NOAA Technical Memorandum NMFS-NE-183

NOAA Fisheries Service's Large Marine Ecosystems Program: Status Report

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

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NOAA Fisheries Service's Large Marine Ecosystems Program: Status Report

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Editorial Notes

Publication Date: In order to distribute a prepublication draft of this document at a September 2004 conference, the issue number (*i.e.*, 183) and publication date (*i.e.*, July 2004) were assigned in summer 2004. Subsequent to that time, some new information was added and some existing information was revised. These actions explain why some 2005 literature citations appear in a document with a July 2004 publication date.

Species Names: The NEFSC Editorial Office's policy on the use of species names in all technical communications is generally to follow the American Fisheries Society's lists of scientific and common names for fishes (*i.e.*, Robins *et al.* 1991a[a],b[b]) mollusks (*i.e.*, Turgeon *et al.* 1998[c]), and decapod crustaceans (*i.e.*, Williams *et al.* 1989[d]), and to follow the Society for Marine Mammalogy's guidance on scientific and common names for marine mammals (*i.e.*, Rice 1998[e]). Exceptions to this policy occur when there are subsequent compelling revisions in the classifications of species, resulting in changes in the names of species (*e.g.*, Cooper and Chapleau 1998[f], McEachran and Dunn 1998[g]).

Internet Availability: This issue of the *NOAA Technical Memorandum NMFS-NE* series is being copublished, *i.e.*, as both a paper and Web document. The Web document, which will be in HTML (and thus searchable) and PDF formats, can be accessed at: *http://www.nefsc.noaa.gov/nefsc/publications/tm/tm183*.

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[a]Robins, C.R. (chair); Bailey, R.M.; Bond, C.E.; Brooker, J.R.; Lachner, E.A.; Lea, R.N.; Scott, W.B. 1991. Common and scientific names of fishes from the United States and Canada. 5th ed. *Amer. Fish. Soc. Spec. Publ.* 20; 183 p.

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Acronyms

FAO	=	UN's Food and Agriculture Organization
GEF	=	UN's Global Environment Facility
IOC	=	UN's Intergovernmental Oceanographic Commission
IUCN	=	International Union for the Conservation of Nature and Natural Resources; also known as World Conservation Union
LME	=	large marine ecosystem
NERRS	=	NOAA's National Estuarine Research Reserve System
NOAA	=	US Department of Commerce's National Oceanic and Atmospheric Administration
SAP	=	strategic action plan
TDA	=	transboundary diagnostic analysis
UN	=	United Nations
UNDP	=	UN Development Program
UNEP	=	UN Environment Program
UNCED	=	1992 UN Conference on Environment and Development
WSSD	=	2004 World Summit on Sustainable Development

INTRODUCTION

Since 1984, the NOAA Fisheries Service's Large Marine Ecosystems (LME) Program has been engaged in the development and implementation of an ecosystem-based approach to support assessment and management of marine resources and habitats. Five linked program modules have been developed for introducing the LME approach: productivity, fish and fisheries, pollution and ecosystem health, socioeconomics, and governance. Taken together, these modules provide time-series measurements used to support actions for the recovery, sustainability, and management of marine resources and habitats. The 10 LMEs of the United States are the Northeast Shelf, Southeast Shelf, Gulf of Mexico, California Current, Gulf of Alaska, East Bering Sea, Beaufort Sea, Chukchi Sea, Insular Pacific-Hawaii, and Caribbean Sea (Figure 1).

A global effort is underway by NOAA in partnership with the World Conservation Union (IUCN), the UN's Intergovernmental Oceanographic Commission (IOC), and other UN agencies to improve the long-term sustainability of resources and environments of the world's 64 LMEs and linked watersheds. Scientific and technical assistance is provided to developing countries committed to policies and actions for eliminating transboundary environmental and resource-use practices that lead to serious degradation of coastal environments and their linked watersheds, and to losses in biodiversity and food security.

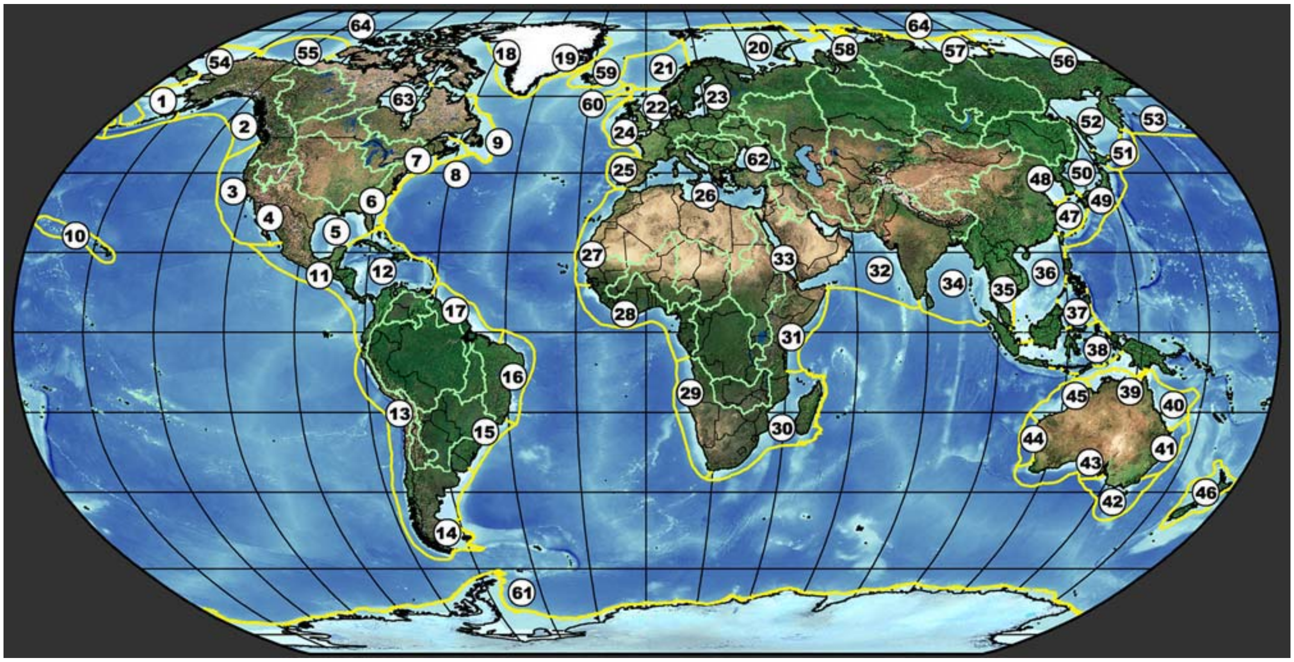
LME DESCRIPTION

DEFINITION

LMEs are natural regions of ocean space encompassing coastal waters from river basins and estuaries to the seaward boundary of continental shelves and the outer margins of coastal currents. They are relatively large regions of 200,000 km^2 or greater, the natural boundaries of which are based on four ecological criteria: bathymetry, hydrography, productivity, and trophically related populations.

The theory, measurement, and modeling relevant to monitoring the changing states of LMEs are imbedded in reports on ecosystems with multiple steady states, and on the pattern formation and spatial diffusion within ecosystems (Holling 1973, 1986, 1993; Pimm 1984; Sherman and Alexander 1986, 1989; Sherman *et al*. 1990; Beddington 1986; Mangel 1991; Levin 1993). The concept that critical processes controlling the structure and function of biological communities can best be addressed on a regional

Figure 1. LMEs correspond to natural features. (The 10 LMEs of the United States are regions of the ocean starting in coastal areas and extending out to the seaward boundaries of continental shelves and major current systems. They take into account the biological and physical components of the marine environment as well as terrestrial features such as river basins and estuaries that drain into these ocean areas. From the final report of the U.S. Commission on Ocean Policy (USCOP 2004).)



1. East Bering Sea
2. Gulf of Alaska
3. California Current
4. Gulf of California
5. Gulf of Mexico
6. Southeast U.S. Continental Shelf
7. Northeast U.S. Continental Shelf
8. Scotian Shelf
9. Newfoundland-Labrador Shelf
10. Insular Pacific-Hawaiian
11. Pacific Central-American
12. Caribbean Sea
13. Humboldt Current
14. Patagonian Shelf
15. South Brazil Shelf
16. East Brazil Shelf
17. North Brazil Shelf
18. West Greenland Shelf
19. East Greenland Shelf
20. Barents Sea
21. Norwegian Sea
22. North Sea
23. Baltic Sea
24. Celtic-Biscay Shelf
25. Iberian Coastal
26. Mediterranean
27. Canary Current
28. Guinea Current
29. Benguela Current
30. Agulhas Current
31. Somali Coastal Current
32. Arabian Sea
33. Red Sea
34. Bay of Bengal
35. Gulf of Thailand
36. South China Sea
37. Sulu-Celebes Sea
38. Indonesian Sea
39. North Australia
40. Northeast Australia
41. East-Central Australia
42. Southeast Australia
43. Southwest Australia
44. West-Central Australia
45. Northwest Australia
46. New Zealand Shelf
47. East China Sea
48. Yellow Sea
49. Kuroshio Current
50. Sea of Japan
51. Oyashio Current
52. Sea of Okhotsk
53. West Bering Sea
54. Chukchi Sea
55. Beaufort Sea
56. East Siberian Sea
57. Laptev Sea
58. Kara Sea
59. Iceland Shelf
60. Faroe Plateau
61. Antarctic
62. Black Sea
63. Hudson Bay
64. Arctic Ocean

Figure 2. Global map showing 64 LMEs and linked watersheds.

