Environmental Development 11 (2014) 19–42

Contents lists available at ScienceDirect

Environmental Development

journal homepage: www.elsevier.com/locate/envdev

The Large Marine Ecosystem approach: Application of an integrated, modular strategy in projects supported by the Global Environment Facility ☆

Keith M. Carlisle *

Koror State Legislature, P.O. Box 116, Koror State, Republic of Palau

ARTICLE INFO

Keywords:
Large Marine Ecosystem
Ecosystem-based management
Transboundary waters
GEF

ABSTRACT

This paper describes the utility and application of a methodology for monitoring, assessing and managing Large Marine Ecosystems (LMEs) that has been applied in projects receiving financial assistance from the Global Environment Facility (GEF) over the last two decades. In particular, the paper focuses on practical integration of the methodology, known as the Large Marine Ecosystem approach (or simply LME approach), into diagnostic and strategic planning documents required by the GEF on collaborative projects to restore and manage LMEs. Examples from several successful LME projects are provided to highlight how this methodology has been adapted and integrated by countries into LME strategic programs and project operation. This paper demonstrates that the LME approach not only provides a useful framework for holistic, ecosystem-based assessment and management of transboundary marine ecosystems but also complements GEF guidance and requirements for monitoring and evaluation on projects in its International Waters focal area.

* Tel.: +680 775 1035; fax: +680 488 3655.
E-mail address: mclaincarlisle@gmail.com

2211-4645/$ - see front matter © 2014 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.envdev.2013.10.003

1. Introduction

The Large Marine Ecosystem approach is a methodology for monitoring, assessing and sustainably managing marine resources whereby information reflecting the changing health and condition of a marine ecosystem's environmental and human elements guides the adoption of policy and management actions through an adaptive approach. At the core of the approach are five focal areas, referred to as modules, which provide a framework for monitoring, evaluating and integrating the environmental and human dimensions of the ecosystem. They are: (i) productivity; (ii) fish and fisheries; (iii) pollution and ecosystem health; (iv) socioeconomics; and (v) governance (Sherman and Duda, 1999). Section 3 of this paper examines the scope of the five modules, the first three of which are based upon natural sciences while the last two are based upon social sciences and human dimensions of ecosystems.

Integral to the Large Marine Ecosystem approach, developed by Kenneth Sherman of the U.S. National Oceanic and Atmospheric Administration (NOAA), is its focus on ecologically-defined, rather than politically-defined, regions of the ocean (Sherman, 1999). The regions, known as Large Marine Ecosystems (LMEs), were first delineated in 1984 by Dr. Sherman and Lewis Alexander of the University of Rhode Island, based upon four distinct characteristics: bathymetry, hydrography, productivity and trophically dependent populations (Sherman and Alexander, 1986). As the name suggests, LMEs are relatively large, on the order of 200,000 km^2 or greater, and generally extend from coastal areas to the seaward boundaries of continental shelves and the outer margins of major coastal currents (Duda and Sherman, 2002). At present, 64 LMEs are recognized globally.

LMEs include the most productive regions of the ocean and account for approximately 80% of the world's marine fisheries catch (Sherman et al., 2009). By one measure, they contribute an estimated US$12.6 trillion (1997 dollars) in market and non-market ecosystem goods and services annually to the global economy (Costanza et al., 1997). Owing to their location along the coastal margins of continents, LMEs are also heavily impacted by development, overfishing, nutrient over-enrichment, invasive species and pollution. Sixty-nine percent of all LMEs occupy the territorial waters and exclusive economic zones (EEZs) of two or more countries. As a result, problems of environmental degradation affecting LMEs frequently extend across jurisdictional boundaries and cannot effectively be addressed without multinational collaboration. To that end, the Global Environment Facility (GEF), an international financial mechanism, has provided financial assistance since the mid-1990s to collaborative, country-driven projects to restore degraded LMEs (Hume and Duda, 2012). In this context, the LME approach has been utilized by countries on GEF-assisted projects in developing comprehensive programs to assess, restore and manage marine resources. As described in Sections 5 and 6 below, the LME approach provides a useful and appropriate framework for developing diagnostics and strategic programs on GEF-supported LME projects and for monitoring and assessing the changing conditions of LMEs during implementation of agreed multi-country programs.

2. The shift to ecosystem-based management

The LME approach supports what is known as “ecosystem-based management,” also commonly referred to as “the ecosystem approach” to marine resources management. As described by Jane Lubchenco, NOAA Administrator, ecosystem-based management represents a shift from a highly focused, single species or short-term sectoral approach to a more comprehensive, longer-term, place-based approach (Lubchenco, 1994). Underlying this approach is the recognition that long-term use and enjoyment of marine resources require the maintenance of healthy and intact ecosystems. In practice, this entails consideration of the cumulative impacts of multiple uses and sectors on ecosystem functioning, and the complex interactions between different ecosystem components, which in turn necessitates intersectoral cooperation, planning and management based upon sound science.

The ecosystem approach has emerged in the last three decades as the favored paradigm for managing human activities that utilize or impact living resources, both terrestrial and marine. The first global convention to adopt the ecosystem approach was the 1980 Convention for the

Conservation of Antarctic Marine Living Resources (CCAMLR) (Wang, 2004a). Subsequently, the Rio Declaration accepted at the 1992 United Nations Conference on Environment and Development (known as the Rio Earth Summit) called on nations to use the ecosystem approach in order to conserve, protect and restore the health and integrity of the Earth (Rio Declaration on Environment and Development, 1992). The Convention on Biological Diversity, which also emerged from the Rio Earth Summit, adopted the ecosystem approach as the framework for implementing and achieving its objectives (CBD, 1992). Shortly thereafter, the GEF, in its original 1995 Operational Strategy, adopted the ecosystem approach as a central objective in each of its focal areas, including International Waters. The GEF continues to promote the ecosystem approach through its support of country-driven initiatives that develop integrated, multisector solutions to address environmental concerns. More recently, representatives at the 2012 Rio+20 Convention reaffirmed international support for the ecosystem approach and added a commitment in the outcome document to apply the ecosystem approach in managing activities that impact the marine environment (The Future We Want, 2012).

In the U.S., the privately funded Pew Oceans Commission and the U.S. Commission on Ocean Policy each endorsed ecosystem-based management (Pew Oceans Commission, 2003 and An Ocean Blueprint for the 21st Century, 2004), and the Obama Administration adopted ecosystem-based management as a foundational principle in its proposed National Ocean Policy (Executive Order 13547, 2010). The ecosystem approach also enjoys broad support in academia. In fact, more than 200 scientists and policy experts at U.S. academic institutions endorsed ecosystem-based management in a Scientific Consensus Statement released in 2005 (McLeod et al., 2005). The authors of the statement also recognized LMEs as an appropriate spatial unit for ecosystem-based management, and they cited the importance of integrating ecological, social, economic and institutional perspectives in implementing ecosystem-based management. These elements are embodied in the LME approach.

3. The five modules of the LME approach

3.1. *Overview of the modules*

The core of the LME approach consists of five modules that comprise the five broad areas of consideration that are fundamental to ecosystem-based management of LMEs. As described more fully in the following sections, the first three modules are based upon natural sciences or the environment while the last two modules are grounded in social sciences and the human dimensions of an LME.

3.1.1. *Productivity module*

The productivity module concerns the base of marine food webs: primary productivity (i.e., phytoplankton) and zooplankton, which constitute the next trophic level up from phytoplankton. Both of these components can be related to a marine ecosystem's carrying capacity for commercial fisheries and other forms of marine biodiversity. In this regard, primary productivity provides the initial level of carbon production to support marine life, and zooplankton serve as prey for larval stages of fish and the principal food source for forage species like mackerel and herring (Duda and Sherman, 2002). It follows that shifts in productivity, such as from climate change, can result in the diminishment or migration of important commercial fisheries and other elements of biodiversity (Sherman et al., 2010b). Phytoplankton are also a fundamental component of the global carbon, oxygen and nitrogen cycles and can significantly influence trophic food-web dynamics and ecosystem health (Ecosystem Assessment Program, 2012). Indeed, measurements of productivity serve as indicators for the growing coastal problems of eutrophication and harmful algal blooms, which affect ecosystem health, human health and socioeconomics (Sherman et al., 2009). Productivity is therefore an extremely important driver of marine ecosystems, and measuring its rate ($g\,C/m^2$/year) and biomass, identifying its species composition and understanding its dynamics are essential for understanding the health and changing states of an LME.

3.1.2. Pollution and ecosystem health module

The health of a marine ecosystem is tied to numerous factors, including its resilience and its maintenance of metabolic activity level, internal structure and internal organization over relevant time and spatial scales (Costanza, 1992). Given the many considerations related to ecosystem health, it should be no surprise that the pollution and ecosystem health module is extremely broad. It concerns not only marine pollution and contaminants, but also any other indicators or issues related to marine ecosystem health that are not covered by the other modules. Pollution, while clearly a factor that impacts ecosystem health, is specifically referenced in the module because it has been a principal driving force in changes of biomass yields in several LMEs (Sherman et al., 2009). Other common concerns that fall within the scope of the module are marine habitat integrity, emergent diseases, invasive species, eutrophication and harmful algal blooms. The broad scope of the pollution and ecosystem health module ensures that the LME approach will remain relevant as new issues affecting ecosystem health emerge over time.

3.1.3. Fish and fisheries module

Broader than its name suggests, this module concerns not only the abundance and health of commercially important fish and shellfish, but also the biodiversity and dynamics of their competitors, prey and predators (Sherman et al., 2009). Fisheries merit special consideration in the LME context because of their economic value, cultural importance and contribution to the nutritional requirements of growing coastal populations. The collapse of a commercially important species may impact more than human welfare, however. Changes in the biodiversity of fish communities can have cascading effects up and down marine food webs, affecting both apex predators and plankton (Pauly and Christensen, 1995). For this reason, general biodiversity issues may be addressed within the context of the fish and fisheries module.

