1997-02-01

Lake Erie Ecological Modelling Project (LEEMP)

International Joint Commission. Lake Erie Task Force

The Lake Erie Ecological Modelling Project
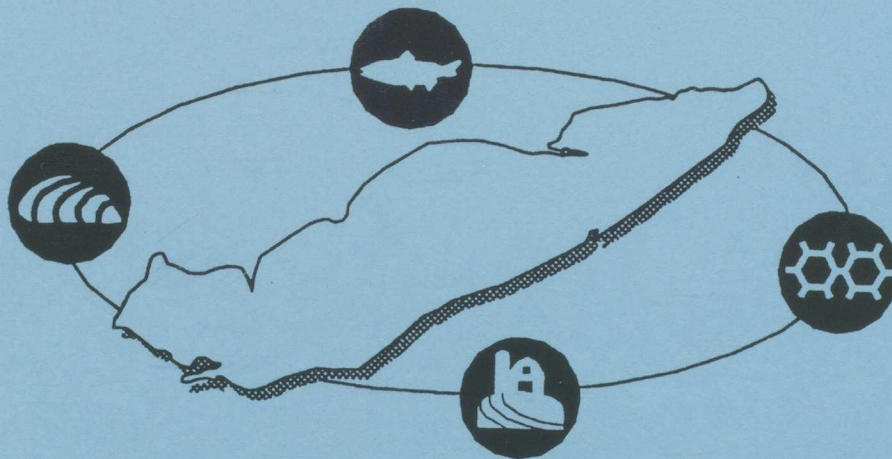
[LEEMP]

Report of the
Lake Erie Task Force
to the
International
Joint Commission
1997

The Lake Erie
Ecological Modelling Project
[LEEMP]

**Report of the
Lake Erie Task Force
To The
International Joint Commission
February 1997**

TABLE OF CONTENTS

LIST OF FIGURES

1.0 Introduction

1.1   Background to the 1995/1997 Priority

In 1993, the International Joint Commission established the Lake Erie Steering Committee, (later the Lake Erie Task Force) to advise the Commission on the impact of various stressors affecting the health of Lake Erie. In particular, the Task Force was to focus its efforts on the adverse effects of stressors on the Lake Erie benthic and fish communities, and report to the IJC at its eighth biennial meeting (1995).

In the spring of 1994, this Task Force convened a conference call of modelling and ecosystem experts. The consensus of the group was that it was indeed appropriate and possible at this time to initiate development of an ecosystem model for Lake Erie. Furthermore, they agreed that this was indeed the best approach to take to gain an understanding of the significant ecological changes occurring in Lake Erie and to evaluate the impact of these changes on management decisions affecting the Great Lakes Water Quality Agreement.

In June 1994, the Task Force hosted a modelling "pre-workshop" involving researchers, modellers and managers, all with an interest in the ecological changes occurring in Lake Erie. Results from this pre-workshop encouraged the Task Force to pursue the development of an ecosystem model for Lake Erie. Workshop participants confirmed the need for a Lake Erie model, and identified key elements of an approach to model development, including:

* a comprehensive review of existing models, focusing on their scope, linkages and data gaps; and
* development of a stress/response model for zebra mussels to test critical questions and linkages between the various components of the ecosystem.

Participants also recognized the benefit of the IJC taking a coordination/leadership role in a Lake Erie model development initiative, and stressed the need for involvement of those who would ultimately use the model including Lake Erie managers within Environment Canada, the United States Environmental Protection Agency, State and Provincial resource management and environmental control agencies, and others.

In December 1994, the Task Force distributed a "Request for Proposals" to modellers in the United States and Canada. In January 1995, after evaluating a number of proposals in an open and competitive process, the Task Force initiated the Lake Erie Ecological Modelling Project (LEEMP) by contracting with a binational consulting team, consisting of the LURA Group of Toronto and Dr. Joseph Koonce and Dr. Ana Locci of Case Western Reserve University in Cleveland.

The purpose of the LEEMP was to:

- develop a comprehensive model which would enhance understanding of changes taking place in the Lake Erie ecosystem;
- provide a tool to assist Lake Erie resource managers; and
- assist the IJC to evaluate progress under the *Great Lakes Water Quality Agreement*.

Throughout the eighth biennial cycle, the Task Force led a collaborative process to develop the LEEMP. A *Core Advisory Group of Lake Erie Managers*, consisting of Lake Erie fishery and water quality managers, was established specifically to work with the contractor/principal investigator and Task Force as part of the LEEMP. The *Core Advisory Group* provided ongoing advice, guidance and data to facilitate model development, as well as feedback on the scope and characteristics of the model. In addition, existing ecological modelling initiatives in the Great Lakes Basin and other parts of North America were reviewed to identify attributes applicable to the design and development of the LEEMP.

The result of this process was a prototype model, focusing on the key factors affecting the Lake Erie ecosystem: zebra mussel invasion, contaminant loading, changes in the fisheries, and declining nutrient loading.

The Task Force then broadened the model development process by hosting an interactive workshop in April, 1995. The workshop involved over 30 Lake Erie researchers, managers and modellers, who explored and critiqued the prototype's capabilities and proposed areas for further model development. Key advice from participants at this workshop included the need to:

- communicate the model's capabilities;
- start an iterative correction process to improve the model;
- consult further with potential users about the model's purpose and possible uses;
- explore partnership opportunities for future model development;
- enhance the sophistication with which the model dealt with base of the food web; and
- examine the possibility of developing basin-specific versions of the model.

The Task Force concluded its work on the 1993/1996 priority by distributing 10 copies of the prototype to workshop participants for them to test and improve specific model components, and reported the progress on this priority during the 1993-1995 Biennium in the IJC 1993-95 Priorities Report (IJC, 1995).

1.2   Goals for the 1995/1997 Priority

Reaffirming the project as a priority for 1995/1997, the IJC directed the Task Force to:

- "adjust and improve the 1993/95 model to incorporate further modifications proposed by the Task Force, contractors and modellers from academia and the Parties", and

- "develop the framework and infrastructure necessary to sustain a process for ecosystem modelling of the Lake Erie situation" (excerpt from IJC 1995/97 *Priority Package IV*).

