Available online at www.sciencedirect.com
SCIENCE DIRECT®
Ocean & Coastal Management
ELSEVIER
Ocean & Coastal Management 45 (2002) 797–833
www.elsevier.com/locate/ocecoaman

A new imperative for improving management of large marine ecosystems

Alfred M. Duda[a], Kenneth Sherman[b,*]

[a] *Global Environment Facility Secretariat, 1818 H Street N.W., Washington, DC 20433, USA*
[b] *Narragansett Laboratory, Northeast Fisheries Science Center, USDOC/NOAA/NMFS, 28 Tarzwell Drive, Narragansett, RI 02882, USA*

Abstract

Continued over-fishing 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. The global environment facility (GEF) has been approached by developing countries in overwhelming numbers for assistance in securing the futures of their shared large marine ecosystems (LMEs). This paper describes GEF supported processes being used to assist them in adopting a science-driven, ecosystem-based approach to the management of human activities affecting coastal and marine ecosystems and linked freshwater basins. At risk are renewable goods and services valued at $10.6 trillion per year. A total of 10 LME projects involving 72 countries have been approved by the GEF Council, and another 7 LMEs involving 54 countries have GEF international waters projects under preparation. A five-module assessment and management methodology is being tested that moves the countries 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. Comprehensive initiatives in four LMEs are described. The importance is underscored for establishing and coordinating partnerships between the North and South for specific LMEs and their linked watersheds. These coordinated North–South partnerships significantly augment catalytic interventions made by the GEF leading to reforms and investments that are helping make the transition to sustainable development.
Published by Elsevier Science Ltd.

*Corresponding author. Fax: +1-401-782-3201.
E-mail address: kenneth.sherman@noaa.gov (K. Sherman).

0964-5691/02/$ - see front matter Published by Elsevier Science Ltd.
PII: S0964-5691(02)00107-2

1. Introduction

A legacy of over-fishing, destruction of coastal habitats, and accelerated pollution loading has dramatically reduced biomass and diversity of the coastal oceans to the point that ecosystems are being degraded, national economic benefits from marine systems are falling, and poor communities depending on the resources for livelihoods and protein are being threatened. The degradation is global, occurring in marine ecosystems adjacent to developing and developed States. Exports to developed countries and their subsidized fleets fuel the depletion. With mismanagement of freshwater basins contributing to the coastal degradation, and with new threats from fluctuating climatic regimes, it is becoming clear that the global life support system anchored, in part, by coastal ecosystems is at risk, and both food security and the socio-economic future of coastal regions are in jeopardy.

Ten years after Rio, more effort is required from all States to meet the goals of Chapter 17 of Agenda 21. Progress in the last decade since Rio has been disappointing. Both developed and developing countries have reforms to enact to reverse the increasing coastal degradation. However, single species management in isolation; bilateral access agreements; illegal, unregulated and unreported fishing; discarded by-catch; trawl damage; perverse government subsidies; ineffective fisheries governance; habitat loss; and coastal pollution continue to degrade coastal ecosystems. Activities under Chapters 17 and 18 of Agenda 21 were conducted in isolation during the last decade rather than linked to restore and protect coastal ecosystems. Initiatives under different legal instruments have been thematic, fragmented, or disconnected with sound science, and consequently they were unable to influence political decisions. Competing programs of competing agencies developed over time, and those driven by the donor community were just not comprehensive or participative enough to capture the commitment of developing nations.

Since the mid-1990s, developing countries have approached the global environment facility (GEF) in increasing numbers for assistance in improving the management of large marine ecosystems (LMEs) shared with neighboring nations. (Fig. 1) This paper describes the processes being undertaken as part of GEF projects focusing on LMEs to foster country-driven commitments to policy, legal, and institutional reforms for changing the way human activities are conducted in the economic sectors that place stress on coastal ecosystems. LMEs serve as place-based, ecologically defined areas for which stakeholder support for integrating essential national and multi-country reforms and international agency programs can be mobilized into a cost-effective, collective response to an array of conventions and programs. Site-specific ocean concerns, those of adjacent coastal areas, and linked freshwater basins are being addressed in LMEs through GEF assistance. Operation of joint management institutions is being supported and tested in order to restore biomass and diversity to sustainable levels to meet increased needs of coastal populations, and reverse the precipitous declines in ecosystem integrity currently being caused by over-fishing, habitat loss, and nitrogen over-enrichment. At risk are renewable goods and services valued at $10.6 trillion per year [1].

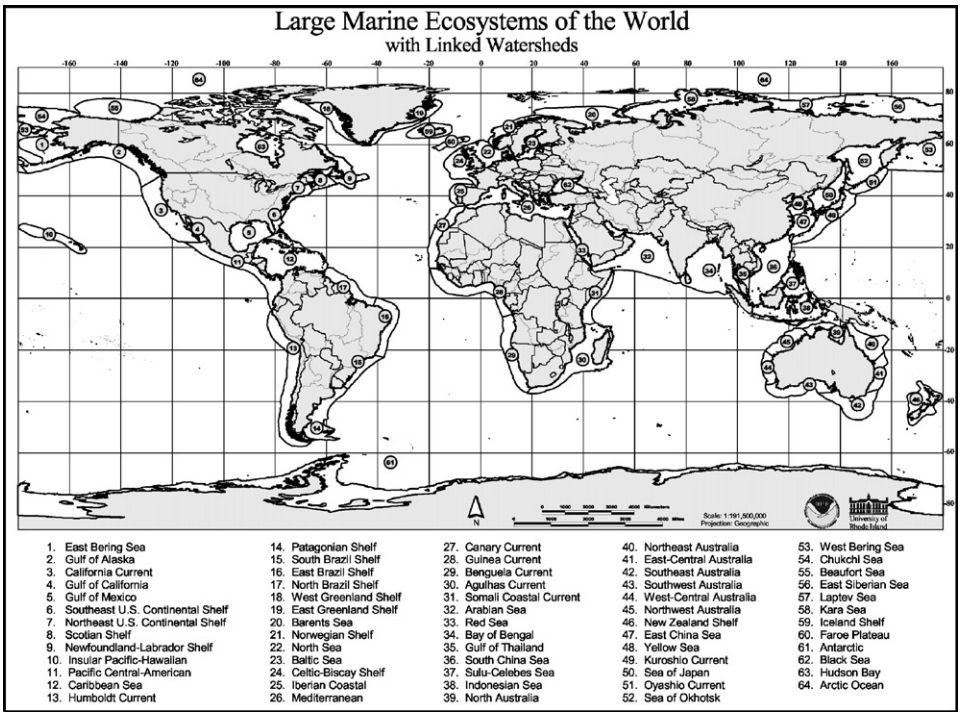

Fig. 1. Large Marine Ecosystems are areas of the ocean characterized by distinct bathymetry, hydrography, productivity, and trophic interactions. They annually produce 95 percent of the world's fish catch. They are national and regional focal areas of a global effort to reduce the degradation of linked watersheds, marine resources, and coastal environments from pollution, habitat loss, and over-fishing.

2. A new imperative for ecosystem-based action

Fishing down food webs and accelerated pollution loading contribute to the degradation of marine ecosystems and loss of habitat and biodiversity around the world as noted by FAO [2], GESAMP [3], Duda and Cruz [4], and others [5–7]. These trends were identified in Stockholm 30 yr ago, and their significance was reaffirmed with actions adopted at the UN Conference on Environment and Development (UNCED) in Rio in 1992. Unfortunately, progress since 1992 under Agenda 21 has been disappointing. Commitments to an alternative, sustainable pathway have been made by the world community in global instruments such as the UN Convention on the Law of the Sea (UNCLOS), the Convention on Biological Diversity (CBD), the Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-based Activities, and the UN Framework Convention on Climate Change (UNFCCC). The UN Fish Stocks Agreement (FSA), regional seas agreements under UNCLOS, and the FAO Code of Conduct for Responsible Fishery practices with its action plans. But they have yet to be effectively implemented by coastal countries.

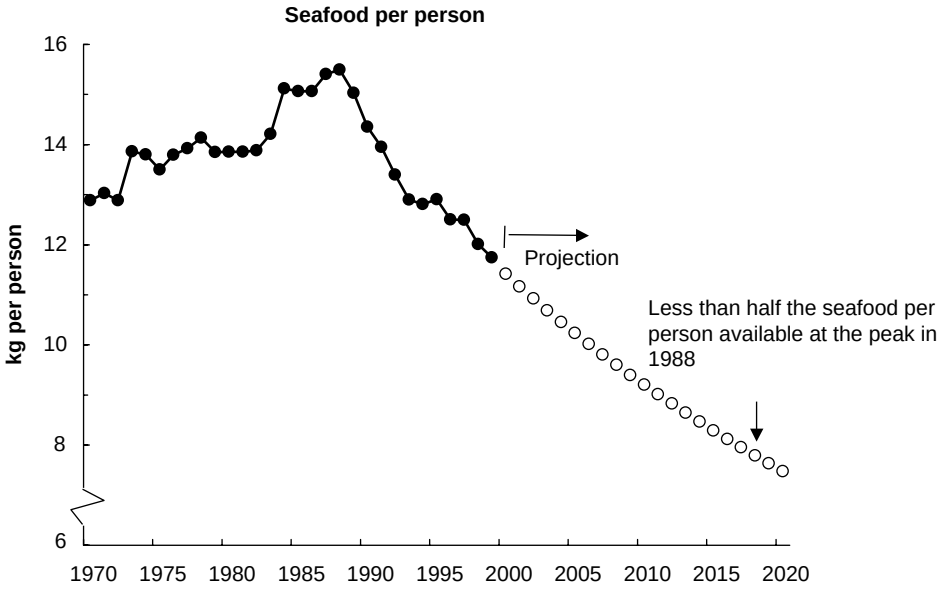

Fig. 2. Projected decline in per capita seafood availability from Watson and Tyedmers [71].

In fact, recent information suggests that the global situation is worse than commonly thought. Jackson and others [7] recently reported that over-fishing has been more important than other causes of marine biomass depletion and biodiversity loss around the world, and that existing fish populations of marine ecosystems are but a fraction of their historical levels. With the need to support growing coastal populations and to maintain the foreign exchange receipts from the $50 billion international trade in marine fisheries [8], positive steps need to be taken toward population restoration. In addition, Watson and Pauly [9] recently reported recalculations of fish catches that show a precipitous global decline since the 1980s. The authors identified inaccurate reporting of data to FAO that has likely distorted global assessments and subsequent policy. The inaccurate capture fisheries data reported to FAO may have maintained a false sense of security through the years, and as burgeoning aquaculture replaced capture fisheries, total production numbers have lulled policymakers into false impressions of the ever deepening global decline.

When these recalculated fisheries statistics are normalized by global population data to provide a per capita annual catch estimate as was reported previously by Duda and Cruz [4], an even more alarming decline in fisheries is evident that should worry policymakers. Based on the new information from Watson and Pauly [9], this decline is depicted in Fig. 2, and the resulting lack of confidence in global fishery statistics is troubling. When combined with estimates that approximately 25% of global capture fisheries is often wasted as by-catch and with up to $15 billion annually in perverse economic subsidies from governments that are often

underreported or not disclosed in compliance with World Trade Organization requirements [10], there is ample evidence that marine ecosystems and their biological diversity are being depleted for short-term gains and that a breakdown of global, regional, and national institutions is responsible.

