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Aggregate performance in managing marine ecosystems of 53 maritime countries

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ABSTRACT

Fourteen indicators of marine living resource management performance by country, reflecting both their intention to sustainably use the resource within their Exclusive Economic Zones and the effectiveness of their policies, were developed and the performances of 53 maritime countries were assessed. Four rankings of the countries, which jointly account for over 95 percent of the world's marine fisheries landings, are presented here as aggregated scores of the fourteen indicators, using different schemes for weighting the indicators, each reflective of the management preferences identified by the Global Environment Outlook 4 (GEO4) future development scenarios: Market First; Policy First; Security First; and Sustainability First. The resulting rankings differed substantially between the weighting schemes for the top performing countries but less so for the countries performing poorly.

1. Introduction

There are increasing public concerns about the environmental impact of fisheries [1,2] and the sustainability of current seafood consumption [3] as attested by the growing popularity of initiatives such as the Monterey Bay Aquarium's and similar wallet cards, and the fisheries certification scheme run by the Marine Stewardship Council (MSC). However, sustainability of fisheries should not only concern the exploited fish populations, but also refer to the ecosystems in which these fisheries are embedded. Ecosystem-Based Fisheries Management (EBFM) is thus a more suitable approach for ensuring that fisheries are 'sustainable' [4].

Pitcher et al. [5] have developed a scoring scheme based on the management criteria in the Code of Conduct for Responsible Fisheries by the Food and Agriculture Organization of the United Nations [6], while Leadbitter and Ward [7] reviewed nine fishery assessment systems and found four areas of concern for sustainability: socio-economic contributions of fisheries; their contribution to food security; flexibility in providing alternative ways to achieve sustainable fisheries; and independent peer review of assessments. Other assessment criteria for sustainability have been provided by MSC [8] and Australia's Fisheries Research and Development Corporation [9]. These approaches are comprehensive in assessing single species capture fisheries and their collateral impacts on marine ecosystems, as well as the social and economic implications of fishing activities. However, they remain fishery-centric in that they do not explicitly consider interactions with and the status of other components of marine ecosystems, specifically seabirds and marine mammals, and the role of mariculture. Moreover, neither biodiversity management nor conservation is prominent in their mandate. This is a reflection of multiple agencies having partial and overlapping jurisdictions, with none of them responsible for the exclusive economic zone (EEZ) as a whole. This makes designing a comprehensive assessment of marine sustainability at the ecosystem level (or of the performance of the responsible agencies) very challenging.

There are at present no practical and comprehensive schemes for assessing the health of ecosystems, even if the concept could

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be defined rigorously. There are global initiatives underway such as the Biodiversity Indicators Partnership funded by the Global Environment Facility, which is developing a range of indicators to assess biodiversity trends including marine biodiversity and fisheries [10]. While developing a scheme one needs to consider the availability and reliability of global data as well as the cost of undertaking such assessments, especially in developing countries, where both factors can be problematic as seen in the few MSC assessments of fisheries from developing countries [3]. What is proposed in this paper are a set of indicators, most of them developed by the authors, which capture how much countries put in towards managing their EEZs (usually including several exploited marine ecosystems), and to a certain extent, how well they succeed.

2. Data and methods

The countries (and territories) evaluated in this study are listed, by region, in Table 1. These countries, which jointly account for 95 percent of the world's marine fisheries landings since 1950, were selected by Pitcher et al. [5] for their assessment of compliance to the FAO Code of Conduct. These countries also are highly diverse in size (both in EEZ and GDP), level of economic development, management regime and ecological characteristics, and are thus considered representative of the world as a whole.

