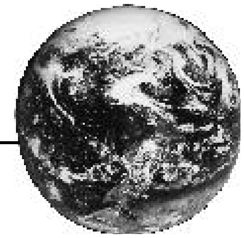

ECOMOD

March 1999

Contents

About ISEM

The International Society for Ecological Modelling (ISEM) promotes the international exchange of ideas, scientific results, and general knowledge in the area of the application of systems analysis and simulation in ecology and natural resource management. The Society was formed in Denmark in 1975, and today has chapters in Europe, Asia, and North- and South-America. ISEM sponsors conferences, symposia, and workshops that promote the systems philosophy in ecological research and teaching, and in the management of natural resources. The Society publishes the newsletter ECOMOD, and its members frequently contribute articles to the official scientific journal of the Society, *Ecological Modelling*.

Perspectives

Rick A. Linthurst, Ph.D., Associate Director for Ecology, National Exposure Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711

Joan H. Novak, Ph.D., Chief, Modeling Systems Analysis Branch, Atmospheric Modeling Division, National Oceanic and Atmospheric Administration, Research Triangle Park, NC 27711

Robert F. Carousel, Ph.D., Senior Science Advisor, Ecosystems Research Division, National Exposure Research Laboratory, Athens, GA 30613

Steven F. Hedtke, Ph.D., Acting Director, Mid-Continent Ecology Division, National Health and Environmental Effects Laboratory, Duluth, MN 55804

Developing the Next Generation of Watershed Risk Assessment and Management Models: Where do we go from here?

ABSTRACT--Wise management decisions to protect ecological resources require an understanding of how the resource is affected by multiple stressors at multiple scales and how it responds to the change(s) effected by the management action. When the complexity of the real world hampers our ability to accurately predict the consequences of management actions, the unintended consequences can be devastating. Considerable research on developing predictive tools relating to environmental

quality is ongoing in many government, private, and academic sectors. But, little effort is being spent on linking these elements in a holistic way to help local, regional, and national managers make the right environmental management decisions—a challenge they face daily. This paper discusses the concept of a common, multimedia, integrated, modeling system (MIMS) for the next generation of ecological modeling. The prototype software framework focuses on water quality, both biological and chemical, as the endpoint, an issue of great importance in all areas of the country. This initial modeling system will serve as the foundation for developing a mathematical model(s) to understand, predict, assess, and manage the exposure and response of aquatic ecosystems to multiple stressors at multiple scales. This approach will enable local, municipal, state, and federal watershed managers to make decisions more confidently that will protect or improve aquatic ecosystem health over the long-term, ensuring the sustained viability, vigor, and health of fishery resources in streams, rivers, and estuaries subject to constantly changing chemical loadings and landscapes. While a modeling system and individual models are useful by themselves from both a scientiic and managerial perspective, coupling them will vastly increase our predictive capabilities. The concept of a common framework for ecological modeling, an integrated, mulimedia approach to watershed modeling, and a summary of current modeling research in the U.S. Environmental Protection Agency's Office of Research and Development applicable to both are discussed. The primary purpose of the paper is to encourage discussion of how best to join together in the modeling community to take a major step forward in helping to protect our aquatic resources with sound science.

Background: A Changing Regulatory Perspective

An important challenge to ecosystem management is the relationship between humans and nature. Until recently, abundant open space provided a buffer for increased resource use and changing public values. This buffer helped foster the "protectionist" approach, the view that natural ecosystems were something to be held apart from human activities, to be set aside and kept pristine. This view is rapidly changing as it becomes clearer that nature does not operate in small, isolated pieces and that the consequences of human activities now pervade the entire earth. There are no pristine ecosystems left. At a minimum, all natural systems are exposed to changes in composition of the atmosphere and solar radiation, and only a few are spared from the profound land use changes sweeping the globe.

Ecological issues can no longer be associated with a single stressor, scale, or medium. Increasingly, it is evident that environmental problems can no longer be solved, but rather must be managed interactively. Society, scientists, and regulators are recognizing that not all ecological changes are necessarily "bad". Ecosystem management has become more a matter of social trade offs among alternative uses rather than simply a matter of protection. People are part of ecosystems—cultural, economic, and ecological well-being are inextricably linked.

The regulatory approach within the U.S. Environmental Protection Agency (EPA) is evolving to keep pace with these newly recognized ecological protection challenges. In particular, two changes have a major impact on the future of environmental protection research:

Less centralized decision making. In the past, the predominant approach to regulation has been one of "command and control." Although this approach will certainly continue in areas where it is the only way to achieve results, when evaluating the trade offs associated with protecting ecosystems, the values of the community clearly must factor into the process. Because of this, the movement toward community-based decision making will increase.

More flexible decision making. Regulations have frequently been inflexible and applicable nationally. Recognizing that "one size does not fit all" and that alternatives do exist, environmental management decisions are increasingly being made to support the central goal of sustaining ecosystems, rather than merely abiding by potentially less effective, universal regulatory standards.

With this change in perspective, there is increasingly a need for more advanced decision tools that help the environmental manager more confidently evaluate what can be done to fix problems that have already occurred but also to be proactive and assess what will happen under alternative change scenarios. Some of those tools will certainly be models.

