



The Large Marine Ecosystem network approach to WSSD targets

Kenneth Sherman*

Narragansett Laboratory, NOAA, NMFS, NEFSC, 28 Tarzwell Drive, Narragansett, Rhode Island 02882, USA

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Abstract

Since the 1992 United Nations Conference on Environment and Development, considerable movement has been made by international organizations engaged in ocean affairs towards adopting ecosystem-based assessment and management practices. A decade later, at the World Summit on Sustainable Development (WSSD), another significant milestone was reached with the support, by over 100 countries, for a Plan of Implementation that agreed on several specific ecosystem-related targets including: achievement of “substantial” reductions in land-based sources of pollution by 2006; introduction of the ecosystems approach to marine resource assessment and management by 2010; designation of a network of marine protected areas by 2012; and the maintenance and restoration of fish stocks to maximum sustainable yield levels by 2015. An international financial mechanism, the Global Environment Facility (GEF), is assisting developing countries in meeting the WSSD targets by supporting Large Marine Ecosystem (LME) assessment and management projects. Of the 29 LMEs for which published case study information is available on analyses of principal forces driving changes in biomass yields, fishing effort was the primary forcing mechanism in 14 LMEs, climate forcing was the principal factor in 13 LMEs, eutrophication in one case and the data were inconclusive in another. Fishing effort was a secondary driver of change in biomass yields in the 13 LMEs driven by climate forcing. Mitigating actions for reducing fishing effort to promote recovery of lost biomass yield is proving successful in one case study. Actions for improving forecasts of oceanographic conditions affecting fish stocks are underway in four GEF-supported LME projects (e.g., Humboldt Current, Canary Current, Guinea Current and Benguela Current); measures to assess and manage excessive fishing effort are planned for eight LME projects, eutrophication reduction and control in another; and six LMEs with relatively stable decadal biomass yields appear suitable for mandating precautionary total allowable catch levels. The GEF/LME projects include countries that contributed to 45% of global marine biomass yields in 1999.

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*Tel.: +1 401 782 3211; fax: +1 401 782 3201.

E-mail address: kenneth.sherman@noaa.gov.

1. The World Summit on Sustainable Development (WSSD) and large marine ecosystems (LMEs)

Significant progress has been made in moving toward the WSSD targets—to reduce land-based sources of pollution by 2006, introduce an ecosystems approach to marine resource assessment and management by 2010, designate a network of marine protected areas (MPAs) by 2012 and maintain and restore fish stocks to maximum sustainable yield (MSY) levels by 2015—within the framework of LMEs-based assessment and management actions in the United States and in developing countries in Africa, Asia, Latin America and emerging economies of eastern Europe. LMEs are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves, enclosed and semi-enclosed seas, and the outer margins of the major current systems (Fig. 1). They are relatively large regions on the order of 200,000 km² or greater, characterized by distinct bathymetry, hydrography, productivity and trophically dependent populations [1]. Sixty-four of the designated LMEs (Fig. 1) produce 95% of the global