Subsequently, the Task Force established two overall goals to guide its work on the 1995/1997 priority:

- to test and improve the prototype to the extent possible with available resources; and
- to develop the foundation for sustained development of the Lake Erie Ecological Model.

2.0 Model Testing and Improvement

With assistance from a binational contractor/principal investigator, the LURA Group and Dr. Joseph Koonce, the Task Force improved the 1993/1995 prototype model by engaging modellers, researchers and resource managers in the Great Lakes Basin to identify how the model could be further tested, developed and enhanced. As a starting point for model testing and improvement during the 1995/1997 cycle, the Task Force and its contractor/principal investigator began work on the following key recommendations in its report to the IJC *(IJC, 1995)*.

Task Force 1995 Recommendations for Further Model Development:

- *Use an Integrated, Collaborative Approach in Developing the Model*
- *Communicate the Model Capabilities*
- *Start an Iterative Correction Process*
- *Consult with Users*
- *Test the Three-Basin Concept*

With these recommendations as a backdrop, the Task Force started a number of interactive, sequential activities to adjust and improve the prototype.

2.1 Prototype Demonstration at Duluth Biennial Meeting

As part of a session on exotic species at the September 1995 IJC Biennial Meeting in Duluth, Minnesota, Dr. Koonce demonstrated the model's capabilities. This demonstration continued the Task Force initiative to broaden the constituency of Lake Erie and Great Lakes managers and researchers who are aware of, and involved in, development of the model.

2.2 Distribution of Prototype for Testing and Development

In addition to copies of the model distributed following the April, 1995 workshop, a worldwide web site was established to enable researchers, modellers, managers and other potential user groups to have access to the model for review and testing. There was

3

considerable activity in 1995, and the Home Page received 163 requests from 43 Internet clients during 1996.

As well, two significant efforts to test and develop the prototype by interested users occurred in 1996. Funded by the Lake Erie Protection Fund, Dr. Robert Heath of Kent State University undertook additional work on the model's depiction of the base of the food web. Mr. Philip Ryan of the Ontario Ministry of Natural Resources worked with the prototype to adapt it to test hypotheses regarding fishery issues in the eastern basin of Lake Erie.

2.3   LEEM Model Testing Workshop, Cleveland, Ohio, February, 1996

As an initial step in the iterative correction process for the prototype, the Task Force convened a model-testing workshop at Case Western Reserve University in Cleveland in February 1996 (Koonce and Locci, 1996). The purpose of the workshop was to analyse the features of the prototype to gather information for future modifications of the model. Modellers and managers shared their testing experiences, and tried various modifications of model structure in a further assessment of the model's capabilities.

The Cleveland workshop examined three deficiencies identified at the April 1995 workshop:

- representation and resolution of the lower trophic level;
- the contaminants component and the issue of bioaccumulation; and
- exploration of the whole lake versus multiple-basin version of the model.

Workshop participants identified approaches and recommendations for further model development in these areas, as summarized below:

Lower Trophic Level Resolution

Participants emphasized concern for the level of resolution required to incorporate lower trophic level dynamics, and proposed a criterion for decisions on levels of detail required. Exploration of the feedback structures necessary to include important effects of lower trophic level structure suggested ways of incorporating these feedback structures within the existing model structure. Further analysis and testing is needed in these areas.

Contaminants

Testing of the simulations for contaminant bioaccumulation in LEEM focused mainly on the assumption that trends in aquatic concentrations were sufficient inputs, and the equations developed by workshop participant Dr. Charles Madenjian were suitable for a model that used an annual time step. Prior to this work, contaminant body-burden predictions by the prototype were inconsistent with observed trends. However, relying on aquatic concentration was probably an adequate assumption, given the lack of a mass-balance or even pseudo mass-balance approach to contaminant bioaccumulation. Linkage to more complete mass-balance

4

models and watershed models should be explored. Participants determined that the failures of model prediction were due to unit conversions implicit in model parameters. With these new parameter values, the contaminant submodel is now more reliable and warrants more extensive testing.

Whole-Lake Versus Multiple-Basin Versions of the Model

There is considerable interest in developing individual basin versions of the model. The current prototype provides for this flexibility, but adjustments are needed in estimates for fish mortality to account for interbasin movement. With the assistance of the Cold Water Task Group of the Lake Erie Committee, Great Lakes Fishery Commission, attempts are underway to develop an Eastern basin version and judge its properties relative to the lake-wide version. Analysis of a Western basin version to explore interactions of productivity and predator abundance has also been conducted.

Overall Workshop Conclusions

None of the model testing led to doubt on the fundamental appropriateness of the prototype to address the original management issues -- interaction of declining nutrient loading, zebra mussel invasion, contaminant loading and decline of major fish species. Some new management issues have arisen, including sea lamprey control options, and effects of the supply of nearshore and tributary habitat on spawning and nursery functions. Model modifications may be required to address these new issues.

In addition, the workshop concluded that agreement is needed on the basic guidelines for judging sufficiency of model scope and resolution. Managers are important to the formulation of such guidelines because their needs ultimately determine the kinds of predictions that the model must make, and the types of model inputs required for linkage to management actions. Similarly, further model testing must continue to be an iterative procedure, with periodic review by managers to ensure that the model remains responsive to their needs. In this regard, future testing should focus on:

- testing of individual basin versions;
- experimentation to allow various habitat types to overlap within the model;
- exploration of alternative representations of lower trophic levels; and
- determination of the relationship between fish recruitment and habitat supply.

2.4   Core Advisory Group Priorities for Model Development

The *Core Advisory Group*, (whose advice was an essential part of progress during the initial phase of model development), met on February 26, 1996 to review progress and revisit its priorities for model development. As an initial step at the meeting, members reviewed the four general management issues for which the Lake Erie prototype was originally developed:

I.   changes in fish species composition (abundance) likely to occur with various combinations of fish management, nutrient loading and mussel effects;

II.   changes in contaminant body burdens with same factors (as #1), as well as changes in contaminant loadings;

III.   status of mussel biomass and effect of nutrient loading on mussel biomass; and

IV.   interaction of changes in community structure including vegetation, fish populations, nutrient loading and water quality.