More and more, European, North American, and Asian nations are importing fish from developing nations to replace their already depleted stocks. With the European fleet more than 40% larger than fish stocks can accommodate, marine resource depletion has expanded to the southern Mediterranean, to West Africa, and to South America [11,12]. Irregularities have been identified in West African waters from excessive over-fishing, excessive by-catch loss, underpayment of licenses, and denial of timely information to coastal states by Kaczynsky and Fluharty [11]. Despite the multi-billion dollar a year international trade in fisheries, developing countries receive relatively little in terms of fees from distant fishing fleets and face a not-too-distant-future of resource depletion and drops in license fees. Even in the rich tuna fishery of the western Pacific, UNDP [13] reported that Pacific Small Island Developing States (SIDS) received only about 4% of the value of the tuna taken by distant fleets. Fishing down the food-wed in proximity to coral reefs contributes much degradation of reefs along with periodic bleaching events that may be related to fluctuating climate. The global status of reefs has declined the last decade as human impacts result in more damage to marine biodiversity such as turtles, dugongs, and other mammals have also declined in response to overfishing, food chain and habitat effects [6,7]. These symptoms of marine degradation serve as indicators that neither global policies nor their uneven implementation are leading towards more sustainable coastal resources and environments; they constitute a new imperative for a radical shift in thinking about how site-specific marine ecosystems can be sustained, and how North-South collaboration can result in changes in the economic sectors that drive ecosystem depletion.

3. An ecosystems-based approach to management

The Ecological Society of America Committee on the Scientific Basis for Ecosystem Management concluded that the overarching principle for guiding ecosystem management is to ensure the intergenerational sustainability of ecosystem goods (e.g. fish, trees, petroleum) and ecosystem services or processes including productivity cycles and hydrological cycles [14]. From a fisheries perspective, the National Research Council [6] concluded that sustaining fishery yields will require sustaining the ecosystems that produce the fish. This approach represents a paradigm shift from the highly focused, single-species or short-term sectoral thematic approach in general practice today to a broader more encompassing ecosystem-based approach that moves spatially from smaller to larger scales, and from short-term to longer-term management practices described by Lubchenco [15]. Included in this approach is movement away from the management of commodities to maintaining the sustainability of the productive resource to ensure benefits from ecosystem goods and services for the future.

This approach builds on an earlier application of "an ecosystem approach" to management of the North American Great Lakes Basin Ecosystem described by the Great Lakes Science Advisory Board [16] and Duda [17] as well as more recent efforts in developing an ecosystem-based approach for assessment and management of the North Sea [18], the Northeast Shelf of the US [19], the Gulf of Mexico [20], and the Baltic Sea [21]. The ecosystem-based approach recognizes the interconnections among living and non-living systems as well as humankind and economic and social systems being considered as integral parts of the ecosystem. The Great Lakes approach led to governance agreements between the US and Canada that follow longer-term pathways for sustainable use of ecological resources and resulted in significant reversal in degradation following adoption of joint assessment and management institutions.

4. Large Marine Ecosystems (LMEs)

On a global scale, 50 LMEs produce most of the world's annual marine fishery biomass yield [22]. Recent new additions in the Arctic and in the Pacific near Australia and New Zealand have been reported [23], bringing the global LME total to 64. 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 as shown in Fig. 1. They are relatively large regions on the order of 200,000 km^2 or greater, characterized by distinct bathymetry, hydrography, productivity, and trophically dependent populations [22]. Within the 64 LMEs, 95% of the global marine capture fisheries are found as well as most of the ocean pollution and coastal habitat alteration. Fig. 2 shows LME interlinkages among the coastal ocean, its coastal margins, and linked freshwater basins as modified from Duda and Cruz [4].

For 33 of the LMEs, studies have been conducted of 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, pollution and environmental perturbation are of secondary and tertiary influence. In contrast, significant coastal pollution and eutrophication have been important factors driving changes in fisheries yields of the Northwest Adriatic, Black Sea, and the Baltic Sea. Following peer-review, the results of these investigations were published in nine volumes (Table 1).

5. Global Environment Facility (GEF)

Following a 3 yr 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: 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 projects are implemented by UNDP, UNEP, and the World Bank and expanded opportunities exist for participation by other agencies.

The only new funding source to emerge from the 1992 Earth Summit, GEF today counts 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 [24] adopted in 1995. The international waters focal area was designed to be consistent with both Chapter 17 and 18 of Agenda 21. In 1995, the GEF Council included the concept of LMEs in its GEF Operational Strategy as a vehicle for promoting ecosystem-based

Table 1
List of 33 LMEs and subsystems for which syntheses relating to primary, secondary, or tertiary driving forces controlling variability in biomass yields have been completed for inclusion in LME volumes

Large marine ecosystem	Volume no.	Authors
US Northeast Continental Shelf	1	M. Sissenwine
		P. Falkowski
	6	S. Murawski
US Southeast Continental Shelf	4	J. Yoder
Gulf of Mexico	2	W. Richards and M. McGowan
	4	B. Brown et al.
	9	R. Shipp
California Current	1	A. MacCall
	4	M. Mullin
	5	D. Bottom
Eastern Bering Shelf	1	L. Incze and J. Schumacher
	8	P. Livingston et al.
West Greenland Shelf	3	H. Hovgård and E. Buch
Norwegian Sea	3	B. Ellersten et al.
Barents Sea	2	H. Skjoldal and F. Rey
	4	V. Borisov
North Sea	1	N. Daan
Baltic Sea	1	G. Kullenberg
Iberian Coastal	2	T. Wyatt and G. Perez-Gandaras
Mediterranean–Adriatic Sea	5	G. Bombace
Canary Current	5	C. Bas

Table 1 (*continued*)

Large marine ecosystem	Volume no.	Authors
Gulf of Guinea	5	D. Binet and E. Marchal
Benguela Current	2	R. Crawford et al.
Patagonian Shelf	5	A. Bakun
Caribbean Sea	3	W. Richards and J. Bohnsack
South China Sea–Gulf of Thailand	2	T. Piyakarnchana
East China Sea	8	Y-Q Chen and X-Q Shen
Sea of Japan	8	M. Terazaki
Yellow Sea	2	Q. Tang
Sea of Okhotsk	5	V. Kusnetsov et al.
Humboldt Current	5	J. Alheit and P. Bernal
Pacific Central American	8	A. Bakun et al.
Indonesia Seas–Banda Sea	3	J. Zijlstra and M. Baars
Bay of Bengal	5	S. Dwivedi
	7	A. Hazizi et al.
Antarctic Marine	1 & 5	R. Scully et al.
Weddell Sea	3	G. Hempel
Kuroshio Current	2	M. Terazaki
Oyashio Current	2	T. Minoda
Great Barrier Reef	2	R. Bradbury and C. Mundy
	5	G. Kelleher
	8	J. Brodie
Somali Current	7	E. Okemwa
South China Sea	5	D. Pauley and V. Christensen

Vol. 1: Variability and management of large marine ecosystems. In: Sherman K, Alexander LM, editors. AAAS Selected Symposium, 99. Boulder, CO: Westview Press, Inc., 1986. 319 pp.
Vol. 2: Biomass yields and geography of large marine ecosystems. In: Sherman K, Alexander LM, editors. AAAS selected symposium 111. Boulder, CO: Westview Press, Inc., 1989. 493 pp.
Vol. 3: Large Marine Ecosystems: Patterns, Processes, and Yields. In: Sherman K, Alexander LM, Gold BD, editors. AAAS Symposium. Washington, DC: AAAS, 1990. 242 pp.
Vol. 4: Food chains, yields, models, and management of large marine ecosystems. In: Sherman K, Alexander LM, Gold BD, editors. AAAS Symposium. Boulder, CO: Westview Press, Inc., 1991. 320 pp.
Vol. 5: Large marine ecosystems: stress, mitigation, and sustainability. In: Sherman K, Alexander LM, Gold BD, Washington, DC: AAAS Press, 1992. 376 pp.
Vol. 6: The Northeast Shelf Ecosystem: assessment, sustainability, and management. In: Sherman K, Jaworski NA, Smayda TJ, editors. Cambridge, MA: Blackwell Science, Inc., 1996. 564 pp.
Vol. 7: Large marine ecosystems of the Indian Ocean: assessment, sustainability, and management. In: Sherman K, Okemwa EN, Ntiba MJ, editors. Malden, MA: Blackwell Science, Inc., 1998. 394 pp.
Vol. 8: Large marine ecosystems of the Pacific Rim: assessment, sustainability, and management. In: Sherman K, Tang Q, editors. Malden, MA: Blackwell Science, Inc., 1999, 455 pp.
Vol. 9: The Gulf of Mexico large marine ecosystem: assessment, sustainability, and management. In: Kumpf H, Stiedinger H, Sherman K, editors. Malden, MA: Blackwell Science, Inc., 1999. 736 pp.

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 [25] related to UNCLOS recognized the contribution of the GEF in addressing LMEs through its science- 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 for bringing 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, their root causes, and setting priorities for action on transboundary concerns. This process has been referred to as a transboundary diagnostic analysis (TDA) and it 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 a country-driven strategic action program (SAP). This allows sound science to become the basis for policy-making and fosters a geographic location upon which an ecosystem-based approach to management can be developed, and more importantly, can be used to engage stakeholders within the geographic area so that they contribute to the dialogue and in the end they 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 policy-making. Furthermore, the science-based approach encourages transparency through joint monitoring and assessment processes (joint cruises for countries sharing an LME) that builds trust among nations over time and can overcome the barrier of false information being reported.

6. GEF bridging the institutional gaps

The GEF-supported processes in LME projects foster "learning by doing" and capacity building as "enabling activities" do in other GEF focal areas. They 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. It provides a framework for those involved in integrated coastal management (ICM) and those addressing land-based activities and freshwater basin management to be integrated into priority setting processes. This process builds confidence among different sectoral interests in a country through establishing a national GEF inter-ministerial committee and then among participating countries sharing the LME by establishing a multisectoral, intergovernmental, GEF project Steering Committee. The process of 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.

Existing international agreements fall short of attaining the goals of the UNCED process for oceans. They are designed around sectoral themes such as pollution, the GPA, sewage, waste disposal, fisheries, biodiversity, or global climate change that fail to link international and local problems in a cross-sectoral strategic approach applicable for the particular priorities of that LME and its coastal area. They remain thematic and have encouraged narrowly focused institutions to develop. To bridge this gap, the GEF, its UN partner agencies, and other organizations including IUCN, IOC of UNESCO and NOAA, have joined together to address these concerns. Developing country officials responsible for coastal and marine resources have understood the ramifications of the declining status of their marine ecosystems and the link to land-based activities that has been so difficult to foster. Across Africa, Asia and the Pacific, Latin America and the Caribbean, and in Eastern Europe, country officials have been experimenting with the GEF to reverse the decline of their marine ecosystems, testing methods for restoring once abundant biomass in order to sustain growing populations of coastal communities and to conserve highly fluctuating systems to ensure continued benefits for future generations. Since the early 1990s, these nations have approached the GEF, its implementing agencies, and other executing agencies like the UN Industrial Development Organization (UNIDO) for assistance in restoring and protecting sustainable use of their LMEs.

Table 2 lists the 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 other OECD countries since the living resources, the pollution loading, or the critical habitats have transboundary implications across rich and poor nations alike. Over one-half billion dollars in total project costs from the North and South are currently being invested as of December 2001 in 10 LME projects in 72 countries with $225 million in GEF grant finance. An additional 7 LME projects are under preparation involving 54 different nations. A total of 126 different countries are involved with these GEF LME projects. With OECD countries involved that share the LMEs with the GEF recipient nations, expectations are 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 LME and adjacent waters.

