Approaches to Large-scale Ecosystem Modeling Across Multiple Trophic Levels: Some Early Lessons from the South Florida ATLSS Experience

Final version 8/8/97

L. J. Gross
The Institute for Environmental Modeling and Departments of Ecology and Evolutionary Biology and Mathematics, University of Tennessee, Knoxville, TN 37996-1610
D. L. DeAngelis
Biological Resources Division, U.S. Geological Survey, South Florida Field Unit, Department of Biology, University of Miami, Coral Gables, FL 33124
M. A. Huston
The Institute for Environmental Modeling and Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN 37996-1610 and Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

Introduction:

The Everglades region of South Florida offers one of the most complex challenges to natural system management we face in the U.S. The region has been greatly affected by many years of active human intervention to control the dominant environmental factor driving the system (water), with tremendous expenditures on a variety of canals, locks and structures to drain certain portions of the system and control flooding. The effects of this intervention on natural components of the system have been extensive, including major declines in many species populations, greatly enhanced fluxes of certain nutrients, changes in plant community composition, and the release of high levels of toxicants including mercury. The complexity of hydrologic management of the system is enhanced by the mixture of agricultural demands, urban requirements from extensive human population growth, and calls for action by people concerned about further environmental degradation of the system. For details on the system and its history see Davis and Ogden (1994).

The development of plans to restore the Everglades ecosystem to something closer to the natural system is ongoing, with significant expenditures for physical modifications being planned over the next several decades. As part of an effort to analyze the potential impacts of alternative restoration scenarios on the biotic systems of South Florida, a modeling project referred to as the Across-Trophic-Level System Simulation (ATLSS) has been ongoing with funding support from several government agencies (Fleming et al., 1994; USGS, 1997). The Home Page for ATLSS is at
http://www.tiem.utk.edu/~gross/atlss_www/atlss_frame.html.

Multimodeling and other approaches:

The Everglades ecosystem is characterized by complex patterns of spatial heterogeneity and temporal variability, with water flow being the major factor controlling the trophic dynamics of the system. ATLSS uses a multimodeling approach, coupling compartment models for lower trophic levels, structured population/community models for intermediate trophic levels, and individual-based models for higher-level consumers. These are coupled in a spatially-explicit manner through interactions on appropriate geographic information systems (GIS) maps, with some of the map layers derived from or directly affected by various model components. The approach allows for direct use of both abiotic and biotic condition data, accounting for the spatial and temporal variability in these. A key objective of modeling studies for South Florida is to compare and evaluate the future effects of alternative hydrologic scenarios on the biodiversity of the system, and to provide a rational basis to prioritize monitoring activities for long-term adaptive management.

The objective of multimodeling is to utilize a mixture of modeling approaches which each take account of the relevant spatial, temporal, and organismal resolutions necessary to address the questions for which the overall model is being developed. In ATLSS, there is an association of the model types with different types of species or functional groups of species in the ecosystem that have different-sized "ecological neighborhoods", defined by Addicott et al. (1987) as "the region within which that organism is active or has some influence during an appropriate period of time". The compartment models deal with variables representing spatially localized biota, mainly the biomasses of lower trophic levels such as periphyton. These biomass variables only interact locally. Therefore, one can represent these variables across a landscape by means of many local uncoupled spatial unit cell models, in which the cell size is chosen small enough to represent a tract relatively homogeneous in substrate and elevation, the linear resolution of which might be several tens of meters in a relatively flat landscape such as the Everglades. The age- and size-structured population and community models represent intermediate trophic levels, such as fish, macroinvertebrates, and small non-flying vertebrates. These may undergo short-distance movements in response to changes in water levels, so their ecological neighborhoods are larger, with a resolution perhaps on the order of up to a square kilometer, thus encompassing perhaps hundreds of unit cell models, coupled now to allow population movements. The individual-based models are employed to represent populations of top predators or other large-bodied species. Individuals of these species cover large areas of land and thus have large ecological neighborhoods. Their movements over short periods of time may span areas of tens of thousands of spatial unit cells.

The ATLSS approach therefore links a variety of modeling methodologies, each of which has been found to be an appropriate means to mimic system components in many other studies. Thus, the approach offers the possibility to link together many of the methodologies presented at this Workshop, including matrix projections (Crowder), bioenergetics (Barber), metapopulation approaches (Akcakaya), continuous structured population approaches (Hallam), and individual-based approaches (Rose). Through a combination of approaches such as these with underlying projections of environmental factors (in the case of ATLSS this involves alternative future hydrologic scenarios), multimodeling offers a methodology for ecological risk assessment (Ginzburg), and uncertainty analysis (Bartell) which takes account of the detailed spatial and temporal interactions between biotic and abiotic factors in a natural system. It also offers the capability through it's modular view of the system to include, when feasible, other detailed modeling efforts such as the Everglades Landscape Model (Fitz et al., 1996), which focuses on nutrient fluxes in the system.

Although carrying out a detailed multimodeling analysis is data-intensive and time-consuming, many of the environmental management problems faced by agencies such as the Corps of Engineers involve complex situations over large spatial regions. For these problems, simplified approaches such as Habitat Evaluation Procedures (HEP) and Hydrogeomorphic (HGM) assessment (Brinson, 1996), which were really designed for relatively quick analysis of small spatial domain problems for regulatory purposes, are inappropriate. One potential use of multimodeling approaches however will be to lead to more appropriate macrodescriptors of wetland systems, and in this way both provide the details on reference systems that are an inherent part of the HGM methodology (Brinson and Rheinhardt, 1996), as well as indicate under what circumstances HEP approaches, which ignore the underlying demographics and dynamics of system components, may have sufficiently small errors to be useful.