This paper focuses on two needs of the ecological modeling research within EPA's Office of Research and Development (ORD): (1) a common software framework for ecological modeling to improve the ability to make management decisions and (2) within that framework, improved watershed-scale (multiscale) modeling to support water quality decision making that addresses multimedia sources of stress. A complete perspective of EPA's ecological research is presented in EPA's Ecological Research Strategy (EPA 1998a) at the web site of: http://www.epa.Governors/ORD/WebPubs/final/

Process and Modeling Research: The longer-term vision

The fundamental understanding and modeling technology to predict future landscapes, stressor patterns, ambient conditions, exposure profiles, habitat suitability, and receptor responses as functions of risk management alternatives are developed through process and modeling research. Future models must account for several factors complicating ecological management decisions: multimedia, multipath stressor sources; intermedia pollutant transfer, transport and transformation; microenvironments; and receptor activity patterns. These factors must be addressed in the context of anticipated regional changes (think regionally, nationally, and globally but act locally) resulting from both natural and anthropogenic causes.

For convenience and simplicity, most current models used to predict the outcome of any individual management option are often single media, involving only a single pollutant or stressor. Recognizing this over-generalization, we must move beyond this piecemeal approach to modeling and begin representing the interactions that occur across multiple scales, media, stressors, and levels of biological organization. The complexity of the problems that environmental managers will face in the future will require models to predict beyond today's physical and chemical conditions to new, never-before-measured conditions. Future models must be sufficiently complex in their description of the underlying processes to enable adequate decision making but not so complex as to become unused. Having such models will allow scientists to best advance the understanding of the whole of the environment and to develop anticipatory and more flexible management strategies that avoid unwanted results. It is the vision for this area of research that future models will be interrogated in the same way that engineering tables and interactive CD-ROM encyclopedias are used today.

A Multimedia Modeling Software Framework: Part I

Rationale

To assist them in making informed assessments, ecological risk managers need models that predict ecological exposure to multiple stressors and the resulting effects on ecosystems. The development of these models should be based on:

- A scientifically accepted systems approach (a common framework) to support multimedia and multistressor modeling;
- State-of-the-science process algorithms and component computational models with flexible scaling to provide problem-solving methodologies that are applicable at multiple geographic and temporal scales;
- State-of-the-science atmospheric, terrestrial, aquatic, and biotic process models and stressors and effects models that predict real-world conditions and their

incorporation into a common framework; and
- Improved ability to interconnect one system with another system (e.g., the atmosphere and surface water ecosystems) and exchange information between.

Since 1992, regional atmospheric pollutant fate and exposure models have matured as a benefit of the high-performance computing age. Although originally limited to a single medium, early regional models were sufficiently sophisticated to address the atmospheric gas and cloud water phases, accommodate biogenic emissions from the terrestrial component, and account for removal by rain and by dry interaction with the land surface and vegetation. A current prototype, air-oriented environmental modeling framework, Models-3 (Dennis 1996, EPA 1998b), has the capability of managing data and models, processing data, computing across platforms, and visualizing and analyzing data for a variety of environmental assessment fields. Models-3 is proposed as a starting point for the development of the broader multistressor, multimedia problem solving environment (Gallopoulous 1994) called MIMS.

MIMS is being developed to achieve the following long-term, overarching goals:

- Make available a common multistressor, multimedia, multiscale environmental modeling system, that incorporates input from federal agencies, research institutes, and academia.
- Foster active multidisciplinary development of scientific, technical, computational, and procedural guidance to facilitate the formulation interoperable environmental modeling systems, interchangeable process components, and accessible data repositories.
- Construct and maintain an open-architecture software system that enables
  - data access and management;
  - user specification of problem domain, spatial and temporal scales, and target issues of interest;
  - feedbacks between related ecosystem components and construction of problem-oriented models from components;
  - selection, linkage, and execution of model components across a full range of networked computers from PCs to scalable parallel supercomputers; and
  - integration of knowledge-assisted geospatial visualization and analysis, to assist user interpretation of modeling and assessment results.
- Formulate and develop state-of-the-science process and component modules to serve as the fundamental building blocks within a flexible problem-solving environment.
- Resolve spatial and temporal mismatches in multiscale, multimedia modeling and provide tight integration of geospatial analysis and process simulation.
- Delineate efficient computational steps to meet increased demands of complex multifaceted models.
- Provide dynamic, intelligent human-computer-network interfaces to assist users in access and synthesis of environmental assessment information, including model specification and application, uncertainty/sensitivity analysis, and innovative visualization and multivariate analysis techniques to assist in user interpretation of assessment results.
- Link a full range of databases (ecological receptor effects, microenvironmental effects, activity patterns) and predictive forcing functions (socioeconomic, demographic, and climatic) to support problem-solving methodologies and tools.

Approach

The approach for developing MIMS should take advantage of rapidly improving computer software and computational calculations; ensure that a standardized, less duplicative, and more efficient assessment platform is provided to promote easy access for upgrading and for use by a broad range of environmental assessors and managers; and provide for flexibility in adapting to expanding exposure and risk assessment needs and emerging environmental management and remediation problems.

Software features of the Models-3 prototype will be expanded into the general MIMS framework, and developmental and upgraded media computational models will be incorporated. The process descriptions (i.e., transport, transformation, sources, and sinks algorithms), of these computational models will be upgraded in a phased manner based on application priorities and resource availability.

