WOODS HOLE OCEANOGRAPHIC INSTITUTION

ACCOUNTING FOR MARINE ECONOMIC ACTIVITIES IN LARGE MARINE ECOSYSTEMS AND REGIONAL SEAS

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User Guide

Our purpose in producing this report 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) located within Regional Seas areas.

We develop an index that is a measure of the intensity of marine activities in these regions. We compare this marine activity index (MAI) with an index of socioeconomic development, the UNDP's human development index (HDI), across ocean regions. This comparison identifies regions that may be capable of achieving on their own the sustainable development of their regional marine environment and those that are less likely to do so. The latter may be candidates for international financial or management assistance. We make no predictions or normative judgments about whether these regions will or should manage for sustainability.

Our index approach is meant as a tool for setting priorities, given limited international financial and management resources for assisting regions in moving toward sustainable development. 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) and Regional Seas. Data on marine activities include fish landings, aquaculture production, shipbuilding orders, cargo traffic, merchant fleet size, oil production, oil rig counts, and tourism arrivals.

These data can be used to compare activity levels in physical units (quantities, not prices) for each individual marine activity across the coastal nations of the world. This kind of comparison is valuable for gauging relative levels of economic activity by marine industrial sector among coastal nations.

Without additional analysis or information, however, these data cannot be used to compare the ***combinations*** of marine activities occurring in each nation across the coastal nations of the world. Further, data in this format can provide only a very crude understanding of activity levels for ***regional aggregates*** of all or portions of nations that are included in LMEs and Regional Seas.

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. There are several possible monetary measures. The preferred monetary metric is "total economic value" (TEV). TEV measures the ***net benefits*** (the sum of consumer and producer surpluses) that derive from a nation's marine activities.

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 (revenues in excess of all costs) 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. We present an application of the resource rent approach in the case of the Benguela Current LME in Annex I.

A second possible monetary metric is known as "direct output impact" (DOI). DOI measures the ***gross revenues*** or ***sales*** that derive 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.

Despite the fact that a DOI metric can be readily calculated for some activities (*e.g.*, offshore oil and natural gas production), it is problematic to calculate such an index for other activities (*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. We present an application of the DOI approach in the case of the Yellow Sea LME in Annex II.

An alternative method for creating a single metric is the index approach that we present in this report. The marine activity index (MAI) does not rely upon monetary values; it relies instead on physical values. Each physical value is converted into an index that ranges from zero to one. These indexes have no dimension; in other words, they are not measured in specific units of any kind. Decision makers must make assumptions about the weights that each activity is to be accorded when compiling an aggregate MAI from its individual activities. Further assumptions must be made to combine each nation's MAI with others' from the relevant region to produce a regional MAI. We present and rank regional MAIs for both LMEs and Regional Seas.

Finally, we compare regional MAIs with a socio-economic index. This comparison is presented in tables and in figures in our report. We classify ocean regions by low, moderate, and high levels of both marine activity and socio-economic development. We expect that nations involved in ocean regions characterized by high levels of socio-economic development and moderate to high levels of marine activity are probably capable of sustainably managing their marine environments themselves. Alternatively, we expect that nations involved in ocean regions characterized by low to moderate levels of socio-economic development and moderate to high levels of marine activity may need assistance in sustainable management. Special opportunities may exist to place ocean regions that embody low levels of both socio-economic development and marine activity on a sustainable path.

The framework developed in our study serves as a first step toward more detailed analyses of socio-economic issues associated with LMEs and UNEP Regional Seas. 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.

EXECUTIVE SUMMARY

Sixty-four large marine ecosystems (LMEs) have been identified around the world's coastal margins. The LMEs are located within the boundaries of 19 Regional Seas. 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 is now 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 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 report, we take an initial step toward the development of a global overview of the socio-economic aspects of LMEs and Regional Seas.

We focus on the following two broad questions regarding the sustainable management of the marine environment in an LME and Regional Sea:

1. Can the level of marine activity in an LME and Regional Sea be considered sustainable?
2. Are the nations participating in the relevant LME and Regional Sea 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 and Regional Sea. Given the nature of the data on economic activity that is available on a consistent basis across nations, our preferred measures of marine activities are sets of indexes. We expect that higher levels of industrial activity exert greater pressure on the ecosystem, say, through pollution or resource depletion, and that lower activity levels exert less pressure.

For a given activity level, however, the scale of negative ecological impacts may not be the same for coastal nations in 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.

In order to begin to address the second question, we examine the relationship between a measure of socio-economic development, namely UNDP’s human development index (HDI), and measures of marine activity. The HDI measure is useful in thinking about the second question, because we expect that 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 and Regional Seas by various measures of marine activity and by socio-economic development. This ranking process should assist responsible international organizations and donors in developing funding and assistance priorities based upon the revealed characteristics of LMEs.

Our study results include the following:

- the compilation of data and the construction of an international database on marine activities for all coastal nations relating to fish landings, aquaculture production, shipbuilding orders, cargo traffic, merchant fleet size, oil production, oil rig counts, and tourism;
- the development of indexes for each of these marine activities, and the aggregation of sets of activities into industry sector indexes;
- the adaptation of these indexes and a separate socio-economic index to characterize the marine activity levels of LMEs and Regional Seas;
- the development of a ranking of LMEs and Regional Seas according to total marine activity levels, industry sectoral activity levels, and socio-economic status;
- a graphical presentation of the rankings to facilitate the identification of international management and development assistance priorities;
- the development of a case study exploring the scale of resource rents in the Benguela Current LME and the management issues and sustainable development priorities of the region;
- the development of a case study exploring the scale of direct output impacts in the Yellow Sea LME and the regional management issues and sustainable development priorities.

We reach six general conclusions relating to the potential for the sustainable management of marine environments in LMEs or Regional Seas:

- Our examination of the two cases—one of an upwelling, the other of a continental shelf LME—have reinforced our original opinions as to the benefit of the GEF-sponsored efforts to encourage sustainable management. In particular, the detailed studies, capacity building, and reorientation of the policy focus from resource exploitation to sustainable management have been the most positive effects in these two cases. Based upon what we have been able to learn about these two cases, we expect that the nations of the region will be fully capable and willing to continue their programs of sustainable development in the future.
- The compilation of data and the development of an international database on marine activity levels in coastal nations, LMEs, and Regional Seas 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.

- For those LMEs or Regional Seas that are identified as priorities from the marine activity and socio-economic 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 and Regional Sea;
    - estimating the scale of resource rents that could obtain from the efficient management of the marine resources of the LME and Regional Sea;
    - 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.
- The efforts of international organizations to encourage the sustainable development of LMEs and Regional Seas 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.
- Whether coastal nations will work together to solve the issues that pervade LMEs or Regional Seas 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 and Regional Seas is of fundamental importance.

ACCOUNTING FOR MARINE ECONOMIC ACTIVITIES IN LARGE MARINE ECOSYSTEMS AND THE REGIONAL SEAS PROGRAMMES

I. Introduction and Purpose

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*., 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 report, we take an initial step toward the development of a global overview of the socioeconomic aspects of LMEs and Regional Seas. 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

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

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 and Regional Sea:

1. Can the level of marine activity in an LME and Regional Sea be considered sustainable?
2. Are the nations participating in the relevant LME and Regional Sea 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 and Regional Sea. Given the nature of the data on economic activity that 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 and Regional Seas 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.

II. Marine Activity Database

This report presents the results of our efforts to compile data on marine activities in the coastal nations comprising large marine ecosystems (LMEs) and Regional Seas. In general, LMEs have been defined primarily in terms of ecological characteristics. In contrast, Regional Seas have been defined primarily in terms of geographic and political characteristics. Regional Seas tend to be larger than LMEs, and Regional Seas comprise one or more (or components of) LMEs. The identities of LMEs and Regional Seas (and a rough concordance between the two types of regions) are presented in the map in Fig. 1.

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 actual data are presented in Table 2.[2] 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).

The data presented in Table 2 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. Further, data in this form can provide only a very crude understanding of activity levels for *regional aggregates* of all or portions of nations that are involved in LMEs or Regional Seas.

III. Methodology

A. 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).[3] To calculate a single metric based upon TEV, one would estimate the *net* benefits in

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[2] We thank Jennifer Skilbred and Chris Vonderweidt for assisting us in the identification and compilation of these data.

[3] From the perspective of the theory of welfare economics, economic value is the only theoretically valid measure of social welfare (*viz.*, Mishan 1980).

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.[4] Such a comparison would increase our understanding of the economic capacity of the nations participating in LMEs and Regional Seas Programs to conserve and manage their marine ecosystems in a sustainable fashion. Unfortunately, there is no readily available compilation of TEVs for marine activities across all coastal nations, however, and the calculation of such values has occurred only on a location- and activity-specific basis to date.

In our case study of the Benguela Current LME, which appears in Annex I, we estimate for the region the scale of "resource rents," which are a constituent of the producer surplus component of TEV, for the offshore oil, marine capture fisheries, and marine diamond dredging activities in the region. Resource rents are therefore a subset of TEV. In the context of sustainable management of the marine environment, we note

[4] 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.

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.

B. 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.[5] As in the case of calculating TEV, one estimates a DOI for each activity, and these impacts are summed to create a single metric. 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.[6]

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

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[5] 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).

[6] 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 GNP less 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 used as measures of welfare change.

industries). In our case study of the Yellow Sea LME, which appears in Annex II below, we calculate and compile a wider range of DOIs for the marine activities of the region.

C. 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 use of either the TEV or DOI metrics.

D. 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.[7] There are five possible scenarios to consider: an LME and Regional Sea comprises: (i) the entire exclusive economic zone (EEZ)[8] 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)

[7] 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.

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

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 or Regional Seas Programs 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 an LME or Regional Sea 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 or Regional Sea.[9] One approach would be to calculate the length of a nation's coastline within an LME and Regional Sea relative to that nation's total coastline.[10] 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 and Regional Sea.[11] 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 or Regional Sea, even though those activities might not take place in that region (*e.g*., the assignment of US offshore oil

[9] 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.

[10] 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 or Regional Sea.

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

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 an LME and Regional Sea relative to the other participating nations in the same LME and Regional Sea. We calculate the share of the total LME and Regional Sea coastline for each nation participating in an LME and Regional Sea 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 and Regional Sea. These shares are presented in Table 4 for the world's LMEs.[12] A concordance exists between LMEs and Regional Seas (Table 5), and we use the concordance to develop a similar weighting procedure for the world's Regional Seas based upon the areal coverage of LMEs. We emphasize that this procedure does not resolve the issue of attributing all of a nation's marine activities to an LME and Regional Sea when only a portion of that nation has been assigned to the LME and Regional Sea. Resolution of that issue is an area for future research.

IV. 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; (iii) constructing weighted average indexes for each LME; and (iv) constructing weighted average indexes for each Regional Sea Program (RSP). We focus on two important

[12] We thank Roger Goldsmith (2005) for calculating the shares that appear in Table 4.

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}) (from an entry for nation i in a column for activity j in Table 2) 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.[13] 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 3) 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 $\Sigma w_j = 1$.

[13] 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, if such weights could be estimated.

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:

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

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 3). In our example, we assign equal weights of 0.20 to each of the five industry sectors (see Table 3).

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).[14]

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), and then for the Regional Seas, which are in effect combinations of LMEs. 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 or Regional Sea.

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

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

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

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 (these shares are compiled in Table 4).[15]

Finally, for each RSP, the LME-level indexes are further aggregated as:

$$MAI_{RSP} = \sum_{q=1}^{p} a_q MAI_q \tag{6}$$

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

[15] LME-level marine activity indexes (*MAI*) can also be calculated using the activity indexes (*AI*) for industry sectors in lieu of the total activity index (*TAI*). We present calculations for three such industry sectors in Table 7.

$$SEI_{RSP} = \sum_{q=1}^{p} a_q SEI_q \tag{7}$$

where q is the index for an LME within a Regional Sea (Table 5), and a is the percentage share of the LME's area (Table 6) relative to the total area of all p LMEs within the Regional Sea.

V. 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).[16] The results are summarized in Table 7. Also included in Table 7 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.

One can compare LMEs based upon these different indexes. The data in Table 7 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)

[16] Five LMEs are not included in our analysis because of the paucity of datat 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.

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*.

In Table 8 and Fig. 2, we rank the data by MAI, which can be interpreted as a measure of the intensity of marine activity in each LME. This ranking is much different from the ranking in Table 7. Even so, 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 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. In Figs. 3 and 4, we also present rankings of *MAI* normalized by total LME area (Fig. 3) and *MAI*/*SEI* (Fig. 4).

The precise relationship between marine industry activities and socioeconomic development is a bit more complex (Figure 5). We group LMEs according to their socioeconomic development levels and marine industry activity levels, using data from Tables 7 and 8. 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 ($MAI < 5$). The resulting nine categories are shown in Table 9 and Figure 5.

In Table 9, 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).

We aggregate the LME index estimates to get the indexes for the Regional Seas, using Equations (6) and (7). We present the results of the Regional Sea index estimates ranked in order of *SEI* (Table 10 and Fig. 6) and *MAI* (Table 11 and Fig. 7). Within the Regional Seas Program, the Eastern Africa region appears to be the least developed, while the South Pacific region has the highest level of socioeconomic development. The Northeast Pacific and Northwest Pacific Regional Seas exhibit the highest intensities of marine activity, while the West Central Africa and Eastern Africa Regional Seas exhibit the lowest.

We develop groupings similar to those for LMEs for the regional seas (see Table 12). In addition, we plot *SEI* against *MAI* for the regional seas in Fig. 8. The two representative cases pictured in Fig. 8 include the BCLME (West Central Africa RSP) and the YSLME (Northwest Pacific RSP). The interpretation of the figure is similar to that for the plot of *SEI* vs. *MAI* for LMEs.

While the results in Tables 10, 11, and 12 are useful in providing a quick overview of relative positions across Regional Seas, they must be used with caution. LMEs are large areas that are often composed of heterogeneous countries. Regional Seas are much larger areas than the LMEs, and the level of heterogeneity in economic development and marine activity within a specific regional sea may be substantial.

Disparities in regional heterogeneity are evident, for example, in the somewhat surprising result that the South Pacific RSP, which is extremely heterogeneous, has a higher level of socioeconomic development than the much more homogeneous North-East Atlantic Regional Sea.[17]

VI. Discussion

We have developed an index approach to provide an overview of the socioeconomic dimension of different LMEs and Regional Seas. The study is unique in its global perspective. The results may be used to address management questions regarding sustainable development and sustainable self-financing of regional programs.

The results may also be used to identify problem areas. Typically, regions with high levels of marine industry activities demand high levels of management attention to address issues related to resource depletion, environmental degradation, and multiple use conflicts. This is particularly true in regions with high marine activity levels and medium levels of socioeconomic development. Efforts must be made to coordinate economic development and environmental and resource protection. Regions with low socioeconomic development levels and low marine activity levels at the present deserve international assistance in preparation for possibly rapid development in the future.

The framework developed in our study serves as a first step toward more detailed analyses of socioeconomic issues associated with LMEs and Regional Seas. 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

[17] Also of relevance is the fact that only three of the 19 states that participate in the South Pacific Regional Sea Programme--Australia, New Zealand, and Papua New Guinea--border on, and are represented in the data assembled for, the four LMEs that occur within that region (LMEs 40, 41, 42, and 46).

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.

To illustrate this point, we present case studies in the Annexes of the Benguela Current LME and the Yellow Sea LME. These two LMEs were selected because they represent different types of marine ecosystems, different levels of marine economic activity, and different geographic locations. The Benguela Current LME, located along the southwest coast of Africa, is the world's most powerful wind-drive coastal upwelling system, and it has a relatively low level of marine economic activity. In contrast, the Yellow Sea LME, a sub-area of the Northwest Pacific Regional Sea, is a continental shelf ecosystem with intense marine activities.

The two case studies use two different approaches for estimating a monetary measure of levels of economic activity in an LME. We present an application of the resource rent approach in the case of the Benguela Current LME in Annex I. In particular, we estimate resource rents, or those producer surpluses attributable to the exploitation of marine resources. If collected by governments, resource rents provide a potential basis for financing the sustainable management of the marine environment.

In many cases, however, it can be difficult to obtain estimates of resource rents. In Annex II, we present an application of the direct output impact (DOI) approach for the Yellow Sea LME. DOI measures the gross revenues or sales that obtain from a nation's marine activities; it can be conceptualized as an upper bound on producer surplus.

Although the DOI approach does not result in as much information about economic value as the resource rent approach, it can be used to gain a sense of the scale of economic activity and as a rough measure of the capacity of the nations of an LME to finance sustainable management.

VII. Summary and Conclusions

Examination of the two cases—one of an upwelling, the other of a continental shelf LME—have reinforced our original opinions as to the benefit of the GEF-sponsored efforts to encourage sustainable management. In particular, the detailed studies, capacity building, and reorientation of the policy focus from resource exploitation to sustainable management have been the most positive effects in these two cases. Based upon what we have been able to learn about these two cases, we expect that the nations of the region will be fully capable and willing to continue their programs of sustainable development in the future.

The compilation of data and the development of an international database on marine activity levels in coastal nations, LMEs, and Regional Seas 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.

For those LMEs or Regional Seas 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 and Regional Sea;

- estimating the scale of resource rents that could obtain from the efficient management of the marine resources of the LME and Regional Sea;
- 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.

