Trends of the Large Marine Ecosystem assessment and management approach as reflected in the literature

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ABSTRACT

The advancement and expansion of a scientific field depends on its ability to organize its findings and establish a basis in the professional literature. In late 2015, a review was undertaken to examine the body of literature regarding the Large Marine Ecosystems (LMEs) of the world. Trends in the literature were studied to explore this approach as a means for implementing ecosystem-based management of coastal and marine resources, with the objective of providing guidance for filling gaps in the scientific literature supporting this concept. Since 1995, there has been an increase in the number of peer-reviewed, scientific journal articles related to the LME approach, termed "LME articles." Based on this review, we observed that between 1983 and early 2016, 392 LME journal articles were published. In the examined literature, there is a strong focus on fisheries and fisheries-related considerations and concerns, with 59% of the most relevant journal articles focused on fish or fisheries. Future publications should draw on the experience of past and current LME projects to inform and provide tools for future projects to address the socioeconomic aspects of implementing ecosystem-based management. This review also highlights a connection between investments in LME projects by the Global Environment Facility and the amount of corresponding publications regarding the supported LMEs.

1. Introduction

The advancement and expansion of a scientific field depends on its ability to organize its findings and establish a basis in the literature (Braun et al., 2000). First developed in the early 1980s (Sherman and Alexander, 1986), the Large Marine Ecosystem (LME) approach to the assessment and management of coastal ocean goods and services is supported by a substantial body of literature that advanced application of the approach over the past several decades. Numerous publications have described the growing LME community of practice in developing countries, with the support of multilateral development funds, UN agencies, and NGO's. By 2014, 110 developing countries had applied $3.15 billion in funding catalyzed by the Global Environment Facility (GEF). The GEF is a financial mechanism located within the World Bank to assist developing countries in improving their environmental conditions around the globe. Marine ecosystems provide an estimated $49.7 trillion in ecosystem services each year (Costanza et al., 2014). Many of these services are concentrated in the coastal areas, which are also the most vulnerable to human activities, such as habitat loss, overexploitation, pollution, and climate change (Millennium Ecosystem Assessment, 2005; Crain et al., 2009).

Ecosystem-based management of resources requires international, transboundary cooperation to achieve sustainable management. For example, the Humboldt Current is an important upwelling boundary current supporting one of the world's most productive LMEs (Gutiérrez et al., 2016). Cooperation and coordination in environmental and resource management policies and procedures between Chile and Peru, two countries adjacent to the Humboldt Current, is critical to ensuring the health and stability of this important ecosystem. Another example, the Wider Caribbean region, is one of the most geopolitically complex areas of the world (Fanning et al., 2007), where 26 nation states and 19 territories, ranging greatly in size, are highly dependent on the resources of the Caribbean Sea LME (Fanning et al., 2013). There are numerous institutional arrangements in the Caribbean region for governing the ecosystem. Coordination between these different governance entities, supported by the GEF-funded Caribbean Sea and North Brazil Shelf LMEs (the CLME+ Project), encourages movement towards the sustainable development goals set forth in the Caribbean Sea Strategic Action Programme (Debels et al., 2016).

As a framework for supporting transboundary assessment and

management of coastal and ocean goods and services, the LME concept was developed and introduced at the annual meeting of the American Association for the Advancement of Science in 1984 (Sherman and Alexander, 1986). This approach first established a set of ecological criteria that delineates distinct coastal ocean areas as Large Marine Ecosystems, based on ecological criteria: bathymetry, hydrography, productivity, and trophic interactions (Sherman and Alexander, 1986). The LMEs, which are predominantly coastal, provide 75% of the global marine fisheries yield (Pauly and Lam, 2016). The LME approach includes a methodology for monitoring, assessing, and sustainably managing marine resources within the spatial domain of these regions where they can be subject to management action (Carlisle, 2014). This methodology is based on the temporal and spatial metrics from monitoring and assessing indicators from five LME modules: (i) productivity, (ii) fish & fisheries, (iii) pollution and ecosystem health, (iv) socioeconomics, and (v) governance (Sherman and Duda, 1999). These five modules define suites of indicators that provide structure for the integration of environmental and human dimensions of marine ecosystems, supporting the paradigm shift from single sector management to multidisciplinary and multisectoral ecosystem-based management (EBM) practices (Carlisle, 2014). In a 2005 Scientific Consensus Statement on Marine Ecosystem-based Management, McLeod et al. explain that "Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impact of different sectors." The five modules are a step towards this cumulative approach and the authors identify LMEs as the broadest spatial classification scale for ecosystem delineation and the implementation of EBM (McLeod et al., 2005).