In addition to the long-term objectives previously discussed, short-term objectives for the development of MIMS, consistent with the model development needs to follow, include:

- develop broad conceptual models for hydrologic and nutrient cycles;
- review conceptual models and seek community assistance and participation to select elements for further development;
- conduct a multimedia, multistressor ecosystem exposure assessment case study on the Albemarle-Pamlico Watershed to provide a framework for development;
- draft and review coding guidelines for MIMS, with emphasis on code and data set integration;
- develop a data dictionary for data shared by the media-specific modules that we anticipate using in the ecosystem exposure assessment case study;
- refine land cover characterization data bases for use in the case study;
- facilitate rapid, phased integration of media/ component modules anticipated for use in the case study;
- initiate simple linkages with predictive meteorological and land use change models to be selected for the case study and incorporate socioeconomic drivers to the extent possible; and
- address spatial and temporal mismatches for those modules to be used in the case study.

Developing New Watershed Risk Assessment and Management Models: Part II

Rationale

The model framework, and the modules and models developed within it, will be focused initially on healthy and edible fin and shellfish, a socially valued endpoint. To that end, the framework will be applied for the purpose of improving the determination of total maximum daily loads (TMDLs) of pollutants that would not be harmful to streams, rivers, and estuaries.

The principal questions for this work in addressing the issue of the total inputs to streams, rivers and estuaries are:

- What is the collective impact of stressors on the health or condition of the aquatic biota?
- What is the relative contribution of each stressor (chemical, physical, and biological) to the condition of the resource?
- What is the relative contribution of each source (atmospheric, terrestrial, and aquatic in origin) for each stressor affecting the condition?
- Given these contributions, what alternative management options are available to achieve the local, regional, or national expectations for the system in question?

The process and modeling research of immediate interest is the improvement of nutrient and sedimentation modeling. Longer term efforts will deal with toxics, pesticides, pathogens, and metals. Research also needs to focus on watershed classification systems that will assist in adapting the models for regional application using the results obtained at single sites–this is an old but important debate. Finally, increased effort is needed to better understand the relationship among stressors, the biological response and the landscape, and how these findings will be incorporated into the future models.

The objectives of the watershed model development program are the following:

- Begin developing the conceptual model for predicting the effects of stressors on fisheries, including source-to-receptor considerations.

- Seek input on the model and identify the primary uncertainties that require concentrated research, by making it available to the scientific community.
- Begin to address the highest priority uncertainties.
- Conduct annual meetings to update progress and needs.
- Begin testing the model framework in multiple areas of the country to refine special conditions needed for application.
- Ensure that all aspects of development are appropriate for the flexible, but common, MIMS framework.

Obviously, we need more research on complex chemical and biological interactions, multimedia modeling at various spatial and temporal scales, grid structures for coupling processes and models, and actual coupling of models, to mention only a few.

The remainder of this paper discusses some of the research within EPA that supports improved watershed management and aquatic resource protection. It's purpose here is to provide an overview of what the Agency is now doing but more importantly, by omission, to provide some insight as to what EPA is not currently doing. How to ensure that all those that could, and want to, contribute to a common endpoint are able to do so is open for discussion.

Ongoing Research in EPA's Office of Research and Development

As noted above, the following is a brief summary of ongoing modeling and related research in ORD that will become elements of the future models or guide our thinking of where weaknesses exist.

Atmospheric Modeling Focus

Consistent with the need to develop a common modeling framework is the need to improve the exposure and effects models that will become part of the MIMS framework. One such model is the atmospheric exposure model, where the goal is to develop a state-of-the-science air quality modeling system that can handle multipollutant issues and cross-media interactions.

Atmospheric pollutant fate and transport research is concentrated on the Community Multiscale Air Quality (CMAQ) modeling system operating within the Models-3 framework. This platform provides an integrating mechanism for such research across EPA and the atmospheric modeling community at large. The initial version of Models-3 focuses on urban- to regional-scale air quality simulation of ground-level ozone, acid deposition, visibility, and fine particulate matter.

Atmospheric processes research focuses on the formation, chemistry, transport, and behavior of gases and aerosols in the atmosphere. Fundamental research in source apportionment, aerosol physics, and the chemistry and fate of particulate matter is also a priority. Pollutants of interest include ozone, nitrogen oxides, metals, and urban hazardous air pollutants.

The objectives of this research are to:

- Develop a state-of-the-science air quality modeling system that can address multipollutant issues.
- Provide advanced air quality modeling capabilities with the flexibility to operate across a spectrum of spatial scales, including regional, urban, and point sources.
- Provide a standard interface that facilitates interchange of science modules models.
- Identify the future for research into advanced science issues, multiscale interactions, mixed-and cross-media issues, and physical and chemical processes.
- Provide diagnostic evaluation and continuing modeling system development.
- Incorporate advanced approaches to sensitivity and uncertainty analysis.
- Couple meteorological models with chemical-transport models.
- Ensure that models can be extended to address anticipated air quality research modeling needs.

- Couple these models with terrestrial and aquatic exposure models in MIMS.

Aquatic and Terrestrial Exposure Modeling

The uncertainties associated with predicting terrestrial and aquatic ecosystem exposures and responses to pollutant stressors result from our inability to quantitatively characterize the processes that control stressors—their cycling, speciation, intermedia transfers, sorption, and transformation and degradation. These processes determine the ambient concentrations of pollutants and their transformation products to which ecosystem receptors are directly or indirectly exposed. They also determine the importance of pathogenic, chemical, microbial, toxic, oxidation-reduction potential, and sediment and nutrient status factors relative to general habitat suitability and overall risk characterization.

