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Ecosystem Managers Can Learn from Past Successes

Can ecosystem managers rely on mechanistic simulation models to guide their decisions? Regional ecosystem restoration efforts in the United States now resemble the large public works projects of past decades, with similar costs and requirements to foster broad public and political support. Because managers use simulation models to set priorities and regulate human activities, problems with implementing and maintaining these models can derail their best efforts.

If the models are perceived as unreliable, the public can reasonably question the validity of these decisions. When problems with the models persist, confidence erodes in the "science-based approach" that is widely touted as the solution to increasingly complex and politically charged environmental issues.

In recent months, ecosystem managers working in south Florida and the Chesapeake Bay were given notice that their highly detailed estuary models may not be performing as expected. In both cases, expert panels from outside of the regions delivered the bad news in the form of technical reviews.

For Florida Bay, a science oversight panel recommends halting a 4-year effort to implement a finite-element hydrodynamic model and advises water managers to consider using other modeling approaches. Another panel of experts, a scientific and technical advisory committee, has advised managers in the Chesapeake Bay Program that their water quality model is flawed and should not be used to make management decisions.

Thirty years ago, the failure in the implementation of detailed ecosystem models compromised the success of the International Biological Program (IBP) in the United States and dealt a setback to the young field of ecosystem ecology [Golley, 1993; Hagen, 1992]. If the lesson from the IBP failure applies to ecosystem management in Florida Bay and Chesapeake Bay today, then recent criticisms of the estuary models point to a flaw in the strategy to incorporate scientific information into management decisions. Fortunately, lessons from successful ecosystem studies of the same period illustrate an alternative strategy that has proven to be effective.

Models as Devices for Synthesis

Objectives for managing regional ecosystems present managers with the difficult task of assembling and synthesizing scientific knowledge over large geographic areas and across scientific disciplines. In both Florida Bay and Chesapeake Bay, managers depend on a hierarchical arrangement of numerical models as the central device for synthesizing knowledge. A detailed physical--that is, hydrodynamical--model of the estuary occupies the primary position in the hierarchy. Biogeochemistry is next, in the form of a water quality model that is coupled with, and entirely dependent upon, the hydrodynamic model.

The hierarchy of models continues up through primary production, the aquatic food web, and top-level consumers until the structure and function of the entire ecosystem is represented within the linked numerical models. Each component model and the sub-models of these components attempts a precise representation of the various intricate physical, chemical, and ecological processes that have been documented and described through painstaking research.

Assembly of these highly detailed, mechanistic models marries the knowledge of the scientist to the craft of the clockmaker. Decades ago, builders of the first estuarine models captured the fluctuations of the tides in whirring gears and spinning dials of meticulously constructed calculating machines. These clockwork devices allowed the user to forecast water levels months and years in advance by running the machinery forward in time.

Present-day numerical models that incorporate the internal mechanics of the ecosystem hold out a similar promise. By running these models forward in time, managers will be able to explore future ecological consequences of today's decisions. As with the earlier mechanical models, confidence that the numerical models faithfully reproduce the behavior of the ecosystem relies on the attention and care taken by the model builders in crafting and assembling the models' components.

Failure of the IBP Grasslands Project

Between 1967 and 1976, the United States spent $57 million on its contribution to the International Biological Program [Golley, 1993]. This was an unprecedented level of investment in ecosystem science. Consequently, the IBP in the United States was conceived as the proving ground for a new approach to ecosystem research, one that could organize large teams in a coordinated attack on problems of great complexity. A similar approach had been used in earlier studies, but in the IBP, it would be applied for the first time on a large scale, similar to that of today's regional ecosystem restoration efforts.

The Grasslands Biome Project was the largest of several related projects in the United States that were each designed to study a broad type of ecosystem (that is, biome). An explicit goal of the project was to capture the detailed mechanics of the ecosystem in numerical models that could then be used by managers to understand and manage grassland ecosystems. The models produced by the grasslands project of the IBP failed to achieve their intended use for ecosystem management.

