Adaptive Integrated Framework (AIF): A New Methodology for Managing Impacts of Multiple Stressors in Coastal Ecosystems

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Overview

This research will calibrate an ensemble of ecosystem models using extensive historical data for Saginaw Bay, develop a watershed and hydrological model for the coastal ecosystem, and develop human dimensions models for evaluating resource outcomes and management plans. These efforts will be undertaken at differing scales of resolution to model and evaluate water quality, fish production and economic metrics that are of importance to management agencies and the public. The modeling efforts will use an iterative process in which modeling outputs will identify knowledge gaps (i.e., drive field and experimental research) and help management agencies identify management alternatives. The results and data needs (gaps) identified by the agencies will, in turn, lead to models being reparameterized, reapplied and reevaluated before the next iteration of management agency input and field research.

The proposed work recognizes the crucial need for developing models that are adaptable across ecological systems and multiple stressors as well as one that provides managers with a means to understand and manage stressor interactions unique to their system. The proposed five year project accomplishes these goals by coupling modeling, observational, and experimental studies with stakeholder workshops and socioeconomic analyses. The resulting AIF approach will be broadly applicable to evaluate the nation's coastal and estuarine ecosystems impacted by multiple stressors.

Objectives

- Increase number of regional coastal and marine ecosystems delineated with approved indicators of ecological health and socioeconomic benefits that are monitored and understood.
- Develop the Adaptive Integrative Framework (AIF) approach to facilitate synthesis and prioritization of research and management pertaining to multiple stressors impacts on coastal ecosystems.
- Provide specific predictions regarding how fish production, human health, and regional economics, respond to multiple stressors (i.e. land use, climate change and invasive species) in Saginaw Bay, MI.

Proposed Work

- Gather/evaluate relevant extant data
- Watershed modeling and sampling for model calibration
- Development/updating of ecosystem models
- Initial field survey (3 sample dates one in spring, summer, and fall) in Saginaw Bay

Scientific Rationale

The proposed research will use Saginaw Bay as a model system to develop, evaluate, and operationalize the Adaptive Integrated Framework. The Saginaw Bay ecosystem of the Great Lakes is a complex coastal ecosystem facing multiple stressors with a management regime similar to coastal ecosystems nationwide. The proposed management framework (AIF) including individual models, experimental protocols, and human dimension research will not only directly benefit the management of Saginaw Bay and the Great Lakes, but will also serve as a blueprint for the improved management and understanding of other coastal systems facing similar stressors and management issues.

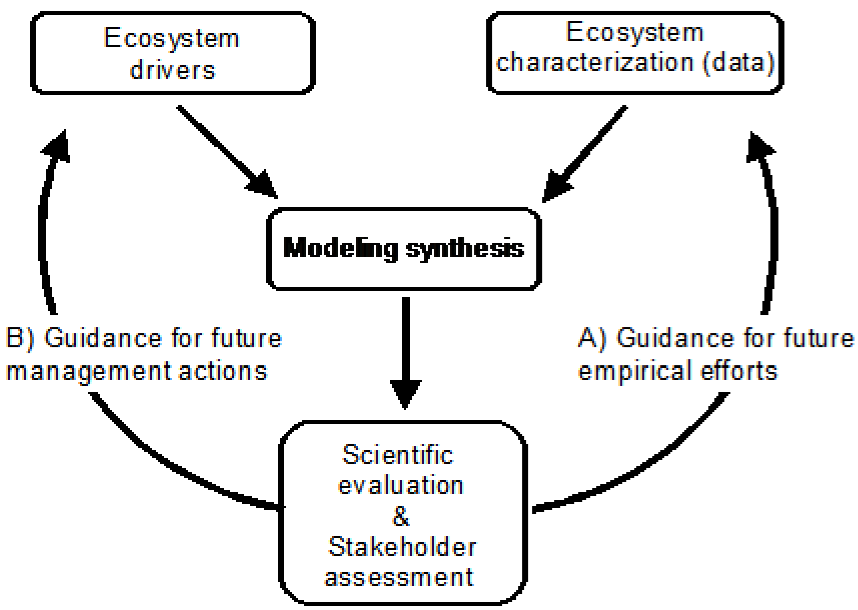

Figure 1. Conceptual diagram describing the Adaptive Integrative Framework (AIF) approach.