Some primary examples of chemical processes about which we are uncertain are:

- pathogenic bacteria and virus viability kinetics and partitioning,
- speciation and sorption of ionizable organic chemicals and metals,
- microbial transformation kinetics and pathways, particularly anaerobic transformation of hazardous chemicals,
- phytotransformation process kinetics and pathways,
- abiotic redox transformation process kinetics and pathways,
- terrestrial cycling, storage, and release of nitrogenous and carbonaceous greenhouse gases and nutrients, and
- sediment-mediated exposure to persistent bioaccumulative chemicals (EPA 1998c).

These uncertainties, when put in the context of multiscale watershed risk management models may or may not be important to achieving a watershed scale goal. That is the impact of landscape changes may overwhelm those resulting from the processes listed above. Therefore, a major goal in attempts to improve aquatic and terrestrial stressor exposure models must include the development and incorporation of physical descriptors necessary to define "suitable habitat" (such as temperature, sediment deposition and transport, riffles and pools, land forms and distribution, corridors, and edge-to-volume configurations). Understanding and then quantifying the importance of such descriptors requires a vigorous program to link geographic information system (GIS) technology to existing and developmental aquatic and terrestrial component exposure and effects models. A comprehensive evaluation and upgrade of the hydrologic, hydraulic, and sediment transport algorithms in component models, along with the pollutant transport and transformation process descriptions, will also be required.

Improving Effects Modeling

Use of the ecological risk assessment process as a foundation for environmental decision-making is currently limited by the science supporting the activities of problem formulation, analysis, and risk characterization (EPA 1998d). Improved knowledge of ecosystem processes will enhance effects modeling and reduce the scope of these limitations. Priorities for the necessary research include the following:

- Identifying scientifically credible assessment endpoints that accurately reflect management goals and societal values.
- Developing and applying measures of effects and ecosystem characteristics to adequately represent assessment endpoints.
- Understanding of ecological processes, mechanisms, and relationships that support development of stressor-response analyses and cause-and-effect relationships.

Evaluating the influence of multiple stressors requires selecting a suite of assessment endpoints that respond differently to different stressors so that cumulative effects can be evaluated and effects among different types of stressors can be evaluated. Multiple stressors may act at different spatial and temporal scales and levels of biological organization, requiring selection of an appropriate set of endpoints that captures both indirect and direct effects (EPA, 1998d).

The impetus for research to improve effects modeling is the need to understand processes and to develop models for determining the relationship between stressor levels and ecological change. Such relationships may be manifested at multiple spatial scales (ranging from regions to sub-organisms) requiring different approaches and techniques. The nature, extent, and type of stressor, along with the intended uses and applications of the information, influence the scale that is most appropriate to study. Current ORD research addresses the following topics:

Watershed and Regional Response Research—Research that addresses the responses of ecosystems to widespread and cumulative impacts of stressors such as regional air quality or land use practices.

This research is being conducted along the Atlantic coast and in the Gulf of Mexico, the Pacific Northwest, and the Great Lakes to determine the effects of land use on water quality (e.g., nutrients and sedimentation) and biological community structure. The goals of this research are to develop and evaluate functional watershed classification systems (e.g., Omernik and Gallant, 1988; Maxwell, et al., 1995; Poff and Allan, 1995), stressor thresholds (e.g., Hey and Wickenkamp, 1996), and diagnostic tools (EPA, 1998e) that can be incorporated into watershed decision-support systems.

Ecosystems Modeling—Research that addresses the responses of ecosystems to physical, chemical, and biological stressors as influenced by abiotic and biotic interactions.

Terrestrial, freshwater, and marine ecosystems are being studied to help define stressor-response relationships, develop techniques for extrapolating from effects on individuals to effects on ecosystems (e.g., Hogsett, et al., 1996), and construct models for predicting the responses of ecosystems to exposures defined by future exposure scenarios (e.g., Munns, et al., 1997). Ozone, ultraviolet radiation, nutrients, habitat alteration, and persistent bioaccumulative toxic chemicals (e.g., PCBs) are examples of the stressors being evaluated.

Collectively, the research efforts in the fields of watershed and regional response, ecosystems modeling, and also more traditional ecotoxicology are aimed at the development of biologically based dose-response models that can be used to link effects on species to stressors (e.g., Nichols et al., 1990; Mekenyan, et al., 1994). Dose-response models can be used as the foundation for predicting effects of chemical stressors across the broad range of species and ecosystems.

Integrating Exposure and Effects Modeling: A major challenge

Ensuring that the developmental exposure assessment framework has the appropriate linkages to ecological effects databases and models for all levels of biological organization is integral to its success. Required linkages include habitat suitability for terrestrial, surface water-sediment, and soil-subsurface environmental compartments to mention but a few. Equally important is characterizing the activity-ranging patterns and predator-prey interrelationships, which are needed for analyzing food-web exposure and impacts and assessing habitat suitability for key species and populations.

The specific objectives of this research are to:

- Develop state-of-the-science, tailored, linked, compartment, and multimedia exposure-risk assessment tools for use in community-based ecoprotection efforts and case studies, and assist in their field testing and application.

- Identify and establish appropriate links for general effects, databases and models, so that the developmental framework can address both pollutant and nonpollutant stressors, including habitat alteration and loss, climate change, and others.
- Ensure that socioeconomic drivers and climate change are accounted for, relative to predicted terrestrial and aquatic land use change and habitat alteration, within the framework.
- Develop and link a spatially distributed watershed response module for multimedia, multistressor ecological risk characterization, assessment, and restoration.
- Test the applicability of the modules for restoration design, watershed diagnosis, and regional ecosystem assessment and rule making.