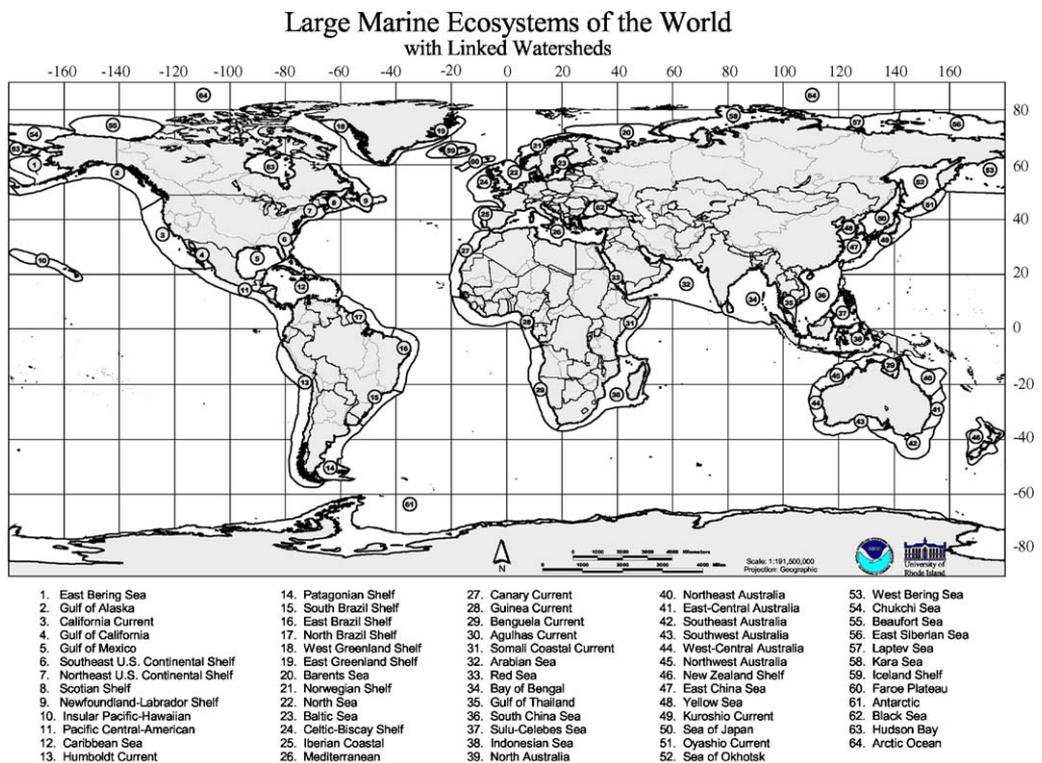


Fig. 1. Large Marine Ecosystems are areas of the ocean characterized by distinct bathymetry, hydrography, productivity and trophic interactions. They annually produce 95% of the world's fish catch. They are national and regional focal areas of a global effort to reduce the degradation of marine resources and coastal environments from pollution, habitat loss and overfishing. Currently there are 121 countries involved in 17 GEF/LME projects: ten projects operational (LMEs 28, 48, 14, 23, 29, 36, 62, 26, 33 and WPWWP (Western Pacific Warm Water Pool)) and seven projects in the planning phase (LMEs 27, 34, 13, 28, 5, 30 and 12).

marine fishery catch. They are also sites subject to coastal ocean pollution and coastal habitat alteration.

For 29 of the LMEs, studies have been conducted on the principal driving forces affecting changes in biomass yields. Changes in biodiversity among the dominant species within fish communities of LMEs have resulted from excessive exploitation, naturally occurring environmental shifts in climate regime or coastal pollution. For example, in the Humboldt Current, Benguela Current and California Current LMEs, the primary driving force influencing variability in fisheries yield is the influence of changes in upwelling strength, fishing and pollution effects are secondary and tertiary effects on fisheries yields. In continental shelf LMEs, including the Yellow Sea and Northeast United States Shelf, excessive fisheries effort has caused large-scale declines in catch and changes in the biodiversity and dominance in the fish community. In these ecosystems, climate changes are of secondary importance. In contrast, significant levels of eutrophication have been a principal force driving changes in fisheries yields, as in the Black Sea, for example. The results of these and other LME studies have been peer reviewed and published in a series of 12 volumes (Tables 1a and b).

Table 1

LME	Primary	Secondary		Expert assessments	Vol. Ref.
<i>(a) Primary and secondary driving forces of LME biomass yields^{a,b}</i>					
Humboldt Current	Climate	Fishing	16	Alheit and Bernal Wolff et al.	5 12
South China Sea	Fishing	Climate	10	Pauly and Christensen	5
East China Sea	Fishing	Climate	3.8	Chen and Shen	8
North Sea	Fishing	Climate	3.5	McGlade	10
Eastern Bering Sea	—	—	2.1	Schumacher et al.	12
Bay of Bengal	Fishing	Climate	2.0	Dwividi Hazizi	5 7
Okhotsk Sea ^c	Climate	Fishing	2.0	Kusnetsov et al.	5
Canary Current	Climate	Fishing	1.8	Roy and Cury Bas	12 5
Norwegian Shelf	Climate	Fishing	1.5	Ellertsen et al. Blindheim and Skjoldal	3 5
Iceland Shelf	Climate	Fishing	1.3	Astthorsson and Villhjálmsson	10
Benguela Current	Climate	Fishing	1.2	Crawford et al. Shannon and O'Toole	2 12
Gulf of Thailand	Fishing	Climate	1.1	Pauly and Chuenpagdee	12
Mediterranean Sea of Japan ^d	Fishing	Eutrophication	1.1	Caddy	5
Sea of Japan ^d	Climate	Fishing	1.0	Terazaki	8
Gulf of Mexico	Fishing	Climate	0.9	Richards and McGowan Brown et al. Shipp	2 4 9
Guinea Current	Climate	Fishing	0.9	Binet and Marchal Koranteng and McGlade	5 11
Baltic Sea	Fishing	Eutrophication	0.8	Kullenberg Jansson	1 12
California Current	Climate	Fishing	0.7	MacCall Lluch-Belda et al.	1 12
United States Northeast Shelf	Fishing	Climate	0.7	Sissenwine Murawski Sherman et al.	1 6 10

