

A Global Movement Toward an Ecosystem Approach to Management of Marine Resources

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The Large Marine Ecosystem Approach

Reports of problems with marine ecosystems are widespread in the scientific literature and the news media. Calls for an ecosystem approach to resource assessment and management are seldom accompanied by a practical strategy, particularly one with a payment plan for the approach in developing countries. However, a global movement that makes the ecosystem approach to management practical already exists. It is known as the Large Marine Ecosystem (LME) approach, and it is being endorsed and supported by governments nationally and worldwide, as well as by a broad constituency in the scientific community.

While we concur with the movement toward an ecosystem-based approach to the management of marine fisheries (Pikitch et al. 2004; Garcia et al. 2003; Sainsbury & Sumaila 2003; Stergiou 2002; Pitcher 2001; Gislason & Sinclair 2000; Browman et al. 2004), [and the Royal Society London special issue on ecosystems management] it is important to recognize that a broader, place-based approach to marine ecosystem assessment and management, focused on clearly delineated ecosystem units, is needed and is presently underway, with the support of financial grants, donor and UN partnerships, in nations of Africa, Asia, Latin America, and eastern Europe. It is within the boundaries of 64 large marine ecosystems that (i) 90 percent of the world's annual yield of marine fisheries is produced (Garibaldi & Limongelli 2003), (ii) global levels of primary production are the highest, (iii) the degradation of marine habitats is most severe, and (iv) coastal pollution is concentrated and levels of eutrophication are increasing (GESAMP 2001). Large marine ecosystems (LMEs) are natural regions of coastal ocean space encompassing waters from river basins and estuaries to the seaward boundaries of continental shelves and outer margins of coastal currents and water masses. They are relatively large regions characterized by

distinct bathymetry, hydrography, productivity, and trophically dependent populations;(www.edc.uri.edu/lme) (Sherman 1994; Alexander 1990; Levin 1990).

Since 1995, the Global Environment Facility (GEF) has provided substantial funding to support country-driven projects for introducing multisectoral ecosystem-based assessment and management practices for LMEs located around the margins of the oceans. At present, 121 developing countries are engaged in the preparation and implementation of GEF-LME projects, totaling \$650 million in start-up funding. A total of 10 projects including 70 countries have been approved by the GEF Council, and another 7 projects involving 51 countries have GEF international waters projects under preparation (www.iwlearn.net).

A five-module indicator approach to assessment and management of LMEs has proven useful in ecosystem-based projects in the United States and elsewhere, using suites of indicators of LME productivity, fish and fisheries, pollution and ecosystem health, socioeconomics and governance. The productivity indicators include spatial and temporal measurements of temperature, salinity, oxygen, nutrients, primary productivity, chlorophyll, zooplankton biomass, and biodiversity. For fish and fisheries, indicators are catch and effort statistics; demersal and pelagic fish surveys, fish population demography, and stock assessments (NOAA, OLO). Pollution and ecosystem health indicators include quality indices for water, sediment, benthos, habitats, and fish tissue contaminants (EPA 2004). Socioeconomic and governance indicators are discussed in Sutinen et al. (2000) and Juda and Hennessey (2001). The modules are adapted to LME conditions through a transboundary diagnostic analysis (TDA) process to identify key issues, and a strategic action program (SAP) development

process for the groups of nations or states sharing an LME to remediate the issues (Wang 2004). These processes are critical for integrating science into management in a practical way, and for establishing appropriate governance regimes. Of the five modules, three apply science-based indicators that focus on productivity, fish/fisheries, and pollution/ecosystem health; the other two, socio-economics and governance, focus on economic benefits to be gained from a more sustainable resource base and from providing stakeholders and stewardship interests with legal and administrative support for ecosystem-based management practices. The first four modules support the TDA process, while the governance module is associated with periodic updating of the SAP development process. Adaptive management regimes are encouraged through periodic assessment processes (TDA updates) and through updating the action programs as gaps are filled.

The GEF-LME projects presently funded or in the pipeline for funding in Africa, Asia, Latin America and eastern Europe represent a growing network of marine scientists, marine managers, and ministerial leaders who are pursuing ecosystem and fishery recovery goals. The annual fisheries biomass yields from the ecosystems in the network are significant at 44.8% of the global total, and are a firm basis for movement by the participating countries toward the 2002 World Summit on Sustainable Development (WSSD) targets for introducing ecosystem-based assessment and management by 2010, and for recovering depleted stocks and achieving fishing at maximum sustainable yield levels by 2015. The FAO Code of Conduct for Responsible Fishery Practice (FAO 2002) is supported by most coastal nations and has immediate applicability to reaching the WSSD fishery goals. The code argues for moving forward with a precautionary approach to fisheries sustainability, using available

information more conservatively to err on the side of lower total allowable catch levels than has been the general practice in past decades. Although fishing effort data are not available in FAO global catch reporting statistics and could bias catch data interpretations, it appears that the biomass and yields of 11 species groups in six LMEs have been relatively stable or have shown marginal increases over the 1990-1999 period. The yield for these six LMEs—the Arabian Sea, Bay of Bengal, Indonesian Sea, North Brazil Shelf, Mediterranean Sea and the Sulu-Celebes Sea—was 8.1 mmt, or 9.5 percent of the global marine fisheries yield in 1999 (Garibaldi & Limongelli 2003). The countries bordering these six LMEs are among the world's most populous, representing approximately one-quarter of the total human population. These LME border countries increasingly depend on marine fisheries for food security and for national and international trade. Given the risks of fishing-down-the-food-web, it would appear opportune for the stewardship agencies responsible for the fisheries of the LME-bordering countries to limit increase in fishing effort during a period of relative biomass stability.