The efforts of international organizations to encourage the sustainable development of LMEs and Regional Seas 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 BCLME) and direct output impacts (in the case of YSLME) 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 or Regional Seas 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 and Regional Seas 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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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)	2^{nd} 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. Socioeconomic and Marine Industry Indicators by Nation

Nation	HDI	Marine Fishery (MT)	Marine Aquaculture (MT)	International Tourism (visitor)	Shipbuilding Orderbook (1000 GT)	Shipping Cargo Traffic (1000 MT)	Merchant Fleet (1000 DWT)	Offshore Oil Production (bbl/day)	Offshore Rig Count (number)
Albania	0.781	1,537	500	40,800	0	0	0	0	0
Algeria	0.704	141,530	65	1,145,200	0	0	0	0	0
Angola	0.381	201,539	0	101,200	0	0	0	653,233	7
Antigua and Barbuda	0.800	2,587	0	244,500	0	0	0	0	0
Argentina	0.853	883,111	80	2,587,000	39	5,207	0	16,075	0
Australia	0.946	219,430	35,154	5,348,800	32	537,391	0	449,475	4
Azerbaijan	0.746	0	0	1,020,200	0	0	0	0	0
Bahamas	0.815	12,694	42	1,545,400	0	0	0	0	0
Bahrain	0.843	13,638	3	3,936,600	0	3,493	0	0	0
Bangladesh	0.509	431,908	56,503	233,200	0	0	0	0	0
Barbados	0.888	2,500	0	501,000	0	0	0	0	0
Belgium	0.942	26,320	0	6,905,400	0	188,544	5,863	0	0
Belize	0.737	5,193	10,160	215,000	0	0	0	0	0
Benin	0.421	11,893	0	36,800	0	3,469	0	0	0
Bosnia and Herzegovina	0.781	0	260	152,600	0	0	0	0	0
Brazil	0.775	582,046	109,615	3,797,200	239	403,490	4,791	0	13
Brunei Darussalam	0.867	1,985	68	1,021,667	0	0	0	0	1
Bulgaria	0.796	10,211	15	3,807,000	153	18,076	0	0	0
Cambodia	0.568	55,607	8,414	998,000	0	0	0	0	0
Cameroon	0.501	52,801	0	223,400	0	5,997	0	0	0
Canada	0.943	1,324,261	142,771	20,585,600	3	185,773	4,323	180,541	5
Cape Verde	0.717	8,721	0	167,000	0	0	0	0	0
Chile	0.839	3,930,356	629,493	1,414,400	8	9,093	0	0	0
China	0.745	14,588,663	20,893,331	49,885,200	17,644	1,310,822	45,552	502,500	10
Colombia	0.773	97,335	16,503	508,400	0	0	0	0	0
Comoros	0.530	14,115	0	23,800	0	0	0	0	0
Congo	0.494	26,346	0	15,167	0	0	0	0	2

Nation	**HDI**	**Marine Fishery** (MT)	**Marine Aquaculture** (MT)	**International Tourism** (visitor)	**Shipbuilding Orderbook** (1000 GT)	**Shipping Cargo Traffic** (1000 MT)	**Merchant Fleet** (1000 DWT)	**Offshore Oil Production** (bbl/day)	**Offshore Rig Count** (number)
Congo, Dem. Rep. of the	0.365	5,000	0	169,800	0	0	0	16,169	0
Costa Rica	0.834	28,327	5,051	1,237,000	0	7,033	0	0	0
Côte d'Ivoire	0.399	45,903	0	0	0	14,728	0	0	0
Croatia	0.830	19,938	4,365	8,576,200	2,247	2,596	0	0	0
Cuba	0.809	38,822	2,686	1,899,600	0	0	0	0	0
Cyprus	0.883	1,741	1,731	2,752,800	0	7,731	0	0	0
Denmark	0.932	2,008,803	73,580	1,996,000	1,661	9,836	16,373	370,800	4
Djibouti	0.454	350	0	0	0	4,548	0	0	0
Dominica	0.743	1,100	0	66,200	0	0	0	0	0
Dominican Republic	0.738	16,591	899	3,219,400	0	0	0	0	0
Ecuador	0.735	397,464	57,493	753,800	0	0	0	0	0
Egypt	0.653	117,439	43,478	5,717,600	15	0	0	0	9
El Salvador	0.720	32,737	473	1,094,200	0	0	0	0	0
Equatorial Guinea	0.703	2,500	0	0	0	0	0	200,000	0
Eritrea	0.439	6,689	0	58,600	0	0	0	0	0
Estonia	0.853	76,615	0	1,711,000	0	37,526	0	0	0
Fiji	0.758	34,531	26	361,000	0	0	0	0	0
Finland	0.935	86,518	10,151	3,036,200	257	61,302	0	0	0
France	0.932	750,844	197,274	81,201,200	470	322,018	4,641	0	0
Gabon	0.648	35,269	0	192,000	0	0	0	15,000	1
Gambia	0.452	34,364	0	80,219	0	0	0	0	0
Georgia	0.739	3,267	0	289,600	0	0	0	0	0
Germany	0.925	238,266	28,653	19,152,400	2,532	253,490	48,335	16,318	0
Ghana	0.568	315,756	0	542,800	0	10,242	0	6,000	0
Greece	0.902	90,221	98,459	16,251,000	20	24,935	156,385	3,850	0
Grenada	0.745	2,544	0	137,000	0	0	0	0	0
Guatemala	0.649	16,834	3,776	1,004,000	0	0	0	0	0
Guinea	0.425	114,845	0	53,200	0	0	0	0	0
Guinea-Bissau	0.350	4,800	0	0	0	0	0	0	0
Guyana	0.719	58,896	162	126,200	0	0	0	0	0

Nation	**HDI**	**Marine Fishery** (MT)	**Marine Aquaculture** (MT)	**International Tourism** (visitor)	**Shipbuilding Orderbook** (1000 GT)	**Shipping Cargo Traffic** (1000 MT)	**Merchant Fleet** (1000 DWT)	**Offshore Oil Production** (bbl/day)	**Offshore Rig Count** (number)
Haiti	0.463	4,510	0	134,010	0	0	0	0	0
Honduras	0.672	10,700	16,527	688,200	0	5,782	0	0	0
Hong Kong, China (SAR)	0.903	157,444	2,748	19,051,200	0	0	31,378	0	0
Iceland	0.941	2,000,068	4,370	338,620	0	1,722	0	0	0
India	0.595	2,920,471	113,240	2,524,200	196	218,182	12,124	305,610	19
Indonesia	0.692	4,407,131	440,373	5,429,000	107	12,461	4,604	282,267	12
Iran, Islamic Rep. of	0.732	299,128	7,462	1,809,600	189	0	8,700	0	8
Ireland	0.936	301,711	61,435	6,698,000	0	31,670	0	0	0
Israel	0.908	2,991	3,359	777,590	0	33,389	0	0	0
Italy	0.920	293,331	148,962	43,510,000	1,500	268,136	11,941	10,385	1
Jamaica	0.764	8,202	456	1,312,200	0	11,141	0	0	0
Japan	0.938	4,649,591	1,277,085	5,702,400	39,377	804,679	109,540	0	0
Jordan	0.750	131	0	1,769,000	0	14,159	0	0	0
Kazakhstan	0.766	0	0	4,090,833	0	0	0	0	0
Kenya	0.488	7,095	0	874,800	0	10,224	0	0	0
Korea, Dem. People's Rep.	n.a.	200,000	504,295	0	0	0	0	0	0
Korea, Rep. of	0.888	1,647,043	826,245	6,017,600	49,919	665,747	25,354	0	0
Kuwait	0.838	5,900	179	71,300	0	0	0	0	0
Latvia	0.823	113,978	0	850,000	3	51,131	0	0	0
Lebanon	0.758	3,613	0	1,093,400	0	0	0	0	0
Liberia	n.a.	0	0	0	0	0	0	0	0
Libyan Arab Jamahiriya	0.794	33,671	0	0	0	0	0	0	1
Lithuania	0.842	155,246	0	1,141,500	7	19,741	0	0	0
Madagascar	0.469	112,731	7,007	224,900	0	0	0	0	0
Malaysia	0.793	1,287,336	135,860	18,084,600	25	110,055	9,568	770,000	14
Maldives	0.752	155,415	0	531,400	0	0	0	0	0
Malta	0.875	1,138	881	1,133,200	0	0	0	0	0
Mauritania	0.465	75,000	0	0	0	0	0	0	0
Mauritius	0.785	11,136	6	758,800	0	5,284	0	0	0
Mexico	0.802	1,398,250	47,991	20,237,400	2	34,776	0	2,603,816	39

Nation	HDI	**Marine Fishery** (MT)	**Marine Aquaculture** (MT)	**International Tourism** (visitor)	**Shipbuilding Orderbook** (1000 GT)	**Shipping Cargo Traffic** (1000 MT)	**Merchant Fleet** (1000 DWT)	**Offshore Oil Production** (bbl/day)	**Offshore Rig Count** (number)
Morocco	0.620	894,612	1,078	4,929,000	0	0	0	0	0
Mozambique	0.354	78,129	542	0	0	2,762	0	0	0
Myanmar	0.551	1,060,252	19,181	221,400	0	0	0	0	1
Namibia	0.607	669,847	102	0	0	0	0	0	0
Netherlands	0.942	547,708	59,525	10,410,600	460	404,348	5,045	5,292	4
New Zealand	0.926	551,362	84,642	2,335,400	1	23,721	0	0	0
Nicaragua	0.667	14,921	7,005	521,800	0	0	0	0	0
Nigeria	0.466	300,194	0	970,800	0	23,351	0	278,360	8
Norway	0.956	2,716,347	582,016	2,973,400	26	18,963	50,788	3,148,481	17
Occupied Palestinian Territories	0.726	1,508	0	0	0	0	0	0	0
Oman	0.770	138,482	352	698,400	0	2,317	0	0	0
Pakistan	0.497	399,040	69	565,600	1	25,852	0	0	0
Panama	0.791	223,398	6,105	592,200	0	0	0	0	0
Papua New Guinea	0.542	174,702	0	42,900	0	0	0	0	0
Peru	0.752	6,060,986	10,021	927,400	5	12,926	0	12,401	0
Philippines	0.753	2,039,438	1,076,118	1,686,000	764	82,898	5,590	14,400	0
Poland	0.850	160,260	0	11,602,000	2,433	42,695	0	6,600	0
Portugal	0.897	213,323	6,875	12,282,200	32	34,190	0	0	0
Qatar	0.833	11,000	0	107,700	0	0	0	0	6
Romania	0.778	1,612	0	3,417,400	925	40,524	0	0	0
Russian Federation	0.795	3,177,230	741	312,200	361	105,971	15,258	0	0
Saint Kitts and Nevis	0.844	370	0	52,600	0	0	0	0	0
Saint Lucia	0.777	1,462	2	253,000	0	0	0	0	0
Saint Vincent and the Grenadines	0.751	4,783	0	81,400	0	0	0	0	0
Samoa (Western)	0.769	10,266	0	95,600	0	0	0	0	0
São Tomé and Principe	0.645	3,283	0	9,900	0	0	0	0	0
Saudi Arabia	0.768	52,929	9,389	8,330,000	1	96,086	12,043	0	6
Senegal	0.437	428,174	84	457,400	0	9,062	0	0	0

Nation	HDI	Marine Fishery (MT)	Marine Aquaculture (MT)	International Tourism (visitor)	Shipbuilding Orderbook (1000 GT)	Shipping Cargo Traffic (1000 MT)	Merchant Fleet (1000 DWT)	Offshore Oil Production (bbl/day)	Offshore Rig Count (number)
Seychelles	0.853	85,785	1,084	134,200	0	0	0	0	0
Sierra Leone	0.273	82,926	0	35,600	0	0	0	0	0
Singapore	0.902	2,085	4,422	7,784,800	203	335,156	23,043	0	0
Slovenia	0.895	1,087	206	1,488,400	0	9,431	0	0	0
Solomon Islands	0.624	39,903	0	0	0	0	0	0	0
Somalia	n.a.	17,850	0	0	0	0	0	0	0
South Africa	0.666	854,024	5,474	6,551,000	1	153,576	0	20,100	1
Spain	0.922	887,837	279,770	55,991,200	536	245,829	4,759	6,114	0
Sri Lanka	0.740	255,453	5,956	338,700	1	0	0	0	0
Sudan	0.505	5,008	0	60,200	0	0	0	0	0
Suriname	0.780	27,930	177	0	0	0	0	0	0
Sweden	0.946	285,389	2,802	10,403,000	0	40,483	5,731	0	0
Syrian Arab Republic	0.710	3,060	0	1,694,600	0	0	0	0	0
Taiwan	n.a.	1,132,746	140,183	0	1,747	207,566	22,678	0	0
Tanzania, U. Rep. of	0.407	54,699	7,000	559,600	0	0	0	0	0
Thailand	0.768	2,620,082	452,462	12,432,600	0	39,453	0	88,503	5
Timor l'Est	0.436	350	0	0	0	0	0	0	0
Togo	0.495	22,485	0	36,700	0	3,976	0	0	0
Tonga	0.787	4,435	23	40,800	0	0	0	0	0
Trinidad and Tobago	0.801	9,740	0	416,600	0	0	0	105,808	3
Tunisia	0.745	89,518	1,271	5,510,600	0	20,027	0	0	1
Turkey	0.751	463,074	39,726	14,415,000	454	28,531	8,715	0	0
Turkmenistan	0.752	0	0	0	0	0	0	0	0
Ukraine	0.777	207,438	236	6,110,600	418	0	0	0	0
United Arab Emirates	0.824	95,150	2,300	6,233,600	4	88,492	3,548	500	5
United Kingdom	0.936	706,418	168,225	22,874,000	6	349,601	18,637	2,002,943	21
United States	0.939	4,971,257	166,951	47,009,933	855	1,028,606	45,347	1,647,389	105
Uruguay	0.833	116,360	0	1,074,400	0	0	0	0	0
Uzbekistan	0.709	0	0	15,400	0	0	0	0	0
Vanuatu	0.570	31,394	0	51,000	0	0	0	0	0

Nation	**HDI**	**Marine Fishery** (MT)	**Marine Aquaculture** (MT)	**International Tourism** (visitor)	**Shipbuilding Orderbook** (1000 GT)	**Shipping Cargo Traffic** (1000 MT)	**Merchant Fleet** (1000 DWT)	**Offshore Oil Production** (bbl/day)	**Offshore Rig Count** (number)
Venezuela	0.778	475,359	14,259	347,800	0	0	0	0	12
Viet Nam	0.691	1,534,560	361,717	2,076,500	79	12,077	0	330,700	9
Yemen	0.482	159,000	0	63,900	0	17,208	0	0	0

Sources: See last column in Table 1.

Note: An entry of zero reflects no activity or a very low level of activity. See the notes to Table 1 for data compilation criteria for individual industries.

Table 3. 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 4. Coastline Length (as Weights) by Nation and by LME

LME #	LME name	% coast	Nation
1	East Bering Sea	100.00	United States
2	Gulf of Alaska	29.64	Canada
2	Gulf of Alaska	70.36	United States
3	California Current	42.96	Mexico
3	California Current	57.04	United States
4	Gulf of California	100.00	Mexico
5	Gulf of Mexico	35.25	Mexico
5	Gulf of Mexico	64.75	United States
6	Southeast U.S. Continental Shelf	24.76	Bahamas, The
6	Southeast U.S. Continental Shelf	75.24	United States
7	Northeast U.S. Continental Shelf	15.78	Canada
7	Northeast U.S. Continental Shelf	84.22	United States
8	Scotian Shelf	100.00	Canada
9	Newfoundland-Labrador Shelf	99.33	Canada
9	Newfoundland-Labrador Shelf	0.67	St. Pierre and Miquelon
10	Insular Pacific-Hawaiian	100.00	United States
11	Pacific Central-American Coastal	11.57	Colombia
11	Pacific Central-American Coastal	10.42	Costa Rica
11	Pacific Central-American Coastal	13.30	Ecuador
11	Pacific Central-American Coastal	4.82	El Salvador
11	Pacific Central-American Coastal	3.59	Guatemala
11	Pacific Central-American Coastal	0.95	Honduras
11	Pacific Central-American Coastal	32.97	Mexico
11	Pacific Central-American Coastal	4.91	Nicaragua
11	Pacific Central-American Coastal	15.42	Panama
11	Pacific Central-American Coastal	2.05	Peru
12	Caribbean Sea	0.18	Aruba
12	Caribbean Sea	9.10	Bahamas
12	Caribbean Sea	0.24	Barbados
12	Caribbean Sea	2.41	Belize
12	Caribbean Sea	0.18	Cayman Islands
12	Caribbean Sea	7.64	Colombia
12	Caribbean Sea	1.29	Costa Rica
12	Caribbean Sea	20.86	Cuba
12	Caribbean Sea	0.45	Dominica
12	Caribbean Sea	5.84	Dominican Republic
12	Caribbean Sea	0.16	Grenada
12	Caribbean Sea	1.12	Guadeloupe
12	Caribbean Sea	0.65	Guatemala

LME #	LME name	% coast	Nation
12	Caribbean Sea	6.62	Haiti
12	Caribbean Sea	5.22	Honduras
12	Caribbean Sea	2.96	Jamaica
12	Caribbean Sea	0.63	Martinique
12	Caribbean Sea	3.40	Mexico
12	Caribbean Sea	0.81	Netherlands Antilles
12	Caribbean Sea	3.68	Nicaragua
12	Caribbean Sea	4.05	Panama
12	Caribbean Sea	2.55	Puerto Rico
12	Caribbean Sea	0.20	St. Kitts and Nevis
12	Caribbean Sea	0.44	St. Lucia
12	Caribbean Sea	0.15	St. Vincent and the Grenadines
12	Caribbean Sea	2.17	Trinidad and Tobago
12	Caribbean Sea	0.30	Turks and Caicos Islands
12	Caribbean Sea	0.11	United States
12	Caribbean Sea	16.26	Venezuela
12	Caribbean Sea	0.29	Virgin Islands
13	Humboldt Current	2.98	Argentina
13	Humboldt Current	86.37	Chile
13	Humboldt Current	10.65	Peru
14	Patagonian Shelf	69.82	Argentina
14	Patagonian Shelf	0.16	Chile
14	Patagonian Shelf	20.86	Falkland Islands
14	Patagonian Shelf	9.16	Uruguay
15	South Brazil Shelf	99.57	Brazil
15	South Brazil Shelf	0.43	Uruguay
16	East Brazil Shelf	100.00	Brazil
17	North Brazil Shelf	70.85	Brazil
17	North Brazil Shelf	5.27	French Guiana
17	North Brazil Shelf	9.28	Guyana
17	North Brazil Shelf	6.01	Suriname
17	North Brazil Shelf	8.58	Venezuela
18	West Greenland Shelf	100.00	Greenland
19	East Greenland Shelf	100.00	Greenland
20	Barents Sea	15.55	Norway
20	Barents Sea	72.43	Russia
20	Barents Sea	12.02	Svalbard
21	Norwegian Sea	100.00	Norway
22	North Sea	1.06	Belgium
22	North Sea	21.79	Denmark
22	North Sea	0.91	France
22	North Sea	7.60	Germany
22	North Sea	9.49	Netherlands
22	North Sea	24.00	Norway

LME #	LME name	% coast	Nation
22	North Sea	6.11	Sweden
22	North Sea	29.03	United Kingdom
23	Baltic Sea	9.23	Denmark
23	Baltic Sea	10.87	Estonia
23	Baltic Sea	19.28	Finland
23	Baltic Sea	7.79	Germany
23	Baltic Sea	4.75	Latvia
23	Baltic Sea	1.50	Lithuania
23	Baltic Sea	7.35	Poland
23	Baltic Sea	8.64	Russia
23	Baltic Sea	30.58	Sweden
24	Celtic-Biscay Shelf	21.31	France
24	Celtic-Biscay Shelf	21.29	Ireland
24	Celtic-Biscay Shelf	0.23	Jersey
24	Celtic-Biscay Shelf	1.17	Man, Isle of
24	Celtic-Biscay Shelf	56.00	United Kingdom
25	Iberian Coastal	1.66	France
25	Iberian Coastal	41.14	Portugal
25	Iberian Coastal	57.20	Spain
26	Mediterranean Sea	1.22	Albania
26	Mediterranean Sea	4.80	Algeria
26	Mediterranean Sea	7.19	Croatia
26	Mediterranean Sea	2.25	Cyprus
26	Mediterranean Sea	5.27	Egypt
26	Mediterranean Sea	4.11	France
26	Mediterranean Sea	0.35	Gaza Strip
26	Mediterranean Sea	20.50	Greece
26	Mediterranean Sea	0.84	Israel
26	Mediterranean Sea	19.17	Italy
26	Mediterranean Sea	0.84	Lebanon
26	Mediterranean Sea	7.04	Libya
26	Mediterranean Sea	0.16	Malta
26	Mediterranean Sea	0.09	Monaco
26	Mediterranean Sea	0.57	Montenegro
26	Mediterranean Sea	1.64	Morocco
26	Mediterranean Sea	0.11	Slovenia
26	Mediterranean Sea	7.16	Spain
26	Mediterranean Sea	0.56	Syria
26	Mediterranean Sea	4.57	Tunisia
26	Mediterranean Sea	11.55	Turkey
27	Canary Current	2.14	Gambia, The
27	Canary Current	2.99	Guinea-Bissau
27	Canary Current	17.54	Mauritania
27	Canary Current	29.38	Morocco

LME #	LME name	% coast	Nation
27	Canary Current	9.98	Senegal
27	Canary Current	16.11	Spain
27	Canary Current	21.87	Western Sahara
28	Guinea Current	1.66	Angola
28	Guinea Current	1.94	Benin
28	Guinea Current	6.20	Cameroon
28	Guinea Current	2.67	Congo-Brazaville
28	Guinea Current	5.74	Equatorial Guinea
28	Guinea Current	16.51	Gabon
28	Guinea Current	8.70	Ghana
28	Guinea Current	6.11	Guinea
28	Guinea Current	4.44	Guinea-Bissau
28	Guinea Current	12.59	Ivory Coast
28	Guinea Current	9.24	Liberia
28	Guinea Current	13.98	Nigeria
28	Guinea Current	1.36	Sao Tome and Principe
28	Guinea Current	7.13	Sierra Leone
28	Guinea Current	1.15	Togo
28	Guinea Current	0.59	Congo-Kinshasa
29	Benguela Current	38.40	Angola
29	Benguela Current	34.08	Namibia
29	Benguela Current	25.73	South Africa
30	Agulhas Current	2.53	Comoros
30	Agulhas Current	47.18	Madagascar
30	Agulhas Current	0.55	Mayotte
30	Agulhas Current	27.61	Mozambique
30	Agulhas Current	20.72	South Africa
30	Agulhas Current	1.41	Tanzania, United Republic of
31	Somali Coastal Current	14.38	Kenya
31	Somali Coastal Current	56.34	Somalia
31	Somali Coastal Current	29.28	Tanzania, United Republic of
32	Arabian Sea	0.45	Bahrain
32	Arabian Sea	1.52	Djibouti
32	Arabian Sea	23.92	India
32	Arabian Sea	16.20	Iran
32	Arabian Sea	0.51	Iraq
32	Arabian Sea	2.20	Kuwait
32	Arabian Sea	13.69	Oman
32	Arabian Sea	7.20	Pakistan
32	Arabian Sea	2.79	Qatar
32	Arabian Sea	4.44	Saudi Arabia
32	Arabian Sea	8.19	Somalia
32	Arabian Sea	6.97	United Arab Emirates
32	Arabian Sea	11.91	Yemen