Table 1 (continued)

LME	Primary	Secondary		Expert assessments	Vol. Ref.
Scotian Shelf	Fishing	Climate	0.7	Zwanenburg et al.	10
				Zwanenburg	12
Black Sea	Eutrophication	Fishing	0.5	Caddy	5
				Daskalov	12
Barents Sea	Climate	Fishing	0.5	Skjoldal and Rey	2
				Borisov	4
				Blindheim and Skjoldal	5
				Matishov et al.	12
Caribbean Sea	Fishing	Climate	0.4	Richards and Bohnsack	3
Iberian Coastal	Climate	Fishing	0.3	Wyatt and Perez-Gandaras	2
Newfoundland-Labrador	Fishing	Climate	0.2	Rice et al.	10
Yellow Sea ^c	Fishing	Climate	0.2	Tang	2
				Tang	12
Great Barrier Reef	Fishing	Climate	0.1	Brodie	12
West Greenland Shelf	Climate	Fishing	0.1	Hovgard and Buch	3
				Pederson and Rice	10
Faroe Plateau	Climate	Fishing	0.1	Gaard et al.	10

(b) Volumes list for peer-reviewed, published LME studies

- Vol. 1 Variability and Management of Large Marine Ecosystems. Edited by K. Sherman and L.M. Alexander. AAAS Selected Symposium 99. Westview Press, Inc., Boulder, CO, 1986. 319p.
- Vol. 2 Biomass Yields and Geography of Large Marine Ecosystems. Edited by K. Sherman and L.M. Alexander. AAAS Selected Symposium 111. Westview Press, Inc., Boulder, CO, 1989. 493p.
- Vol. 3 Large Marine Ecosystems: Patterns, Processes, and Yields. Edited by K. Sherman, L.M. Alexander, and B.D. Gold. AAAS Symposium. AAAS, Washington, DC, 1990. 242p.
- Vol. 4 Food Chains, Yields, Models, and Management of Large Marine Ecosystems. Edited by K. Sherman, L.M. Alexander, and B.D. Gold. AAAS Symposium. Westview Press, Inc., Boulder, CO, 1991. 320p.
- Vol. 5 Large Marine Ecosystems: Stress, Mitigation, and Sustainability. Edited by K. Sherman, L.M. Alexander, and B.D. Gold. AAAS Press, Washington, DC, 1992. 376p.
- Vol. 6 The Northeast Shelf Ecosystem: Assessment, Sustainability, and Management. Edited by K. Sherman, N.A. Jaworski, and T.J. Smayda. Blackwell Science, Inc., Cambridge, MA, 1996. 564p.
- Vol. 7 Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability, and Management. Edited by K. Sherman, E.N. Okemwa, and M.J. Ntiba. Blackwell Science, Inc., Malden, MA, 1998. 394p.
- Vol. 8 Large Marine Ecosystems of the Pacific Rim: Assessment, Sustainability, and Management. Edited by K. Sherman and Q. Tang. Blackwell Science, Inc., Malden, MA, 1999. 455p.
- Vol. 9 The Gulf of Mexico Large Marine Ecosystem: Assessment, Sustainability, and Management. Edited by H. Kumpf, K. Stiedinger, and K. Sherman. Blackwell Science, Inc., Malden, MA, 1999. 736p.
- Vol. 10 Large Marine Ecosystems of the North Atlantic: Changing States and Sustainability. Edited by H.R. Skjoldal and K. Sherman. Elsevier, Amsterdam and New York. 2002. 449p.
- Vol. 11 Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Edited by J. McGlade, P. Cury, K. Koranteng, N.J. Hardman-Mountford. Elsevier Science, Amsterdam and New York. 2002. 392p.
- Vol. 12 Large Marine Ecosystems of the World: Trends in Exploitation, Protection, and Research. Edited by G. Hempel and K. Sherman. Elsevier Science, Amsterdam and New York. 2003. 423p.