Fourteen indicators, covering the period between 2000 and 2004, were assembled and assigned to one of the three categories ('biodiversity', 'value' or 'jobs') depending on their roles in the four GEO4 scenarios described below:

Biodiversity-related indicators (b):

(1) marine protected area coverage (MPA_{area});
(2) investment to marine protected areas (MPA_{inv});
(3) change in EEZ area trawled (EEZ_{trawl});
(4) ecological components of mariculture sustainability index (MSI_{ecol});
(5) seabird protection index ($BIRD_{prot}$);
(6) marine mammal protection index (MAM_{prot});

Value-related indicators (v):

(7) landed value relative to GDP (LV_{GDP});
(8) fishmeal consumption by mariculture ($MEAL_{mar}$);
(9) compliance with the FAO code of conduct ($CODE_{FAO}$);
(10) context-adjusted fisheries statistics indicator ($STAT_{rep}$);
(11) 'Good' to 'Good+Bad' subsidies ratio (SUB_{good});

Job-related indicators (j):

(12) catch relative to fuel consumption ($CATCH_{fuel}$);
(13) subsides relative to landed value (SUB_{LV}); and
(14) socioeconomic components of mariculture sustainability index (MSI_{soc}).

Table 1
Maritime countries (and territories) evaluated in this study.

Region	Countries (and territories)
Africa	Angola, Egypt, Ghana, Morocco, Namibia, Nigeria, Senegal, South Africa
Asia	Bangladesh, China, India, Indonesia, Iran, Japan, North Korea, South Korea, Malaysia, Myanmar, Pakistan, Philippines, Sri Lanka, Taiwan, Thailand, Turkey, Viet Nam, Yemen
Europe	Denmark, Faeroes, France, Germany, Iceland, Ireland, Italy, Latvia, Netherlands, Norway, Poland, Portugal, Russian Federation, Spain, Sweden, Ukraine, United Kingdom
N. America	Canada, Mexico, USA
Oceania	Australia, New Zealand
S. America	Argentina, Brazil, Chile, Ecuador, Peru

Marine protected area coverage (MPA_{area}) is expressed as the area of officially designated MPAs relative to the area of that country's claimed EEZ. MPA data were taken from MPA Global (www.mpaglobal.org; [11]), while the area of EEZs are from the *Sea Around Us* Project (www.seaaroundus.org). The indicator ranges from 0 to 10, corresponding to a range of 0–10 percent MPA coverage. Ten percent coverage was selected as an anchor in accordance with the CBD-stated conservation goal of protecting at least 10 percent of the world's marine coastal and ecological regions by 2012 [12].

Investment to marine protected areas (MPA_{inv}) is an index of the government expenditure, or maintenance costs, of its MPAs relative to the value of the fisheries within its EEZs [13]. The estimates of MPA costs were derived from Balmford et al. [14] using the MPA data from Wood et al. [11] and the value of fisheries landings generated by the *Sea Around Us* Project [15].

Balmford et al. [14] presented a number of empirical models for estimating MPA costs from other variables. The simplest of their models was used:

$$\log_{10}(C) = 5.02 - 0.8 \cdot \log_{10}(A) \quad (1)$$

where C is the annual cost of MPA, expressed in real year 2000 US dollars, and A is the MPA area, expressed in km^2. Note that, for each country, the cost estimates were computed for each MPA separately and then aggregated (as opposed to calculating a single estimate derived from the total MPA area). This model explained almost 80 percent of the variance in the dataset (r^2=0.79).

Eq. (1) provides approximate costs of MPAs for a developmentally 'average' country and fails to capture the variation in costs owing to the economic status of a country. Therefore, the estimates derived from the equation were improved using a two-step procedure. First, countries were grouped into five categories based on their per capita GDP using year 2000 estimates from the World Bank (www.worldbank.org) and the International Monetary Fund, IMF (www.imf.org). Then, a correction factor was applied to each estimate, based on Balmford et al.'s [14] median costs for developed and developing countries (Table 2).

Using Australia (one of the most advanced countries for MPA investment) as our baseline, we considered the investment of >10 percent of the landed value of fisheries towards MPAs to be the target investment. A score of 10 was assigned to such countries, while countries with investments of 0.5 percent or less were assigned a score of zero.

Change in EEZ area trawled (EEZ_{trawl}) is an indicator of the change in extent of the trawl fisheries within the EEZ, and hence

Table 2
Correction factors for adjusting the cost estimates from Eq. (1) based on 2000 per capita GDPs of countries.

