ACCOUNTING FOR MARINE ECONOMIC ACTIVITIES IN LARGE MARINE ECOSYSTEMS

Porter Hoagland and Di Jin

Marine Policy Center
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

Abstract

We develop an index that is a measure of the intensity of marine activities in large marine ecosystems (LMEs). We compare this marine activity index with an index of socioeconomic development across ocean regions. This comparison identifies regions that may be capable of achieving the sustainable development of their regional marine environment on their own and those that are less likely to do so. The latter may be candidates for international financial or management assistance. An important next step is to carry out detailed case studies designed to improve our understanding of any specific ocean region.

Keywords: economics; indexes; large marine ecosystems; marine activity; sustainable management

1. Introduction

Sixty-four large marine ecosystems (LMEs) have been identified around the world's coastal margins. The large ecological zones of these LMEs are economically important, producing 95 percent of the world's marine fisheries biomass, among other goods and services valued at many trillions of dollars each year. Counterbalancing these economic benefits is the fact that pollution is more severe in LMEs than in other ocean areas, and some LME coastal habitats are among the most seriously degraded on earth. It is in the world's interest to ensure that those marine resources and habitats at risk are protected and managed sustainably for both present and future generations.

A pragmatic approach to the sustainable management of LMEs now is being implemented by nations in Africa, Asia, Latin America, and Eastern Europe, supported by $650 million in start-up funds from the Global Environment Facility (GEF) and other international donors. This approach uses suites of environmental indicators to assess the physical, biological, and human forcings on ecosystem productivity, fish and fisheries, pollution and ecosystem health, economic development, and governance.

Over the past several years, a rapidly growing literature on large marine ecosystems (LMEs) has emerged, focused mostly on issues of biological conservation; the sources, transport, and fate of pollutants; and regional governance (Duda and Sherman 2002; Sherman *et al*. 1996). Increasingly, the results of scientific research have revealed the degradation of ocean regions, including coastal pollution, the over-exploitation of fisheries, invasions of exotic species, and blooms of harmful algae, among other effects. The hope is that increased attention to these problems will motivate the nations of the relevant regions to manage their marine environments more sustainably.

In sharp contrast to these scientific studies, analysis of the socioeconomic characteristics of large ocean regions has received relatively little attention to date.[1] Although a general framework for monitoring and assessing the socioeconomic aspects of LMEs has been developed (*viz*., Olsen *et al.* 2006; Wang 2004; Sutinen 2000), few detailed studies grounded in empirical data have been undertaken. Characterizing the socioeconomic features of ocean regions is critical to developing an understanding of the extent to which nations have the financial resources to undertake programs of sustainable development.

In this study, we take an initial step toward the development of a global overview of the socioeconomic aspects of LMEs. We focus our attention on the development of measures of the intensity of human activities in the marine environment that may be useful in identifying regions that may need international assistance to initiate and carry out programs of sustainable management. Although other types of economic measures may be preferable to our measure of the intensity of marine activities, their practical use is severely constrained by data limitations.

We focus on the following two broad questions regarding the sustainable management of the marine environments of an LME:

1. Can the level of marine activity in an LME be considered sustainable?
2. Are the nations participating in the relevant LME capable of financing programs of sustainable management themselves?

In order to begin to address the first question, we develop a measure of marine industry activities for each LME. Given the nature of the data on economic activity that

[1] One example is a calculation of the direct, indirect, and induced economic impacts of the marine sector in the Northeast Shelf LME (Hoagland *et al*. 2005).

is available on a consistent basis across nations, our preferred measures of marine activities are sets of indexes. We expect that, *ceteris paribus*, higher levels of industrial activity exert greater pressure on the ecosystem, say, through pollution or resource depletion, and *vice versa*.

For a given activity level, however, the scale of negative ecological impacts may not be the same across different stages of economic development, as measured by income levels or some other metric. For example, the environmental Kuznets hypothesis suggests that there exists an inverted U-shape relationship in an economy between pollution intensity and income per capita. At low levels of income, economic development would lead to increasing levels of pollution emissions. As economic growth leads to income levels that exceed a threshold, however, a society's demand for environmental quality increases, and its pollution emissions decline (Tisdell 2001; Grossman and Krueger 1995).

In order to begin to address the second question, we examine the relationship between a measure of socioeconomic development, namely UNDP's human development index (HDI), and marine activity. The HDI measure is useful in helping to answer the second question, because we expect that, *ceteris paribus*, developed nations that exhibit higher levels of income are more likely to be capable of financing programs of sustainable LME management themselves.

We develop a ranking of LMEs by various measures of marine activity and by socioeconomic development. This ranking process should prove useful for responsible international organizations and donors in developing funding and assistance priorities based upon the revealed characteristics of LMEs. Indeed, our purpose is to provide a decision-making tool for international financial and natural resource management institutions to use in setting priorities for allocating financial resources toward the sustainable management of Large Marine Ecosystems (LMEs), given limited financial and management resources.

The tool should be used in conjunction with additional information, such as data and expertise on environmental conditions and ecological status. Knowledge of the national and international legal institutions and the political context of each region is obviously important as well.

The index approach is based on actual industrial and recreational activities occurring at the national level in coastal nations. We compile publicly available worldwide data on marine activities occurring in those coastal nations comprising large marine ecosystems (LMEs). Data on marine activities include fish landings, aquaculture production, shipbuilding orders, cargo traffic, merchant fleet size, oil production, oil rig counts, and tourism arrivals.

The framework developed in our study serves as a first step toward more detailed analyses of socio-economic issues associated with LMEs. Thus, the index approach is a useful first cut at prioritizing regions that deserve closer attention as candidates for international financial assistance to promote sustainable marine environmental management. An important next step is to carry out detailed case studies designed to improve our understanding of any specific ocean region, including its environmental circumstances, its ecological conditions, its economic value, and the political feasibility of organizing a collaboration among nations participating in the region to share the costs of sustainable management.