LME #	LME name	% coast	Nation
33	Red Sea	0.68	Djibouti
33	Red Sea	25.04	Egypt
33	Red Sea	3.35	Egypt, administered by Sudan
33	Red Sea	17.13	Eritrea
33	Red Sea	0.16	Israel
33	Red Sea	0.27	Jordan
33	Red Sea	34.60	Saudi Arabia
33	Red Sea	9.94	Sudan
33	Red Sea	8.83	Yemen
34	Bay of Bengal	8.09	Bangladesh
34	Bay of Bengal	29.79	India
34	Bay of Bengal	16.82	Indonesia
34	Bay of Bengal	7.17	Malaysia
34	Bay of Bengal	21.81	Myanmar (Burma)
34	Bay of Bengal	11.12	Sri Lanka
34	Bay of Bengal	5.19	Thailand
35	Gulf of Thailand	12.93	Cambodia
35	Gulf of Thailand	19.41	Malaysia
35	Gulf of Thailand	56.32	Thailand
35	Gulf of Thailand	11.34	Vietnam
36	South China Sea	1.54	Brunei
36	South China Sea	27.94	China
36	South China Sea	1.01	Hong Kong
36	South China Sea	21.37	Indonesia
36	South China Sea	11.63	Malaysia
36	South China Sea	12.15	Philippines
36	South China Sea	0.43	Singapore
36	South China Sea	2.99	Taiwan
36	South China Sea	20.95	Vietnam
37	Sulu-Celebes Sea	13.96	Indonesia
37	Sulu-Celebes Sea	8.42	Malaysia
37	Sulu-Celebes Sea	77.61	Philippines
38	Indonesian Sea	100.00	Indonesia
39	North Australian Shelf	100.00	Australia
40	Northeast Australian Shelf	98.53	Australia
40	Northeast Australian Shelf	1.47	Papua New Guinea
41	East Central Australian Shelf	100.00	Australia
42	Southeast Australian Shelf	100.00	Australia
43	Southwest Australian Shelf	100.00	Australia
44	West Central Australian Shelf	100.00	Australia
45	Northwest Australian Shelf	100.00	Australia
46	New Zealand Shelf	100.00	New Zealand
47	East China Sea	44.37	China
47	East China Sea	30.83	Japan

LME #	LME name	% coast	Nation
47	East China Sea	18.21	South Korea
47	East China Sea	6.59	Taiwan
48	Yellow Sea	70.36	China
48	Yellow Sea	13.65	North Korea
48	Yellow Sea	15.99	South Korea
49	Kuroshio Current	95.48	Japan
49	Kuroshio Current	4.52	Taiwan
50	Sea of Japan	41.93	Japan
50	Sea of Japan	9.35	North Korea
50	Sea of Japan	43.07	Russia
50	Sea of Japan	5.65	South Korea
51	Oyashio Current	26.42	Japan
51	Oyashio Current	73.58	Russia
52	Sea of Okhotsk	4.37	Japan
52	Sea of Okhotsk	95.63	Russia
53	West Bering Sea	89.89	Russia
53	West Bering Sea	10.11	United States
54	Chukchi Sea	0.37	Canada
54	Chukchi Sea	0.91	Greenland
54	Chukchi Sea	38.92	Russia
54	Chukchi Sea	59.79	United States
55	Beaufort Sea	65.62	Canada
55	Beaufort Sea	34.38	United States
56	East Siberian Sea	100.00	Russia
57	Laptev Sea	100.00	Russia
58	Kara Sea	100.00	Russia
59	Iceland Shelf	100.00	Iceland
60	Faroe Plateau	100.00	Faroe Islands
61	Antarctica	100.00	Antarctica
62	Black Sea	4.05	Bulgaria
62	Black Sea	4.77	Georgia
62	Black Sea	6.44	Romania
62	Black Sea	19.81	Russia
62	Black Sea	24.45	Turkey
62	Black Sea	40.48	Ukraine
63	Hudson Bay	100.00	Canada

Data Source: Goldsmith (2005).

Table 5. Mapping of LMEs to Regional Seas

Regional Sea	**LME #***
Antarctic	61
Arctic	54, 55, 56, 57, 58, 64
Baltic Sea	23
Black Sea	62
Caspian Sea	--
East Asian Seas	35, 36, 37, 38, 39, 44, 45
Eastern Africa	30, 31
Mediterranean	26
North-East Atlantic	19, 20, 21, 22, 24, 25, 59, 60
North-East Pacific	1, 2, 3, 4, 11
North-West Pacific	47, 48, 49, 50, 51, 52, 53
Red Sea and Gulf of Aden	33
ROPME Sea Area	32
South Asian Seas	34
South Pacific	40, 41, 42, 46
South-East Pacific	13
South-West Atlantic	14, 15, 16, 17
West and Central Africa	27, 28, 29
Wider Caribbean	5, 6, 12

Source: UNEP (2004).

* See Table 6 for LME names.

Note: In our calculation, LME 19 and LME 60 were excluded from Northeastern Atlantic Seas and LME 64 was excluded from Arctic Seas for lack of socioeconomic and marine industry activity data.

Table 6. LME Areas

LME #	LME	Area (km2)
1	East Bering Sea	1,356,989
2	Gulf of Alaska	1,465,110
3	California Current	2,208,710
4	Gulf of California	221,575
5	Gulf of Mexico	1,529,669
6	Southeast U.S. Continental Shelf	316,855
7	Northeast U.S. Continental Shelf	303,175
8	Scotian Shelf	282,953
9	Newfoundland-Labrador Shelf	896,468
10	Insular Pacific-Hawaiian	979,225
11	Pacific Central-American Coastal	1,982,191
12	Caribbean Sea	3,259,214
13	Humboldt Current	2,544,850
14	Patagonian Shelf	1,163,067
15	South Brazil Shelf	565,471
16	East Brazil Shelf	1,074,984
17	North Brazil Shelf	1,049,727
18	West Greenland Shelf	374,941
19	East Greenland Shelf	319,087
20	Barents Sea	1,714,095
21	Norwegian Shelf	1,116,127
22	North Sea	693,840
23	Baltic Sea	390,077
24	Celtic-Biscay Shelf	755,886
25	Iberian Coastal	303,054
26	Mediterranean Sea	2,516,484
27	Canary Current	1,121,173
28	Guinea Current	1,919,654
29	Benguela Current	1,456,812
30	Agulhas Current	2,622,579
31	Somali Coastal Current	840,709
32	Arabian Sea	3,929,701
33	Red Sea	458,617
34	Bay of Bengal	3,660,127
35	Gulf of Thailand	386,878
36	South China Sea	3,159,956
37	Sulu-Celebes Sea	1,007,498
38	Indonesian Sea	2,261,845
39	North Australian Shelf	778,782
40	Northeast Australian Shelf/Great Barrier Reef	1,281,041
41	East-Central Australian Shelf	651,044

LME #	LME	Area (km2)
42	Southeast Australian Shelf	1,187,652
43	Southwest Australian Shelf	1,047,703
44	West-Central Australian Shelf	543,733
45	Northwest Australian Shelf	911,306
46	New Zealand Shelf	963,394
47	East China Sea	775,065
48	Yellow Sea	437,376
49	Kuroshio Current	1,316,879
50	Sea of Japan	983,843
51	Oyashio Current	530,381
52	Sea of Okhotsk	1,552,663
53	West Bering Sea	1,992,919
54	Chukchi Sea	556,899
55	Beaufort Sea	772,183
56	East Siberian Sea	926,721
57	Laptev Sea	499,039
58	Kara Sea	797,171
59	Iceland Shelf	315,535
60	Faroe Plateau	149,946
61	Antarctic	4,328,522
62	Black Sea	460,151
63	Hudson Bay	841,214
64	Arctic Ocean	6,048,285

Source: The Sea Around Us Project (2005).

Table 7: 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

LME	LME#	Socioeconomic Index (HDI)	Fishery & Aquaculture Index	Tourism Index	Ship & Oil Index*	Marine Industry Activity Index
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
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

LME	LME#	Socioeconomic Index (HDI)	Fishery & Aquaculture Index	Tourism Index	Ship & Oil Index*	Marine Industry Activity Index
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
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) on pages 11 and 12.

Table 8: Socioeconomic and Marine Industry Activity Indexes for LMEs (ranked in order of Marine Activity Index)

LME	LME#	Socioeconomic Index	Fishery & Aquaculture Index	Tourism Index	Ship & Oil Index*	Marine Industry Activity Index
Yellow Sea	48	73.442	71.837	44.410	36.865	45.369
East China Sea	47	84.076	51.891	30.773	42.147	41.821
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
Gulf of Mexico	5	89.071	13.021	46.271	36.611	33.825
Kuroshio Current	49	93.628	18.324	6.705	45.846	32.514
California Current	3	88.015	12.055	43.729	35.002	32.158
Gulf of Alaska	2	94.019	13.716	48.248	32.496	31.891
Southeast U.S. Continental Shelf	6	90.830	13.131	44.030	33.082	31.282
Chukchi Sea	54	87.433	14.683	34.858	27.524	26.422
South China Sea	36	73.777	34.521	22.269	14.902	20.299
Beaufort Sea	55	94.163	9.198	36.539	18.570	20.289
Gulf of California	4	80.200	4.907	24.923	23.096	19.823
Norwegian Shelf	21	95.600	10.703	3.662	27.969	19.654
Sea of Japan	50	83.263	13.262	3.529	23.976	17.744
Celtic-Biscay Shelf	24	92.204	2.482	38.841	14.639	17.048
North Sea	22	94.021	5.275	14.384	16.405	13.775
Oyashio Current	51	83.278	13.031	2.138	14.904	11.976
Iberian Coastal	25	91.188	2.482	47.324	3.155	11.854
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	Fishery & Aquaculture Index	Tourism Index	Ship & Oil Index*	Marine Industry Activity Index
Newfoundland-Labrador Shelf	9	93.668	4.848	25.182	5.227	9.142
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
Northeast Australian Shelf/Great Barrier Reef	40	94.006	0.833	6.491	12.540	8.989
Mediterranean Sea	26	83.262	1.087	27.192	4.595	8.413
Barents Sea	20	83.939	10.839	1.288	9.972	8.409
West Bering Sea	53	80.956	11.553	6.199	7.251	7.901
Indonesian Sea	38	69.200	16.159	6.686	3.872	6.892
Pacific Central-American Coastal	11	77.304	2.431	8.856	7.634	6.838
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
Gulf of Thailand	35	73.826	7.309	13.395	3.268	6.102
Sea of Okhotsk	52	80.125	11.245	0.675	5.071	5.426
Patagonian Shelf	14	86.846	2.763	8.225	5.085	5.249
Bay of Bengal	34	63.400	7.675	4.571	4.088	4.902
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
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
Canary Current	27	61.160	2.365	14.278	0.806	3.812
Humboldt Current	13	83.015	15.241	1.721	0.178	3.499

LME	LME#	Socioeconomic Index	Fishery & Aquaculture Index	Tourism Index	Ship & Oil Index*	Marine Industry Activity Index
Baltic Sea	23	90.324	2.120	8.086	2.378	3.468
Black Sea	62	77.323	2.859	7.941	1.176	2.865
Arabian Sea	32	62.635	2.895	2.300	2.766	2.698
Benguela Current	29	53.103	1.805	2.127	2.791	2.461
Caribbean Sea	12	73.177	1.010	3.603	2.197	2.241
Red Sea	33	62.564	0.268	5.583	1.381	1.999
Iceland Shelf	59	94.100	6.865	0.417	0.029	1.474
New Zealand Shelf	46	92.600	2.092	2.876	0.403	1.235
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
Somali Coastal Current	31	34.710	0.098	0.357	0.025	0.106

* Including shipbuilding, shipping, and offshore oil.

Note: All values are 100 times the indexes calculated using Eqs. (3) and (4) on pages 11 and 12.

Table 9: Classification of LMEs

	Low socioeconomic development ($SEI < 50$)	**Medium socioeconomic development** ($50 \leq SEI < 80$)	**High socio- development** ($SEI \geq 80$)
High marine industry activity ($MAI \geq 30$)	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 ($5 \leq MAI < 30$)	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

	Low socioeconomic development (*SEI* < 50)	**Medium socioeconomic development** (50 ≤ *SEI* < 80)	**High socio- development** (*SEI* ≥ 80)
			42. Southeast Australian Shelf 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

Table 10: Socioeconomic and Marine Industry Activity Indexes for Regional Seas (ranked in order of the Socioeconomic Index)

RSP	Socio-economic Index	Fishery & Aquaculture Index	Tourism Index	Ship & Oil Index*	Marine Industry Activity Index
Eastern Africa	44.483	0.688	1.459	0.463	0.708
West-Central Africa	52.771	1.324	4.374	1.411	1.986
Red Sea and Gulf of Aden	62.564	0.268	5.583	1.381	1.999
ROPME Sea Area	62.635	2.895	2.300	2.766	2.698
South Asian Seas	63.400	7.675	4.571	4.088	4.902
Black Sea	77.323	2.859	7.941	1.176	2.865
East Asian Seas	77.887	17.733	12.137	9.810	11.860
Wider Caribbean	79.034	5.360	18.895	14.424	13.505
South-West Atlantic	80.203	2.276	5.388	6.952	5.704
South-East Pacific	83.015	15.241	1.721	0.178	3.499
Mediterranean	83.262	1.087	27.192	4.595	8.413
North-West Pacific	83.332	20.584	9.238	21.476	18.850
Arctic	83.931	11.117	13.649	10.306	11.137
North-East Pacific	87.160	10.545	37.170	28.314	26.531
Baltic Sea	90.324	2.120	8.086	2.378	3.468
North-East Atlantic	90.402	7.957	12.271	14.642	12.831
South Pacific	93.942	1.132	5.681	9.761	7.219

*Including shipbuilding, shipping, and offshore oil.

Note: All values are 100 times the indexes calculated using Eqs. (5) and (6). The Caspian Sea Regional Sea is not on this list because there is no corresponding LME. The Antarctic Regional Sea is not on this list because there is little economic activity.

Table 11: Socioeconomic and Marine Industry Activity Indexes for Regional Seas (ranked in order of the Marine Industry Activity Index)

RSP	Socio-economic Index	Fishery & Aquaculture Index	Tourism Index	Ship & Oil Index*	Marine Industry Activity Index
North-East Pacific	87.160	10.545	37.170	28.314	26.531
North-West Pacific	83.332	20.584	9.238	21.476	18.850
Wider Caribbean	79.034	5.360	18.895	14.424	13.505
North-East Atlantic	90.402	7.957	12.271	14.642	12.831
East Asian Seas	77.887	17.733	12.137	9.810	11.860
Arctic	83.931	11.117	13.649	10.306	11.137
Mediterranean	83.262	1.087	27.192	4.595	8.413
South Pacific	93.942	1.132	5.681	9.761	7.219
South-West Atlantic	80.203	2.276	5.388	6.952	5.704
South Asian Seas	63.400	7.675	4.571	4.088	4.902
South-East Pacific	83.015	15.241	1.721	0.178	3.499
Baltic Sea	90.324	2.120	8.086	2.378	3.468
Black Sea	77.323	2.859	7.941	1.176	2.865
ROPME Sea Area	62.635	2.895	2.300	2.766	2.698
Red Sea and Gulf of Aden	62.564	0.268	5.583	1.381	1.999
West-Central Africa	52.771	1.324	4.374	1.411	1.986
Eastern Africa	44.483	0.688	1.459	0.463	0.708

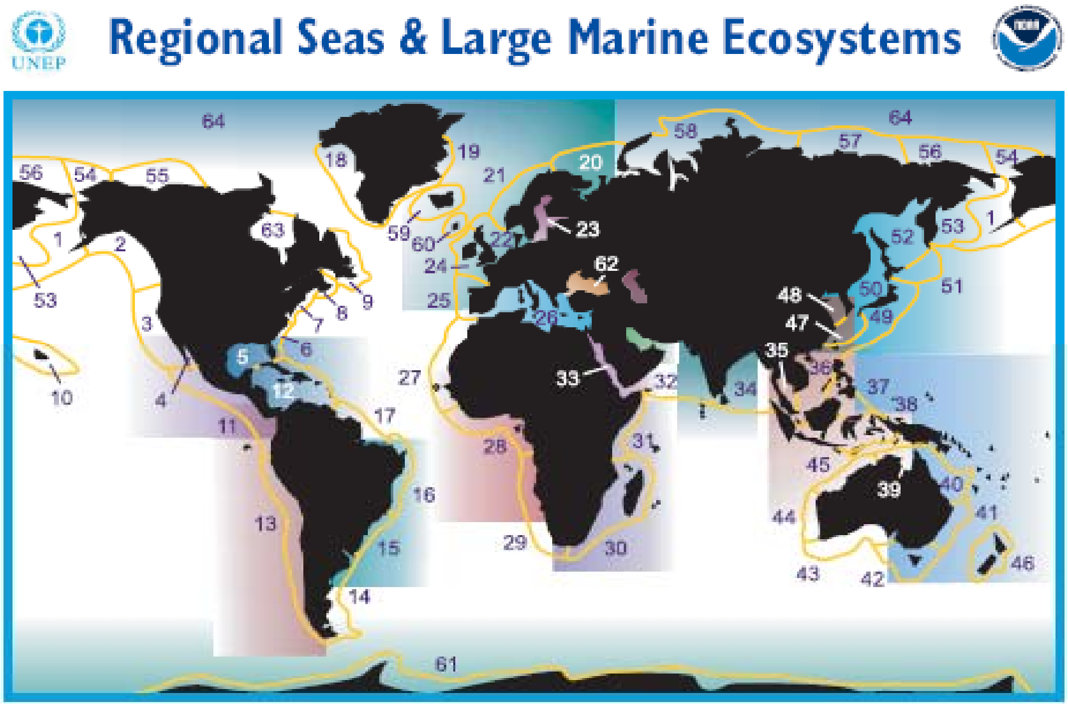
*Including shipbuilding, shipping, and offshore oil.

Note: All values are 100 times the indexes calculated using Eqs. (5) and (6). The Caspian Sea Regional Sea is not on this list because there is no corresponding LME. The Antarctic Regional Sea is not on this list because there is little economic activity.

Table 12: Classification of Regional Seas

	Low socioeconomic development ($SEI < 50$)	**Medium socioeconomic development** ($50 \leq SEI < 80$)	**High socioeconomic development** (SEI ≥ 80)
High marine industry activity ($MAI \geq 20$)			North-East Pacific
Medium marine industry activity ($5 \leq MAI < 20$)		Wider Caribbean East-Asian Seas	North-West Pacific South-West Atlantic South Pacific Mediterranean Arctic North-East Atlantic
Low marine industry activity ($MAI < 5$)	Eastern Africa	West & Central Africa Red Sea & Gulf of Aden ROPME Sea Area Black Sea South Asian Seas	Baltic Sea South-East Pacific

Fig. 1: Regional seas and large marine ecosystems
Source: UNEP and NOAA (2005).