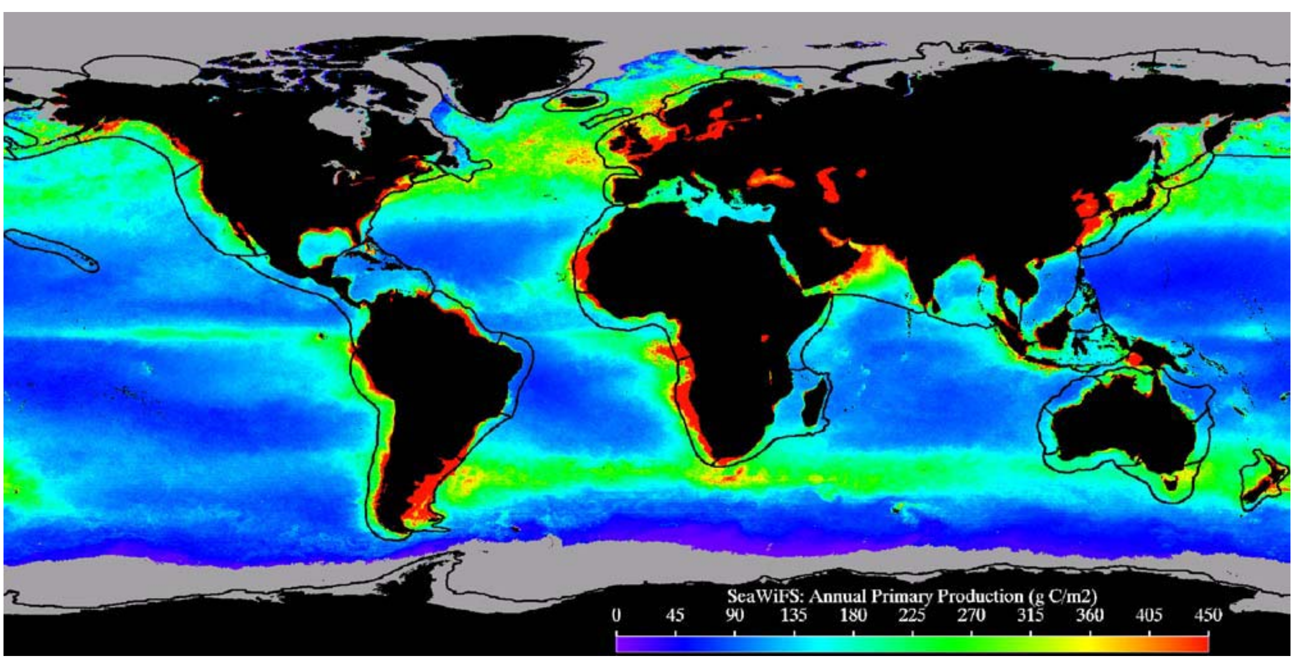


Figure 3. Global map showing 64 LMEs and their estimated average annual primary productivity. (Estimates are based on SeaWIFS satellite data collected between September 1998 and August 1999, and the model developed by Behrenfeld and Falkowski (1997). The color-enhanced image (provided by courtesy of Rutgers University) depicts a shaded gradient of primary productivity from a high of 450 $gCm^{-2}yr^{-1}$ in red to <45 $gCm^{-2}yr^{-1}$ in purple.)

basis (Ricklefs 1987) has been applied to the ocean by using LMEs as the distinct units for marine resources assessment, monitoring, and management. In turn, the concept of assessment, monitoring, and management of marine resources from an LME perspective has been the topic of a series of ongoing national and international studies, symposia case studies, and workshops initiated in 1984; in each instance, the geographic extent of the LME has been defined on the basis of bathymetry, hydrography, productivity, and trophodynamics. A list of peer-reviewed published volumes of LME case studies is given in Table 1.

DELINEATION AND MAJOR STRESSORS

Within the geographic limits of LMEs, domains or subsystems can be defined. For example, the Adriatic Sea is a subsystem of the Mediterranean Sea LME. In other LMEs, geographic limits are defined by the character of continental shelves. Among these are the U.S. Northeast Continental Shelf and its four subsystems -- Gulf of Maine, Georges Bank, Southern New England, and Mid-Atlantic Bight (Sherman *et al*. 1988, 1998). Other examples of continental shelf LMEs are the Icelandic Shelf, Yellow Sea, East Bering Sea, North Sea, and Barents Sea. For LMEs with narrow shelf areas and well-defined currents, the LMEs are bounded by the outer margins of the major coastal currents. The Humboldt Current, California Current, Canary Current, Kuroshio Current, and Benguela Current are examples of coastal current LMEs.

The areas of the world most stressed from habitat degradation, pollution, and overexploitation of marine resources are the coastal ecosystems. Ninety percent of the usable annual global biomass yield of fish and other living marine resources is produced in 64 LMEs (Figure 2) identified within, and in some cases extending beyond, the boundaries of the exclusive economic zones of coastal nations located around the margins of the ocean basins (Sherman 1994; Garibaldi and Limongelli 2003). Levels of primary production are persistently higher around the margins of the ocean basins than in the open-ocean pelagic areas (Figure 3). High population density characterizes these coastal ocean areas and contributes to the pollution that has its greatest impact on natural productivity cycles through eutrophication from high levels of nitrogen and phosphorus effluent from estuaries. Toxins in poorly treated sewage discharge, harmful algal blooms, and loss of wetland nursery areas to coastal development are ecosystem-level problems that also need to be addressed (GESAMP 1990).

MONITORING AND ASSESSMENT

Temporal and spatial scales influencing biological production and changing ecological states in marine ecosystems have been the topic of a number of theoretical and empirical studies. The selection of scale in any study is

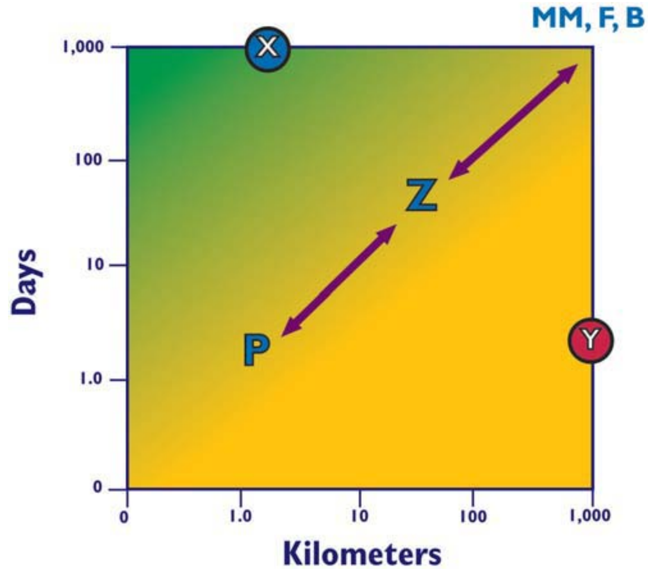


Figure 4. A simple set of scale relations for the pelagic food web. (P = phytoplankton, Z = zooplankton, F = fish, MM = marine mammals, B = birds, X = predictable fronts with small cross-front dimensions, and Y= weather events occurring over relatively large scales. Adapted from Steele (1988).)

related to the processes under investigation. An excellent treatment of this topic can be found in Steele (1988). Steele indicates that in relation to the general ecology of the sea, the best-known models in marine population dynamics include those by Schaefer (1954) and Beverton and Holt (1957), following the earlier pioneering approach of Lindemann (1942). However, as noted by Steele (1988), this array of models is unsuitable for dealing with temporal or spatial variability in the ocean. A heuristic projection was produced by Steele (1988) to illustrate scales and ecosystem indicators of importance in monitoring pelagic components of the ecosystem, including phytoplankton, zooplankton, fish, frontal processes, and short-term but large-area episodic effects (Figure 4).

A key factor in reaching a determination on the status of ecosystem condition is the quantitative output from spatial and temporal time series of indicators of condition in productivity, fish and fisheries, pollution and ecosystem health, socioeconomics, and governance. Advances in technology now allow for cost-effective measuring of the changing states of LMEs using suites of indicators, including those depicted in Figure 5.

LME INDICATOR MODULES

A five-module indicator approach to assessment and management of LMEs has proven useful in ecosystem-based projects in the United States and elsewhere. The modules are customized for each LME through a transboundary diagnostic analysis (TDA) process and a strategic action plan (SAP) development process for the