The remainder of this paper is organized as follows. Section 2 describes the marine industry and the economic data used in our study. Section 3 presents a review of relevant methods for assessing the economic significance of marine industries in different coastal regions and a specific method for constructing marine industry activity indexes for LMEs. Results of the index approach are discussed in Section 4. Section 5 presents the summary and conclusions.

2. The Marine Activity Database

We present first the results of our efforts to compile data on marine activities in the coastal nations comprising large marine ecosystems (LMEs). In general, LMEs have been defined heretofore primarily in terms of their ecological characteristics (see the map of 64 LMEs in Fig. 1).

<Insert Fig. 1 here>

Data on marine and relevant non-marine activities include fish landings (metric tons), aquaculture production (metric tons), shipbuilding orders (gross tons), cargo traffic (metric tons), merchant fleet size (deadweight tons), oil production (average barrels per day), oil rig counts (numbers of facilities), and tourism (international arrivals). The published sources, units, and vintage of the data on marine activities are presented in Table 1. The data are from the most recent years available (*i.e.*, between 2002 and 2004). Most data are measures of quantities, with the exception of the dimensionless Human Development Index (HDI).

<Insert Table 1 here>

The national data for each industry sector (e.g., commercial fishing) can be used to compare levels for *each individual* marine activity across the coastal nations of the world. This kind of comparison is valuable for analyzing relative levels of economic development by industrial sector in coastal nations and, if collected over time, can help in understanding changes in relative sectoral economic development for these nations. Without additional analysis or information, however, these data cannot be easily used to compare across the coastal nations of the world the *combination* of marine activities occurring in each nation.

3. Methodology

3.1. Total economic value (TEV) as a single metric

One method of creating a single metric that combines all marine activities is to express the levels of each activity in units of a common monetary measure, such as US dollars. In theory, the ideal monetary metric would be "total economic value" (TEV). To calculate a single metric based upon TEV, one would estimate the *net* benefits in dollars that obtain from each of a nation's marine activities and sum these benefits across all activities. Net benefits are the sum of consumer surpluses (what consumers are willing to pay over and above the market price for a good or service) and producer surpluses (what firms earn from the sale of goods and services over and above their costs of production). Net benefits from non-market activities, such as environmental services, would need to be estimated using one of several methods of environmental valuation, and these benefits should be added to the TEV metric as well. The cost of implementing government policies to help manage the marine environment should be subtracted from TEV.

As a single metric, TEV could be compared across all coastal nations.[2] Such a comparison would increase our understanding of the economic capacity of the nations participating in LMEs to conserve and manage their marine ecosystems in a sustainable fashion. Unfortunately, a readily available compilation of TEVs for marine activities in coastal nations does not exist. TEVs would need to be calculated on activity- and location-specific bases, and there are few studies that do so.

In some cases, estimates of the producer surplus component of TEV can be compiled. In particular, resource rents, or those producer surpluses attributable to the exploitation of marine resources may be estimated. If captured by governments, resource rents provide a potential basis for financing the sustainable management of the marine environment. In Table 2, we present the results of an effort to estimate economic rents for the Benguela Current LME (Hoagland and Jin 2006). In particular, we estimate the scale of "resource rents" for the offshore oil, marine capture fisheries, and marine diamond dredging activities in the region. In the context of sustainable management of the marine environment, we note that resource rents could be a relevant source of financing. We note further, however, that the use of rents for such a purpose is a political decision that must be agreed upon at both regional (*i.e.*, international) and domestic levels.

<Insert Table 2 here>

[2] The most important use of total economic value for each coastal nation or for regional aggregations of nations would be to understand how it grows or shrinks with changes in both the mix of marine activities and the implementation of government policies. In principle, the combination of activities and policies can be adjusted so as to maximize total economic value.

3.2. Direct output impacts (DOIs) as a single metric

Another single metric that can be constructed using a monetary measure is called the "direct output impact" (DOI). DOIs are the product of the physical quantities of goods or services flowing from marine activities (*e.g.*, fish landings, oil production, etc.) and their market prices.[3] As in the case of calculating TEV, one estimates a DOI for each activity, and these impacts are summed to create a single metric. DOI measures the gross revenues (or sales) that obtain from a nation's marine activities. As the product of price times quantity, DOI represents the sum of benefits to producers (producer surplus) and the costs of production. Because it includes costs and excludes benefits to consumers, DOI is not an accurate measure of economic value. DOI can be conceptualized as an upper bound on producer surplus, which again is only one component of TEV. This metric is less difficult to construct than TEV, but it does not account for the cost of inputs in production, including the degradation of the environment, or the depreciation of capital assets or the depletion of natural resource stocks.[4]

Despite the fact that a DOI metric can be readily calculated for some activities (*e.g.*, offshore oil and natural gas production), it can be more problematic to calculate for others (*e.g.*, tourism visits). As in the case of the resource rent approach, a DOI metric would need to be calculated on an activity- and location-specific basis. In Table 3, we

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[3] If the marine activities are "final" goods and services (*i.e.*, they are consumed and not used to produce another good or service in an economy), then the direct output impact measure would be equivalent to the marine component of gross national product (GNP).

[4] Much recent effort has been directed at "greening" the national accounts, which would involve accounting for changes (depletion) in natural resource stocks, such as offshore oil, capture fisheries, or marine minerals (see Lange 2003). Green accounting involves the use of the net national product (NNP), which is defined as gross national product (GNP) less the depreciation of capital assets. According to this approach, the depletion of natural resources through changes in resource stocks are viewed as the analog to the depreciation of capital assets. Changes in green NNP over time can then be interpreted as measures of welfare change.

present an estimate of direct output impacts in the case of the Chinese coastal provinces in the Yellow Sea LME (Hoagland and Jin 2006).