Category	Per capita GDP (US$ $\times 10^3$)	Correction factor
I	>14.0	1.70
II	4.0–13.9	1.35
III	2.0–3.9	1.00
IV	0.8–1.9	0.65
V	<0.8	0.30

Table 3
Attributes used for assessing the ecological impacts of mariculture.

Attributes	Scoring scheme
Native or introduced	Mariculture of native species=10; foreign and introduced species=1. Intermediary scores for native but non-local species. Based on the potential impacts of escaped farmed species onto local biodiversity
Use of fishmeal	Mariculture for herbivorous species=10 with carnivorous species scoring lower, proportionally to the fishmeal used in feed
Stocking density	Mariculture assigned to one of the three intensity levels (intensive, semi-intensive and extensive) and scored 1, 5 and 10, respectively, with variations due to polyculture or feed requirements at different ontogenetic stages
Larvae and seed provenance	Hatcheries are major providers of larvae, fry and seeds. Broodstock origin and strain will also affect the score. Wild seed collection and its relative importance contribute to a low score, due to bycatch and other impacts on non-target species
Habitat impacts	Scores based on farm location, impact to the surrounding ecosystem and on biodiversity impacts are considered, with low impacting species (e.g. mussels) scoring high (10) and high-impact species (e.g. shrimp farms in coastal mangrove) scoring low (1)
Waste treatment	The scoring based on the type of water exchange with the surrounding environment, with considerations for output fate and the use of recycling and filtering equipments. Closed-containment systems score 10, while open systems without waste treatments score 1

of marine habitat degradation from gears that greatly impact sea bottom structures [16]. The 2000 and 2004 estimates of areas impacted by trawls and dredges were taken from Watson et al. [11,17]. Relative changes in the area trawled from 2000 and 2004 were standardized using the proportion of trawlers and dredgers in the total fleet (in Gross Registered Tonnage, GRT) based on the FAO fleet composition data [26]. EEZ_{trawl} is thus computed using

$$EEZ_{trawl} = (\text{area trawled}_{2000}/\text{area trawled}_{2004})/(1 - \%\text{fleet}_{\text{trawlers+dredges}}/100) \quad (2)$$

Subsequently, the indicator is standardized from 0 to 10 using the extreme values as anchors and scoring intermediate values proportionately.

Ecological components of mariculture sustainability index (MSI_{ecol}) is an aggregate of six attributes (Table 3) indicative of the ecological impacts of mariculture as identified and described by Trujillo [18]. It is based on scores assessed for each species cultured, per country, aggregated using their relative production as weighting factors. All attributes were designed to be expressed within a range of 1–10.

Seabird protection index ($BIRD_{prot}$) measures intention of maritime countries and effectiveness of measures taken to protect seabird populations breeding in these countries [19]. This indicator is the aggregate score of three attributes described in Table 4 using the data compiled by Karpouzi et al. [20]. However, for five out of 53 countries in the study (Bangladesh, Iran, North Korea, Malaysia, and Myanmar), no seabird population information was available, and hence these countries

Table 4
Attributes and scoring schemes used in $BIRD_{prot}$.

Attribute 1	Conventions and agreements for seabird protection relevant to each country
0	No relevant conventions and agreements signed and ratified
5	Half of relevant conventions and agreements signed and ratified
10	All relevant conventions and agreements signed and ratified
Attribute 2	**Annual percent change of seabird populations breeding in each country**
0	Maximum annual percent decrease in population size
5	No change in population size
10	Maximum annual percent increase in population size
Attribute 3	**Quality of population size data**
0	No data available for all the years considered
5	Data available for half of the years considered
10	Data available for all the years considered

Table 5
Attributes and scoring schemes used in MAM_{prot}.