3.1.4. Socioeconomics module

The socioeconomics module is perhaps less well developed than the three natural science modules and therefore warrants a more thorough discussion. The socioeconomics module concerns the value of ecosystem goods and services provided by an LME to human populations as well as other measures of human well-being associated with the use and health of the LME. Ecosystem goods and services are the benefits that humans derive, directly and indirectly, from the functioning of ecosystems (Costanza et al., 1997). Economists often refer to ecosystem goods and services collectively as "ecosystem services," and they typically categorize them into four types: (i) *provisioning services*, which provide goods such as seafood, genetic resources and other products that depend on healthy, intact ecosystems; (ii) *regulating services*, which maintain environmental quality (e.g., water quality regulation and disease regulation); (iii) *cultural services*, which provide non-material benefits such as spiritual, esthetic and recreational amenities; and (iv) *supporting services*, such as primary production and nutrient cycling, without which other ecosystem services could not be sustained (UNDP/GEF, 2009).

In valuing ecosystem services, economists recognize a number of categories of value that correspond to the ways in which humans benefit from an ecosystem. For purposes of this discussion, however, they can be collapsed into the two main categories: (i) *use value*, which is the benefit one receives from direct or physical use of a resource, such as the harvest of fish or the use of a beach; and (ii) *non-use* or *passive use value*, which is the benefit one might receive from merely knowing that an ecosystem like a coral reef exists or from having the option to use or visit a resource in the future. The sum of all use and non-use values is referred to as *total economic value*. Calculating total economic value for ecosystem services can be difficult given that most are not traded or captured in commercial markets. Economists have developed techniques, however, for estimating their value, such as contingent valuation and hedonic pricing. Guidance on these techniques is beyond the scope of this paper, but readers wishing to learn more about them are directed to the GEF's IW:LEARN website, which has posted several resources that explore these techniques further.[1]

The socioeconomics module also concerns other measures of human well-being related to the use and enjoyment of LME resources, including measures relating to distribution and equity. Thus, issues

[1] See, e.g., *Guideline for Economic Analyses of Environmental Management Actions for the Yellow Sea.* Available from: ⟨http://iwlearn.net/news/iwlearn-news/new-publication-from-unep-gef-yslme-project-guideline-for-economic-analyses-of-environmental-management-actions-for-the-yellow-sea⟩.

of poverty, conflict, education, employment, food security and disease associated, at least in part, with the health of, or access to, LME resources are relevant to the socioeconomics module. As recognized in the Plan of Implementation of the World Summit on Sustainable Development, social development, economic development and environmental protection are interdependent and mutually reinforcing (Johannesburg Declaration, 2003). Addressing issues that relate to poverty is therefore essential to achieving sustainable use and management of natural resources.

3.1.5. Governance module

Like the socioeconomics module, the governance module pertains to the human dimensions of an LME. Specifically, it concerns the formal and informal arrangements or mechanisms that influence human behaviors having a material impact on an LME and its resources. Although we traditionally think of laws, policies and institutional arrangements in this context, governance also includes market forces and cultural norms that affect how humans interrelate with an LME (Juda and Hennessey, 2001). Governance arrangements exist at multiple, often overlapping, scales, from local to international. Countries engaged in collaborative efforts to manage LME resources should develop a clear picture of the interrelated drivers or influencers of human activities that impact the LME in order to identify the root causes of environmental degradation and to formulate effective strategic interventions.

In the context of marine resource management, governance institutions, policies and laws have traditionally been focused on single uses or sectors. However, the shift to ecosystem-based management requires integration of, and/or coordination among, sector-focused arrangements. For multinational LME projects, where partnering countries may have unequal levels of economic development and scientific capacity as well as contrasting social and political systems, achieving the necessary level of coordination and cooperation may be challenging. Nevertheless, there have been some notable achievements in this regard on GEF-assisted LME projects.[2]

3.2. Aspects of the modular framework relevant to GEF-supported Projects

3.2.1. An accommodating framework

In GEF-supported LME projects, collaborating countries conduct joint diagnostics and prepare strategic plans to identify priority concerns, immediate and root causes, objectives and potential interventions. In the context of these documents, the modules provide a logical thematic framework for describing and analyzing the environmental and human dimensions of an LME. Each of the modules is quite broad in scope and represents an essential area of consideration for initiatives to restore and sustainably manage an LME. A thorough examination of an LME's characteristics corresponding to each of the modules provides a sound basis for identifying or substantiating transboundary problems and their causes and impacts.

While many typical LME problems correspond naturally to a single module for organizational purposes (e.g., the correspondence between the problem of unsustainable fishing and the fish and fisheries module), others cut across multiple modules and could be addressed under more than one module. Biodiversity loss, for example, is a concern that is common to a number of LME projects currently underway. While there is no single module dedicated solely to biodiversity under the LME approach, biodiversity issues could be addressed under any of several modules. The fish and fisheries module, for example, would be a logical choice because it encompasses not only changes in the biodiversity of commercially exploited finfish and shellfish, but also the impacts of such changes on other species in marine food webs (e.g., marine mammals and seabirds). Alternatively, biodiversity could be addressed under the pollution and ecosystem health module, as biodiversity is an important contributor to ecosystem functioning and is an indicator of ecosystem health. A third approach would be to divide biodiversity into functional or thematic categories and to address these categories of

[2] For example, as discussed in greater length in Section 6.5.2 below, the Benguela Current LME countries formed the first LME Commission, known as the Benguela Current Commission, to enhance coordination among the countries and to support project initiatives including implementation of the regional BCLME Strategic Action Program.

biodiversity under separate modules. Biodiversity of planktonic communities could thus be addressed under the productivity module, while marine habitat, such as coral reefs, mangroves and seagrasses, could be addressed under the pollution and ecosystem health module. All other categories of biodiversity would then fall under the fish and fisheries module as components of marine food webs. Any of these approaches would be an appropriate application of the modules from an organizational perspective.

The foregoing example illustrates an important point concerning the LME approach: it is not prescriptive. It recognizes that each LME is unique and that the most successful efforts to restore and manage marine resources occur when countries adapt the modules to fit their needs. This is true not only for how the countries represent their efforts in project documents, but also for how they choose and prioritize their objectives and implement their strategic plans. On the other hand, there are fundamental issues and considerations common to all LMEs, and the LME approach requires that they be a part of any comprehensive strategy for assessing and managing marine resources. These fundamental commonalities are represented by the five modules, but the modules are broad enough and adaptable enough to accommodate cross-cutting issues and innovative, country-driven programs.

3.2.2. Measurable indicators and adaptive management

It should be stressed that the modules represent much more than a template for organizing LME plans and programmatic documents. More importantly, they serve an essential role in relation to determining the status and trends of ecosystems. In this regard, each module may be thought of as representing a suite of measurable indicators that are selected to provide reliable information on the status of a module's focal area (Sherman et al., 2009). The indicators are essentially metrics or statistics that are representative of a particular aspect of an ecosystem. Through systematic measuring or monitoring of the indicators, time series are developed that reveal the changing states of an ecosystem. A further discussion of GEF indicators is found in Section 6.4 of this document. Analysis of time series data allows managers to identify areas of the ecosystem in need of management action as well as the effectiveness of management actions already in place. While this strategy may seem more applicable to the three natural science modules, it is also very useful to develop indicators for the socioeconomics and governance modules in order to understand how changes in the natural environment affect economic benefits and other measures of human welfare and whether institutional arrangements are advancing towards an ecosystem approach.

It must be stressed that the process of monitoring and evaluating indicators described above is critical to ecosystem-based management because it provides a basis for determining the extent to which progress towards a project's objectives are being achieved. This, in turn, supports an adaptive management approach, which entails periodic assessment of results and adjustment of management actions and strategies when necessary to meet objectives. The development of time series information and the practice of adaptive management are integral components of the LME approach (Sherman et al., 2009).

3.2.3. Interdependence of modules

A final point is that the modules are not independent of one another. Indeed, a change in the status of one will very likely impact the others. The productivity module, for example, is directly related to an ecosystem's carrying capacity. If productivity were to drop for a prolonged period, the biomass and structure of fish communities would be impacted. A decrease in productivity would also signal a potential issue with pollution and ecosystem health (e.g., the immediate cause could be contaminant pollution). To the extent commercially important fish stocks decline as a result of the drop in productivity, the livelihoods of fishermen and the health of coastal populations could also be affected. Finally, tracing the drop in productivity back to its root cause could reveal institutional gaps or weaknesses, suggesting the need for governance reform. This very simplistic example illustrates how a change in the status of one module impacts all the others.

Similarly, strategies to address a single LME concern typically require consideration of multiple modules. If, for example, LME countries wish to focus on dwindling fish catches, a comprehensive strategy might include not only addressing fishing effort, but also identifying, monitoring and/or understanding changes in productivity and water quality; critical habitat; predator, prey and competitor interactions; availability of alternative livelihoods for fishermen; the costs and potential benefits of management options; and necessary policy and governance reforms. The foregoing list is hardly exhaustive, yet it implicates all five modules.

The modules are also interrelated in a very practical way: a single indicator may provide useful information for multiple modules. For example, fish caught through standardized sampling procedures serve as useful indicators for both the fish and fisheries module (e.g., to provide stock assessment information and information concerning changes in fish communities) and for the pollution and ecosystem health module (e.g., to serve as monitors for pathological conditions associated with coastal pollution). Indicators of photosynthetic activity for the productivity module also serve as indicators of eutrophication, harmful algal blooms, or climate change driven shifts in upwelling regimes for the pollution and ecosystem health module. Finally, a wide range of indicators from the natural science modules and the socioeconomics module could conceivably be used as indicators to determine the effectiveness of specific governance mechanisms (i.e., to determine whether governance reforms have resulted in desired changes in management and ecosystem status).

The important takeaway point is simple: the modules are strongly interdependent. Therefore, when collaborating countries seek to address issues of environmental degradation, they cannot simply focus on a single use, sector, institutional arrangement or environmental parameter. They must consider how all of these elements interrelate and impact one another in determining the causes of a transboundary problem and in developing strategic interventions to address it. This is the essence of holistic, ecosystem-based management.