<Insert Table 3 here>

As in the case of TEV, there is no readily available compilation of DOIs for all marine activities across all coastal nations, and the calculation of such values has occurred only on a location- and activity-specific basis to date. Some estimates of DOI can be calculated (using a world oil price times oil production, for example) and others have been compiled on an *ad hoc* basis (FAO has calculated for most nations the ex-vessel value of landed capture fisheries and the farmgate value of some aquaculture industries).

3.3. Marine activity indexes (MAIs) as a single metric

A third approach to the problem of constructing a single metric does not involve the use of a monetary measure. Instead, indexes, ranging from zero to one, are created for each marine activity by ranking each nation's activity level relative to all others on a worldwide basis. These indexes can be combined in a variety of ways into one or more aggregate indexes by assigning weights to each individual index and then summing across weighted index values. (We describe one way of accomplishing this weighting process below.) The indexes are dimensionless, but they convey information about the relative activity level (or the "intensity" of activity) for nations in the marine environment. We develop the index approach in this report because of data limitations that affect the estimation of both the TEV and DOI measures.

3.4. The problem of regional aggregation

Once a single metric has been developed for each coastal nation, a procedure needs to be established for aggregating individual national metrics to a regional level.[5] There are five possible scenarios to consider: an LME comprises (i) the entire exclusive economic zone (EEZ)[6] of only one coastal nation (*e.g.*, the Iceland Shelf); (ii) a portion of the EEZ of only one coastal nation (*e.g.*, the Northeast Shelf); (iii) the entire EEZs of two or more coastal nations (*e.g.*, the Humboldt Current); (iv) the entire EEZ of one or more coastal nations and portions of the EEZs of one or more other coastal nations (*e.g.*, the Benguela Current); and (v) portions of the EEZs of multiple coastal nations (*e.g.*, the Yellow Sea). For each coastal nation, we need a method for attributing national-level data on its marine activities to the one or more LMEs in which it participates. This issue does not present itself for scenarios (i) or (iii), because we can readily use the national-level data in both cases to develop aggregate indexes.

Scenarios (ii), (iv), and (v) involve situations in which only a portion of a nation participates in a LME project. In these situations, we need to find a way in which to attribute only a portion of a nation's marine activities to the LME.[7] One approach would

[5] This issue applies to the marine activity indexes as well as to other single metrics that might be utilized, including the TEV and DOI metrics.

[6] We assume here that the geographic coverage of an LME is limited to EEZs, although that is not precisely true in practice.

[7] Ideally, we would like to have subnational-level data on marine activities for each coastal nation. With such data, we could create a single metric for each region.

be to calculate the length of a nation's coastline within a LME relative to that nation's total coastline.[8] That ratio could be used to weight national marine activity.

We encounter two problems with this approach. First, although data exist on total coastlines for all coastal nations, there are no data that measure the coastline length of each nation for each LME.[9] Second, even if such data exist, without a detailed case study of the geographic distribution of marine activities for each nation, we might assign part of a nation's marine activities to an LME, even though those activities might not take place in that region (*e.g.*, the assignment of US offshore oil and natural gas exploration and production to the Northeast Shelf, where no such activity occurs).

Given the data constraints, we design a method for weighting the marine activity for each individual nation that participates in a LME relative to the other participating nations in the same LME. We calculate the share of the total LME coastline for each nation participating in a LME program, and we use that share to weight that nation's marine activity levels as its contribution to the marine activity of the whole LME. We emphasize that this procedure does not resolve the issue of attributing all of a nation's marine activities to a LME when only a portion of that nation has been assigned to the LME. Resolution of that issue is an area for future research.

3.5. Calculation of the Marine Activity Index (MAI)

Our methodology involves four basic steps: (i) compiling nation-level data for a set of indicator variables; (ii) converting all indicator variables into indexes; and (iii)

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[8] Other measures of national contribution could be used, such as the area of a nation's total EEZ or its outer continental shelf that lies within an LME.

[9] Data exist in ARCVIEW format that permits the calculation of the *shares,* but not the *length*, of each nation's coastline within any LME.

constructing weighted average indexes for each LME. We focus on two important descriptors for each LME and each RSP: a measure of marine industry activities and a measure of socioeconomic development.

We construct marine activity indexes by ranking nations within each activity category. For example, all nations would be ranked in terms of average barrels per day of oil production from the highest to the lowest. Then each nation would be assigned a number that represents its scale of oil production from the highest to the lowest value. The values for each index for each activity are standardized to lie between zero and one. Specifically, for any marine industry activity indicator variable j occurring in nation i, its measure (x_{ij}) is converted into an index (I_{ij}) as follows:

$$I_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \tag{1}$$

One can then combine indexes for different marine industry activities in various ways.[10] We construct a combined marine industry activity index for each nation in two steps. First, a weighted average index AI_i is calculated across n related activities for nation i:

$$AI_i = \sum_{j=1}^{n} w_j I_{ij} \tag{2}$$

where the w_j are weights (please see the last column in Table 4) assigned by the analyst or decision maker across related marine activities, which are grouped into "industry sectors" (*e.g.*, fisheries landings and aquaculture production), and $\Sigma w_j = 1$.

[10] One way to make such a combination is to assign equal weights to each activity index by averaging across indexes. In principle, unequal weights could be assigned to activity indexes.