REGIONAL SEAS, WEST TO EAST:
North-East Pacific ◆ South-East Pacific ◆ Wider Caribbean ◆ South-West Atlantic
West & Central Africa ◆ Mediterranean ◆ Black Sea ◆ Eastern Africa ◆ Red Sea & Gulf of Aden
ROPME Sea Area ◆ South Asian Seas ◆ East Asian Seas ◆ North-West Pacific ◆ South Pacific

INDEPENDENT PARTNERS:
Arctic ◆ North-East Atlantic ◆ Baltic Sea ◆ Caspian Sea ◆ Antarctic

64 LMEs OF THE WORLD

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

Fig 2: Ranking of LMEs by Marine Industry Activity

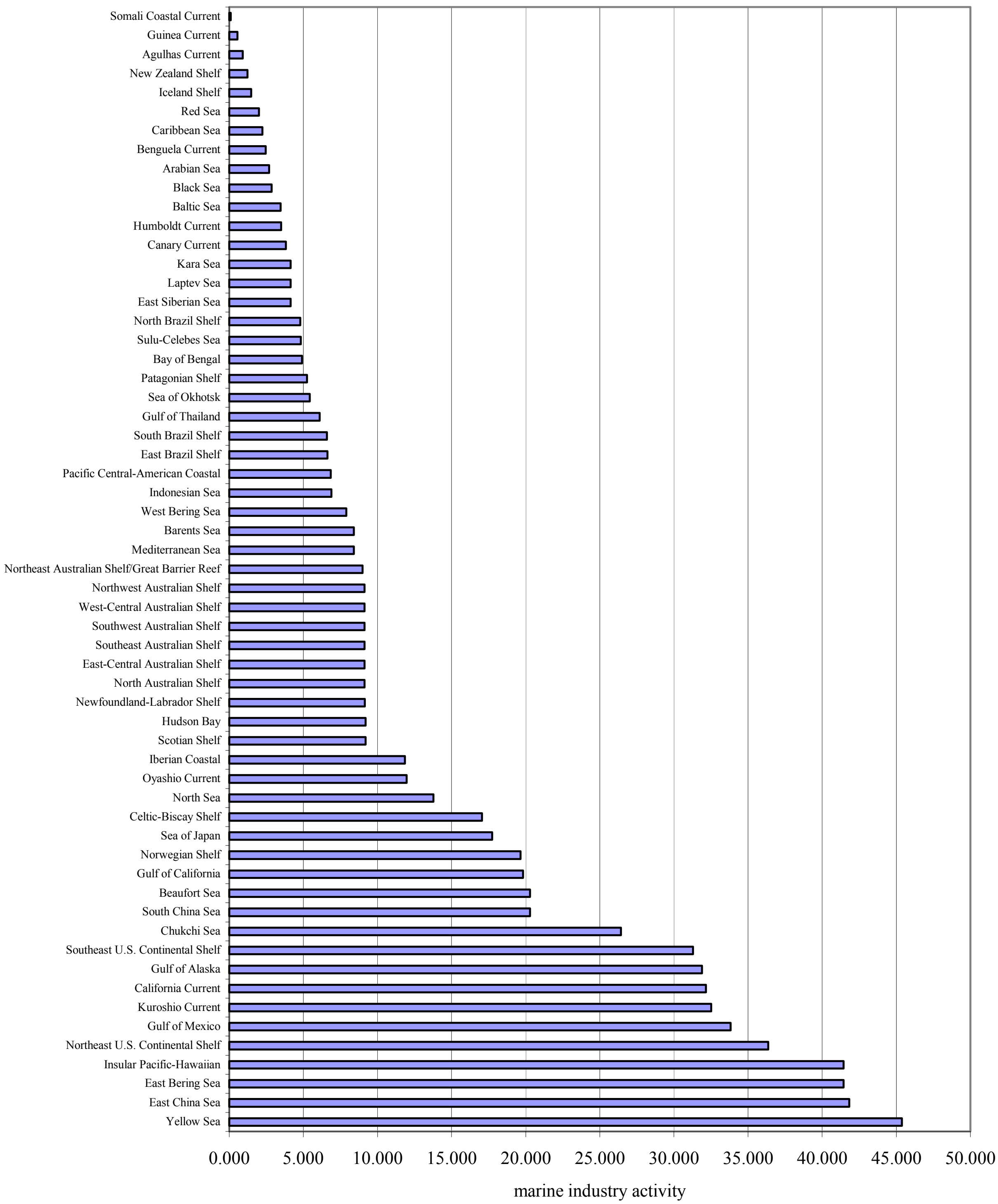


Figure 3: Ranking of LMEs by Area-adjusted Marine Industry Activity

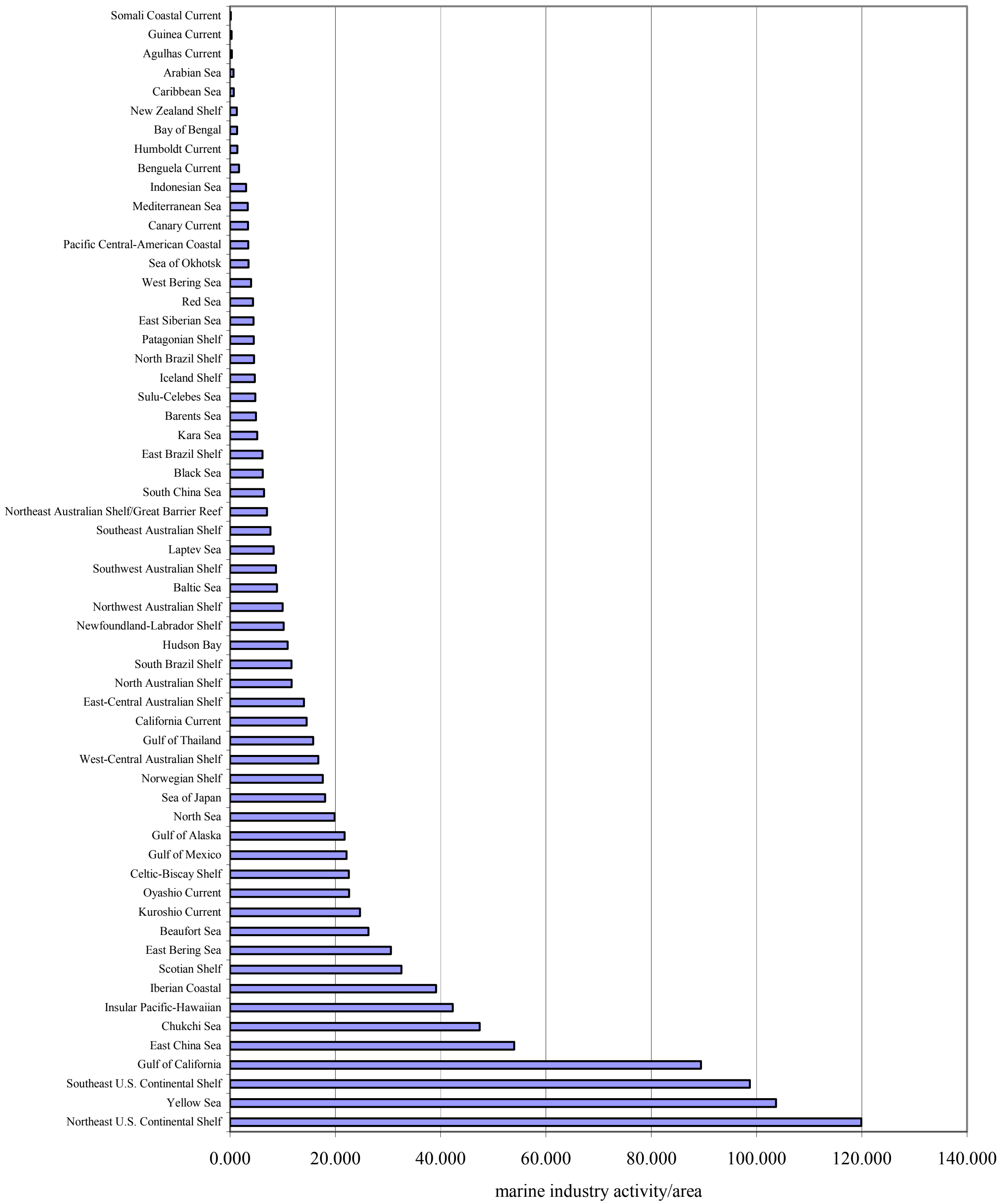


Figure 4: Ranking of LMEs by MAI/SEI

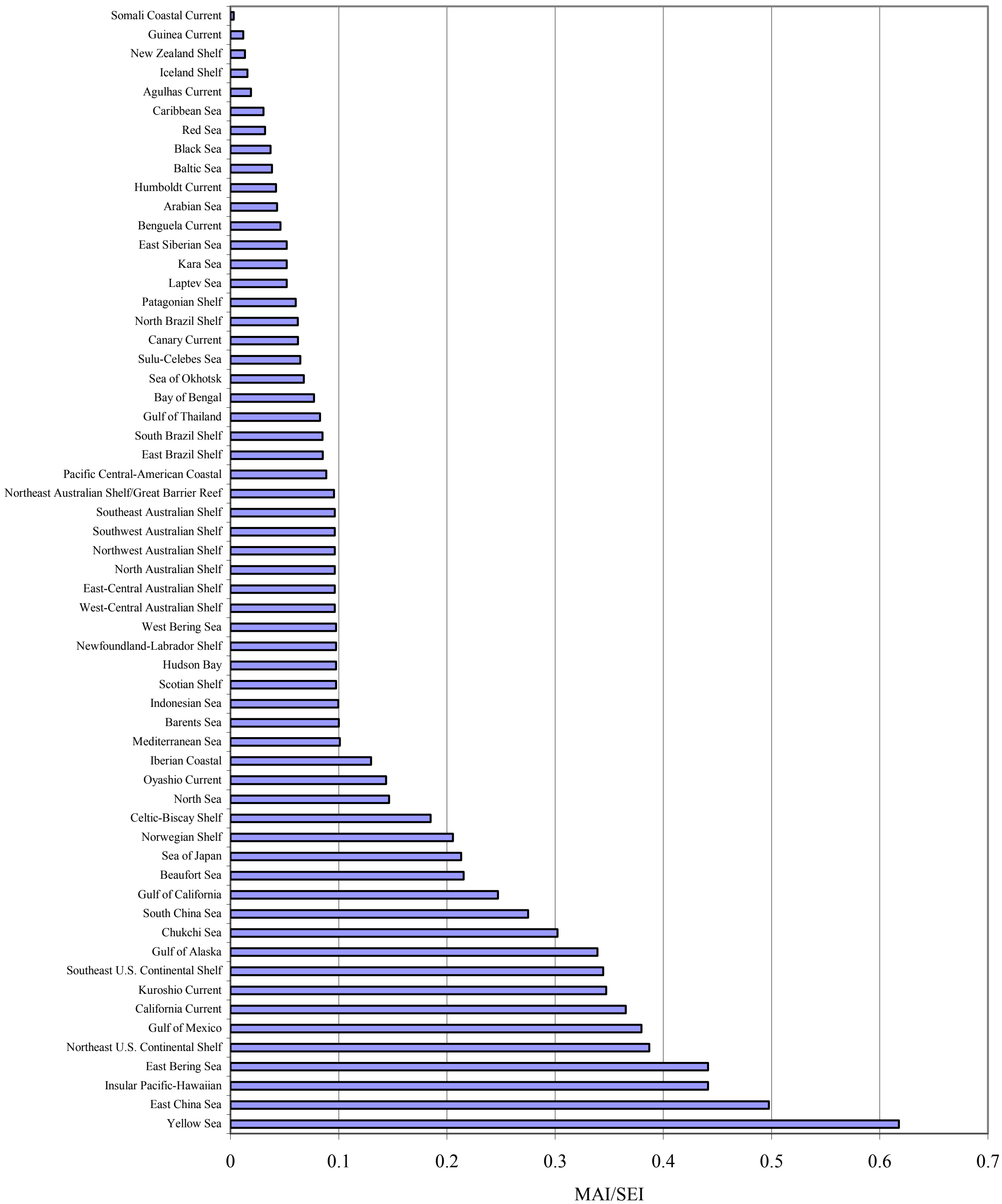


Fig.5: Intensity of activity in large marine ecosystems: indexes showing the relationship between marine industry activity and socioeconomic development. The data for four representative LME cases are labeled on the graph.