4. The Global Environment Facility

4.1. Support for LMEs

The GEF emerged from the Rio Earth Summit in 1992 and was restructured after a three-year pilot phase. The GEF's mandate is to provide catalytic funding to developing and economically transitioning countries to allow them to address global environmental concerns in any of six areas: (i) biodiversity loss, (ii) climate change, (iii) degradation of international waters, (iv) ozone depletion, (v) persistent organic pollutants, and (vi) land degradation (Duda and Sherman, 2002). According to the GEF's 1995 Operational Strategy, the goal of the International Waters focal area is the promotion of collective management for transboundary freshwater and marine systems and the implementation of reforms and investments to ensure sustainable use and maintenance of ecosystem services (GEF, 1995a). Significantly, the GEF Council adopted the concept of LMEs in the 1995 Operational Strategy as a program area for promoting the ecosystem approach in its International Waters focal area.

The commitment to LMEs by the international community has been remarkable. According to a report compiled by NOAA's Large Marine Ecosystem Program in 2010, GEF-supported projects that benefited LMEs received $3.1 billion in financial support during the period 1995–2009 (Sherman et al., 2010a). Another roughly $1 billion in funding has been committed to LME-related projects during the GEF's fifth funding cycle, covering the period 2010–2014 (Sherman et al., 2010a). Both figures include not only catalytic funding from the GEF in the form of grants, but also investment funds (loans) from the World Bank and substantial co-financing funds from the countries themselves and other international partners. At present, 110 GEF recipient countries and 20 non-recipient countries are collaborating on projects involving 23 of the world's 64 LMEs (Hume and Duda, 2012). These GEF-supported projects are implemented through partnerships with one or more U.N. agencies, including the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), the World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Industrial Development Organization (UNIDO) (Hume and Duda, 2012). Additionally, at the project level numerous intergovernmental organizations, non-governmental organizations and community-based organizations actively participate in the execution of project initiatives (Chazournes, 2005).

4.2. The GEF project cycle

In order to secure financial assistance from the GEF, the first step after LME countries have identified a project opportunity is to work with GEF agency partners to prepare a Project Identification Form (PIF) and a Project Preparation Grant (PPG) request in consultation with the GEF (GEF, 2011). If the GEF clears the PIF and approves the PPG, the LME countries prepare a more detailed Project Document with limited financial assistance from the GEF. Once the agency and the GEF approve the Project Document, the countries receive additional funding and proceed to the first major phase of project development, the Transboundary Diagnostic Analysis (TDA).

The TDA is a joint fact-finding process undertaken by the countries to identify and prioritize major transboundary water concerns and to determine their impacts and root causes (Wang, 2004b). The development of a TDA should be based upon the best available scientific, socioeconomic and technical information. Teams of experts, usually referred to as Technical Task Teams, are established to assist with this process (UNIDO/GEF, 2011). It must be acknowledged, however, that LME countries commonly lack sufficient information upon which to base strategic action and often do not have the capacity or funding to develop missing information prior to TDA finalization. Where additional information is required to fully evaluate concerns and develop management strategies, this need not necessarily delay TDA finalization. Instead, the TDA should make clear reference to any information deficit, and the countries should plan to fill the gaps as best possible during the next major phase of a project, the development of a Strategic Action Programme (SAP).[3]

The TDA must also clearly indicate which of the identified concerns are transboundary in nature, as the GEF only funds the portion of LME initiatives that produce global, or transboundary, benefits. In GEF parlance, the covered costs are referred to as "incremental costs" (GEF, 1995a). All other costs (i.e., those associated with achieving benefits only at a national level) are supposed to be borne entirely by the countries themselves (GEF, 1995a). Transboundary concerns for the GEF's purposes include transboundary issues with national causes; regional or national issues with transboundary causes; national issues that are common to at least two countries and require a common strategy and collective action to address; and issues that have transboundary elements or implications (Wang, 2004b).

The TDA provides the scientific and factual basis for the SAP, which in very basic terms is a joint program of action among LME countries that describes national and regional reforms, strategies and funding plans required to fulfill LME long-term sustainability objectives (Duda and Sherman, 2002). The SAP represents a political commitment of the governments concerned to accept agreed management principles and to implement agreed actions that are based upon scientific evidence of key drivers and changing conditions in the LME. The actions are developed by each country and are ultimately compiled and agreed upon by all countries in a negotiated SAP. Very often, countries also develop individual national action plans, referred to as NAPs, which generally describe the commitments that a country makes in response to the multi-country SAP (Duda, 2002).

A SAP should reflect a more integrated, ecosystem approach and incorporate an adaptive management regime informed by continuous monitoring and evaluation of measurable indicators (GEF, 1995b). Additionally, in accordance with Principle 15 of the Rio Declaration, the SAP should embody the precautionary approach, which recognizes that scientific uncertainty is inevitable but should not be grounds for postponing cost-effective measures to prevent serious or irreversible environmental degradation (Rio Declaration on Environment and Development, 1992). Thus, the lack of complete scientific information should not stall countries' efforts to address serious transboundary concerns.

In terms of process, stakeholder involvement is crucial to both TDA and SAP development (GEF, 1995b). For this purpose, stakeholders include not only government agencies but also members of the public, non-governmental organizations, academia and representatives of the sectors that place stress on the LME (Wang, 2004b). Stakeholders offer additional, often anecdotal or based on traditional

[3] See, e.g., the report appended to the TDA for the Benguela Current LME project concerning oceanography and variability, which identifies gaps in knowledge and understanding. Shannon, L.V. and O'Toole, M.J. Synthesis and Assessment of Information on the Benguela Current Large marine Ecosystem (BCLME), Thematic Report No. 2, Integrated Overview of the Oceanography and Environmental Variability of the Benguela Current Region. See also Table 18 in the TDA for the Yellow Sea LME project, which lists data gaps relating to the Yellow Sea ecosystem.

knowledge, information concerning the uses and health of the LME as well as perspectives that can help the project team identify potential constraints on action. Creating a dialogue and shared vision with stakeholders fosters ownership of project initiatives, bolstering public support and increasing the likelihood of success.[4]

Given that LME projects are intended to be country-driven initiatives applying an adaptive management approach, the GEF has not produced a prescriptive list of elements that must be incorporated in every TDA and SAP. However, in the late 1990s the GEF and its agencies collaboratively prepared generic guidance and associated curricula describing the TDA and SAP processes which were applicable to both marine and freshwater systems; this guidance has been used by many GEF LME and shared freshwater system projects over the years. Nevertheless, there are differences in the contents, structure, terminology and general approach of published TDAs and SAPs. Not all projects, for example, have incorporated the modular LME approach, though as described in Sections 5 and 6 below, some of the most successful projects have utilized the five modules. The failure of some projects to incorporate the LME approach may be due, in part, to a lack of practical guidance concerning integration of the five modules into TDAs and SAPs. In response to this gap, the GEF, through its IW:LEARN programme, is presently conducting an update of the TDA/SAP guidance, which will address this issue, among others. The remainder of this paper describes the core elements of TDAs and SAPs and explains, in practical terms, how the five modules may be incorporated into the documents. Examples from several LME projects are provided to illustrate different approaches to TDA and SAP formulation.

5. The transboundary diagnostic analysis

5.1. Key elements

Notwithstanding the variety of approaches to TDA formulation, a core of fairly essential elements appears in many, if not most, TDAs. It consists of:

(i) *a description of the LME and its significance*, which summarizes not only the physical and biological characteristics of an LME (e.g., geographic boundaries, currents, major water masses and species groups), but also the human dimensions of the LME, including the major sectors and stakeholder groups that impact or rely upon its resources;
(ii) a *characterization of transboundary concerns*, which describes the major LME problems identified in the joint fact-finding process and evaluates the extent to which they are transboundary in nature;
(iii) *a prioritization of transboundary concerns*, which ranks, weights or provides some measure of priority to the identified concerns – an implicit requirement for projects in the International Waters focal area (GEF, 1995a), though one that is not explicitly addressed in all published TDAs;
(iv) *a causal chain analysis*, which relates the identified concerns to their immediate and root causes as well as to their impacts;
(v) *a statement of objectives*, which describes the general goals of the project, such as reduction of harmful algal blooms or development of sustainable mariculture; and
(vi) *a preliminary formulation of interventions*, which, while sometimes deferred entirely until SAP development, identifies possible options for restorative and preventive action.

The above list does not describe every element or consideration that may be appropriate for a particular TDA. Collaborative projects aimed at restoring degraded LMEs involve too many complex environmental issues and political constraints for a one-size-fits-all approach. On the other hand,

[4] See, e.g., comments by Michael J. O'Toole, the Chief Technical Advisor to the Benguela Current LME project in an undated document entitled The Benguela Current Large Marine Ecosystem Programme (BCLME): Experiences and Some Lessons Learned. O'Toole relays that a participatory and consulting process involving key stakeholders during TDA and SAP preparation was essential for obtaining a sense of regional ownership and formulating and defining project documents. Document may be downloaded at ⟨http://iwlearn.net/⟩.

a greater degree of conformity in the approach to TDA and SAP formulation could facilitate better replication of project successes. To that end, the LME approach strikes an appropriate balance in that it provides a replicable and scalable framework comprised of five fundamental areas of consideration that are broad enough to accommodate tailored and innovative initiatives.

5.2. Integration of the modules into the TDA

In terms of integrating the five modules into the TDA document, there is no single correct approach. The focal area of each module should be fully explored during the joint fact-finding process in order to identify or substantiate transboundary concerns and to begin development of a baseline against which to measure future changes in LME conditions. The representation of the modules and associated findings in the TDA document may vary, however. A useful approach is to develop a profile for each module, describing the characteristics of the LME that relate to the module's focal area. Each profile then provides the foundation and context for identification of priority transboundary concerns, analysis of causation and formulation of objectives and interventions.

This approach may be more intuitive for the three natural science modules. The basic idea is to separately describe the LME's productivity, pollution and ecosystem health, and fish and fisheries (and the other ecological parameters relevant to these modules) based upon the best available scientific information and in sufficient detail to support characterization of the transboundary priority concerns. Where there is insufficient information, this should be clearly indicated in the TDA. The causal chain analysis could be documented within these profiles or separately, bearing in mind that many of the immediate causes and impacts of the transboundary problems will relate to the three natural science modules, while most of the root causes will relate to the socioeconomics and governance modules. From an organizational perspective, the countries may therefore find that it makes for a more natural progression in the TDA document to first develop all five modular profiles and to identify priority transboundary concerns before analyzing the causes and impacts of the concerns.