Evidence for species biomass recovery following significant reduction in fishing effort through mandated actions is encouraging. In the U.S. Northeast Shelf LME, management actions to reduce fishing effort, combined with the robust condition of average annual primary productivity ($350\text{gCm}^2\text{yr}^{-1}$) for the past three decades, a relatively stable zooplankton biomass at or near $33\text{cc}/100\text{m}^3$ for the past 30 years (Sherman et al. 2002), and an oceanographic regime marked by a recurring pattern of interannual variability, but showing no evidence of temperature shift of the magnitude described for other North Atlantic LMEs, including the Scotian Shelf (Zwanenburg et al. 2003), the Newfoundland-

Labrador Shelf (Rice 2003), the Iceland Shelf (Astthorsson & Vilhjálmsson 2002) and the North Sea (Perry et al. 2005), contributed to: a recovery of depleted herring and mackerel stocks and an initiation of the recovery of depleted yellowtail flounder and haddock stocks (Sherman et al. 2003). Three LMEs remain at high risk for fisheries biomass recovery—expressed as a pre-1960s ratio of demersal to pelagic species—the Gulf of Thailand, East China Sea, and Yellow Sea (Pauly & Chuenpagdee 2003, Chen & Shen 1999; Tang & Jin 1999). The People's Republic of China has initiated steps toward recovery by mandating 60-90 day closures to fishing in the Yellow Sea and East China Sea (Tang 2003) and in the South China Sea (MOA, Ministry of Agriculture 2001) during summer months. The country-driven planning and implementation documents supporting the ecosystem approach to LME assessment and management practices can be found at www.iwlearn.net.

Nitrogen loadings

Globally, LME projects, in addition to rebuilding depleted fish stocks and restoring degraded coastal habitats, are also concerned with mitigating effects of nitrogen loadings. Nitrogen over-enrichment has been a coastal problem for two decades in the Baltic Sea LME (Helsinki Commission 2001). More recent human-induced increases in nitrogen flux range from 4- to 8-fold in the U.S. from the Gulf of Mexico to the New England coast (Howarth et al. 2000). In European LMEs, recent nitrogen flux increases have ranged from 3-fold in Spain to 11-fold in the Rhine River basin draining to the North Sea LME (Howarth et al. 2000). This disruption of the nitrogen cycle originated in the Green Revolution of the 1970s as the world community converted wetlands to agriculture, utilized more chemical fertilizer, and expanded irrigation to feed the world (Duda & El-Ashry 2000). For the Southeastern estuaries of the U.S. (Duda 1982) and for the Gulf of Mexico (Rabalais et al. 1999), much of the large increase in nitrogen export to LMEs is from agricultural inputs, from the increased

delivery of nitrogen fertilizer as wetlands were converted to agriculture, and from livestock production (NRC 2000). Also, sewage from large cities is a significant contributor to eutrophication, as is increased nitrogen in atmospheric deposition resulting from combustion of fossil fuels by automobiles and industrial activities (GESAMP 2001).

Global forecast models of nitrogen export from freshwater basins to coastal waters indicate that there will be a 50% increase world-wide in dissolved inorganic nitrogen (DIN) export by rivers to coastal systems from 1990 to 2050 (Seitzinger & Kroeze 1998; Kroeze & Seitzinger 1998). Such increases in nitrogen export are alarming for the future sustainability of LMEs. Given the expected future increases in population and in fertilizer use, without significant N mitigation efforts, LMEs will be subjected to a future of increasing harmful algal bloom events, reduced fisheries, and hypoxia that further degrades marine biomass yields and biological diversity. Models of nitrogen loading from land-based sources and models of ecosystem structure and function are being applied to LMEs with financial assistance from the GEF. Estimates of carrying capacity using ECOPATH-ECOSIM food web approaches for the world's 64 LMEs are being prepared in a GEF-supported collaboration between scientists of the University of British Columbia and marine specialists from developing countries. Similarly, a 24-month training project is being implemented by scientists from Rutgers University in collaboration with IOC/UNESCO to estimate expected nitrogen loadings for each LME over the next decade. Scientists from Princeton University and the University of California, Berkeley are examining particle spectra and pattern formation within LMEs. Additionally, the American Fisheries Society and the World Council of Fisheries Societies are collaborating in an electronic network to expedite

information access and communication among marine specialists. For more detail on the GEF-LME project, see www.gefonline.org/projectDetails.cfm?projID=2474.

The growing number of country-driven commitments to move toward ecosystem-based assessment and management of marine resources and environments provides an unprecedented opportunity for accelerating the transition to sustainable use, conservation, and development of marine ecosystems. The social, economic, and environmental costs of inaction are just too high for multilateral and bilateral institutions and international agencies not to support the initial efforts of 121 countries attempting to reach the WSSD marine ecosystem targets for restoration and sustainability. Both developed and developing nations have a stake in moving toward the use of sustainable ecosystem resources. Momentum should not be lost. The result may be irreversible damage to coastal ecosystems, to the livelihoods and security of poor coastal communities, and to the economies of coastal nations.

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Figure legend:

Fig. 1: Global map of average primary productivity and the boundaries of the 64 Large Marine Ecosystems (LMEs) of the world, available at www.edc.uri.edu/lme, Introduction. The annual productivity estimates are based on SeaWiFS satellite data collected between September 1998 and August 1999, and the model developed by Behrenfeld & Falkowski (1997). The color-enhanced image provided by Rutgers University depicts a shaded gradient of primary productivity from a high of $450 \text{ gCm}^2\text{yr}^{-1}$ in red to less than $45 \text{ gCm}^2\text{yr}^{-1}$ in purple.

