COASTAL RESOURCE PLANNING SYSTEM: INTEGRATING EVALUATION OF ECOLOGICAL INTEGRITY AND ECOSYSTEM SERVICES VALUATION

Harry J. Stone* and Leslie-Ann S. McGee

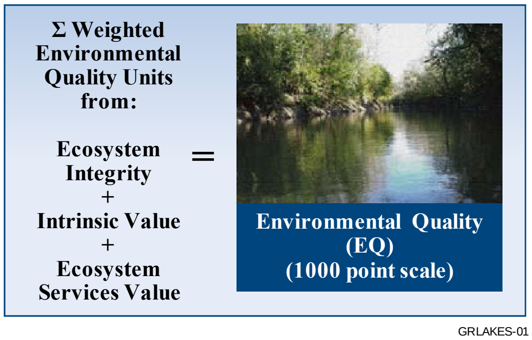
Introduction

Efficient and effective coastal management decisions rely on knowledge of the impact of human activities on ecosystem integrity, vulnerable species, and valued ecosystem services—collectively, human impact on environmental quality (EQ). Ecosystem-based management (EBM) is an emerging approach to address the dynamics and complexities of coupled social-ecological systems. EBM "is intended to directly address the long-term sustainable delivery of ecosystem services and the resilience of marine ecosystems to perturbations" (Rosenberg and Sandifer, 2009). The lack of a tool that integrates human choices with the ecological connections between contributing watersheds and nearshore areas, and that incorporates valuation of ecosystem services, is a critical missing piece needed for effective and efficient coastal management. To address the need for an integrative tool for evaluation of human impacts on ecosystems and their services, Battelle developed the EcoVal™ Environmental Quality Evaluation System. The EcoVal system is an updated (2009) version of the EQ Evaluation System for Water Resources developed by Battelle for the U.S. Bureau of Reclamation (Dee et al., 1972). The Battelle EQ evaluation system has a thirty-year history of providing a standard approach to evaluate watershed EQ. This paper describes the conceptual approach and methodology of the updated EcoVal system and its potential application to coastal ecosystems.

Overview of the EcoVal System

The EcoVal system scientifically assesses three categories of EQ, as shown in Figure 1: ecosystem integrity; intrinsic value, expressed as maintenance of rare and endangered species; and monetized ecosystem service value. The system incorporates an ecologically and economically based conceptual model (see Figure 1). The overall aggregated EQ value is then derived from the relative social value weighting applied to each categorical EQ.

Figure 1. EcoVal EQ Categories



The definition of Ecosystem Integrity used in the EcoVal system is "the capacity of an ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of similar, undisturbed ecosystems in the region" Carignan and Villard, 2002). Ecosystem Integrity includes indicators of human stressors and biotic indicators of ecosystem impacts.

Intrinsic Value is a philosophical and ethical concept that holds that "[t]he well-being and flourishing of human and non-human life on Earth have value in themselves. (…) These values are independent of the usefulness of the non-human world for human purposes" (Naess, 2003). Intrinsic value of species is the ethical basis for the Endangered Species Act. Therefore, intrinsic value of endangered and threatened species may be a component of coastal management decision processes and is evaluated in the Intrinsic Value category.

Ecosystem Services Value, the monetized utilitarian value for the "customer of nature," is defined as "personal perception of advantage arising out of a customer's association with an ecosystem's offering, and can occur as reduction in sacrifice; presence of benefit; the resultant of any weighed combination of sacrifice and benefit" (adapted fromWoodall, 2003). Ecosystem Services Value may be impacted directly by human decisions (e.g., feces in water may reduce recreational use without impacting ecological integrity) or indirectly through a change in ecological integrity (e.g., nutrients resulting in anoxic zones, business failures, job loss). The broad range of ecosystem goods and services, as identified by the Millennium Ecosystem Assessment is the framework for identification of ecosystem services.

