Developing Quantitative Ecosystem Indicators of Environmental State

MARES Whitepaper No. 2

William Nuttle (Eco-hydrology.com), Chris Kelble (NOAA/AOML), and Pamela Fletcher (Florida Sea Grant)

Purpose

This whitepaper describes the approach used to develop quantitative indicators of environmental State in the coastal marine ecosystems of South Florida.

Background

The MARES project is developing a suite of indicators that provides an integrated assessment of the South Florida coastal marine ecosystem. One of the main objectives of the MARES project is to develop a report card on the status of the coastal marine ecosystem of South Florida. Identifying a set of ecosystem indicators is a necessary step toward this objective. Two types of ecosystem indicators are being developed. State indicators, which are the subject of this report, measure the condition of the environmental components of the ecosystem. Human dimensions are the second type of indicators, and these will be covered in a separate report.

Definition

We adopt the following definition from the report The State of the Nation's Ecosystems 2008 (Heinz Center 2008):

> “The term ‘indicator’ is used in this report to refer to a specific, well-defined, and measurable variable that reflects some key characteristic that can be tracked through time to signal what is happening within and across ecosystems. Indicators may include biological, physical, and chemical measurements. Besides communicating the current condition, or “state,” of an ecosystem to policymakers and the public, indicators can also be used by land managers to determine if objectives are being met or by scientists to detect unexpected changes in ecosystems.”

Ecological indicators come in many different formats, forms, levels of detail or resolution, organizational schemas, and environmental metrics. They also have many different purposes and applications and no one set or method of application or means of developing indicators seems to work or apply in all situations or ecosystems. However, each individualized set of indicators is designed to capture the "essence" or defining set of features of the ecosystem. The features of the marine and coastal components of the South Florida Total Marine Ecosystem (SFTME) include those characteristics distinctive of its biological, chemical and physical properties and their close relationship to the adjacent watershed.

Process for Developing State Indicators

The process of developing State indicators begins with the information assembled by the MARES project in conceptual ecosystem models of the coastal marine ecosystem. These models are based on the DPSER framework, which describes the ecosystem in terms Drivers, Pressures, State, Ecosystem Services, and Response. The State component describes key attributes of the marine environment, interrelationships among the attributes, and changes resulting from Pressures. The development of State indicators begins with the definition of key attributes that can be measured. State indicators are quantitative in nature, and data collected on these attributes, as in a monitoring program, are essential to their use.

The overall approach used here follows what has been done previously to develop indicators used in the System Status Report produced for the South Florida Ecosystem Restoration (SFER) Task Force.[1] Beginning in 2005, the Task Force directed the Science Coordination Group (SCG) to develop a "suite" of system-wide indicators of ecosystem restoration. The timeline for this work was short (1 year), and the SCG recognized that "indicator gaps" might result; therefore, additional indicators may be developed in the future as new scientific information and findings become available. A four-step process was used to develop an initial suite of twelve system-wide indicators (Doren et al. 2009), shown in the left hand column of Table 1.

The approach being used by the MARES project differs from the SCG's approach in two ways. First, where it was necessary for the SCG to select an approach based on a broad review of indicators for comparable application, the MARES project builds directly on the approach decided on by the SCG. In contrast with the SCG's effort, which could reference an existing set of conceptual ecosystem models for the Everglades, the MARES project must start by articulating conceptual ecosystem models that describe the South Florida coastal marine ecosystem. Second, where Doren et al. (2009) reference a set of twelve desirable criteria in developing indicators, the MARES project principal investigators have elected to use eleven criteria to guide indicator development.

[1] The 2009 System Status Report is available at this link: http://www.evergladesplan.org/pm/ssr_2009/cerp_ssr_2009.aspx

Table 1: Comparison of four-step process used to develop quantitative ecosystem indicators by the South Florida Ecosystem Restoration Science Coordination Group and in the MARES project

	SFER (Doren et al. 2009)	**MARES State Indicators**
1	Survey other regional ecosystem restoration programs for applicable indicators and process for developing indicators in the Everglades.	Identify "attributes that we can measure" for each State sub-model of the ICEM in each of three coastal sub-regions. This assures coverage of all regions of the coast and all major components of the environment by the indicator suite.
2	Use established criteria (list of 12) to select relevant indicators from CERP CEMs and performance measures.	Use guiding criteria (7 questions) to develop and describe ecosystem indicators based on data available for the "attributes we can measure." Document results in an indicator report.
3	Identify gaps in terms of geographic coverage and categories of ecosystem structure and function.	Review the suite of indicators. Identify and report gaps where science or data does not yet exist to support full development of an indicator. Obtain feedback and guidance from managers and NGOs.
4	Select final set of system-wide indicators, document and communicate results in form of a system status report card.	Select final set of system-wide indicators, document and communicate results in form of a system status report card.