Adaptive Integrative Framework

The proposed Adaptive Integrative Framework (AIF) merges two well-regarded but heretofore separate natural resource management approaches–Adaptive Management (AM) and Integrated Assessment (IA). Both AM and IA have been heralded as worthwhile approaches for addressing uncertainty in natural resource management (e.g., NRC 2004; van der Sluijs 2002). AM is based on the tenet that management actions in ecosystems may be treated as ecosystem-scale experiments capable of generating new information for updating and improving management decisions (Holling 1978, Lee 1993). AM uses an iterative approach with continuous feedback between management actions and scientific understanding of observed changes. However, AM typically lacks a rigorous short-term framework for facilitating and interpreting such feedback, thereby confounding the true integration of scientific investigation and ecosystem management. Moreover, such integration is often complicated by divergent expectations and goals of multiple researchers and managers. That is, the information needs for management decision-making are often not novel and sometimes not attractive to researchers who are rewarded for innovative work that results in peer-reviewed publications, while the manager is judged on the fishery created, the issues managed, or the number of adversarial interactions with legislators or stakeholder groups. The successful integration of the interests of these two groups occurs when managers identify, prioritize, and articulate their information needs (relative to management endpoints) to researchers and when researchers incorporate those needs into novel research approaches. Therefore, modifying AM so that managers and researchers may both be engaged in a mutually beneficial process may allow for short-term assessment of specific environmental issues and long-term management of ecosystems.

Integrated Assessment typically involves a multi-step process for assessing the status of key ecosystem properties and characteristics; making and testing quantitative predictions (including an explicit assessment of uncertainty) of how ecosystems will respond to specific stressors; and developing technical guidance based upon such predictions (van der Sluijs 2002). IA is a timely, linear approach which facilitates the integration and analyses of diverse ecosystem data and subsequent communication with key stakeholders. Unfortunately, IA alone and its stepwise approach fails to provide a rigorous framework for data synthesis and analysis efforts to guide future data acquisition and adaptive management actions. Such feedback is critical to promote improved modeling and management integration (as suggested above), and facilitate and prioritize generation of relevant data. Unfortunately, in most cases development and parameterization of ecosystem models are based on ad hoc collections of data (i.e., data collected for some other purpose) which results in modeling syntheses that are linear processes--first, data collection and then modeling synthesis. One improvement of the proposed AIF will be the incorporation of adaptive process on IA so explicit uncertainty and sensitivity of model outputs can provide the basis for future monitoring and experimental efforts.

This multi-step process will:

1. use model-appropriate techniques (e.g., Monte Carlo techniques, error propagation analysis, qualitative uncertainty analysis) to consider the uncertainty associated with specific, management-relevant predictions;
2. identify model components with low confidence and high leverage for model predictions using qualitative and quantitative sensitivity and uncertainty analysis; and
3. compare and rank based upon defined criteria (e.g., match with a verification data set) the performance of individual models to identify a best model (or model averaging)

The results of these evaluations and assessments will feed back to guide future empirical efforts (A in Figure 1). In this case, key knowledge gaps and potential model improvement associated with new data acquisition are then considered in conjunction with the likely financial costs of obtaining information (i.e., a cost-benefit analysis to identify the empirical efforts with the most bang-for-the-buck). The results of these evaluations and assessments will feed back to guide management actions (B in Figure 1). In this case, using the most appropriate model (or average model), the projected ecosystem consequences of potential management actions are evaluated including assessing the impacts on stakeholders and the economy. These consequences are communicated to managers who in turn must make management decisions based upon both the best available ecosystem information (and model) and interacting socioeconomic factors. The subsequent iteration of the AIF incorporates new information and updates ecosystem drivers; leading to reparameterization (incl. potential restructuring), reapplication, and ultimately reevaluation of individual models.

