



Letter to the Editor

Suitability of the large marine ecosystem concept

In a recent Viewpoint, Longhurst (2003) questions the concept of Large Marine Ecosystems (LMEs) and its application in two recently published volumes on the North Atlantic and Gulf of Guinea (Sherman and Skjoldal, 2002; McGlade et al., 2002). His arguments are a mixture of criticism and opinion about marine research which do little to elucidate any genuine scientific concerns. It is our intention in this Letter to the Editor to correct the inaccuracies in Longhurst's article and demonstrate how the systematic application of the LME concept has fostered an adaptive approach to fisheries management and ecosystem protection issues, worldwide.

To counter Longhurst's scepticism, it is important to examine the context in which the concept of LMEs arose. At the 1992 UN Conference on the Environment and Development (UNCED) in Rio, the oceans declaration called for countries to prevent, reduce, and control degradation of the marine environment so as to maintain and improve its life-support and productive capabilities, develop and increase the potential of marine living resources to meet human nutritional needs, as well as social, economic and development goals, and promote the integrated management and sustainable development of coastal areas and the marine environment. To achieve these goals, it was recognised that a more systematic approach, linking the ecological, social and economic would be needed—one based on ecosystems rather than individual resources. The need and urgency for developing such an approach came from a growing awareness that the overexploitation of fish stocks was having a significant negative effect on the health of marine ecosystems around the world (Pauly et al., 1998, 2000). In addition, land-based chemical pollutants such as tributyltriethylene (TBT), polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls were degrading the quality of coastal waters

for a growing number of marine populations (McGlade, 2002; Ten Hallers-Tjabbes et al., 1994; Intermediate Ministerial Conferences, 1993/1997).

In the intervening 10 years, much progress has been made on the development of ecosystem-based approaches to marine resources, both in scientific and policy terms (e.g. Convention on Biological Diversity and the Jakarta Mandate, the Global Program of Action for Land-based Sources of Pollution, the UN Framework on Climate Change and the FAO Code of Conduct for Responsible Fishing Practices). By the time of the 2002 Johannesburg World Summit on Sustainable Development (WSSD), there was clear support for redefining the original UNCED declaration into an ecosystem-based policy framework. To assist in this move from a tradition of managing individual commodities and resources towards an ecosystem-based approach, the financial mechanism known as the Global Environment Facility (GEF) has invested \$ 3.2 billion in developing nations and those in economic transition. In 1998 the GEF Council adopted the LME framework as a way of implementing an ecosystem-based approach to the assessment and management of marine resources. So what is an LME?

LMEs are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margins of the major coastal currents. They are relatively large, in the order of 200,000 km² or greater, characterised by distinct (1) bathymetry, (2) hydrography, (3) productivity and (4) trophically dependent populations (Sherman, 1992). One of Longhurst's criticisms is that the LME boundaries are largely symbolic, being laterally bounded by coastal features, national boundaries or arbitrary seaward extensions and not by ecological discontinuities, yet as the criteria above indicate this statement is inaccurate and misdirected. His arguments appear to be driven by the fact that they differ in places from the divisions used in his own volume on biomes (Longhurst, 1998),

inferred largely by regional discontinuities in the physical processes in the Sverdrup model. But a close examination of both classifications shows that where such processes dominate, there is in fact a good match between the LME and Longhurst boundaries; however, where other factors are more important in determining ecosystem dynamics, the match is weak. For example, in the Gulf of Guinea, the northern edge of the ecosystem is dominated by a powerful upwelling system, so we see that the northern boundary of Longhurst's Guinea Current Coastal province coincides with that of the LME. But to the south, Longhurst simply gives the national boundary of Cameroon as he considers that the adjacent area has not been fully investigated; however, the southern LME boundary lies further down at Cape Lopez, a position derived from analyses of ecological components and physical forcing (Binet and Marchal, 1993; Tilot and King, 1993) and confirmed through the analysis of the physical forcing presented in the LME volume (Hardman-Mountford and McGlade, 2002). More important, however, is the fact that the processes and linkages defined within the geographic area of an LME are systematically analysed in the context of its coastal and ocean basin surroundings through its modular structure of case studies.