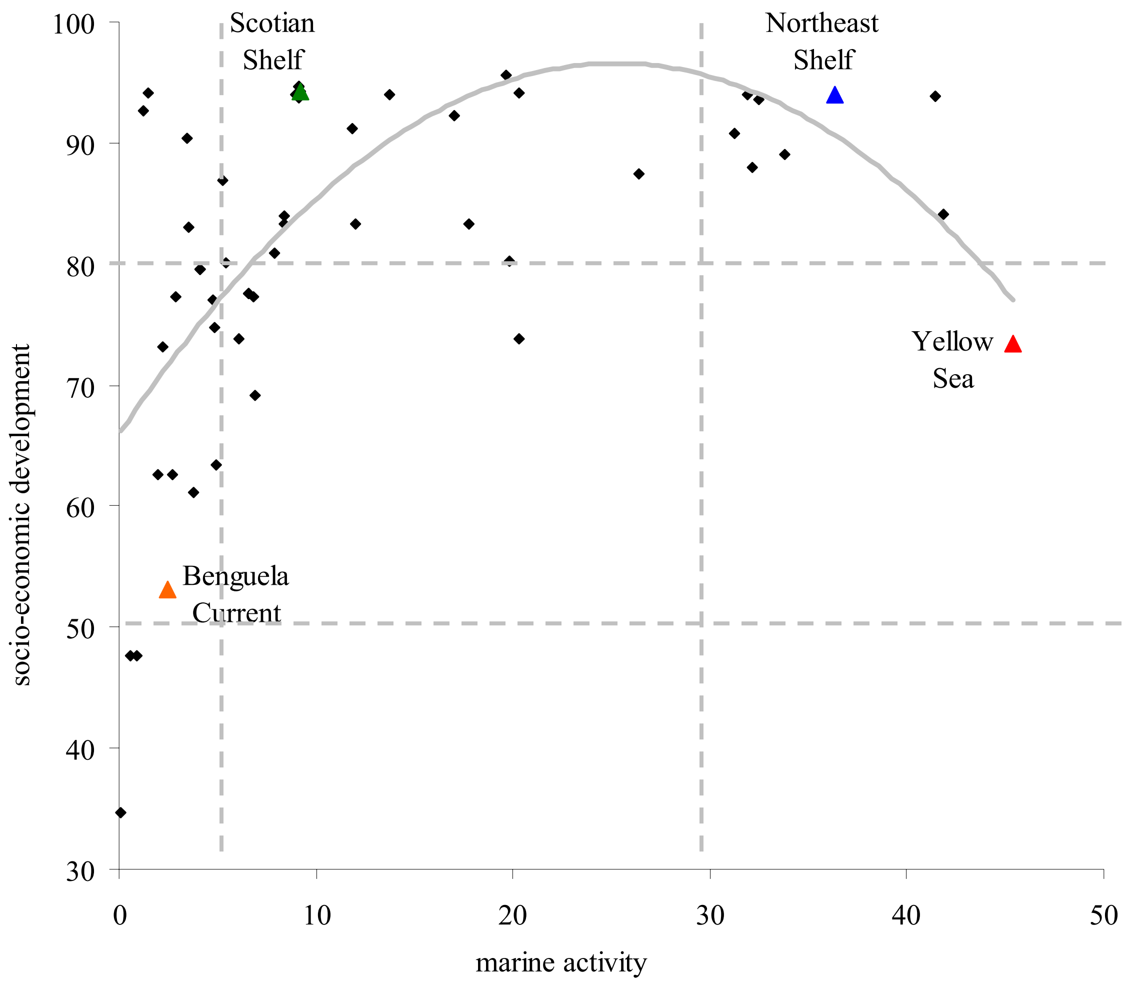


Figure 6: Ranking of Regional Seas by Marine Industry Activity

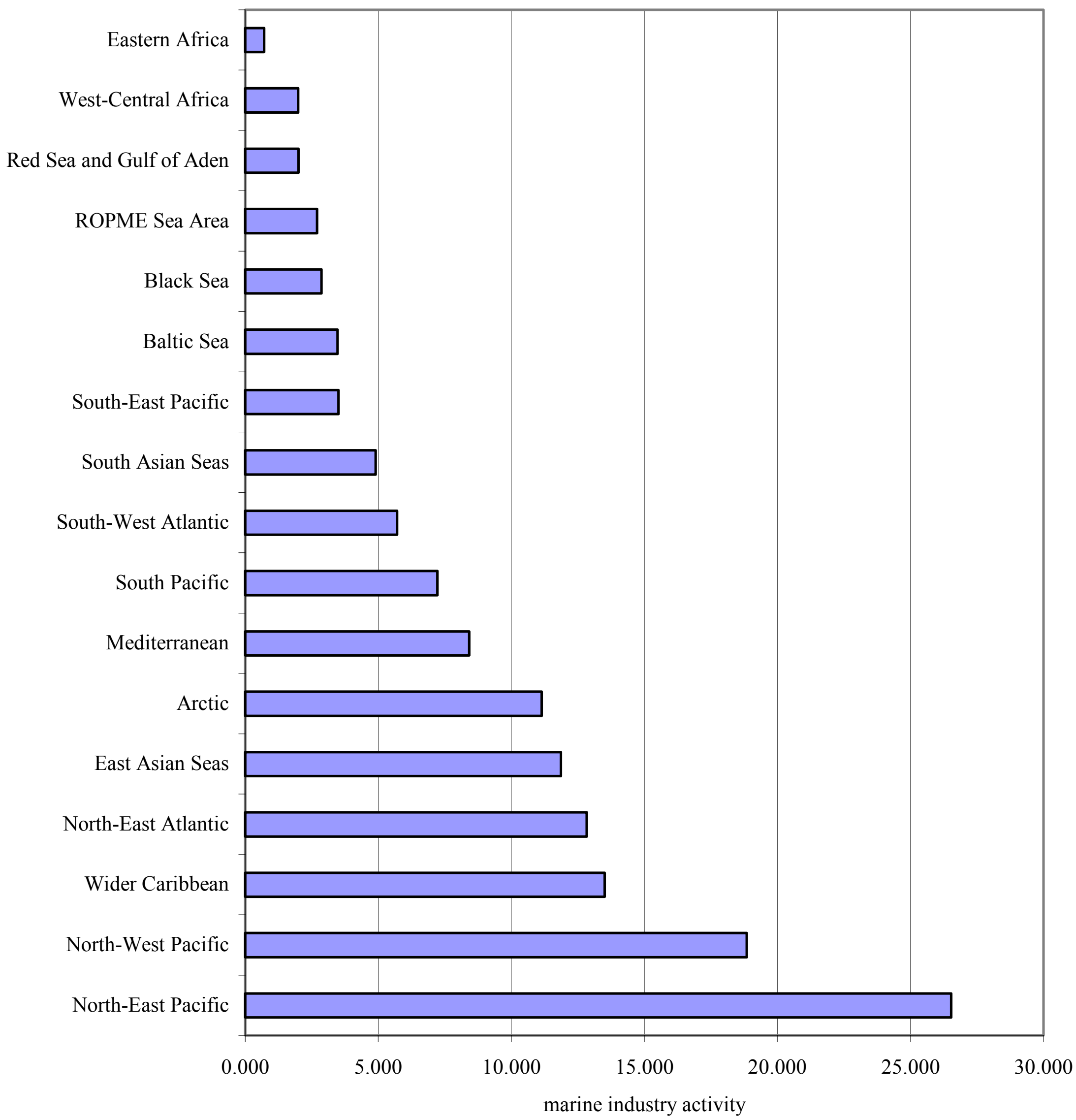


Figure 7: Ranking of Regional Seas
by MAI/SEI Ranking

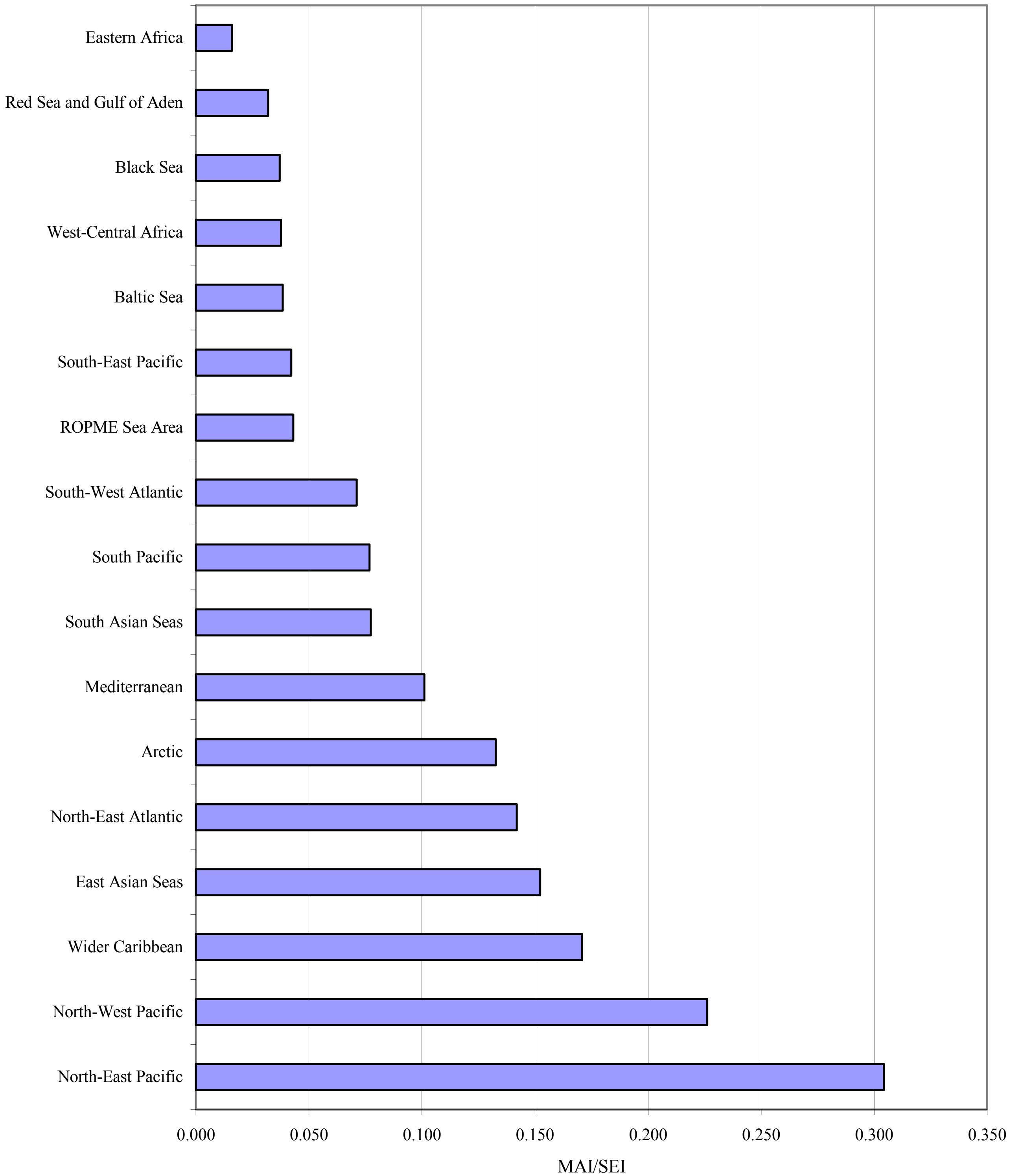
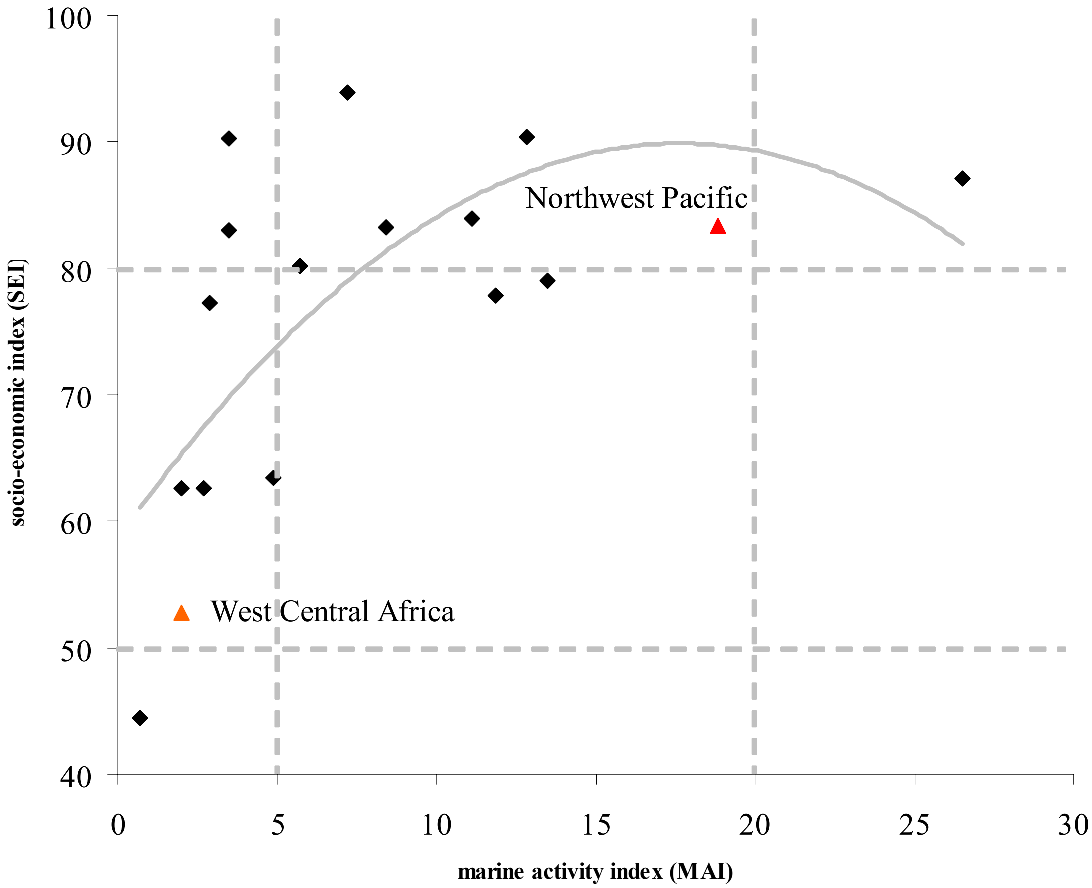


Fig.8: Intensity of activity in Regional Seas: indexes showing the relationship between marine industry activity and socioeconomic development. The data for two representative Regional Seas are labeled on the graph.



Annex I

Case Study: Benguela Current Large Marine Ecosystem[1]

I. Introduction

This case study focuses on characterizing the potential for the nations of the Benguela Current large marine ecosystem (BCLME), which include Angola, Namibia, and South Africa, to manage and conserve the marine environment in a sustainable fashion. We identify the ocean-related activities of the nations in the region, review the literature relating to the potential effectiveness of political institutions, and develop an estimate of the scale of resource rents that obtain from the use of marine resources. We rely upon a rapidly growing body of literature that describes the economic, social, and political features of the region (*e.g.*, Cullinan *et al*. 2005; Prochazka *et al*. 2005; Sumaila *et al*. 2005; Lange 2004, 2003; Russo *et al*. 2004; Blackie and Tarr 1999; Shannon and O'Toole 1999; Tapscott 1999; UNDP *et al*. 1999), as well as published and unpublished data from both international and domestic sources (Anon. 2005, 2003; BAA 2005a, b, c; Coakley 2003a, b; FAO 2004, 2002, 2001; McLean 2005).

We find that the scale of resource rents from the use of BCLME resources is significant, on the order of $4 billion a year. Annual rents are expected to grow with expanding worldwide demand for petroleum products, especially natural gas, and forage fish landings, especially pilchards and mackerels. At present, the source of rents from ocean resources is heavily skewed toward Angola, deriving mainly from offshore oil

[1] Chris Vonderweidt assisted in the initial literature searches and discussions about this case study.

production. In the future, we expect this distribution to persist, although increasingly the production of oil will take place off South Africa, and natural gas will be produced off the coastlines of all three nations.

Although the typical range of marine pollution problems exists on a small scale, the clearest market failure involves the historical overexploitation of the fisheries, particularly those in the potentially most productive upwelling region, off the coast of Namibia (Prochazka *et al*. 2005). Importantly, with efficient management, considerable potential exists for the continued recovery of the capture fisheries, particularly in Namibia and Angola. Rational fishery management in this region may require international cooperation on transboundary straddling stocks (Sumaila *et al*. 2005). Expansion of the offshore hydrocarbon sector could continue to be a source of resource rents for all three nations.

The implementation of a program of sustainable management of the marine environment is a political decision, involving gains and losses to different sectors of a nation's economy and to the peoples of the region now and in the future. The three BCLME nations continue to face significant environmental, public health, and social welfare problems, which are mostly unrelated to the status of the marine environment. These problems may deserve the priority attention of political leaders, ahead of issues of marine policy.

Notwithstanding the priority to devote resource rents from the development of marine natural resources to improve social welfare, the scale of these rents is sufficient to continue to support existing efforts to improve marine management. At the very least, the sustainable management programs, involving scientific research and capacity building, which have been organized by GEF and the BCLME nations, might be continued at the same or even a slightly expanded scale. In an optimistic future, as the economies of these nations develop, and hopefully as their social problems abate, any residual problems of marine pollution and resource misallocations can be accorded a higher priority in national and regional public policy.

II. Background

A. Benguela Current Region

The Benguela Current large marine ecosystem is located along the southwest coast of Africa (Fig. 1). It runs along the western coast of South Africa, including its two Cape Town provinces, past the coast of Namibia, and up to and including Angola. The Angolan enclave of Cabinda is considered to be a part of both the BCLME and the adjacent Guinea Current large marine ecosystem to the north. Cabinda is a small enclave that is not contiguous with the main Angolan state. It lies to the north of the short coast of the Democratic Republic of the Congo (formerly Zaire). The coast of the Congo is not considered to be a part of the BCLME.

The geographic region has been described by Clark *et al*. (1999) and Crawford *et al*. (1989). The BCLME is one of the world's four major eastern boundary current systems. It is the world's most powerful wind-driven coastal upwelling system, characterized by annual upwelling along the coast of southern Namibia and seasonal upwelling to the north and south. It is bounded by sharp fronts where it abuts warm-water regimes to the north (the south equatorial eastern Atlantic counter current) and the south (the Agulhas current), making it somewhat unique in that respect. The main Benguela Current runs from south to north along the coasts of the three BCLME nations.

Climate is the primary driver of the BCLME system, and evidence is beginning to mount that environmental variability is increasing as a consequence of climate change. Teleconnections have been theorized between the Benguela Current and ocean-climate processes in the North Atlantic and the Pacific (including El Niño). The BCLME is very productive, and satellite primary production samples rate this region as a Class I (high biological productivity) ecosystem (>300gC/m^2/yr). For decades, the BCLME has been exploited heavily for pelagic forage stocks, especially pilchards and mackerels, and for other species, including groundfish, rock lobster, high seas tunas, shrimps, and deepsea species (Nichols 2004). Total yields of all stocks are reasonably stable, although regime shifts have been experienced, probably exacerbated by heavy commercial exploitation. The area now comprising the Namibian fisheries zone was especially overfished by distant water fleets prior to Namibian independence in 1990. Pollution is mainly localized in small harbor environments, but all major forms of pollution and ecosystem degradation are known to exist, including excessive nutrient inputs in coastal waters, hazardous wastes from mine tailings, dredge spoils, coastal mangrove deforestation, soil erosion, oil spills, marine debris, and invasive species.

B. Marine Industries

Table 1 identifies the array of marine activities by nation as discussed by Tapscott (1999) and others. Fig. 2 compares BCLME index values of some of these activities with the world average across all large marine ecosystems (see section 1 of this report). This comparison suggests that, although the BCLME is known to have significant development potential, levels of marine activities are relatively minor to date. In the future, we expect to see these activity levels expand, particularly through the further development of offshore hydrocarbon resources, more effective exploitation of the capture fisheries, and growth in the tourism sector.

Tables 2-5 present the annual scale of various activities in physical quantities and, where available, as direct output impacts (US dollars). Fig. 3 depicts the scale of direct output impacts by resource type for the BCLME region taken as a whole. These data are updates of estimates provided by Tapscott (1999) that have been obtained from a variety of international data sources. Offshore oil production in Angola (~$10 billion per year) and offshore diamond dredging in Namibia (~$2 billion per year) are unquestionably the most economically important marine activities in the region. Coastal tourism in Namibia (~0.7 billion per year) and Cape Town (scale unknown) are the next most significant economic activities.

Fisheries in Namibia (~$0.4 billion per year) and Cape Town (~$0.2 billion per year) are valuable as well. Fisheries in Angola are less important (less than $0.2 billion per year), and continued pressure on the pilchard stocks by South Africa may limit their growth in the near term (Strømme and Sætersdal 1986). Small-scale coastal fisheries in Angola play important social and food security roles, however (Sumaila *et al*. 2003). None of these nations has a merchant fleet to speak of, and none has a shipbuilding capacity. Only South Africa reports significant shipping and cargo traffic. There are very significant efforts to explore for offshore hydrocarbons; these efforts are well advanced in both near shore and deep offshore environments on the outer continental shelves of Angola, southwestern Namibia, and Cape Town.

C. Socio-Political Issues

The three nations of the BCLME are relatively young and developing. All three are characterized by dichotomous economies in which a well-developed industrial sector (oil in Angola, mining in Namibia and South Africa, and industrial agriculture in South Africa) is mirrored by an undeveloped, agrarian sector. Although civil wars and insurgencies appear to have dissipated, all three countries continue to experience a number of serious political and social problems. These problems make it more difficult for the issue of sustainable marine resource management to be accorded a priority in the foreseeable future, except on paper.

Notwithstanding the policy and management challenges posed by these problems, three regional characteristics do encourage some optimism about the more distant future. These characteristics include a mutual recognition that the marine environment is highly productive; growing evidence of slow but measurable progress in resolving some political issues; and the interest of international development agencies in providing foreign aid.

Angola is still in the early stages of shaking off the debilitating effects of a multi-decadal civil war that ended only in 2002. Roughly ten percent of the Angolan population was killed in the war, and another 40 percent was displaced from their homes and lands. The World Bank has committed some $100 million to assist Angola in the resettlement of internally displaced persons. Angola has experienced recent floods and droughts, both of which have led to famine in certain locations. Ironically, Angolan lands have the potential to be highly productive for agriculture, but many areas continue to be riddled with land mines, which has stalled the rehabilitation of the agricultural sector and exacerbates the hunger problem. A clear near-term priority is the rebuilding of the transportation infrastructure, which was severely damaged during the civil war and is needed to help move oil resources to markets.

Namibia's situation is brighter than Angola's, but the country still faces a wide array of economic development issues. Namibian minerals and fisheries are potentially among the most valuable in the world, which bodes well for the country's future. One legacy of the historical South African occupation is a largely inadequately trained workforce, inexperienced in corporate and public administration (McLean 2005). Namibia also has one of the most skewed income distributions in Africa. Land redistribution is a major policy hurdle, as nearly one-quarter of a million people require resettlement and most farmers are reluctant to sell their private lands. Current policy mandates the sale of private farmlands to the government, which will then be redistributed to internally displaced persons. This policy necessitates sources of hard currency to fund the compensation of private farmers. About 40 percent of Namibia's arable land remains in a communal status, and there are proposals to establish property rights for these lands. As the future ownership status of communal lands is as yet undetermined, incentives for their efficient management have disappeared (Blackie and Tarr 1999).

South Africa is much further along in the process of economic development than either Angola or Namibia, yet it faces continuing pervasive unemployment (just under 30 percent) and associated impoverishment, difficulties with the redistribution of wealth, and the curse of widespread disease. The South African government has boosted spending on public infrastructure, particularly in the transportation sector, in an effort to grow the economy and reduce unemployment. Like Namibia, South Africa also faces the problem of redistributing private lands to the disenfranchised, and government budgetary constraints have seriously slowed the implementation of this policy. Cape Town is not as densely populated as the eastern sections of the country, but issues of dense coastal development, including nutrient pollution, habitat destruction, and shoreline erosion, have emerged. Cape Town represents about 15 percent of South Africa's GDP, and its two western coastal provinces have the lowest unemployment rate in the country (about 17 percent).

D. Management Organizations

Several recent studies have assessed the legal regimes and institutional capacities of the three BCLME nations for managing the marine environment. Russo *et al*. (2004) find that the national constitutions, public policies, and long-term planning efforts provide evidence that these countries are seriously concerned with managing their marine resources in ways that protect the marine environment. In particular, a formal assessment of environmental impacts is required by all three nations before the initiation of any significant marine activity. Unlike Namibia and South Africa, Angola has not implemented its policy of requiring environmental management plans for marine activities. Angola is party to the relevant international conventions, however, whereas Namibia and South Africa lag to some extent in signing, ratifying, or implementing agreements such as the Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC).

The recognition of the BCLME as a large marine ecosystem, which has led to significant funding from GEF (US$15 million) and the three BCLME nations (US$18 million), sends a strong signal that these nations are sincere about the sustainable management of the BCLME system. Notwithstanding this signal, Russo *et al*. (2004) find that institutional capacity is lacking with respect to the enforcement of marine policies in these nations. In particular, pollution controls are undeveloped, and the potential for transboundary impacts from marine activities is ignored. A more critical problem is that the relevant managing agencies face internal conflicts of interest, being assigned roles for both promotion and regulation of exploitative activities. In their study of sustainable development policies in Namibia, Blackie and Tarr (1999) find that the impact of such policies on decision-making needs improvement. Cullinan *et al*. (2005) echo these criticisms, reporting that national and international ocean governance are inadequate for long-term protection and sustainable use of the BCLME.

To be fair, all three nations are just now emerging from significant internal tribulations, and even the existence on paper of institutions for the sustainable management of marine resources in the region seems nothing short of a miracle. International funds will help to clarify institutional inadequacies and scientific uncertainties, thereby revealing the path to improvements in marine policy. For example, Sumaila *et al*. (2005) demonstrate the need for transboundary management of the shared commercial fish stocks of the BCLME, and they calculate the economic benefits from such an effort. Cullinan *et al*. (2005) present a number of options for international cooperation in the BCLME, and they develop a strong argument for the establishment of a formal Benguela Current Commission.

III. Resource Rents from Marine Activities

In this section we elaborate on marine activities in the BCLME, and we present estimates of resource rents from the most important activities, including offshore oil production, marine diamond mining, and marine fisheries. Our estimates of rents in all of these categories are presented in Table 6. Resource rents by type of resource are depicted in Fig. 4. Where relevant, we explain possible alternative sources of data that can be used to estimate resource rents. In the next section, we discuss the distributional issue of whether resource rents from marine activities ought to be used to enable the sustainable management of marine resources in the BCLME in the future.

A. Offshore Hydrocarbons

Only Angola has offshore oil concessions that are currently in production. Exploration efforts are underway in southern Namibia, particularly in the Kudu gas field to the west of Alexander Bay, South Africa. Exploration efforts are also well advanced off the coast of Cape Town. There they focus on the Ibhubesi natural gas field, which may be geologically connected to the Kudu prospect, and on oil fields both inshore and further offshore of Ibhubesi. There is no current production of either oil or natural gas in this part of the BCLME to date, although there is considerable potential for the future.

Angola relies predominantly on the development of offshore oil in the northern section of the country off the Cabinda enclave and slightly further south off the province of Zaire. Angolan production amounts to approximately $10 billion annually, and this production is second only to Nigeria's in sub-Saharan Africa. The terms of each Angolan oil concession are unique to that concession, but there are general policies in place calling for income taxation, royalty payments, and profit sharing arrangements. Sonangol, the state oil company, is a partner in many of these concessions. Without specific information on the costs of production, it is impossible to estimate resource rents from this sector. Quite a bit of exploration effort is now focused on deepwater prospects, and it is to be expected that rents will be comparatively smaller for these plays.

