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INTRODUCTION

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Introduction to the NOAA Integrated Ecosystem Assessment Program: Advancing Ecosystem Based Management

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ABSTRACT
In the marine science community of practice, the concept of ecosystem-based management (EBM) is a management strategy that incorporates the entire ecosystem, including humans, into resource management decisions and is growing in its use to integrate and manage complex social and marine ecosystems. The National Oceanic and Atmospheric Administration's (NOAA) Integrated Ecosystem Assessment (IEA) program uses a multidisciplinary framework to help advance EBM and to manage marine resources in an ecosystem context. NOAA has conducted integrated ecosystem assessment research for many years, however, 2020 was the 10-year anniversary of implementation of NOAA's formal IEA framework around the country. This Coastal Management Journal special issue discusses the ten-plus years of IEA experiences with perspectives about and successes in the development and implementation of the NOAA IEA approach. This volume on the NOAA IEA program comprises six manuscripts ranging in content from the history and origin of IEAs in NOAA, to the development and application of IEA components to advance the tenets of EBM in coastal and marine environments.

KEYWORDS
ecosystem based management; integrated ecosystem assessment; interdisciplinary framework; NOAA Integrated Ecosystem Assessment program

Introduction

This special Coastal Management Journal (CMJ) volume on the National Oceanic and Atmospheric Administration's (NOAA) Integrated Ecosystem Assessment (IEA) program comprises six manuscripts ranging in content from the history and origin of IEAs in NOAA, to the development and application of various components (e.g., ecological indicators) of the IEA framework, to data access and visualization. The collective body

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of work within the IEA Program advances the overall tenets of Ecosystem Based Management (EBM) in coastal and marine environments across multiple spatial scales. EBM is an integrated approach that recognizes a broad array of interactions within social-ecological systems (Levin, Francis, and Taylor 2016), rather than considering single issues, species, sectors, or services in isolation (Arkema, Abramson, and Dewsbury 2006; Levin et al. 2009; Link and Browman 2014). Managing complex marine ecosystems and humans who desire ecological services from nature requires new and flexible approaches to meet today's coastal conservation challenges and sustainable use of marine resources. IEAs are an important approach to address the complex issues of the coupled natural and social systems operating within the oceans.

NOAA's IEA program

Based in part on the information above, NOAA formally launched its IEA program in 2010 with the intent of providing science to support the EBM approach. The program was the result of many years of conducting integrated ecosystem research and assessments (e.g., Monaco et al. 2005; Levin et al. 2008; Caldow et al. 2015) and significant internal agency discussions along with consultation with external partners that culminated in publication of the keystone IEA paper (Levin et al. 2009) and related technical report (Levin et al. 2008). These publications define the IEA framework for performing EBM and are being used to advance NOAA's goal to "conserve and manage coastal and marine ecosystems and resources" (Levin et al. 2009; Samhouri et al. 2014; Harvey, Kelble, and Schwing 2017). These background documents describe the IEA framework to conduct multi-disciplinary science to support EBM. Although there are significant impediments (e.g., multiple management entities) to implementation of EBM, the NOAA IEA program and associated regional studies have demonstrated success in advancing aspects of EBM. The IEA program continues to evolve and improve the multidisciplinary framework to advance management of marine resources. The program strives to balance the needs of nature and society to address diverse marine resource management objectives in an ecosystem context. It provides a formal synthesis and quantitative and qualitative analysis of information on relevant natural and socioeconomic factors, in relation to specified ecosystem management objectives (Levin et al. 2009, Levin, Wells, and Sheer 2013). The manuscripts in this issue demonstrate how use of IEAs has made significant strides in addressing the coupling of natural and social sciences with local to regional to national governance structures to advance EBM.

NOAA IEA program coverage

The NOAA IEA program has developed multi-year regional implementation plans to conduct effective ecosystem assessments that provide high quality science-based products that are relevant to management needs across a suite of coastal and marine science issues. Currently, the NOAA IEA program is focused on five regions across the United States (Figure 1). Several representative case studies from these regions are highlighted herein to describe how NOAA's IEA approach provides scientists, stakeholders, and natural resource managers a framework needed to conserve and maintain healthy

