

# WHITE PAPER

## INTEGRATED ECOSYSTEM ASSESSMENTS

### Background

The NOAA 2005-2010 Strategic Plan highlights the importance of incorporating ecosystem principles in resource management. Specifically, a critical agency objective is to “Protect, Restore, and Manage the use of Coastal, Ocean, and Great Lakes resources through an Ecosystem Approach to Management (EAM)”. An ecosystem approach to management is one that provides a comprehensive framework for marine, coastal, and Great Lakes resource decision making. In contrast to individual species or single issue management, EAM considers a wider range of relevant ecological, environmental, and human factors bearing on societal choices regarding resource use and protection.

### What is an Integrated Ecosystem Assessment?

Integrated ecosystem assessments (IEAs) are a critical element of an EAM strategy. **An IEA is a formal synthesis and quantitative analysis of existing information on relevant natural and socio-economic factors in relation to specified ecosystem management objectives.** It involves and informs citizens, industry representatives, scientists, resource managers, and policy makers through formal processes to contribute to the goals of EAM.

IEAs begin with an identification of critical management and policy questions. IEAs use quantitative analyses and ecosystem modeling to integrate a range of social, economic, and natural science data and information to assess the condition of the ecosystem. IEAs also identify potential management options, and these are evaluated against EAM goals. IEAs are peer-reviewed and communicated to stakeholders, resource managers and policy makers. IEAs may be communicated in the form of a static document, but may also be a web-based dynamic document that are updated as new data become available. IEAs differ from other assessments like Environmental Impact Statements in that they explicitly consider all components of the ecosystem and address the broad goals of EAM.

An IEA consists of the following components:

- Identification of key management or policy questions
- Assessment of status and trends of the ecosystem condition
- Assessment of the environmental, social, and economic causes and consequences of these trends
- Forecast of ecosystem status under a range of policy and/or management actions
- Identification of crucial knowledge and data gaps that will guide future research and data acquisition efforts.

## Why IEAs?

Periodic assessment of biological, physical and socio-economic attributes of ecosystems allows for coordinated evaluations of national marine, coastal and Great Lakes ecosystems to promote their sustainability under a variety of human uses and environmental stresses. Moreover, IEAs involve and inform a wide variety of stakeholders and agencies that rely on science support. IEAs integrate knowledge and data collected by NOAA and other regional entities including other federal agencies, states, non-governmental organizations, and academic institutions. IEAs also identify critical knowledge and data gaps, which, if filled, will reduce uncertainty and improve our ability to fully employ ecosystem approaches to management.

## What is an ecosystem?

An ecosystem is defined by NOAA as:

*“An ecosystem is a geographically specified system of organisms (including humans), the environment, and the processes that control its dynamics.” NOAA further defines the environment as “The environment is the biological, chemical, physical, and social conditions that surround organisms. When appropriate, the term environment should be qualified as biological, chemical, and/or social.”*

## The importance of scale

IEAs must explicitly consider both spatial and temporal scales. Scales must be consistent with the ability to recognize and explain the most important drivers and threats to the ecosystem. Ecosystems typically do not have sharp boundaries; rather one ecosystem blends into another. As a consequence, ecosystem boundaries are human constructs, and a first step in any IEA endeavor must be to identify the spatial scale of the problem under consideration. The spatial scale of an IEA is a function of the ecology and oceanography of a region as well as the scale of management issues and governance structures. For example, while an IEA may focus on a small embayment, consideration of large-scale issues such as climatic variability as well as linkages to adjacent ecosystems is important. Additionally, IEAs must be cognizant of appropriate temporal scales. In particular, IEAs require attention to the temporal baseline against which current status is compared. For example, different conclusions may be drawn when comparing current ecosystem conditions to those of 25 years versus 75 years ago.

## Applying the IEA Concept

An IEA uses approaches that determine the probability that ecological or socio-economic properties of systems will move beyond acceptable limits as defined by management objectives. A useful IEA must provide an efficient, transparent means of summarizing the status of ecosystem components, screening and prioritizing potential risks, and evaluating alternative management strategies against a backdrop of environmental (e.g., climatic, oceanographic, seasonal) variability. An IEA provides a means of evaluating tradeoffs in management strategies among potentially competing ecosystem use sectors.

*A 5 step process for an Integrated Ecosystem Assessment*

Figure 1 illustrates a five step process that forms an IEA.

Step 1. A scoping process initiates the IEA. Scoping begins with a review of existing documents and information and concludes with stakeholder involvement to identify the management objectives, articulate the ecosystem to be assessed, identify ecosystem attributes of concern, and identify stressors relevant to the ecosystem being examined. While general EAM goals may be broad, a key component of an IEA is to move from broad goals to specific ecosystem objectives that management and policy need to consider.