As well, members revisited the original Management Questions, identified by the Lake Erie Task Force for model development in December, 1994, and a list of potential Management Issues identified by the Core Advisory Group at its first meeting in January, 1995. There was general agreement that the four general management issues listed above should continue to provide the focus for further model development during the current phase of the LEEMP.

In view of the April and February workshop results, Core Group members also identified specific management questions they wanted the model address, in both the short- and long-term. The full set of questions identified by the group is attached as Appendix A. Of the questions identified, the Core Group advised that the following questions should be considered in the second iteration of the prototype:

•   Can we sustain significant production and harvest of smelt with current mussel and phosphorus regimes?
•   Is the current decline of walleye, yellow perch and smelt due to lower phosphorus loadings and/or mussel invasion?
•   What would be the effect of reducing predation by walleye and lake trout on the smelt and yellow perch harvests?
•   Should changes in contaminant body burdens be expected as a result of decreased phosphorus loadings?
•   What are the consequences of the major part of the food-web changing from open-water to a lake-bottom focus as a result of mussels?

2.5   Second Iteration of the LEEM

Based on input from modellers and researchers at the February testing workshop, and the management priorities identified by the *Core Advisory Group*, a second version of the model was developed.

With the limited time and resources available for further model development during this phase of the LEEMP, modifications to the model centered on two primary areas:

•   resolution of lower trophic level processes, and

6

- spatial resolution of the model.

In addition, the model is now able to address the four specific management issues (listed in Section 2.4) identified as priorities by the *Core Advisory Group* (see Figure 1).

Key Modifications to Model in Second Iteration:

Lower Trophic Level Resolution

The LEEM now has an explicit component for primary production that represents both edible and inedible fractions of aquatic primary production. LEEM can now represent the effects of zebra mussel density on both the allocation of primary production into edible and inedible fractions, and the recycling of phosphorus. To move toward more explicit mass-balance accounting of energy flows, primary production has been reformulated in biomass terms and partitioned between zebra mussels and zooplankton on the basis of zebra mussel demand. Because the prototype does not have an explicit component for detritus, the macrobenthos is the only implicitly mass-balance(d) component in the model.

Spatial Resolution

In the revised LEEM, fish reproduction components have been modified to allow for constraints resulting from availability of habitat (Minns, et al. 1996). Each fish species thus has a density-dependent effect on the success of its own reproduction. Including such a parameter in the model will provide the option for future simulations to incorporate information on supply of habitat for various life history stages with predicted abundance. Using the approach of Minns et al. (1996), availability of habitat will be most limiting for one life history stage (spawning, nursery habitat, juvenile habitat, or adult habitat) and that critical habitat supply and predicted abundance will determine density. The function added to LEEM thus predicts habitat-dependent survival probability using a single-parameter.

In addition, an Eastern Basin version of the input spreadsheets has been developed so that fish managers can compare multi-basin versions with the whole-lake version. Additional fish species have been included in the Eastern Basin version, bringing the total to 24 (Koonce and Locci, 1996).

2.6 Meeting with Modellers at IAGLR '96, University of Toronto, Erindale Campus, Mississauga, Ontario, May, 1996

On behalf of the Task Force, Dr. Koonce met with modellers at the International Association of Great Lakes Researchers [IAGLR] Conference, as part of a special session on Lake Erie. The purpose of the meeting was to discuss the scope of the modelling workshop which the Task Force intended to host in September, 1996 (see Section 2.8). As a result, an approach for comparing various Lake Erie modelling initiatives (including the LEEM) was identified

Figure 1(a) **Lake Erie Ecological Model:
Energy, Nutrient and Contaminant Flows, from IJC (1995)**

Fishing Mortality   Stocking

PO$_4$

Zooplankton

Primary Production → Zebra Mussel ← PCB → Prey Fish → Predator Fish

Zoobenthos

Harvest

→ Energy and Nutrient Flow
⇒ Contaminant Flow
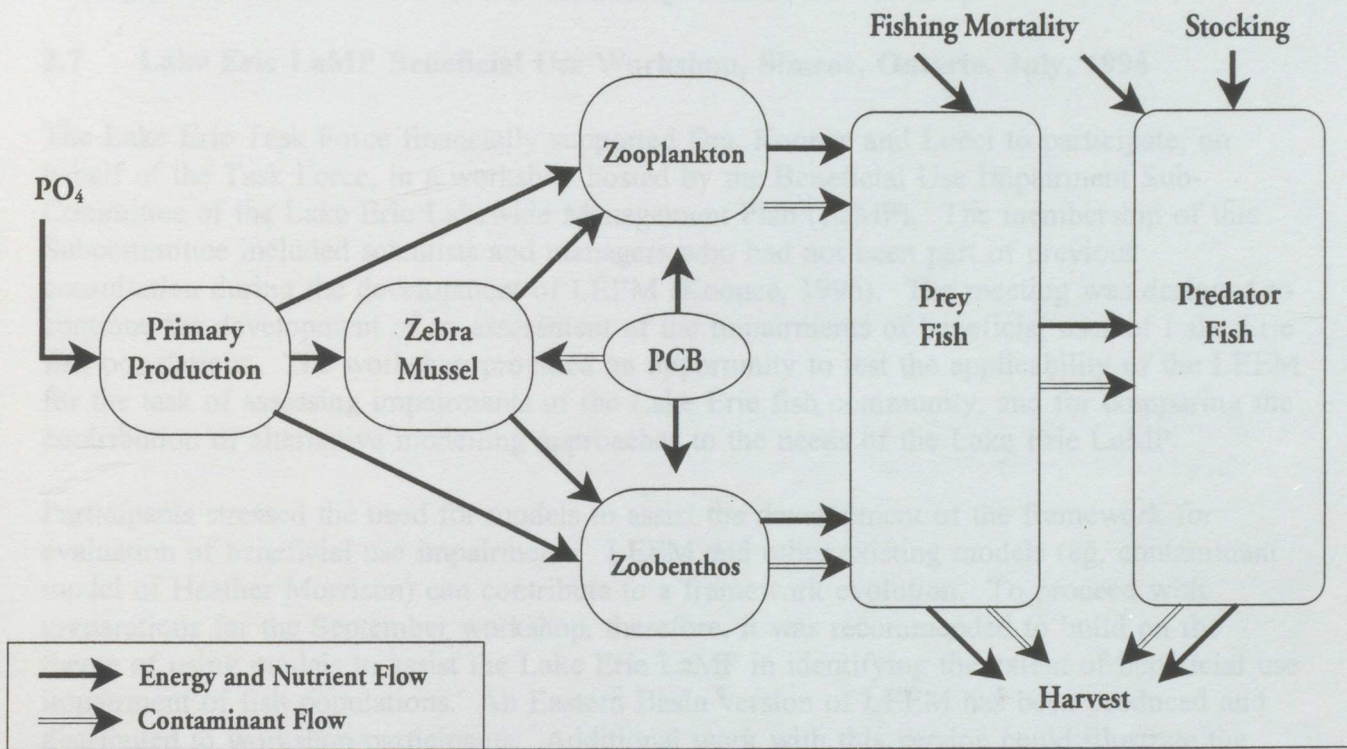
Figure 1(b) **Revised Structure, Lake Erie Ecological Model, 1996**