Recently, Angola has hired KPMG, an international accounting firm, to conduct an assessment of the Angolan petroleum sector (KPMG International 2004). Part of the assessment is an accounting of incoming revenue from Angolan oil production for the year 2000. The incoming revenue totaling US$5,472 million in that year is broken down into the following categories: (1) taxes collected from private concessionaires (including profit oil,[2] the petroleum income tax, and the petroleum transactions tax) amounting to US$1,697 million; (2) taxes collected from Sonangol (US$1,355 million); (3) profit oil for the concessionaires (US$1,075 million); (4) payments to the provinces of Cabinda and Zaire (US$149 million); (5) signature bonus payments (US$0); (6) loans received (US$1,000 million); (7) loans between states (US$94 million); and (8) sales by Sonangol of petroleum products (US$102 million).

We assume that the first five categories represent resource rent. This amounts to US$4,276 million, or roughly 78 percent of incoming revenues. (Note that the total incoming revenue does not equal total sales of Angolan oil, because the private

[2] "Profit oil" represents that portion of production that remains after all costs have been covered, including income taxes, royalties, and profit sharing. As such, it represents a portion of economic rent.

concessionaires sell much of the oil that has been produced.) In Table 6, we sum only categories 1, 2, 4, and 5 as an estimate of resource rent from Angolan oil fields. While category 3, relating to profit oil for the concessionaires, is legitimately counted as a portion of resource rent, we assume that it is unavailable to the Angolan government for use in the sustainable management of marine resources. Thus we estimate annual resource rent to be approximately US$3 billion, which amounts to about one-third of Angolan offshore oil revenues. We expect that this estimate of rent is conservative because oil prices have increased within the last year, production from Angolan oil fields has been growing, and typically one-time bonus payments are made to obtain concessions. The latter did not appear in the year 2000 incoming revenue accounts, but earlier payments represent a not insignificant proportion of resource rent.

B. Living Resources

Sumaila *et al*. (2005) [hereinafter referred to as "SMK"] develop an estimate of the potential resource rents that could obtain from the marine fisheries in the BCLME nations. Their first objective is to demonstrate that some of the important commercial stocks in the region are transboundary in geographic distribution. Because some of the stocks are transboundary, the efficient management of these stocks necessitates international cooperation. International cooperation, in turn, requires the establishment of an international institutional capacity. The authors compare potential resource rents from efficient management with three alternative institutional scenarios.

In estimating resource rents for commercial fisheries, SMK rely upon the work of Lange (2003) on selected Namibian fisheries. Lange has developed estimates of annual and capitalized resource rents for the Namibian pilchard, hake, and horse mackerel fisheries for the period 1990-98. Lange's purpose is to enable the incorporation of values in the Namibian national accounts for the economically most important capture fishery stocks. Using national data, Lange's measure of resource rent is total revenues minus average costs for each of the three fisheries. Lange assumes a normal profit of 30 percent as one element of average cost.

We rely upon Lange's estimate of total rent for the three fisheries combined of N$816 million in 1998 (equivalent to $205 million in 2005 US dollars). This estimate differs from that reported by SMK in that the latter use an average of total rent over the five-year period from 1994 to 1998, and they assume a normal profit of only 20 percent. The effect of the average is to lower the estimate of total rent, while the effect of the lower profit assumption is to raise the estimate. The net effect of the two assumptions leads to an estimate of N$602 million. We prefer the higher estimate because it incorporates Lange's preferred profit of 30%, it is the most recent estimate available, and the combination of improved fishery management and expanded demand in the forage fish market are likely to lead to higher estimates of resource rent in the Namibian fisheries in the future.

SMK develop an estimate of rent in the South African fisheries that relies upon the ratio of rents to revenues in the Namibian fisheries. Using our higher estimate of rent in the Namibian fisheries, we calculate that ratio to be 68 percent (the ratio used by SMK is 51 percent). Applying this ratio to South African landings of ₽1,291 million, we calculate resource rents in the South African fisheries of ₽879 million (equivalent to $176 million in 2005 US dollars).

SMK use a similar technique to calculate resource rents in the Angolan fisheries, assuming that those fisheries are only 75 percent as efficient as the South African fisheries due to the significant proportion of artisanal fishermen in the former. Seventy-five percent of 68 percent is 51 percent. Applying this ratio to Angolan landings of ₭11.9 billion, we calculate resource rents in the Angolan fisheries of ₭6.1 billion (equivalent to about 68 million in US dollars). Notably, another estimate of resource rents is possible in the case of Angola, which is the only BCLME nation to enter into an agreement with the European Union to allow access to its fish stocks.[3] During 1993-97, The EU and private European fishing firms paid Angola about €11 million annually (equivalent to $13 million in 2005 US dollars) for access primarily to shrimp and groundfish stocks (IFREMER 1999).

C. Marine Minerals

Marine mineral development in the BCLME is limited mainly to diamond mining off the coast of Namibia. The production of phosphate derived from seabird guano deposited on platforms off the Namibian coast takes place on a small scale, but these operations gross only about $1 million annually. There are marine diamond exploration efforts occurring in both South Africa and Angola, but we are unaware of any significant production in the latter at present. Marine diamond mining in South Africa[4] occurs at a

[3] In their analysis of European fishery policy in West Africa, Kaczynski and Fluharty (2002) suggest that there has been an underpayment of license fees to African coastal nations, especially in the case of the tuna fisheries. Further, they anticipate that subsidization of the European distant water fishing fleets and excessive bycatch, among other factors, will lead eventually to the overexploitation of the coastal fisheries of Africa. As a consequence, the value of these fisheries may decline.

[4] In Table 6, we calculate annual economic rents of about US$4 million for South Africa by using the ratio of rents to sales revenues for marine diamond mining in Namibia of 27 percent.

small scale (about US$17 million in sales per year) relative to Namibia and is thought to be declining relative to onshore and fluvial operations.

Diamond mining is important to Namibia in both onshore and offshore locations, but, as onshore deposits are played out, the production share from marine deposits has increased. According to reports in the trade media, in 2002, about 1,569,882 carats of diamonds were produced in Namibia. Of this total, 807,036 carats (52%) were produced from marine operations, 65,932 (4%) were produced from inshore beach mining and shallow water deposits, and 696,914 (44%) were produced from onshore mines. Ninety-five percent of the marine production is of high-valued gem-quality diamonds.

NamDeb, a 50-50 joint venture with De Beers Centenary AG and the Namibia government, is the largest diamond producer. In 2004, NamDeb's total production was 1.9 million carats with sales totaling about N$4 billion. Using the 2004 figures and the 2002 production share (56%), we estimate that sales of marine diamonds totaled about N$2.22 billion in 2004, or approximately $338 million in US dollars. Other producers, including Samicor, Diamond Fields, Diaz, and Reefton, operate offshore, but their total production is relatively minor at present. Production from these producers could expand in the future. Coakley (2003b) provides a current description of the industry's structure and its exploration and production activities.

In March of 2003, Namibia established a new policy to encourage the sustainable development of its minerals and to ensure that such development would contribute to the nation's socioeconomic development. Consistent with this policy, the Namibian Diamond Act No. 13 imposes a tax of 55 percent of taxable income plus a 10 percent royalty of the market value of diamonds (Coakley 2003b). The royalty can be applied to reduce the size of the income tax. If taxable income were publicly available, we could estimate the size of rents from this sector. This information is unavailable, however. Lange (2003) calculates rents in the Namibian mineral sector of about $13 billion for 1998, but these rents include diamond mining as well as mining for uranium and zinc.

To develop an estimate of resource rents from the Namibian marine diamond mining sector, we rely instead upon a report in the industrial trade literature for NamDeb's total payments to shareholders (Inambao 2005). Because Namibia is a "shareholder," these payments include royalties, income tax, non-resident's shareholder's tax, and dividends. Total payments of shareholders are N$1.05 billion. We estimate the marine share of these payments as 56 percent of the total, or N$580 million. Using the current exchange rate of N$6.35, we estimate annual marine diamond mining rents of approximately $90 million in US dollars. We note that there may be fluctuations in this value over time, and that this estimate is likely to be an underestimate, as NamDeb is not the only offshore producer.

IV. Conclusions

The three nations bordering the BCLME already garner significant resource rents from the use of their marine resources. These rents are expected to grow in the future as the demand for oil and natural gas continues to expand, as the growth of livestock and aquaculture markets calls for increased supplies of fishmeal, and as the BCLME nations develop coastal tourism industries. Pollution problems have been identified in the region, but these are believed to be relatively minor at present when compared with the same problems faced by other large marine ecosystems. Overexploitation of the forage fisheries may be the most significant market failure and source of unsustainability. As the economies of the region continue to develop, more attention will need to be paid to the potential for the imposition of social costs of oil production and coastal development on the coastal and marine environments of the BCLME.

The distribution of resource rents is important, as Angolan oil production is the largest source of this value in the region. Angola might use a portion of its offshore oil and gas rents to encourage South Africa to reduce its exploitation of the pilchard stocks, thereby enabling the potential expansion of a coastal fishery in Angola with potential for benefiting the local population.

Even with other activities operating at orders of magnitude smaller than offshore oil production in Angola, any one of the three nations could easily continue the existing GEF program at currently funded levels to help refine and operationalize a plan for sustainable development of the marine sector. More work is required to understand the costs of implementing sustainable management programs, which should be compared with resource rents. Sumaila et al. (2005) have taken an important first step along these lines in the area of capture fisheries, showing that fisheries management at existing scales is economically justified in the three nations and arguing that international cooperation could exploit economies in the management of transboundary stocks.

A final caveat concerns the pressing need to devote the resource rents from marine resources to begin to resolve some of the very serious public health, human rights, and social welfare problems faced by all three of these nations. The notion of sustainable management surely must involve prioritizing the needs of the present generation in the BCLME region when their situation is so dire. Establishing public policy priorities is a political decision to be debated and agreed upon by each of the jurisdictions independently and, where relevant, in concert. As these debates ensue, the importance of the BCLME as a source of economic value that could be used to mitigate social problems should be recognized and nurtured. In particular, the marine environment should not be despoiled and thereby wasted through unnecessarily shortsighted policy choices.

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Table 1: Marine Activities in the BCLME Nations [after Tapscott (1999)]

	Angola	Namibia	South Africa (Cape Town)
Offshore Oil and Gas	X		X
Offshore Diamond Mining		X	X
Offshore Guano Mining		X	
Industrial Fisheries	X	X	X
Marine Mammal Fisheries		X	
Artisanal Fisheries	X		
Marine Aquaculture			X
Fish Processing	X	X	X
Recreational Fishing			X
Tourism		X	X
Coastal Real Estate			X
Merchant Fleet			
Shipbuilding			
Shipping			X
Renewable Energy			

Table 2: Marine Living Resource Production Activities for the BCLME Nations

	Fish Landings (000MT)	Value of Fisheries Output (US$m/yr)	Aquaculture Production (000MT)	Value of Aquaculture Output (US$m/yr)
Angola	202	179	--	--
Namibia	670	357	<1	<1
South Africa	854	227	5	24
World Average	593	--	321	415
World Median	77	--	6	23

Note: World average (median) is the average (median) value of non-zero entries for all countries.

Table 3: Shipping and Shipbuilding Activities for the BCLME Nations

	Shipping & Cargo Traffic (000MT)	Merchant Fleet (000DWT)	Shipbuilding Orderbook (000GRT)
Angola	--	--	--
Namibia	--	--	--
South Africa	154	--	1
World Average	131	24	2,390
World Median	25	12	50

Note: World average (median) is the average (median) value of non-zero entries for all countries.

Table 4: Offshore Oil and Mineral Production Activities for the BCLME Nations

	Rig Count (oil rigs)	Offshore Oil Production (bbl/day)	Value of Offshore Oil Production (US$m/yr)	Offshore Diamond Production (000CT/yr)	Value of Offshore Mineral Production (USm/yr)
Angola	7	653,233	10,252	--	--
Namibia	--	--	--	1,064	2,220
South Africa	1	20,100	315	54	17
World Average	44	n.a.	n.a.	n.a.	n.a.
World Median	8	n.a.	n.a.	n.a.	n.a.

Table 5: Tourism Activities for the BCLME Nations

	Tourist Visits (000 visits/yr)	Tourism and Travel Demand (US$m/yr)
Angola	--	38
Namibia	--	723
South Africa	339	19,522
World Average	4,187	34,760
World Median	726	2,918

Table 6: 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

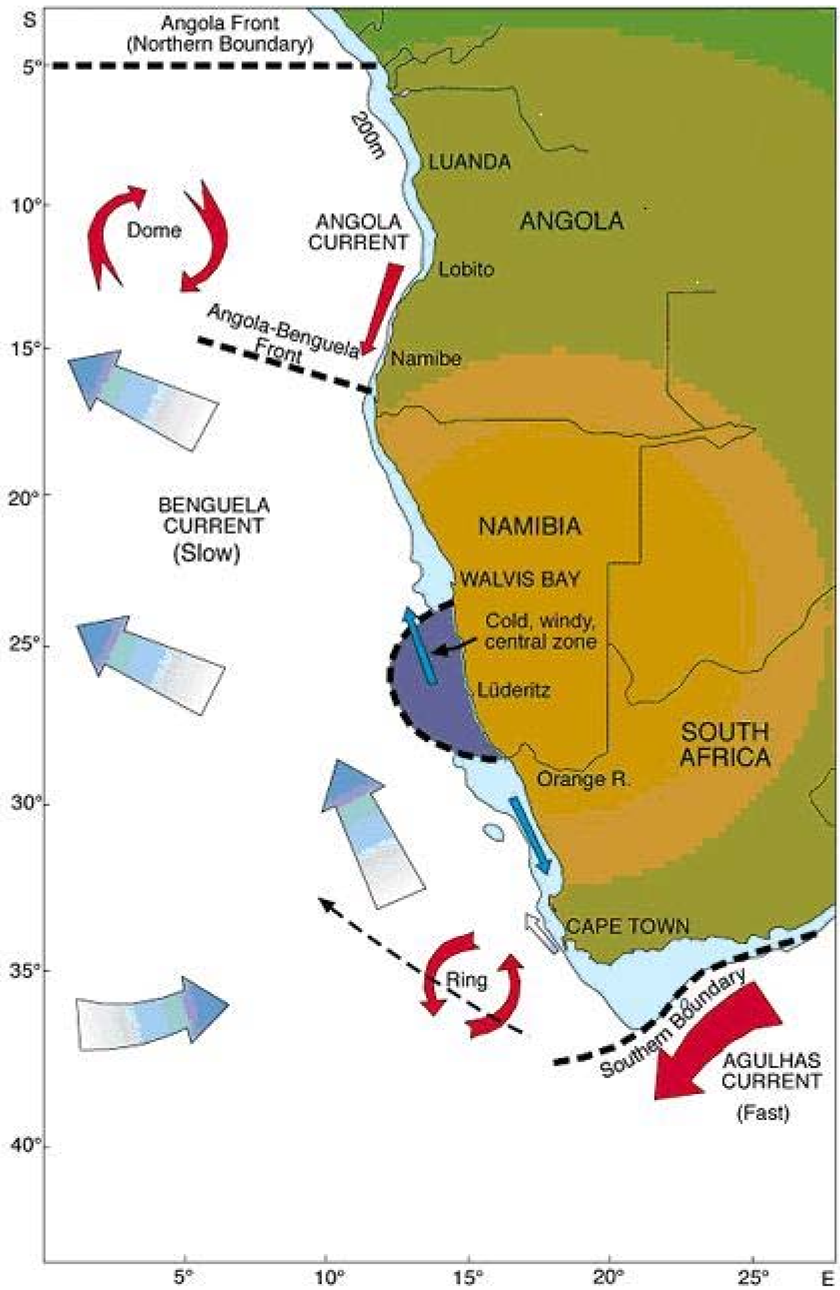

Figure 1: The Benguela Current large marine ecosystem. Source: Benguela Current Large Marine Ecosystem Programme. Last accessed on March 30, 2006 at http://www.bclme.org/.

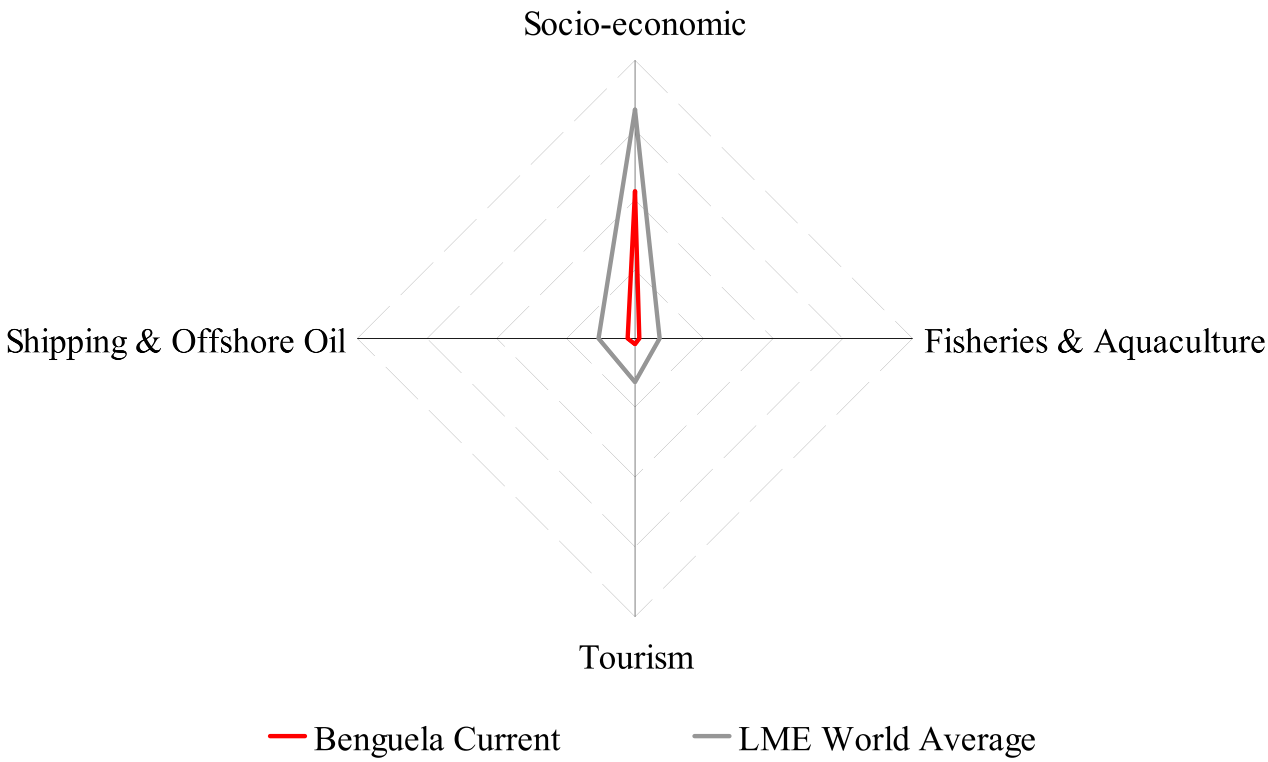

Figure 2: Marine activity index comparison between the BCLME region (red) and the world average (gray). This comparison suggests that marine activities in the BCLME region occur at a relatively low level in comparison with other large marine ecosystems of the world.