In our study, as an example, we have grouped related activities into five marine industry sectors: marine fisheries and aquaculture, tourism, shipbuilding, shipping, and offshore oil. In the case of the first industry sector, we consider fisheries and aquaculture equally important, and we assign weights of 0.50 to each. The next two sectors, tourism and shipbuilding, have one indicator each, so there is no need to assign weights. In the case of the fourth sector (*i.e.*, shipping), we consider cargo traffic more important than the size of fleet, and we assign weights of 0.67 and 0.33, respectively. In a similar vein, we consider offshore oil production more important than drilling (*i.e.*, rig counts), and we assign weights of 0.67 and 0.33, respectively, in the last sector.

Next, a weighted average across all m industry sectors is computed:

$$TAI_i = \sum_{k=1}^{m} v_k (AI_i) \quad (3)$$

where TAI_i is the total marine industry activity index for nation i, and v_k is the weight assigned by the analyst or decision maker for marine industry sector k (please see the second column in Table 4). In our example, we assign equal weights of 0.20 to each of the five industry sectors (Table 4).

<Insert Table 4 here>

For any particular nation i, TAI_i will be large if most of its marine industry indicators are ranked relatively high in comparison with the rest of the world. Importantly, a nation with only a few highly ranked industry sectors could have a total activity index close in value to a nation with all of its industry sectors ranked in the medium category. Thus, the total marine industry activity index (TAI_i) can be interpreted as the overall "intensity" of nation i's marine activities.

We use the Human Development Index (*HDI*) for each nation reported in the United Nations Development Program's *Human Development Report* (UNDP 2004). *HDI* is a measure of a nation's socioeconomic development. It is based upon three key indicators: life expectancy (at birth); education (*i.e.*, adult literacy rate and combined gross enrollment ratio for primary, secondary, and tertiary schools); and GDP per capita (purchasing power parity in US dollars).[11]

The national-level *TAI* and *HDI* can be used to construct relevant indexes for the LMEs, which often are combinations of nations (or parts of nations). As described above, due to data constraints, the national *TAI* value must be used even in cases in which only a portion of a nation's coastline occurs in an LME.

For each LME, we compute both the marine industry activity index (*MAI*) and the socioeconomic index (*SEI*) as:

$$MAI_{LME} = \sum_{i=1}^{s} l_i TAI_i \tag{4}$$

$$SEI_{LME} = \sum_{i=1}^{s} l_i HDI_i \tag{5}$$

where i is the index for a nation bordering the LME, and l_i is the percentage share of nation i's coastline length relative to the total coastline length of all s nations bordering the LME.[12]

[11] For a detailed description of HDI and its calculation, see UNDP (2004), p.259.

[12] LME-level marine activity indexes (*MAI*) can also be calculated using only the activity indexes (*AI*) for each industry sector in lieu of the total activity index (*TAI*). We present calculations for three such industry sectors in Table 5.

4. Results of the Index Approach

We calculate the marine industry activity index (*MAI*) and the socioeconomic index (*SEI*) for each LME using Equations (4) and (5).[13] The results are summarized in Table 5. Also included in Table 5 are calculations of marine activity indexes based upon industry sectors: (i) the fishery and aquaculture index and (ii) the tourism index, both of which depend upon a relatively clean marine environment, and (iii) the shipping, shipbuilding, and oil production index, which includes three industry sectors that do not necessarily depend upon a clean environment and which, in some cases, may in fact be the cause of environmental degradation.

<Insert Table 5 here>

One can compare LMEs based upon these different indexes. The data in Table 5 are sorted by the socioeconomic index, which can be used as an indicator of the potential for LMEs to undertake self-financing management programs. The Somali Coastal Current (#31), Agulhas Current (#30), Guinea Current (#28), and Benguela Current (#29) are among the LME regions with lowest *SEI*. In contrast, the Norwegian Shelf (#21) and several LMEs along the Australian coast have the highest *SEI*.

The Somali Coastal Current (#31), Guinea Current (#28), and Agulhas Current (#30) exhibit the lowest levels of intensity of marine activity, consistent with their low

[13] Five LMEs are not included in our analysis because of the paucity of data on either the socioeconomic index, marine activity, or both. These five LMEs are: the Arctic Ocean (64); Antarctica (61); the Faroe Plateau (60); the East Greenland Shelf (19); and the West Greenland Shelf (18). Table 2 does not include all the countries (or territories) listed in Table 4. This creates a data gap that leads to biased estimates for LME indexes. To address the issue, we bridged the data gaps with data from related countries as follows: Morocco for Western Sahara, UK for Falkland Islands, Suriname for French Guiana, US for Puerto Rico, and Norway for Svalbard. Several countries with missing data and also with very small weights were excluded from the calculation of weighted average indexes. We assigned HDI values for Liberia (0.3), North Korea (0.5), Somalia (0.28), and Taiwan (0.9) based mostly on income levels.

levels of *SEI*. In contrast to the results for the *SEI* ranking, the Yellow Sea (#48) and the East China Sea (#47) exhibit the highest *MAI* levels.

The precise relationship between marine industry activities and socioeconomic development is a bit more complex (Fig. 2). We group LMEs according to their socioeconomic development levels and marine industry activity levels, using data from Table 5. We specify three development levels: high ($SEI \geq 80$), medium ($50 \leq SEI < 80$), and low $SEI < 50$); and three marine activity levels: high ($MAI \geq 30$), medium ($5 \leq MAI < 30$), and low ($MAI < 5$).

