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Rapid prioritization of marine ecosystem services and ecosystem indicators

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ABSTRACT

An ecosystem services (ES) approach to managing marine and coastal resources has increasingly emerged as a core requirement of ecosystem-based management (EBM). However, little practical guidance exists to help structure and implement such an approach. This paper outlines the linkages between ecosystems, ES and EBM in a practical framework that could be applied to marine environmental management. Using the northwestern, deepwater Gulf of Mexico as a case study, a three-stage approach was devised: (1) prioritizing relevant ES according to perceived financial and societal value and level of stress, (2) assessing the effectiveness of a wide range of indicators of ES health, and (3) ranking indicators to identify those whose monitoring would be most effective in tracking ES health. The first stage of this approach identified food provision, recreational fishing, and the non-use ethical value derived from the presence of iconic species as the highest-priority ES in the case study region. The second and third stages suggested four indicators as having the highest priority for supporting key ES: (1) levels of selected chemical compounds in key species of fish, (2) marine sound, (3) concentration of chlorophyll-*a* as a proxy for phytoplankton, and (4) economic and ecological values added by artificial structures. Results of this study will be helpful in prioritizing the allocation of resources for marine environmental monitoring. The approach described here will also be applicable, with appropriate adaptations, to ES analysis in other environmental settings.

1. Introduction

A core requirement of implementing ecosystem-based management (EBM) for marine and coastal environments is the adoption of an ecosystem services (ES) approach [1,2]. This approach advocates protecting key ES and offers improved evaluation of marine resource uses, impacts and trade-offs based on human wellbeing [3,4]. Nonetheless, the ES approach remains difficult to put into practice [5,6], with little practical guidance available.

This paper explores how an ES approach could be applied to marine environmental management. The aim was to develop a simple, systematic process to determine what environmental indicators would best support EBM. To achieve this, a three-stage approach was developed. The first stage focused on the development of a simple methodology for prioritizing ES using qualitative and comparative valuation. The second and third stages identified potentially relevant environmental monitoring indicators and their relative priority for associated monitoring measures. Through this approach, linkages between ecosystems, ES and EBM were outlined in a practical framework that could be used to facilitate environmental management decisions.

There were several drivers behind this study: First, to understand how best to safeguard the environment and its ability to provide important ES. Second, to address evolving government policies which increasingly require EBM and some form of marine spatial planning (MSP). Third, to make the ES concept more tangible to industry. All of these drivers point toward the need for a systematic framework that can help guide environmental

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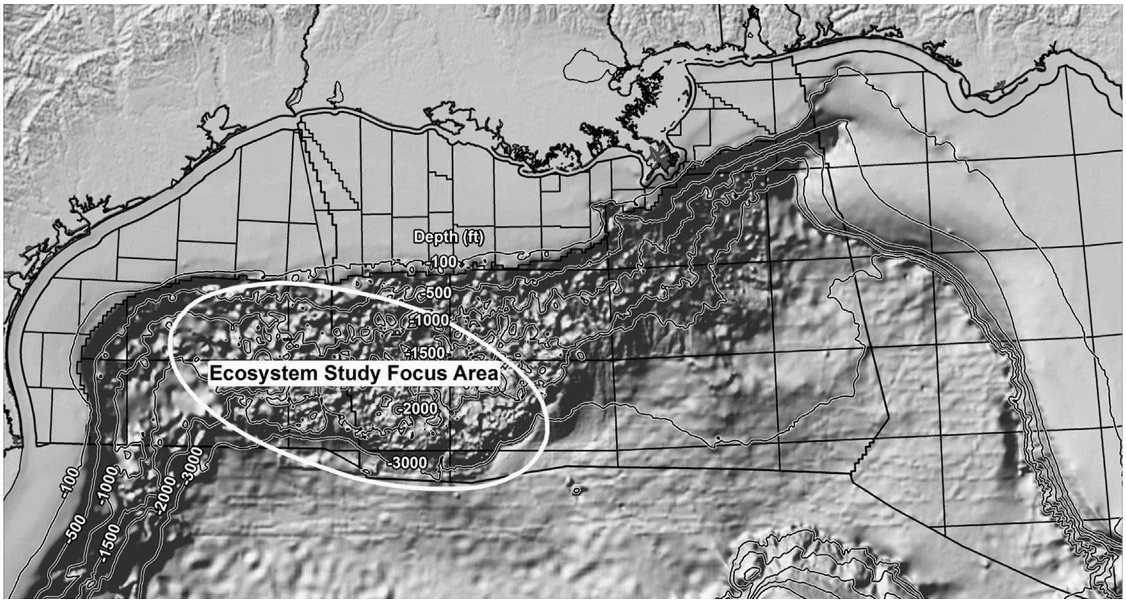