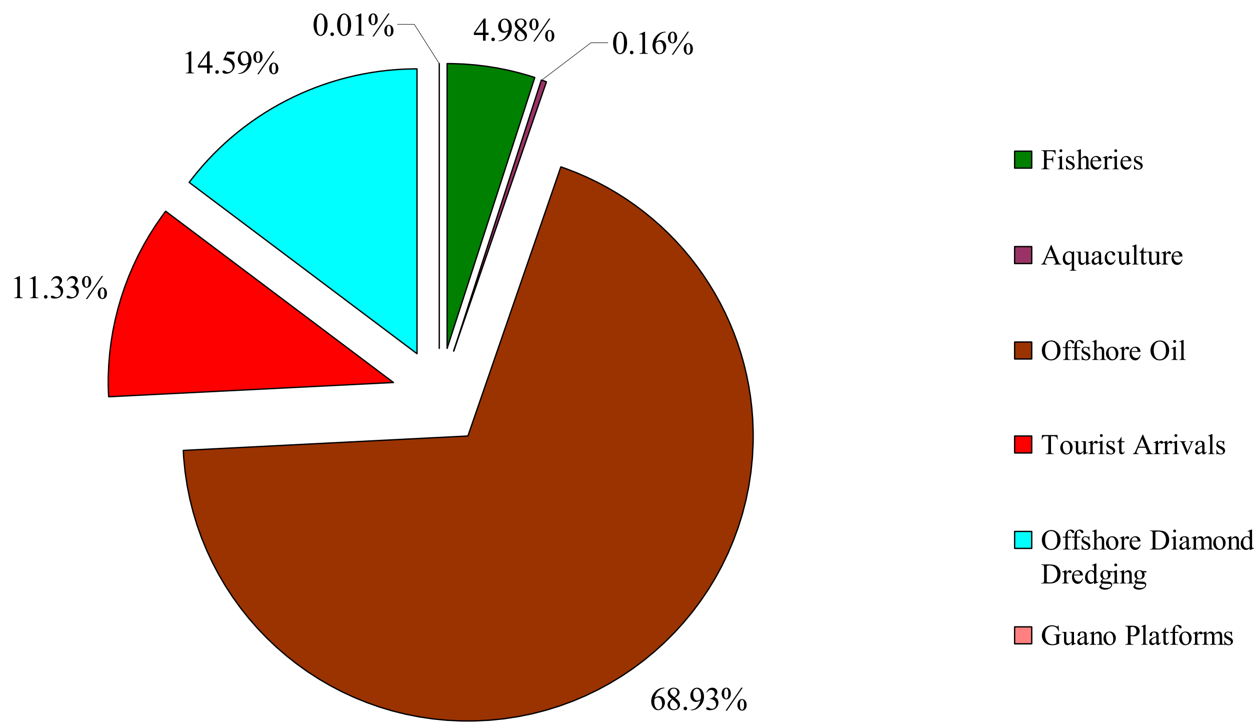

Figure 3: Economic significance of BCLME marine activities. The pie chart depicts a percentage breakdown across activities of total direct output impacts of ~$15 billion per year out of a total GDP for the BCLME nations of ~$300 billion per year. (The total direct output impact of an industry is the gross output value, or revenue from sales, of that industry.)

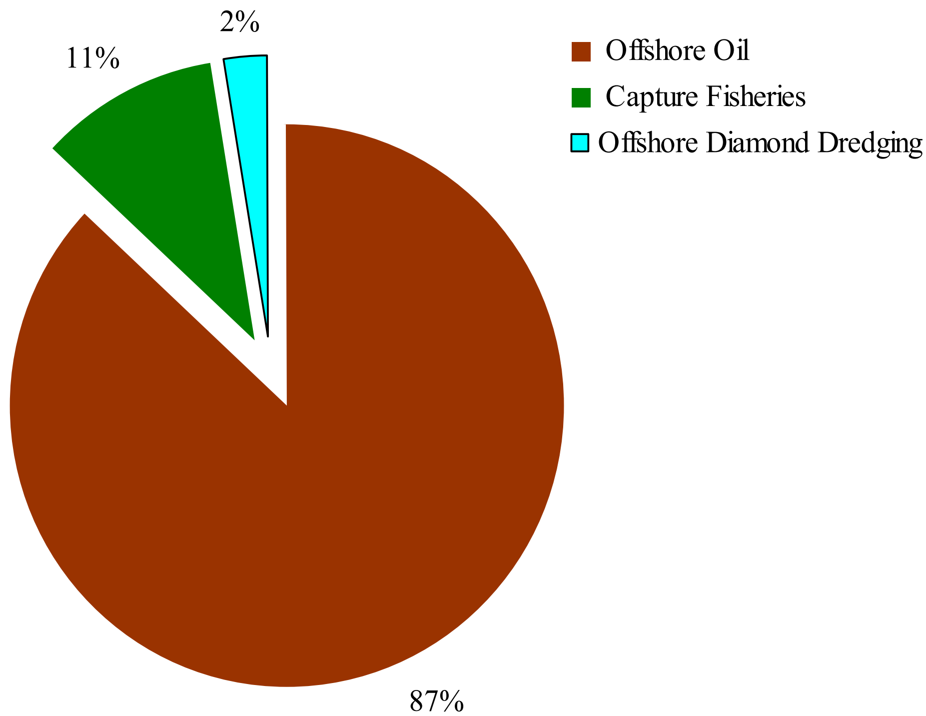

Figure 4: Resource rents arising from BCLME marine activities. The pie chart depicts a percentage breakdown across activities of resource rents of ~$4 billion per year, which is about 27 percent of total direct output impacts for the region. Offshore oil production dominates the estimate, and all of this production occurs in Angola

Annex II

Case Study: Yellow Sea Large Marine Ecosystem[1]

I. Introduction

The Yellow Sea LME (YSLME) is a potentially valuable focus for a case study for two reasons. First, the Yellow Sea is a continental shelf ecosystem and has been selected as a representative LME for this major ecosystem type. In addition, it is bordered by developing nations, which poses a particular set of challenges for managing the LME.

The Yellow Sea LME is a semi-enclosed sea surrounded on three sides by countries with large populations and rapidly growing economies. One of the key challenges is to coordinate economic growth with environmental and natural resource protection to achieve sustainability. In recent decades, there has been a lack of solid balance between economic development and environmental protection in the Yellow Sea region. Most management policies did not connect water quality problems with land-use management and economic development, nor did they correlate fishery depletion with pollution or habitat loss (Lee 1998).

In this case study, we examine whether or not the Yellow Sea region is on a sustainable path for marine resource use and, if so, whether it has the capability to continue on this course; or, if not, what measures are needed to enhance the prospects for sustainability.

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[1] Jennifer Skilbred contributed to the background research and writing of an initial draft of this Annex.

II. Background

A. YSLME Region

YSLME is a subsection of the Northwest Pacific Regional Sea (Fig. 1). It is a continental shelf ecosystem bordered by the People's Republic of China (China), the Democratic People's Republic of Korea (North Korea), and the Republic of Korea (South Korea).[2]

The Yellow Sea is dominated by the interactions of the high temperature and high salinity Kuroshio Current with the coastal cold-water masses from some of the regional spawning and feeding grounds. The weather in the Yellow Sea is dominated by strong northerly monsoon winds from late November through March. Cold-temperate fish species often dominate the Yellow Sea, particularly in its northern and central parts (Biodiversity Clearinghouse 2005). Due to marked seasonal variations, the sea can support both cold-temperate and warm water species (NOAA 2004). The northern portion of the Yellow Sea, the semi-enclosed Bohai Sea, is a spawning and nursing ground for many commercially important fish and shrimp.

The Yellow River is a major source of sediments and industrial wastes into the Yellow Sea. The discharges from the Yellow River and the Yangtze River flow across the continental shelf and introduce large quantities of sediment that affect the salinity and hydrography of the Yellow Sea. Other rivers, including the Han, Datung, Yalu, Guang, Sheyang, Liao He, and Hai He rivers, all discharge into the Yellow Sea (YSLME Project 2005).

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[2] Throughout this case study, we use the term "Korea" either in reference to South Korea (especially when discussing economic data, which are unavailable for North Korea), or, occasionally, in reference to the entire Yellow Sea coast of the Korean Peninsula.

Fully five percent of the world's population inhabits the area that drains into the Yellow Sea. According to the 2000 China census, there were close to 300 million people living in the Yellow Sea coastal regions of Beijing, Tianjin, Hebei, Liaoning, Jiangsu, and Shangdong, in China (NBS 2005). Coastal cities are growing rapidly in the region (Li 2003). Large metropolitan areas on the Yellow Sea include Qiangdao, Tianjin, Dalian, and Shanghai in China, as well as Seoul/Inchon in South Korea and Pyongyang-Nampo in North Korea (YSLME Project 2005).

B. Marine Industries

The economies of the Yellow Sea region have been growing rapidly over the last several decades. Table 1 and Fig. 2 illustrate the increase in marine industry output in Yellow Sea coastal regions in China from 1996 to 2004, when the output value of the Bohai region was 412 billion Yuan (US$ 50 billion; Fig. 2). Fig. 3 compares YSLME index values of some of these activities with the world average across all large marine ecosystems (see section 1 of this report). This comparison suggests that the YSLME has much higher than average marine activity levels for most of its major marine industries. One implication of this comparison is that, relatively speaking, the YSLME environment has been utilized at levels that may be unsustainable.

Fisheries is an important economic sector throughout the entire region. China is the world's top fish producer (FAO 2005),[3] and the fishing industry in Korea averages about tenth largest in the world (Kwak *et al.* 2005). In 2003, fish landings in five major Yellow Sea coastal cities in Korea amounted to 66 thousand metric tons (MT) valued at

[3] The accuracy of the Chinese figures for fish production has been called into question by some researchers; see Watson and Pauly (2001) and Watson *et al*. (2001). FAO and China are examining this issue.

250 billion Won (US$ 210 million; see Table 2). Fish landings in Yellow Sea coastal regions in China were 5.6 million MT in 2000 (see Table 4). Seafood is an essential dietary component for people in the region. Mariculture is one of the main industries in the region and has been greatly increasing in recent decades (Tables 3 and 4). China has been the world's leader in marine aquaculture, and its aquaculture industry is continuing to develop (FAO 2001).

Tourism is an infant industry in the coastal Yellow Sea, but there is much promise for its future (Cheong 2003; China Oceanic Information Network 2005). The Republic of Korea has been working to increase tourism, especially coastal and marine tourism (Tyrrel *et al.* 1999). The declining availability of fish resources is leading small Korean fishing villages to concentrate more effort in developing the local tourism industry (Cheong 2003), and the economy in these areas is becoming more dependent on tourism. As shown in Table 5, the number of tourists in the cities of Mokpo and Inchon grew from nearly 3.8 million in 1996 to 6.7 million in 2003. In Mokpo, the value of coastal tourism rose from 526 billion Won (US$ 375 million) in 1998 to 1 trillion Won (US$ 872 million) in 2003 (KORDI 2005).

Coastal tourism by domestic and foreign visitors has been on the rise in China as well. Revenue from international tourists increased from US $620 million in 1997 to US $879 million in 2000 in the five Yellow Sea coastal regions (Table 6).

The waters of the Yellow Sea are heavily used for shipping, which is an important component of growth for the region's economies. Table 7 depicts the growth in shipping vessel traffic in five major Korean ports on the Yellow Sea. The ports of Tianjin, Qingdao, Inchon, Dalian, and Qinhuangdao are among the top 25 in the world in terms of cargo throughput (ISL 2004). Shipbuilding is also a very important industry in the region, with Korea and China ranking as the first and the third shipbuilding countries in the world, respectively (ISL 2004). Major shipyards in the region include Dalian, New Century, and Nantong (ISL 2004).[4]

Offshore oil and gas activities are concentrated mostly in the Bohai Sea and northern part of the Yellow Sea. China's oil and gas revenue from the Yellow Sea was 10.9 billion Yuan (US$ 1.3 billion) in the year 2000. Other important industries that comprise China's marine industry output revenue structure for the Yellow Sea coastal area include sea salt production and sand and gravel mining (Table 8).

C. Management Organizations

There are a number of governmental and non-governmental organizations in the Yellow Sea region that are involved in the protection of the YSLME through donations and/or management help. The infrastructure necessary to make positive management changes for the marine resources of the area is steadily growing. The Partnership in Environmental Management for the Seas of East Asia (PEMSEA), a GEF/UNDP/IMO (International Maritime Organization) partnership, is a significant infrastructure-building and information-sharing agency in the Yellow Sea region. All three countries surrounding the Yellow Sea are participating members of PEMSEA. Relevant national governmental agencies include the State Oceanic Administration (SOA) and the State Environmental Protection Administration (SEPA) in China, and the Ministry of Maritime

[4] Note that major Korean Shipyards (e.g., Hyundai, Samsung, and Daewoo) are located on the southeastern coast.

Affairs and Fisheries (MOMAF) in South Korea. China and South Korea have both ratified UNCLOS—the UN Convention on the Law of the Sea—and the two nations have relied mainly on fishery agreements to resolve fisheries disputes (Kang 2003).

D. Political Issues

The historical relationships among the nations surrounding the Yellow Sea are complex, and the three countries have significant differences in terms of their political institutions. According to a World Bank Institute study on governance, South Korea, China, and North Korea are ranked from relatively high to low, respectively, on various indicators for voice and accountability, government effectiveness, regulatory quality, rule of law, and control of corruption (Kaufmann *et al.* 2005). These differences have led to complications in working together to manage a shared ecosystem.

One area of contention among the countries has been the delimitation of their individual exclusive economic zones (EEZs) (Kim 2003). Temporary agreements have been made until final delineations can be agreed upon. Along with these debates, there has been an often violent ongoing dispute between North Korea and South Korea, as to where the land boundary between their nations lies.[5]

III. Management Issues

The health of the YSLME has changed greatly over the past five decades, due to the ever-increasing pressures on the marine resources of the region (Bohai Sea

[5] These disputes are the result of high tensions following the unresolved Korean War, a disputed boundary, and hence disputed rights to a highly valued blue crab species (Van Dyke *et al*. 2003).

Environmental Management Program 2005). Some of these changes include a decreased number of fish, a lowering of trophic levels of the remaining individuals (Fig. 4), and a smaller average size of fish. The most common species have also changed over the years. Increasing pollution in the Yellow Sea as the surrounding nations continue to develop quickly is having a strong negative effect on the health of this marine ecosystem. In recent years, the frequency of harmful algal blooms has increased as well (Tang *et al.* forthcoming).

A. Living resources

The YSLME is one of the most intensively exploited LMEs in the world (Fig. 5). Living resources in the Yellow Sea are severely threatened due to overfishing. The major fisheries are at extremely low levels today compared with three decades ago, and are now no longer economically or ecologically sustainable (NOAA 2004). There have been significant changes in catch composition due to overfishing and destructive fishing methods, such as trawling, which can destroy benthic habitats.

Subsidies were often granted to fishermen in both China and Korea (Pak and Joo 2002).[6] Since the 1960s there has been a steady increase in the number of fishing boats and the improvement of fishing gear, both of which leads to excessive fishing efforts and overfishing (Biodiversity Clearinghouse 2005). This has caused a decrease in high-value species and an increase in the amount of low-value species caught. The biological characteristics of some species have also changed, and there are many instances of smaller individuals with a reduced average age of spawning populations.

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[6] Forms of subsidies include tax-free oil for fisherman to run boats, construction of fishing ports, and support for fishing technology improvement.

Habitat destruction has also impacted the Yellow Sea. Reclamation of land throughout the 1960s has harmed biodiversity in China, and reclamation is a major cause of habitat destruction in South Korea as well. With land reclamation, fisheries declined due to a loss of nursery grounds and an increase in pollutant inputs (Cicin-Sain and Knecht 1998).

Mariculture production has been greatly increasing in the region in recent decades. In many coastal areas mariculture activities are intensive. Although growth in aquaculture has increased the total seafood supply and reduced the pressure on wild stocks, this has come at the cost of biodiversity reduction (Biodiversity Clearinghouse 2005). Modern aquaculture practices are often unsustainable, due to water pollution and other environmental effects (Midlen and Redding 1998).

B. Marine Pollution

YSLME is threatened by both land- and sea-based pollution. The increasing amount of international shipping traffic has led to collisions and spills, and the region has also been severely impacted by eutrophication. The occurrence of red tides is increasing in frequency and has become all too common over the past ten years or so (Tang *et al*. forthcoming). Pollution problems are most severe in the Bohai Sea. Since the 1970s, water quality in the area has been quickly deteriorating due to the offshore oil industry, as well as the direct drainage of industrial and domestic wastes into the sea. Such problems have led to a sharp decline in the environmental services functioning of the sea. This environmental degradation has been a result of rapid economic development in the region. Currently there is an extremely high rate of land-based pollutants discharged into the Bohai Sea (Xin 2004). The pollution problems are exacerbated by the fact that the system is semi-enclosed and fairly shallow.

There has also been a distinct loss (or in some cases modification) of ecotones, including the disappearance of some species and the concentration (bioaccumulation) of pollutants in other species. These problems threaten human health (*e.g.*, through seafood poisoning), aquatic production, and the recreational and aesthetic value of the sea.

IV. Management Efforts

A. Environmental Awareness

For a region of developing nations, the marine environment of the Yellow Sea offers many important resources and chances for economic development. It is an essential area for ocean transportation as well as an essential food source.[7] South Koreans as well as Chinese citizens are now seeing greater incomes and more leisure time then ever before, which has increased the importance of the Yellow Sea coastline as a recreational area as well (Lee 1998). At the same time, there has been an increase in environmental awareness in the region.

South Korea has created a national ocean governance policy entitled Ocean Korea 21 (OK 21), which is administered by the Ministry of Maritime Affairs and Fisheries (MOMAF). The objectives of OK 21 involve enhancing the vitality of territorial waters, developing knowledge-based maritime industry, and promoting sustainable development of marine resources (Kwak *et al.* 2005). Similar ocean management policy has been

[7] Seafood has been an essential staple of the Korean diet. It is essential in Korean cultural foods, and it is the main source of protein for the majority of the nation's people.

developed by China's State Oceanic Administration (SOA) as well, and is enshrined in a Marine Environmental Protection Law adopted in April 2000.

A key source of support for the YSLME has been the Global Environment Facility (GEF), which is funding a project entitled, "Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem." This project, as well as a number of related GEF, World Bank, and PEMSEA projects, is focused on the sustainability of marine resource use in this region. The project was designed to enhance cooperation among the coastal countries by building on existing policies as well as the planning and implementation elements of UNEP's Regional Seas Programme. The objective for this project involves ecosystem-based environmentally sustainable management and use of the Yellow Sea. The program promotes the reduction of development stress and the sustainable use of marine resources in this densely populated, heavily urbanized, and heavily industrialized semi-enclosed continental shelf LME (YSLME Project 2005). To date, GEF has devoted approximately $13 million to support and enchance the efforts of regional governments on projects designed to reduce environmental stress and improve the sustainability of marine resource use in the YSLME (GEF Council, n.d.).

B. Protecting Living Resources

There have been growing efforts to control fishing capacity in the region. Government subsidies in fisheries are being provided in both China and South Korea (Pak and Joo 2002). South Korea has implemented a program to reduce fishing fleet capacity in which the government pays fishing vessel owners to decommission their vessels (FAO 2003). To control the intense fishing pressures, starting in 1995 China has practiced a midsummer moratorium in July and August for their fishery (Information Office 1998). All fishing vessels are docked during the moratorium to allow the fish stocks to recover.

Coastal fishing communities in the region are now exploring other economic opportunities. For example, the declining fish resources in the region have led many small traditional fishing villages in South Korea to look to tourism to boost their economies (Cheong 2003).

C. Pollution Control

Pollution discharge and water quality in the YSLME region are now being monitored. China's SEPA has enacted laws on air and water pollution, which involve the polluter pays principle. The Bohai environmental management project, with a budget of 27.66 billion Yuan (US$3.4 billion) for 2001-2005, has halted the upward trend in the discharge of several major pollutants (e.g., COD and petroleum) (SEPA 2005).

D. Green Accounting

Green accounting has been promoted by the United Nations as a step toward sustainability (UN Statistics Division 2004). China is a participant in the UN program and has begun to bring environmental costs into the accounting framework (Xie 2000; Wang *et al.* 2005). According to the *China Daily* (2005), green GDP calculations are underway for ten municipalities and provinces. Integrated coastal management efforts are ongoing in both South Korea and China (PEMSEA 2005).

E. Regional Cooperation

China and South Korea have been actively participating in and implementing several LME program plans, such as the Yellow Sea GEF program. International, national, and non-governmental organizations, such as PEMSEA, SEPA, and Friends of the Earth China, are sharing information on the Yellow Sea and its marine resource sustainability issues (YSLME Project 2005).[8]

V. Conclusion

The YSLME region faces a very challenging task to achieve sustainable development. Rapid economic growth in the densely populated region has led to severe marine pollution, habitat destruction, and fish stock depletion. As environmental conditions deteriorate, however, public environmental awareness grows. There have been some significant efforts by governments in the region to control pollution discharge and to improve resource management. Nonetheless, there remains a great deal to be done.