7. Features and early results of LME projects

Through the GEF LME projects, countries are testing methods to demonstrate how integrated management of oceans, coasts, estuaries, and freshwater basins can be implemented though an ecosystem-based approach. It is noteworthy that non-recipient OECD countries also share these LMEs or are located in contributing

Table 2
Countries Participating in GEF/large marine ecosystem projects

LME	Countries
Approved GEF Projects	
Gulf of Guinea (6)	Benin, Cameroon, Côte d'Ivoire, Ghana, Nigeria, Togo[a]
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[b], Namibia, South Africa[b]
South China Sea (7)	Cambodia, China, Indonesia, Malaysia, Philippines, Thailand, Vietnam
Black Sea (6)	Bulgaria, Georgia, Romania, Russian Federation, Turkey[b], Ukraine
Mediterranean (19)	Albania, Algeria, Bosnia-Herzegovina, Croatia, Egypt[b], France, Greece, Israel, Italy, Lebanon, Libya, Morocco[b], Slovenia, Spain, Syria, Tunisia, Turkey, Yugoslavia, Portugal
Red Sea (7)	Djibouti, Egypt, Jordan, Saudi Arabia, Somalia, Sudan, Yemen
Western Pacific Warm	Cook Islands, Micronesia, Fuji, Kiribati, Marshall Islands, Nauru, Niue, Papua New
Water Pool-SIDS (13)	Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu Total number of countries: 72[c]
GEF Projects in the preparation stage	
Canary Current (7)	Cape Verde, Gambia, Guinea,[b] Guinea-Bissau,[b] 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, Sao Tome and Principe, Sierra Leone, Togo
Gulf of Mexico (3)	Cuba[b], Mexico[b], 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, Columbia, Costa Rica, Cuba, Grenada, Dominica, Dominican Republic, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, Venezuela Total number of countries: 54[c]

[a] The six countries participating in the Gulf of Guinea project also appear in a GEF/LME project in the preparatory phase.
[b] Countries that are participating in more than one GEF/LME project.
[c] Adjusted for multiple listings.

basins such as Germany and Austria in the Danube Basin draining to the Black Sea. Emphasizing the global situation in which both the developed and developing nations must cooperate in order to reverse the continuing degradation of coastal and marine ecosystems, a total of 18 non-recipient, developed States are collaborating with the GEF recipient States in those LME projects on the particular high priority

concerns relevant for each waterbody—some focused on the depletion of fisheries, others on habitat restoration and protection, and still others on the reduction of pollution from land-based sources.

7.1. Danube/Black Sea Basin LME

An example where GPA concerns prevail is the case of accelerated eutrophication of the Danube Delta and Black Sea LME from excessive levels of nitrogen loading. A series of small GEF projects for the Danube and Dnipro River basins and the states of the Black Sea LME since the early 1990s have been programmed to focus on reducing nitrogen loadings from the 17 contributing nations. Following successful completion of the TDA and SAP processes in the mid and late 1990s for the Black Sea LME [26] and the Danube Basin [27], political commitments were achieved for nutrient reduction and abatement of persistent toxic substances being released from hotspots. Reforms in policy, laws, institutions, and investments are now being supported by GEF in each country for nitrogen abatement from the agriculture, municipal, and industrial sectors. Billions of dollars of water quality investments are being mobilized through EU accession, agriculture pollution is being reduced, and wetlands are being restored in the upstream basins to serve as nutrient sinks to protect the LME.

A GEF Strategic Partnership is in place for 2001–2006 with all 3 GEF implementing agencies to assist the 17 collaborating nations. Through the GEF recommended strategic processes, political commitments have been agreed to among the states (including nutrient reduction action by the Danube basin states of Austria and Germany supported by national funding). The Partnership among the 3 GEF agencies, donors, and the 17 States is now bringing coordinated support and benefits to the transboundary basin and its linked marine environment under the Bucharest Convention and the Istanbul Convention and has fostered an adaptive management approach. Community and NGO participation is fostered with extensive small grants programs for mobilizing support for hotspot cleanup. GPA Protocols to the conventions are to be adopted codifying country commitments to action, and a fisheries convention is to be negotiated by the six Black Sea states to adopt an ecosystem-based management approach. This is the largest GEF international waters initiative of its kind and is intended to serve as a test of whether a more comprehensive level of participation by GEF and streamlined sub-project approvals can leverage significant environmental improvements for a large LME and its drainage basin.

7.2. Red Sea LME

The Red Sea and Gulf of Aden LME represents another example of all three GEF implementing agencies working together to assist the collaborating States in a modest, catalytic project with GEF finance being just a small part of a much larger effort in different economic sectors funded through other sources that help protect the unique coral reefs of the sea. Formulation of the Red Sea SAP [28] was initiated in 1995 and was the first one completed under the GEF Operational Strategy in 1997. The processes of formulating the TDA and the SAP played an important role in

uniting the countries under their previously adopted regional seas convention, the Jeddah Convention. The SAP identifies actions needed to protect the uniquely fragile coral reefs, sea grass beds, and mangroves of the Red Sea coast. And an array of actions are supported in implementation, including development and implementation of ICM plans for specific coastal areas and the development of marine protected areas (MPAs).

The Red Sea project was programmed with a complementary GEF international waters project for the pollution hotspot of the Gulf of Aqaba in Jordan to accompany World Bank assistance. The reefs in the Gulf are the northern most warm-water-type coral reefs on Earth and the 17 km marine park protected area shared by Israel and Jordan serves as an example of how developed and developing countries may work together jointly to sustain their valuable coastal and marine resources. The marine park serves as a haven for fish and contributes to repopulation of other areas subject to exploitation. The use of MPAs is an essential management component of LMEs in order to conserve biomass and biodiversity. The project also assisted Jordan to develop a modern environmental management institution as part of its economic development processes in areas to protect the sensitive reefs from excesses of tourism, pollution discharges, and industrial development. The institution is now more stringent in its development requirements to protect the marine ecosystem than the rest of the country.

7.3. Western Pacific warm pool marine ecosystem

While not strictly an LME, The western pacific marine ecosystem is the life blood of pacifc sids economies with its rich tuna fisheries and with its island archipelagos represents an agglomeration of a number of LMEs. Heads of states of the 13 PACSIDS adopted their GEF SAP [29] in september 1997 and began implementation of their GEF/UNDP international waters project thereafter. While a number of components were involved including community-based fisheries management, ICM, and interventions addressing their water supplies; An important component included GEF support to the countries through the forum fisheries agency included in the establishment of a regional convention on conservation, management, and sustainable use of their highly migratory fish stocks. A commission is being established to oversee a more ecosystem-based approach to management, known as the "Convention on the Conservation and Management of Highly Migratory Fish Stocks of the Western and Central Pacific Ocean". The GEF assistance helped level the playing field among the Pacific SIDS as they negotiated the Convention with Asian, North American and European nations. Following 7 sessions of what was known as the MHLC process [30], the Convention was signed in September 2000 and is the first agreement to be successfully negotiated on the basis of the 1995 UN Fish Stocks Agreement.

7.4. Mediterranean LME

In the Mediterranean project, GEF assistance resulted in a SAP for land-based sources of marine pollution being adopted by all 20 nations under their Barcelona

Convention [31] with enforceable commitments to action on pollution reduction for specific pollutants with specific timetables and targets—the first such commitments to action in the program's 20 yr history as GEF played a catalytic role in its transition from a research focus to an on-the-ground implementation focus. The eight non-recipient nations must also adhere to the pollution reduction timetables as the SAP process operationalized their GPA Protocol under their regional seas convention and expanded the collaboration from just the saltwater to the basins draining to the sea. The UNEP and World Bank are assisting the Mediterranean countries according to their comparative advantages. UNEP is assisting in the more controversial processes of developing a TDA and SAP for living resources and their critical habitats that will take a number of years to complete in conjunction with the review of the EU Common Fisheries Policy. The World Bank is assisting with feasibility studies for high priority bankable investments that will help the states implement their Mediterranean SAP for land-based sources of pollution.

7.5. South China Sea LME

The South China Sea project with UNEP has been programmed in conjunction with two other GEF international waters projects to fit programmatically in the attempt to restore and protect the globally significant coral reefs, sea grass beds, mangroves, and wetlands of the LME and its coast. The Mekong Basin project with its valuable delta receives GEF assistance through the World Bank while the complementary hotspot remediation demonstration activities conducted through the GEF/UNDP/IMO program entitled *Partnerships for Environmental Management of the Seas of East Asia* (*PEMSEA*) are also an integral part of GEF's programmatic approach. While the South China Sea project undertakes collective strategic processes for developing a more ecosystem-based approach to management through production of a TDA [32] and SAP, *PEMSEA* has supported a number of complementary local demonstrations of ICM since 1996 that are well-known throughout the ICM community [33].

Of global policy significance has been the *GEF/PEMSEA* assistance to the Government of the Philippines as it developed the Manila Bay Declaration and Manila Bay Coastal Strategy in its part of the South China Sea. This complementary initiative is multi-jurisdictional in nature with respective national governments, provinces in the drainage area, and the large municipalities of Manila and represents a GPA-equivalent of a SAP for the contributing freshwater basin that is enacted in the framework of coastal sustainable development. The political declarations have been adopted at the highest level and represent a decade-long commitment to action.

7.6. Patagonia Shelf LME

Two international waters projects cover the Patagonia Shelf LME in Uruguay and Argentina. The Plata Maritime Front area is subject to management under a commission and bilateral treaty. The remainder of the LME is in Argentina and suffers from land-based pollution from hotspots as well as extreme amounts of

over-fishing recently brought about through agreements with the EU and Asian distant fleets. As noted by UNEP [12], depletion of the ecosystem as a result of trade distortions and EU subsidies was rapid with the fishery lasting but 10 yr with modern equipment of the EU and Asian fleets. UNDP is assisting the countries with the highly polluted and over-fished Maritime Front and the World Bank is assisting Argentina with two loans (one for land-based pollution abatement and another related to reforms in the fishery sector) to which GEF has added an incremental amount of grant funding toward restoration and protection of the marine biodiversity. The projects are under implementation.

8. Comprehensive LME demonstration projects and project modules

Four of the LME project areas involve testing comprehensive attempts at resolving complex and interlinked ecosystem problems: the Guinea Current, the Benguela Current, the Yellow Sea, and the Baltic Sea LMEs. A five-module approach to the assessment and management of LMEs has been proven to be useful in other LMEs and is being applied in these four areas to test its utility. The processes are customized to fit the situation within the context of the TDA process and the SAP 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. The five modules (productivity, fish/fisheries, pollution/ecosystem health, socio-economics, and governance) are in the process of being adapted to four of the Comprehensive LME Demonstration projects. The first four models support the TDA process while the governance module is associated with periodic updating of the Strategic Action Program or SAP. Adaptive management regimes are encouraged through periodic assessment processes (TDA updates) and updating of SAPs as gaps are filled.

8.1. Productivity module

Productivity can be related to the carrying capacity of an ecosystem for supporting fish resources [34]. Recently, scientists have reported that the maximum global level of primary productivity for supporting the average annual world catch of fisheries has been reached, and further large-scale "unmanaged" increases in fisheries yields from marine ecosystems are likely to be at trophic levels below fish in the marine food chain [35]. Measuring ecosystem productivity also can serve as a useful indication 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, paralytic shellfish toxins), and explosive growth of non-indigenous species [36].

The ecosystem parameters measured in the productivity module are zooplankton biodiversity and information on species composition, zooplankton biomass, water

column structure, photosynthetically active radiation (PAR), transparency, chlorophyll-*a*, NO_2, NO_3, and primary production. Plankton of LMEs have been measured by deploying Continuous Plankton Recorder (CPR) systems monthly across ecosystems from commercial vessels of opportunity over decadal time scales. 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 the calibration of satellite-derived oceanographic conditions relating to changes in phytoplankton, zooplankton, primary productivity, species composition and dominance, and long-term changes in the physical and nutrient characteristics of the LME and in the biofeedback of plankton to the stress of environmental change [37,38].