^aBased on published expert assessments.^bAnnual biomass yield levels based on 1990–1999 mid-decadal data (1995) from FAO, 2003.^cOkhotsk Sea LME data from Kusnetsov et al. [8] based on mid-decadal (1972) data on fishing yields from 1962 to 1982.^dBiomass yield data from Terazki [9] based on mid-decadal data (1985) from Sea of Japan 1980–1990.^eBiomass yield data from Tang [7] based on mid-decadal data for demersal species for the Yellow Sea, 1952–1992.

2. Global Environment Facility (GEF)

Following a 3-year pilot phase (1991–1994), the GEF was formally launched to forge cooperation and finance actions in the context of sustainable development that address critical threats to the global environment, such as biodiversity loss, climate change, degradation of international waters, ozone depletion and persistent organic pollutants. GEF projects are implemented by the United Nations Development Program, United Nations Environment Program (UNEP), and the World Bank; expanded opportunities exist for participation by other agencies.

In 1995, the GEF Council included the concept of LMEs in its GEF Operational Strategy as a vehicle for promoting ecosystem-based management of coastal and marine resources in the international waters focal area within a framework of sustainable development. The Report of the Second Meeting of the United Nations Informal, Open-ended Consultative Process on Ocean Affairs [2] related to the UN Convention on the Law of the Sea recognized the contribution of the GEF in addressing LMEs through its science-based and ecosystem-based approach.

The geographic area of the LME, its coastal area and contributing basins constitute the place-based area for assisting countries to understand linkages among root causes of degradation and integrating needed changes in sectoral economic activities. The LME areas serve to initiate capacity building and bring science to pragmatic use in improving the management of coastal and marine ecosystems. The GEF Operational Strategy recommends that nations sharing an LME begin to address coastal and marine issues by jointly undertaking strategic processes for analyzing factual, scientific information on transboundary concerns and their root causes, as well as setting priorities for action on transboundary concerns. This process has been referred to as a Transboundary Diagnostic Analysis (TDA) and provides a useful mechanism to foster participation at all levels. Countries then determine national and regional policy, legal and institutional reforms and investments needed to address the priorities in a country-driven Strategic Action Program (SAP). This allows sound science to become the basis for policymaking and fosters focus on a geographic location where an ecosystem-based approach to management can be developed. More importantly, the LME strategy engages stakeholders within the geographic area to contribute to the dialog and in the end support the ecosystem-based approach that can be pragmatically implemented by the communities and governments involved. Without such participative processes to engage specific stakeholders in a place-based setting, marine science has often remained confined to the marine science community or has not been embraced in policymaking. Furthermore, the science-based approach encourages transparency, which builds trust among nations over time and can overcome the barrier of false information being reported, through joint monitoring and assessment processes (joint cruises for countries sharing an LME).

Table 2 lists LME projects that have been approved by the GEF or are under preparation with GEF funding. The approved GEF/LME projects include developing nations or those in economic transition, as well as Organisation for Economic Co-operation and Development (OECD) countries since living resources, pollution loading and critical habitats have transboundary implications across rich and poor nations alike. A sum of \$650 million in total project costs from the North and South were invested as of October 2003 in 10 LME projects in with \$225 million in GEF grant finance; an additional seven LME projects are under preparation. The GEF/LME projects involve 121 countries.