The LME framework integrates five modules made up of case studies on: (1) ecosystem productivity, (2) fish and fisheries, (3) pollution and ecosystem health, (4) socioeconomic conditions, and (5) governance. The modules provide indicators of the changing states of LMEs with regard to ecological condition, socioeconomic consequences and governance rules. The productivity module indicators are based on scientific data on photosynthetic activity, zooplankton biodiversity and oceanographic variability. The pollution and ecosystem health module indicators are based on scientific data on eutrophication, biotoxins, pathology, emerging disease and habitat conditions. The fish and fisheries module indicators depend on science-based assessments of biodiversity, finfish, shellfish, demersal species and pelagic species. The theory, measurement and modelling relevant to monitoring the changing states of LMEs are embedded in reports on ecosystems with changing states, pattern formations, and spatial diffusion (Mangel, 1991; Levin, 1993). The socioeconomic module indicators evaluate integrated science-based assessments from

the three modules with human forcing, and the sustainability of long-term socioeconomic benefits. The governance module indicators include stakeholder participation and adaptive management practices undertaken in the full knowledge of the up-to-date scientific assessments of the first three modules, and with awareness of the complex issues revealed in the socioeconomic indices. Longhurst takes the stand that without primary science, by which he means biochemico-physical analysis, the secondary matters of governance are based in sand; but experience from LME programmes and other activities associated with the recovery of natural resources has shown that the pedigree of ecological/chemical/physical knowledge in many ecosystems is very often much less than that of the social, political and economic domains. In the context of food security, sustainability and ecosystem health, the LME modules allow all aspects to be properly weighed up.

Longhurst also regards LMEs solely as a reflection of a new sensitivity to environmental issues; they simply build on collaborations between pre-existing organisations and it is these institutions that must remain the backbone of fisheries control. Only through the narrow, focussed studies of institutions can any penetration of the problems of marine resources be achieved. He thus questions whether a symbolic programme which "pretends to embrace comprehensively everything from socio-economics to oceanography" can make any real progress. What Longhurst fails to recognise is the fact that countries throughout the world are attempting to effect significant social, political and economic change in their management of marine resources, in order to address the problems of overexploitation and pollution—issues which decades of focussed research on fisheries and biological oceanography have been unable to deal with effectively.

National officials have not been helped in this process by the fact that many of the existing international agreements have fallen short of helping them prevent the decline in the status of their marine ecosystems. This is because the agreements, and their associated research programmes, are aligned to specific narrowly focussed sectoral themes such as pollution, fisheries, biodiversity or global climate change, rather than cross-sectoral strategic analyses of international and local issues. By contrast, LMEs, through their

geographic area, coastal surrounding and contributing basins constitute a place-based area to assist countries to build the human capacity needed to understand the linkages among the root causes of degradation, integrate changes needed in sectoral economic activities and thereby put the results of scientific case studies to pragmatic use in improving the management of coastal and marine ecosystems. Thus Longhurst misses the point when he says the meagre resources of the region should not be wasted in programmes that combine primary science and governance; it is the very fact that they are being combined that is beginning to create a clearer understanding of the interplay between human and biophysical dynamics.

The GEF, its UN partner agencies and other organisations including IUCN, IOC of UNESCO and NOAA, are recommending that nations sharing an LME first begin by addressing coastal and marine issues by undertaking jointly strategic processes to analyse factual, scientific information on transboundary issues, their root causes, and to set priorities for action. This process is referred to as a transboundary diagnostic analysis (TDA) and it provides a powerful mechanism to foster participation at all levels. Each country can then determine the national and regional policy, legal, and institutional reforms and investments needed to address its own priorities in a country-driven Strategic Action Program (SAP). This enables sound science to become the basis for policy-making and fosters a geographic location upon which an ecosystem-based approach can be developed, and more importantly, can be used to engage stakeholders within the whole geographic area and gain their support for its implementation. Experience in developed countries has shown that it has been the lack of such participative processes which has meant that marine science has often remained confined to the marine science community and not been embraced by policy-makers and industry. Furthermore, the science-based approach encourages transparency through joint monitoring and assessment processes (i.e. joint assessment surveys for countries sharing an LME) that builds trust among nations over time and can overcome the barrier of false information being reported. This runs counter to Longhurst's argument that national programmes are the sole locus of information and expertise. Whilst this may have been the case in the colonial period, as suggested by

Longhurst with reference to work along the Guinea Coast (Longhurst, 1998), there has been a significant trend in the past decade towards the integration of national programmes into regional programmes. Since the early 1990s, researchers and country officials in Africa, Asia and the Pacific, Latin America and the Caribbean, Eastern Europe, and North America have been experimenting with the ideas brought out through the LME concept to seek ways to reverse the decline of their marine ecosystems, test 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.

By combining financial and human resources, many developing and transitional countries have been successful in securing political backing beyond their own state boundaries and hence longer term stability for their research. This has been achieved in part because all the approved GEF-LME projects include scientific and technical assistance from more economically advanced OECD member countries, in recognition of the fact that the state of living resources, pollution loadings and habitat degradation have transboundary implications across rich and poor nations. As of December 2001, \$ 500 million in total project costs has been invested in 10 LME projects in 72 countries, of which \$ 225 million has come from GEF grants. An additional seven LME projects are being prepared involving 54 different nations, giving a total of 126 countries that are involved in these GEF-LME projects (Duda and Sherman, 2002).