For an ecosystem, EQ consists of three categories, with each category (e.g., Ecosystem Integrity) incorporating one or more components (e.g., Biota). Each component is assigned one or more ecosystem-specific measurable parameters (e.g., index of biotic integrity; see Figure 2). Components are designed to be comprehensive for application across a broad spectrum of ecosystems. For each component, one or more parameters are selected to reflect the state of ecological or economic knowledge for a given ecosystem.

Five criteria are used to select parameters: (1) parameters should be highly comprehensive indicators of EQ; (2) parameters should be easily measurable in the field; (3) parameters should be capable of being measured on a relevant scale; (4) parameters should exhibit an empirically-grounded causal relationship with the resilience of ecosystems or ecosystem services or represent a desired ecosystem/service endpoint; and (5) the total list of parameters should be as compact as possible.

Heuristics are then developed for the metrics needed to evaluate EQ based on a review of ecological and ecological economics knowledge. These units are summed to determine overall EQ within the three categories, and social weighting is applied to derive the aggregate EQ value. By comparing a current or planned condition to a reference condition, the actual or likely impacts on EQ can be systematically and consistently estimated.

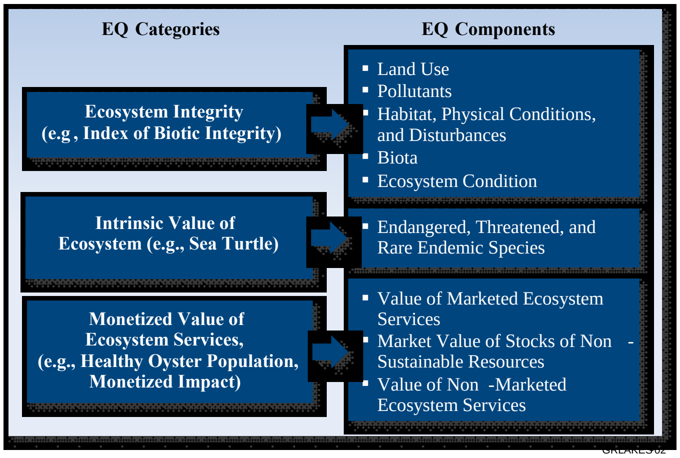


Figure 2. EcoVal™ EQ Structure

Methodology

The EcoVal system approach includes the following steps:

1. Use social processes to select highest priority ecosystem integrity, intrinsic value, and ecosystem service endpoints, and to develop relative social weighting values for ecosystem integrity and intrinsic value relative to the value of ecosystem services.

Example Endpoint: Healthy Oyster Community (HOC)

2. Develop/select conceptual models linking parameters, e.g., nutrients, to impacts on ecological endpoints, e.g., healthy oyster communities (HOC). Critical parameters are identified for inclusion in the models linking human activities to ecological endpoints.

Example Conceptual Model: HOC = f(nutrients, turbidity, sea level, …)

3. Identify sources of data, or develop and implement methods to gather data, necessary for the parameters in the ecological models.
4. Develop statistical models to link critical drivers/stressors to ecological endpoints. The modeling approach follows previously-demonstrated methods (Stone, 2004) using statistical methods described by Hosmer and Lemeshow (1989). The output of the model is the probability of observing the desired dichotomous endpoint (e.g., “yes” to ecological endpoint attainment of “good oyster community”).

Example of statistical model (hypothetical):
Probability of “Good” HOC = $e^{-6.412}$ x ($e^{-2.06 \text{ x NUTRIENTS}}$) x ($e^{0.149 \text{ x TURBIDITY}}$) x …

5.

5. Develop heuristics for parameters based on the statistical and sensitivity analyses. Heuristics are developed by examining the modeling analysis and empirical data to determine the “shape” of the heuristic for a given value of the parameter. (See Figure 3.) All heuristics are on a 0–1 scale. For example, the phosphorus of 0.05 mg/L may have no known negative impact on the identified biological endpoint and would be assigned a value of 1. At a phosphorus concentration of 10 mg /L, the ecological endpoint may never be observed, and a value of 0 would be assigned. Between extremes, the change in probability of observing the desired endpoint is used to determine the shape of the heuristic curve.