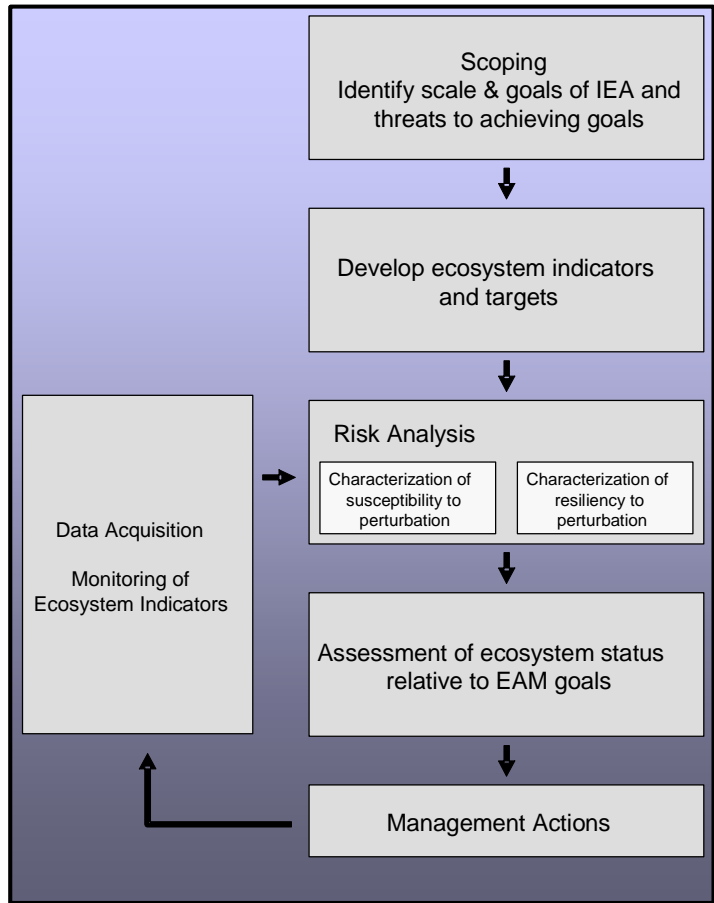


Figure 1. A 5 step process for an Integrated Ecosystem Assessment

Step 2. Following the scoping process, researchers must develop and test indicators that reflect the ecosystem attributes specified in the scoping process. Specific indicators are dictated by the problem at hand and must be linked objectively to decision criteria. In some cases, this simply means following the abundance of a single species (for instance in the case of an endangered species) or suites of species (e.g., coral reefs, harmful algal blooms). In other instances, the indicator may be a proxy for an ecosystem *attribute* we are interested in. For example, resiliency to perturbation might be an attribute and researchers may choose species diversity as one *indicator* of resiliency. For many problems, suites of indicators that span a wide range of processes (with different associated rates), biological groups, and indicator types (e.g., “early warning,” “integrated system state”) will be most useful. Importantly, this step allows us to identify indicators that we should be monitoring even when current monitoring efforts are insufficient.

Step 3. Once indicators are chosen, an analysis that evaluates the risk to the indicators posed by human activities and natural processes is performed. This analysis is hierarchical in approach and moves from a comprehensive, but qualitative analysis initially, through a more focused and semi-quantitative approach, and finally to a highly focused and fully quantitative approach. This step initially screens out many potential risks, so that more intensive and quantitative analyses are limited to a subset of

ecosystem indicators and human or natural threats. The goal of these risk analyses is to fully explore the susceptibility of an indicator to natural or human threats as well as the ability of the indicator to return to its previous state after being perturbed. A full discussion of ecological risk analysis as it pertains to marine ecosystems can be found in Hobday et al. (2006).

The state of an ecosystem can be viewed as the relationship of the susceptibility of a particular indicator to impact versus the resiliency of the indicator (Figure 2). An indicator is at high risk when susceptibility to impact is high and resiliency is low, while an indicator is at low risk when susceptibility to impact is low and resiliency is high.

Step 4. Results from the risk analysis for each ecosystem indicator are then integrated in the assessment phase of the IEA. Using multivariate models, the assessment quantifies the status of the ecosystem relative to historical status and prescribed targets. Thus, the risk analysis rigorously quantifies the status of individual ecosystem indicators, while the full assessment considers the state of all indicators simultaneously.