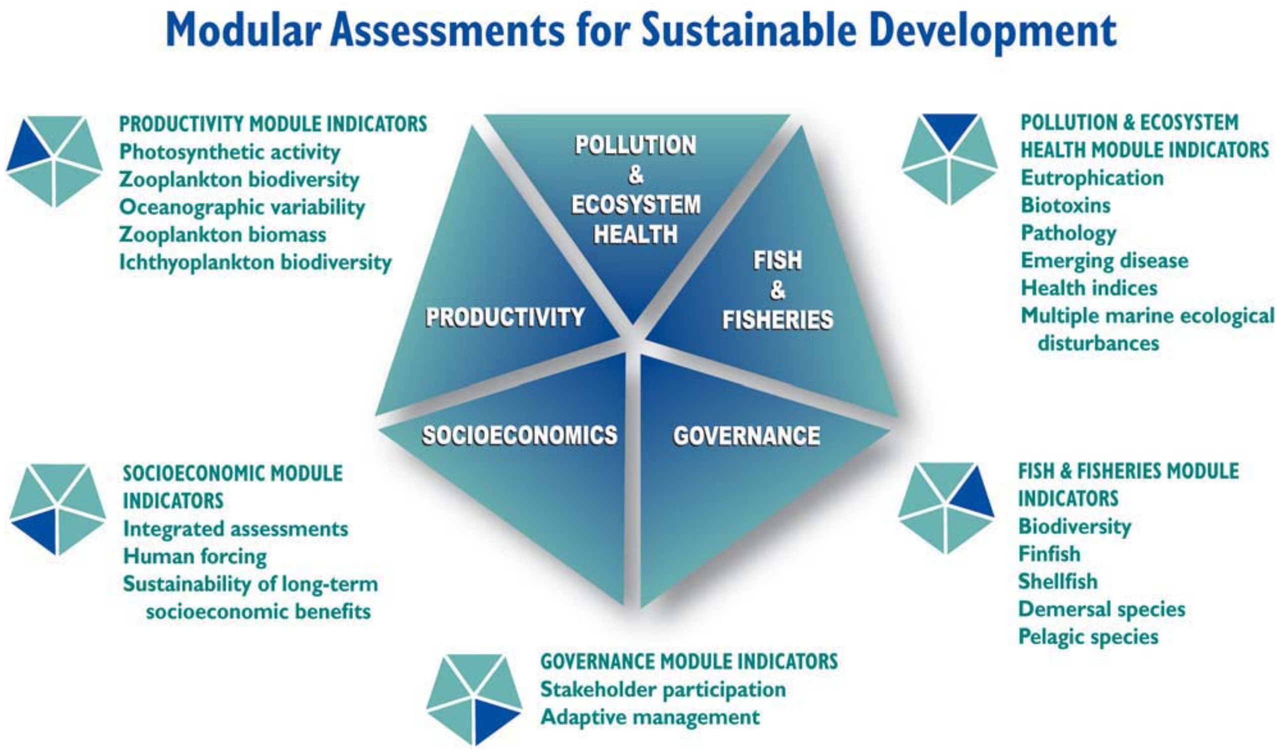


Figure 5. LME modules as suites of condition indicators.

groups of nations or states sharing an LME. These processes are critical for integrating science into management in a practical way, and for establishing appropriate governance regimes.

Of the five modules, three are science-based indicators that focus on productivity, fish/fisheries, and pollution/ecosystem health. The other two modules, socioeconomics and governance, support the development of indicators that improve measures of economic benefits to be derived from a more sustainable resource use, as well as advance 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 (*i.e.*, TDA updates) and through updating the action plans as gaps are filled (Wang 2004).

PRODUCTIVITY MODULE INDICATORS

Primary productivity can be related to the carrying capacity of an ecosystem for supporting fish resources (Pauly and Christensen 1995). It has been reported that the maximum global level of primary productivity for supporting the average annual world catch of fisheries has been reached, and that further large-scale unmanaged increases in fisheries yields from marine ecosystems are likely to be at trophic levels below fish in the marine food web (Beddington 1995).

Measurements of ecosystem productivity can be useful indicators of the growing problem of coastal eutrophication. In several LMEs, excessive nutrient loadings of coastal waters have been related to algal blooms implicated in mass mortalities of living resources, emergence of pathogens (*e.g.*, cholera, vibrios, red tides, and paralytic shellfish toxins), and explosive growth of nonindigenous species (Epstein 1993).

The ecosystem parameters measured and used as indicators of changing conditions in the productivity module are zooplankton biodiversity and species composition, zooplankton biomass, water-column structure, photosynthetically active radiation, transparency, chlorophyll-*a*, nitrite, nitrate, and primary production. Plankton inhabiting LMEs have been measured over decadal time scales by deploying continuous plankton recorder systems monthly across ecosystems from commercial vessels of opportunity. Advanced plankton recorders can be fitted with sensors for temperature, salinity, chlorophyll, nitrate/nitrite, petroleum, hydrocarbons, light, bioluminescence, and primary productivity, providing the means for in-situ monitoring and for calibrating satellite-derived oceanographic data. Properly calibrated satellite data can provide information on ecosystem conditions including physical state (*i.e.*, surface temperature), nutrient characteristics, primary productivity, and phytoplankton species composition (Berman and Sherman 2001; Aiken *et al*. 1999).

FISH AND FISHERIES MODULE INDICATORS

Changes in biodiversity and species dominance within fish communities of LMEs have resulted from excessive exploitation, naturally occurring environmental shifts due to climate change, and coastal pollution. Changes in biodiversity and species dominance in a fish community can cascade up the food web to apex predators and down the food web to plankton components of the ecosystem.

The fish and fisheries module includes both fisheries-independent bottom-trawl surveys and pelagic-species acoustic surveys to obtain time-series information on changes in fish biodiversity and abundance levels. Standardized sampling procedures, when employed from small calibrated trawlers, can provide important information on changes in fish species (Sherman 1993). Fish catch provides biological samples for stock identification, stomach content analyses, age-growth relationships, fecundity, and coastal pollution monitoring for possibly associated pathological conditions, as well as data for preparing stock assessments and for clarifying and quantifying multispecies trophic relationships. The survey vessels can also be used as platforms for obtaining water, sediment, and benthic samples for monitoring harmful algal blooms, diseases, anoxia, and changes in benthic communities.

POLLUTION AND ECOSYSTEM HEALTH MODULE INDICATORS

In several LMEs, pollution and eutrophication have been important driving forces of change in biomass yields. Assessing the changing status of pollution and health of an entire LME is scientifically challenging. Ecosystem health is a concept of wide interest for which a single precise scientific definition is difficult. The health paradigm is based on multiple-state comparisons of ecosystem resilience and stability, and is an evolving concept that has been the subject of a number of meetings (Sherman 1993). To be healthy and sustainable, an ecosystem must maintain its metabolic activity level and its internal structure and organization, and must resist external stress over time and space scales relevant to the ecosystem (Costanza 1992).

The pollution and ecosystem health module measures pollution effects on the ecosystem through the bivalve mollusk monitoring strategy of the U.S. Environmental Protection Agency's Mussel-Watch Program, through the pathobiological examination of fish, through the estuarine and nearshore monitoring of contaminants and contaminant effects in the water column, substrate, and selected groups of organisms, and through similar efforts. Where possible, bioaccumulation and trophic transfer of contaminants are assessed, and critical life history stages and selected food web organisms are examined for indicators of exposure to, and effects from, contaminants. Effects of impaired reproductive capacity, organ disease, and impaired growth from contaminants are measured. Assessments are made of contaminant impacts at both species and population levels. Implementation of protocols to assess the frequency and effect of harmful algal blooms, emergent diseases, and multiple marine ecological disturbances (Sherman 2000) are included in the pollution module.

In the United States, the EPA has developed a suite of five coastal condition indices -- water quality, sediment quality, benthic communities, coastal habitat, and fish tissue contaminants -- as part of an ongoing collaborative effort with NOAA, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, and other agencies representing states and tribes. The 2004 report, "National Coastal Condition Report II," includes results from EPA's analyses of coastal condition indicators and NOAA's fish stock assessments by LMEs aligned with EPA's national coastal assessment regions (USEPA 2001, 2004).

SOCIOECONOMIC MODULE INDICATORS

This module emphasizes the practical application of scientific findings to managing LMEs, and the explicit integration of social and economic indicators and analyses with all other scientific assessments, to assure that prospective management measures are cost-effective. Economists and policy analysts work closely with ecologists and other scientists to identify and evaluate management options that are both scientifically credible and economically practical with regard to the use of ecosystem goods and services.

In order to respond adaptively to enhanced scientific information, socioeconomic considerations must be closely integrated with science. This component of the LME approach to marine resources management has recently been described as the human dimensions of LMEs. A framework has been developed by the Department of Natural Resource Economics at the University of Rhode Island for monitoring and assessment of the human dimensions of LMEs, and for incorporating socioeconomic considerations into an adaptive management approach for LMEs (Sutinen *et al*. 2000). One of the more critical considerations, a method for economic valuations of LME goods and services, has been developed using framework matrices for ecological states and economic consequences of change (Hoagland *et al*. 2004).

GOVERNANCE MODULE INDICATORS

The governance module is evolving, based on demonstration projects now underway in several ecosys-