Attributes	Scoring
Targeted hunts (pressure)	For each marine mammal group (pinnipeds, small cetaceans and great whales), scores between 0 and 3 were assigned based on the size of the hunts and the number of species targeted (includes scientific whaling)
Incidental kills (pressure)	Scores based on the size of gillnet fisheries landings relative to the total fisheries landings in the EEZ
Species extinction risk (state)	For each species inhabiting the EEZ (based on [39]), scores are assigned based on the IUCN Red List [40]. An aggregated score for the EEZ was computed using the habitat–EEZ overlap ratio
Species abundance (state)	Scores based on the relative abundance of marine mammal species inhabiting the EEZ (from [41]). Again, aggregated using the habitat–EEZ overlap ratio
International treaties (response)	Scoring based on the country participation to selected international treaties that were deemed relevant to the marine mammal protection
Domestic policies (response)	Scoring based on the relative size of MPAs implemented in the EEZ

scored 5 on the second attribute (no change in population size) by default.[1]

Marine mammal protection index (MAM_{prot}) is a composite performance index that evaluates the performances of maritime countries based on three components of marine mammal protection-degree of pressure exerted on marine mammal species through human activities (pressure); their conservation status (state); and government response (response) in mitigating or preventing human-induced damages to marine mammal populations [21]. It is based on six independent attributes, weighed to represent the three components equally (Table 5). All attributes were transformed to standardize their dimensions and to remove skewness within attributes.

Landed value relative to GDP (LV_{GDP}) is expressed as the landed value of the total fisheries catch of a country [22] relative to its GDP [23]. Previous studies have found a general trend of well-managed fisheries where they are a significant contributor to GDP as seen in some developed countries [24]. Landed value and GDP data, both for

[1] We see the potential shortcoming in this approach; however, we hope to make appropriate in the future continuation of this work. In any case, it has a miniscule effect on one of the 14 attributes for only five countries listed above.

2000, were obtained from the *Sea Around Us* Project and the World Bank, respectively [23].

Again, the indicator is standardized from 0 to 10 using the extreme values as anchors and the intermediate values were scored proportionately.

Fishmeal consumption by mariculture ($MEAL_{mar}$) is defined as the total fishmeal consumed by mariculture relative to its total production, ranging from 0 (fishmeal consumption greater than or equal to mariculture production) to 10 (consumption <0.1 of production) [23]. The estimates of fishmeal consumption per unit of aquaculture production were taken from Campbell and Alder [25]. The fishmeal consumption for countries not available in Campbell and Alder [25] was obtained from FAO's database of Processed Products [26]. Both data sets refer to the year 2000.

Compliance with the FAO code of conduct ($CODE_{FAO}$) is an indicator based on the quantified assessment of countries' compliance to the FAO code of conduct by Pitcher et al. [5]. The evaluation of the data was based on an adaptation of the appraisal scheme of 44 management related questions, each scored on a scale of 0–10. The scores were based on published and unpublished literature, and expert opinion [5].

Context-adjusted fisheries statistics indicator ($STAT_{rep}$) assesses the quality of each country's reporting system in a regional context (defined by shared taxa) through the percentage of reported commercial taxa to commercial, but unreported taxa occurring in a country's EEZ [27]. The distribution range map of taxa will overlap with the EEZ of at least one country that reports on it and often overlaps with the EEZs of other countries. The fact that different countries may report the same fish or invertebrates at different taxonomic levels is accounted for and described in detail in Pauly and Watson [27].

An overlap of at least 10 percent of the distribution range map of a taxon with the EEZ of a country is needed for this taxon to 'occur in' that country, where it may be reported from the catch, or not. (Non-reporting may be because these taxa are not targeted and they appear only in the by-catch, and/or because these countries do not monitor their fisheries adequately—hence this indicator). Data were derived from the *Sea Around Us* landings and species distributions constructed as outlined in Close et al. [28].

'Good' to 'Good+Bad' subsidy ratio (SUB_{good}) measures financial resource allocated to management and surveillance relative to the sum of such 'good' subsidies and 'bad' (capacity enhancing) subsidies [22,23]. Good subsidies as a fraction of the sum of good and bad subsidies represent efforts towards fisheries management, services and research, and therefore can be expected to improve the sustainability of fisheries. The subsidies, which are 'bad' for fisheries sustainability when they lead to fleet capacity growth, and 'good' otherwise, refer only to marine capture fisheries, and were estimated when reported data were not available [29]. The data were derived for the year 2000 from the subsidies data in Sumaila and Pauly [22] and the *Sea Around Us* database, respectively.