Golley [1993] attributes this failure to a basic contradiction in the research strategy. The goal from the outset was to study the ecosystem as a unit. However, investigators were distracted from this goal by the immediate attention given to cataloging the components of the grassland ecosystem and describing their interactions. In the view of grassland managers, the resulting models were overly complex and did not address management concerns. Neglected, the IBP grasslands models soon became obsolete as more novel modeling approaches and programming techniques caught the attention of researchers.

In the end, general application of numerical models that captured a highly detailed mechanistic description of the whole ecosystem proved to be an illusion [Hagen, 1992].

Success of the Whole-system Approach

Contemporaneous with the IBP, other ecosystem research was taking a different approach, one that ultimately proved more useful in guiding the response of ecosystem managers to regional-scale environmental problems. This approach is now referred to as either the "whole-system" [Golley, 1993], the "empirical," or the "predictive" approach [Peters, 1986]. At the time it was perhaps best illustrated by work on experimental watersheds at Hubbard Brook in New Hampshire. Results obtained from research there were instrumental in demonstrating the effects of acid rain on forests and in informing and motivating a management response to the problem [e.g., Kaiser, 2000].

Similarly, results from whole-system research on eutrophication at the Experimental Lakes Area, Ontario, Canada, provided the scientific evidence needed to justify a drastic reduction in phosphate discharges into the Great Lakes. In contrast to the IBP biome studies, research based on the whole-system approach succeeded in bringing critical scientific information to bear on environmental problems of the day.

The whole-system approach has been described as the application of "normal science" to the study of ecosystem behavior [Golley, 1993]. The ecosystem is regarded as a discrete object for study. Investigators first establish patterns of behavior from variations in observable attributes, such as, in the case of an estuary, salinity, chlorophyll concentration, species abundance, etc. These findings lead to questions about the origins of the observed behavior, which in turn may require that the ecosystem be dissected into subsystems. Then, new observations are attempted to describe and explain the behavior of these subsystems and their interactions.

In this way, investigators build an understanding of predictable patterns of ecosystem behavior by working inward from the whole. Relatively simple, empirically-based models are used to objectively test hypotheses about the factors that give rise to these patterns based on comparison against the observed behavior of the ecosystem; for example, through the analysis of variance [Peters, 1986]. In the whole-system approach, models are simply one tool, along with observation and experimentation, for understanding the ecosystem; they are not a primary goal for the research.

Lessons for Ecosystem Management

Are ecosystem managers for Florida Bay and Chesapeake Bay repeating the failure of the IBP grasslands project? Perhaps not. For one thing, we are now fully immersed in the types of systemic ecological problems that few people recognized 30 years ago. Where the IBP grasslands project sought to construct models that might eventually find use by managers, current modeling efforts are conducted as part of ongoing ecosystem management. Integration of modeling with ecosystem management activities decreases the chance for a mismatch between the needs and expectations of managers on one hand and the complexity and types of information provided by the models on the other.

The problems that ecosystem managers now face due to criticism of the models for Florida Bay and Chesapeake Bay are a direct consequence of relying on a tool--the model--that is constantly being refined and revised. Critical review is a normal, foreseeable part of this process. Ecosystem restoration efforts are vulnerable to the potential negative consequences for public support only as long as managers regard the mechanistic, numerical models as the primary tool for synthesizing scientific information and incorporating it into ecosystem management.

Ecosystem managers can reduce this vulnerability by relying on the other components of the whole-system approach, that is, by obtaining scientific information directly through observation and experimentation. Simple, empirically-based models serve here by identifying predictable patterns in ecosystem behavior. These models provide ways of synthesizing scientific information that complement the use of detailed mechanistic models.

Observation, experiment, and modeling together are the essential components of the whole-system approach. This approach has proven successful in synthesizing scientific information and guiding management's response to the complex problems of acid rain and eutrophication of lakes. The lessons of these 30-year-old success stories are relevant today.

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