Contrary to Longhurst's suggestion that the LME approach is limited to symbolism, genuine reforms are taking place both within LME projects in developing countries and in OECD nations to improve the prospects for the recovery and sustainability of marine resources. Thus it is inaccurate when he states that if insufficiently active science agencies are in place, political agreements are just words and will not be implemented; it was the political and scientific commitment engendered in discussions between under-resourced institutions in the Gulf of Guinea that led ultimately to the Accra Declaration (Ibe and Sherman, 2002) and the additional funding from the European Union and Global Environment Fund to enable scientists in the region to work on the wide variety of issues concerning the future sustainabil-

ity of resources across the LME. But perhaps of more importance for the scientists and individuals concerned, the LME programme has led to a strong network of scientists, their wider recognition through the publication of their work in mainstream widely accessible books and scientific papers, significant investment in further education and training, the recovery of historical datasets and the extension of a number of critical surveys that were in danger of being discontinued. Over the past 15 years the LME programmes have made use of and contributed to a number of global databases including FishBase (Froese and Pauly, 2003; FishBase World Wide Web electronic publication: <http://www.fishbase.org>, version 15 April 2003); ReefBase (Oliver and Noordeloos, 2002; ReefBase: A Global Information System on Coral Reefs. World Wide Web electronic publication: <http://www.reefbase.org>, 16 April 2003); Continuous Plankton Recorder Surveys (Sir Alister Hardy Foundation for Ocean Science: <http://www.sahfos.org>); the Sea Around Us Project (<http://www.saup.fisheries.ubc.ca>) and extensive satellite images from the National Oceanographic and Atmospheric Administration (<http://www.noaa>) and the European Commission Joint Research Centre (<http://www.jrc.org>).

Since its inception, scientists and other specialists from OECD and developing countries have been invited to examine the changing states of LMEs to evaluate the effects of perturbation and remediation efforts for improving the sustainability of LMEs (Knauss, 1996). One of these reviews was organised by the Institute of Marine Science of Norway, ICES, IUCN and NOAA for the LMEs of the North Atlantic with a focus on the principal driving forces for the observed decline in fishing yields across the North Atlantic (Sherman and Skjoldal, 2002). For the LMEs of the Western North Atlantic, climate variability proved to be an important consideration in the multidecadal time series declines of cod and other demersal species of the North Scotian Shelf and the Labrador-Newfoundland Shelf LMEs. In the case of the Scotian Shelf, both overfishing and cooling of the waters were attributed as causes for the declining trends in fish biomass (Zwanenburg et al., 2002). For the Labrador-Newfoundland Shelf, the consequences of the combination of overfishing and cooling events resulted in the collapse of the historic cod fishery. In the absence of recovery, the

stewardship agencies responsible for management of the fishery resources face a daunting problem. The cooler climate, and reduction of cod predation on crab and shrimp populations has fostered biomass increases and a growing fishery for these species, whose annual landed value now exceeds the average annual landed value of cod. The challenge now is how best to achieve a balance between cod recovery plans and maintenance of a lucrative shrimp and crab fisheries (Rice, 2002).

In contrast, the US Northeast Shelf LME is showing evidence of significant recovery. The principal driving force in biomass yield for this LME is overfishing with environmental influences playing a relatively minor role in shaping the multidecadal fish and fishery trends. With the imposition of reduced fishing effort through the exclusion of foreign fisheries and the robust condition of primary productivity 350 g C/m^2 per year and zooplankton biomass and biodiversity, the zooplankton spawning stock biomass (SSB) of herring and mackerel stocks are at an unprecedented high level of 5.5 mmt. Since the 1994 management imposed reductions in fishing effort, both SSB and recruitment success have been increasing for the haddock and yellowtail flounder populations (Sherman et al., 1998, 2002). For the Iceland Shelf LME, the interaction of temporal shifts between dominant relatively warm Atlantic water masses and cooler Polar water masses and linked calibrated fishing effort levels, are reflected in cod growth rate and total biomass estimates of cod with higher values correlated to dominance of Atlantic water masses (Astthorsson and Viljálmsson, 2002). East of Iceland, the ecosystem approach to fisheries management is important in adjusting fishing effort to changing oceanographic regimes over the Faroes Plateau (Gaard et al., 2002). On the eastern side of the Atlantic, efforts are underway by Norway to adjust fishing effort to indices of changing ecological conditions in the Barents Sea (Dalpadado et al., 2002). For the North Sea, a significant regime shift has been reported for coastal ocean conditions (Reid and Beaugrand, 2002), but up to now, changing ecological conditions have not been introduced to the fish stock assessment process, although environmental and fisheries ministries are taking the option under consideration.

