Large Marine Ecosystems: Their Status and Role in Ocean Governance

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Introduction

As a participant in the Intergovernmental Oceanographic Commission’s (IOC) annual meetings in the 1980s, I remember at one of the sessions a particularly passionate and forceful delivery by Professor Elisabeth Mann Borgese on the need to advance the legal authority for management of the oceans under the terms of the law of the sea. That memorable delivery was later shared with Professor Lewis Alexander, of the University of Rhode Island (URI), who directed the Marine Affairs Program at URI and was a longtime colleague of Professor Mann Borgese. Professor Alexander participated with her in many law of the sea conferences and workshops.

As Director of the US National Oceanic and Atmospheric Administration (NOAA) Fisheries Laboratory at URI’s Bay Campus, I served as a guest lecturer on marine fisheries science in Professor Alexander’s seminar courses and was well aware of his expertise in law of the sea matters. It was in the course of joint study with Professor Alexander that we developed the concept of adapting the management principles from the law of the sea to the assessment and management of large marine ecosystems (LMEs) defined on the basis of four ecological criteria: bathymetry, hydrography, productivity, and trophic linkages. Following an initial period of joint study, Professor Alexander and I convened the Symposium on Variability and Management of Large Marine Ecosystems at the annual meeting of the American Association for the Advancement of Science (AAAS) in 1984. We were invited by the AAAS to prepare a peer-reviewed volume of selected papers from the Symposium that was published by the AAAS and serves as the seminal volume on large marine ecosystems.

1 For maps of the 66 large marine ecosystems (LMEs) globally, see the US NOAA LME Portal, http://lme.edc.uri.edu.
2 K. Sherman and L.M. Alexander (eds.), Variability and Management of Large Marine Ecosystems, American Association for the Advancement of Science (AAAS) Selected Symposium 99 (Boulder, CO: Westview Press, 1986).
Large Marine Ecosystems’ Fusion of Science and Governance

The fusion of the LME approach to the assessment and governance of coastal ocean goods and services evolved and has emerged as a global LME movement during the past three decades. Among the invited speakers to the initial AAAS LME Symposium and contributors to the seminal LME volume was a multidisciplinary cross-section of well-known experts in marine fisheries (M. Sissenwine), marine population dynamics (J. Beddington, N. Dann), marine economics (G. Pontecurvo, F. Christy), oceanography (A. Bakun, N. McCall), as well as marine law and governance (M. Belsky, T. Scully). From the inception of the Symposium in 1984 and forward over three decades of the LME movement to the present, a concerted effort has been directed towards the integration and fusion of natural sciences with social sciences as an essential foundation of the LME approach to ecosystem-based management (EBM). The LME approach is based on the best available science applied to assess changing conditions or states of the environment and major components of the biogeochemical processes to support governance of marine goods and services within the spatial domains of entire LMEs.

The LME approach to assessment and governance is dependent on quantitative metrics from time-series measurements of suites of indicators under the broad umbrella of five LME modules: (i) productivity, (ii) fish and fisheries, (iii) pollution and ecosystem health, (iv) socio-economics, and (v) governance (Figure 1). The metrics of the first three modules are based on natural science data, and the metrics of the last two modules are based on social science metrics. During the intervening 33 years since the initial 1984 LME Symposium, a firm science foundation has been established through the contributions of 450 authors of 18 volumes of LME studies published by AAAS, Westview Press, Blackwell Science, Elsevier Science, the International Union for Conservation of Nature, and several United Nations agencies. In addition, 304 articles on LMEs have been published in marine science journals. An annotated list of volumes and published journal articles was published in 2016.3 The published literature includes results of LME assessments based on the broad umbrella of science-based modular indicators.

The productivity module metrics are based on primary productivity measured as gCm²y⁻¹. The primary productivity drives the trophodynamics of the LME and can be related to the carrying capacity of the ecosystem in relation

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3 E. Kelley, ed., Large Marine Ecosystems of the World: An Annotated Bibliography, NOAA Technical Memorandum NMFS-F/SPO-167 (Silver Spring, MD: National Oceanic and Atmospheric Administration, 2016).
Other biogeochemical indicators of change in LMEs include photosynthetically active radiation, chlorophyll a, zooplankton, and ichthyoplankton and oceanographic conditions including water temperature, salinity, density, circulation nutrient flux, and acidification. Application of satellite derived data is useful for monitoring temperature, chlorophyll, and primary productivity.