PO$_4$

Fishing Mortality   Stocking

Zooplankton

Edible Algae

Inedible Algae

Zebra Mussel ← PCB → Prey Fish → Predator Fish

Zoobenthos

Harvest

⋈ Flow Regulators   ⇒ Contaminant Flow
→ Energy and Nutrient Flow   --→ Regulation Feedback

8
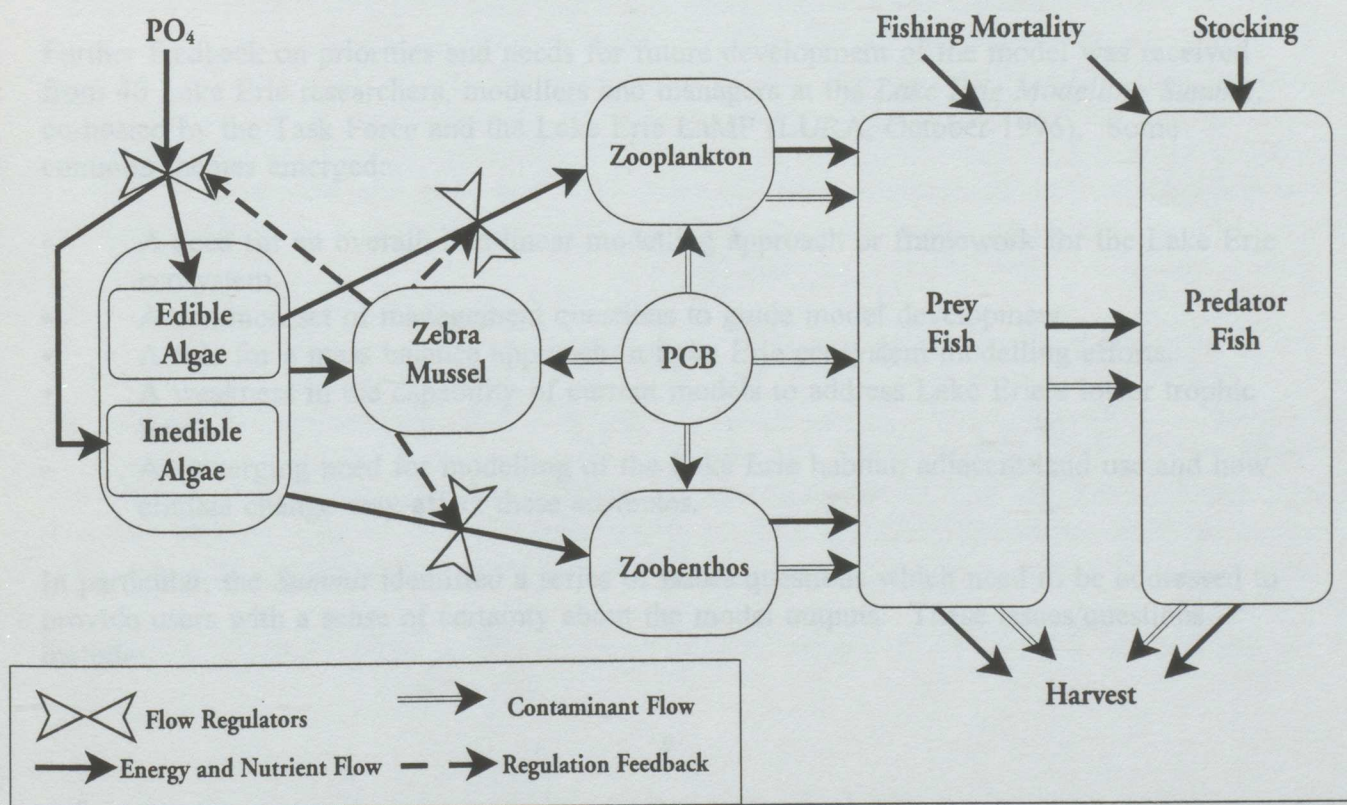
for consideration by the Task Force. In addition, several participants expressed interest in making presentations on their current modelling work at the workshop.

2.7   Lake Erie LaMP Beneficial Use Workshop, Simcoe, Ontario, July, 1996

The Lake Erie Task Force financially supported Drs. Koonce and Locci to participate, on behalf of the Task Force, in a workshop hosted by the Beneficial Use Impairment Sub-Committee of the Lake Erie Lakewide Management Plan (LaMP). The membership of this Subcommittee included scientists and managers who had not been part of previous consultation during the development of LEEM (Koonce, 1996). The meeting was designed to continue the development of an assessment of the impairments of beneficial uses of Lake Erie fish populations. The workshop provided an opportunity to test the applicability of the LEEM for the task of assessing impairments of the Lake Erie fish community, and for comparing the contribution of alternative modelling approaches to the needs of the Lake Erie LaMP.