Conclusions

In conclusion, we propose that the scientific community collectively work toward a common goal of developing the next generation of management models. To maximize benefits to the scientific community, environmental mangers, and those being managed, holistic models must be developed within a common framework that permits flexible use of alternative models and management strategies. Therefore, it is vital that we gain a holistic understanding of the physical, chemical, and biological functioning of watersheds at all scales. We must attend to the goal of sustaining healthy and edible fish, and, by our collective efforts, gain command of the tools that will help us achieve that goal. Hopefully, this paper will begin to stimulate more discussion and more research within the scientific community toward the development of the next generation of tools with direct applicability to the problems facing water quality managers today- tools that will allow the watershed manager to compare risks, and the expected reults of solutions, to maximize effectiveness and minimize costs.

References

Dennis, R.L., D.W. Byun, J.H. Novak, K.L. Galluppi, C.J. Coats, and M.A. Vouk. 1996. The next generation of integrated air quality modeling: EPA's Models-3. Atmospheric Environment 30:1925-1938.

EPA. 1998a. Ecological Research Strategy. EPA/ 600/R-98/086.

EPA. 1998b. Third-generation Air Quality Modeling System, Models-3. Volume 9b: User Manual.

EPA. 1998c. National Sediment Quality Survey. EPA 823-R-97-006.

EPA. 1998d. Guidelines for Ecological Risk Assessment. EPA 630-R-95-002F.

EPA. 1998e. Water Quality Criteria and Standards Plan. EPA 822-R-98-003.

Gallopoulous, E., E. Houstis, and J.R. Rice. 1994. Problem-solving environments for computational science. IEEE Computational Science and Engineering. Summer 11-23.

Hey, D.L., and J. A. Wickenkamp. 1996. Some hydrologic effects of wetlands in nine watersheds of southeastern Wisconsin. Great Lakes Wetlands 7:4-9.

Hogsett, W.E., A.A. Herstrom, J.A. Laurence, E.H.Lee, J.E. Weber, and D.T. Tingey. 1996. An approach for characterizing tropospheric ozone risk to forests. Environmental Management 20:1-17.

Maxwell, J.R., D.J. Edwards, M.E. Jensen, S.J. Paustian, H. Parrott, and D.M. Hill. 1995. A Hierarchical Framework of Aquatic Ecological Units in North America (Nearctic Zone). USDA Forest Service, North-Central Forest Experiment Station, General Technical Report NC-176.

Mekenyan, O.G., J.M. Ivanov, G.D. Veith, and S.P. Bradbury. 1994. Dynamic QSAR: A new search for active conformations and significant stereoelectronic indices. Quantitative Structure Activity Relationships 13:302-307.

Munns, W.R., Jr., D.E. Black, T.R. Gleason, K. Salomon, D. Bengston, and R. Gutjahr-Gobell. 1997. Evaluation of the effects of dioxin and PCBs on *Fundulus heteroclitus* populations using a modeling approach. Environmental Toxicology and Chemistry 16:1074-1081.

Nichols, J.W., J.M. McKim, M.E. Anderson, M.L.

Gargas, H.J. Clewell III, and R. J. Erickson. 1990. A physiologically based toxicokinetic model for the uptake and disposition of waterborne organic chemicals in fish. Toxicological and Applied Pharmacology 106:433-447.

Omernik, J.M., and A.L. Gallant. 1988. Ecoregions of the upper Midwest states. U.S. Environmental Protection Agency. EPA/600/3-88/037.

Poff, H.L., and J.D. Allan. 1995. Functional organization of stream fish assemblages in relation to hydrological variability. Ecology 76:606-627.

President's Address

The future is upon us.

The imminent arrival of the new millennium, whether one considers that to be the year 2000 or 2001, is a wellspring of "hooks" for columns like this. One can talk about the Y2K bug -- but I won't. Or one can talk about future directions, bridges to the future, etc. -- which I will.

One of ISEM's missions is to promote simulation modelling in ecology and natural resource management. I think it fair to say that this particular "battle" has largely been won. Simulation is widely used in both research and management circumstances. There is little, if any, serious debate about *whether* simulation models should be used, only entirely appropriate discussion of *which* models and *how* they should be used. Indeed the acceptance of simulation models has reached the point where their use is in some ways analogous to statistics and statistical tools. Most users of statistics in ecology and natural resource management feel no need to identify themselves as statisticians or to belong to statistical societies. The same can be said of many users of simulation models. ISEM can justifiably be proud of the role we have played in, ironically, promoting simulation to the point where it is increasingly viewed as "just" another tool. A tool that is used, along with others, to address questions within the environmental disciplines with which the user does identify.

Which is not to say that our job is over. Far from it. ISEM will continue to promote simulation in ecology and natural resource management. But with our success in the acceptance of simulation models and modelling we can now turn more of our attention, efforts, and energy to other issues. I believe that ISEM should consider the following as part of our refocused mission for the 21st Century.