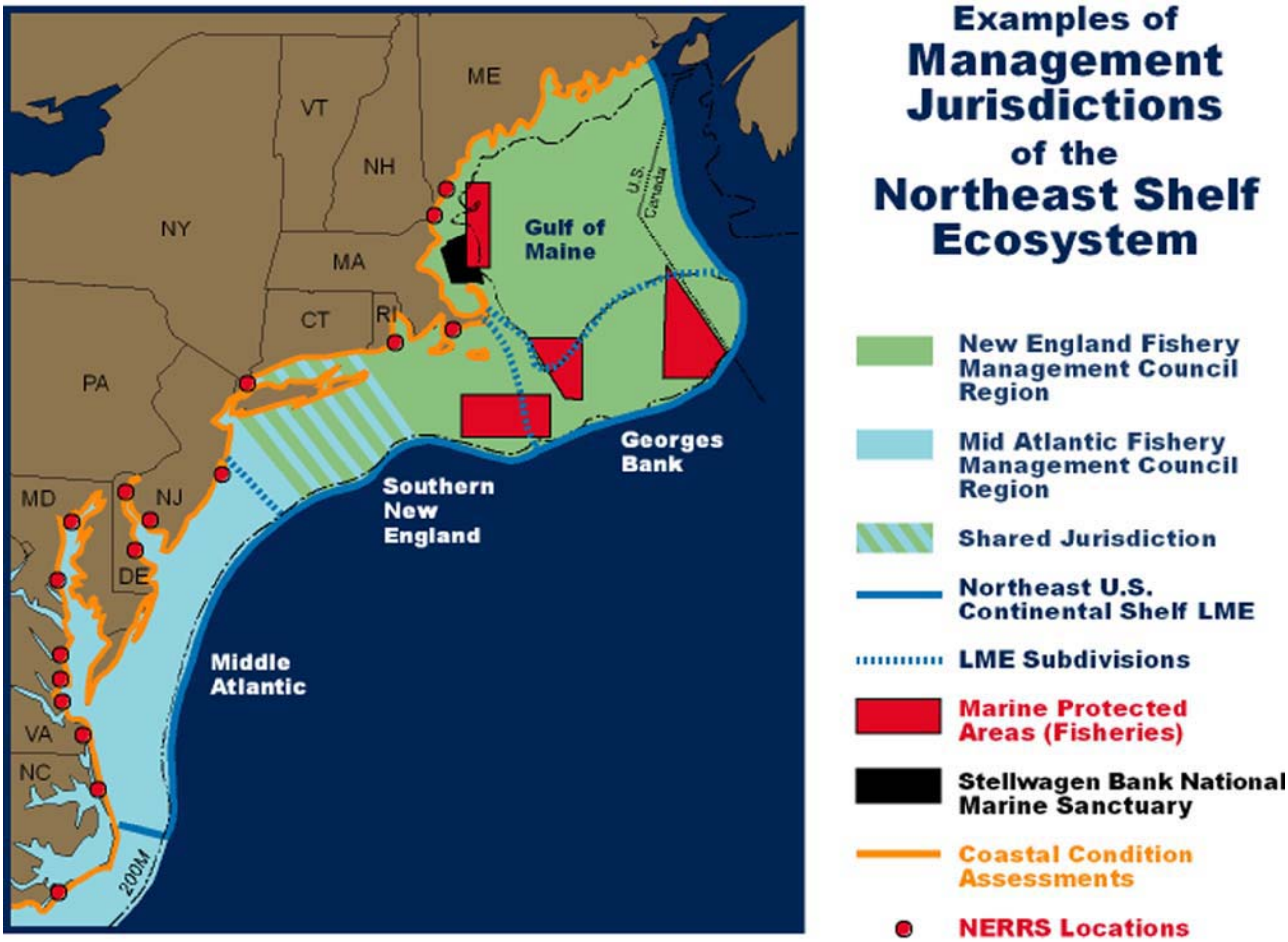


Figure 6. Example of multijurisdictional LME governance. (Included are: 1) jurisdictions covered by the New England and Mid-Atlantic Fishery Management Councils; 2) LME subareas; 3) marine protected areas and the boundaries of the Stellwagen Bank National Marine Sanctuary; 4) near-coastal areas assessed for "condition" determinations by the EPA; and 5) locations of National Estuarine Research Reserve Sites (NERRS).)

tems, such that ecosystems will be managed more holistically than in the past. In LME assessment and management projects supported by the Global Environment Facility (GEF) for the Yellow Sea, Guinea Current, and Benguela Current LMEs, agreements have been reached among the environmental ministers of the countries bordering these LMEs to enter into joint resource assessment and management activities. Elsewhere, the Great Barrier Reef and Antarctic LMEs are also being managed from an ecosystem perspective, the latter under the Commission for the Conservation of Antarctic Marine Living Resources.

Governance profiles of LMEs are being explored to determine their utility in promoting long-term sustainability of ecosystem resources (Juda and Hennessey 2001). In each of the LMEs, governance jurisdiction can be scaled to ensure conformance with existing legislated mandates and authorities. An example of multiple governance-related jurisdictions is shown in Figure 6.

APPLICATION OF INDICATOR MODULES TO LME MANAGEMENT

Indicator data derived from spatial and temporal applications of the five modules are being applied by a growing number of nations in the assessment and management of LMEs with the financial assistance of the Global Environment Facility. Among the stressors affecting the sustainability of LMEs are the growing problem of coastal eutrophication, and the depletion of fish and fishery resources and biomass yields.

ESTABLISHMENT OF THE GLOBAL ENVIRONMENT FACILITY

Continued overfishing in the face of scientific warnings, fishing down food webs, destruction of habitat, and accelerated pollution loading, especially nitrogen export, have resulted in significant degradation to coastal and marine ecosystems of both rich and poor nations. Fragmentation among institutions, international agencies, and disciplines, lack of cooperation among nations sharing marine ecosystems, and weak national policies, legislation, and enforcement all contribute to the need for a new imperative for adopting ecosystem-based approaches to managing human activities in these systems in order to avoid serious social and economic disruption.

Following a 3-yr pilot phase (1991-1994), the Global Environment Facility was formally launched to forge cooperation and to finance actions in the context of sustainable development -- actions that address critical threats to the global environment from biodiversity loss, climate change, degradation of international waters, ozone depletion, and persistent organic pollutants. Activities concerning land degradation, primarily desertification and deforestation as they relate to these threats, are also addressed. GEF-LME projects are implemented by the UN Development Program (UNDP), UN Environment Program (UNEP), and World Bank. Expanded opportunities exist for participation by other agencies.

SCIENCE-BASED ASSESSMENTS OF LME BIOMASS YIELDS

The growing awareness that biomass yields are being influenced by multiple driving forces has broadened monitoring strategies to encompass food chain dynamics and the effects of environmental perturbations and pollution on living marine resources from an ecosystem perspective. To assist stewardship agencies in implementing ecosystem-based assessment and management practices, TDAs are being focused on the root causes of trends in LME biomass yields. In addition, information on principal driving forces of biomass yields from 29 LME case studies by marine resource experts has been analyzed. A list of the principal investigators, constituting the expert-systems analyses, appearing in 12 peer-reviewed and published LME volumes, is given in Table 1. The biomass yields in Table 2 are based largely on the mid-point value (*i.e.*, 1995) of LME yields compiled by FAO for 1990-1999 (Garibaldi and Limongelli 2003). Biomass yield data for three LMEs not included in the FAO report were taken from published LME case studies, and are based on the mid-point value for other periods of time.

Based on the expert systems analyses, principal and secondary driving forces were assigned to each LME using four categories (climate, fisheries, eutrophication, and inconclusive) as seen in Table 2. Of the 29 LME case studies, 13 were assigned to climate forcing as the principal driver of change in biomass yield, 14 were assigned to fishing as principal driver, one was assigned to eutrophication, and the remaining one was deemed inconclusive. In all but three of the 29 LMEs, fishing and climate accounted for all of the primary and secondary drivers. Eutrophication was the principal driver in the Black Sea LME, and was the secondary driver in the Mediterranean and Baltic Seas LMEs.

The contribution of the 29 LMEs to the annual global biomass yields amounts to 54.4 million metric tons (mmt), or 64% of the total, based on the average annual global biomass yield from 1995 to 1999 of 85 mmt (Garibaldi and Limongelli 2003). It would appear that the management regime for nearly half of this yield from the 29 case-study LMEs (27.0 mmt) will need to focus primarily on the climate signal and secondarily on catch control, whereas the management regime for slightly less of this yield (24.8 mmt) will need to focus primarily on catch control and secondarily on the climate signal, to recover depleted fish stocks and achieve maximum sustainable yield levels (Table 3).

The influence of climate forcing in biomass yields for the California Current LME has been analyzed and illustrated by Lluch-Belda *et al*. (2003). Evidence of climate forcing for the Humboldt Current LME has been given by Wolff *et al*. (2003), and for the Iceland Shelf LME by Astthorsson and Vilhjálmsson (2002). In contrast, the argument for urgent reduction in fishing effort is supported by the data in Sherman *et al*. (2003) for the U.S. Northeast Shelf LME, and by the expert analysis of Pauly and Chuenpagdee (2003) for the Gulf of Thailand.

The observation that excessive fishing effort can alter the structure of the ecosystem, resulting in a shift from relatively high-priced, large-sized, long-lived, demersal species, down the food chain toward lower-valued, smaller-sized, shorter-lived, pelagic species (Pauly and Christensen 1995), is supported by the LME data on species biomass yields. Evidence from the East China Sea, Yellow Sea, and Gulf of Thailand suggests that these three LMEs are approaching a critical state of change, wherein recovery to a previous ratio of demersal-to-pelagic species may become problematic. In all three cases, the fisheries are now being directed toward fish protein being provided by catches of smaller-sized species of low value (Chen and Shen 1999; Pauly and Chuenpagdee 2003; Tang 2003).

The species change in biomass yields of the Yellow Sea, as shown in Figure 10 in Tang (2003), represents an extreme case wherein the annual demersal species biomass yield was reduced from 200,000 mt in 1955 to less than 25,000 mt through 1980. The fisheries then targeted the pelagic anchovy, and between 1990 and 1995, landings of anchovy reached an historic high of 500,000 mt.