Guiding Criteria

Ecological systems are complex, and efforts to design and implement easily understood indicators immediately raises a number of questions. Exactly what is an indicator? What is the indicator supposed to indicate? What makes a good indicator? Will this indicator be explicable to managers and policy makers? How do these indicators integrate into the "big picture" – the vision of a restored, sustainable ecosystem? These questions are answered by the overall approach taken to develop indicators and, especially in the criteria selected to guide how the indicators are defined in terms of the available data.

The guiding criteria used here were selected to meet the particular needs of the South Florida coastal marine ecosystem. The MARES project convened a workshop in March 2010 to develop indicators for the Florida Keys. This followed a conceptual modeling workshop, but occurred while the development of the Florida Keys integrated conceptual ecosystem model was still in progress. At the indicators workshop, participants reviewed in detail the approach used by the SCG to develop ecosystem indicators for the Everglades and applied this approach to identify indicators for the Florida Keys marine ecosystem. Based on their experience at this workshop principal investigators reviewed and revised the list of twelve guiding criteria used by the SCG. The revised list of eleven criteria, Table 2, is distilled from a larger list (see Appendix) compiled from a review of similar efforts to develop quantitative ecosystem indicators.

Table 2: Criteria to guide development of indicators from attributes that we can measure

Primary Criteria

1. Does the indicator provide an integrative measure of the overall status of the ecosystem or of essential ecosystem structures, functions or processes? (Doren et al. 2009, Dale & Beyeler 2001, Luckey 2002)
2. Does the indicator relate to ecosystem service(s)? (modified from Feld et al. 2009)
3. Is the indicator relevant to management goal(s)? (Bradley et al. 2010)
4. Is the indicator sensitive to system Drivers and Pressures? (Doren et al. 2009, Dale & Beyeler 2001, ICES 2002)

Data/Analysis Criteria

5. Is the indicator based upon data that can be generated with accuracy and precision relatively easily and for which there is sufficient existing data to evaluate change going forward? (Doren et al. 2009, ICES 2002, Dale & Beyeler 2001, Rice & Rochet 2005)
6. Is it possible to predict how the indicator will respond to changes in the ecosystem (including societal changes) over management-relevant time scales? (Feld et al. 2009, Dale & Beyeler 2001)
7. Does the indicator have a response that is easily detectable above the background variability to make it useful in measuring response to management actions or a change in a Pressure that may or may not be a result of management action(s)? (This also means the response signal should be attributable to a change in management or pressure.) (ICES 2002, Bradley et al. 2010)

Communication

8. Is the indicator understood by managers and the public? (Rice & Rochet 2005)
9. Does the indicator respond to stress earlier than the rest of the system (i.e. is it a leading indicator?)? (Dale & Beyeler 2001)
10. How long will it take for the indicator to show a response to possible management actions? (Dale & Beyeler 2001)
11. Has the indicator been employed effectively either in south Florida or elsewhere? (NRC 2000)

Indicator Report

The indicator report, Table 3, defines the indicator, evaluates recent status and trends in ecosystem State, and documents the applicability of the indicator in terms of the guiding criteria. In this form, the proposed set of indicators are subject to broader review and feedback from managers and NGOs, Step 3 in Table 1, before being incorporated in a system-wide report card.

The indicator report comprises a substantial technical product for each possible indicator that includes at a minimum:

- Scientific consensus on the quantitative desired future condition. This quantitative description is equivalent to the development of a performance measure target (in the language being used in the Comprehensive Everglades Restoration Plan CERP)
- A description of the current trajectory (status/trends), using available monitoring data
- Analysis of the relevant stressors/drivers, using available field data, or numerical models
- An explicit discussion of the gaps in the information required to rigorously assess the degree of change in an indicator and the cause of that change

Table 3: Topic outline of indicator report for a State indicator

Indicator Name:

What is this indicator?

What has happened to affect this indicator? (recent changes, drivers, pressures and qualitative response, historical)

What areas of the coast does this indicator cover?

