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# Towards marine ecosystem based management in South Florida: Investigating the connections among ecosystem pressures, states, and services in a complex coastal system

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ABSTRACT

Marine ecosystem based management plans are gaining popularity with natural resource managers, but examples of their successful implementation remain few. The complexity inherent in marine ecosystems presents a major obstacle to understanding how individual ecosystem pressures impact multiple ecosystem states that in turn impact the provisioning of ecosystem services. To create and implement successful ecosystem based management plans will require tools for understanding these processes. Over the past three years integrated conceptual ecosystem models of the coastal marine environment have been developed as part of the Marine and Estuarine Goal Setting for South Florida (MARES) project. Here we use these conceptual models in conjunction with a modified DPSIR model, expert opinion and matrix-based analyses to explore the direct and indirect relative impact of 12 ecosystem pressures on 11 ecosystem states and 11 ecosystem services identified through MARES. Within the South Florida coastal ecosystem the most pervasive pressures were freshwater delivery, temperature effects of climate change, and impacts of climate change on weather. For the study region the least pervasive pressures were recreational fishing, commercial fishing, and invasive species. The most at risk ecosystem states, as determined by cumulative impacts were fish and shellfish, protected species, and marine birds. By the same measure, the least at risk states were oyster reefs and inshore flats. The most at risk ecosystem services were existence of a natural system, pristine wilderness experience, and non-extractive recreation. The least impacted ecosystem services were commercial extraction, recreational fishing and climate stability. When the relative direct and indirect (i.e. including state to state interactions) impacts of ecosystem pressures were traced to individual ecosystem services, it was apparent that within the study domain a lack of freshwater delivery to coastal estuaries was the predominant pressure, and recreational fishing had the lowest relative impact on the provisioning of ecosystem services. Through this expert opinion analysis and exploration of the interaction strength among various ecosystem pressures, states, and ecosystem services, we can begin to understand the diverse manners in which ecosystem services are impacted by various pressures. In so doing we provide a tool for resource managers to understand the trade-offs among individual user groups and the possible impact on provisioning of ecosystem services that may occur when considering various management strategies.



## 1. Introduction

In recent years, marine ecosystem based management (EBM) has received growing attention as a framework for mitigating anthropogenic impacts on the world's oceans, but its implementation has proved challenging (Halpern et al., 2008a,b; Samhouri et al., 2010; Tallis et al., 2010). Global-scale analyses have generated quantitative comparisons among pressures impacting different portions of the marine environment (e.g. Halpern et al., 2012), but owing to the complexities in the successful implementation of EBM (see below), the knowledge generated by these broad-scale analyses provides limited guidance for actionable science at smaller spatial scales (Game et al., 2013). To understand the unique properties, stressors, interactions, and vulnerabilities of local and regional marine ecosystems, and how to successfully manage complex coastal systems, will require complementary

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focused analyses (Stelzenmuller et al., 2010; Teck et al., 2010; Altman et al., 2011; Grech et al., 2011; Game et al., 2013).

In theory, EBM is a holistic strategy for dealing with the complexities of diverse ecosystems; its strength lies in the ability to simultaneously explore the trade-offs among social, cultural, economic, and environmental factors that may influence an ecosystem, and to find optimal solutions for all stakeholders (Leslie and McLeod, 2007). In practice, and despite federal mandates to utilize EBM approaches (Lubchenco and Sutley, 2010) a move from traditional single-sector management strategies to holistic EBM has been slow. Some local-regional scale EBM plans have been developed (e.g. the Puget Sound Partnership, Massachusetts Ocean Management Plan), but in many instances, particularly within the realm of fisheries management, the implementation of EBM is viewed as a sequential process where first single-species stock assessment methods are explored and adapted to assemblages of multiple species, after which it is believed managers will become more receptive to an ecosystem approach to managing fisheries, which ultimately will lead to a broader acceptance and application of multi-sectoral EBM of complete ecosystems, including humans (Agardy et al., 2011).

One of the primary challenges associated with the successful implementation of EBM is consensus building among a diverse group of stakeholders (Leslie and McLeod, 2007). Without a clear and unified vision of what defines the ecosystem in question and what aspects of the ecosystem people care about, endpoints and management targets remain elusive (Game et al., 2013). Making this challenge greater is the high degree of complexity inherent in ecosystems and a lack of understanding about how various pressures impact ecosystem states and services. In addition, those involved in the creation of an EBM plan need to identify which metrics can be used to gauge the success of various management strategies. Without predefining critical ecosystem components and metrics, evaluating the success of an EBM plan can be tenuous and uncertain (Leslie and McLeod, 2007; Game et al., 2013). Another challenge to the successful implementation of EBM is a paucity of examples of successfully implemented EBM approaches that can act as a blueprint for others to follow (Leslie and McLeod, 2007). Finally, while it is unrealistic to manage every aspect of the marine environment, there is a need to identify and prioritize the key components of an ecosystem, which can and should be the focus of management actions (Altman et al., 2011; Game et al., 2013).