<Insert Fig. 2 here>

In Table 6, the top two boxes on the left do not have entries, suggesting that LME regions with low levels of economic development generally do not have high levels of marine industry activities. In contrast, LME regions with high levels of economic development may or may not have high levels of marine industry activities. For example, the Iceland Shelf (#59) is a region with a high level of socioeconomic development but a low level of marine industry activities, while the Northeast Shelf (#7) is a region with high levels of both economic development and marine industry activities. The Yellow Sea (#48) region is unique in that it has a high level of marine industry activities and a medium level socioeconomic development. This combination suggests a major management challenge to achieve sustainability (i.e., balancing economic growth with environmental and resource protection).

<Insert Table 6 here>

5. Discussion

Over the past several years, a rapidly growing literature on LME studies has emerged, focused mostly on issues of biological conservation; the sources, transport, and fate of pollutants; and regional governance. In sharp contrast, analysis of the socio-economic characteristics of LMEs has received relatively little attention to date. Although a general framework for monitoring and assessing the socio-economic aspects of LMEs has been developed, few detailed studies grounded in empirical data have been undertaken. In this study, we take an initial step toward the development of a global overview of the socio-economic aspects of LMEs.

The compilation of data and the development of an international database on marine activity levels in coastal nations and LMEs is likely to be of considerable value for conducting preliminary screening and prioritization of marine regions that are in need of international attention and support for organizing programs of sustainable development. As suggested by a reviewer, the index itself could be extended to include additional types of information, including measures of population density in coastal regions, coastal development, and levels of pollution. Data about these measures obviously are not now compiled consistently at the international level, and considerable effort would be needed to implement such extensions.

For those LMEs that are identified as priorities from the marine activity and socioeconomic development rankings, detailed case studies should be conducted. Case studies should focus on the following:

- characterizing marine activities at the sub-national level within the LME;
- estimating the scale of resource rents that could obtain from the efficient management of the marine resources of the LME;

- clarifying, where relevant and necessary, the need for and the costs involved in the international regulation of natural resources or the management of transboundary environmental degradations;
- identifying the set of sustainable development policy priorities in each of the nations of the region (including priorities unrelated to the marine environment); and
- understanding the willingness of the nations participating in the region to devote some fraction of rents from marine resources to the sustainable management of their shared ecosystem.

Characterizing the scale of resource rents in priority LMEs is obviously only one step toward the sustainable management of LMEs. Situations may arise where the pursuit of resource rents from industrial activities, such as hydrocarbon development or the prosecution of wild-harvest fisheries, conflict with smaller-scale artisanal or non-consumptive uses of the relevant marine environment. Case studies will need to help identify all beneficial activities without making explicit value judgements about the relative social worth of activities that generate variable levels of resource rents. Decisions about the appropriate mix of uses in a region are inherently political, but estimates of resource rents that may be realized or foregone should play an important role as management options are debated. Clearly management is not costless, and a decision to forego activites that generate significant resource rents could have important implications for the scale and effectiveness of management activities.

The efforts of international organizations to encourage the sustainable development of LMEs is obviously an important goal. We recognize, however, that decisions about sustainable development are policy decisions that must be made by each coastal nation independently and, where feasible, in concert with the other nations of the region.

Notwithstanding the priority to devote resource rents from the development of marine natural resources to improve environmental, public health, and social welfare conditions, the scale of rents (in the case of the Benguela Current LME) and direct output impacts (in the case of the Yellow Sea LME) appear to be sufficient to continue to support existing efforts to improve marine management. At the very least, the sustainable management programs, involving scientifically based assessments, which have been organized by GEF and the nations of both LMEs, might be continued at the same or even a slightly expanded scale.

Whether coastal nations will work together to solve the issues that pervade LMEs will depend upon the benefits that each nation expects from its cooperation with others. Hence, clarifying in detail the nature of the benefits to individual nations of international cooperation within LMEs is of fundamental importance. In an optimistic future, as the economies of the nations develop, and hopefully as their social problems begin to be resolved, any residual problems of marine pollution and resource misallocations can be accorded a higher priority in national and regional public policy.

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Fig. 1: Large marine ecosystems
Source: UNEP and NOAA (2005).