Again, the indicator is standardized from 0 to 10 using the extreme values as anchors.

Catch relative to fuel consumption ($CATCH_{fuel}$) is based on Tyedmers et al. [30] and expressed as the amount of fish caught (kg) per litre (L) of fuel used by the fleet. The type of fishing gear used to catch fish is obviously the key factor determining the amount of fuel consumed. Passive fishing gear (nets or traps) used to catch pelagic and groundfish have lower fuel consumptions than active fishing gear which are dragged long distances through the water (e.g., bottom trawl), thereby contributing to fossil fuel consumption and greenhouse gas emissions. Catch per litre of fuel consumed for the year 2000 was retrieved from the *Sea Around Us* project database and is based on the study by Tyedmers et al. [30]. The logarithm of catch (in kg) per litre of fuel was used as an indicator, to provide a better spread among countries with low scores. This was then rescaled to scores between 0, reflecting low catch per fuel consumed, and 10, for the converse [23].

Subsides relative to landed value (SUB_{LV}) are computed from overall subsidies relative to the value of the catch [22], expressed on a scale of 0–10 as detailed in Mondoux et al. [23]. Countries with higher levels of subsidies relative to the value of the landings have less incentive to manage their fisheries [22]. See above for source of subsidies and landed value data.

Socioeconomic components of the mariculture sustainability index (MSI_{soc}) is an aggregate of several socio-economic attributes (Table 6) identified and described by Trujillo [18]. The attribute scores are determined for each species, with the aggregated score for a country computed from the relative weight of their annual production of the various farmed species.

Some indicators described above use multiple attributes, reflecting both the country's intentions to manage the resources and its actual implementation. However, a correlation analysis including these variables suggested strong auto-correlation. Thus, single, combined scores were used for these indicators (Appendix A).

Aggregate score was computed as the average score of the 14 indicators described above, (except for countries without a sizable mariculture industry, in which case their scores for two mariculture based indicators (MSI_{ecol} and MSI_{soc}) were omitted. Pair-wise correlation coefficients were calculated to investigate auto-correlation among the 14 variables. The behaviour of the 14 indicators was investigated using a principal component analysis (PCA) using the STATA statistical package [31].

Other approaches could be taken to derive an aggregate score, e.g., through varying weighting schemes of the indicators. However, weighting of indicators is largely subjective. Thus, persons concerned with conservation may weigh indicators associated with seabirds and marine mammals higher than people who are interested in fisheries or mariculture development.

One solution to this problem is to make individual indicator scores widely available (Appendix A) and allow users to determine their own weightings and conduct their own analysis. To allow

Table 6
Socioeconomic attributes used for the computation of MSI_{soc}.

Attributes	Scoring scheme
Product destination	Culture is to satisfy international (1) or domestic demand (10)
Use of chemicals and pharmaceuticals	Indiscriminate use of antibiotics, pesticides, disinfectants, anti-foulants, hormones and vaccines (1), or no use of chemicals or pharmaceuticals (10)
Genetic manipulation	Aquaculture of genetically modified organisms or transgenic species score 0, while absence of such organisms is assigned a score of 10
Code of practice usage	Certification, up to date set of standards and principles, i.e., the FAO code of conduct, or eco-labeling schemes are scored high; no certification or similar scheme scores low (1)
Traceability	Food safety related to a specific geographical origin or processing facility, and batches of fish that can be identified scores relatively high (8–9). If, additionally, the origin and preparation of the feed used in the farmed sector is also included, then score very high (10)
Employment	Jobs created or strong community focus scores high (8–10); where jobs are lost to the farming operations, or a weak local community focus, score is low (1–3)

Table 7
GEO4 scenario-based weightings used in computing the aggregated scores of country performance.