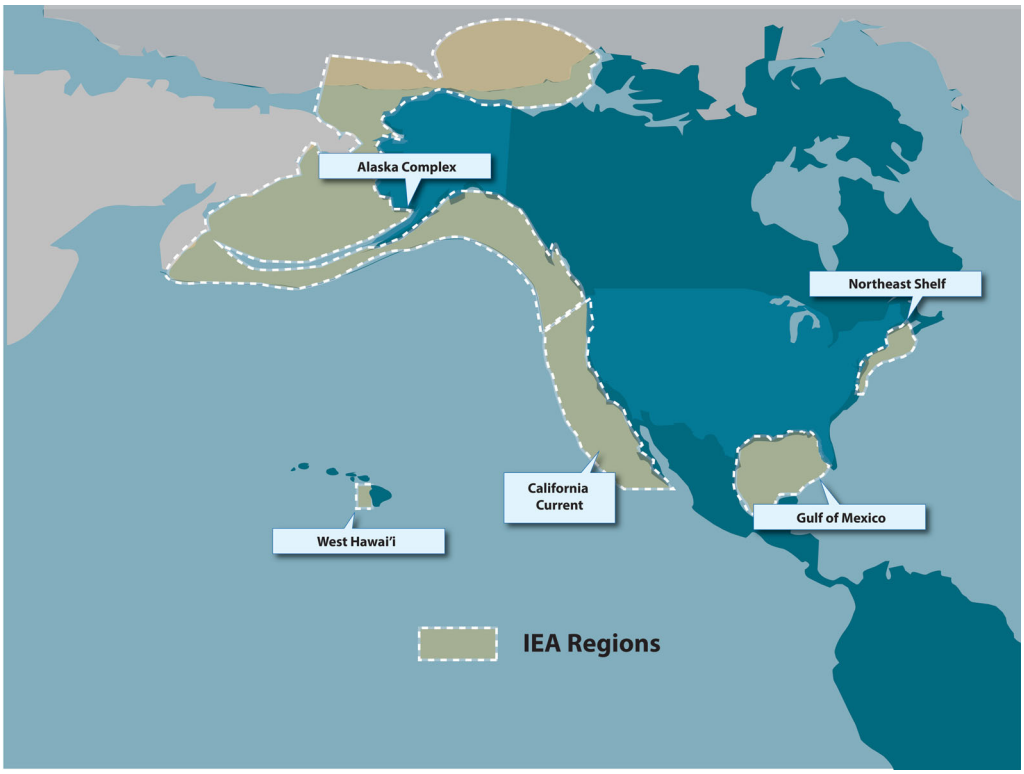

Figure 1. Map of NOAA Integrated Ecosystem Assessment program study areas throughout the United States. NOAA IEA Program, https://www.integratedecosystemassessment.noaa.gov/.

ecosystems and coastal communities (Spooner et al. this issue). Examples range from application of the IEA framework for the management of multispecies fisheries, to habitat restoration, to complex integration of social and ecological systems across various spatial and temporal time scales. It can be difficult to change management systems accustomed to evaluating a constrained set of objectives, often on a species-by-species basis. Thus, the IEA framework was designed to be flexible and address ecosystem considerations in decision making. For example, the IEA framework was adapted to address species, fleet, habitat, and climate interactions by the U.S. Mid-Atlantic Fishery Management Council as part of their Ecosystem Approach to Fisheries Management plan in 2016 (Muffley et al. this issue).

The IEA approach

The IEA approach can be adapted to meet the goals for an ecosystem as defined by users through six fundamental steps. Each step does not need to be taken to make progress nor do they need to be done in order. Thus, taken together or independently, the steps provide a guidance framework and are displayed in the IEA "loop" (Figure 2). Each step is defined in the Levin et al. (2009) paper, but they are briefly described below to serve as a reference when reading the manuscripts in this special issue.