1. Systems Analysis. The ISEM mission statement says that ISEM "promotes the international exchange of ideas, scientific results, and general knowledge in the area of the application of systems analysis and simulation in ecology and natural resource management." I agree with those of our membership who feel that application of systems analysis and a systems perspective has not kept apace with the appreciation and acceptance of simulation modelling. And I believe that ecology and natural resource management is the weaker for it. ISEM should redouble its efforts to promote the value of a systems perspective and the methods of systems analysis in environmental science and management. One of the goals of ISEM's Standing Committee on Education and Outreach is to promote the use of a systems approach and systems analysis in undergraduate education. Promotion of the systems approach can of course be applied at all levels of education and practice. Many of our members have long been involved in workshops that promote and teach a systems approach. We should be active supporters of these activities, and we can all become more vocal and visible advocates for systems analysis and a systems approach to ecological research and natural resource management.

2. Model Documentation. Good model

documentation serves a variety of purposes, not the least of which is clarity of communication. In addition: (A) It provides a resource for future model development. Successful concepts, functional forms, algorithms, and computer code can be efficiently accessed and incorporated into new models or revisions of existing models. (B) Standards of model documentation can also aid model development by providing a formal symbolic language with which to describe the conceptualization of the system before committing the concept to computer code. The formalism should clarify concepts, aid in model intercomparisons, and improve the translation of the concepts to mathematical forms and source code. (C) As models continue to play a larger role in the formulation and implementation of environmental policy and natural resource management, it becomes increasingly important that model documentation can withstand the adversarial scrutiny of legal and quasi-legal proceedings. Documentation that can "hold up in court" is likely to be an increasingly important part of using simulation modeling in natural resource management. Several activities are underway within ISEM, or in association with ISEM, that address model documentation. I refer you to the Perspectives columns by J. Benz et al. in the December 1997 issue of ECOMOD and by H. T. Odum in the December 1998 issue of ECOMOD, and also the University of Kassel's ECOBAS Web site at http://dino.wiz.uni-kassel.de/ecobas/ecobas.html. ISEM should become a leader in establishing the appropriate standards and mechanisms for model documentation.

3. Model Testing. As Ed Rykiel pointed out in his article on testing ecological models (Ecological Modelling 90 [1996] 229-244), model validation "is a thorny issue for both ecological model builders and model users." The debate over concepts and definitions of model verification, model validation, etc. is a long and continuing one. ISEM, as individuals and as a professional society should participate in these discussions, perhaps to the point of taking a leadership role in establishing conventions and standards for model validation. We should do more to promote the development and *use* of formal, quantitative methods for evaluating model performance. I do not think we can continue to be "satisfied" with simple time-series plots of data versus model output where too often a "match" is, like beauty, in the eye of the beholder. There are better, more informative methods of evaluating model performance. We should promote their use and encourage the development of new and improved methods where they are needed.

4. Error and Uncertainty Analysis. With the possible exception of a few universal constants (e.g., the speed of light) and the like, the inputs to ecological simulation models all have error and uncertainty associated with them. The ecological data required by our models is often highly uncertain. Consequently, the results of our simulations are uncertain and are best represented as a distribution of model outcomes. A variety of good methods exist for the analysis of model sensitivity, error, and uncertainty. Some of these methods are well developed (e.g., parameter sensitivity), others need to be developed further (e.g., uncertainty analysis of georeferenced, spatially-explicit models). I think as a community, and as a professional organization, we have been somewhat remiss in not placing greater emphasis on sensitivity and error/uncertainty analysis as a normal part of ecological modelling. I believe ISEM should be more aggressive in promoting error and uncertainty analysis and in establishing conventions for including these analyses in model documentation and in reporting model results. With some hyperbole, I look forward to the day where model results are always presented as a distribution of values rather than as single values.

5. Computational Ecology. Advances in computational technology, both hardware and software, have recently fostered the evolution

of new subdisciplines in the natural sciences. Computational physics and computational biology are good examples. These disciplines are involved in much more than just fast solutions to old questions. They are working toward answers to questions that simply could not be answered before the arrival of the enabling computational technology. Moreover, they are generating questions and hypothesis that previously could hardly be imagined, much less proposed with the expectation of obtaining an answer. I suspect that ecology is posed on the brink of a similar evolution, the emergence of computational ecology. Large-scale, high resolution spatially explicit models and individual-based models of large populations and communities are leading the way. ISEM should be in the forefront of this evolution, fostering the emergence of computational ecology.

I believe these topics should become part of ISEM's mission, or in the case of systems analysis be the target of renewed efforts. But how do we as a Society best accomplish this? At least some of the systems analysis and model documentation issues are being addressed by newly formed Standing Committees within ISEM. As noted above, the Standing Committee on Education and Outreach is addressing training in systems analysis. A subcommittee within the Standing Committee on the World Wide Web and Electronic Media is addressing model documentation. Perhaps we need additional committees charged to address the other issues, a Standing Committee on Computational Ecology, for example. Alternatively, we might establish Sections within the Society that are focused on these areas, a Model Validation Section, for example. I welcome your suggestions on how we might best focus ISEM efforts on these mission targets as we approach the next century and new millennium.

I suspect, indeed hope, that some of the opinions I have expressed here will be controversial and stimulate discussion and debate. I encourage you to respond, pro and con, in Letters to the President or Letters to the Editor that will be published in future issues of ECOMOD. Now. I wonder if C programmers will celebrate the new millennium in 2000 while the FORTRAN programmers celebrate in 2001?