Some Lessons from the ATLSS Experience to Date:

The ATLSS project has involved a wide variety of individuals from government agencies (both U.S. and non-U.S.), academia, and private firms. Over the relatively short span of it's existence (the initial funding of what eventually became part of the ATLSS project was in 1991), the main funding agency has changed three times (from the National Park Service, to the National Biological Survey, to the USGS). Involving as it does a highly contentious region, agencies and stakeholders with greatly varying agendas, and individuals from a very diverse set of scientific backgrounds, we thought it would be appropriate to summarize our impressions of key take-home messages from the project to date. These are not meant to focus on the scientific aspects of the project, but more on our impressions of how to carry out a successful multimodeling project of this type. The below are not ranked in any particular priority order, though we have placed those dealing more with the modeling aspects first.

Work closely with those with long experience in the system being modeled and use their experience to determine key species, guild and trophic functional groups on which to focus. As with any model, there are parts of the system which will be investigated in more detail than others. We have fostered close relationships with individuals who are very knowledgable from their own fieldwork about detailed components of the system, and encouraged them to become part of the various modeling teams.

Moderate the above based first on the availability of data to construct reasonable models, and secondly on the difficulty of constructing and calibrating the models. In deciding what components to include, not only is it necessary to have an appropriate set of data, but due to both staff, time and computational constraints, a more simplified approach than might initially be viewed as feasible could be appropriate.

Don't try to do it all at once - start small - but have a long-term plan for what you wish to include overall, given time and funding. This allows you to quickly get some results for funding agencies, but at the same time provide a clear vision as to what you would accomplish with further support.

Leave room for multiple approaches: don't limit your options. Accept the fact that other approaches will be taken and accept that for some purposes these other approaches may add significantly to the overall effort.

In the face of limited or inappropriate data, use this as an opportunity to encourage further empirical investigations of key components of the system. As one example of this, due to initial efforts to carry out an alligator model, a study of food habits of South Florida alligators was needed. Although the assumption had been made that fish are a major prey of gators, the study found that fish make up a relatively minor proportion of the diet.

Build flexibility in as much as possible. This is to account for the possibility of different funding levels through time, the various needs of different funding agencies, and the potential for changing the criteria of success due to these factors.

Be flexible about what counts as success - e.g. don't expect the world to suddenly take your view. Be willing to adjust your efforts regularly to meet short term needs of stakeholders, but maintain an overall vision for longer-term project goals.

Be persistent, and have at least one member of the team who is totally dedicated to the project and willing to stake their future on it. Major projects such as ATLSS have the potential to simply fall by the wayside in funding decisions without a regular supporter willing to argue for support. This is particularly true for the long-term scientific aspects of the project, which may be considered of secondary interest to funding agencies more concerned with short-term management of natural systems.

Do whatever you can to maintain continuity in the source of long-term support for the project. Associated with this is the need to maintain continuity in key technical staff associated with the project, since no matter how well documented a programmer's code is, there is inefficiency associated with staff turnover.

Build a quality team who respect each others abilities and won't second guess each other, but who accept criticism in a collegial manner. This is also important for publication aspects of the project, plans for which should be part of regular project meetings, with agreements on authorship clearly specified and agreed to by all involved.

Keep some part of the team out of the day-to-day political fray. The regular infighting that is typical of contentious public-policy projects can be very distracting to team members who do not need to be actively involved in responses on such matters to various agencies. Protecting team members from such distractions can greatly increase the overall efficiency of the project.

Constantly communicate with stakeholders - set up a liasson with a critical representative of each stakeholder.

Don't limit your approach because one stakeholder/funding agency wants you to - maintain the highest scientific standards you can and be honest about the limitations of your approach.

Be prepared for criticism based upon non-scientific criteria, including personal attacks.

Ignore any of the stakeholders at your peril.

Acknowledgements: This document was accomplished with the assistance of the U.S. Geological Survey, Biological Resources Division. The statements, findings, conclusions, recommendations, and other data in this report are solely those of the authors and do not necessarily reflect the views of the U.S. Geological Survey.

References:
Addicott, J. F., J. M. Aho, M. F. Antolin, D. K. Padilla, J. S. Richardson, and D. A. Soluk. 1987. Ecological neighborhoods: scaling environmental patterns. Oikos **49**:340-346.

Brinson, M. M. 1996. The HGM approach explained. National Wetlands Newsletter **17**:7-13.

Brinson, M. M. and R. D. Rheinhardt. 1996. The role of reference wetland in functional asessment and mitigation. Ecological Applications **16**:69-76.

Davis, S. M. amd J. C. Ogden. 1994. Everglades: the system and its restoration. St. Lucie Press, Delray Beach, Florida, USA.

Fitz, H. C., E. B. DeBellevue, R. Costanza, R. Boumans, T. Maxwell, L. Wainger and F. H. Sklar. 1996. Development of a general ecosystem model for a range of scales and ecosystems. Ecological Modelling **88:**263-295.

Fleming, D. M., D. L. DeAngelis, L. J. Gross, R. E. Ulanowicz, W. F. Wolff, W. F. Loftus, and M. A. Huston. 1994. ATLSS: Across-Trophic-Level System Simulation for the Freshwater Wetlands of the Everglades and Big Cypress Swamp. National Biological Service Technical Report. Available at http://www.tiem.utk.edu/~gross/atlss_www/atlss_frame.html

USGS, Biological Resources Division. 1997. ATLSS: Across-Trophic-Level System Simulation: An Approach to Analysis of South Florida Ecosystems. USGS Technical Report. Available at http://www.tiem.utk.edu/~gross/atlss_www/atlss_frame.html