8.2. Fish and fisheries module

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. Changes in the biodiversity of a fish community can generate cascading effects up the food chain to apex predators and down the food chain to plankton components of the ecosystem. The fish and fisheries module includes fisheries-independent bottom-trawl surveys and acoustic surveys for pelagic species to obtain time-series information on changes in fish biodiversity and abundance levels. Standardized sampling procedures, when deployed from small calibrated trawlers, can provide important information on diverse changes in fish species [39]. Fish catch provides biological samples for stock assessments, stomach analyses, age, growth, fecundity, and size comparisons; data for clarifying and quantifying multispecies trophic relationships; and the collection of samples for monitoring coastal pollution. Samples of trawl-caught fish can be used to monitor pathological conditions that may be associated with coastal pollution and can be used as platforms for obtaining water, sediment, and benthic samples for monitoring harmful algal blooms, diseases, anoxia, and changes in benthic communities.

8.3. Pollution and ecosystem health module

In several LMEs, pollution has been a principal driving force in changes of biomass yields. Assessing the changing status of pollution and health of the entire LME is scientifically challenging. Ecosystem "health" is a concept of wide interest for which a single precise scientific definition is problematical. 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 [40]. 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 [41]. The ecosystem sampling strategies are focused on parameters related to overexploitation, species protected by legislative authority (marine mammals), and other key biological and physical components at

the lower end of the food chain (plankton, nutrients, hydrography) as noted by Sherman [22].

Fish, benthic invertebrates, and other biological indicator species are used in the Pollution and Ecosystem Health module to measure pollution effects on the ecosystem, including the bivalve monitoring strategy of "Mussel-Watch;" the pathobiological examination of fish; and the estuarine and nearshore monitoring of contaminants and contaminant effects in the water column, substrate, and in selected groups of organisms. The routes of bioaccumulation and trophic transfer of contaminants are assessed, and critical life history stages and selected food chain organisms are examined for parameters that indicate exposure to, and effects of, contaminants. Effects of impaired reproductive capacity, organ disease, and impaired growth from contaminants are measured. Assessments are made of contaminant impacts at the individual species and population levels. Implementation of protocols to assess the frequency and effect of harmful algal blooms, emergent diseases and multiple marine ecological disturbances [42] are included in the pollution module.

8.4. Socio-economic module

This module is characterized by its emphasis on practical applications of its scientific findings in managing an LME and on the explicit integration of economic analysis with science-based 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.

Designed 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 an LME and the socioeconomic considerations important to the implementation of an adaptive management approach for an LME [43]. One of the more critical considerations, a methodology for considering economic valuations of LME goods and services has been developed around the use of interaction matrices for describing the relationships between ecological state and the economic consequences of change and is included in the framework.

8.5. Governance module

The Governance module is evolving based on demonstrations now underway among ecosystems to be managed from a more holistic perspective than generally practiced in the past. In projects supported by GEF—for the Yellow Sea ecosystem, the Guinea Current LME, and the Benguela LME—agreements have been reached

among the environmental ministers of the countries bordering these LMEs to enter into joint resource assessment and management activities as part of building institutions. Among other LMEs, the Great Barrier Reef ecosystem is being managed from an ecosystem-based perspective; the Antarctic marine ecosystem is also being managed from an ecosystem perspective under the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). Governance profiles of LMEs are being explored to determine their utility [44] in promoting long-term sustainability of ecosystem resources.

9. Comprehensive LME demonstrations

In essence, systematic application of the 5 modules through the TDA-SAP processes can help foster an adaptive management approach to joint governance based on iterative assessments of indicator parameters (GEF monitoring and evaluation indicators) as part of establishing commitments to action and periodically reviewing progress made toward the indicators. These processes help to integrate science into the management regime and establish governance regimes for a collective response to site-specific priorities under various environmental conventions and action programs. Joint monitoring surveys are being employed to provide transparency in collection of data and confidence and trust among participating nations. As noted in the Gulf of Guinea and Benguela Current LME projects in Africa, such joint cruises also serve to build capacity among nations to utilize sound science so that management decision-making may be improved.

9.1. Gulf of Guinea Pilot Project

The GEF is supporting the coastal nations all along the western coast of Africa in the establishment of ecosystem-based assessment and management of their coastal environments and resources. Included among the projects was the pilot phase of the Guinea Current LME project from 1995 to 1999. The six participating countries—Benin, Cameroon, Ghana, Ivory Coast, Nigeria, and Togo—have used the GEF Grant to strengthen national infrastructure in staffing positions and engaging government support. The long-term objective of the project is to restore and sustain the health of the Guinea Current Large Marine Ecosystem and its living resources, particularly with regard to biological diversity, coastal habitats, and the control of water pollution.

Project participants included: networks of national environmental protection Agencies and Departments, public health Administrations, sewage work Authorities, industries, and Universities/Research Institutions in the participating countries. Non-governmental organizations (NGOs) and Community Based Organisations (CBOs) have been very active particularly as it relates to public awareness and environmental education aspects. In order to provide the necessary focus, National Focal Point Agencies and National Focal Point Institutions were designated. National and regional experts were designated to support the monitoring and

assessment module of the project at the national and regional level. The capacity of national institutes and experts was reinforced through the supply of appropriate equipment and by a series of workshops aimed at standardizing methodological approaches in the afore mentioned components. Activity groups on specific topics (productivity, fish and fisheries, pollution monitoring, socioeconomics, and governance) were convened regularly to discuss the progress made and problems encountered, and to undertake joint assessments.

At the international level, UNDP served as the Implementing Agency, UNIDO as the Executing Agency and UNEP as a co-operating organization. The United States Department of Commerce through its National Oceanic and Atmospheric Administration (NOAA) provided technical support particularly in capacity building initiatives in addition to in-kind contribution to the funding of the project. Other United Nations and non-United Nations Agencies such as the Intergovernmental Oceanographic Commission (IOC) of UNESCO, IMO, FAO, and IUCN provided guidance at specific stages in project implementation.

Actions included joint identification of major transboundary environmental and living resources management issues and problems, and adoption of a common regional approach, in terms of strategies and policies for addressing these priorities in the national planning process at all levels of administration, including local governments. Among the successfully completed activities is a cooperative survey of the bottom fish stocks using a chartered Nigerian vessel with representatives of each of the participating countries taking part in the trawling and data reporting operations. Funds were used to complete a report on the major multidecadal shifts in the abundance of fish stocks in the ecosystem, caused principally by environmental perturbations affecting the annual upwelling cycle and temperature regime of the ecosystem. In addition to the cooperative trawl survey, surveys of the plankton community to address the carrying capacity of the Gulf of Guinea for supporting sustainable fisheries were conducted at six-week intervals using plankton recorder systems deployed from large container vessels transiting the region. The samples are being processed in a Plankton Center established with GEF funds in Tema, Ghana in collaboration with the Sir Alister Hardy Foundation of the UK.

Forty region-wide workshops attended by nearly 900 participants were held on the key transboundary concerns, including: pollution monitoring, ecosystem productivity studies; natural resources management and planning, development of institutional capacities (including administrative and legal structures), and data and information management and exchange. The pilot project for the Guinea Current LME established intra- and international networks of scientific institutions and non-governmental organizations, with a total of more than 500 scientists, policy makers and other participants (making it the African continent's single largest network for marine and coastal area management), to undertake studies on ecosystem degradation, to assess living resources availability and biodiversity, and to measure socio-economic impacts of actions and non-actions. The capacity of the networks has been reinforced through the supply of appropriate equipment and by a series of group training workshops aimed at standardizing methodological approaches

around five project modules: (1) productivity, (2) fish and fisheries, (3) pollution and ecosystem health, (4) socioeconomics, and (5) governance.

Restoration has been initiated of mangrove areas along the coast. And assessments of the principal sources of coastal pollution have been initiated. National State of the Marine Environment Reports were issued as "initial assessments," encompassing published and unpublished data and including policy options and past interventions. Plans for the management of transboundary coastal resources were completed by each of the countries [45–50]. Several studies have suggested options for increasing the long-term sustainability of coastal resources and increasing socioeconomic benefits to the people of the region [51]. A detailed assessment of the nature and quantities of urban wastes and sewage and the present status of their management was completed. With due recognition of the ongoing government efforts with the World Bank to implement master plans for urban wastes and sewage management, the project focused with municipal authorities on novel and low technology options, such as the use of settling pits in Ghana for sewage treatment in small communities and the sorting of domestic wastes prior to disposal as a means of encouraging recycling and reuse. In addition, a parallel effort was made to develop strategies and policies to encourage reduction, recycling, recovery and reuse of industrial wastes. One such initiative, now at the pilot stage in Ghana, is the establishment of Waste Stock Exchange Management System. This concept, which has been enthusiastically embraced by manufacturing industries in Ghana and has as a slogan "one person's waste, another person's raw material," holds considerable promise as a cost effective waste management tool.

An Accra Declaration has been signed by the Environmental Ministers from each of the six countries indicating joint commitment for taking steps to promote the long-term sustainability of the Gulf of Guinea resources [52]. The ministers of the environment, fisheries, tourism, energy, mining, and finance of the six countries engaged in the first phase of the Guinea Current project agreed with counterpart ministers of 10 neighboring countries along the coastal margins of the ecosystem to extend the project in phase two from Guinea Bissau on the northwest part of the coast to Angola in the southwest. Phase two is presently focused on development of and expanded TDA and strategic action plan (SAP) in collaboration with the GEF, United Nations Industrial Development Organization (UNIDO), the UN Development Programme, NOAA, and IUCN.

9.2. Benguela Current LME Project

The GEF is supporting an ecosystem-based project requested by the governments of Angola, Namibia and South Africa for the "Integrated Management, Sustainable Development, and Protection of the Benguela Current Large Marine Ecosystem (BCLME)." The project is focused on sustainabile management and utilization of living marine resources, mining and environmental variability, ecosystem forecasting, management of pollution, ecosystem health and protection of biological diversity, and capacity strengthening. Within an overall ecosystem approach, specific actions have been agreed upon through a series of meetings between stakeholders

and government representatives. During a 12-month planning period, the three countries reached consensus on a strategic approach for the project, based on the preparation of a TDA and a strategic action plan (SAP). With regard to the fish and fisheries of the BCLME, the countries agreed to establish a regional structure to: (1) conduct transboundary fish stock and ecosystem assessments; (2) evaluate transboundary resource and environmental linkages; and (3) provide advice to the three governments based on the assessment results. They agreed to conduct joint surveys and assessments of shared fish stocks over a 5 yr period beginning in 2002 as a demonstration of the benefits to each of the countries of joint assessments for compiling baseline data and validating survey and assessment methodology.

The countries are establishing an Interim Benguela Current Commission (IBCC) to strengthen regional cooperation. The IBCC is to be supported by a project coordinating unit and advisory groups. Within a period of 5 yr it is expected that the IBCC will become a fully functioning Benguela Current Commission (BCC) with a supporting secretariat. The BCC is to serve as the organization for harmonizing technical issues including fishing gear, mesh size and type, data compatibility, and assessment methodology. Cooperative assessments of non-exploited species will also be made. Effort will be directed by the BCC to develop a viable mariculture policy for the three countries. Cooperative analyses of the socioeconomic consequences of harvesting methods will be undertaken by the IBCC with a view to appropriate intervention within the framework of improving sustainable use of the BCLME resources, and in compliance with the FAO Code of Conduct for Responsible Fishing. In addition to fisheries, the IBCC will develop a regional framework for enhancing consultations for the purpose of mitigating the negative impacts of marine mining particularly with regard to any potential or actual conflicts among fisheries and coastal and offshore diamond/gold mining and oil and gas exploration and/or production.