The approach for the socioeconomics and governance modules is essentially the same in that a profile would be developed that describes, and in some cases quantifies, the characteristics of the LME that relate to the two modules. Thus, a socioeconomics profile would identify and describe all of the ecosystem services provided by the LME, including any threats to them. It would also identify the various industries that extract or rely upon LME resources and describe or quantify their economic contributions to the countries (e.g., the amount of revenues generated and the number of jobs created by a sector). Issues related to equity and distribution are also relevant to the socioeconomics module, and the profile should therefore describe any concerns the countries have identified regarding access to LME resources and distribution of benefits.

If possible, the countries should estimate values for the ecosystem services identified in the TDA. Countries may lack the time and resources to conduct a thorough valuation analysis prior to TDA finalization, but where it is feasible, it can be extremely useful, particularly as a tool to influence national decision-makers such as in planning and finance ministries. Assigning values to ecosystem services gives policymakers and stakeholders an easily understood metric (currency) for assessing the magnitude of an LME's contribution to human welfare. This, in turn, can help them to prioritize the transboundary concerns identified in the TDA. It also provides them a means to compare and evaluate potential interventions or management actions and the trade-offs they entail. In this regard, any projected gains in ecosystem services should be quantified and considered when evaluating the cost-effectiveness of a proposed action.[5] In GEF-supported LME projects, comprehensive benefit–cost analysis of this sort has typically been undertaken during SAP development, but only on a few occasions. Whether ecosystem values are included in the TDA, the SAP or in another project output document, however, the countries should be completely transparent about how the values were

[5] See, e.g., a benefit–cost analysis undertaken for the implementation of a plan to improve the water quality of a South Korean tidal flat in connection with the Yellow Sea LME project. Endo, I., Walton, M., Chae, S., Park, G.-S., 2012. Estimating benefits of improving water quality in the largest remaining tidal flat in South Korea. Wetlands 32:487–496.

derived. There are a number of different methods for valuing ecosystem services, all of which entail making certain assumptions that can significantly affect the conclusions. It is important to the integrity and replicability of the countries' efforts that others are able to determine how the countries arrived at their valuation results.

For purposes of the governance module, a profile would map out the legal, policy and regulatory frameworks and mechanisms that are relevant to the use or health of the LME. These frameworks and mechanisms occur and interact at local, national, regional and international levels, and to the extent they have a material influence on behaviors impacting the LME, they should be captured in the governance profile. A governance profile would also identify major stakeholder groups and any cultural values, norms or market incentives that significantly influence usage of LME resources. The objective is to develop and convey a thorough understanding of how existing systems of governance operate and ultimately impact the LME and how needed reform may emerge given the structures and constraints in place (Juda and Hennessey, 2001). Such an understanding also allows for a meaningful analysis of the intermediate and root causes of identified concerns, which may often be traced back to market failures and ineffective, sector-focused government regulation.

5.3. Approach to the TDA in practice

5.3.1. The Gulf of Mexico LME

The approach described in Section 5.2, which entails the development of profiles that correspond to the modules, is represented in the TDA for the GEF co-financed, UNIDO implemented, Gulf of Mexico LME project, a partnership between Mexico and the United States.[6] The countries released a preliminary TDA in 2005 and a final TDA in 2011 (UNIDO/GEF, 2005 and UNIDO/GEF, 2011). Although only the final TDA is examined here on account of its organizational approach and representation of the modules, it should be noted that the preliminary document contains the bulk of the findings and much of the analysis upon which the more concise final TDA is based. The preliminary TDA therefore represents an integral part of the TDA process for the Gulf of Mexico LME and provides support for the final output document.

In the final TDA, the countries develop profiles for each module that very succinctly describe the relevant characteristics of the Gulf of Mexico LME and identify transboundary concerns and impacts. The result is a compact TDA document that reflects the countries' key findings across the full range of environmental and societal considerations that are fundamental to ecosystem-based management of an LME. Their approach is best illustrated by the following examples:

Section 1 of the TDA contains a profile for productivity with the following elements:

(i) definition of productivity;
(ii) description of the characteristics and drivers of productivity in the Gulf of Mexico, including its role in supporting biodiversity and fish communities;
(iii) identification of the problem: “unbalanced biological productivity” (meaning either too high or too low at various times and places);
(iv) identification of three main “factors”: habitat destruction from coastal development; eutrophication; and low quantity, quality and timing of freshwater inflows to the Gulf of Mexico;
(v) description of transboundary elements: strong trophic links throughout the LME and impacts that extend beyond the immediate area where the problem occurs; and
(vi) identification of challenges to effective management of the problem: differences between the two countries in coastal assessments and lack of monitoring programs to support adaptive management.

[6] Cuba is the only other country that borders the LME, and in the TDA, the U.S. and Mexico recognize the importance of Cuba’s participation in the project and note that Cuban scientists and environmental managers participated in various project working groups.

Similarly, Sections 2-5 of the TDA develop profiles for pollution and ecosystem health, fish and fisheries, socioeconomics and governance. While they are not necessarily identical to one another in approach, the same major elements appear in each of them. It is worth noting, however, that biodiversity is a priority issue on the project, and the countries elected to create a separate profile for biodiversity as a subsection of the pollution and ecosystem health module. In addition, they identified two priority issues which cut across all five modules: climate change and environmental education and outreach. Rather than address these issues within a profile for one of the five modules, the countries created additional, separate profiles for them in Sections 6 and 7 of the TDA.

The Gulf of Mexico TDA also follows a very succinct approach in its analyses of causality and identification of action areas. The countries identify a total of nine root causes and eight action areas, and they link each of the transboundary concerns to root causes and action areas in a matrix structure. By way of example, for climate change-related problems, the matrix identifies the following root causes: (i) ecosystem concerns not sufficiently considered in planning and management; and (ii) planning and management done on a per-sector basis without proper accounting of externalities and proper accounting of resources. In addition, the matrix identifies five action areas for climate change: (i) capacity building; (ii) strengthening of the institutional framework; (iii) development and strengthening of intersectoral planning mechanisms; (iv) development of common institutional know-how on ecosystem-based management; and (v) development of common strategies to face the effects of climate change. The TDA concludes with summaries of the main challenges and the path forward for the two countries in restoring and managing the Gulf of Mexico.

With the U.S. and Mexico having only recently finalized the TDA, it is not possible to evaluate how their findings were translated into a SAP. However, two other projects, the Yellow Sea and the Benguela Current LME projects, have completed both documents using elements of the modular framework. Their approaches are examined in the remaining sections of this paper.

5.3.2. The Yellow Sea LME

While the Gulf of Mexico TDA represents the most faithful adoption of the five modules, other TDAs incorporate elements of the LME approach with noteworthy results. One example is the TDA for the Yellow Sea LME, a project between the People's Republic of China and the Republic of Korea (UNDP/GEF, 2007).[7] The Yellow Sea LME has been very heavily impacted by human development and resource extraction, and the project was initially conceived to improve water quality and the sustainability of fisheries in the LME (UNDP/GEF, 2012). The countries organized TDA output into five project areas or modules:

(i) *sustainable management of fisheries and mariculture*;
(ii) *biodiversity protection*;
(iii) *ecosystem* (which includes productivity considerations);
(iv) *pollution*; and
(v) *institutional development and capacity-building* (which concerns both socioeconomic and governance considerations).

The five modules are clearly represented in this framework, as the parentheticals clarify, but the countries adapted them to reflect their priorities. The project areas serve as thematic units in the TDA for describing and analyzing the LME and also as focal areas for five regional working groups established by the countries. Only the first four project areas (i.e., those that correspond to the natural science modules) are fully developed in the TDA, however. The countries elected to defer most socioeconomic and governance considerations to the SAP, noting that they were in the process of

[7] The Yellow Sea LME is also bordered by the Democratic People's Republic of Korea, which is currently an observer on the project and has formally supported the TDA and SAP. See UNDP/GEF. International Waters Delivering Results. New York, NY. 2012, (http://www.undp.org/content/undp/en/home/librarypage/environment-energy/water_governance/international-waters–delivering-results/).

producing a valuation of the Yellow Sea's ecosystem services and an assessment of the countries' governance regimes.

Compared to the final TDA for the Gulf of Mexico, the profiles for the four natural science project areas are fairly detailed. Whereas the bulk of the findings for the Gulf of Mexico project are in a separate preliminary document, much of the information used to support characterization of the Yellow Sea project's transboundary concerns are in the TDA. It includes, for example, graphics that illustrate time series trends for identified problems, such as harmful algal blooms and the decline in landings of commercially important species. The TDA also expressly incorporates a prioritization methodology for weighting or ranking transboundary concerns, and it reflects a fairly elaborate and methodical causal chain analysis that identifies impacts and a hierarchy of causal elements. The document concludes with a discussion of potential options for intervention, leaving the development of more specific policies and actions to the SAP.

The Yellow Sea TDA, when considered together with the countries' subsequent efforts to value ecosystem services and assess governance regimes, reflects a holistic approach that left the countries in good stead for the SAP phase of project development. In particular, their findings provided the countries a strong foundation for the development of relatively specific restorative actions for the Yellow Sea. As discussed in Section 6.5.1 below, the commitments made by the People's Republic of China and the Republic of Korea to restore the Yellow Sea and its resources have already resulted in some positive changes in institutional capacity and ecosystem status.

5.3.3. *The Benguela Current LME*

The Benguela Current LME countries took a different approach in their TDA, but with a result that nevertheless reflects a fairly comprehensive analysis of the ecosystem, including the human elements. The Benguela Current LME is bordered by the African nations of Angola, Namibia and South Africa. It is considered a highly productive ecosystem, but total fish landings peaked in 1975 and have declined by almost two-thirds since that time (UNDP/GEF, 2012). Before the three countries embarked on a GEF-supported LME project in 2002, they launched a cooperative marine scientific and capacity-building program in 1997 known as BENEFIT (shortened from Benguela-Environment-Fisheries-Interaction & Training). With international support, the countries surveyed the Benguela Current LME and generated fisheries- and environment-related data to support sustainable resource usage in the region (UNDP/GEF, 1999). When they subsequently developed a TDA for the LME project, the countries were able to leverage the research that had been conducted through BENEFIT, producing an output document that, while stressing the need for additional scientific capacity to monitor the LME, produced a fair amount of findings and analysis.