Criteria \GEO4 scenarios	Market First	Policy First	Security First	Sustainability First
Biodiversity (b)	*2.00*	*5.00*	*0.00*	*10.00*
Value (v)	*1.00*	*1.00*	*0.30*	*0.10*
Jobs (j)	*0.33*	*1.00*	*1.00*	*0.10*
Indicators				
MPA_{area} (b)	2.00	5.00	0.00	10.00
MPA_{inv} (b)	2.00	5.00	0.00	10.00
EEZ_{trawl} (b)	2.00	5.00	0.00	10.00
MSI_{ecol} (b)	2.00	5.00	0.00	10.00
$BIRD_{prot}$ (b)	2.00	5.00	0.00	10.00
MAM_{prot} (b)	2.00	5.00	0.00	10.00
LV_{GDP} (v)	1.00	1.00	0.30	0.10
$MEAL_{mar}$ (v)	1.00	1.00	0.30	0.10
$CODE_{FAO}$ (v)	1.00	1.00	0.30	0.10
$STAT_{rep}$ (v)	1.00	1.00	0.30	0.10
SUB_{good} (v)	1.00	1.00	0.30	0.10
$CATCH_{fuel}$ (j)	0.33	1.00	0.10	1.00
SUB_{LV} (j)	0.33	1.00	0.10	1.00
MAR_{soc} (j)	0.33	1.00	0.10	1.00

this, we will make these data available on the website of the *Sea Around Us* Project (www.seaaroundus.org).

The other solution is to use weights reflecting different pre-existing attitudinal configurations, here called 'scenarios,' which constrain the subjective components of assessments (see e.g. [32]). As in Alder et al. [33], we chose here to weight the indicators by mapping the global scenarios used in the GEO4 [34] to the 14 indicators of this study (Table 7). The weights used in the GEO4 are based on consensus among country experts participating in the GEO4 process in 2006. The current four GEO4 scenarios represent four plausible futures for the world in terms of economic development, social policies, technological advances and ecosystem management. As the names suggest, the Market First future is focused on using economic policies to drive development, including economic incentives to improve environmental management and technology to mitigate impacts. In the Policy First future, the focus is on the economic and social policies that facilitate development and on overriding environmental concerns. In the Security First world, it is the rich and powerful who seek to optimize their economic and social well-being; they support environmental policies only if it is in their benefit to do so. Finally, in the Sustainability First scenario, the environmental and social policies are balanced [34].

3. Results and discussion

The correlation matrix of the 14 variables across the 53 countries indicated seven of the 91 correlation coefficients (r) were >0.40; the maximum r value, pertaining to the correlation between the two mariculture indicators (ecological and socio-economic sustainability) was 0.72. The PCA of the unweighted scores accounted for more than 50 percent of the variation of the 14 scores in three dimensions. A plot of the country scores in the first two dimensions (Fig. 1) illustrates the relative positions of countries along the first and the second dimensions of the PCA. The results of the PCA correspond to the unweighted aggregate score of the 53 countries (Table 8), where New Zealand scored the highest (5.5 out of 10) and Bangladesh the lowest (2.3). There is a trend for the developed countries to score higher than developing

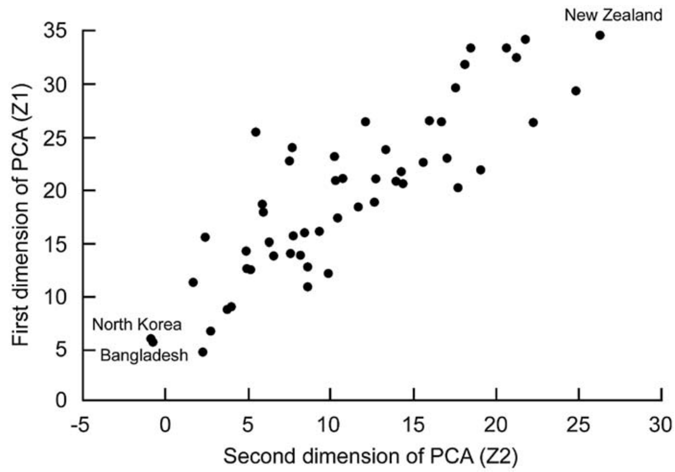

Fig. 1. Principal component analysis of the unweighted scores of 53 countries, showing the clear separation of countries in a plot of the first dimension (Z1) versus the second dimension (Z2). Countries characterizing the extreme are labeled.