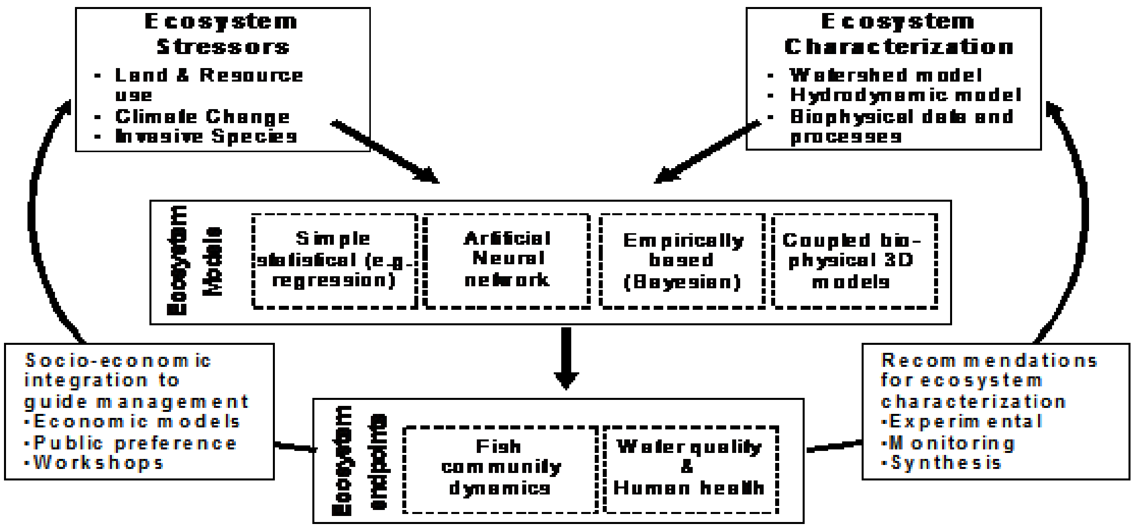

Figure 2. The Adaptive Integrated Framework (AIF) to study the response of the Saginaw Bay ecosystem to multiple stressors.

We will use the AIF approach as a basis for model development and application to understand and forecast the cumulative effects of multiple stressors (i.e., climate change, land use, and invasive species) on fish production, human health and economics of the Saginaw Bay ecosystem and surrounding region (Figure 2). This approach should prove particularly useful for multiple stressors as it provides the ability to integrate and organize complex data in a manner that can help inform management decisions. Although this project will focus on multiple stressors in Saginaw Bay, the outcome of this effort should provide an updated and improved adaptive management model for addressing stressors in other coastal ecosystems.

Our study will combine:

1. model integration and comparison,
2. management and scientific integration,
3. extensive existing data,
4. field monitoring,
5. manipulative experiments and
6. whole system (biophysical and human) evaluation

We will evaluate the effectiveness of existing management policies in Saginaw Bay and determine how this system is changing and responding to new stressors. In turn, our improved understanding of system behavior will facilitate our partnering management agencies (Michigan Departments of Environmental Quality and Natural Resources) to enhance policies, regulations, and laws pertinent to Fish Production, Human Health and Economics.

Relevance to Ecosystem Forecasting

This project will feature the update and parallel development of several ecosystem models. The existing model is a deterministic process-based model of moderate complexity – originally developed in the 1970s. This model will be updated to reflect new data and changes to the system. A newer model based on Bayesian principles will also be developed in as part of the project. This model will likely be coarser in scale than the existing model, but will include a full probabilistic uncertainty capability.