The Benguela Current TDA does not, in form at least, explicitly reflect the LME approach. The five modules are not referenced per se, and analysis of the ecosystem is not organized around focal areas or thematic units representing the fundamental natural science and human dimensions of an LME. That is not to suggest, however, that that these elements are not addressed in the TDA. In fact, a final GEF evaluation report on the Benguela Current LME states that the project "was designed according to a process typical of GEF [International Waters] projects and LME projects in particular, and was based on a combination of the TDA/SAP process and application of the 5 LME modules (productivity; fish and fisheries; pollution and ecosystem health, socioeconomics and governance) (Cooke, 2008)." Indeed, the focal area of each module is reflected in the countries' analysis of transboundary concerns and in the comprehensive thematic reports that accompany the TDA.

The countries identify seven priority transboundary concerns and three broad action areas to address the root causes and impacts of the concerns. In the project's final evaluation report, the countries note that the action areas were intended to correspond to the three natural science LME modules as indicated in Table 1 below.

The seven identified priority transboundary concerns and the corresponding action areas are represented in Table 2 below.

Table 1
Correspondence between Benguela Current LME action areas and modules.

Symbol (for purposes of Table 2 below)	Action area	Corresponding LME module
A	Sustainable management and utilization of resources	Fish and fisheries
B	Assessment of environmental variability, ecosystem impacts and improvement of predictability	Productivity
C	Improvement of ecosystem health and management of pollution	Pollution and ecosystem health

Table 2
Priority transboundary concerns for the Benguela Current LME[a].

Transboundary concern	Action areas (from Table 1)
Decline in commercial fish stocks and non-optimal harvesting of living marine resources	A, B, (C)
Uncertainty regarding ecosystem status and yields in a highly variable environment	A, B, C
Deterioration in water quality	C
Habitat destruction and alteration	A, C, (B)
Loss of biotic integrity and threat to biodiversity/endangered and vulnerable species	A, C, (B)
Inadequate capacity to assess ecosystem health	A, B, C
Harmful algal blooms	A, B, C

[a] Table adapted from a matrix on p. 15 of the Benguela Current LME TDA.

For each of the three broad action areas, the TDA identifies a group of generic actions, a number of which apply to all three broad action areas. Common generic actions include capacity strengthening and training, policy harmonization and regional collaboration on surveys and assessments.

The Benguela Current TDA also addresses socioeconomic and governance considerations in several ways. The opening section of the TDA, for example, describes the countries' colonial past and the ways in which their histories have shaped their laws and institutions relating to the use and extraction of LME resources. In this regard, the TDA states that a legacy of colonialism is a lack of integration, nationally and regionally, in the management of the various uses of LME resources. In a subsequent section of the TDA, socioeconomic consequences are identified for each of the LME problems in matrixes that also summarize the following: (i) causes; (ii) impacts; (iii) risk/uncertainties; (iv) transboundary consequences; (v) activities/solutions; (vi) incremental cost; and (vii) anticipated outputs. Governance issues and arrangements are often cited on these matrices as either causes of identified problems or part of the solutions and anticipated outputs. Finally, governance and socioeconomic characteristics for the countries are expanded upon in comprehensive thematic reports that are appended to the TDA. A detailed report on fisheries, for example, provides not only catch and abundance data but also information about the legal and regulatory framework applicable to the countries' fishing industries and the socioeconomic importance of fisheries to the region (Hampton et al., 1999). A second report provides an overview of socioeconomic characteristics of the three countries, including demography and settlement patterns, social services, key industries and other economic activity (Tapscott, 1999).

As the above discussion illustrates, the Benguela Current LME countries explored a wide range of environmental and societal considerations in their TDA, and these considerations can all be related to the five modules. This was a critical step in the project because it allowed the countries to begin to develop policy actions in the SAP that integrated their knowledge about the state of the natural environment with socioeconomic considerations and an understanding of governance weaknesses, constraints and possibilities. In particular, this led to the formation of the world's first regional LME Commission, a remarkable cooperative effort that is discussed in greater detail in Section 6.5.2 below.

6. The Strategic Action Programme

6.1. Key elements

Finalized SAPs are fewer in number and greater in heterogeneity than TDAs. This is not entirely surprising, however, given that a SAP is a negotiated document that must be tailored to fit a unique combination of objectives, economic considerations, political constraints and environmental complexities. That said, as with TDAs, there are a number of fundamental elements that are common to many SAPs. All SAPs, for example, restate or refine previously identified priority concerns and objectives. They also formulate, in general or specific terms, actions aimed at achieving those objectives – i.e., restorative and preventive interventions. These actions typically include arrangements to facilitate institutional coordination and information sharing within and among the countries. While most SAPs also address project financing, there is considerable variability in the depth of analysis and the extent to which costs are estimated and funding sources are identified. Other elements reflected in one or more SAPs include: (i) the establishment of a regional commission to facilitate joint management; (ii) the formation of working groups in scientific, technical and managerial areas (also addressed in some TDAs); (iii) the evaluation of proposed interventions through benefit–cost analysis; and (iv) the development of a strategy to monitor conditions in the LME and evaluate progress towards project objectives, an integral component of the LME approach.

6.2. Integration of the modules in the SAP

In terms of organization, the modules generally play a less visible role in the SAP than they do in the TDA. To the extent the SAP reiterates or reformulates transboundary concerns and project objectives, it is certainly useful to present them under the same modular framework used in the TDA for purposes of logic and consistency. The modules play an important role, however, in the countries' analysis of options for intervention, as the interdependencies among the five modules should be considered before implementing restorative and preventive interventions. As previously described, a change in the state of one environmental or societal parameter may very well have consequences, intended and unintended, for a number of other parameters. The range of potential consequences should be explored in developing strategic interventions for the SAP, though much of this analysis will likely not be reflected in the output document.

Perhaps the most significant contribution of the modules to the SAP, and indeed to the success of the project, relates to their use in developing indicators that are monitored and evaluated to track the status of the LME and to inform adaptive SAP implementation. In this regard, the adoption of a strategy to monitor and evaluate the changing state and health of the ecosystem by tracking changes in key indicators is essential to ecosystem-based management (Yáñez-Arancibia and Day, 2004). Indeed, as discussed in Section 6.4 below, the GEF requires funded projects to develop plans for the monitoring and evaluation of key indicators related to accomplishment of project objectives and ecosystem health. “Monitoring” in this context refers to a process of continually or regularly collecting, measuring and analyzing data, while “evaluating” refers to a process of systematic assessment of the data in relation to a project's objectives. The results of systematic monitoring of indicators are used to develop time series data that reveal trends in ecosystem health. This provides a basis for countries to evaluate their progress in achieving project objectives and to adjust their management decisions when necessary. This strategy, including the identification of measurable indicators corresponding to each of the five modules, should be documented in every SAP, so fundamental is it to ecosystem-based management and adaptive management regimes.

6.3. Selection of indicators

Indicators should be selected by the countries with an eye towards the environmental and societal attributes on which management objectives are focused (Samhouri et al., 2009). Appropriate indicators will therefore vary according to the physical and biological characteristics of the LME, the scientific capacity of the countries, their objectives on the project and a number of other factors. While it is not possible to describe a single portfolio of indicators appropriate for all LME projects, the following sections describe the types of indicators typically associated with the modules.

6.3.1. Productivity indicators

Productivity indicators serve as a measure of an ecosystem's carrying capacity for fisheries and other components of biodiversity. They also relate to issues of coastal eutrophication, harmful algal blooms and environmental variability resulting from climate change. The parameters that are measured under the productivity module include primary production (g C/m^2/year), zooplankton and phytoplankton biodiversity and species composition; zooplankton biomass; water column structure; photosynthetically active radiation (PAR), transparency, chlorophyll-a (a common proxy measure of phytoplankton biomass), nitrite, nitrate and phosphate (Sherman, 2005). Continuous Plankton Recorder (CPR) systems can be used to develop a proxy measure of phytoplankton biomass. CPRs are mechanical units that are towed from commercial vessels, filtering water through a piece of silk and capturing a representative sample of plankton. The color of the silk is assessed against standard color charts to estimate the quantity and density of phytoplankton (Ecosystem Assessment Program, 2012). CPRs deployed from commercial vessels of opportunity have been used to measure plankton in LMEs over decadal time scales (Sherman, 2005). Satellite data can also be used to develop information on an LME, including sea surface temperature, nutrient characteristics, primary productivity and chlorophyll concentration (Sherman et al., 2010c). The development of time series from this information reveals trends in the health and carrying capacity of an LME.

6.3.2. Fish and fisheries indicators

Fish and fisheries indicators shed light on fish biodiversity and abundance, including shifts in species dominance, and can signal not only excessive exploitation but also environmental variability and coastal pollution (Sherman, 2005). The indicators are typically derived from fisheries-independent bottom trawls and acoustic surveys (Sherman, 2005) and fisheries industry data such as catch volumes and discards. Standardized sampling from small, calibrated trawlers provides biological samples for stock assessments, stomach analyses, age, growth, fecundity and size comparisons; data for clarifying and quantifying multispecies trophic relationships; and samples for monitoring coastal pollution (Sherman, 2005). In this regard, an FAO programme started in 2007 and supported by Norway provides subsidized cruise time on the Norwegian research vessel *Dr. Fridtjof Nansen* to all African LMEs (FAO/UNEP/GEF). Other indicators of fisheries health include mean trophic level of captured fish species, species condition (i.e., weight in relation to length) and average temperature preference of finfish species (Ecosystem Assessment Program, 2012). The Sea Around Us project at the University of British Columbia provides time series data from 1950 to the present for fisheries-related indicators for all LMEs. This includes indicators of fisheries health such as mean trophic level and mean maximum length of exploited species as well as primary production required for catches in the LME (Sea Around Us Project).