Table 8
Aggregated score (unweighted) of marine resource management performance.

Country	Aggregate score	Country	Aggregate score
New Zealand	5.5	Portugal	4.0
Peru	5.2	Latvia	3.9
Germany	5.2	Ukraine	3.9
Netherlands	5.1	Malaysia	3.9
USA	4.8	Philippines	3.9
South Africa	4.8	Morocco	3.9
Australia	4.8	Argentina	3.8
UK	4.8	Mexico	3.8
Sweden	4.6	China	3.7
Senegal	4.6	Turkey	3.6
Spain	4.5	Angola	3.6
Japan	4.5	Taiwan	3.6
Chile	4.4	Ghana	3.6
Namibia	4.4	Thailand	3.6
Canada	4.4	Indonesia	3.5
Ireland	4.4	Pakistan	3.4
France	4.4	Viet Nam	3.3
Denmark	4.4	Myanmar	3.3
Iceland	4.3	Yemen	3.3
South Korea	4.2	Sri Lanka	3.2
Poland	4.2	Iran	3.0
Norway	4.2	North Korea	2.8
Nigeria	4.1	Brazil	2.8
Russia	4.1	India	2.7
Egypt	4.0	Faeroes	2.7
Ecuador	4.0	Bangladesh	2.3
Italy	4.0	–	–

countries. However, Peru,[2] South Africa and Senegal are in the top 10 scoring countries, while the Faeroes Islands are among the lowest 10 of countries scored.

The suite of 14 indicators when aggregated to a single (unweighted) score appear to be consistent in identifying high, average and poor performers across the 53 countries. For example, countries that scored well on fisheries statistics reporting and

[2] Given the attention which Peruvian media gave to a preliminary release of these results (see for example [42]), we wish to emphasize that this positive ranking is mainly caused by what Peru does *not* do (e.g., have an extensive mariculture industry), and not by what it does (see text). Our rankings are thus not an endorsement of Peruvian fisheries management—although we do acknowledge that the reforms currently underway in Peruvian fisheries appear very encouraging.

mariculture tended to have a high overall score, and conversely, the opposite was true.

The scores weighted according to the GEO4 scenarios resulted in different rankings from the unweighted analysis (Table 9). For example, in the Policy First scenario, Egypt was in the top 5, while in the Security First scenario, it was in the bottom 5. Overall, however, the countries that scored low tended to score low in all scenarios (including Bangladesh and Faeroes Island). The top and middle rankings of countries were not consistent, except for a few such as New Zealand in the top performing countries (average ranking=9), and Portugal (average ranking=25) and Malaysia (average ranking=29) in the middle performing countries.

The PCA analysis of the weighted indicators also illustrates the differences in country rankings between the four GEO4 scenarios (Fig. 2). The trend in the four scenarios is less well defined than for the unweighted PCA analysis (Fig. 1). As well, the PCA trend for Security First (Fig. 2C) and Sustainability First (Fig. 2D) are orthogonal to the Market First (Fig. 2A) and Policy First (Fig. 2B) scenarios, and different from the unweighted analysis (Fig. 1). The Security First and Sustainability First scenarios were expressed as orthogonal or at the opposite end of the spectrum to Market First and Policy First scenarios, which is reflected in the PCA analysis (Fig. 2).

The distribution of country scores in the PCA unweighted analysis is largely due to SUB_{good} in the first and second dimensions. In the Market First analysis (Fig. 2A), the same subsidies indicators have a strong effect on the distribution of the points (countries) along the first dimension. Along the second dimension, it is a combination of $CODE_{FAO}$ and $STAT_{rep}$, while in Policy First (Fig. 2B) it is EEZ_{trawl} and other ecosystem related indicators and MSI_{ecol} in the second dimension. In the Security First (Fig. 2C) analysis it is subsidies related indicators (SUB_{good} and SUB_{LV}) dominating the first dimension and $STAT_{rep}$ in the second dimension, while in Sustainability First (Fig. 2D) it is MPA based indicators (MPA_{area} and MPA_{inv}) along the first dimension and MAM_{prot} along the second.