Table 2
121 countries involved in GEF/LME Projects

LME	Countries
<i>Approved GEF Projects</i>	
Gulf of Guinea (6)	Benin, Cameroon, Côte d'Ivoire, Ghana, Nigeria, Togo
Yellow Sea (2)	China, Korea
Patagonia Shelf/Maritime Front (2)	Argentina, Uruguay
Baltic (9)	Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, Sweden
Benguela Current (3)	Angola, Namibia, South Africa
South China Sea (7)	Cambodia, China ^a , Indonesia, Malaysia, Philippines, Thailand, Vietnam
Black Sea (6)	Bulgaria, Georgia, Romania, Russia ^a , Turkey, Ukraine
Mediterranean (19)	Albania, Algeria, Bosnia-Herzegovina, Croatia, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Morocco, Slovenia, Spain, Syria, Tunisia, Turkey ^a , Yugoslavia, Portugal
Red Sea (7)	Djibouti, Egypt ^a , Jordan, Saudi Arabia, Somalia, Sudan, Yemen
Western Pacific Warm Water Pool-SIDS ^b (13)	Cook Islands, Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu
<i>GEF Projects in the Preparation Stage</i>	
Canary Current (7)	Cape Verde, Gambia, Guinea, Guinea-Bissau, Mauritania, Morocco ^a , Senegal
Bay of Bengal (8)	Bangladesh, India, Indonesia ^a , Malaysia ^a , Maldives, Myanmar, Sri Lanka, Thailand ^a
Humboldt Current (2)	Chile, Peru
Guinea Current (16)	Angola ^a , Benin ^a , Cameroon ^a , Congo, Democratic Republic of the Congo, Côte d'Ivoire ^a , Gabon, Ghana ^a , Equatorial Guinea, Guinea ^a , Guinea-Bissau ^a , Liberia, Nigeria ^a , Sao Tome and Principe, Sierra Leone, Togo ^a
Gulf of Mexico (3)	Cuba, Mexico, United States
Agulhus/Somali Currents (8)	Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa ^a , Tanzania
Caribbean LME (23)	Antigua and Barbuda, The Bahamas, Barbados, Belize, Columbia, Costa Rica, Cuba ^a , Grenada, Dominica, Dominican Republic, Guatemala, Haiti, Honduras, Jamaica, Mexico ^a , Nicaragua, Panama, Puerto Rico ^c , Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, Venezuela

^aAdjusted for multiple listings.

^bProvisionally classified as insular Pacific Provinces in the global hierarchy of LMEs and Pacific Biomes (Watson et al., 2003).

^cA self-governing commonwealth in union with the United States.

With participating OECD countries that share the LMEs with the GEF recipient nations, it is expected that reforms will take place in both the North and the South in order to operationalize this ecosystem-based approach to managing human activities in the different economic sectors that contribute to place-specific degradation of the LMEs and adjacent waters.

3. LME modules

A five-module approach to the assessment and management of LMEs has been proven useful in ecosystem-based projects in the United States, Africa, Asia, Eastern Europe and

Latin America. The modules are customized to the situation within the context of the TDA process and the SAP development process for the groups of nations sharing the particular LME based on available information and capacity. These processes are critical to integrate science into management in a practical way and to establish governance regimes appropriate for the particular situation. Three of the five modules are science-based activities focused on productivity, fish/fisheries and pollution/ecosystem health. The other two modules, socioeconomics and governance, are focused on socioeconomic benefits to be derived from a more sustainable resource base and implementing governance mechanisms for 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. Adaptive management regimes are encouraged through periodic assessment processes (TDA updates) and the updating of SAPs as gaps are filled [3].

4. The LME network and progress toward WSSD targets

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 several hundred marine scientists, marine managers and ministerial leaders from 121 countries who are engaged in pursuing the ecosystem and fishery recovery goals. The significant annual global biomass yields of marine fisheries from ecosystems in the GEF/LME Network (44.8%) provides a firm basis for moving toward the WSSD goals regarding the introduction of an ecosystem-based assessment and management approach to global fisheries by 2010, and maintaining and restoring fishing MSY levels by 2015 (Table 3). There is now an international fisheries practice code (supported by most coastal nations) that could have immediate applicability to reaching WSSD fishery goals. The Food and Agriculture Organization's Code of Conduct for Responsible Fisheries Practice of 2002 argues for moving forward with a "precautionary approach" to fisheries sustainability, given a situation wherein available information can be used to recommend a more conservative approach to fish and fisheries' total allowable catch levels than has been the general practice over the past several decades. Based on the decadal profile of LME biomass yields from 1990 to 1999 [4], it appears that the yields of total biomass and the biomass of 11 species groups of six LMEs have been relatively stable or have shown marginal increases over the decade [5]. The yield of marine biomass for these six LMEs was 8.1 MMT, or 9.5% of the global marine fisheries yield in 1999. The countries bordering these six LMEs—Arabian Sea, Bay of Bengal, Indonesian Sea, Northeast Brazil Shelf, Mediterranean Sea and the Sulu-Celebes Sea—are among the world's most populous, representing approximately one-quarter of the total human population. These LME border countries are increasingly dependent 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 bordering countries to consider options for mandating precautionary total allowable catch levels during a period of relative biomass stability.