In 1995, ten years prior to the 2005 Scientific Consensus Statement, the GEF adopted the LME approach as the marine component of its International Waters Focal Area, which addresses transboundary water issues globally. Since that time, the GEF and their United Nations agencies have supported projects in 22 LMEs (see Table 1). These projects use the LME approach to implement ecosystem-based management of coastal and marine resources of one or more countries, using the five modules to provide the metrics to support EBM actions (Sherman, 2014). For each LME project, the GEF has mandated the preparation of a Transboundary Diagnosis Analysis (TDA) to reach consensus on assessment and management priorities, and preparation of a Strategic Action Programme (SAP) to operationalize the objectives for mitigation of stressors for restoring and sustainably managing priority issues identified in the TDA (Duda, 2016).

This objective of restoration and sustainability of marine resources aligns closely with the recently adopted United Nations Sustainable Development Goal (SDG) #14 of the 2030 Agenda for Sustainable Development: Conserve and sustainably use the oceans, seas, and marine resources (General Assembly resolution 70/1, 2015). This SDG embodies the vision advanced by the GEF-funded LME projects for the past two decades. In addition to working towards SDG #14, these projects have also delivered measurable environmental and socioeconomic status improvements directly related to the other SDGs, including ending poverty and hunger, ensuring healthy lives, ensuring sustainable consumption, and taking urgent action to combat climate change and its impacts. For example, the Yellow Sea Large Marine Ecosystem (YSLME) Project promoted and advanced sustainable mariculture that achieved better economic yield for farmers, with less impact on the marine environment than traditional methods (UNDP/GEF, 2012). These project results align with the first (End poverty in all its forms everywhere) and twelfth (Ensure sustainable consumption and production patterns) SDGs. The Chinese government has initiated closed seasons in the YSLME and reduced the number of fishing motor boats by 30% (Tang et al., 2016). Similar actions are underway in the Republic of Korea to recover depleted fish stocks (UNDP/GEF, 2009). These actions are intended to prevent further over exploitation for fisheries, which play critical roles in providing food and income in developing countries, thereby contributing to the first, second (End

hunger, achieve food security and improved nutrition and promote sustainable agriculture), twelfth and fourteenth (Conserve and sustainably use the oceans, seas and marine resources for sustainable development) SDGs. An in-depth analysis of the LME approach as an engine for achieving the SDGs is available (GEF LME:LEARN, 2017).

A substantial body of literature captures the knowledge generated through the development and application of the LME concept and its practice. Until now, this literature had not been reviewed in its entirety and in an organized manner. In late 2015, a library was built for "LME articles," that is, articles that include, to varying degrees, the LME concept or a specific LME. After gathering and organizing this library, a literature review was undertaken to understand the progress of this concept through trends in the literature and to identify gap areas where future efforts can be focused.

2. Methodology

2.1. Review questions

Several research questions were developed to guide this review and identify trends in the body of LME literature.

- Is the number of LME articles published annually increasing, decreasing, or staying the same?
- Is there a modular focus in the literature?
- Is there a geographic focus in the literature? If so, does it correspond with GEF investments?
- Are there gaps in the topics covered in the literature that should be addressed in future work?

2.2. Literature search strategy

Literature searches for scientific, peer-reviewed journal articles were conducted in late 2015 and early 2016, using the Web of Science database, the Duke University online databases, and the Google Scholar search engine. Keyword search results for each database/search engine were first screened based on inclusion and exclusion criteria. The full text article was retrieved for each result entry that met these criteria. The *Find* tool was used to check the entire document for keywords. Documents with at least one of the keywords were imported to EndNote, which was used to organize and compile a literature library. These articles will henceforth be referred to as "LME articles."

In addition to peer-reviewed journal articles, eighteen books have been published on the LME approach since 1986 – the LME Volumes. Studies reported in these seminal volumes have provided a growing scientific foundation for practicing the LME Approach to the assessment and management of coastal and ocean goods and services. Each volume consists of a number of chapters ranging from nine to forty-two and has a general focus, typically a geographic range or a topic such as climate change or human dimensions of LMEs. Although they are peer-reviewed, these volumes were not included in the count of LME articles.

2.2.1. Keyword search criteria

The keywords used to search for LME articles were (Large marine ecosystem), (Large marine ecosystems), (LME), and (LMEs).

2.2.2. Inclusion and exclusion criteria

Inclusion and exclusion criteria helped identify the articles relevant to this study.

Inclusion criteria included: i) keywords in the abstract, key words, or the full text of the document at least once, and ii) published between 1983 and present day.

Exclusion criteria included: i) book chapters, ii) dissertations/theses not published in an academic journal, iii) conference papers not published in an academic journal, and iv) not in English. The exclusion of literature in non-English languages is not to imply that these sources are