Participants stressed the need for models to assist the development of the framework for evaluation of beneficial use impairments. LEEM and other existing models (eg. contaminant model of Heather Morrison) can contribute to a framework evolution. To proceed with preparations for the September workshop, therefore, it was recommended to build on the theme of using models to assist the Lake Erie LaMP in identifying the extent of beneficial use impairment of fish populations. An Eastern Basin version of LEEM has been produced and distributed to workshop participants. Additional work with this version could illustrate the applicability of LEEM to this activity of the LaMP, and lead to more general ways other modelling initiatives could also assist the LaMP.

2.8   Lake Erie Modelling Summit, Windsor, Ontario, September, 1996

Further feedback on priorities and needs for future development of the model was received from 40 Lake Erie researchers, modellers and managers at the *Lake Erie Modelling Summit*, co-hosted by the Task Force and the Lake Erie LaMP (LURA, October 1996). Some common themes emerged:

- A need for an overall, non-linear modelling approach or framework for the Lake Erie ecosystem.
- A common set of management questions to guide model development.
- A role for a mass balance approach in Lake Erie ecosystem modelling efforts.
- A weakness in the capability of current models to address Lake Erie's lower trophic levels.
- An emerging need for modelling of the Lake Erie habitat, adjacent land use and how climate change may affect these attributes.

In particular, the *Summit* identified a series of issues/questions which need to be addressed to provide users with a sense of certainty about the model outputs. These issues/questions include:

9

1.	Does the model adequately represent actual changes in the Lake Erie fishery (with or without the presence of zebra mussels in the system)?

2.	What is the ability of the model to predict the impact of changes in phosphorus loadings (and resulting impacts on zooplankton and fish production, with or without the presence of zebra mussels in the system)?

3.	Can the model account for the impact of fish harvest regulations on fish production and consumption?

4.	What are the effects of increased transparency and visibility on habitat requirements for fish?

The *Summit* also concluded that the spatial and temporal issues surrounding the model need to be resolved before further model testing and development occurs. These issues include technical concerns with the adequacy of assumptions and aggregation of variables, with the goals of model use, and with the availability of information to estimate model parameters and test model predictions. The experience in developing LEEM revealed the critical importance of iteration between review of goals for model development and discussion of levels of spatial and temporal resolution necessary to make contributions to these goals. Further model development without reconsideration of modelling goals by the users of the model, therefore, may lead to uncoupling of essential feedback to guide future model development.

The *Summit* examined a wide range of past and current Lake Erie modelling initiatives (in addition to the LEEMP), and the role that these models can play in meeting the needs of the Lake Erie LaMP, resource managers and researchers. In effect, the *Summit* brought the Task Force and meeting participants back "full circle" to the question first considered in 1994 when the Task Force was formed -- how can modelling assist with understanding and decision-making for the complex and changing Lake Erie ecosystem. The *Summit* illustrated the important role that models play in addressing these needs, as well as showing the value of bringing together Lake Erie managers, researchers and modellers to share information and to explore potential links among their work. The Lake Erie Task Force has been quite successful in bringing managers and modellers together in demonstrating the capability and value of models to assist with management decisions.

3.0 Foundation for Future Model Development

In addition to the testing and improvement of the Lake Erie Ecological Model described in Section 2, the Task Force was active to ensure that model development would be sustained. This effort is consistent with the original intent of the IJC in supporting the Task Force's modelling initiative, that is to provide leadership, facilitation and coordination for the LEEMP until the Parties and/or other partners assumed interest and responsibility for this initiative.

For this purpose, the Task Force has pursued two interrelated tactics:

- facilitating transfer of the Lake Erie modelling initiative to the Parties; and
- encouraging our principal investigator to seek additional funding partners for further model development.

3.1 Transfer to the Parties

Beginning in the Fall of 1995, the Task Force Co-Chairs met with representatives of Environment Canada and the United States Environmental Protection Agency -- two agencies which would be key users of the model and which are leading the Lake Erie LaMP process. Specifically, meetings were held with senior representatives of the Parties in December 1995, with the Lake Erie LaMP Work Group in January 1996, and with the LaMP Work Group Co-Chairs in January 1997. To Summarize:

- the binational Lake Erie Committee of the Great Lakes Fishery Commission will use and enhance the existing model, which has already been modified to allow a separate focus on the Eastern Basin of Lake Erie, to examine fisheries issues; and,
- the Lake Erie LaMP Work Group will create a modelling subcommittee which will use and enhance this model and others to assist in the development of the Lake Erie LaMP.

Throughout the eighth and ninth biennial cycles, the Task Force regularly shared its experience in developing the LEEMP with managers and agencies involved in the Lake Erie LaMP. This interaction occurred primarily through involvement by LaMP participants in the LEEMP *Core Advisory Group*, in model development workshops, and in working with and testing the LEEM. This approach to the LEEMP, with its emphasis on sound technical modelling coupled with an interactive, collaborative *process* for model development has provided an effective blueprint for future model development. The experience in developing a model in concert with an advisory group, the learning that occurred about the uses of the model and compromise in model resolution, and heuristics of model use were all positive, and the transfer to the LaMP has occurred through the involvement of LaMP participants in the LEEMP. The Task Force has created a much larger group or nucleus of people working together on ecosystem issues and have crossed boundaries -- agencies, offices, communities, disciplines, etc.

3.2 Funding for Ongoing Model Development

The model's principal investigator, Dr. Joseph Koonce of Case Western Reserve University, has received a substantial EPA Research Grant to pursue further model development. Dr. Koonce's grant of approximately $250,000 (U.S.) is for an overall project entitled "Modelling and Multiobjective Risk Decision Tools for Assessment and Management of Great Lakes Ecosystems", and will enable continued expansion of the Lake Erie model to address issues such as habitat, hydrology and climate change.

In addition, this funding will enable further development of the model to meet the specific

11

needs of the Beneficial Use Impairment Sub-Committee of the Lake Erie LaMP. In particular, the Sub-Committee has expressed interest in using the model to examine issues such as: effect of water transparency on predator-prey relations; habitat complexity effects; winter die-off of clupeids; and, "in lake" concentrations of phosphorus.