Tony King
President ISEM

Note from the Secretary-General

For a brief time, Elsevier handled the invoicing of our membership dues. This procedure was not very efficient, and as of now we are back to collecting our dues directly. Thus, we have the same system in place as before - with one exception: Invoicing for *Ecological Modelling* will be handled directly by Elsevier. Please follow the procedure for membership renewal as described on our website. We are currently testing a new website, and by linking with a commercial provider, we will be able to handle monetary transactions. If indeed we can be implement our own efficient dues collection system over this year, then we will issue those members who also want to subscribe to Ecological Modelling a voucher with which they can claim the discounts we negotiated with Elsevier.

The membership may (rightly so) ask if it is not time solve these logistic problems once and forever. However, please keep in mind that all our activities are voluntary, and we are all faced with time constraints.

Several members have expressed an interest in participating in the editorship of ECOMOD and/or become Editor in Chief. This opens the exciting possibility of establishing regional editors who could collect and prepare contributions within regions, to be coordinated by the Editor in Chief. We have tried hard over the last years to establish more diversity in the contributions to ECOMOD; however, with editors physically located in different parts of the world, this effort will be much facilitated and ECOMOD will gain in quality.

Hopefully, we can get the new editors assembled within the next few months.

Membership continues to grow, and the new members come from many different countries around the world. The level of membership involvement has improved, but we need more input and participation from you. Tell us what ISEM should do to improve its services; tell us your concerns.

One of the biggest concerns I have is the organization of regional membership chapters. We have heard from colleagues in Japan and Italy that such efforts are under way; the most pressing need, however, is the organization of the South-American Chapter. We have now a good number of members in South-American countries. Many South-American scientists have an internationally renowned standing in ecological modeling; we must give this potential a structure and a face. We will contact our South-American members soon with the intent to assist in the formation of a chapter. Please help us in this effort! ISEM must grow, but it must also grow together.

The following colleagues joined us since last ECOMOD:

Magdiel Ablan, Venezuela
Jon Anderson, USA
Nixon Bahamon, Spain
Mark Brush, USA
R. Bun, Ukraine
Richard Busing, USA
Graciela Caniani, Argentina
Ronghua Chen, USA
M. Claasse, South-Africa
Karl Didier, USA
Bertil Hägerhäll, Sweden
Jan H. Hanse, Netherlands
C. Lancelot, Belgium
Paul H. Lord, USA
Daniel Mailly, Canada
Sara Moola, USA
Soeren Nors Nielsen, Denmark
Won Park, USA
José Paruelo, Argentina
William Porter, USA
Almeida A. Sitoe, Costa Rica
Donald E. Weller, USA
Tristram O. West, USA
Georg Wohlfahrt, Austria
Jia Long Xie, USA

Welcome to ISEM, and thanks for joining ISEM, a growing international community. We are looking for forward to meeting you in person at our next conference.

Wolfgang Pittroff
Secretary-General ISEM

Book Review

❄ *Mathematical Methods for Oceanographers is, Review of 3D Geoscience Modelling: Computer techniques for Geological Characterization.* SIMON HOULDING Simon Houlding, ISBN-3-540-58015-8, Springer-Verlag, DM148, 1994

Techniques which make use of the ever increasing capabilities of computer graphics have found their place in the repertoire of most researchers who have the need to display information with more than two dimensions.
Geologists have some very particular requirements from computer graphics software. Sampling is invariably irregular in three dimensions and the data available are discrete samples of a discontinuous body. The assumption which can be applied in the atmosphere and ocean that the concentration of materials can, to a first order, be interpolated between sample points is not applicable to the study of the solid earth. The three dimensional structure of the Earth's crust is not immediately obvious to an observer and this makes the use of three dimensional computer graphics even more valuable. As the author notes in the introduction, the text is about techniques for creating computer representations of a complex environment. It is not a text about computer models in the

sense of mathematical models of the behaviour of a physical system; rather, it is about models which are used for geological interpretation, geostatistical prediction and graphical visualization of inaccessible geological conditions from limite information. The material is addressed at a level which would make it suitable for a final year course in computer-aided geological interpretation or as a primer for new graduates. The book is split into two parts. Part I discusses the details of computer techniques and the geology-specific aspects of data structures, analysis and statistical prediction techniques.

Part II deals with applications of these techniques in the geosciences. The book is not mathematically complex (there are very few equations at all) and there are no recipes or programs which the user might apply to replicate some of the techniques illustrated. The breadth of the area covered in the book precludes any detailed treatment of any one component and the reader is left with a general overview of the topic. The interested reader can follow up further by using the bibliography at the back of the book. The bibliography is not detailed, but should provide the reader with a useful path into the relevant literature. Part II of the book is a series of example projects with which the author illustrates the applications of the techniques discussed in Part I to a range of problems such as prediction of mineral grades, modelling of groundwater reservoir structure, geotechnical characterization and underground mine planning. The book is a fine description of a range of applications which are often negleted in conventional computer graphics literature. It is well illustrated with many colour prints and will form a valuable part of the evolving literature on environmental computing.

Kendal McGuffie
Department of Applied Physics
University of Technology, Sydney

❄ *Review of "Frontiers of population ecology"*, edited by R. B. Floyd, A. W. Sheppard and P. J. De Barro, CSIRO Publishing, 1996, 639pp.