For the Gulf of Guinea ecosystem, Longhurst's view is that few of the papers covered the whole region and

that nothing new on the demersal and pelagic fish and macrofaunal benthic communities was presented in the LME volume since the work undertaken 40 years ago or reported in the French publications of ORSTOM (Cury and Roy, 1991; le Loeuff et al., 1993). The volume included not only analyses of new data on different populations from all trophic levels (e.g. from the Continuous Plankton Recorder (John et al., 2002)) and molecular markers in fish and invertebrate species (Lovell and McGlade, 2002) but also extensive numerical analyses of pre-existing and reconstructed historical time series (Koranteng, 2002; Joanny and Ménard, 2002; Ménard et al., 2002; Cury and Roy, 2002; le Loeuff and Zabi, 2002). Overall, these analyses confirmed that the generic groupings of species and their distributions had not significantly altered over time but that major multidecadal shifts in the abundance of fish stocks in the ecosystem had been observed in certain areas along the continental shelf, caused principally by environmental perturbations affecting the annual upwelling cycle and temperature regime of the ecosystem. Despite these major shifts, the ecosystem had returned to an earlier state, a result of great interest to those trying to understand and build policies based on the long-term dynamics of continental shelf resources in the region.

The work on coastal lagoons has shown that human activities leading to eutrophication and pollution have had a large negative effect on these restricted exchange environments. In the very shallow Sakumo lagoon, this impacts on the tight competitive interactions between the dominant detritus-feeding tilapia and the clupeid *Ethmalosa dorsalis*, which has a high dietary overlap with the tilapia (Pauly, 2002). Longhurst queries this result, not recognising that the *Ethmalosa* in Sakumo Lagoon is very different from the one which he had studied, which lived and fed in open waters. More broadly, coastal pollution is on the increase throughout the Gulf of Guinea; but under the aegis of the LME programme national integrated coastal area management plans that incorporate measures for cost effective pollution prevention and control are now being implemented (Scheren and Ibe, 2002).

Another criticism of the Gulf of Guinea LME volume is that only five chapters discuss the whole system and that the editing was sloppy. The editors will have to accept the latter criticism, but the reproduction of images in their original form on page 133 was

seen as a positive rather than negative aspect—there is also no text missing—and the indexing was seen to benefit from completeness. Of the 26 chapters, 4 are concerned with generic principles and a description of the programmes undertaken, 8 relate to the spatial and temporal variability in physical and chemical attributes, productivity, ecosystem health and governance of the whole LME whilst the remainder present detailed analyses of trends in the status of resources of Ghana and Ivory Coast, where fisheries are major industrial and artisanal activities, and analyses of the markets, utilisation and development research. The main aim of these papers was to test particular methodologies and hypotheses concerning fluctuations in marine and coastal resources, identify key trends related to more global and regional drivers and suggest future strategic options for the region.

Longhurst states that the region is under-endowed in marine science and what exists many not be very stable; the contents of the LME volume which represent the first stage in implementing an ecosystem-based approach to the management of the whole region suggest that this is not the case. Some of the key activities of the participating six countries in the Gulf of Guinea GEF/LME project (Benin, Cameroon, Ghana, Ivory Coast, Nigeria, Togo) documented in the volume include the joint identification of major transboundary environmental and living resources management issues and problems, 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, and 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. Surveys of the plankton community to address the carrying capacity of the Gulf of Guinea for supporting sustainable fisheries were also conducted at 6-week intervals using plankton recorder systems deployed from large container vessels transiting the region, and the samples processed in a Plankton Center established in Ghana in collaboration with the Sir Alister Hardy Foundation of the UK. These data are now part of a global inventory that is helping to document temporal changes in global and regional plankton abundance and hence health of the oceans.

At the beginning of this new century, a global common understanding is emerging in recognition of the accelerated degradation of coastal and, further, 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 stakeholders 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 spiralling degradation of coastal and marine ecosystems is to be reversed so that these ecosystems can sustain livelihood benefits to coastal communities as well as foreign exchange for governments, drastic reforms are necessary. The GEF-LME projects are demonstrating that ecosystem-based approaches to managing human activities in coastal areas 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 currently the norm, the LME projects foster action on priority transboundary issues in an integrated manner across policy instruments such as the United Nations Convention on the Law of the Sea (UNCLOS), Chapter 17 of Agenda 21, the Jakarta Mandate of the Convention on Biodiversity (CBD), the Global Program of Action (GPA) and its pollution loading reductions, and in dealing with inevitable adaptation issues under the UN Framework Convention on Climate Change (UNFCCC). The ecosystem-based approach, centred around LMEs and participative processes for countries to undertake for building political and stakeholder commitment and inter-ministerial support, can serve as the way ahead for the recovery and sustainability of marine ecosystems consistent with Chapter 17 of the UNCLOS.

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