Step 5. The next phase of the IEA uses ecosystem modeling frameworks (e.g., the Atlantis ecosystem model, Brand et al. in press) to evaluate the potential of different management strategies to influence the status of natural and human system indicators. To accomplish this, a formal Management Strategy Evaluation (MSE) is employed (Figure 3). In MSE, a simulation model is used to generate 'true' ecosystem dynamics. Data are sampled from the model to simulate research surveys, and then these data are passed to risk analysis and assessment models. These assessment models estimate the predicted status of individual indicators and the ecosystem as a whole. Based on this assessment of the simulated ecosystem, a management decision is simulated. Human response to this simulated decision is modeled, and potentially influences the simulated ecosystem state. By repeating this cycle, we can simulate the full management cycle. This allows us to test the utility of modifying assessments, monitoring plans, management strategies, or decision rules. Management Strategy Evaluation in the context of an IEA can thus serve as a filter to identify which policies and methods meet stated management objectives (e.g. Butterworth and Punt 1999).

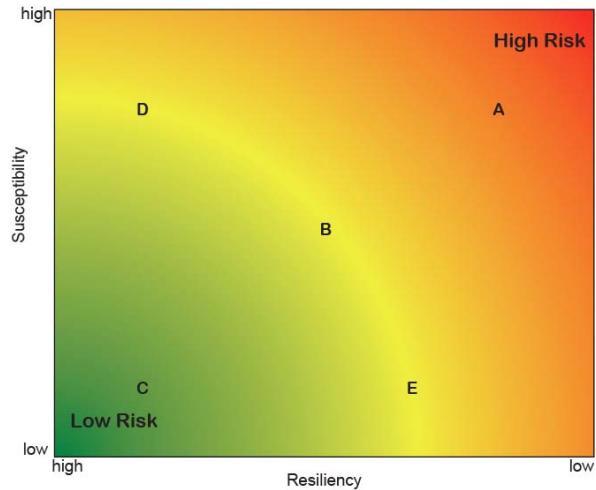


Figure 2. A visualization of the risk status of 5 indicators. Indicator A has low resiliency and high susceptibility to natural or human disturbance; thus, it has a high risk. C shows an indicator with low susceptibility and high resilience and thus has low risk. B, D, and E have different combinations of susceptibility and resilience yielding a moderate level of risk

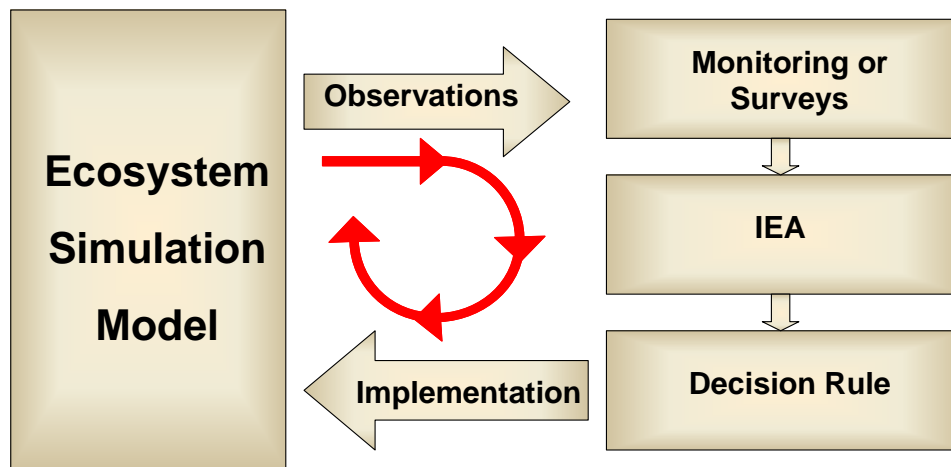


Figure 3. A schematic of the Management Strategy Evaluation (MSE) framework. In MSE, an ecosystem model is used to simulate the ecosystem. The ecosystem is then “sampled”, an IEA is performed and a management strategy is implemented. The cycle is repeated, and ultimately, the potential outcome of a range of management strategies can be estimated.

### Implementation of IEAs

In this white paper, we have outlined a stepwise approach that will guide the science of IEAs. In forthcoming papers, the NOAA IEA Priority Area Task Team will tackle such issues as who leads the IEA process and how leadership engages various line offices; how final IEA products should be delivered and used; how frequently should IEAs be conducted, and how IEAs conducted at different spatial scales may be integrated into a coherent whole.