What does the research say? (status and trends, with indicator)

Why is the indicator important? (selection criteria)

1. Does the indicator provide an integrative measure of the overall status of the ecosystem or of essential ecosystem structures, functions or processes?
2. Does the indicator relate to ecosystem service(s)?
3. Is the indicator relevant to management goal(s)?
4. Is the indicator sensitive to system Drivers and Pressures?
5. Is the indicator based upon data that can be generated with accuracy and precision relatively easily and for which there is sufficient existing data to evaluate change going forward?
6. Is it possible to predict how the indicator will respond to changes in the ecosystem (including societal changes) over management-relevant time scales?
7. Does the indicator have a response that is easily detectable above the background variability to make it useful in measuring response to management actions or a change in a Pressure that may or may not be a result of management action(s)? (This also means the response signal should be attributable to a change in management or pressure.)
8. Is the indicator understood by managers and the public?
9. Does the indicator respond to stress earlier than the rest of the system (i.e. is it a leading indicator?)?
10. How long will it take for the indicator to show a response to possible management actions?
11. Has the indicator been employed effectively either in south Florida or elsewhere?

Discussion

Longer-term science needs

References

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Appendix: Exhaustive List of Relevant Indicator Criteria

Goal: Select indicators of a south Florida marine ecosystem that is sustainable and capable of providing the diverse ecological services upon which our society depends.

Relevance and feasibility

Is the indicator relevant to the ecosystem? (Doren et al. 2009)

Is the indicator feasible to implement (i.e. is someone already doing it?) (Doren et al. 2009, Bradley et al. 2010)

Is the indicator conceptual based? (NRC 2000)

Is the indicator scientifically defensible? (Doren et al. 2009)

Is the indicator internationally accepted and employed? (NRC 2000)

Data Availability

Is the indicator based on an existing body or time series of data to allow a realistic setting of objectives? (ICES 2002, Rice & Rochet 2005)

Is the indictor easily and accurately measured with a low error rate? (ICES 2002, Dale & Beyeler 2001, Rice & Rochet 2005)

Is the indicator measureable over a large portion of the area to which the indicator will be applied? (ICES 2002)

Is the indicator cost-effective? (Rice & Rochet 2005, NRC 2000)

Sensitivity

Is the indicator sensitive to system drivers? (Doren et al. 2009)

Is the indicator sensitive to stressors? (Dale & Beyeler 2001)

Is the indicator sensitive to ecosystem sustainability/health, and/or services? (Rice & Rochet 2005)

Is the indicator relatively tightly linked in time to its management activity? (ICES 2002)

Does the indicator affect or assess ecosystem services? (modified from Feld et al. 2009)

Is the indicator the appropriate spatial and temporal scale? (Feld et al. 2009)

Can the indicator be upscaled or downscaled? (Feld et al. 2009)

Is a clear, measureable target available? Already applied? Possible? (Feld et al. 2009, Doren et al. 2009)

Can the indicator status be remotely sensed? (Feld et al. 2009)

Applicability

Is the public aware of the indicator and its meaning? (Rice & Rochet 2005)

Is the indicator relatively easy to understand by non-scientists and decision makers? (ICES 2002, Doren et al. 2009)

Is the indicator a concrete property of the physical/biological world, versus an abstract property? (Rice & Rochet 2005)

Is the indicator relevant to management purpose/goal? (Bradley et al. 2010)

Is the indicator interpretable and useful to management? (Bradley et al. 2010)

Responsiveness

Are there situations where an “optimistic” trend in the indicator might suggest a “pessimistic” trend in ecosystem health? (modified from Doren et al. 2009)

Is the indicator responsive to management actions? (Rice & Rochet 2005)

Is there a theoretical basis for the indicator to respond to ecosystem sustainability/health or services? (Rice & Rochet 2005)

Does the indicator have enough specificity to assess individual management actions? (modified from Doren et al. 2009 and Rice & Rochet 2005)

Is the indicator responsive to a human activity, with low responsiveness to other causes of change? (ICES 2002, Bradley et al. 2010)

Does the indicator have a known response to natural disturbances, anthropogenic stresses and changes over time? (Dale & Beyeler 2001)

Does the indicator respond to stress in a predictable manner? (Dale & Beyeler 2001)

Does the indicator have low variability in response (Dale & Beyeler 2001)?

Does the indicator measure a human behavior that is related to environmental conditions? (FK-DT indicator workshop)

Early Warning

Is the indicator anticipatory, signify an impending change in the ecological system? (Dale & Beyeler 2001)

Does the indicator predict changes that can be averted by management action? (Dale & Beyeler 2001)

Completeness

Is the indicator integrative? (Doren et al. 2009, Dale & Beyeler 2001)

Does the suite of indicators cover the critical range of ecosystem “features” including processes and structures? (Doren et al. 2009, Dale & Beyeler 2001)

Does the indicator status reflect overall ecosystem health? (Luckey 2002)

Is the indicator relevant to ecological structure and function? (Bradley et al. 2010)