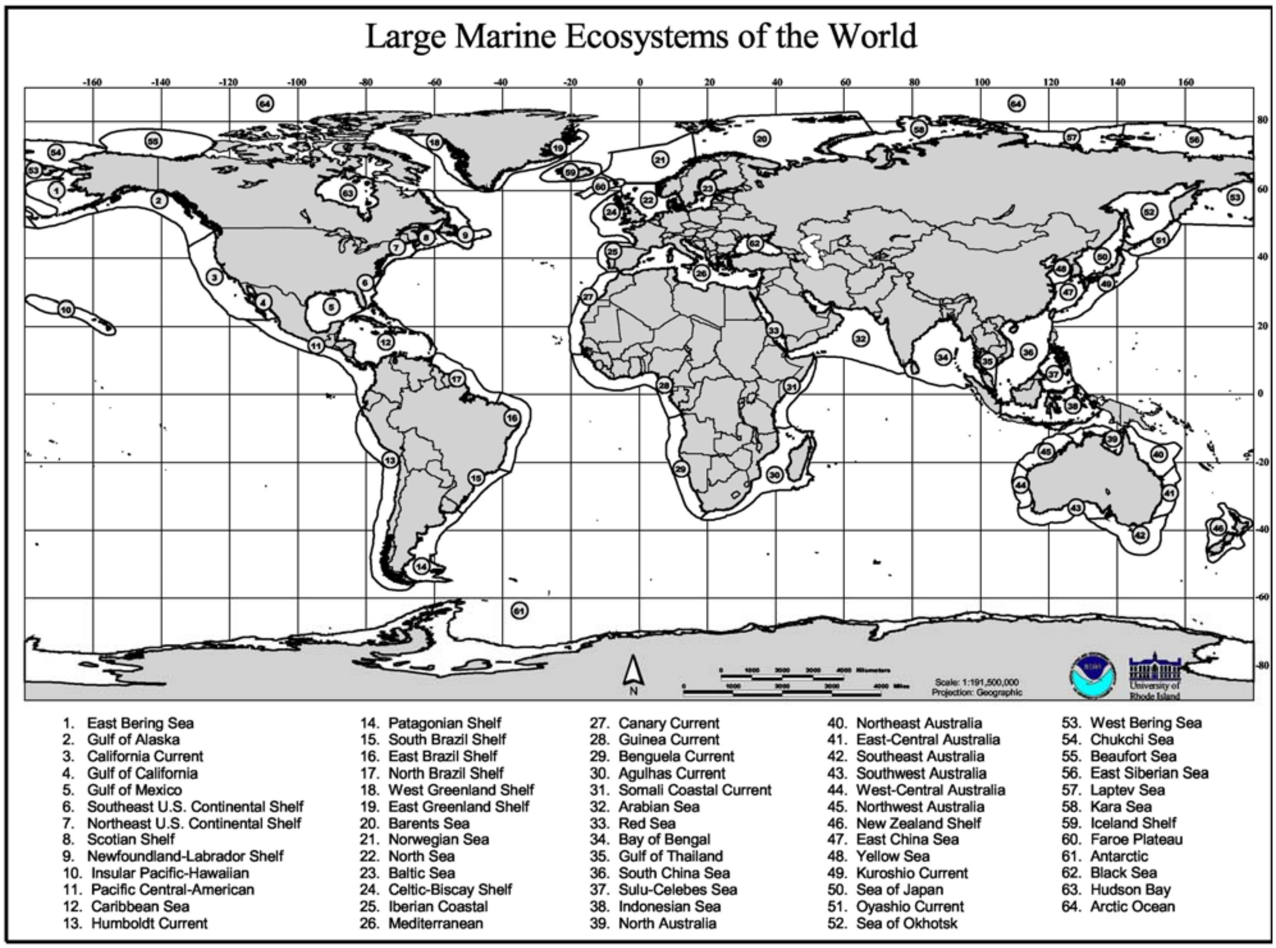

Fig.2: Intensity of activity in large marine ecosystems: indexes showing the relationship between marine industry activity and socioeconomic development. The data for four representative LME cases are labeled on the graph.