Among the principles adopted by the IBCC are: (1) the concept of sustainable development shall be used in a way that does not destroy the integrity of the BCLME ecosystem, or otherwise foreclose on options for use and enjoyment for future generations; (2) the precautionary principle where appropriate, shall be applied, preventative measures being taken when there are reasonable grounds for concern that an activity may increase the potential hazards to human health, living marine resources or marine ecosystems, damage amenities, or interfere with other legitimate uses of the sea, even when there is no conclusive evidence of a causal relationship between the activity and the effects and by virtue of which greater caution is required when information is uncertain, unreliable or inadequate; and (3) the use of economic and policy instruments that foster sustainable development shall be promoted through, inter alia, the implementation of economic incentives for introducing environmentally friendly technologies, activities and practices; the phasing-out of subsidies which encourage the continuation of non-environmentally friendly technologies, activities and practices; the introduction of user fees and the polluter pays principle; and that environmental, ecosystem, and human health considerations shall be included into all relevant policies and sectoral plans, especially those

concerning marine industrial development, fisheries, mariculture and marine transport.

The structure of the Interim Benguela Current Commission (IBCC) and terms of reference of the Advisory Groups to the Commission for fisheries, environment, pollution, legal affairs, and data exchange have been approved at the ministerial level in the participating countries.

9.3. The Yellow Sea LME Project

Notable progress has been made in the introduction of the ecosystem-based management and assessment activities for the Yellow Sea LME (YSLME) by ministerial representatives of China and South Korea serving together in a joint steering committee for a GEF-sponsored International Waters project. The project is being carried out in collaboration with the UNDP and other international partners including NOAA and IUCN. The Yellow Sea LME is an important global resource. This international water-body supports substantial populations of fish, invertebrates, marine mammals, and seabirds. Many of these resources are threatened by both land and sea-based sources of pollution and habitat loss resulting from extensive economic development in the coastal zone, and by the unsustainable exploitation of natural resources (primarily overfishing). Additionally, there is significant international shipping traffic through the waters of the Yellow Sea, with associated threats from spills and collisions with marine mammals.

In the western Yellow Sea, pollution sources include wastewater from Qingdao, Dalian, And Lianyungang port cities; oil discharged from vessels and ports; and oil and oily mixtures from oil exploration. More than 100 million tons of domestic sewage and about 530 million tons of industrial wastewater from coastal urban and rural areas are discharged into the nearshore areas of the Yellow Sea each year. The major pollutants carried by sewage and waste water are oils, mercury, cadmium, lead, COD, and inorganic nitrogen.

The eastern Yellow Sea has significant pollution in the shallow inlets of its southern coastline where the many islands prevent mixing with open ocean water and red tides persist. Demersal species used to be the major component of the resources and accounted for 65 to 90 percent of annual total catch. The resource populations of demersal species such as small yellow croaker, hairtail, large yellow croaker, flatfish, and cod declined in biomass by more than 40 percent when fishing effort increased threefold from the early 1960s to the early 1980s. Shifts in species dominance and biodiversity in the Yellow Sea are significant. The dominant species in the 1950s and early 1960s were small yellow croaker and hairtail, while Pacific herring and chub mackerel became dominant during the 1970s. Some smaller-bodied, fast-growing, short-lived, and low-value fish (e.g., *Setipinna taty*, anchovy, scaled sardine) increased markedly in about 1980 and have taken a prominent position in the ecosystem resources thereafter. As a result, some larger-sized and higher trophic level species were replaced by smaller-bodied and lower trophic level species, and the resources in the Yellow Sea declined in quality. About 70 percent of the biomass in 1985 consisted of fish and invertebrates smaller than 20 cm, and the

mean body length in the catches of all commercial species was only 12 cm while the mean body length in the 1950s and 1960s exceeded 20 cm. The trophic levels in 1985 and in the 1950s were estimated to be 3.2 and 3.8, respectively. Thus, it appears that the external stress of fishing has affected the trophic structure of the Yellow Sea ecosystem.

Aquaculture is a major use of the coastal waters of the Yellow Sea. Mariculture is commonly practiced in all coastal provinces of China, and it is most advanced in Shandong and Liaoning provinces. The total yield of invertebrate mariculture of ROK in 1997 was 301,873 metric tons (MT) representing 29.7 percent of ROK's total mariculture production (1,015,134 MT), including 200,973 MT of oysters (20 percent) and 63,572 MT of mussels (6.3 percent).

Offshore oil exploration has been successful in the Chinese and DPRK portions of the Yellow Sea. In addition, the sea has become more important with the growth in trade among its bordering nations. The main Chinese ports are Shanghai, Lu-ta, Tientsin, Qingdao, and Chin-huang-tao; the main ROK port is Inchon, the outport of Seoul; and that for DPRK is Nampo, the outport for P'yongyang. Tourism is an industry in its infancy in both China and Korea. Several sites of picturesque beauty around the coastlines of these countries could be promoted as tourist attractions. As access to China and Korea becomes easier for foreign visitors, the tourist industry will expand; and the granite mountains of the western Liaoning coast in China and the islands and swimming beaches of ROK, in particular Cheju Island, will be in even greater demand.

The Yellow Sea is an international water-body and many of its problems can be solved only through international cooperation. The management of the Yellow Sea is especially complicated in that it is surrounded by nations that share some aspects of their historical and cultural background, but differ in internal political systems, external political and economic alignment, and levels of economic development. For the future of the Yellow Sea, it is thus imperative for the coastal nations to realize the importance of regional cooperation. There are currently several agreements for bilateral regulation or development of the Yellow Sea and East China Seas, but none of them are binding on all the coastal nations; nor is any nation a party to all the agreements. Of global policy significance has been the GEF/PEMSA assistance to the Government of China as it developed the Bohai Sea Declaration for the internal sea connected to the Yellow Sea. This initiative is multi-jurisdictional in nature with the national government, provinces in the drainage area, and large downstream municipality of Tianjin, and it represents the national equivalent of SAP enacted in the framework of coastal sustainable development. The political declaration represents a decade-long commitment to on-the-ground action that will total billions of dollars of investments and policy/legal/institutional reforms to reduce the coastal degradation. Such commitments are unprecedented in GEF recipient countries, and they are quite similar to the Chesapeake Bay Basin cleanup program in the United States that has been at work for two decades in coastal restoration.

The principal activities to be operationalized within the framework of the YSLME project are listed below. The activities include measurements of stock size and primary productivity for carrying capacity determinations for capture fisheries

mariculture and pollution assessments. Other activities involve the assessments of fish stocks and establishment of total allowable catch quotas for fish. A China–Korea forum for annual determination of TAC levels, based on the results of joint bottom trawl and acoustic surveys, will be introduced. Budgets have been provided for improving analyses of socioeconomic benefits in relation to short- and long-term resource sustainability options. Consideration will also be given by both countries to the optimization of management actions for all shared marine resources. A bilateral China-Korea Project Coordination Unit (PCU) has been established to oversee the project for both countries.

9.4. Baltic Sea Regional Project

As late as 1950 the Baltic Sea was still regarded as environmentally "healthy;" its ecological deterioration has been caused in recent years by an increase of point source industrial and non-point source agricultural pollutants, degradation of the coastal zone and non-sustainable use of living marine resources. The natural vulnerabilities have been seriously aggravated by anthropogenic causes of environmental change and degradation. These problems of the Baltic Sea are transboundary in nature, and difficult to address on an individual country basis. The need to address the management of agricultural inputs into international waters, improve coastal zone management and adopt sustainable management of living marine resources has been highlighted in the "Baltic Sea Joint Comprehensive Environmental Action Program (JCP)" which was prepared under the coordination of the Helsinki Commission by a broad based task force. The JCP was adopted as the strategic action program for the region by the Ministers of Environment in 1992 and was updated and strengthened in 1998. HELCOM prepares assessments of transboundary trends and impacts in the form of Pollution Load Compilations and Periodic Assessments which support implementation of the JCP. The JCP recognizes the need to use an ecosystem-based management approach that recognizes the freshwater, coastal and marine resources as a management continuum. This GEF Project responds to the need to address regional transboundary issues and to establish a coordinated approach to ecosystem-based management, in order to alleviate burdens from anthropogenic impacts and meet the objectives of the JCP. In fact, for the first time, this project has all three international commissions with responsibilities in the Baltic working together. In addition to HELCOM, the Baltic Sea Fisheries Commission and the International Commission for the Exploration of the Sea are collaborating in the GEF project to address overfishing, the loss of genetic resources of valuable fisheries in the LME, and contaminants that bioaccumulate to pose ecosystem and human health threats.

The Baltic Sea ecosystem and its catchment area have a range of ecotones and biological diversity. The brackish waters of the Baltic Sea contain a mixture of marine and freshwater species. The coastal areas serve as spawning, nursery, and feeding areas for several species of fish. Baltic 21 statistics have indicated that the fishery industry contributes significantly to regional and local economy, and sustenance fishing is critical to the social and economic welfare of the coastal

communities in the eastern Baltic. Major coastal and marine transboundary issues prevail due to current land, coastal and marine practices; they include: (i) changes in the productivity of the near coastal and offshore waters from eutrophication; (ii) unsustainable condition of fish stock yields; and (iii) degraded condition of coastal water quality from pollution, harmful algal blooms, multiple ecological disturbances, and contaminant loading.

The Project components are based on the LME concept and include integrated land, coastal and open sea activities to strengthen the local and regional capacity to achieve sustainable ecosystem management of the Baltic Sea resources. Sustainable management will improve ecosystem health while providing social and economic benefits to farming, coastal and fishing communities and sectors such as businesses and tourism. The Project introduces jointly planned and implemented multi-national monitoring and assessment surveys that facilitate local cooperation and coordination and use of innovative methodologies for assessing the changing state of the ecosystem and development of effective strategies for the management of these shared resources. Component activities provide the mechanisms to meet these objectives through improving coastal and open sea monitoring and assessment practices, understanding the carrying capacity of the coastal and open sea ecosystem, and promoting sustainable fishery practices.

The Project supports activities in the coastal near shore environment of the Eastern Baltic Sea and in selected adjacent sections of the open sea environment. In general, the coastal near shore activities and monitoring network will correlate with land-based coastal and associated demonstration activities addressing land-based agricultural inputs to coastal and open sea waters and improving coastal zone management are critical for management of the Baltic Sea ecosystem. The JCP highlights management of agriculture inputs and coastal areas of the Baltic as priority issues. The agricultural element of the Component will (i) test administrative and organizational mechanisms (regional and local) and provide advice and support to the farming community; (ii) assess farmers' interest in and willingness to pay for improving their environmental management practices; (iii) assist farmers to lower both the risk and barriers that currently hinder adoption of new practices; and (iv) provide support for small-scale environmentally responsible agricultural investments.

The Project partially finances investment costs for on-farm environmental facilities, operating expenses of local implementers, equipment recommended by the farm management plans, and recurrent costs for local capacity building. The coastal zone management element of the Component covers the following: (i) focuses on the role that can be played by local communities in sustainable management of coastal resources; (ii) links activities in the demonstration watershed to activities being taken on the coast; (iii) supports implementation of previously prepared management plans; and (iv) assists local communities to overcome barriers to adoption of new planning and management methods in these sensitive areas. The Project will partially finance costs for management activities, small-scale investments and demonstration activities and selected costs for local capacity building as well as encourage the three commissions to work together.

10. Reversing biomass depletion is possible in LMEs

Recent carefully controlled ecosystem-based management actions in two LMEs are serving to reverse multidecadal declines in biomass yields. Since 1994, reductions in fishing effort increased the spawning stock biomass (ssb) levels of cod on the Icelandic Shelf ecosystem, and haddock, yellowtail flounder, and other species in the US Northeast Shelf ecosystem.

From the mid-1960s through the early 1990s, the biomass of principal groundfish and flounder species inhabiting the US Northeast Shelf ecosystem declined significantly from overfishing of the spawning stock biomass [53]. In response to the decline, the biomass of skates and spiny dogfish increased from the 1970s through the early 1990s [53]. The impact of the increase in small elasmobranches, particularly spiny dogfish, shifted the principal predator species on the fish component of the ecosystem from silver hake during the mid-1970s to spiny dogfish in the mid-1980s [54]. By the mid-1990s a newly developing fishery for small elasmobranches initiated a declining trend in biomass for skates and spiny dogfish [53].