RECOVERING FISHERIES BIOMASS

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

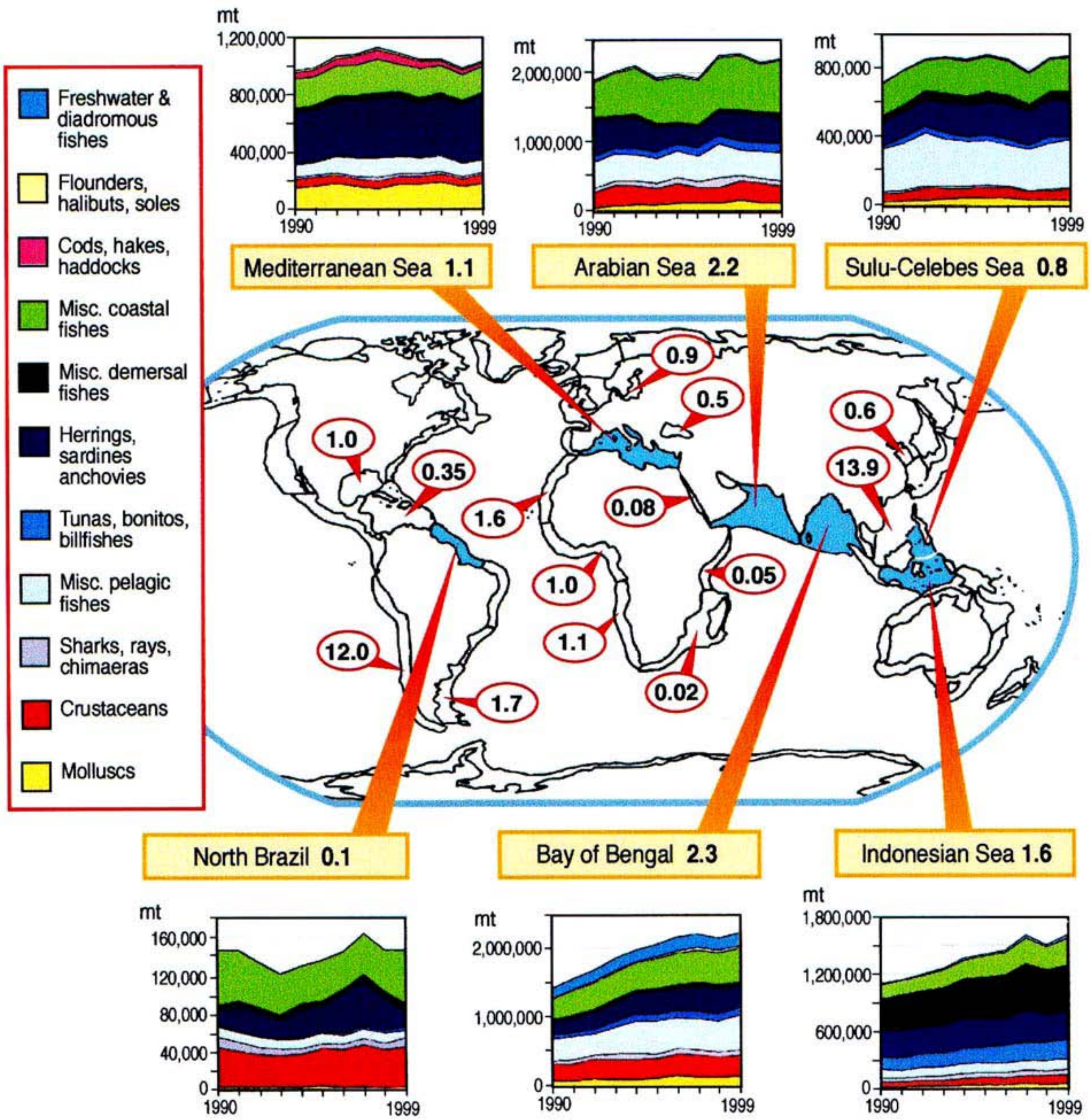


Figure 7. Decadal trends (1990-1999) in biomass yields (mmt) of the six candidate LMEs for precautionary approach actions to preclude total fish biomass reductions. (Value after LME name represents 1999 biomass yield level. Data are based on FAO statistics, as reported to the FAO by official national sources, in Garibaldi and Limongelli (2003). Unfortunately, fisheries effort data are not available for trend analyses. Reproduced with permission from FAO.)

annual fisheries biomass yields from the ecosystems in the network are significant at 44.8% of the global total (Table 3), and are a firm basis for moving toward the goals of the 2002 World Summit on Sustainable Development (WSSD) for introducing an ecosystem-based assessment and management approach to global fisheries by 2010, and for achieving fishing at maximum sustainable yield (MSY) 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 in a more conservative approach to total allowable catch levels than has been the general practice in past decades. Based on Garibaldi and Limongelli (2003), 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 % of the global marine fisheries yield in 1999 (Figure 7). The countries bordering these six LMEs are among the world's

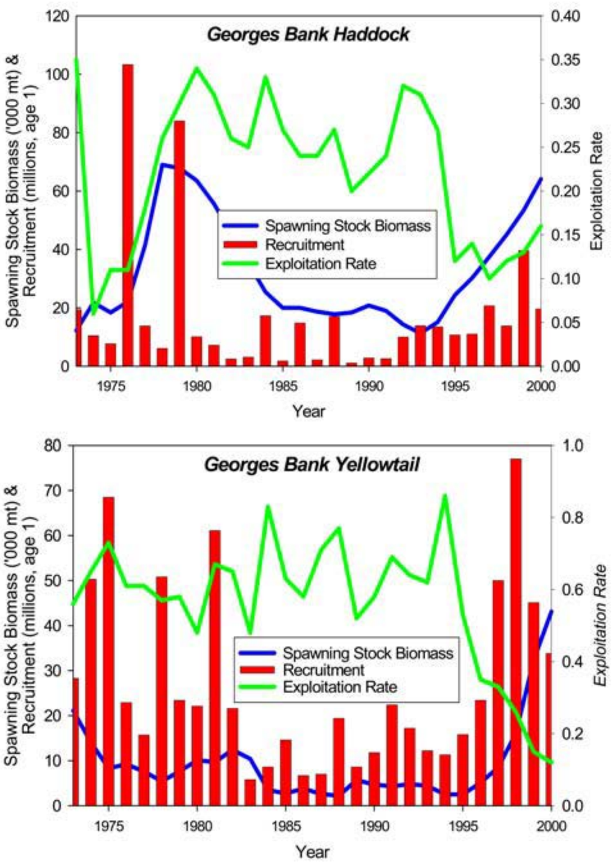


Figure 8. Increase in biomass (spawning stock) of Georges Bank yellowtail flounder and haddock following reduction in fishing effort (exploitation rate). (Information is taken from NEFSC (2002).)

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. In the absence of national reporting of effort data for catches in these six LMEs, and given the risks of fishing-down-the-food-chain, it would appear opportune for the stewardship agencies responsible for the fisheries of the LME-bordering countries to mandate precautionary total allowable catch levels.

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 primary productivity (350 gCm^{-2} yr^{-1}), stable zooplankton levels (33 cc/100m^3), and a relatively stable oceanographic regime (Sherman *et al*. 2002), contributed to: 1) a relatively rapid recovery of depleted Atlantic herring and Atlantic mackerel stocks (NEFSC 1999), and 2) initiation of the recovery of depleted yellowtail flounder and haddock stocks following a mandated 1994 reduction in fishing effort (Figure 8) (NEFSC 2002). 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. However, the People's Republic of China has initiated recovery by mandating 60-90 day closures to fishing in the Yellow Sea and East China Sea during summer months (Tang 2003). The country-driven planning and implementation documents supporting the ecosystem approach to LME assessment and management practices can be found at *www.iwlearn.org*.

EUTROPHICATION AND NITROGEN OVERENRICHMENT

Nitrogen overenrichment has been reported as a coastal problem for two decades, from the southeast coast of the United States (Duda 1982) to the Baltic Sea and other systems (Helsinki Commission 2001). More recent estimates of nitrogen export to LMEs from linked freshwater basins are summarized in Figure 9 [as adapted from an image provided courtesy of N.A. Jaworski; see further Jaworski (1999)]. These recent human-induced increases in nitrogen flux range from 4- to 8-fold in the United States from the Gulf of Mexico to the New England coast, while no increase was documented in areas with little agricultural or few population sources in Canada (Howarth *et al*. 2000).

In European LMEs, recent nitrogen flux increases have been recorded ranging from 3-fold in Spain to 4-fold in the Baltic Sea to 11-fold in the Rhine River basin draining to the North Sea LME (Howarth *et al*. 2000). Duda and El-Ashry (2000) described the origin of this disruption of the nitrogen cycle from the Green Revolution of the 1970s as the world community converted wetlands to agriculture, utilized more chemical inputs, and expanded irrigation to feed the world. As noted by Duda (1982) for the Southeast estuaries of the United States and by Rabalais (1999) for the Gulf of Mexico, much of the large increase in nitrogen export to LMEs is from agricultural inputs, both from the increased delivery of fertilizer nitrogen as wetlands were converted to agriculture and from concentrations of livestock (Duda and Finan 1983) for eastern North Carolina, where the increase in nitrogen export over the forested areas ranged from 20- to 500-fold in the late 1970s. Industrialized livestock production during the last two decades increases the flux, the eutrophication, and the oxygen depletion even more as reported by the National Research Council (NRC 2000). The latest GESAMP assessment (GESAMP 2001) also identifies as significant contributors to eutrophication both sewage from drainages from large cities and atmospheric deposition from automobiles and agricultural activities, with the amounts depending on proximity of sources.