Population ecology is the study of the interactions that determine the distribution and abundance of natural, exploited and managed populations. A. J. Nicholson (1895-1969) has made fundamental and lasting contributions to theoretical population ecology and is recognised as one of the leading ecologists of this century. In April 1995, the Nicholson Centenary Conference held in Canberra brought together two hundred ecologists to celebrate the centenary of the birth of A. J. Nicholson. The purpose of this meeting was to generate debate on a range of key issues in theoretical and experimental population ecology and population management. This book represents a selection of essays from presentations at that conference.

A. J. Nicholson's life and achievements are eloquently presented in the first two chapters of the book. A. J. Nicholson's underlying motivation to develop a theory of population regulation was to answer some questions raised in evolutionary ecology. A. J. Nicholson's view was that the effects of natural selection on species survival could only be understood in the light of knowledge about mechanisms of population regulation. The principal feature of his theory is that populations are governed by density-dependent causes, especially by competition. His seminal work on population ecology has considerably influenced the ecologists and generated widespread debate. The diversity of opinions resulting from this debate is well expressed in chapters contained in this book. The book is organised in five distinct sections. The first section focuses on population regulation and on the density dependent factors which control population distribution and abundance. This section offers a selection of theoretical and empirical

studies in which the strengths and weaknesses of the current state of research in population regulation are highlighted. The second section examines the effects of interactions between species on the dynamics of population. This section contains discussion about the predator/ prey and parasite/host interactions and the role of mutualisms on population dynamics. The importance of spatial scale processes in population dynamics are discussed in the third section. Various mathematical and analytical modelling approaches to study the effects of spatial patterns and spatial processes in population ecology are presented. The fourth section reviews the potential of molecular techniques in the study of population ecology, and demonstrates, though a number of specifc examples, that the tools of so-called "molecular ecology" can be an effective complement to traditional field studies. Finally, the last section focuses on population management and discusses the utility of the theory and tools of population ecology when applied to the management of plant and animal populations.
This book represents without doubt a comprehensive review of the current state of research in population ecology. The numerous chapters of this book cover a wide range of themes: discussions about ecological theory and experimental techniques, presentation of several case studies dealing with a large range of organisms, description of new technologies and modelling approaches, reflections about the impact of population ecology on decision-making and society. As sought by the editors of the book, a balance between theoretical and empirical contributions is achieved.

The two introduction chapters describing A. J. Nicholson's life and legacy and the review chapters are clearly written. The book is, overall, well organised, each section contains an introduction and each chapter an abstract, allowing easy access to information. Perhaps two minor criticisms are that there is no glossary of terms, and the index is rather incomplete. Although most parts of the book are clearly aimed at the specialist, the book could also be used as a good introductory manual by anyone who wants to learn about the history, the recent advances and the future evolution of population ecology.

Cathy Ciret
Centre for Environmental Modelling and Prediction
University of New South Wales, Australia.

Note from the Editor.

The article “Standardization of model documentation part II: Usage of the ECOBAS model documentation system - a short introductory manual” by Gabele, Benz and Hoch will be in next issue of ECOMOD. Sorry for the inconvenience that this may cause.
We will also provide details about our next meeting in Spokane, WA, in August.

Ellen Pedersen
Editor ECOMOD

Publication Information

ECOMOD - Newsletter of the International Society for Ecological Modelling is published four times per year. Subscription is included with annual membership dues. Submissions by members and nonmembers of news items, articles, reviews (books, software), comments, and suggestions are welcomed. If possible, submissions over one-hundred words in length should be E-mailed or submitted in Microsoft Word for Windows format on 3.5" high density diskettes. All submissions are subject to editing prior to publication. Signed articles are the opinions of the authors and are not necessarily those of ISEM. ECOMOD articles may be reproduced without permission, but must be accompanied by acknowledgment of the source. ECOMOD is published simultaneously on the Internet: http://ecomod.tamu.edu/ecomod/isem.html. FTP site for paper submission is: ecomod.tamu.edu (anonymous FTP). FTP submissions must be accompanied by e-mail notifcation.

EDITORS:
Ellen K. Pedersen
Wolfgang Pittroff (assoc.)
P. Fred Dahm (assoc.)

ECOMOD c/o Ellen K. Pedersen, US Sheep Experiment Station, HC 62 Box 2010, Dubois ID 83423, USA
Phone: +1 (208) 374-5310
Fax: +1 (208) 374-5582
Internet: ellen@stat.tamu.edu

Submission deadline for next ECOMOD:
May 10, 1999

Please
Place
Stamp
Here

ECOMOD
c/Ellen Pedersen
US Sheep Experiment Station
HC 62 Box 2010
Dubois ID 83423
USA

1999 INTERNATIONAL SOCIETY FOR ECOLOGICAL MODELLING

NAME:
DEPARTMENT:
INSTITUTION:
CITY, STATE/PROVINCE, ZIP:
ELECTRONIC MAIL ADDRESS:

ISEM Membership
Student and Associate members receive ISEM newsletters and discounts on books, software and meeting fees. Full members receive these benefits and a year's subscription to *Ecological Modelling*.

Student Members:	$10.
Regular Members:	$20.
Student Member & Ecological Modelling:	$196.
Regular Member & Ecological Modelling:	$206.
Institutional Membership:	$100.

Payment Enclosed______________________________

Send payment in U.S. funds to:
ISEM c/o Wolfgang Pittroff, Secretary-General
US Sheep Experiment Station, HC 62 Box 2010, Dubois ID 83423, USA
Phone: 208-374-5306, **Fax:** 208-374-5582
Email: wolfgang@stat.tamu.edu