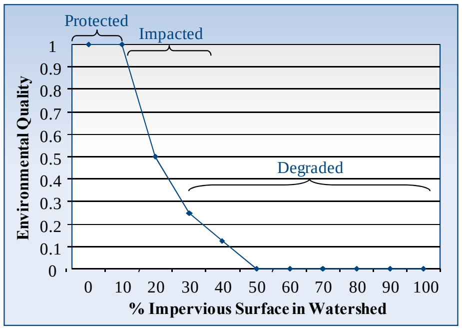


Figure 3. Example of Heuristic Curve

6. Develop model and heuristics for monetized ecosystem services linked to the probability of observing a resilient ecosystem to provide the service.

Example of ecosystem services value: \$/km^2-year = f([*site-good characteristics, social characteristics]* x probability of a “good” HOC)

7. Vet the fully-parameterized model, heuristics, and environmental evaluation system with experts, stakeholders, and potential users.
8. Validate the statistical model.

Discussion

The updated environmental evaluation system established a conceptual framework linking human stressors (or natural drivers) to resilience of ecosystem functioning, preservation of intrinsic value, and changes in ecosystem services – collectively, EQ. The EcoVal system may be useful to support coastal EBM to screen the likely impacts of alternative scenarios on ecosystem integrity and ecosystem services values. The output from the environmental evaluation system can provide an EQ baseline, be used to evaluate temporal changes in EQ compared to the baseline, and can be used to anticipate likely changes in EQ resulting from changing drivers and human activities. The methodology supports estimation of the impact of stressors and drivers (natural or human) at various levels of data intensity from a screening level, supported by heuristics derived from empirical data, to incorporation of rigorous modeling. The output of the standardized environmental evaluation system provides individual outcomes for scientifically-sound ecological integrity measures, intrinsic value, and human-valued ecological services, as well as an integrated overall evaluation of EQ.

Acknowledgments

The development of the EcoVal™ Environmental Quality Evaluation System was funded by the 2009 Battelle Internal Research and Development program.

References

Carignan, Vincent and Marc-André Villard. 2002. Selecting indicator species to monitor ecological integrity: a review. Environmental Monitoring and Assessment, 78:45–61.

Dee, Norbet, Janet Baker, Neil Drobney, Ken Duke, and Dave Fahringer. 1972. Environmental Evaluation System for Water Resource Planning. Report prepared by Battelle for: U.S. Bureau of Reclamation..

Hosmer, D. S. and S. Lemeshow. 1989. Applied Logistical Regression. New York, John Wiley & Sons, Inc.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC.

Naess, Arne. 2003. “The deep ecological movement: some philosophical aspects.” Environmental Ethics. Ed. by Andrew Light, Holmes Rolston), 264.

Rosenberg, Andrew A. and Paul A. Sandifer. 2009. “What do managers need?” Ecosystem-based Management for Oceans. Ed.Karen McLeod and Heather Leslie. Washington, D.C.: Island Press, 13-30.

Stone, H. 2004. The Political Economy of Ecological Research Analyzing the “Total Maximum Daily Load” in the Upper Mill Creek Cincinnati. Dissertation: <http://rave.ohiolink.edu/etdc/view?acc_num=miami1082567599>.

Woodall, Tony. 2003. “Conceptualising ‘value for the customer’: an attributional, structural and dispositional analysis.” The Nottingham Academy of Marketing Science Review 2003(12).

Harry J. Stone
Battelle
10300 Alliance Rd., Suite 155
Cincinnati, OH 45241
Ph (513) 362-2600 Ext. 12
Email address: stoneh@battelle.org