Fig. 1. General outline of the northern Gulf of Mexico study area. Depth contours are shown in feet below sea-level. The grid overlay shows the US Government lease blocks. The Mississippi River's bird-foot delta is shown in the top center portion of the map. Bathymetry *Source*: [25].

decision making. In the USA, the National Ocean Policy is underpinned by a set of recommendations [7] and a draft policy implementation plan [8]. EBM is highlighted as a core principle, with MSP specified as an important tool for implementing EBM. In Europe, the EU Marine Strategy Framework Directive [9] and EU Roadmap for Maritime Spatial Planning [10] also have EBM as an overarching principle.

Several international best practice documents are available to help businesses incorporate ES into their environmental decision making [11–14]. These reports provide useful generic guidance on how to assess ES impacts and dependencies, but do not provide practical advice on how to implement EBM. Existing guidance on how to implement EBM in a marine context and identify relevant indicators to monitor also remains fairly generic and conceptual [15,5,1]. Given the complex nature of the marine environment, a common recommendation is to focus on the highest-priority ES, management actions and monitoring indicators. Research has addressed the challenges of developing ES-specific indicators [16], and proposed useful criteria against which to select key indicators for EBM [17].

There is a growing body of literature on regional applications of promising marine ES approaches. For example, based on a study in San Francisco Bay, Tallis et al. [18] propose a framework for MSP that assesses the condition of ecosystems, the amount of resources used, and the value of people's preference for ES. Altman et al. [19] developed a systematic approach to evaluate key interactions between humans and natural components in the Gulf of Maine, USA. Maynard et al. [20] developed an ES framework that identifies the linkages between ecosystems, ecosystem functions, ES and the community's wellbeing in South East Queensland, Australia. Raheem et al. [21] developed an ES and ecosystem-matrix based approach to help document ES values to assist with coastal policy decisions in California. Furthermore, Wiggin et al. [22] developed a set of recommended indicators, based on expert input and indicator ranking, to evaluate the Massachusetts Ocean Management Plan.

The literature stresses the need for the development of additional operational tools that can be used to put the concept of ES and EBM into practice [23]. Although various valuation tools are being developed to help do this, they tend to be restricted in terms of the range of ES they evaluate, and are not ready for widespread application [24]. Indeed, Tallis et al. [5] highlight that a key challenge of implementing EBM is the perception that it is too complicated and has prohibitive information requirements. This perception emphasizes the need for a set of guidelines that outline a logical, step-by-step process through which EBM can be applied.

EBM should be adaptive, science-based, and provide for the sustainability of important ES. A robust approach to adaptively manage potential impacts by ocean users and achieve sustainable, shared use of ecosystem resources therefore should consist of the following key elements:

1. Identification of sensitive ES,
2. Determination of relevant indicators for sensitive services,
3. Indicator monitoring and analysis, and
4. Action to correct and mitigate when and where indicators show loss of sustainability.

This paper presents a simple method to address the first three of these elements and thereby provide a basis for effective decision making concerning the fourth. The northwestern, deep-water Gulf of Mexico was selected as a location to develop and test the approach (Fig. 1). This was due to the importance of the Gulf of Mexico for the oil and gas industry and the considerable volume of existing data available for the region.

2. Methodology

2.1. General approach

A multi-disciplinary team was established to apply the EBM thought process to industry activities in the Gulf of Mexico. The team comprised in-house environmental staff with backgrounds in oceanography, marine biology, chemistry, hydrology and risk management as well as two external experts in the fields of environmental economics and biology. The external economist and biologist had 20 years of experience evaluating ecosystem services and 35 years of experience working in the Gulf of Mexico, respectively.