The goods and services of LMEs are tightly integrated in the fish and fisheries module. In LMEs, monitoring data on fish and fisheries serve as economic goods and vital trophodynamic services transforming primary productivity to small pelagic fish species, up the food web to mid-size bottom feeders, and on to apex predators, including sharks and marine mammals. Human interaction through overfishing can affect the structure and sustainability of the fisheries, underscoring the need for ecosystem-based adaptive fisheries management.

The pollution and ecosystem health indicators for LMEs include an index to assess the health of coastal ocean waters based on a consideration of LME capacity for (i) food provisioning, (ii) artisanal fishery support, (iii) natural

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4 M.J. Fogarty et al., “Fishery Production Potential of Large Marine Ecosystems: A Prototype Analysis,” Environmental Development 17, no. 1 (January 2016): 211–219.
productivity, (iv) carbon storage, (v) coastal protection, (vi) tourism and recreation, (vii) coastal livelihoods and economics, (viii) clean water, (ix) biodiversity, and (x) multiple marine ecological disturbance. Total dissolved inorganic nitrogen loading from land-based sources of nutrient over-enrichment can lead to extreme conditions of oxygen deficiencies in LMEs and formation of dead zones.

It is the socio-economics module wherein the programmatic application of scientific findings are applied in decision-making, including the results of time-series monitoring of LME productivity, fish and fisheries, pollution and ecosystem health, and habitat conditions (e.g., sea grasses, corals, mangroves). Integration of social and economic indicators is factored into management decisions for recovery, development, and sustainability of LME goods and services. The socio-economics dimension of LME management is critical to the global economy and well-being. An estimated 80 percent of the global marine fishery catch is produced annually in the world’s LMEs.

The total goods and services within the spatial domains of the world’s LMEs contribute an estimated US$12.6 trillion annually to the global economy. To respond and manage adaptively to changing ecological conditions, socio-economic considerations in operationalized LME projects are being closely integrated with science-based assessments designed to monitor LMEs at appropriate spatial and temporal scales to implement ecosystem-based management practices.

**Governance Module V**

The application of the science-based assessment modules has evolved over three decades. Those of us engaged in the development of the LME approach to the assessment and management of coastal ocean goods and services were

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5 B. Halpern et al., “Ocean Health Index for the World’s Large Marine Ecosystems,” in *Large Marine Ecosystems: Status and Trends*, IUC-UNESCO and UNEP (Nairobi: United Nations Environment Programme, 2016), 239–249.

6 B.H. Sherman, “Multiple Marine Disturbance Assessments for Latin American and Caribbean Large Marine Ecosystems,” *Environmental Development* 22 (June 2017): 129–142.

7 A.M. Duda, “Strengthening Global Governance of Large Marine Ecosystems by Incorporating Coastal Management and Marine Protected Areas,” *Environmental Development* 17, no. 1 (January 2016): 249–263.

8 V. de Barros Neto et al., “Two Decades of Inter-governmental Collaboration: Three Developing Countries on the Move towards Ecosystem-Based Governance in the Benguela Current Large Marine Ecosystem,” *Environmental Development* 17, no. 1 (January 2016): 353–356.
acutely aware that we were among those in the marine science community undertaking a paradigm shift. The shift from single species and single sector focused management actions to multispecies and multisectoral ecosystem-based management was seen as a more effective strategy for moving toward sustainable development of the oceans.

The changeover movement towards EBM in the United States had its origins with the Stratton Commission Report that argued for establishment of a cabinet level organization to consolidate and oversee US ocean activities. Professor Alexander was active in drafting the Stratton Commission Report. He believed that reorganization of the federal government for advancing a national oceans agenda and principles of the law of the sea was desirable and practical. In this regard the legal opinions of Martin Belsky, as published in several LME volumes, supported the legal status of LMEs as an ecologically defined domain for implementing EBM practice.\(^9\) When Professor Alexander and I conceived of the LME approach in 1983, we were in step with a growing movement towards an ecosystem-based governance system. I had been drafted from my plankton research in the National Marine Fisheries Service (NMFS) in the early 1970s to serve on a planning group in NMFS’s Washington, DC, headquarters to plan a conversion to multidisciplinary fishery science for the entire NMFS as a national Marine Research Monitoring, Assessment, and Prediction program (MARMAP).