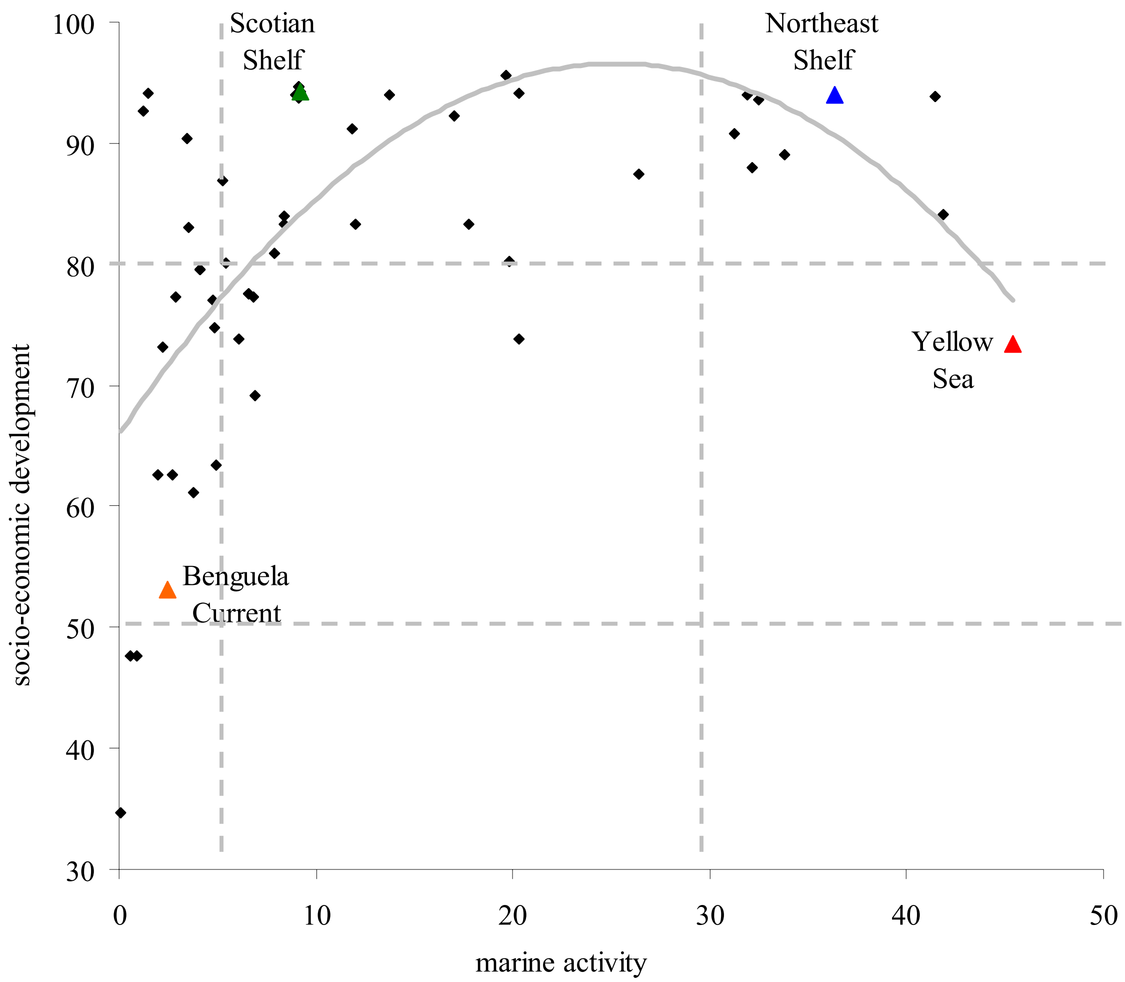

Table 1. Marine Industry Indictors and Data Sources

Indicator	Unit	Year	Data Source
Human Development Index (HDI)	Dimensionless	2002	*Human Development Report 2004* (UNDP 2004)
Fishery landings	Metric tons (MT)	2003	Fisheries Global Information System 2003 (FAO 2005)
Aquaculture production	Metric tons	2003	Fisheries Global Information System 2003 (FAO 2005)
International tourism number of arrivals	Number of visitors	2004	World Development Indicators 2004 (World Bank 2004)
Shipbuilding orderbook*	Gross tonnage (GT)	2nd quarter 2004	*Shipping Statistics Yearbook 2004* (ISL 2004)
Shipping cargo traffic	Metric tons**	2002	*Shipping Statistics Yearbook 2004* (ISL 2004)
Merchant fleet***	Deadweight tons (DWT)	Jan. 1, 2004	*Shipping Statistics Yearbook 2004* (ISL 2004)
Offshore oil production****	Average barrel/day	2004	*Oil and Gas Journal Databook 2004 (OGJ 2004)* US Department of the Interior (2005)
Offshore rig count	Number	Dec., 2003	*Oil and Gas Journal Databook 2004* (OGJ 2004)

* Ships of 100 GT and over.
** Units for a small fraction of ports are in freight tons, revenue tons, or harbor tons (see ISL 2004).
*** By nation of domicile; ships of 1000 GT and over.
**** Data for some countries are partial due to (1) missing data for some offshore fields and (2) lack of separate statistics for offshore (vs. onshore) production.

Table 2: Estimated Resource Rents from Marine Activities for the BCLME Nations

(millions of 2005 US dollars)

	Offshore Oil Production	Capture Fisheries Harvests	Offshore Diamond Mining	TOTALS
Angola	3,201	13	0	3,214
Namibia	0	200	88	288
South Africa	0	175	4	179
TOTALS	3,201	388	92	3,681

Table 3: Estimated Marine Industry Output Value by Yellow Sea Coastal Areas in China, 2000

($US millions)

Industry	Shandong	Liaoning	Tianjin	Jiangsu	Hebei	Total	Percent
Fishery and Mariculture	6,665	2,553	80	1,321	399	11,018	64.3
Port & Shipping	548	453	462	136	235	1,834	10.7
Offshore Oil & Gas	438	59	815	0	0	1,312	7.7
Shipbuilding	315	571	28	117	33	1,064	6.2
Sea Salt	691	53	58	126	97	1,025	6
Tourism*	255	256	232	64	71	878	5.1
Sand & Gravel	1	0	0	0	0	1	0
Total	8,912	3,945	1,675	1,764	836	17,132	100

Note: * International visitors only.
Source: SOA (2005).

Table 4. Construction of Marine Industry Activity Index

Industry Sector	**Activity Weight** (v_k)	**Indicator**	**Indicator Weight** (w_j)
Marine fishery and aquaculture	1/5	Fishery landings	1/2
		Aquaculture production	1/2
Tourism	1/5	Number of international visitors	1
Shipbuilding	1/5	Orderbook (ships on order)	1
Shipping	1/5	Cargo traffic	2/3
		Merchant fleet	1/3
Offshore oil	1/5	Production	2/3
		Rig count	1/3

Note: Weights are assigned by the authors as an illustration. These weights may be adjusted by analysts or decision makers based on different economic or ecological criteria. See discussions following Eqs. (2) and (3) on pages 10 and 11.

Table 5: Socioeconomic and Marine Industry Activity Indexes for LMEs (ranked in order of the Socioeconomic Index)

LME	LME#	Socioeconomic Index (HDI)	Fishery & Aquaculture Index	Tourism Index	Ship & Oil Index*	Marine Industry Activity Index
Somali Coastal Current	31	34.710	0.098	0.357	0.025	0.106
Agulhas Current	30	47.616	0.878	1.813	0.604	0.900
Guinea Current	28	47.619	0.350	0.294	0.718	0.560
Benguela Current	29	53.103	1.805	2.127	2.791	2.461
Canary Current	27	61.160	2.365	14.278	0.806	3.812
Red Sea	33	62.564	0.268	5.583	1.381	1.999
Arabian Sea	32	62.635	2.895	2.300	2.766	2.698
Bay of Bengal	34	63.400	7.675	4.571	4.088	4.902
Indonesian Sea	38	69.200	16.159	6.686	3.872	6.892
Caribbean Sea	12	73.177	1.010	3.603	2.197	2.241
Yellow Sea	48	73.442	71.837	44.410	36.865	45.369
South China Sea	36	73.777	34.521	22.269	14.902	20.299
Gulf of Thailand	35	73.826	7.309	13.395	3.268	6.102
Sulu-Celebes Sea	37	74.778	10.078	4.420	3.212	4.827
North Brazil Shelf	17	77.055	1.772	3.364	6.284	4.798
Pacific Central-American Coastal	11	77.304	2.431	8.856	7.634	6.838
Black Sea	62	77.323	2.859	7.941	1.176	2.865
East Brazil Shelf	16	77.500	2.257	4.676	8.716	6.616
South Brazil Shelf	15	77.525	2.249	4.662	8.679	6.589
East Siberian Sea	56	79.500	10.891	0.385	3.122	4.128
Laptev Sea	57	79.500	10.891	0.385	3.122	4.128
Kara Sea	58	79.500	10.891	0.385	3.122	4.128
Sea of Okhotsk	52	80.125	11.245	0.675	5.071	5.426
Gulf of California	4	80.200	4.907	24.923	23.096	19.823