6.3.3. Pollution and ecosystem health indicators

For the pollution and ecosystem health module, fish, benthic invertebrates and other indicator species are often used to measure pollution effects on the ecosystem (Sherman, 2005). An examination of selected food web organisms can reveal bioaccumulation and trophic transfer of contaminants. Mollusks, for example, can serve as indicators of metal and organic contaminants in an LME, and the pathological examination of fish can reveal the effects of coastal pollution and contaminants (e.g., through impaired reproductive capacity, organ disease and impaired growth). As well, standardized sampling of the water column and substrate provide measurements of contaminants, nutrient load and other parameters associated with ecosystem health (Sherman, 2005).[8]

[8] See also Seitzinger, Sybil P., Lee, Rosalynn Y. *Land-based Nutrient Loading to LMEs: A Global Watershed Perspective on Magnitudes and Sources* from The UNEP Large Marine Ecosystem Report: A perspective on changing conditions in LMEs of the world's Regional Seas. UNEP Regional Seas Report and Studies No. 182. United Nations Environment Programme. Nairobi, Kenya

6.3.4. Socioeconomics indicators

Indicators for the socioeconomics module provide a measure of the economic benefits and associated social well-being from the health and use of the LME. A key indicator of the magnitude of benefits to human populations is derived from valuing ecosystem services that flow from the LME. As described in Section 5.2, this is accomplished through an analytical process that assigns monetary value to various LME ecosystem services. Tracking these values over time permits policymakers to see how changes in the health and use of the LME impact the benefits to human populations. Other indicators of social well-being in the relevant region include the profitability of fishing fleets; the number of small, artisanal fisheries; the number of jobs created by industries that extract LME resources; the unemployment rate; per capita income and distribution of income; morbidity rates; rate or magnitude of conflict over LME resources; and measures of food security and access to LME resources.

6.3.5. Governance indicators

Governance indicators provide evidence of a shift or advancement towards an integrated, ecosystem approach in policies, institutions, laws and other governance arrangements. In general, they may relate to process or result (Juda and Hennessey, 2001). In this context, "process" refers to changes in the way decisions are made and institutions function, while "results" focus on whether process changes have resulted in better management (Juda and Hennessey, 2001). Examples of governance process indicators include: reform aimed at increasing interministerial or intergovernmental coordination in decision making; harmonization of natural resource use policies among countries sharing an LME; establishment of scientific task forces to advise policymakers; adoption of the precautionary principle and requirement of environmental impact assessments when a proposed action may have ecosystem consequences; and greater participation or involvement of the public in governance and decision-making (Juda and Hennessey, 2001). The selection of results indicators should be driven by the project's objectives, bearing in mind that it may take many years before material changes can be detected in the transboundary water environment (Duda, 2002).

6.4. GEF-required monitoring and evaluation

As noted above, the GEF requires funded projects to develop a fully budgeted Monitoring and Evaluation (M&E) Plan. Feedback from these plans allows the GEF to evaluate progress on projects and to understand and generate knowledge about good practices.[9] Pursuant to GEF policy, the M&E Plan must include indicators that are specific, measurable, achievable, relevant and time-bound (denoted by the acronym SMART). For projects in the GEF's International Waters focal area, these indicators fall within three required categories: (i) *process indicators*, which characterize the completion of institutional processes, such as the enactment of legal reforms or the ratification of treaties at the national level and the completion of a TDA or SAP at the regional level; (ii) *stress reduction indicators*, which relate to specific, on-the-ground measures taken by countries, such as the establishment of a marine protected area or the implementation of a non-point source pollution program; and (iii) *environmental status indicators*, which are measures of actual performance or success in restoring an ecosystem, such as improved water quality parameters, improved recruitment classes of targeted fish species, and any associated socioeconomic improvements (Duda, 2002). Stress reduction and environmental status indicators reflect conditions at a particular point in time and are typically reported against a baseline year and level in order to demonstrate change or improvement.

(*footnote continued*)
(the authors describe a global watershed model that relates human activities and natural processes in watersheds to nutrient inputs to LMEs).

[9] A thorough explanation of the GEF's M&E objectives, processes and general requirements may be found in its most recent Monitoring and Evaluation Policy, available on the GEF website at: ⟨http://www.thegef.org/gef/sites/thegef.org/files/documents/ME_Policy_2010.pdf⟩.

Importantly, the adoption of a strategy to monitor and evaluate indicators represented by the five modules (referred to collectively as the “modular indicators”) complements and supports a Monitoring and Evaluation Plan. In this regard, the focal areas of the five modules directly relate to the indicators required by the GEF (referred to collectively as “GEF International Waters indicators” for the sake of clarity). Indicators for the governance module, for example, are largely focused on process and include the completion of a TDA, the adoption of a SAP and the passage of relevant legislative reforms. These same achievements also serve as process indicators for purposes of the GEF International Waters indicators. Measurements of nutrient loading, which serve as indicators for the ecosystem health module, also serve as stress reduction indicators for GEF purposes when used to demonstrate a reduction in nutrient loading. Most of the indicators associated with the three natural science modules and the socioeconomics module, however, can be mapped directly onto the GEF's environmental status indicators to show changes in environmental conditions or associated socioeconomic parameters, such as job creation or industry revenues. The modular indicators are essentially the metrics that are monitored over time in order to demonstrate the changes and improvements that are reported as GEF International Waters indicators.

The GEF recognized very early the importance of selecting appropriate metrics for purposes of monitoring, evaluation, and adaptive ecosystem management. Paragraph 21 of the GEF's 1995 *Scope and Preliminary Operational Strategy for International Waters* provides:

> A key feature of successful programs and organizations is their ability to learn from experience. The capacity to absorb information, assess performance, and respond flexibly is vital for achieving progress. This element of evaluating lessons learned, facilitating the sharing of experiences among different GEF international waters projects, and disseminating results will be an integral part of work in this focal area. Consequently, special attention will be paid to including a monitoring and evaluation framework in each GEF project with appropriate environmental and other types of indicators that can be tracked to determine progress, relative success, and project completion. Of course, baselines must be established early in project planning so that monitoring can detect changes in the environment (GEF, 1995b).

As noted in the above Paragraph 21, Monitoring and Evaluation Plans should identify appropriate indicators that can be tracked over time to measure change in ecosystem health and the attainment of project objectives. For this purpose, the five modules of the LME approach provide an appropriate framework for the identification of relevant indicators. They also inform and support adaptive management and are therefore an important component of the SAP.

6.5. Approach to the SAP in practice

6.5.1. The Yellow Sea LME

The SAP for the Yellow Sea LME was finalized in November, 2009 with the signatures of representatives from the People's Republic of China and the Republic of Korea (UNDP/GEF, 2009). Its approach is innovative in that its central feature or concept is ecosystem carrying capacity, defined in the SAP as the capacity of the Yellow Sea to provide ecosystem goods and services. It thus represents a very broad conception of carrying capacity that takes into account the LME's capacity to provide provisioning, regulating, cultural and supporting ecosystem services. The countries further provide that sustaining ecosystem services should be the ultimate target of ecosystem-based management, requiring long-term scientific research and adaptive strategies.

In the SAP, the countries outline their strategy for sustaining ecosystem services, which revolves around the goal of meeting eleven regional targets related to improving ecosystem carrying capacity by the year 2020. Ecosystem services, as described in Section 3.1.4 above, are a major focus of the socioeconomics module, and the regional targets identified in the SAP can all be related to the three natural science modules. Table 3 below illustrates the relationships among the four categories of ecosystem services, the eleven regional targets and the three natural science modules.

The SAP also lays out specific management actions aimed at achieving each of the regional targets. Some of the management actions entail concrete commitments, and in this regard, the SAP is fairly

Table 3
Relationship among ecosystem services, regional targets and the modules for the Yellow Sea LME.

Ecosystem service	Linked regional target[a]	Related LME modules
Provisioning	25–30% reduction in fishing effort	Fish and fisheries
	Rebuilding of overexploited fish stocks	Fish and fisheries
	Improved mariculture techniques	Fish and fisheries
Regulating	International contaminant requirements met	Pollution and ecosystem health
	Reduction in nutrient loading	Pollution and ecosystem health
Cultural	Reduction in marine litter	Pollution and ecosystem health
	Reduction in contamination of beaches	Pollution and ecosystem health
Supporting	Better prediction of ecosystem change	Productivity
	Improved biodiversity status	Fish and fisheries; pollution and ecosystem health
	Maintenance of habitats	Pollution and ecosystem health
	Reduction in risk from introduced species	Pollution and ecosystem health

[a] Regional targets may be linked to multiple categories of ecosystem services; principal relationships are represented in the table.

remarkable. For example, the countries agree to continue existing efforts to buy back fishing boats, control the building of new fishing boats and provide fishermen with alternative livelihoods in an effort to achieve a 25–30% fishing effort reduction by 2020. The countries also agree to adopt sustainable Integrated Multitrophic Aquaculture methods in connection with their regional target to improve mariculture techniques. Finally, the countries agree to continue a policy of reducing nutrient loading from wastewater, fertilizer use, and industrial discharges by 10% every 5 years in an effort to achieve the regional nutrient loading reduction target by 2020.

The SAP addresses economic considerations in its adoption of benefit–cost analysis for purposes of assessing the economic consequences of management actions. Specifically, the countries advocate a benefit–cost approach that entails comparing the net benefits (total benefits less total costs) of implementing a proposed management action against the net benefits of doing nothing and allowing the status quo to continue. In this regard, the SAP provides considerable guidance on the calculation of benefits and costs and the integration of economic analysis into ecosystem management. With respect to governance, the SAP establishes a framework for a non-legally binding Yellow Sea LME Commission that would promote coordination between the countries and support project initiatives. At this point, however, the Commission has not been formally established.

Importantly, the SAP describes the countries' monitoring and evaluation strategy and also identifies indicators related to its Monitoring and Evaluation Plan for the GEF (i.e., process, stress reduction and environmental status indicators). It does not, however, address the specific metrics or modular indicators to be used for measuring changes in environmental or socioeconomic conditions. A 2011 Final Evaluation Report for the project states that in 2009, baselines and more explicit and detailed criteria were established to track progress against long-term objectives (Kullenberg and Huber, 2011). This is reflected in reports from meetings of regional working groups on pollution and ecosystem in 2008 which discuss the results of cooperative research cruises. During the cruises, scientists collected data on a number of physical and biological parameters, including metals; organic compounds; suspended solids; nitrogen; carbon; silicon; temperature; salinity; dissolved oxygen; bacteria; blue-green algae; chlorophyll-a; phytoplankton and zooplankton composition, distribution and diversity; sediment profiles; and deposition rates (UNDP/GEF, 2008). Additionally, the countries held a workshop in Shenyang, China, in May, 2008, to improve their techniques and methods of assessment. The workshop included presentations and discussion sessions on assessment strategies, monitoring for various purposes and assessment of trends (UNDP/GEF, 2008). Thus, while not clearly reflected in the SAP, the countries began developing time series data on a number of key indicators prior to SAP finalization in 2009 in accordance with the LME approach.