4.0 Lessons Learned in Developing the LEEMP

Integrated modeling of living system/environs complexes, e.g., the Lake Erie Ecosystem, is one of the more promising ways to marshal tools of decision support so the Parties may fulfill their agreement "to make a maximum effort to develop programs, practices and technology necessary for a better understanding of the Great Lakes Basin Ecosystem". The Lake Erie Task Force has concluded that the most recent iteration of its LEEM warrants a place in the suite of models of several logical types (graphic landscape models, word models, process-function models, mass balance models, community models, population models, watershed models, etc.) which must be interlinked in order to ascertain where our understanding of the Lake Erie Ecosystem is a robust understanding and where lie the important gaps in our understanding. However, integration of such models for enabling explorations of ecosystem integrity, type and scale, requires that there be a legitimate unified approach.

The Lake Erie Task Force has taken as a given the fact that the ecospheric complex is fully interrelated, an unseamed whole in which everything is connected to everything else. The reason for doing ecological research is to find which connections are stronger and more significant (given certain criteria) than others. The goal in developing predictive models such as the LEEM was not to show that everything is connected but to show which minimal number of connections that we can measure may be used as a reasonable surrogate for the whole system, in this case Lake Erie. Models of any type are abstracted and, hopefully, realistic. They are, however, models of reality and are not themselves reality.

Through its work on the LEEMP during the past two biennial cycles, the Task Force has developed considerable insight regarding the effort to develop a comprehensive, ecosystem model for Lake Erie. Several key "lessons learned" are summarized below:

No one model can adequately address *all* the issues and problems associated with the dynamic Lake Erie ecosystem. By definition, ecosystems like Lake Erie involve many complex, interactive processes and components which are in a constant state of change. Capturing all of these processes and components in any one model while ensuring model outputs are realistic, certain and verifiable for users is extremely challenging. In our view, emphasis in the future should be placed on exploring ways of facilitating interface and possibly integration between complementary Lake Erie Modelling initiatives. In fact, our ultimate "Lake Erie ecosystem model" may be a large comprehensive model capable of being the interface between numerous smaller models each dealing with a specific component of the ecosystem.

We believe the IJC's Lake Erie Task Force has been successful in accomplishing its goals. We

have developed an ecosystem model for Lake Erie which has been deemed useful and will be used by the Lake Erie LaMP and the Lake Erie Committee of the GLFC. We have had an impact on the LaMP process which will include a modeling subcommittee in the future. Furthermore, our principal investigator, Dr. Joseph Koonce has received additional funding from U.S. EPA to allow further development of the model. Therefore, the results of IJC efforts will not sit on the shelf. They will be used. And, the parties themselves will continue the development and improvement of the work initiated by IJC.

The *process* by which a model is developed is at least as important as the technical capabilities of the model itself. From the outset of the LEEMP, the Task Force pursued a collaborative, inclusive approach to model development. The Task Force believes that the constituency of over 60 Lake Erie modellers, researchers and managers which has been actively involved in the model's development, testing and use is one of the LEEMP's greatest strengths and accomplishments.

Criteria for closure are essential to model design. All models are simplifications of real systems and are thus incorrect at some level of detail. Establishing criteria for closure provides a way of judging model adequacy. Nothing in the testing of the LEEM prototype has indicated that it is inappropriate to address the range of problems for which it was designed. The initial problem focus included questions about the interaction of reductions in nutrient loading, invasion of zebra mussels, contaminants and fish management policies in causing the decline of important Lake Erie fisheries. However, review and testing of the prototype has not been limited to those involved with its initial design. By opening the evaluation of the prototype to a wider audience, much can be learned about model weaknesses and the implication of these weaknesses to use of the model for the intended purposes. At the same time, broader review can result in new perspectives on problem definition for the model. It is important to recognize that model development is, and should be, an iterative process. Within this context, criteria for closure are needed for each iteration of a model to enable the model development process to move forward.

Strong project management is a prerequisite for success, particularly with multi-faceted projects spanning one or more years in duration. During its work in the eight and ninth biennial cycles, the Task Force met regularly (either in person or through teleconferences) to review progress, address and resolve issues and provide direction to our contractor/principal investigator. We also believe that the diverse mix of members on the Task Force -- with unique ideas, perspectives and areas of expertise -- also contributed to successful completion of work on the Lake Erie priority.

5.0 Conclusions and Recommendations

5.1 Conclusions

We believe that both of our overall goals for the 1995/1997 priority have been achieved.

Model Modification and Improvement

By starting an iterative correction process for the Lake Erie Ecological Model, the prototype has been further tested, developed and improved. This has been accomplished through a series of interactive demonstrations, testing exercises, and workshops, culminating in the development of a second iteration of the model. At this stage in its development, the model remains in a prototype state. Further evaluation and testing is needed to move from the prototype stage to application of the model to the Lake Erie condition. It is important to note that even a fully evaluated and tested version will not be able to address all the ecological issues confronting management of Lake Erie. However, testing and evaluation of the prototype to date has indicated that the LEEM will have primarily heuristic value in addressing the range of problems for which it was originally designed: to illustrate interactions between the key stresses affecting the Lake Erie ecosystem -- zebra mussel invasion and contaminant loading -- and the fisheries and declining nutrient loading.

Sustainable Model Development; Framework and Infrastructure

A strong foundation for future model development has been developed by securing additional substantial funding for further model development. The model's principal investigator, Dr. Joseph Koonce of Case Western Reserve University, has received a substantial EPA Research Grant to pursue further model development. In addition, we believe that the transfer of the Task Force's experience (in developing the LEEMP) to the LaMP has occurred through the involvement of LaMP participants in our process. Furthermore, the Lake Erie LaMP Work Group will be creating a modelling subcommittee which will use the LEEM and other models, and the Lake Erie Committee of its Great Lakes Fishery Commission will be using the Eastern Basin version of the LEEM to evaluate a variety of fishery, contaminant and nutrient issues.

Finally, the Task Force believes that the LEEMP process has made a substantial contribution to the effort to use models and modelling applications to enhance understanding and decision-making about Lake Erie. Key benefits and accomplishments include:

- active involvement of more than 60 Lake Erie managers, researchers and modellers in model development;
- information-sharing regarding models, modelling applications and issues confronting Lake Erie; and
- development of a prototype which, with additional evaluation, testing and improvement, can be used and applied heuristically to assist:
  Managers - in exploring alternative management options, hypotheses and scenarios; clarifying issues and problems; and communicating and justifying management preferences;
  Scientists - in screening hypotheses; and identifying research priorities.