Following the secession of foreign fishing on the Georges Bank-Gulf of Maine herring complex and the Atlantic mackerel stock in the late 1970s, and over a decade of very low fishing mortality, both species began to recover to high stock sizes in the 1990s. Bottom trawl survey indices for both species increased dramatically, showing over a ten fold increase in abundance (average of 1977–1981 vs. 1995–1999) by the late 1990s [55,56]. Stock biomass of herring increased to over 2.5 million metric (mm) tons by 1997 and ssb was projected to increase to well over 3.0 mm tons in 2000 [53]. The offshore component of herring, which represents the largest proportion of the whole complex, appears to have fully recovered from the total collapse it experienced in the early 1970s [55]. For mackerel, the situation is similar, total stock biomass has continued to increase since the collapse of the fishery in the late 1970s. Although absolute estimates of biomass for the late 1990s are not available, recent analyses concluded that the stock is at or near a historic high in total biomass and ssb [56]. Recent evidence following mandated substantial reductions in fishing effort indicate that both haddock and yellowtail flounder stocks are responding to the catch reductions rather favorably with substantial growth reported in ssb size, since 1994 for haddock and flounder. In addition, in 1997 a very strong year-class of yellowtail flounder was produced, and in 1998, a strong year-class of haddock was produced (Fig. 3).

At the base of the food web, primary productivity provides the initial level of carbon production to support the important marine commercial fisheries [57]. Zooplankton production and biomass in turn provide the prey-resource for larval stages of fish, and the principal food source for herring and mackerel in waters of the NE Shelf ecosystem. Over the past two decades the long-term median value for the zooplankton biomass of the NE Shelf ecosystem has been about 29 cc of zooplankton per $100\,m^3$ of water strained produced from a stable mean-annual primary productivity of $350\,gC\,m^2\,yr$. During the last two decades, the zooplanktivorous herring and mackerel stocks underwent unprecedented levels of growth,

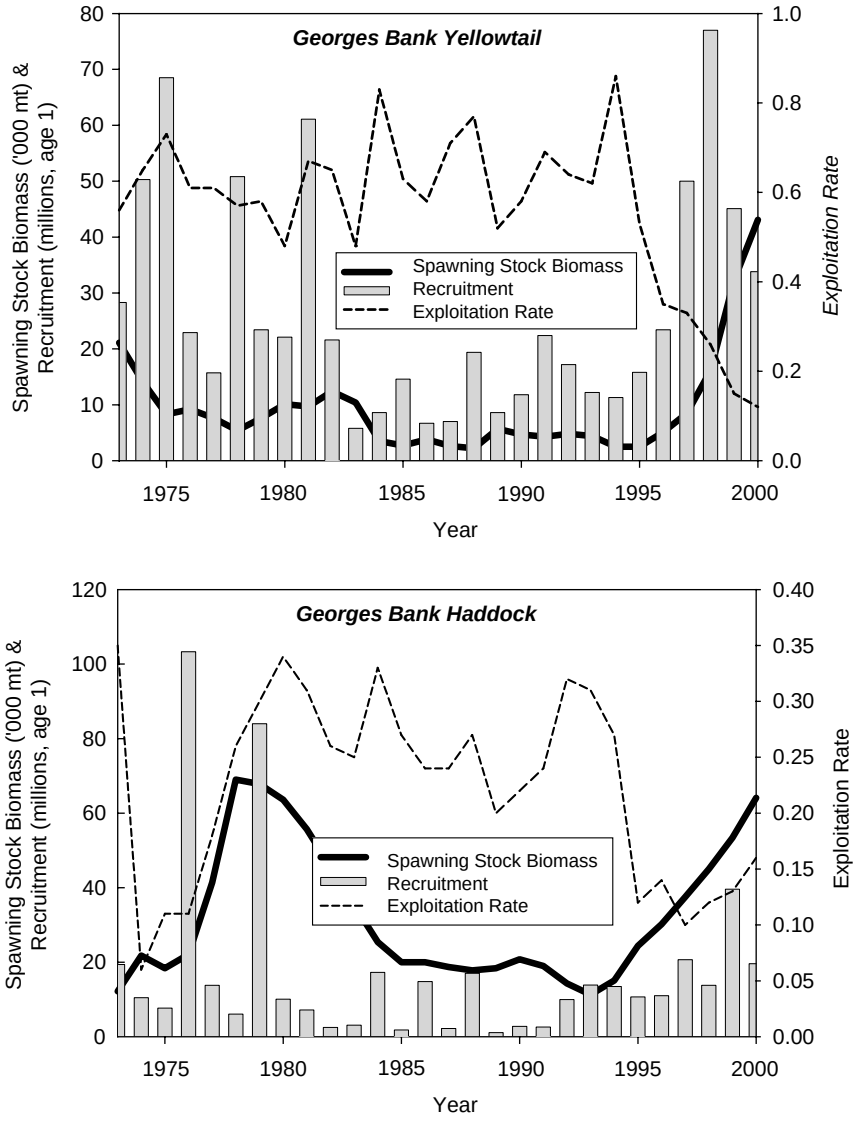

Fig. 3. Increasing trends in spawning stock biomass (ssb) and recruitment in relation to reductions in exploitation rate (fishing effort) for two commercially important species inhabiting the Georges Bank subarea of the Northeast Shelf ecosystem, haddock (top) and yellowtail flounder (bottom).

approaching an historic high combined biomass. This growth is taking place during the same period that the fishery management councils for the New England and Mid-Atlantic areas of the NE Shelf ecosystem have sharply curtailed fishing effort on haddock and yellowtail flounder stocks. Given the observed robust levels of primary productivity and zooplankton biomass, it appears that the "carrying capacity" of

zooplankton supporting herring and mackerel stocks and larval zooplanktivorous haddock and yellowtail flounder is sufficient to sustain the strong year-classes reported for 1997 (yellowtail flounder) and 1998 (haddock).

The zooplankton component of the Northeast Shelf ecosystem is in a robust condition at biomass levels at or above the levels of the long-term median values of the past two decades, providing a suitable prey base for supporting a large biomass of pelagic fish (herring and mackerel), while providing sufficient zooplankton prey to support strong year-classes of recovering haddock and yellowtail flounder stocks [58]. No evidence has been found in the fish, zooplankton, temperature, or chlorophyll component that is indicative of any large-scale oceanographic regime shifts of the magnitude reported for the North Pacific or northeast Atlantic Ocean areas.

The robust condition of the plankton components at the base of the food web of the Northeast Shelf ecosystem was important to the relatively rapid rebuilding of zooplanktivorous herring and mackerel biomass from the depleted condition in the early 1980s to a combined biomass in 1999 of an unprecedented level of approximately 5.5 mm tons, following the exclusion of foreign fishing effort and the absence of any significant US fishery on the stocks. The milestone action leading to the rebuilding of lost herring and mackerel biomass was the decision by the United States to extend jurisdiction over marine fish and fisheries within 200 miles of the coastline. Recently the Fishery Management Councils of New England, and the mid-Atlantic coastal states agreed to reduce fishing effort significantly on demersal fish stocks of the NE Shelf ecosystem. With the reduction of exploitation rate, the spawning biomass of haddock and yellowtail flounder increased over a 4 yr period and led to the production of large year-classes of haddock in 1998 and yellowtail flounder in 1997.

The Northeast Shelf ecosystem is presently undergoing a significant trend toward biomass recovery of pelagic and demersal fish species important to the economy of the adjacent northeast states from Maine to North Carolina. Although the recovery has not as yet been fully achieved, the corner has been turned from declining overharvested fish stocks toward a condition wherein the stocks can be managed to sustain their long-term potential yield levels. The management decisions taken to reduce fishing effort to recover lost biomass was supported by science-based monitoring and assessment information forthcoming from the productivity, fish and fisheries, pollution and ecosystem health, socioeconomics, and governance modules that have been operational by NOAA's Northeast Fisheries Science Center for several decades in collaboration with state, federal, and private stakeholders from the region. This case study can serve to underscore the utility of the modular approach to ecosystem-based management of marine fish species. In an effort to stem the loss of fisheries biomass in other parts of the world, applications of this modular approach to LME management are presently underway by countries bordering the Yellow Sea, Benguela Current, Baltic Sea, and Guinea Current LMEs [59], with financial assistance of the GEF, collaborating UN agencies, and the technical and scientific assistance of other governmental and non-governmental agencies and institutions.

11. Special concerns about nitrogen over-enrichment of LMEs

A common thread regarding degradation of LMEs in GEF projects is the large number of eutrophication cases. More and more, GEF receives requests for interventions in LMEs for such eutrophication concerns. Nitrogen over-enrichment has been reported as a coastal problem for two decades, from the southeast coast of the US as described by Duda [60] 20 yr ago to the Baltic and other systems [61]. More recent estimates of nitrogen export to LMEs from linked freshwater basins are summarized in Fig. 4 as adapted from Jaworski [62]. These recent human-induced increases in nitrogen flux range from 4–8 times during the past 20 years in the US from the Gulf of Mexico to the New England coast [62] while no increase was documented in areas with little agricultural or population sources in Canada [63].

In European LMEs, recent nitrogen flux increases of from three fold in Spain to four fold in the Baltic and 11 fold in the Rhine basin draining to the North Sea LME have been recorded [63]. Duda and El-Ashry [64] 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 [60] for the Southeast estuaries of the US and Rabalais [65] 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 as shown Duda and Finan [66] for eastern North Carolina, where the increase in nitrogen export over the forested situation ranged

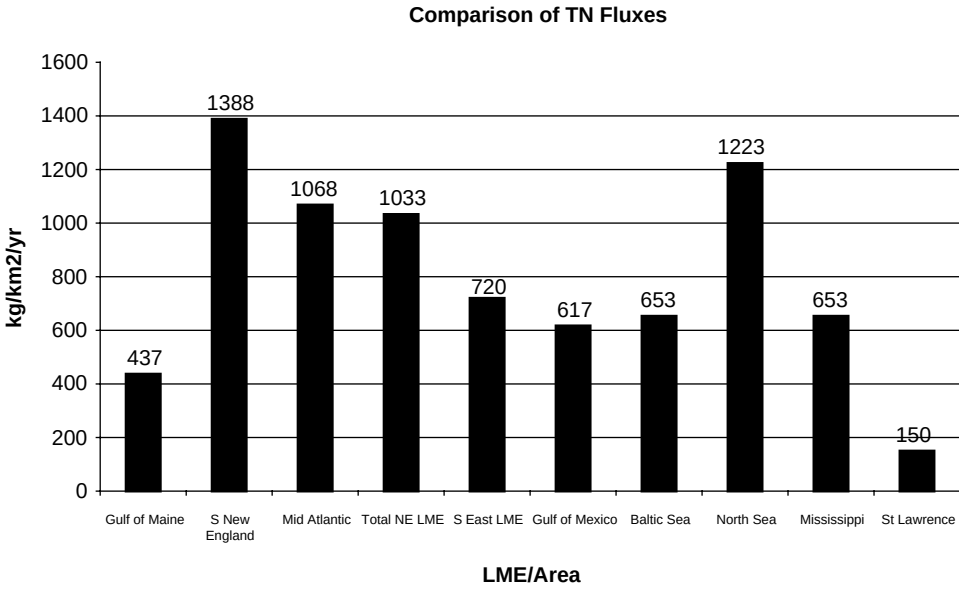

Fig. 4. Comparison of total nitrogen fluxes from select LME watersheds from Jaworski [62].

from 20–500 fold in the late 1970s. Industrialized livestock production the last two decades increases the flux, the eutrophication, and the oxygen depletion even more as reported by the NRC [67]. The latest GESAMP Assessment [2] also identified sewage as a significant contributor to the eutrophication in drainages from large cities and atmospheric deposition from automobiles/agricultural activities may also contribute depending on proximity to sources.