In terms of results, a 2011 evaluation of the project for the GEF states that it had a significant impact in building scientific capacity in the countries, including through participation in joint research cruises, workshops and training activities (Kullenberg and Huber, 2011). The project also resulted in the establishment of a regional marine protected area network for the conservation of biodiversity and the development of new waste water treatment plants and improved waste water treatment abilities to reduce nutrient discharges into the LME (UNDP/GEF, 2012). With respect to improvements in the environment, while it is still too early to expect material changes as a result of project efforts, the countries' joint regional fishery stock assessment found that total biomass of the Yellow Sea is slowly recovering, although the trophic level of fish species in the LME continues to decline (UNDP/GEF, 2012). In addition, through their research on cooperative cruises, the countries found that while some environmental problems, such as harmful algal blooms, have improved, other new problems, such as jellyfish overabundance and hypoxia, have arisen (UNDP/GEF, 2012). More generally, it has been reported that the project has resulted in better cooperation and coordination both within and between the countries and has increased awareness of issues of marine environmental protection and sustainable resource use among local and provincial governments (Kullenberg and Huber, 2011).

6.5.2. The Benguela Current LME

The SAP for the three Bengeula Current LME countries was adopted in 1999 and was later updated in 2002 (UNDP/GEF, 2002). Two overarching issues appear to have significantly influenced the commitments made by the countries: (i) the Benguela Current LME is a wind-driven coastal upwelling system that experiences substantial environmental variability; and (ii) the countries lack sufficient scientific capacity to adequately assess the ecosystem and predict extreme events (UNDP/GEF, 2002). As a result, a number of the strategic actions described in the SAP relate to capacity building and information gathering. In that sense, the SAP offers fewer concrete management actions than does the SAP for the Yellow Sea LME. This is intended less as a criticism of the Benguela Current SAP than as a recognition of the unique circumstances and constraints that shaped the output document.

As with the countries' TDA, the SAP does not explicitly incorporate the five modules per se, though they are reflected in the policy actions and institutional arrangements described in the document. At the outset, the countries restate the seven priority transboundary issues identified in the TDA, and they formally adopt a set of principles and guidelines that reflect an ecosystem approach. These include the precautionary principle; the use of environmental impact assessments; the use of economic and policy instruments to foster sustainable development; the encouragement of transparency and public participation in project initiatives; and the integration of environmental, ecosystem and human health considerations in relevant policy and sectoral plans. At the heart of the SAP are the agreed policy actions that are grouped in six thematic areas. Table 4 below illustrates the relation between the policy action areas and the modules of the LME approach.

As reflected in Table 4, many of the agreed actions call for enhanced cooperation and development of better information and scientific capacity as well as harmonization of policies relating to marine resources. Where there exists a convention or agreement relevant to the project's objectives (e.g., the FAO Code of Conduct for Responsible Fishing and MARPOL 73/78), the countries commit to implementing it or complying with its terms. One of the more specific actions agreed in the SAP relates to the development of a regional early warning system to monitor major environmental events, reflecting the significance of environmental variability in the LME. In this regard, the SAP provides for a demonstration project to assess the feasibility of linking a regional early warning network into an existing moored ocean-monitoring buoy network in the equatorial Atlantic.

A particularly noteworthy accomplishment reflected in the SAP is the countries' establishment of a regional institutional structure known as the Interim Benguela Current Commission (IBCC). Membership on the IBCC consists of voting representatives of the three countries and non-voting representatives of international partners. Its principal function is to strengthen coordination among the three countries and to support project objectives and initiatives. To assist the IBCC, the SAP establishes seven advisory groups that reflect the countries' priority concerns and technical needs. These include advisory groups concerned with fisheries and living marine resources, environmental variability and predictability, biodiversity and ecosystem health and training and capacity development. The advisory groups are comprised of experts who are expected to gather pertinent information and to provide advice and technical support to the IBCC and to the Program Coordination Unit.

Table 4
Correspondence between action areas and the modules for the Benguela Current LME.

Action area	Examples of agreed actions	Corresponding LME modules
Sustainable management and utilization of living marine resources	Undertake joint surveys and assessment of shared stocks of key species	Fish and fisheries
	Harmonize management of shared stocks	Fish and fisheries; governance
	Analyze the socioeconomic consequences of various harvesting methods and the economic value of the Benguela ecosystem	Socioeconomics
Management of mining and drilling activities	Harmonize policy relating to shared resources, cumulative impacts and their mitigation	Governance
	Undertake impact assessments of the cumulative effects of mining activities on the LME	Pollution and ecosystem health
Assessment of environmental variability, ecosystem impacts and improvement of predictability	Develop early warning system for monitoring major environmental events in the LME	Productivity; pollution and ecosystem health; socioeconomics
	Analyze existing data series to establish a baseline against which future transboundary variability and change can be measured	Productivity; pollution and ecosystem health
Management of pollution	Ensure that national oil pollution contingency plans are complementary and develop a regional policy to minimize transboundary impacts of oil pollution	Governance; pollution and ecosystem health
Maintenance of ecosystem health and protection of biological diversity	Undertake a regional assessment of the status of vulnerable species and habitats	Pollution and ecosystem health
	Develop a regional policy on ballast water management	Governance
Capacity strengthening	Determine existing human and infrastructure capacity in region, as well as capacity and training needs, to develop strategic plan for capacity strengthening	Cuts across all modules

The SAP concludes with brief acknowledgments of the countries' need to seek additional funding for the agreed actions and their intent to continue the project beyond the GEF intervention. The countries do not identify indicators or outline a strategy for monitoring and evaluation in the SAP. In this respect, the SAP does not embody the principal import of the LME approach. Monitoring is clearly contemplated, however. With respect to living marine resources, for example, the SAP calls for the joint assessment of key species over a five-year period in order to demonstrate the benefits of transboundary fisheries assessments. It also assigns the relevant advisory group the responsibility of conducting socioeconomic assessments relating to the harvest of living marine resources. In the area of environmental variability, it assigns high priority to the development of baseline data on ecosystem parameters for purposes of measuring future environmental variability and change. Finally, the advisory group on marine pollution is tasked with developing a regional framework for monitoring marine pollution and assessing water quality.

It should be noted that the countries have made progress with respect to capacity building, allowing them to focus on developing a strategy for monitoring and evaluation (Cooke, 2008). In this regard, they have initiated projects under their Science Program that will enable them to establish an environmental status baseline and to identify appropriate indicators (Cooke, 2008). In addition, the countries are conducting a valuation of the LME's goods and services that will provide them a baseline of information on socioeconomic status as well as appropriate indicators, enabling them to better monitor and assess the impact of SAP implementation on socioeconomic benefits (Cooke, 2008). Other major outcomes since SAP adoption include the formal establishment of the Benguela Current Commission (BCC), which is now fully operational. In addition, the countries completed a Benguela Current LME Convention on 18 March 2013 and have agreed to a Regional Data and Information Sharing Policy and Protocol that will be signed once the Convention is finalized and signed (UNDP/

GEF, 2012). The BCC, the Convention and the Information Sharing Policy and Protocol all represent important frameworks for cooperation that should help to sustain the countries' joint commitment to restoring the Benguela Current LME (UNDP/GEF, 2012).

7. Conclusion

For the last 15 years, the GEF has been the most significant catalyst for environmental projects that produce global benefits, with projects such as those for the Benguela Current and Yellow Sea LMEs illustrating the potential for capacity development and ecosystem restoration through regional cooperation and collective action. A key to the preliminary success of those projects was their adoption of a holistic ecosystem approach, reflected in their TDAs and SAPs, that considered how existing governance arrangements and the various uses of LME resources impacted environmental health and socioeconomic benefits. This comprehensive approach facilitated the countries' identification of the root causes and multiple impacts of transboundary water problems and allowed them to begin integrating their understanding of the environment into management solutions. Sustaining progress, however, requires that governance reforms and management actions be supported by systematic monitoring and evaluation of environmental and socioeconomic indicators.

The LME approach supports and guides the two contributors to project success described above; namely, a holistic, ecosystem approach to analyzing LME concerns and formulating interventions and the development of a strategy to monitor, evaluate and track progress in achieving project objectives. With respect to the latter, it also complements the GEF's guidance and requirements for monitoring and evaluation on International Waters projects. In this regard, the LME approach provides a framework for the selection of measurable indicators, the monitoring of which allows for the development of a baseline and time series information on the changing states of fundamental components of the ecosystem. This not only provides a foundation for GEF-required monitoring and evaluation plans but also gives countries the means to continually measure progress on a project and to practice adaptive management.

While it is clear that GEF-supported environmental projects should be country driven and participatory, the degree of variability among TDAs and SAPs, including the extent to which they incorporate important GEF principles such as adaptive management and the ecosystem approach, suggests that future LME projects could benefit from more targeted TDA/SAP guidance specifically designed for the LME context versus a more generic approach. At the time of this writing, IW:LEARN,[10] the GEF's portfolio-wide International Waters knowledge sharing program, is updating the TDA/SAP methodology including in this aspect. To that end, the LME approach, with its adaptable modular framework, supports the ecosystem approach and adaptive management without being prescriptive or stifling innovative, country-driven initiatives. Continued integration of the LME approach in GEF projects would help to ensure that countries systematically analyze and address the critical linkages among environmental, socioeconomic and governance aspects of an LME, thereby fostering sustainable use and management of marine resources.

Acknowledgments

The author wishes to express his sincere gratitude and thanks to Dr. Kenneth Sherman, Director of NOAA's Large Marine Ecosystem Program, without whose guidance, input and encouragement this paper could not have been written. The author also wishes to thank Dr. Andrew Hudson, Head of the UNDP Water & Ocean Governance Programme, for his thorough review of multiple drafts of this paper, which benefited greatly from his insight and contributions. Finally, the author wishes to acknowledge the invaluable support and assistance of the staff and others associated with NOAA's Large Marine Ecosystem Program including Deborah Curtner, Sandra Elvin and Sally Adams.

