan food web, 1970-2000. Abstracts of the Ecological Society of America Annual Meeting, August 6-9, 2001, published online by Allen Press: http://abstracts.allenpress.com/esa-cgi/authidx.cgi?YEAR=2001&STARTSWITH=M

Madenjian, C. P., D. M. Benjamin, E. B. Smith, J. R. Bence, E. S. Rutherford, and P. J. Schneeberger. Dynamics of salmonine, lake whitefish, burbot and yellow perch populations in Lake Michigan, 1970-2000. International Association for Great Lakes Research. June 10-14, 2001. University of Wisconsin - Green Bay. Abstract published by IAGLR, 2205 Commonwealth Blvd, Ann Arbor, Michigan 48105.

Smith, E. B., G. Fleischer, and J. R. Bence, Modeling time-varying growth for bloater in Lake Michigan. Abstracts of the American Fisheries Society Meeting, Madison Wisconsin, August 19-23, 2001, published online by the American Fisheries Society: http://www.fisheries.org/annual2001/Tuesday.htm#Tuesday AM Series 2 .

Schrouder, J. R., J. R. Bence (presenter), and M. P. Ebener. Evaluating fish community objectives for Lake Huron. International Association for Great Lakes Research. June 10-14, 2001. University of Wisconsin - Green Bay. Abstract published by IAGLR, 2205 Commonwealth Blvd, Ann Arbor, Michigan 48105.

Woldt, A. P., S. P. Sitar, J. R. Bence, and M. P. Ebener. Status of lake trout in Lake Huron: partitioning mortality using statistical catch at age modeling. International Association for Great Lakes Research. June 10-14, 2001. University of Wisconsin - Green Bay. Abstract published by IAGLR, 2205 Commonwealth Blvd, Ann Arbor, Michigan 48105.

During 2000:

Bence, J. R, M. A. Rutter, R. A. Bergstedt, W. Swink, G. Christie, P. Cochran, M. P. Ebener, and J. Koonce. Sea lamprey parasite-host interactions in the Great Lakes. Sea Lamprey International Symposium II. Lake Superior State University, Walker Cisler Center, August 13-18, 2000. Hosted by Great Lakes Fishery Commission, Fisheries and Oceans Canada and Upper Lakes Environmental Research Network.

Rutter, M. A., and J. R. Bence. 2000. Summarizing sea lamprey wounds on lake trout in Lake Huron: a length based approach. Sea Lamprey International Symposium II - Paper Summaries (published abstract, no presentation). Lake Superior State University, Walker Cisler Center, August 13-18, 2000. Hosted by Great Lakes Fishery Commission, Fisheries and Oceans Canada and Upper Lakes Environmental Research Network.

Woldt, A., S. P. Sitar, J. R. Bence, and M. P. Ebener. Status of lake trout in Lake Huron: partitioning mortality using statistical catch-age modeling. The 62nd Midwest Fish and Wildlife Conference. Minneapolis, Minnesota. Dec. 5-8, 2000. (Abstract 191, jointly published by Minnesota DNR, USFWS, and University of Minnesota.)

During 1999:

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. East Lansing, Michigan. October 4, 1999.

Bence, J. R. A comparison of fishery and environmental assessments. Invited Seminar. Department of Fisheries and Wildlife GSO. March 4, 1999.

Bence, J. R., C. Bronte, M. Ebener, G. Fleischer, M. Hansen, M. Holey, J. Jonas, J. Peck, S. Sitar, and A. Woldt. Collapse and Partial Recovery of Lake Trout in the Upper Great Lakes: Success, Failure and Uncertainty. American Fisheries Society Annual Meeting, August 30, 1999.

Rutter, M. A., and J. R. Bence. Incorporating a sea lamprey/lake trout functional response model into a lake trout population model for the upper Great Lakes. American Fisheries Society Annual Meeting, August 31, 1999.

During 1998:

Bence, J. R., A. E. Krause, M. A. Rutter, and C.T. Weeks. Sampling designs uncertainty and implications for fishery management. International Association for Great Lakes Research. May 18-22, 1998.

Krause, A. E., D. B. Hayes, J. R. Bence, and C. Madenjian. Uncertainty in Lake Michigan alewife and bloater population abundance indices and mortality rates. International Association for Great Lakes Research. May 18-22, 1998.

Rutter, M. A., and J. R. Bence. Estimating uncertainty in a sea lamprey wounding model. International Association for Great Lakes Research. May 18-22, 1998.

Weeks, C. T., and J. R. Bence. Estimation of Growth, Mortality, and Abundance of Wild Lake Trout in Michigan Waters of Lake Superior, 1971-1995. American Fisheries Society Annual Meeting, August 25, 1998.

During 1997:

Benjamin, D. M., and J. R. Bence. Chinook population dynamics in Lake Michigan. 59th Midwest Fish and Wildlife Conference, Milwaukee, Wisconsin, December 7-10, 1997.