GEF is being asked more frequently by countries to help support the agreed-upon incremental cost of actions to reduce such nitrogen flux. Actions range from assisting in: 1) development of joint institutions for ecosystem-based approaches for adaptive management described in

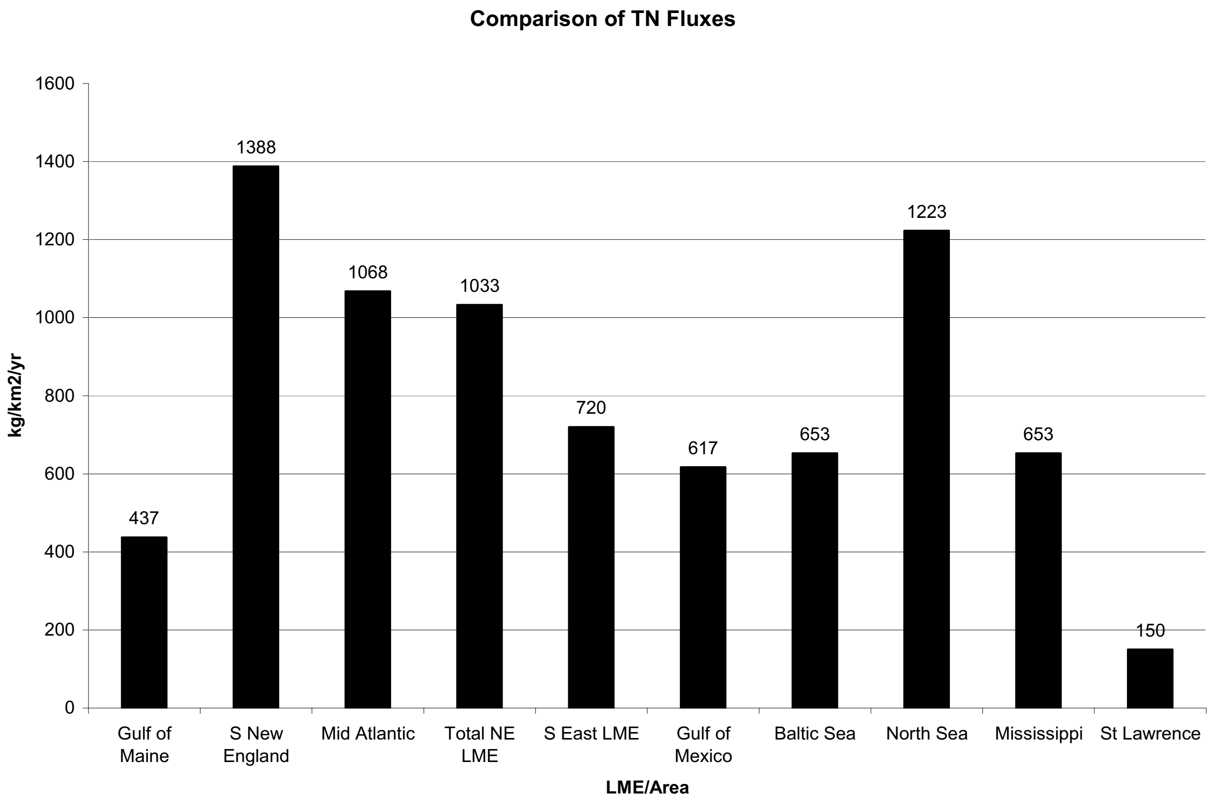


Figure 9. Comparison of total nitrogen fluxes from select LME watersheds. (Adapted from an image provided courtesy of N.A. Jaworski; see further Jaworski (1999).)

this document; 2) on-the-ground implementation of nitrogen abatement measures in the agricultural, industrial, and municipal sectors; and 3) breaching of floodplain dikes so that wetlands recently converted to agriculture may be reconverted to promote nitrogen assimilation. The excessive levels of nitrogen contributing to coastal eutrophication constitute a new global environment problem that is cross-sectoral in nature. Excessive nitrogen loadings have been identified as problems in the following LMEs that are receiving GEF assistance: Baltic Sea, Black Sea, Adriatic portion of the Mediterranean, Yellow Sea, South China Sea, Bay of Bengal, Gulf of Mexico, and Plata Maritime Front/Patagonia Shelf.

In fact, preliminary global estimates of nitrogen export from freshwater basins to coastal waters were assembled by Seitzinger and Kroeze (1998). Their model predicts a doubling of nitrogen to coastal waters by 2050. Included as Figure 10 and adapted from an image provided courtesy of S.P. Seitzinger [see further Kroeze and Seitzinger (1998)], these preliminary estimates of global freshwater basin nitrogen export are alarming for the future sustainability of LMEs. Given the expected future increases in population and in fertilizer use, without significant nitrogen mitigation efforts, LMEs will be subjected to a future of increasing harmful algal bloom events, reduced fisheries, and hypoxia that further degrades marine biomass and biological diversity.

A WAY FORWARD: THE GEF- LME PROJECT APPROACH TO MANAGEMENT

The only new funding source to emerge from the UN Conference on Environment and Development (UNCED) held in Brazil in 1992, GEF counts -- as of this publication date -- 171 countries as members. During its first decade, GEF allocated $US 3.2 billion in grant financing, supplemented by more than $US 8 billion in additional financing, for 800 projects in 156 developing countries and those in economic transition. All six thematic areas of GEF, including the land degradation cross-cutting theme, have implications for coastal and marine ecosystems. Priorities have been established by the GEF Council in its Operational Strategy adopted in 1995 (GEF 1995). The international waters focal area was designed to be consistent with both Chapter 17 and 18 of Agenda 21 of UNCED. In 1995, the GEF Council included the concept of LMEs in its 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 UN Informal, Open-ended Consultative Process on Ocean Affairs (UNGA 2001), which was related to the UN Convention on the Law of the Sea,

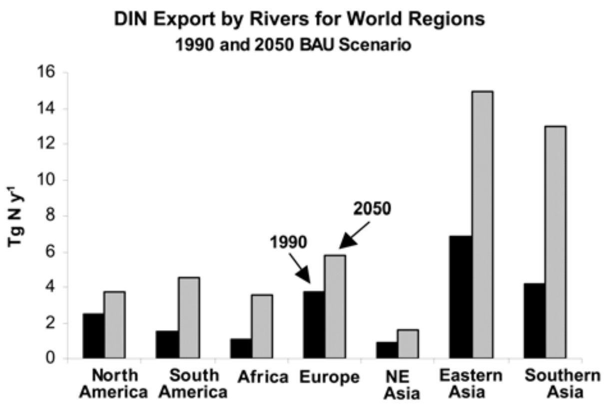


Figure 10. Model-predicted dissolved inorganic nitrogen (DIN) export by rivers to coastal systems in 1990 and 2050. (Predictions are based on a business-as-usual (BAU) scenario. Adapted from an image provided courtesy of S.P. Seitzinger; see further Kroeze and Seitzinger (1998).)

recognized the contribution of 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 for integrating needed changes in sectoral economic activities. The LME areas serve to initiate capacity building and to bring science into 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 problems and their root causes, and for setting priorities for action. The transboundary diagnostic analysis process provides a useful mechanism to foster participation at all levels. Countries then determine the national and regional policy, legal, and institutional reforms and investments needed to address the priorities in the strategic action plan. This approach allows sound science to become the basis for policy-making, and establishes a geographic location upon which an ecosystem-based approach to assessment and management can be developed. More importantly, these projects engage stakeholders in dialogue that results in their practical support within the geographic area for implementing an ecosystem-based approach. 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 policy-making. Furthermore, the science-based approach encourages transparency through joint monitoring, including joint survey cruises, and joint assessment processes for countries sharing an LME, building trust among nations and overcoming any sense that false information is being reported.

Both developing countries and those in economic transition have requested and received GEF support for LME projects through GEF's international waters focal area. The approved GEF-LME projects include not only developing nations and those in economic transition, but also the developed countries of the Organization for Economic Cooperation and Development, since living resources, pollution loading, and critical habitats cross the borders of rich and poor nations alike. The total of $US 650 million which is currently being invested in the global network of LME projects, is funded by GEF, other donors, and national governments. At risk in this global network of LME projects are renewable goods and services valued at $US 10.6 trillion per year. A total of 121 countries have LME projects approved and/or under preparation for approval by the GEF Council: 70 of the 121 countries are involved with 10 projects already approved; 63 of the 121 countries are involved with seven projects under preparation (Table 4).

The GEF's LME projects are generally funded for an initial 3-5 yr phase, followed for successful projects by a second 3-5 yr grant. The two phases result in a 6-10 yr window for participating countries to establish a self-financed, comprehensive, ecosystem-based assessment and management system. The five-module assessment and management methodology is being tested by countries moving toward adopting practical joint governance institutions through place-based management. This LME approach engages stakeholders, fosters the participation of the science community, and leads to the development of adaptive management institutions.

The GEF-supported processes in LME projects foster learning-by-doing and capacity building just as enabling activities do in other GEF focal areas. These processes allow the science community to become engaged and provide interim outputs that serve as vehicles for stimulating stakeholder participation. These processes foster cross-sectoral integration so that an ecosystem-based approach to improving management institutions may be pursued. The LME approach provides a framework for those involved in integrated coastal management, as well as those addressing land-based sources of pollution and freshwater basin management, to be integrated into priority setting. This process builds confidence among different sectoral interests in a country by establishing a national GEF interministerial committee, and then among participating countries sharing the LME by establishing a multisectoral, intergovernmental, GEF project steering committee. Producing the SAP facilitates development of country-driven, politically-agreed ways ahead for commitments to action that address the priorities, in a framework that encourages adaptive management. This shared commitment and vision for action has proven essential in GEF projects that have completed the processes in securing commitments for policy, legal, and institutional reforms in different economic sectors. GEF may then fund an implementation project to assist countries in addressing the country-driven priorities for reform and investments.

LME MODELING CONTRIBUTES TO POLICY-MAKING

Empirical and theoretical aspects of yield models for LMEs have been reviewed by several ecologists. According to Beddington (1986), Daan (1986), Levin (1990), and Mangel (1991), published dynamic models of marine ecosystems offer little guidance on the detailed behavior of communities. However, these authors concur on the need for covering the common ground between observation and theory by implementing monitoring efforts on the large spatial and long temporal scales (decadal) of key components of the LMEs.