In this paper, we highlight a marine EBM project addressing these challenges in South Florida and provide guidance on how to quantify the relative strength of "the complex interconnections that exist among many species, habitat types, and human activities" in an ecosystem threatened by various pressures both natural and anthropogenic (Altman et al., 2011; Kelble et al., 2013). We introduce a matrix-based method for estimating the interaction strength among ecosystem pressures, states, and services, and show how these data can be used to implement marine ecosystem based management successfully. This methodology could be categorized as a qualitative or semi-quantitative ecosystem risk assessment (*sensu* Hobday et al., 2011), as it builds upon extensive scoping, identifies the most vulnerable ecosystem states, and explores all possible pressure to state to ecosystem service interactions within the MARES study domain (see Sections 1.1 and 2 below). Furthermore through an exploration of the direct and indirect pathways by which various pressures impact the provisioning of ecosystem services we provide a manner for decision-makers to explore the susceptibility of states to impacts and the inherent trade-offs among possible management actions and the costs and benefits to multiple user groups. We base this analysis on reviews of published documents, grey literature, as well as information gathered from key personnel and collaborative MARES workshops from 2009–2012.

### 1.1. MARES

From late 2009–2012 more than 100 South Florida scientists, managers, and stakeholders have participated in a protracted planning process called the MARine and Estuarine goal Setting (MARES) project. MARES is an attempt to make holistic ecosystem-based management more central to restoration activities in South Florida, and to rectify the shortcomings identified from the Comprehensive Everglades Restoration Plan (CERP), the world's largest and most expensive ecosystem restoration effort (please see Doren (2009) and articles therein, Nuttle and Fletcher, 2013a). For an in-depth description of the MARES process and the defining habitats, species, ecology, and socio-economic components of this system please see Nuttle and Fletcher (2013a,b) and Kelble et al. (2013), Leeworthy et al., Lorenz et al., Lovelace et al., Ortner et al., Patterson et al. (all this issue). The stated goal of MARES is to "reach a science-based consensus about the defining characteristics and fundamental regulating processes of a South Florida coastal marine ecosystem that is both sustainable and capable of providing the diverse ecosystem services upon which our society depends" (Nuttle and Fletcher, 2013a). To achieve this goal, MARES addresses the primary EBM challenges outlined by Leslie and McLeod (2007) (see above). First, MARES developed integrated conceptual ecosystem models through consensus-building workshops that included resource managers, representatives of federal (e.g. US National Park Service, National Oceanic and Atmospheric Administration, US Geological Survey, US Environmental Protection Agency, US Fish and Wildlife Service), state (e.g. Florida Department of Environmental Protection, Florida Fish and Wildlife Conservation Commission, South Florida Water Management District), county (e.g. Miami-Dade County, Broward County, Monroe County), and non-Governmental Organizations (e.g. Audubon, The Nature Conservancy), stakeholders, and biophysical and human dimensions scientists. MARES identified quantitative ecosystem indicators of both the biophysical and human components of the ecosystem that should be used to evaluate the efficacy of management strategies. Lastly, if successful, MARES will provide an example of a successfully implemented EBM approach.

The integrated conceptual ecosystem models depicted the key attributes of the ecosystem and the key linkages to human society (Nuttle and Fletcher, 2013a). To create these models the MARES project built upon a Drivers-Pressures-State-Impact-Response (DPSIR) framework (Harremoes, 1998). The DPSIR framework evolved from a Pressure-State-Response model describing the interactions between pressures impacting various ecosystem states, and the responses that in turn influence pressures (Bowen and Riley, 2003). The DPSIR model was meant to explain cause-and-effect relationships among indicators that describe how human society impacts the various states comprising an ecosystem, and has been widely adopted for its ability to better communication among policymakers, stakeholders, and scientists (Kelble et al., 2013). However, traditional DPSIR models lack a direct linkage to ecosystem services, and so the original DPSIR model was adapted to create an EBM-Driver-Pressure-State-Ecosystem Service-Response (DPSER) model (Kelble et al., 2013). In the EBM-DPSER model Drivers, such as human population growth, reflect the ultimate causes of impacts on ecosystems, but management actions rarely target underlying human needs (e.g. the energy requirements associated with an increasing human population; Kelble et al., 2013). Therefore, in this study we focus on the pressures that manifest from these ultimate drivers (e.g. ocean acidification resulting from fossil fuel burning), and which are the targets of management responses. With this in mind we identified the predominant pressures to the coastal marine ecosystem (e.g. recreational fishing, boating activities, marine construction) along with their