I returned from NMFS headquarters following the two-year (1970–1972) effective transition from individually operating NMFS laboratories around the United States to a formally organized national system of four fisheries science centers. The Northeast Fisheries Science Center, Southeast Fisheries Science Center, Southwest Fisheries Science Center, and Northwest and Alaska Fisheries Science Center were merged into the newly established NOAA in 1970. The MARMAP program was described for implementation as a groundfish monitoring component modeled after the US Northeast Continental Shelf groundfish monitoring program at the NEFSC and an oceanographic–ichthyoplankton/zooplankton monitoring program modeled after the California Comparative Fisheries Investigation (CALCOFI). Both activities were incorporated into a long-term assessment of the changing conditions of the US Northeast Continental Shelf LME extending 260,000 km\(^2\) from the Gulf of Maine to Cape

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\(^9\) M.H. Belsky, “Legal Regimes for Management of Large Marine Ecosystems and their Component Resources,” in *Large Marine Ecosystems: Stress, Mitigation and Sustainability*, eds., K. Sherman, L.M. Alexander and B.D. Gold (Washington, DC: AAAS, 1993), 227–236.
Hatteras. It was largely from this experience that the MARMAP program served as the precursor to the global LME approach.

In 1993 I was invited by the Global Environment Facility (GEF) to brief them on the LME approach. The GEF provides financial support to economically developing countries that are committed to improving their environment, including sustaining the goods and services of LME. In 1995 the GEF adopted the LME approach in their operational program as a means to introduce and support EBM practices for developing coastal countries around the globe. Since these initiatives, NOAA has been providing scientific and technical assistance to the development and implementation of 22 LME-based EBM projects in Africa, Asia, Latin America, Eastern Europe, and the Pacific. The GEF support for advancing the LME approach to sustainable development of the oceans is consistent with the statements of world political leaders made at three global environmental summits (1992 United Nations Conference on Environment and Development; 2002 World Summit on Sustainable Development; 2012 Rio +20) and the United Nations commitment in 2015 to the Sustainable Development Goal for the oceans (SDG 14).

**GEF and LME Governance Strategy Supporting Ocean Sustainability**

The commitment of the GEF is in keeping with Professor Mann Borgese's idea of international peace and order through the oceans. One can view it as a tangible expression of the community of nations contributing substantial amounts of financial support to economically developing countries to empower their people in a global effort to advance sustainable development of LMEs along their coasts. Since 1995, 110 countries have been provided with US$3.15 billion in catalytic financial support from the GEF and its co-financing partners for the planning and implementation of EBM practice in LMEs. This global movement is consistent with the goal and targets of the SDG14 practice of EBM in LMEs. This practice is based on a governance regime that is in keeping with the country-driven proposition of bottom-up solidarity in joint planning of a transboundary diagnostic analysis (TDA). It uses science-based methods for addressing the complex interactions among the physical, biological, and human systems that comprise these ecosystems.
determining the priority of ecosystem issues to be addressed by the participating countries planning and implementing GEF supported LME projects. The TDA phase is followed by the policy-driven Strategic Action Programme (SAP) to be implemented over an initial typically five-year operational phase. In some cases, the GEF will support successful SAPs for several multi-year cycles into a self-financing sustainable project future. The TDA and SAP processes serve as a bottom-up governance approach to reach consensus in prioritizing stressors to be mitigated by countries sharing the goods and services of LMEs wherein they join together in moving towards ecosystem-based governance practices. The movement is multidisciplinary in strategy and multisectoral in operation across the five modules (Figure 1) and major socio-economic sectors, namely, fishing, energy, tourism, shipping, and mining.

From a philosophical perspective, the LME approach is in keeping with Professor Mann Borgese’s ocean vision for the “making of a new integrated order based on new forms of international cooperation and organization.”13 Countries have shown a willingness to come together for the common purpose of developing and sustaining their shared LME goods and services across national boundaries within the spatial domain of ecologically defined LMEs of the world. The world’s first LME governance Commission and Convention was established by the three nations sharing the goods and services of the Benguela Current LME, namely, Angola, Namibia, and South Africa. The Commission was established in 2007 and the Convention for the Benguela Current LME was ratified by the three countries in 2014.14 Together they reflect a new way of ocean governance that is very much in keeping with Professor Mann Borgese’s philosophy wherein the common ocean interests bind countries together in peaceful pursuit of socio-economic benefits on behalf of their people.

13 E. Mann Borgese, The Future of the Oceans: A Report to the Club of Rome (Montreal: Harvest House, 1986).
14 De Barros Neto et al., supra note 8.