GEF is being asked more frequently by countries to help support the agreed upon incremental cost of actions that reduce such nitrogen flux. Actions range from assisting in development of joint institutions for ecosystem-based approaches for adaptive management described in this paper to on-the-ground implementation of nitrogen abatement measures in the agricultural, industrial, and municipal sectors and 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 transboundary 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 [68] as part of a contribution to better understanding LMEs. Included as Fig. 5 and adapted from Kroeze and Seitzinger [69], 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 fertilizer use, LMEs may be, without significant N mitigation efforts, subjected to a future of increasing harmful algal bloom events, reduced fisheries, and hypoxia that further degrades marine biomass and biological diversity.

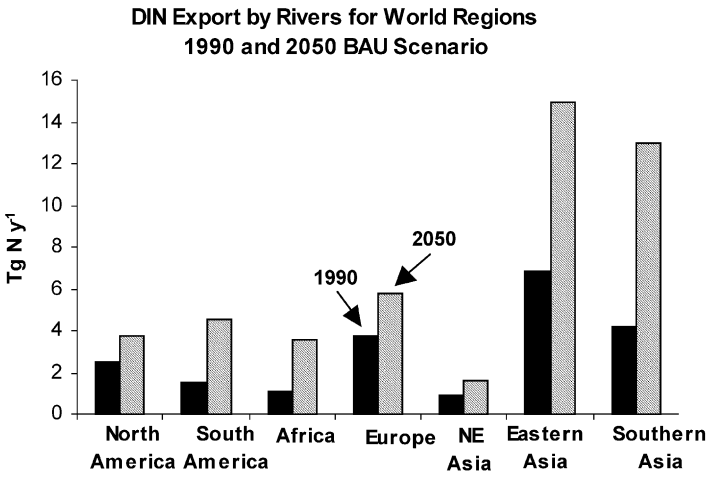

Fig. 5. Model-predicted nitrogen (dissolved inorganic N) export by rivers to coastal systems in 1990 and in 2050 (based on a business-as-usual [BAU] scenario). Figure modified from Kroeze and Seitzinger [69].

12. Sustaining momentum created in 126 countries

An increasing number of developed and developing countries, now totaling 126 around the world, are concerned enough with the degraded condition of their coastal and marine ecosystems to collaborate on GEF LME projects. Ministerial level commitments to ecosystem-based approaches for assessment and management may ultimately lead to establishing joint adaptive management regimes in support of the global objectives of Chapter 17 of Agenda 21, the Jakarta Mandate of the CBD, UNCLOS, the GPA, and the regional seas agreements countries have signed. It appears that an important corner has been turned by these countries toward a focused global effort to restore biomass and biological diversity to coastal oceans as concerned governments understand the poverty reduction and security enhancement that accompanies more sustainable management regimes. The GEF international waters focal area has played a catalytic role through its emphasis on joint management of LME, their coastal assets, and linked river basins in an integrated manner. Through tests of these approaches, countries are starting to establish practical, science-based management regimes that address in collective and ecosystem-oriented ways the themes and programs under existing Agenda 21 and otherglobal instruments.

While many of the multi-country-driven LME initiatives supported with GEF grant funding have just started, and in others the national and regional reforms in progress will take a number of years to achieve, several lessons are becoming evident for the world community to consider in reversing the decline of its coastal oceans. A geographic approach, based on the LMEs of the world, their adjacent coastal areas and linked freshwater contributing basins (where appropriate), is likely to overcome the limits of more thematically directed activities to address global environmental problems (e.g. fisheries, sewage, sediment, contaminants). In this manner, the different stresses that are important to each specific area can be addressed jointly through processes that result in collective national actions in different economic sectors where needed. Processes such as the TDA and SAP foster multi-stakeholder dialogue, inter-ministerial dialogue, and a discourse with the science community in unraveling complex situations so they can be divided into priority components for more effective management than is now in general practice. Fragmented, thematic, single purpose agency programs are just not able to harness stakeholder involvement sufficiently to drive needed reforms compared to geographic-based initiatives.

The assessment and management cycle based on the five modules in the TDA and SAP processes, fosters an adaptive management approach through establishment of monitoring and evaluation indicators that are periodically measured by the nations and tracked over time for reporting to stakeholders and the GEF. GEF agencies have fostered participation of multiple levels of institutions (multi-country, national-interministerial, and local government/communities) for buy-in and adoption of reforms. The geographic nature of LME areas is conducive for harnessing stakeholder participation and gaining political commitments to change. Thematic programs which are not place-based cannot garner real commitments for change in economic sectors without mobilizing local stakeholders as driving forces for reforms

[70]. The national interministerial committee established in each country to operationalize reforms and programs is particularly important to achieve practical integration of needed actions in different economic sectors. However, GEF was designed to play a minor, catalytic role and new Partnerships are needed to sustain the momentum that has been created.

13. New partnerships for sustaining momentum

Now, at the beginning of this new century, a global common understanding is emerging in recognition of the accelerated degradation of the world's largest marine ecosystems and that the decline is not just a problem of developing nations but is also driven by over-consumption from developed nations. The $50 billion annual trade in fisheries makes those nations a stakeholder in LMEs of the South in addition to their own LMEs. Indeed, rich countries now acknowledge the need to adopt many reforms as well, not only for their degraded marine waters but also to provide a safety net to conserve marine waters of developing nations that are exploited for global commerce. The $15 billion in annual fishing subsidies represent a powerful driving force for depletion and reforms in those countries are just as essential as the reforms needed in developing nations. Many developed nations share LMEs with developing nations and the GEF has shown that they can work together for adopting an ecosystem-based approach for joint assessment and management purposes.

If the spiraling degradation of coastal and marine ecosystems is to be reversed so that these ecosystems continue to provide both livelihood benefits to coastal communities as well as foreign exchange for governments, drastic reforms are necessary. Competing global programs, competing interests of donors, competing priorities of international finance institutions also face an imperative to collaborate in harmony if the early momentum catalyzed through the GEF is to be sustained. Donor organization assistance and international agency support for the strategic, country-driven reforms being identified through LME projects need to be delivered in a coordinated and sequenced manner to build capacity of nascent institutions that must learn to implement difficult reforms. New geographic-based partnerships are necessary to ensure completion of the reform processes and the North is an essential member of those partnerships.

Perhaps most importantly, the GEF LME projects are demonstrating that holistic, ecosystem-based approaches to managing human activities in LMEs, their coasts, and their linked watersheds are critical, and provide a needed place-based area within which to focus on multiple benefits to be gained from multiple global instruments. Instead of establishing competing programs with inefficiencies and duplication, which is the norm now, the LME projects foster action on priority transboundary issues ACROSS instruments in an integrated manner—across UNCLOS, Chapter 17 of Agenda 21, the Jakarta Mandate of the CBD, the GPA and its pollution loading reductions, and in dealing with inevitable adaptation issues under UNFCCC. In fact, this ecosystem-based approach, centered around LMEs

and participative processes for countries to undertake for building political and stakeholder commitment and interministerial buy-in, can serve as the way ahead on reversing the degradation of marine ecosystems consistent with Chapter 17.

The adaptive management framework resulting from iterative application of the GEF Operational Strategy allows for sequential capacity building, technology introduction, and investments to an ecosystem-based group of nations by the world community so that this collective response to global conventions and other instruments can be achieved in a practical manner. However, if international finance institutions, bilateral donors, and agencies cannot work collaboratively in partnership with their client countries that have identified their needs for reforms and investments, continued fragmentation and duplication will serve as a barrier to reversing the accelerated depletion of coastal and marine ecosystems. The five modules, including the results of joint surveys across the LMEs for transparency of information, capacity building and technology transfer, ensure that management institutions are engaged with the science community in joint efforts developed in conjunction with stakeholders. In this way, ecological surprises of the future such as those generated by fluctuating climate may be able to be handled by the joint institutions and may have a chance to insulate the poor communities that are the first to suffer adverse effects of inadequate management efforts.

This growing number of country-driven commitments to change as fostered by the GEF and the global imperative to change because of the degraded condition of the global coastal oceans provides an unprecedented opportunity for accelerating the transition to the sustainable use, the conservation, and the development of coastal and marine ecosystems. The social, economic, and environmental costs of inaction are just much too high for multilateral and bilateral institutions and international agencies not to support the fledgling efforts of 126 countries trying to implement Chapter 17 of Agenda 21 by focusing on specific, shared LMEs. A new partnership on ecosystem-based approaches to assessment and joint management of LMEs and linked watersheds is urgently needed to restore biomass and diversity. This is needed to broaden and deepen reforms and investments triggered by initial GEF catalytic action LME by LME and to involve both developed and developing nations that have a stake in each particular LME and linked watershed. Momentum must not be lost. The result may be irreversible damage to coastal and marine ecosystems, the livelihoods and security of poor communities depending on them, and the economy of many coastal nations.

References

[1] Costanza R, d'Arge R, de Groots R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, van den Belt M. The value of the world's ecosystem services and natural capital. Nature 1997;387:253–60.

[2] The Food and Agriculture Organization. The state of the world fisheries, aquaculture. Rome: FAO, 2000. 142 pp.

[3] GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) and Advisory Committee on Protection

of the Sea. Protecting the oceans from land-based activities—land-based sources and activities affecting the quality and uses of marine, coastal, and associated freshwater environment. Rep. Stud. GESAMP, 2001. No. 71, 162 pp.

[4] Duda AM, Cruz MCJ. Partnerships to sustain international waters. Report in valuing the global environment: actions & investments for the 21st century. Washington DC: Global Environment Facility, 1998.

[5] Pauly D, Christensen V, Dalsgaard J, Froese R, Torres Jr. F. Fishing down marine food webs. Science, 1998;279:860–3.

[6] NRC (National Research Council). Sustaining marine fisheries. Washington, DC: National Academy Press, 1999.

[7] Jackson JBC, Kirby MX, Berger WH, Bjorndal KA, Botsford LW, Bourque BJ, Bradbury RH, Cooke R, Erlandson J, Estes JA, Hughes TP, Kidwell S, Lande CB, Lenihan HS, Pandolfi JM, Peterson CH, Steneck RS, Tegner MJ, Warner RR. Historical over fishing and the recent collapse of coastal ecosystems. Science 2001;293:629–38.

[8] Valdimarsson G, James D. World fisheries—utilization of catches. Ocean & Coastal Management 2001;44:619–33.

[9] Watson R, Pauly D. Systematic distortions in world fisheries catch trends. Nature 2001;414:534–6.

[10] Virdin J.Hardfacts, hidden problems: a review of current data on fishing subsidies. WWF technical paper, World Wildlife Fund, Gland, Switzerland, 2001. 27 pp.

[11] Kaczynski VM, Fluharty DL. European policies in West Africa: who benefits from fisheries agreements? Marine Policy 2002;26:75–93.

[12] UNEP (United Nations Environment Programme). Economic reforms, trade liberalization, and the environment: a synthesis of UNEP country projects. Division of Technology, Industry, and Economics, Geneva, Switzerland, 2001. 21 pp.

[13] UNDP (United Nations Development Program). Implementation of the Strategic Action Programme of the South Pacific Developing States. Project Document, UNDP/RAS/98/G32/A/1G/99, New York, 1999. 93 pp.

[14] Christensen NL, Bartuska AM, Brown JH, Carpenter S, D'Antonio C, Francis R, Franklin JF, MacMahon JA, Noss RF, Parsons DJ, Peterson CH, Turner MG, Woodmansee RG. Report of the Ecological Society of America committee on the scientific basis for ecosystem management. Ecological Applications 1996;6(3):665–91.

[15] Lubchenco J. The scientific basis of ecosystem management: framing the context, language, and goals. In: Zinn J, Corn ML, editors. Ecosystem management: status and potential. 103rd Congress, 2nd Session, Committee Print. US Government Printing Office, Superintendent of Documents. 1994. p. 33–39.