[10] International Waters Learning Exchange and Resource Network.

References

An Ocean Blueprint for the 21st Century, 2004. Final Report of the USA Commission on Ocean Policy to the President and Congress. Washington, DC, USA.

Chazournes, 2005. Chazournes LBd. The Global Environment Facility (GEF): a unique and crucial institution. Rev. Eur. Community & Int. Environ. Law 14, 193–201.

CBD, 1992. Convention on Biological Diversity. The 1992 United Nations Conference on Environment and Development. United Nations Environment Programme. Rio de Janeiro, Brazil.

Cooke. A., 2008. Final Evaluation of the Project "Integrated Management of the Benguela Current Large Marine Ecosystem (BCLME)". 〈http://iwlearn.net/iw-projects/3305/evaluations/789%20Benguela%20LME%20TE.pdf/view〉.

Costanza, R., 1992. Toward an operational definition of ecosystem health. In: Norton, B.G., Haskell, B.D. (Eds.), Ecosystem Health: New Goals for Environmental Management. Island Press, Washington, DC, USA, pp. 239–256.

Costanza, R., d'Arge, R., Rd, Groot, Farber, S., Grasso, M., Hannon, B., et al., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253–260.

Duda A.M., 2002. Monitoring and Evaluation Indicators for GEF International Waters Projects, GEF. 〈http://iwlearn.net/publications/mne/mne-others/mne-nov2004/GEF_IW_MNE_Indicators.pdf〉.

Duda, A.M., Sherman, K., 2002. A new imperative for improving management of large marine ecosystems. Ocean Coast. Manage 45, 797–833.

Ecosystem Assessment Program, 2012. Ecosystem Status Report for the Northeast Shelf Large Marine Ecosystem – 2011. U.S. Department of Commerce, Northeast Fisheries Science Center Ref. Doc. 12-07. National Marine Fisheries Service. Woods Hole, MA, USA.

Executive Order 13547, 2010. Executive Order 13547: Stewardship of the Ocean, Our Coasts, and the Great Lakes. 76 Federal Register 14392011.

FAO/UNEP/GEF, FAO/UNEP/GEF Project: Canary Current Large Marine Ecosystem. Project Document. 〈http://iwlearn.net/iw-projects/1909/project_doc/clme-project-document/view〉.

GEF, 2011. Format for Reporting on Resources Provided to the Agencies for Administrative Purposes. 〈http://www.thegef.org/gef/sites/thegef.org/files/documents/C.40.Inf_.11Fee.Reporting.Matrix.%20final,%20April%2026,%202011.pdf〉.

GEF, 1995a. Operational Strategy. 〈http://www.thegef.org/gef/sites/thegef.org/files/documents/GEF.C.6.3.pdf〉.

GEF, 1995b. Scope and Preliminary Operational Strategy for International Waters. 〈http://www.thegef.org/gef/sites/thegef.org/files/documents/GEF.C.3.7.pdf〉.

Hampton I., Boyer D.C., Penney A.J., Pereira A.F., Sardinha M., et al., 1999. Integrated Overview of Fisheries of the Benguela Current Region: Thematic Report No. 1. Synthesis and Assessment of Information on the BCLME. Windoek, Namibia: UNDP. p. 87.

Hume, A.C., Duda, A.M., 2012. Global Environment Facility strategy for assessing and managing large marine ecosystems during climate change. In: Sherman, K., McGovern, G. (Eds.), Frontline Observations on Climate Change and Sustainability of Large Marine Ecosystems. UNDP/GEF, New York, NY, USA, pp. 1–15.

Johannesburg Declaration, 2003. Johannesburg Declaration on Sustainable Development and Plan of Implementation of the World Summit on Sustainable Development: the Final Text of Agreements Negotiated by Governments at the World Summit on Sustainable Development. 26 August–4 September 2002, Johannesburg, South Africa New York, NY, USA.

Juda, L., Hennessey, T., 2001. Governance profiles and the management of the uses of large marine ecosystems. Ocean Dev. Int. Law 32, 41–67.

Kullenberg G., Huber M.E., 2011. Reducing Environmental Stress in the Yellow Sea Ecosystem: Final Evaluation Report. UNDP/GEF.

Lubchenco, J., 1994. The scientific basis of ecosystem management: framing the context, language, and goals. In: Zinn, J., Corn, D. L. (Eds.), Ecosystem Management: Status and Potential. U.S. Government Printing Office, Superintendent of Documents, pp. 33–39. (103rd Congress, 2d Session, Committee Print).

McLeod K.L., Lubchenco J., Palumbi S.R., Rosenberg A.A., et al., 2005. Scientific Consensus Statement on Marine Ecosystem-Based Management. 〈http://doc.nprb.org/web/BSIERP/EBM%20scientific%20statement.pdf〉.

Pauly, D., Christensen, V., 1995. Primary production required to sustain global fisheries. Nature 374, 255–257.

Pew Oceans Commission, 2003. America's Living Oceans: Charting a Course for Sea Change. Summary Report. Arlington, VA, USA.

Rio Declaration on Environment and Development, 1992. The 1992 United Nations Conference on Environment and Development. United Nations Environment Programme Rio de Janeiro, Brazil..

Samhouri, J.F., Levin, P.S., Harvey, C.J., et al., 2009. Quantitative Evaluation of Marine Ecosystem Indicator Performance Using Food Web Models. Ecosystems 12, 1283–1298.

Sea Around Us Project. The University of British Columbia, Canada. 〈www.seaaroundus.org〉.

Sherman, K., 2005. The large marine ecosystem approach for assessment and management of ocean coastal waters In: Hennessey, T.M., Sutinen, J.G. (Eds.), Sustaining Large Marine Ecosystems: The Human Dimension. Elsevier B.V., pp. 368.

Sherman, K., 1999. Modular approach to the monitoring and assessment of large marine ecosystems. In: Kumpf, H., Steidinger, K., Sherman, K. (Eds.), The Gulf of Mexico Large Marine Ecosystem: Assessment, Sustainability, and Management. Blackwell Science, Inc., Malden, MA, USA.

Sherman, K., Alexander, L.M., 1986. Variability and Management of Large Marine Ecosystems. Westview Press (AAAS), Boulder.

Sherman, K., Duda, A.M., 1999. An ecosystem approach to global assessment and management of coastal waters. Mar. Ecol. Prog. Ser. 190, 271–287.

Sherman K., Aquarone M.-C., Adams S., et al., 2010a. Scope and Objectives of Global Environment Facility Supported Large Marine Ecosystems Projects. NOAA Large Marine Ecosystem Program Report. NOAA Large Marine Ecosystem Program. Narragansett, RI, USA.

Sherman, K., Belkin, I., Friedland, K.D., O'Reilly, J., Hyde, K., et al., 2010. Accelerated warming and emergent trends in fisheries biomass yields of the world's large marine ecosystems. In: Sherman, K., Adams, S. (Eds.), Sustainable Development of the

World's Large Marine Ecosystems during Climate Change: A Commemorative Volume to Advance Sustainable Development on the Occasion of the Presentation of the 2010 Goteborg Award. IUCN, Gland, Switzerland, pp. 52–73.
Sherman, K., O'Reilly, J., Belkin, I.M., Melrose, C., Friedland, K.D., et al., 2010. The application of satellite remote sensing for assessing productivity in relation to fisheries yields of the world's large marine ecosystems. ICES J. Mar. Sci. 68, 667–676.
Sherman, K., Belkin, I., Seitzinger, S., Hoagland, P., Jin, D., Aquarone, M.-C., et al., 2009. Indicators of changing states of large marine ecosystems. In: Sherman, K., Aquarone, M.-C., Adams, S. (Eds.), Sustaining the World's Large Marine Ecosystems. IUCN, Gland, Switzerland.
Tapscott C., 1999. An Overview of the Socio-Economics of Some Key Martime Industries in the Benguela Current Region: Thematic Report No. 6. Synthesis and assessment of information on BCLME. Windhoek, Namibia, UNDP. pp. 17.
The Future We Want, 2012. Outcome Document from the 2012 United Nations Conference on Sustainable Development. Rio de Janeiro, Brazil.
UNDP/GEF, 2012. International Waters Delivering Results New York, NY. pp. 74. 〈http://iwlearn.net/publications/ll/international-waters-2013-delivering-results-2/view〉.
UNDP/GEF, 2009. UNDP/GEF Project. Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem. Strategic Action Programme. New York, NY, USA.
UNDP/GEF, 2008. UNDP/GEF. Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem. Report of the Fifth Meeting of the Regional Working Group for the Pollution Component. UNDP/GEF/YS/RWG-P.5/3.
UNDP/GEF, 2007. UNDP/GEF Project. Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem. Transboundary Diagnostic Analysis. New York, NY, USA.
UNDP/GEF, 2002. UNDP/GEF Project. Benguela Current Large Marine Ecosystem Programme. Strategic Action Programme. New York, NY, USA.
UNDP/GEF, 1999. UNDP/GEF Project. Benguela Current Large Marine Ecosystem Programme (BCLME). Transboundary Diagnostic Analysis. Windhoek, UNDP. pp. 291.
UNIDO/GEF, 2011. UNIDO/GEF Project. Integrated Assessment and Management of the Gulf of Mexico Large Marine Ecosystem. Transboundary Diagnostic Analysis.
UNIDO/GEF, 2005. UNIDO/GEF Project. Gulf of Mexico Large Marine Ecosystem. Preliminary Transboundary Diagnostic Analysis. 〈http://www.gulfofmexicoproject.org/pdf/tda/TDA&Chapters_MexUS.pdf〉.
Wang, H., 2004. Ecosystem management and its application to large marine ecosystems: science, law, and politics. Ocean Dev. Int. Law 35, 41–74.
Wang, H., 2004. An evaluation of the modular approach to the assessment and management of large marine ecosystems. Ocean Dev. Int. Law 35, 267–286.
Yáñez-Arancibia, A., Day, J.W., 2004. The Gulf of Mexico: towards an integration of coastal management with large marine ecosystem management. Ocean Coast. Manage. 47, 537–563.