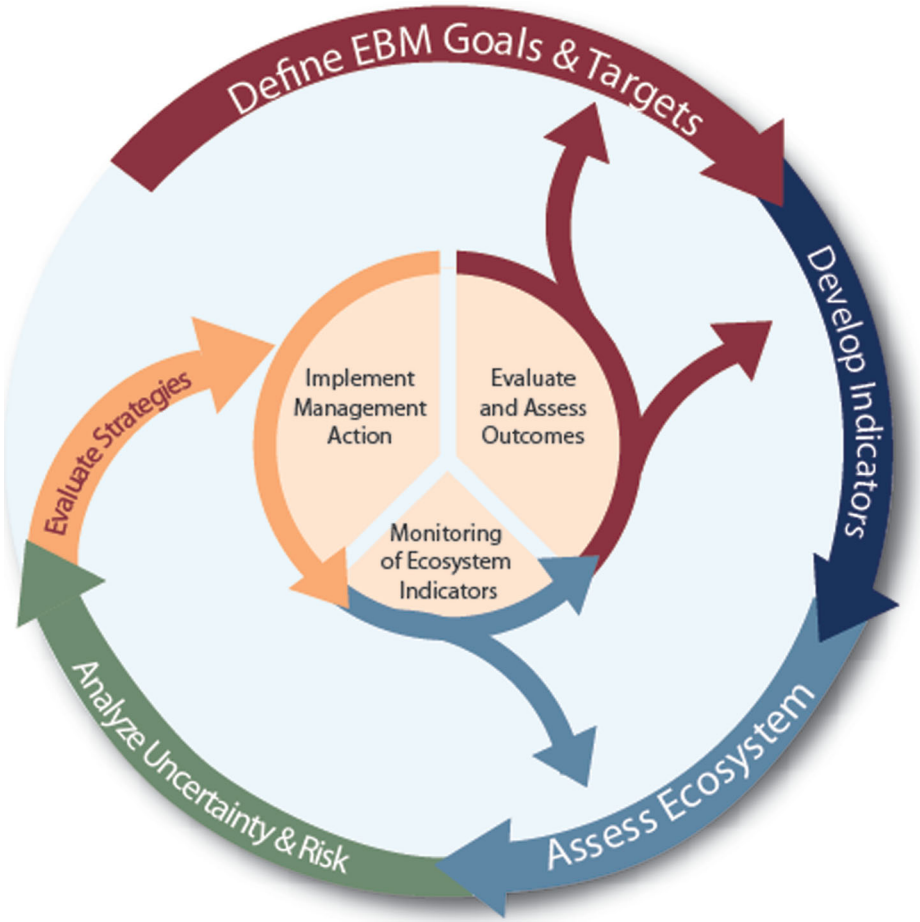

Figure 2. The NOAA Integrated Ecosystem Assessment Approach. NOAA IEA Program, https://www.integratedecosystemassessment.noaa.gov/national/IEA-approach Samhouri et al. 2014.

The first step of the IEA approach is to define the goals for the ecosystem of interest (Levin et al. 2014; Caldow et al. 2015). The IEA approach encourages engagement early and often with relevant managers, stakeholders, and other scientists throughout the entire process, but especially when defining the goals for the ecosystem of interest (deReynier, Levin, and Shoji 2010; Levin et al. 2014). The ecosystem of interest includes relevant ecological, social, and economic characteristics, and their importance to partners and stakeholders. Defining goals provides a way to measure progress, and to achieve those goals it is key to understand the coupled social and ecological systems. A common tool used to define the ecosystem is a conceptual model. Conceptual models are developed through a consensus-based process and include diverse user groups, other stakeholders, managers, and social and natural scientists (Fletcher et al. 2014). Through these interactions participants define the components of the ecosystem (e.g., species, habitats) and characterize the relationships and connections between those components.

The second step of the IEA approach is to identify or if necessary develop indicators for each of the ecosystem components identified in the previous step. Ecosystem

indicators are quantitative biological, chemical, physical, social, or economic measurements that serve as proxies for the condition of ecosystem attributes, such as habitat quality or community composition (Landres, Verner, and Thomas 1988; Kurtz, Jackson, and Fisher 2001; Fleishman and Murphy 2009). Indicators provide a practical means for measuring changes in ecosystem attributes that relate to management objectives (Levin et al. 2011; Brown et al. 2019).

The third step of the NOAA IEA approach is assessing the status of the ecosystem using the previously selected indicators. This is often captured in scientific products such as Ecosystem Status Reports (EAP 2012) that are tailored for specific management needs. The fourth step is to conduct a risk assessment across ecosystem components. Risk assessments help prioritize management action and set the stage for analysis of tradeoffs through management strategy evaluations. Management strategy evaluation is the fifth step of the IEA approach, which evaluates the potential outcomes of management actions (alternative or adaptive) on ecosystem components (natural and human) and identifies tradeoffs within management objectives. Once the optimum management strategy is identified that action is then implemented and the process may start over again while the ecosystem indicators are monitored to determine whether goals have been achieved and whether new goals are necessary (e.g., adaptive management actions).