The sequence for improving the understanding of the possible mechanisms underlying observed patterns in LMEs is described by Levin (1990) as: 1) examination of statistical analyses of observed distributional patterns of physical and biological variables, 2) construction of competing models of variability and patchiness based on statistical analyses and natural scales of variability of critical processes, 3) evaluation of competing models through experimental and theoretical studies of component systems, and 4) integration of validated component models to provide predictive models for population dynamics and redistribution. The approach suggested by Levin (1990) is consistent with the observation by Mangel (1991) that empirical support for the currently used models of LMEs is relatively weak, and that a new generation of models is needed that serves to enhance the linkage between theory and empirical results.

Three models of ecosystem structure and function are being applied to LMEs with financial assistance from GEF through one mid-sized project, "Promoting Ecosystem-based Approaches to Fisheries Conservation and LMEs" (*www.gefonline.org/projectList.cfm*). Estimates of carrying capacity using ECOPATH/ECOSIM food web approaches for the world's 64 LMEs are being prepared in a collaboration among scientists of the University of British Columbia and marine specialists from developing countries. Similarly, a 24-mo training project is being implemented by scientists from Rutgers University in collaboration with the IOC to estimate expected nitrogen loadings for each LME over the next 50 yr. Scientists from Princeton University are examining particle spectra pattern formation within LMEs. Additionally, the American Fisheries Society and the World Council of World Fisheries Societies are collaborating to create an electronic network that will expedite information access and communication among marine specialists participating in GEF-supported LME projects.

There is a growing awareness among marine scientists, geographers, economists, government representatives, and lawyers of the utility of a more holistic ecosystem approach to resource management (Byrne 1986; Christy 1986; Alexander 1989; Belsky 1989; Crawford *et al*. 1989; Morgan 1989; Prescott 1989). On a global scale, the loss of sustained biomass yields from LMEs from mismanagement and overexploitation has not been fully investigated, but is likely very large. Effective management strategies for LMEs will be contingent on identification of major driving forces causing large-scale changes in biomass yields. Management of species responding to strong environmental signals will be enhanced by improving the understanding of the physical factors forcing biological change, thereby enhancing forecasts of El Niño-type events. In other LMEs, where the prime driving force is overfishing, options can be explored for reductions of fishing effort and implementing adaptive management strategies (Collie 1991). Further, remedial actions are required to ensure that the pollution of the coastal zone of LMEs is reduced and does not become a principal driving force in an LME. Recent reports explore the application of ecosystem-based research and modeling that are focused on management (Browman and Stergiou 2004) and on macroecology (Belgrano 2004; Hoagland *et al*. 2005; Edwards 2005; Grigalunas *et al*. 2005).

LME APPROACH TO WORLD SUMMIT TARGETS

Since 1993, the NOAA Fisheries Service has been cooperating with GEF, IUCN, IOC, and several other UN agencies, (*i.e.*, Industrial Development Organization, UNDP, UNEP, and FAO) to assist developing countries in planning and implementing ecosystem-based management focused on LMEs as the principal assessment and management unit for coastal ocean resources. NOAA contributes scientific and technical assistance and expertise to aid developing countries in reaching the targets of the 2002 WSSD (Duda and Sherman 2002). The targets, agreed on by officials of more than 100 countries, call for the 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 MSY levels by 2015.

The GEF-LME strategy supports the WSSD targets for addressing coastal and marine issues by jointly analyzing scientific information on transboundary problems and their root causes, and setting priorities for action on these problems. The TDA process noted earlier provides a useful mechanism to foster participation at all levels in this information analysis and priority-setting effort. Countries then determine the national and regional policy, legal, and institutional reforms and investments needed to address the priorities in a country-driven SAP. Project goals and milestones of the SAP promote vertical integration across

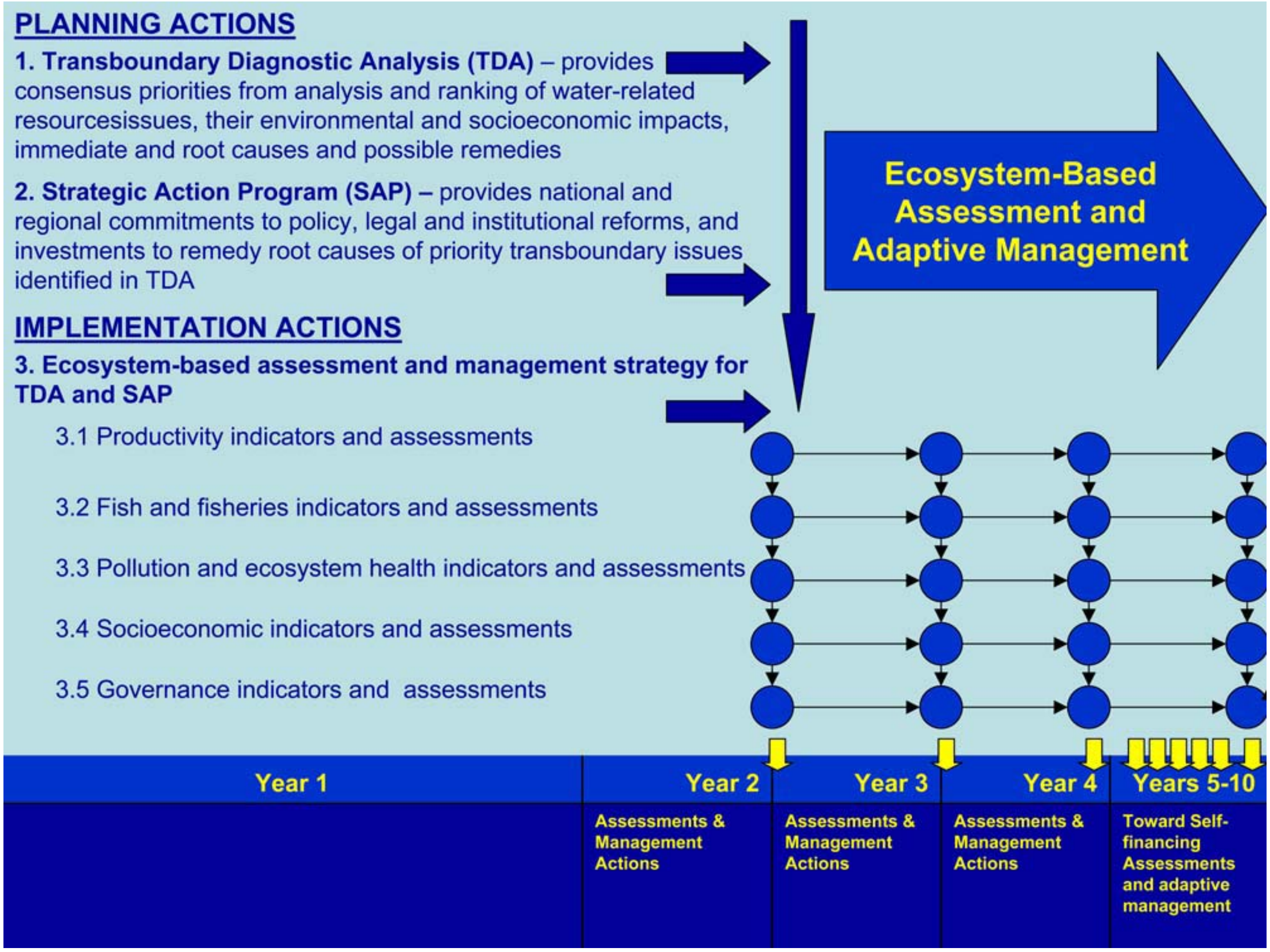


Figure 11. Large Marine Ecosystems Program planning and implementation process and schedule.

the LME indicator modules on an annual basis, leading to an adaptive, ultimately self-financing, management regime (Figure 11).

Reforms are taking place among the participating countries in operationalizing this ecosystem-based approach to managing human activities in the different economic sectors that contribute to place-specific degradation of the LME and adjacent waters. The WSSD target for introducing ecosystem-based assessment and management practices by 2010 is likely to be met by most of the countries constituting the existing LME network. 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 (Sherman *et al*. 2002). 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," whereas good progress has been made in designating marine protected areas within the GEF-LME project network.

The "U.S. Ocean Action Plan" published on 17 December 2004 by the Office of the President, Washington DC, in response to the U.S. Commission on Ocean Policy's Final Report (USCOP 2004), supports the LME concept and strategy for ecosystem-based management within the UN regional seas programs and by international fisheries bodies (EOPUS 2004a,b):

> ***Advancing International Oceans Science***
>
> ***Advance the Use of Large Marine Ecosystems.*** *The United States will promote, within the UN Environment Program's regional seas programs and by international fisheries bodies, the use of the Large Marine Ecosystems (LME) concept as a tool for enabling ecosystem-based management to provide a collaborative approach to management of resources within ecologically bounded transnational areas. This will be done in an international context and consistent with customary international law as reflected in 1982 UN Convention on the Law of the Sea.*

Additional information on NOAA's contributions to the global LME movement toward ecosystem-based management and resource sustainability is available from the LME Program Office, Northeast Fisheries Science Center, Narragansett Laboratory, Narragansett, RI, and from the LME website: *http://www.lme.noaa.gov*.