5.2   Recommendations

The Task Force provides the following recommendations to the Commission for its consideration:

1.   In hosting the initial model demonstration workshop in April, 1995 and the recent *Lake Erie Modelling Summit* in September, 1996, the Task Force observed the value of IJC's role in providing opportunities for information-sharing and discussion among Lake Erie researchers, modellers and managers. Both meetings provided an excellent setting to exchange ideas, review progress and determine priorities for action.

The IJC's Council of Great Lakes Research Managers (CGLRM) is ideally suited and should, as an ongoing priority, serially explore various ecological avenues for enhanced interfacing and integration among complementary Lake Erie modelling efforts. Therefore, **"The Task Force recommends that the IJC assign to the CGLRM (as a priority for the next biennium) the mandate to provide a regular forum for Lake Erie modellers, researchers and managers to convene to share information, discuss progress and explore potential linkages among complementary Lake Erie modelling initiatives."**

These meetings will need to focus on:

- testing of multiple basin versions;
- experimentation to allow various habitat types to overlap within the model(s);
- exploration of alternative representations of lower trophic levels; and
- determination of the relationship between fish recruitment and habitat supply.

2.   **"The Task Force further recommends that the IJC use ecosystem models in its evaluation of progress under the Agreement".** The LEEMP experience supports the view that management models can support such evaluation but only if this provision of support is explicitly considered during model development.

6.0   BIBLIOGRAPHY

IJC Priorities and Progress Under the Great Lakes Water Quality Agreement (1993-95). August 1995. IJC Windsor.

IJC Task Force on Chemical Loadings of the Toxic Substances Committee. October 1988. "Report on Modeling the Loading-Concentration Relationship for Critical Pollutants in the Great Lakes."

Koonce, Joseph F. July 9-11, 1996. Report on Participation in Workshop on Impairment of the Beneficial Use of Fish Populations in Lake Erie. Simcoe, Ontario.

Koonce, Joseph F. and Locci, Ana B. March 31, 1995. Final Report on the Development of a Prototype Model for the Lake Erie Ecosystem.

Koonce, Joseph F. and Locci, Ana B. February 15-16, 1996. Final Report on the LEEM Model Testing Workshop.

Koonce, Joseph F. and Locci, Ana B. March 29, 1996. Final Report on Phase II Development of the Lake Erie Ecological Model.

LURA Group. June 13-14, 1994. Lake Erie Pre-Workshop, Lake Erie Steering Committee.

LURA Group. March 31, 1995. Initiative I Report: Review of Existing Ecological Models.

LURA Group. May 3, 1995. Lake Erie Prototype Model Workshop Summary Report.

LURA Group. October 1996. Lake Erie Modelling Summit Report.

LURA Group. November 1996. The Lake Erie Ecological Modelling Project - Final Report on 1995/1996 Priority.

Minns, C.K., Randall, R.G., Moore, J.E., and Cairns, V.W. 1996. A model simulating the impact of habitat supply limits on a population of northern pike, *Esox lucius*, in Hamilton Harbour, Lake Ontario. Can. J. Fish. Aquat. Sci. 53 (Suppl. 1).

7.0   MEMBERSHIPS

LAKE ERIE STEERING COMMITTEE

Douglas Alley (Secretary, Parties Implementation Work Group)
John M. Cooley (Council of Great Lakes Research Managers)
Douglas P. Dodge (Water Quality Board)
G. Douglas Haffner (Science Advisory Board)
John McDonald (Secretary, Water Quality Board)
Jeffrey M. Reutter (Council of Great Lakes Research Managers)
James D. Rozakis (Water Quality Board)
James W.S. Young (International Air Quality Advisory Board)

LAKE ERIE TASK FORCE

Douglas Alley (Secretary, Lake Erie Task Force)
Ted Bailey (International Joint Commission)
Bruce Bandurski (International Joint Commission)
Stephen B. Brandt (Science Advisory Board)
Kelly Burch (Water Quality Board)
John M. Cooley (Council of Great Lakes Research Managers)
Douglas P. Dodge (Water Quality Board) Canadian Co-Chair
Jeffrey M. Reutter (Council of Great Lakes Research Managers) U.S. Co-Chair
James D. Rozakis (Water Quality Board)
Harvey Shear (Council of Great Lakes Research Managers)
Nelson Thomas (Council of Great Lakes Research Managers)
James W.S. Young (International Air Quality Advisory Board)

CORE ADVISORY GROUP

Dieter Busch, U.S. Fish & Wildlife Service
William Culligan, New York State Department of Environmental Conservation
David Dolan, International Joint Commission
Sandra George, Environment Canada
Del Graf, Pennsylvania Fish Commission
Ava Hottman, Ohio Environmental Protection Agency
Douglas Jester, Jr., Michigan Department of Natural Resources
Robert Lange, New York State Department of Environmental Conservation
Julie Letterhos, Ohio Environmental Protection Agency
Rob MacGregor, Ontario Ministry of Natural Resources
Francine Norling, U.S. Environmental Protection Agency, Region 5
Kenneth Paxton, Ohio Department of Natural Resources, Division of Wildlife
Philip Ryan, Ontario Ministry of Natural Resources
Craig Selby, Ontario Ministry of Natural Resources
Harvey Shear, Environment Canada
Ian Smith, Ontario Ministry of Environment & Energy