Benjamin, D., J. R. Bence, G. P. Rakoczy, and B. T. Eggold. Trends in the Lake Michigan salmonine fishery, 1986-1995. Annual Meeting, Michigan Academy of Science, Arts and Letters. March 22, 1997.

Hansen, M. J., J. R. Bence, R. G. Schorfhaar, and W. W. Taylor. Relative importance of stocked and wild lake trout on population recoveries in Lake Superior lake trout. 40th Conference of the International Association for Great Lakes Research, Buffalo, New York, June 1-5, 1997.

Krause, A. E., D. B. Hayes, J. R. Bence, and C. Madenjian. The impact of measurement variability on the interpretation of long term fish population data. 59th Midwest Fish and Wildlife Conference, Milwaukee, Wisconsin, December 7-10, 1997.

Krause, A., D. Hayes, J. R. Bence, and D. Passino-Reader. How measurement error affects indices of abundance in several Lake Michigan Fish Species. Annual Meeting, Michigan Academy of Science, Arts and Letters. March 22, 1997.

Rutter, M. A., and J. R. Bence. Modeling sea lamprey wounding rates as a function of lake trout length. 59th Midwest Fish and Wildlife Conference, Milwaukee, Wisconsin, December 7-10, 1997.

During 1996:

Hansen, M. J., J. R. Bence (presenter), R. G. Schorfhaar, S. T. Schram, D. R. Schreiner, J. H. Selgeby, and W. W. Taylor. Evaluation of the relative importance of hatchery-reared and wild fish in the restoration of Lake Superior lake trout. Second World Fisheries Congress, Brisbane, Australia. July 28-2 August, 1996.

Hayes, D. B., and J. R. Bence. Managing under uncertainty, or, statistics is never having to say you=re sure. Michigan Chapter of the American Fisheries Society, East Lansing, Michigan. 1996.

Reid, D. M., J. R. Bence, J. Clevenger, J. E. Johnson, and M. Keller. Chinook salmon movements and estimates of natural reproduction in Lake Huron. Poster presentation at American Fisheries Society meeting, Dearborn MI, August 1996.

Sitar, S. P., J. R. Bence, W. W. Taylor, and J. E. Johnson. Patterns in sea lamprey wounding rates on lake trout in Lake Huron. Michigan Academy of Science, Arts and Letters meeting, Alma College, Alma, Michigan. March 1996.

Weeks, C. T., J. R. Bence, W. Mattes, J. W. Peck, and R. G. Schorfhaar. Dynamics of lake trout size and age structure in Michigan=s waters of Lake Superior. American Fisheries Society meeting, Dearborn MI, August 1996.

During 1995:

Bence, J. R. Environmental impact assessment and fishery stock assessment: contrasting approaches and recent advances. Invited seminar. Ecology and Evolutionary Biology Program, Michigan State University, East Lansing Michigan. October 1995.

Bence, J. R. Environmental assessment and fishery stock assessment: a comparison of approaches. Invited seminar. Kellogg Biological Station, Hickory Corners, Michigan. October 1995.

Bence, J. R., C. T. Weeks, and S. P. Sitar. Estimating abundance, recruitment, and other parameters by fitting flexible models to fishery data. Midwest Fish and Wildlife Conference, Detroit Michigan. December 1995.

Sitar, S. P., J. R. Bence, W. W. Taylor, and J. E. Johnson. Estimation of mortality rates of lake trout in U.S. waters of Lake Huron. Midwest Fish and Wildlife Conference, Detroit, Michigan. December 1995. (Honorable Mention, Best Student Paper Award.)

Job 8. Title: Lake trout model development.–Statistical catch at age models have been developed for most of Michigan's waters of lakes Michigan, Huron, and Superior. This project provided for initial model development and oversight and assistance for additional modeling by collaborators in the Fisheries Division, Michigan Department of Natural Resources, and other involved agencies. Detailed findings are reported by Sitar (1996), Weeks (1997), Sitar et al. (1999), Bence (2002), and Bence and Ebener (2002).

Job 9. Title: Publish report.–Results have been published in journal papers and book chapters and in several completed Fisheries Division Research Reports (see job 7).

References

Additional references that were not listed in Job 7 are:

Dobiesz, N. 2002. Projection and evaluation of the consumption of prey fish by the open-water predator community in the main basin of Lake Huron. Ph.D. Dissertation (draft, Attached with final report for Study 689), Michigan State University. East Lansing, Michigan.

Jones, M. L., J. F. Koonce, and R. O'Gorman. 1993. Sustainability of hatchery-dependent salmonine fisheries in Lake Ontario: The conflict between predator demand and prey fish supply. Trans. Am. Fish. Soc. 122:1002-1018.

Lockwood, R. N., D. M. Benjamin, and J. R. Bence. 1999. Estimating angling effort and catch from Michigan roving and access site angler survey data. Michigan Department of Natural Resources, Fisheries Division, Fisheries Research Report 2044. Ann Arbor, Michigan.

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