Financial and technical support from GEF and other international organizations has played a vital role in the last decade in setting up the management framework for YSLME, in facilitating collaboration among countries in the region, in developing local demonstration projects for sustainable development, and in prompting local governments to invest in LME management.

The push for a more sustainable path for marine resource use and a cleaner environment in the YSLME is expected to become stronger as people's standard of living rises. The growing economies in the region should further improve local management

[8] Although there is a recent report on North Korea's state of the environment (UNEP 2003), there are few YSLME-related data available from North Korea.

agencies' capability to self-finance future ecosystem management projects, although continued technical support from international organizations will remain essential in the years to come.

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Table 1. Marine Industry Output Value by Yellow Sea Coastal Areas in China
($US millions)

Year	Shandong	Liaoning	Tianjin	Jiangsu	Hebei	Total
1996	6,179	2,496	1,340	1,499	656	12,170
1997	6,873	3,176	1,395	1,985	728	14,156
1998	8,176	3,328	1,116	2,069	727	15,416
1999	8,880	3,359	1,251	1,721	684	15,895
2000	8,912	3,945	1,675	1,764	836	17,132
2001	10,159	4,380	3,247	2,079	1,399	21,263
2002	12,035	5,558	5,035	2,681	1,541	26,848

Note: Marine industries include marine fisheries, mariculture, offshore oil and gas, marine transportation, tourism, shipbuilding, sea salt, and sand and gravel.
Source: SOA (2005).

Table 2. Marine Fisheries Landings and Value by Yellow Sea Coastal Cities in Korea

Year	Mokpo		Inchon		Kunsan		Seosan		Total	
	MT	$US mill	MT	$US mill	MT	$US mill	MT	$US mill	MT	$US mill
1996	47,798	223	51,000	237	--	--	10,238	19	109,036	479
1997	40,498	139	43,600	189	--	--	6,333	14	90,431	342
1998	35,940	56	38,900	89	32,391	46	2,573	4	109,804	195
1999	38,956	69	45,400	148	34,564	51	2,082	4	121,002	271
2000	33,874	71	41,258	164	58,058	49	5,601	7	138,791	292
2001	31,444	55	35,889	138	26,776	43	4,271	3	98,380	239
2002	28,981	58	39,221	160	18,276	43	16,065	16	102,543	276
2003	23,840	56	25,079	119	13,610	29	3,081	6	65,610	210

Source: KORDI (2005).

Table 3. Mariculture Output Value by Yellow Sea Coastal Cities in South Korea
($US millions)

Year	Mokpo	Inchon	Kunsan	Seosan	Total
1997	4	16	17	8	45
1998	3	11	11	6	31
1999	3	12	11	6	31
2000	3	10	9	5	27
2001	2	11	8	4	26
2002	3	13	9	5	30
2003	4	19	14	7	44

Source: KORDI (2005).

Table 4. Fishery and Mariculture Outputs by Yellow Sea Coastal Areas in China
(000 MT)

Year		1997	1998	1999	2000
Shandong	Fishery	2,975	3,326	3,325	3,078
	Mariculture	2,384	2,340	2,698	2,872
Liaoning	Fishery	1,457	1,606	1,577	1,502
	Mariculture	1,123	1,208	1,391	1,521
Tianjin	Fishery	29	30	34	35
	Mariculture	2	3	3	5
Jiangsu	Fishery	711	708	683	660
	Mariculture	139	174	219	249
Hebei	Fishery	261	302	328	327
	Mariculture	77	83	95	155
Total	Fishery	5,433	5,972	5,947	5,602
	Mariculture	3,725	3,808	4,406	4,802

Source: SOA (2005).

Table 5. Coastal Tourism by Yellow Sea Coastal Cities in Korea (number of visitors)

Year	Mokpo	Inchon	Total
1996	1,977,519	1,800,087	3,777,606
1997	1,993,160	1,630,285	3,623,445
1998	2,120,826	2,564,498	4,685,324
1999	2,660,614	2,672,046	5,332,660
2000	2,950,735	2,952,436	5,903,171
2001	2,978,681	2,697,414	5,676,095
2002	3,077,562	2,912,454	5,990,016
2003	3,639,807	3,062,542	6,702,349

Source: KORDI (2005).

Note: Including domestic and foreign visitors.

Table 6. Coastal Tourism Revenues by Yellow Sea Coastal Areas in China ($US millions)

Year	Shandong	Liaoning	Tianjin	Jiangsu	Hebei	Total
1997	160.88	178.74	180.09	51.67	49.02	620.40
1998	179.63	163.07	201.76	58.30	49.25	652.01
1999	209.33	191.51	209.03	49.72	67.23	726.82
2000	254.97	256.76	231.76	64.03	71.44	878.96

Source: SOA (2005).

Note: International visitors only.

Table 7. Shipping Vessel Traffic by Yellow Sea Coastal Cities in Korea (000 GT)

Year	Mokpo	Inchon	Kunsan	Seosan	Total
1996	10,155	222,883	26,257	39,728	299,023
1997	11,471	239,621	33,113	44,285	328,490
1998	10,446	202,388	33,291	53,797	299,922
1999	11,452	222,613	40,147	69,907	344,119
2000	13,121	240,086	45,416	79,166	377,789
2001	17,479	251,701	43,043	82,541	394,764
2002	26,324	261,721	41,082	61,545	390,672
2003	25,456	264,597	50,274	58,824	399,151

Source: KORDI (2005).

Note: The sum of inbound and outbound coastal and ocean-going vessels.

Table 8. 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

Source: SOA (2005)

* International visitors only.

MAP of YELLOW SEA REGION

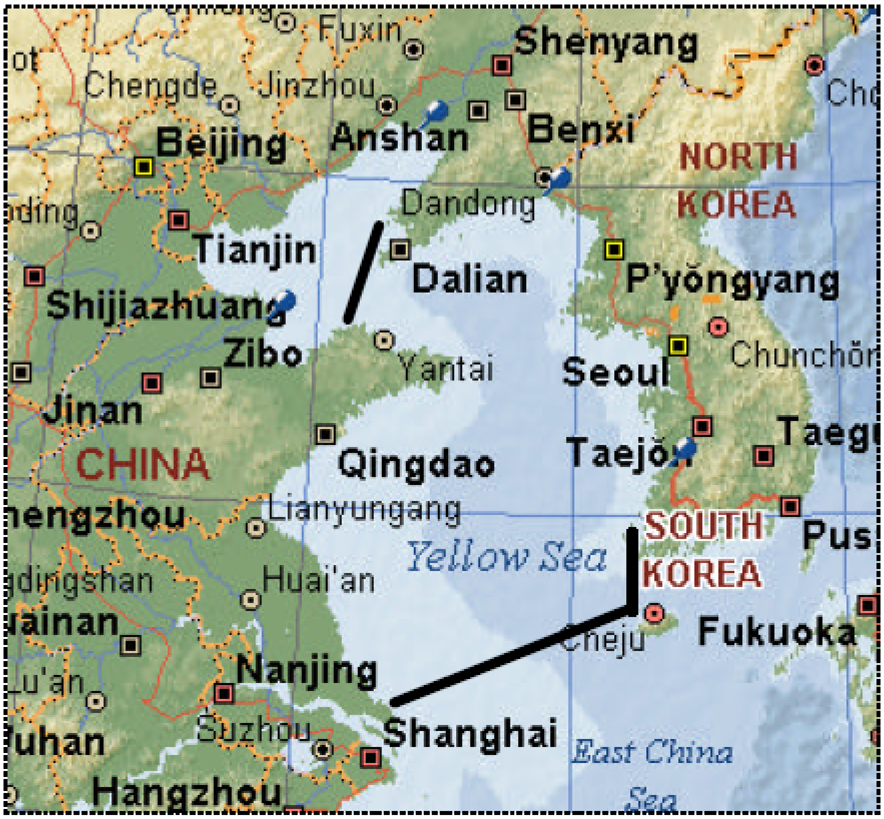

Figure 1: Map of the Yellow Sea region, comprising a large marine ecosystem.
Source: GEF (2002).

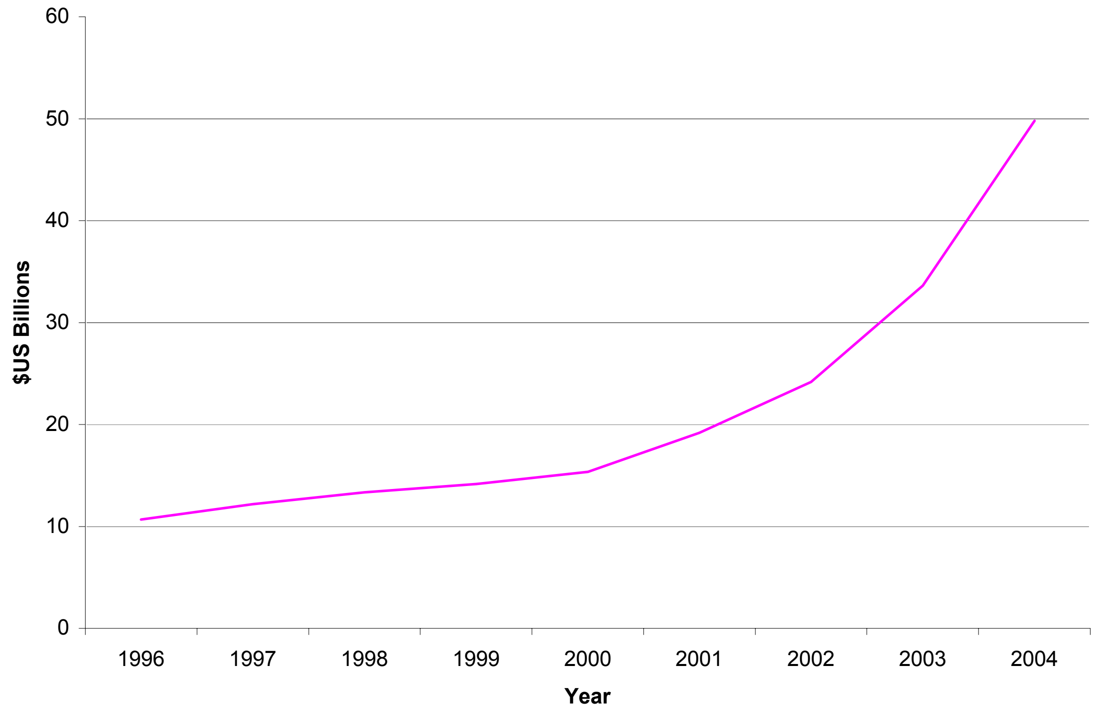

Figure 2: Bohai Region Marine Industry Output Value. Note: (1) Including Shandong, Liaoning, Tianjin, and Hebei in China. (2) Domestic tourism value has been included since 2001. In 2004, the values of fishery, mariculture, tourism, and marine transportation accounted for 70% of the total. Source: SOA (2005).

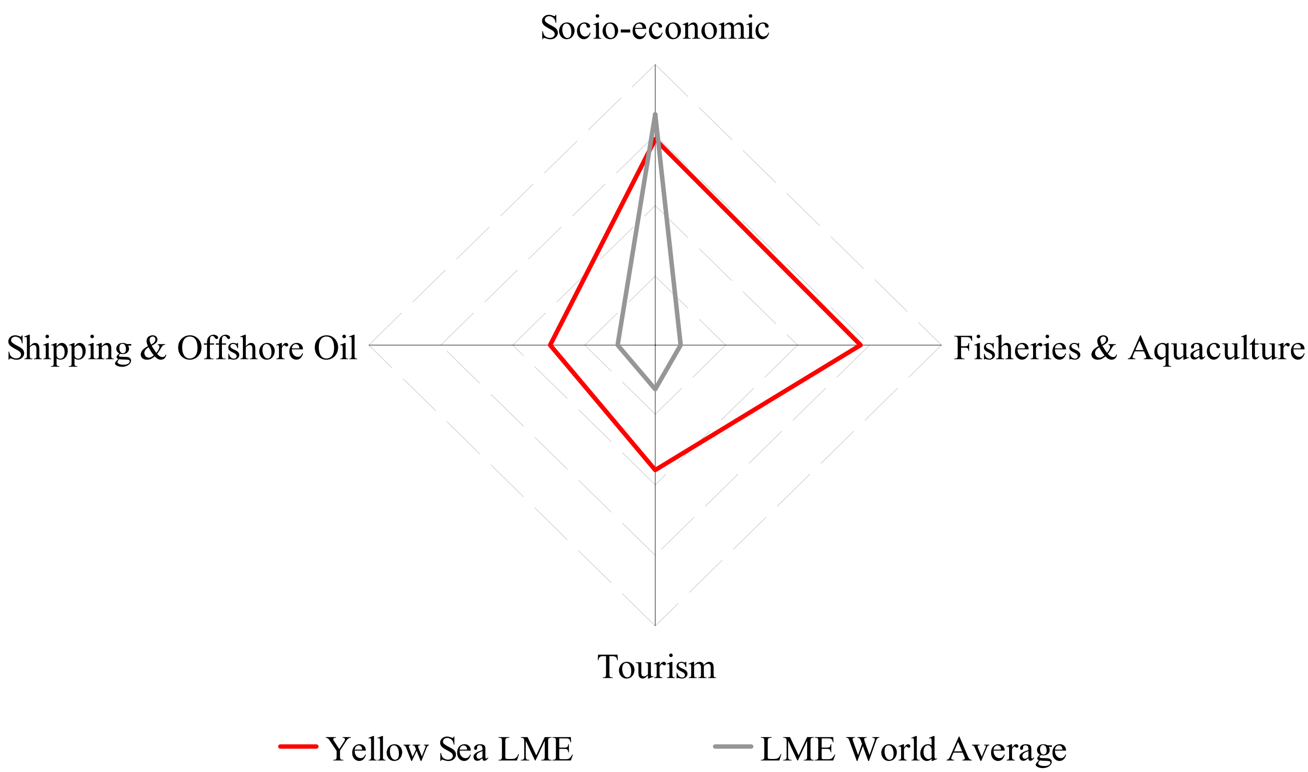

Figure 3: YSLME activity index values for three major marine sectors and the HDI ("socioeconomic") in comparison to the LME world average.

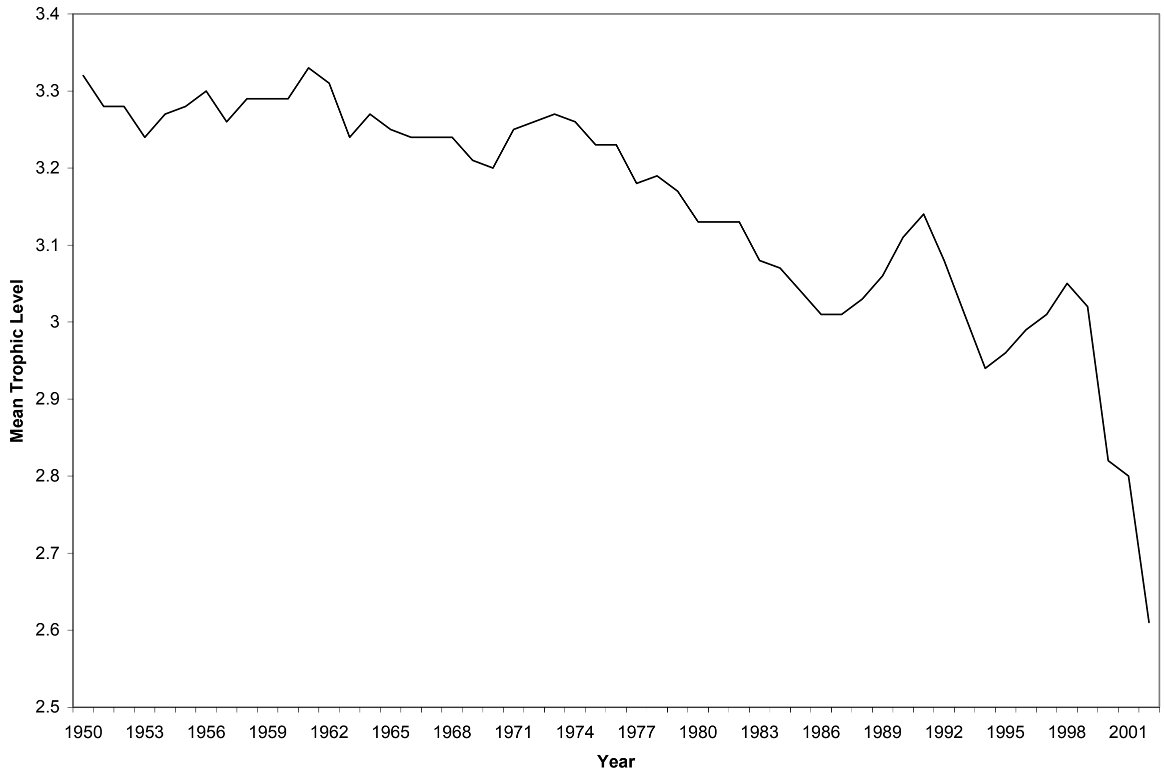

Figure 4: Marine Trophic Index for YSLME. Source: Sea Around Us Project (2005).

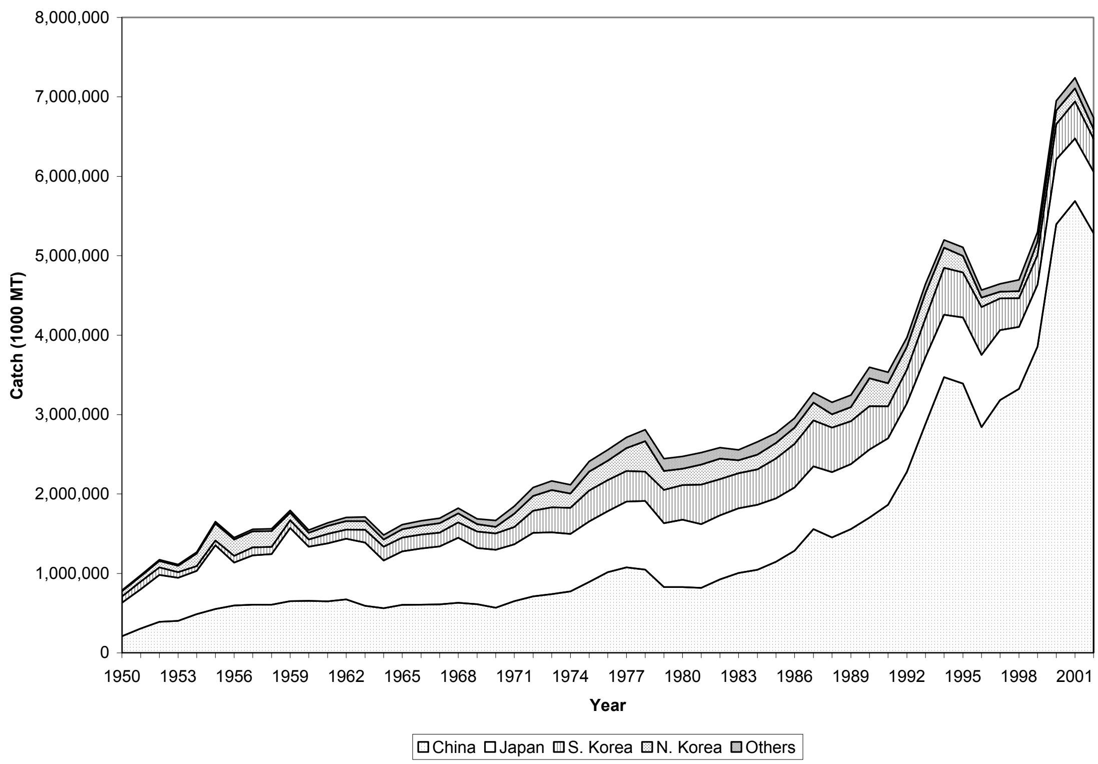

Figure 5: Fish Landings in YSLME by Country. Note: the category "Others" includes Taiwan, Hong Kong, Russian Federation, and Macau. Source: Sea Around Us Project (2005).