[16] Great Lakes Science Advisory Board. The Ecosystem Approach. Scope and implications of an ecosystem approach to transboundary problems in the Great Lakes Basin: special report to the International Joint Commission. Great Lakes Science Advisory Board, Washington DC, 1978. 42pp.

[17] Duda AM. Cross-media management of toxic pollutants in the Great Lakes Basin Ecosystem. In: McNeil RY, Windsor JE, editors. Innovations in river basin management. Cambridge, Ont: Canadian Water Resources Association, 1990. p. 321–33.

[18] Reid PC. North Sea ecosystem: status report. In: Kumpf H, Steidinger K, Sherman K, editors. The Gulf of Mexico Large marine ecosystem: assessment, sustainability, and management. Malden: Blackwell Science, Inc., 1999. p. 476–89.

[19] Sherman K, Jaworski NA, Smayda TJ, editors. The Northeast Shelf Ecosystem: assessment, sustainability, and management. Cambridge: Blackwell Science, Inc., 1996.

[20] Kumpf H, Steidinger K, Sherman K, editors. The Gulf of Mexico large marine ecosystem: assessment, sustainability, and management. Malden: Blackwell Science, Inc., 1999.

[21] ECOPS, ESF, European Commission DG XII, and Institute for Baltic Sea Research. Joint Baltic Sea ecosystem studies: a science plan for an interdisciplinary ecosystem analysis in the Baltic Sea. Report of 4 international Baltic Sea Workshops—18–19 March 1993, 4–10 November 1993, 6–8 June 1994, and 22–25 January 1995, HELCOM, Helsinki, 1995.

[22] Sherman K. Sustainability, biomass yields, and health of coastal ecosystems: an ecological perspective. Marine Ecology Progress Series 1994;112:277–301.
[23] IOC (Intergovernmental Oceanographic Commission). IOC-IUCN-NOAA Consultative Meeting on Large Marine Ecosystems (LMEs). Fourth Session, Paris, France, 8–9 January 2002, Paris, October 2002.
[24] GEF (Global Environment Facility). GEF Operational Strategy. Washington, DC: Global Environment Facility, 1995.
[25] United Nations General Assembly. Report on the work of the United Nations Open-ended Informal Consultative Process established by the General Assembly in its resolution 54/33 in order to facilitate the annual review by the Assembly of developments in ocean affairs at its second meeting. Report A/56/121, 22 June, New York, 2001. 62 pp.
[26] Black Sea Environment Programme. Strategic action plan (SAP) for the rehabilitation and protection of the Black Sea, Istanbul, 1996. 29 pp.
[27] Environmental Programme for the Danube River Basin. Strategic action plan (SAP) for the Danube River Basin, 1995–2005; Revision 1999, Vienna, 138 pp.
[28] Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden. Strategic Action Programme (SAP) for the Red Sea and Gulf of Aden, 1998. 89 pp.
[29] South Pacific Regional Environment Programme. Strategic Action Plan (SAP) for the South Pacific Island States, Apia, 1997. 92 pp.
[30] Sydnes AK. Establishing a regional fisheries management organization for the Western and Central Pacific tuna fisheries. Oceans and Coastal Management 2001;44:787–811.
[31] Mediterranean Action Plan. Strategic Action Programme (SAP) to address pollution from land-based activities, Athens, 1999. 164 pp.
[32] East Asian Seas Regional Coordinating Unit. Transboundary Diagnostic Analysis (TDA) for the South China Sea. EAS/RCU Technical report series no. 14. 2000. 107 pp.
[33] Chua T-E. Lessons learned from practicing integrated coastal management in Southeast Asia. Ambio 1998;27(8):599–610.
[34] Pauly D, Christensen V. Primary production required to sustain global fisheries. Nature 1995;374:255–7.
[35] Beddington JR. The primary requirements. Nature 1995;374:213–4.
[36] Epstein PR. Algal blooms and public health. World Resource Review 1993;5(2):190–206.
[37] Berman MS, Sherman K. A towed body sampler for monitoring marine ecosystems. Sea Technology 2001;42(9):48–52.
[38] Aiken J, Pollard R, Williams R, Griffiths G, Bellan I. Measurements of the upper ocean structure using towed profiling systems. In: Sherman K, Tang Q, editors. Large marine ecosystems of the Pacific Rim: assessment, sustainability, and management. Malden: Blackwell Science, Inc., 1999.
[39] KSherman, Okemwa EN, Ntiba MJ, editors. Large marine ecosystems of the Indian Ocean: assessment, sustainability, and management. Cambridge: Blackwell Science, Inc., 1998.
[40] NOAA (National Oceanic and Atmospheric Administration). Emerging theoretical basis for monitoring the changing states (Health) of large marine ecosystems. Summary report of two workshops: 23 April 1992, National Marine Fisheries Service, Narragansett, Rhode Island, and 11–12 July 1992, Cornell University, Ithaca, New York. NOAA technical memorandum NMFS-F/NEC-100, 1993.
[41] Costanza R. Toward an operational definition of ecosystem health. In: Costanza R, Norton BG, Haskell BD, editors. Ecosystem health: new goals for environmental management. Washington DC: Island Press, 1992. p. 239–56.
[42] Sherman B. Marine ecosystem health as an expression of morbidity, mortality, and disease events. Marine Pollution Bulletin 2000;41(1-6):232–54.
[43] Sutinen J. editor. 2000. A framework for monitoring and assessing socioeconomics and governance of large marine ecosystems. NOAA technical memorandum NMFS-NE-158, 2000. 32 pp.
[44] Juda L, Hennessey T. Governance profiles and the management of the uses of large marine ecosystems. Ocean Development and International Law 2001;32:41–67.

[45] Adam KS. Towards integrated coastal zone management in the Gulf of Guinea: a framework document. Les Editions du Flamboyant, Cotonou (Bénin), 1998. 85 pp.
[46] Ibe C, editor. Perspectives in integrated coastal areas management in the Gulf of Guinea. Center for Environment and Development in Africa (Ceda), Cotonou (Bénin). 91 pp.
[47] Ibe C, Zabi SG, editors. State of the coastal and marine environment of the Gulf of Guinea. Center for Environment and Development in Africa (CEDA), Cotonou (Bénin), 1998.
[48] Mondjanagni AC, Adam KS, Langley P. Côte d'Ivoire—Profil environnemental de la zone côtière. Centre pour l'environnement et le développement en Afrique (Ceda), Cotonou (Bénin), 1998. 87 pp.
[49] Mondjanagni AC, Adam KS, Langley P. Profil de la zone côtière du Bénin. Centre pour l'environnement et le développement en Afrique (Ceda), Cotonou (Bénin), 1998. 93 pp.
[50] CEDA (Center for Environment and Development in Africa). Coastal profile of Nigeria. Ceda, Cotonou (Bénin), 1997. 93 p.
[51] Ibe C, Oteng-Yeboah AA, Zabi SG, D Afolabi D, editors. Integrated environmental and living resources management in the Gulf of Guinea: the large marine ecosystem approach. Proceedings of the first Symposium on GEF's LME Project for the Gulf of Guinea. Abidjan, 26–30 January 1998, Institute for Scientific and Technological Information, CSIR, Accra, Ghana, 1998. 274 pp.
[52] Ibe C, Regional Coordinator. GOG LME Newsletter, No. 8, 10/97–3/98. Centre de Recherches Oceanologiques, Abidjan, Cote d'Ivoire. 1998. 28 pp.
[53] NEFSC. G. Atlantic Herring. Report of the 27th Northeast Regional Stock Assessment Workshop (27th SAW). Stock Assessment Review Committee (SARC) Consensus Summary of Assessments, Woods Hole Laboratory Reference Document No. 98–15. 1999.
[54] Sissenwine MP, Cohen EB. Resource productivity and fisheries management of the Northeast Shelf ecosystem. In: Sherman K, Alexander LM, Gold BD, editors. Food chains, yields, models, and management of large marine ecosystems. Boulder: Westview Press, Inc., 1991.
[55] NEFSC. In: Steve C, editor. Status of Fishery Resources off the Northeastern United States for 1999. NOAA Technical Memorandum NMFS-NE-115. 2000.
[56] NEFSC. D. Atlantic mackerel. Report of the 30th Northeast Regional Stock Assessment Workshop (30th SAW). Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. Woods Hole Laboratory Reference Document No. 00–03. 2000.
[57] Nixon SW, Oviatt CA, Frithsen J, Sullivan B. Nutrients and the productivity of estuarine and coastal marine ecosystems. Journal of the Limnology Society of South Africa 1986;12:43–71.
[58] Sherman K, Kane J, Murawski S, Overholtz W, Solow A. The US northeast shelf large marine ecosystem: zooplankton trends in fish biomass recovery. In: Large Marine Ecosystems of the North Atlantic: Changing States and Sustainability. Amsterdam: Elsevier Science 2002.p. 195–216.
[59] IOC (Intergovernmental Oceanographic Commission). IOC-IUCN-NOAA Consultative Meeting on Large Marine Ecosystems (LMEs). Third Session, Paris, France, 13–14 June 2000, IOC-IUCN-NOAA/LME-III/3. IOC Reports of Meetings of Experts and Equivalent Bodies, Series 162, 2000. 20 pp.
[60] Duda AM. Municipal point sources and agricultural nonpoint source contributions to coastal eutrophication. Water Resources Bulletin 1982;18(3):397–407.
[61] Helsinki Commission. Environment of the Baltic Sea Area 1994–1998. Baltic Sea Environment Proceedings No. 82A, Helsinki, 2001. 23 pp.
[62] Jaworski NA. Comparison of nutrient loadings and fluxes into the US Northeast Shelf LME with the Gulf of Mexico and other LMEs. In: Kumpf H, Steidinger K, Sherman K, editors. The Gulf of Mexico large marine ecosystem: assessment, sustainability, and management. Malden: Blackwell Science Inc., 1999.
[63] Howarth R, Anderson D, Cloern J, Elfring C, Hopkinson C, Lapointe B, Malone T, Marcus N, McGlathery K, Sharpley A, Walker D. Nutrient pollution of coastal rivers, bays, and seas. ESA Issues in Ecology 2000;7:1–15.
[64] Duda AM, El-Ashry MT. Addressing the global water and environmental crises through integrated approaches to the management of land, water, and ecological resources. Water International 2000;25:115–26.
[65] Rabalais NN, Turner RE, Wiseman Jr. WJ. Hypoxia in the Northern Gulf of Mexico: linkages with the mississippi river. In: Kumpf H, Steidinger K, Sherman K, editors. The Gulf of Mexico large

marine ecosystem: assessment, sustainability, and management. Malden, MA: Blackwell Science, Inc., 1999. p. 297–322.
[66] Duda AM, Finan DS. Influence of livestock on nonpoint source nutrient levels of streams. Transactions of American Society of Agricultural Engineers 1983;26(6):1710–6.
[67] NRC (National Research Council). Clean coastal waters: understanding and reducing the effects of nutrient pollution. Washington, DC: National Academy Press 2000.
[68] Seitzinger SP, Kroeze C. Global distribution of nitrous oxide production and N inputs to freshwater and coastal marine ecosystems. Global Biogeochemical Cycles 1998;12:93–113.
[69] Kroeze C, Seitzinger SP. Nitrogen inputs to rivers, estuaries and continental shelves and related nitrous oxide emissions in 1990 and 2050: a global model. Nutrient Cycling in Agroecosystems 1998;52:195–212.
[70] Sherman K, Duda AM. An ecosystem approach to global assessment and management of coastal waters. Marine Ecology Progress Series 1999;190:271–87.
[71] Watson R, Tyedmers P. Projected decline in per capita seafood availability. Fisheries Centre, University of British Columbia (www.data.fisheries.ubc.ca).