Key activities and results from the decade-long program using the IEA framework and its guidance steps are presented to disseminate NOAA's collective lessons learned and plans for the future to enhance IEAs. The activities include development of new techniques and approaches for the integration of humans and their well-being into coupled social and ecological systems. Publishing this special issue on IEAs for CMJ provides a suite of papers to facilitate further conversations across the national and international IEA community of scientists and managers to significantly improve our collective capability to utilize the principles of EBM in the conservation, protection, and sustainable use of coastal and marine resources.

Enhancing future IEAs

Several manuscripts in this issue identify and address the challenges to develop, implement, and maintain the IEA program over the last 10-15 years. While the work accomplished by the IEA program is supported by mandates for fisheries stock assessments, marine managed areas, and protected species assessments (e.g., Magnuson Stevens Act, National Marine Sanctuaries Act, Endangered Species Act, Marine Mammal Protection Act), IEAs do not have a standalone mandate. NOAA Fisheries policy on Ecosystem Based Fisheries Management (EBFM) identifies the IEA approach as an appropriate framework to address the guiding principles of EBFM (NOAA Fisheries 2016). Regardless of changing mandates and agency priorities, the need and continued push for IEAs is driven by a clear understanding in the scientific community that a comprehensive and enduring approach is needed to produce robust science to address the complex environmental issues of the day.

The IEA program has achieved incremental successes and some of these results and benefits may not lend themselves to be evaluated with quantitative metrics. The community of scientists involved with IEAs has become close-knit over time, sharing lessons

learned, such that work in each region builds on previous approaches. The cross-disciplinary nature of the work requires individuals to push their own boundaries and develop as scientists. Use of the IEA framework has improved the practice of integrating social science and economics at the start of an assessment, thus expanding the range of ecosystem components included in the assessment process. IEAs have also expanded experience with engaging stakeholders and managers to co-produce conceptual models, define ecosystem goals, and develop potential scenarios to evaluate and build strong and trusted relationships (deReynier, Levin, and Shoji 2010; Levin et al. 2014; Samhouri et al. 2014; Rosellon-Druker et al. 2019).

The perspective gained from those involved in the early development of the IEA program is invaluable and they were asked to provide recommendations for the future of IEAs (Harvey et al., this issue). Many of these recommendations resonate with scientists actively engaged in IEA work around the U.S. These include very broad ideas such as to communicate and collaborate more effectively, to more specific aspects of strengthening connections to the public beyond resource managers in order to increase diversity and reflect the coastal communities that the IEA program serves. Other recommendations reiterate the need to solve issues that have been around since the program began, such as defining what an IEA is (e.g., program, process, products) and whether it has an endpoint, criteria for when a full IEA is needed, and clear ecosystem objectives and reference points. There is also a need to demonstrate ways to measure performance that capture non-quantifiable progress such as building enduring partnerships, breaking down perceptions that approaching problems from an ecosystem perspective threatens existing governance structures, and how knowledge of the coupled social-ecological systems contribute to current and future management practices.

The IEA program moves into a new decade with increasingly complex ecosystem issues on the horizon. Climate change impacts predicted at the turn of the century are occurring now (USGCRP, 2017) and the global oceans are warming, perhaps faster than predicted (Cheng et al. 2019; Lyman et al. 2010). The IEA framework can be used to formulate approaches to address increased pressure on ecosystems in response to environmental and human induced variables from marine heat waves and shifting species distributions that require rapid adaptive management, to increased efforts for aquaculture and offshore renewable ocean energy production. Over the next 10 years the IEA program will work to address high level goals while remaining flexible enough to address emerging themes through shorter term regional implementation plans. These goals include:

- Balancing existing IEA work with requests to expand NOAA IEAs within current and additional geographic regions. This will require a combination of efforts that include expanding partnerships and encouraging other entities (e.g. local and state governments, non-governmental organizations) to adopt the IEA process where possible using existing and future resources.
- Including approaches to evaluate management strategies beyond management strategy evaluations as defined in Levin et al. (2009) and expanding beyond a single species focus in management strategy evaluation.
- Transitioning from static ecosystem status and state of the ecosystem reports to readily accessible and continuously updated IEA products.

Defining success in implementing IEAs can have its challenges. Is it the inclusion of ecosystem concepts developed through the IEA process into management decisions? Or facilitating a fundamental change in the way federal, state, and local agencies manage coastal and ocean resources? As evidenced by the manuscripts that comprise this special issue of CMJ, continued enhancement of IEAs within and outside of NOAA, enables the IEA community to advance EBM of marine ecosystems.

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