### References

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## Appendix A. The Driver-Pressure-State-Impact-Response (DPSIR) framework

The strategy described above can be cast in the context of a Driver-Pressure-State-Impact-Response (DPSIR) framework for classification of selected indicators. The DPSIR approach has now been broadly applied in environmental assessment in both terrestrial and aquatic systems. *Drivers* are factors that result in system change that in turn exert pressures on components of the system. For our purposes, we are interested in both natural anthropogenic forcing factors; an example of the former is climate variability while the latter include factors such as human population size in the coastal zone and associated coastal development, demand for seafood, etc. In principle, human driving forces can be assessed and controlled. Natural environmental changes cannot be controlled but must be accounted for in management. *Pressures* include factors such as coastal pollution, habitat degradation, and fishing effort that can be mapped to specific drivers. For example, coastal development results in increased coastal armoring and the loss of associated intertidal habitat. State variables are indicators of the condition of the environment (including physical, chemical, and biotic factors). *Impacts* comprise measures of the effect of change in these state variables such as loss of biodiversity, declines in productivity and yield, etc. Impacts are measured with respect to management reference points and the risks associated with exceeding these targets and limits. *Responses* are the actions (regulatory and otherwise) that are taken in response to perceived impacts. Forcing factors under human control trigger regulatory response when management targets are not met as indicated by risk assessments. Natural drivers may require adaptational response to minimize risk. For example, changes in climate conditions that in turn affect the basic productivity characteristics of a system may require changes in ecosystem reference points that reflect the shifting environmental states.

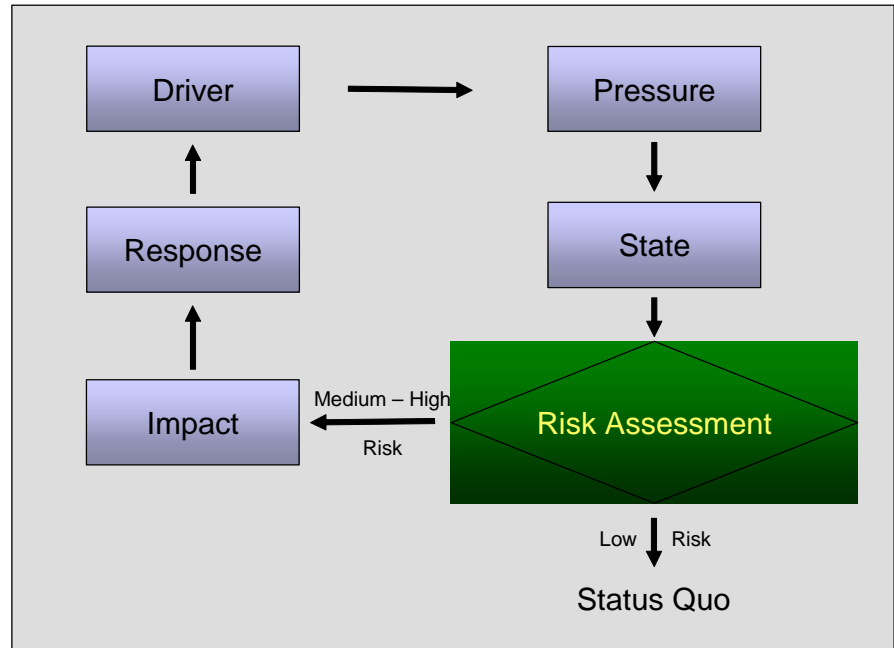


Figure 4. The Driver-Pressure-State-Impact Response framework for classification of ecosystem indicators

The different classes of indicators identified within the DPSIR framework can be mapped to the needs for the management strategy evaluation as described above and identified with respect to their roles in model formulation, parameterization, and validation.

**Table 1. Examples of drivers, pressures, states, and impacts of interest for integrated ecological assessments**

	Anthropogenic	Natural
Drivers	Human Population Size in the Coastal Zone Per Capita Seafood Demand Water-dependent international trade Coastal Development	Temperature Precipitation Winds Ice Cover Hydrodynamics
Pressures	Fishing Effort Habitat Loss/Degradation Pollution transport and fate Marine Transportation Effluent Discharges Oil and hazardous material spills Pathogens Land use patterns	Extent of Thermal Habitat Nutrient Regeneration Current speed and direction Habitat change Species range shifts
States	Commercial Fishery Landings Recreational Fishery Landings Aquaculture/Fish Farming Production Water quality	Chlorophyll Concentration Zooplankton Biomass Benthic Biomass Shellfish Biomass Fish Biomass Harmful Algal Blooms Pathogens
Impacts	Changes in Fishery Yield Changes in Aquaculture Production Recreational Income Losses Non-indigenous species Human health risks	Changes in Biodiversity Impacts on Ecosystem Function