ADDITIONAL PARTICIPANTS IN LAKE ERIE TASK FORCE WORKSHOPS AND CONSULTATIONS

Steven M. Bartell, SENES Oak Ridge Inc.
Keith Bedford, Ohio State University
Peter Boyer, International Joint Commission
Murray Charlton, Environment Canada
Murray Clamen, International Joint Commission
David A. Culver, Ohio State University
Joseph V. DePinto, University of Buffalo
David Dilks, LURA Group
Michael Gilbertson, International Joint Commission
Frank Gobas, Simon Fraser University
Lorne Greig, ESSA Technologies Ltd.
Ron Griffiths, Ontario Ministry of Environment & Energy
Andrew Hamilton, International Joint Commission
Reed Harris, Tetra Tech, Inc.
Robert J. Heath, Kent State University
Robert Hecki, Environment Canada
Ben Hobbs, Johns Hopkins University
Todd Howell, Ontario Ministry of Environment & Energy
Ora Johannsson, Department of Fisheries & Oceans
Kevin Kayle, Ohio Division of Wildlife
Roger Kenyon, Pennsylvania Fish & Boat Commission
Joseph F. Koonce, Case Western Reserve University
Roger L. Knight, Ohio Division of Wildlife
Betsy Kozuchowski, U.S. Fish & Wildlife
Ana Locci, Case Western Reserve University
Morgan L. McCosh, U.S. Fish & Wildlife Service
Ellen McDonald, Ohio State University
Scott Millard, Department of Fisheries & Oceans
Kenneth Minns, Department of Fisheries & Oceans
Heather Morrison, Department of Fisheries & Oceans
Mohi Munawar, Department of Fisheries & Oceans
Kenneth M. Muth, Lake Erie Biological Station
James J. Nicita, University of Michigan
Sandra Parker, International Joint Commission
Henry Regier, University of Toronto
William Richardson, U.S. Environmental Protection Agency
Paul W. Rodgers, LTI-Limno-Tech, Inc.
David Schwab, NOAA, Great Lakes Environmental Research Lab
Rochelle Sturtevant, Coordinator, Great Lakes Task Force for the U.S. Senate
Francine Margaret Thielke, U.S. Environmental Protection Agency, Region 5
Stuart Whipple, University of Toronto

Appendix A: Core Advisory Group - Priority Management Issues

I. Changes is fish species composition (abundance) likely to occur with various combinations of fish management, nutrient loading and mussel effects. [Fish species include: walleye, yellow perch, ruffe, trout perch, white perch, white bass, emerald shiners, spottail shiners, lake herring, lake whitefish, smelt, gizzard shad, alewife, burbot, smallmouth bass, drum, sturgeon, round goby, coho salmon, chinook salmon, brown trout, lake trout, rainbow trout, sea lamprey]	
1. *Can we sustain significant production and harvest of smelt with current mussel and phosphorus regimes?*	A
2. *Is the current decline of walleye, yellow perch and smelt due to lower phosphorus loadings and mussel invasion?*	A
3. Would yellow perch and other species' harvest increase if phosphorus loads increase?	A
4. *What would be the effect of reducing the predation effects of walleye and lake trout on smelt and yellow perch harvest?*	A
5. What (if any) is the interaction between sustainable harvest of yellow perch and sustainable harvest of walleye?	A/B
6. What is the impact of ruffe invasion on yellow perch and young of year classes of walleye?	B
7. What is the impact of reduced sea lamprey controls on: salmonids, coregonine, burbot and smelt?	B

II. Changes in contaminant body burdens with same factors (as in #1) as well as changes in contaminant loadings (PCB, DDT, Mercury and Atrazine).	
1. *Should changes in body burdens be expected as a result of decreased phosphorus?*	A
2. Latency of response of body burdens to changes in phosphorus or mussels? [complete list of species, as relevant]	B
3. Do concentrations of contaminants in various species show consistent ratios or divergent ratios?	B

III. Current mussel biomass status and effect of nutrient loading on mussel biomass.

1. Do mussels increase primary production?	B
2. What are the net effects of mussels on primary, secondary and benthic production and latency of those interactions?	B
3. *What are the consequences of system changing from pelagic to benthic as a result of mussels?* (Phil Ryan to refine)	B

IV. Interaction of community structure changes including vegetation, fish populations, nutrient loading (including silica) and water quality.

1. What are the impacts of atrazine on food web, energy transfer changes in "vegetation", plankton, and "algae"?	B
2. What are the effects of silica or other secondary nutrient limitations on food web dynamics and fish community structure? [edible/inedible - spatial distribution of productivity]	B
3. What is the effect of fish harvest on water quality parameters of specific interest?	B
4. What is relationship between walleye abundance and distribution with water quality (transparency)?	B

Notes

Right-hand column shows priorities assigned by Core Group: A = address before March 31, if possible; B = address after March 31. Italics indicate questions which Koonce/Locci believe can be developed further prior to March 31.

Appendix B: Task Force Correspondence to IJC Commission Co-chairs

International Joint Commission
Commission mixte internationale
LAKE ERIE TASK FORCE

February 18, 1997

Mr. Thomas L. Baldini
Chair, U.S. Section
International Joint Commission
815 Pine Street
Marquette, MI 49855

Mr. Pierre Béland
Acting Chair, Cdn. Section
International Joint Commission
100 Metcalfe Street, 18th Floor
Ottawa, ON K1P 5M1

During discussions at the Semi-Annual meeting of the Commission in April 15-19, 1996, you asked us to comment about the "apparent" success of the Lake Erie Task Force, i.e. what had we learned that might assist the Commission the next time it created a task force.

We offer the following observations for your consideration.

We will begin with some generic points. We had:

1. An active, participating membership in the Task Force, each member contributing ideas and setting aside the time needed to meet the individual's commitment.

    Most of our meetings were through conference calls at, at least, monthly intervals whereby the Task Force did its business in two to three hours, without incurring long travel times and travel costs.

2. A science based, binationally developed and broadly accepted task, e.g. understanding the dramatic changes occurring in the Lake Erie ecosystem.

    This allowed the Task Force to develop a focused Request-for-Proposals (RFPs).

3. A specific mandate, charge and time-line.

    Although the Task Force could have used more time and resources to produce a broader-scoping model, we did what was possible with available resources because we had specific deadlines to meet.

4. Excellent support by staff at the Regional and Section offices.

    Our operation was enhanced by the assistance of Doug Alley; the chemistry between Doug Alley and the Task Force was a high energy, non-explosive, steady-burning reaction.

5. Direct access and reporting of the Task Force to the Commission.

    There are efficiencies when a Task Force is directly appointed by the Commission, charged to keep its Board or Council informed, but, ultimately responsible directly to the Commission

6. Supportive Commissioners who provided strong encouragement and positive feedback.