Evidence for species recovery following a significant reduction in fishing effort through mandated actions is encouraging. Following management actions to reduce fishing effort, the robust condition of the United States Northeast Shelf ecosystem with regard to the average annual level of primary productivity ($350 \text{ gCm}^{-2} \cong \text{yr}$), stable annual average levels

Table 3
 Fisheries biomass yields of LMEs where stewardship ministries implementing or planning GEF/LME Projects^{a,b}

LME	Reported 1999 Annual Biomass Yield in Million Metric Tons
South China Sea	13.9
Humboldt Current	12.0
Bay of Bengal	2.3
Patagonian Shelf	1.7
Canary Current	1.6
Benguela Current	1.1
Guinea Current	1.0
Mediterranean Sea	1.0
Gulf of Mexico	1.0
Baltic Sea	0.9
Yellow Sea ^c	0.6
Black Sea	0.5
Caribbean Sea	0.35
Red Sea	0.08
Agulhas/Somali Currents	0.07
Total	38.10 MMT
Percentage of Annual Global Marine Yield	44.8%

^aData from 1999 annual landings reported in FAO Fisheries Technical Paper 435 [4].

^bNo information available for the Western Pacific Warm Water Pool.

^cBiomass Yield Data for 1995 from Tang [7].

of zooplankton (33 cc/100 m³), and a relatively stable oceanographic regime [6], contributed to: (1) a relatively rapid recovery of depleted herring and mackerel stocks, with the cessation of foreign fisheries in the mid-1970s; and (2) initiation of the recovery of depleted yellowtail flounder and haddock stocks following a mandated 1994 reduction in fishing effort [6].

Three LMEs—the Gulf of Thailand, East China Sea and Yellow Sea—remain at high risk for fisheries biomass recovery, expressed as a pre-1960s ratio of demersal to pelagic species [5]. However, mitigation actions have been initiated by the People's Republic of China toward recovery by mandating 60–90-day closures to fishing in the Yellow Sea and East China Sea during summer months [7]. The country-driven planning and implementation documents supporting the ecosystem approach to LME assessment and management practices can be found at www.iwlearn.org.

The WSSD target for introducing ecosystem-based assessment and management practices by 2010 is likely to be met by the 121 countries constituting the existing LME Network (Table 2). All participating countries develop TDAs and SAPs that are ecosystem-based, and they apply the LME approach to the assessment and management of marine resources and their environments. It is unlikely that the WSSD target for maintaining and restoring fishery resources to MSY levels by 2015 will be met. However, progress is being made in recovery of depleted fish stocks through mandated reductions in fishing effort [6]. With regard to the target for control and reduction of land-based sources of pollution, considerable additional effort will be required to achieve “substantial reductions in land-based sources of pollution by 2006.” Under a partnership agreement

between the National Oceanic and Atmospheric Administration of the United States Department of Commerce (NOAA), UNEP and the World Bank, significant reductions in land-based sources of pollution consistent with the objectives of UNEP's Global Program of Action are expected. An estimated \$1.8 billion in construction and operation of wastewater treatment plants and other actions to reduce non-point source inputs of pollutants are being supported jointly by the World Bank and countries in Southeast Asia bordering on the Yellow Sea, East China Sea, Sulu-Celebes Sea, Indonesia Sea and South China Sea LMEs. Beginning early in 2006, UNEP and NOAA will be working jointly with countries of Southeast Asia in assessing the impact of pollution reduction on the "health" of the five bordering LMEs. Some progress has already been made in mapping and designating MPAs within the GEF/LME project Network, including the Benguela Current LME project (www.bclme.org). Significant progress toward the designated global network of MPAs by 2012 is expected through the GEF-supported LME projects.

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