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Table 1. Published studies and volumes on LMEs

LME	Vol.[a]	Author(s)	LME	Vol.[a]	Author(s)
Somali Coastal Current	7	Okemwa	East China Sea	8	Chen & Shen
Bay of Bengal	5	Dwividi	Yellow Sea	2, 5, 12	Tang
	7	Hazizi	Kuroshio Current	2	Terazaki
East Bering Sea	1	Incze & Schumacher	Sea of Japan	8	Terazaki
	8	Livingston *et al*.	Oyashio Current	2	Minoda
West Greenland Shelf	3	Hovgård & Buch	Okhotsk Sea	5	Kusnetsov *et al*.
	5	Blindheim & Skjoldal	Gulf of Mexico	2	Richards & McGowan
	10	Rice		4	Brown *et al*.
Barents Sea	2	Skjoldal & Rey		9	Shipp
	4	Borisov		9	Gracia & Vasquez Baden
	5	Skjoldal	Southeast U.S. Shelf	4	Yoder
	10	Dalpadado *et al*.	Northeast U.S. Shelf	1	Sissenwine
	12	Matishov		4	Falkowski
Norwegian Shelf	3	Ellertsen *et al*.		6	Anthony
	5	Blindheim & Skjoldal		10, 12	Sherman
North Sea	1	Daan	Scotian Shelf	10	Zwanenburg *et al*.
	9	Reid	Caribbean Sea	3	Richards & Bohnsack
	10	McGlade	Patagonian Shelf	5	Bakun
	12	Hempel	South Brazil Shelf	12	Ekau & Knoppers
Iceland Shelf	10	Astthorsson & Vilhjálmsson	East Brazil Shelf	12	Ekau & Knoppers
Faroe Plateau	10	Gaard *et al*.	North Brazil Shelf	12	Ekau & Knoppers
Antarctic	1	Scully *et al*.	Baltic Sea	1	Kullenberg
	3	Hempel		12	Jansson
	5	Scully *et al*.	Celtic-Biscay Shelf	10	Lavin
California Current	1	MacCall	Iberian Coastal	2	Perez-Gandaras
	4	Mullin		10	Wyatt & Porteiro
	5	Bottom	Mediterranean Sea	5	Caddy
	12	Lluch-Belda *et al*.	Canary Current	5	Bas
Pacific American Coastal	8	Bakun *et al*.		12	Roy & Cury
Humboldt Current	5	Bernal	Guinea Current	5	Binet & Marchal
	12	Wolff *et al*.		11	Koranteng & McGlade
Gulf of Thailand	5	Piyakarnchana		11	Mensah & Quaatey
	12	Pauly & Chuenpagdee		11	Lovell & McGlade
South China Sea	5	Christensen		11	Cury & Roy
Indonesian Sea	3	Zijlstra & Baars		11	Koranteng
Northeast Australian Shelf	2	Bradbury & Mundy	Benguela Current	2	Crawford *et al*.
	5	Kelleher		12	Shannon & O'Toole
	8, 12	Brodie	Black Sea	5	Caddy
				12	Daskalov

[a]1 = Sherman and Alexander (1986); 2 = Sherman and Alexander (1989); 3 = Sherman *et al*. (1990); 4 = Sherman *et al*. (1991); 5 = Sherman *et al*. (1993); 6 = Sherman *et al*. (1996); 7 = Sherman *et al*. (1998); 8 = Sherman and Tang (1999); 9 = Kumpf *et al*. (1996); 10 = Skjoldal and Sherman (2002); 11 = McGlade *et al*. (2002); and 12 = Hempel and Sherman (2003).

Table 2. Primary and secondary driving forces of biomass yields for 29 LMEs. (Driving forces based on published expert assessments in LME volumes listed in Table 1. Annual biomass yields based on 1990-1999 mid-decadal data (*i.e.*, 1995) from Garibaldi and Limongelli (2003), unless specified otherwise.)

LME	Driving Force		Annual Biomass Yield (mmt)	Source(s)	Volume
	Primary	Secondary			
Humboldt Current	climate	fishing	16.0	Alheit and Bernal	5
				Wolff *et al*.	12
South China Sea	fishing	climate	10.0	Pauly and Christensen	5
East China Sea	fishing	climate	3.8	Chen and Shen	8
North Sea	fishing	climate	3.5	McGlade	10
East Bering Sea	inconclusive	inconclusive	2.1	Schumacher *et al*.	12
Bay of Bengal	fishing	climate	2.0	Dwividi	5
				Hazizi	7
Okhotsk Sea[a]	climate	fishing	2.0	Kusnetsov *et al*.	5
Canary Current	climate	fishing	1.8	Roy and Cury	12
				Bas	5
Norwegian Shelf	climate	fishing	1.5	Ellertsen *et al*.	3
				Blindheim and Skjoldal	5
Iceland Shelf	climate	fishing	1.3	Astthorsson and Vilhjálmsson	10
Benguela Current	climate	fishing	1.2	Crawford *et al*.	2
				Shannon and O'Toole	12
Gulf of Thailand	fishing	climate	1.1	Pauly and Chuenpagdee	12
Mediterranean	fishing	eutrophication	1.1	Caddy	5
Sea of Japan[b]	climate	fishing	1.0	Terazaki	8
Gulf of Mexico	fishing	climate	0.9	Richards and McGowan	2
				Brown *et al*.	4
				Shipp	9
Guinea Current	climate	fishing	0.9	Binet and Marchal	5
				Koranteng and McGlade	11
Baltic Sea	fishing	eutrophication	0.8	Kullenberg	1
				Jansson	12
California Current	climate	fishing	0.7	MacCall	1
				Lluch-Belda *et al*.	12
U.S. Northeast Shelf	fishing	climate	0.7	Sissenwine	1
				Murawski	6
				Sherman *et al*.	10
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	Hovgård and Buch	3
				Pederson and Rice	10
Faroe Plateau	climate	fishing	0.1	Gaard *et al*.	10

[a]Annual biomass yield data based on 1962-1982 mid-decadal data (*i.e.*, 1972) from Kusnetsov *et al*. (1993).
[b]Annual biomass yield data based on 1980-1990 mid-decadal data (*i.e.*, 1985) from Terazaki (1999).
[c]Annual biomass yield data based on 1952-1992 mid-decadal data (*i.e.*, 1972) for demersal species from Tang (2003).

Table 3. Reported 1999 annual fisheries biomass yields of LMEs where stewardship ministries are implementing or planning GEF-LME projects

LME	Biomass Yield (mmt)		LME	Biomass Yield (mmt)
South China Sea	13.9		Gulf of Mexico	1.0
Humboldt Current	12.0		Baltic Sea	0.9
Bay of Bengal	2.3		Yellow Sea	0.6
Patagonian Shelf	1.7		Black Sea	0.5
Canary Current	1.6		Caribbean Sea	0.35
Benguela Current	1.1		Red Sea	0.08
Guinea Current	1.0		Agulhas/Somali Currents	0.07
Mediterranean Sea	1.0			
Total in million metric tons: 38.10				
Total as percentage of global marine yield: 44.8				

Table 4. The 121 countries participating in GEF-LME projects

LME (no. of countries)	Countries
APPROVED GEF PROJECTS	
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, Indonesia, Malaysia, Philippines, Thailand, Vietnam
Black Sea (6)	Bulgaria, Georgia, Romania, Russia, Turkey, Ukraine
Mediterranean (19)	Albania, Algeria, Bosnia-Herzegovina, Croatia, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Morocco, Slovenia, Spain, Syria, Tunisia, Turkey, Yugoslavia, Portugal
Red Sea (7)	Djibouti, Egypt Jordan, Saudi Arabia, Somalia, Sudan, Yemen
Western Pacific Warm Water Pool-SIDS[a] (13)	Cook Islands, Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu
Total number of countries with approved GEF projects: 70[b]	
GEF PROJECTS IN THE PREPARATION STAGE	
Canary Current (7)	Cape Verde, Gambia, Guinea, Guinea-Bissau, Mauritania, Morocco, Senegal
Bay of Bengal (8)	Bangladesh, India, Indonesia, Malaysia, Maldives, Myanmar, Sri Lanka, Thailand
Humboldt Current (2)	Chile, Peru
Guinea Current (16)	Angola, Benin, Cameroon, Congo, Democratic Republic of the Congo, Côte d'Ivoire, Gabon, Ghana, Equatorial Guinea, Guinea, Guinea-Bissau, Liberia, Nigeria, São Tomé and Principe, Sierra Leone, Togo
Gulf of Mexico (3)	Cuba, Mexico, United States
Agulhus/Somali Currents (8)	Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa, Tanzania
Caribbean LME (23)	Antigua and Barbuda, The Bahamas, Barbados, Belize, Colombia, Costa Rica, Cuba, Grenada, Dominica, Dominican Republic, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Puerto Rico[c], Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, Venezuela
Total number of countries with GEF projects in the preparation stage: 63[b]	

[a]Provisionally classified as Insular Pacific Provinces in the global hierarchy of LMEs and Pacific biomes (Watson *et al*. 2003).
[b]Adjusted for multiple listings.
[c]A self-governing commonwealth in union with the United States.

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The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

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Northeast Fisheries Science Center Reference Document -- This series is issued irregularly. The series typically includes: data reports on field and lab studies; progress reports on experiments, monitoring, and assessments; background papers for, collected abstracts of, and/or summary reports of scientific meetings; and simple bibliographies. Issues receive internal scientific review, but no technical or copy editing.

Resource Survey Report (formerly *Fishermen's Report*) -- This information report is a quick-turnaround report on the distribution and relative abundance of selected living marine resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. There is no scientific review, nor any technical or copy editing, of this report.

OBTAINING A COPY: To obtain a copy of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, or to subscribe to the *Resource Survey Report*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2228) or consult the NEFSC webpage on "Reports and Publications" (*http://www.nefsc.noaa.gov/nefsc/publications/*).