LME	LME#	Socioeconomic Index (HDI)	Fishery & Aquaculture Index	Tourism Index	Ship & Oil Index*	Marine Industry Activity Index
West Bering Sea	53	80.956	11.553	6.199	7.251	7.901
Humboldt Current	13	83.015	15.241	1.721	0.178	3.499
Mediterranean Sea	26	83.262	1.087	27.192	4.595	8.413
Sea of Japan	50	83.263	13.262	3.529	23.976	17.744
Oyashio Current	51	83.278	13.031	2.138	14.904	11.976
Barents Sea	20	83.939	10.839	1.288	9.972	8.409
East China Sea	47	84.076	51.891	30.773	42.147	41.821
Patagonian Shelf	14	86.846	2.763	8.225	5.085	5.249
Chukchi Sea	54	87.433	14.683	34.858	27.524	26.422
California Current	3	88.015	12.055	43.729	35.002	32.158
Gulf of Mexico	5	89.071	13.021	46.271	36.611	33.825
Baltic Sea	23	90.324	2.120	8.086	2.378	3.468
Southeast U.S. Continental Shelf	6	90.830	13.131	44.030	33.082	31.282
Iberian Coastal	25	91.188	2.482	47.324	3.155	11.854
Celtic-Biscay Shelf	24	92.204	2.482	38.841	14.639	17.048
New Zealand Shelf	46	92.600	2.092	2.876	0.403	1.235
Kuroshio Current	49	93.628	18.324	6.705	45.846	32.514
Newfoundland-Labrador Shelf	9	93.668	4.848	25.182	5.227	9.142
East Bering Sea	1	93.900	17.438	57.893	43.969	41.448
Insular Pacific-Hawaiian	10	93.900	17.438	57.893	43.969	41.448
Northeast U.S. Continental Shelf	7	93.963	15.456	52.758	37.861	36.360
Northeast Australian Shelf/Great Barrier Reef	40	94.006	0.833	6.491	12.540	8.989
Gulf of Alaska	2	94.019	13.716	48.248	32.496	31.891
North Sea	22	94.021	5.275	14.384	16.405	13.775
Iceland Shelf	59	94.100	6.865	0.417	0.029	1.474
Beaufort Sea	55	94.163	9.198	36.539	18.570	20.289
Scotian Shelf	8	94.300	4.880	25.351	5.262	9.204
Hudson Bay	63	94.300	4.880	25.351	5.262	9.204

LME	LME#	Socioeconomic Index (HDI)	Fishery & Aquaculture Index	Tourism Index	Ship & Oil Index*	Marine Industry Activity Index
North Australian Shelf	39	94.600	0.836	6.587	12.727	9.121
East-Central Australian Shelf	41	94.600	0.836	6.587	12.727	9.121
Southeast Australian Shelf	42	94.600	0.836	6.587	12.727	9.121
Southwest Australian Shelf	43	94.600	0.836	6.587	12.727	9.121
West-Central Australian Shelf	44	94.600	0.836	6.587	12.727	9.121
Northwest Australian Shelf	45	94.600	0.836	6.587	12.727	9.121
Norwegian Shelf	21	95.600	10.703	3.662	27.969	19.654

* Including shipbuilding, shipping, and offshore oil.

Note: All values are 100 times the indexes calculated using Eqs. (3) and (4).

Table 6: Classification of LMEs

	Low socioeconomic development ($SEI < 50$)	**Medium socioeconomic development** ($50 \le SEI < 80$)	**High socio- development** ($SEI \ge 80$)
High marine industry activity ($MAI \ge 30$)	none	48. Yellow Sea	1. East Bering Sea 2. Gulf of Alaska 3. California Current 5. Gulf of Mexico 6. Southeast U.S. Continental Shelf 7. Northeast U.S. Continental Shelf 10. Insular Pacific-Hawaiian 47. East China Sea 49. Kuroshio Current
Medium marine industry activity ($5 \le MAI < 30$)	none	11. Pacific Central-American Coastal 15. South Brazil Shelf 16. East Brazil Shelf 35. Gulf of Thailand 36. South China Sea 38. Indonesian Sea	4. Gulf of California 8. Scotian Shelf 9. Newfoundland-Labrador Shelf 14. Patagonian Shelf 20. Barents Sea 21. Norwegian Shelf 22. North Sea 24. Celtic-Biscay Shelf 25. Iberian Coastal 26. Mediterranean Sea 39. North Australian Shelf 40. Northeast Australian Shelf/Great Barrier Reef 41. East-Central Australian Shelf 42. Southeast Australian Shelf

	Low socioeconomic development (*SEI* < 50)	**Medium socioeconomic development** (50 ≤ *SEI* < 80)	**High socio- development** (*SEI* ≥ 80)
			43. Southwest Australian Shelf 44. West-Central Australian Shelf 45. Northwest Australian Shelf 50. Sea of Japan 51. Oyashio Current 52. Sea of Okhotsk 53. West Bering Sea 54. Chukchi Sea 55. Beaufort Sea 63. Hudson Bay
Low marine industry activity (*MAI* < 5)	28. Guinea Current 30. Agulhas Current 31. Somali Coastal Current	12. Caribbean Sea 17. North Brazil Shelf 27. Canary Current 29. Benguela Current 32. Arabian Sea 33. Red Sea 34. Bay of Bengal 37. Sulu-Celebes Sea 56. East Siberian Sea 57. Laptev Sea 58. Kara Sea 62. Black Sea	13. Humboldt Current 23. Baltic Sea 46. New Zealand Shelf 59. Iceland Shelf