Weighting has a significant impact on the ranking of all but the poorly performing countries. However, in the PCA analysis, for most scenarios, the countries that were the unweighted top performers were still positioned ahead of countries that performed poorly. Both analyses, using unweighted and weighted data, suggest that the 14 indicators used to estimate an aggregate marine resource management score do differentiate between performing countries in terms of how they manage the resource and ecosystems in their EEZs.

Although some indicators were explicitly designed to overcome this bias (e.g., $STAT_{rep}$, see [27]), the indicators, in the aggregate, appear to favour developed countries. It could be argued that the reason why the poor performers were usually developing countries is because they do not have the funds to comply with the FAO code of conduct, and do not have the luxury of designating MPAs and financing their management. However, a closer look at the indicators suggests that this is not the case, since there is a range of indicators where developing countries are not disadvantaged, including marine mammal and seabird protection and status, use of fishmeal in aquaculture, and fisheries subsidies.

Table 9
The top and bottom five countries when the indicators are aggregated using the GEO4 scenario-based weightings.

Ranking	Market First	Policy First	Security First	Sustainability First
Top 5	Poland	Poland	New Zealand	Germany
	Senegal	Senegal	Peru	Australia
	South Africa	Egypt	Iceland	Sweden
	USA	Spain	USA	Denmark
	Spain	South Africa	Norway	Spain
Bottom 5	Bangladesh	Bangladesh	Bangladesh	Bangladesh
	Iran	Iran	North Korea	Faeroes
	Ukraine	Argentina	India	Iran
	Argentina	Faeroes	Brazil	Myanmar
	Faeroes	Ukraine	Egypt	Iceland

Indeed, the countries that were found here to perform poorly include, at least for some scenarios, developed countries which could be expected to have better scores (e.g., Iceland, see Table 9), in addition to countries which, because of their poverty and ultimately, their governance (Bangladesh, North Korea, Myanmar), end up at the bottom of most lists of this sort.

On the other hand, the reason why countries such as New Zealand, the USA or Germany are among the top performers in Table 9 is mainly because these countries have been implementing, at least partly, measures to sustainably manage their marine resources, such as establishing networks of MPAs and financing their implementation, reducing or eliminating perverse subsidies, reducing trawling in their marine waters and reducing the fuel consumed in the fishing sector. These indeed, are the very actions whose full implementation is recommended in sector studies such as, e.g., the Pew Ocean Commission for the USA [35]. Some other countries—for example Peru—show up as top performers in Table 9 not because they have actively implemented such measures, but because the specific structure of their fisheries (overwhelmingly concentrated on anchovy in the case of Peru), and their state of development, happened to generate a high score under a given scenario, given the weights of each indicator (see Table 7). This emphasizes the need to screen the indicators and weighting factors used in a study of this type, our final theme.

These findings, and the quantitative data upon which they are based, suggest that ranking countries in terms of how sustainably they manage their EEZs is both straightforward and complex. It is straightforward—though work intensive—in terms of specific indicators, which can be designed to capture a specific aspect of EEZs, e.g., their marine mammal populations, and how different countries manage them (see [21]). This is the reason why many indicators exist (see [36,37]). It is complex, and fraught with subjective hurdles, because it involves explicit values which are usually implicitly held [38]. This is why we used scenarios, with explicit emphasis on certain indicators and the consequent de-emphasis of others (Table 9).

Clearly, future work on the issue of indicators for EEZ management will have to focus on scenarios, and on the corresponding weighting schedule, which, this study shows, is crucial to the credibility of any ranking scheme.

4. Conclusion

This assessment found that, while we can rank countries from the highest to the lowest, the highest ranking country does not approach the high standards set either by international conventions or by consensus among scientists and managers [11]. This is clearly seen with the actual area of designated MPAs compared to the CBD's interim target of 10 percent of national EEZs protected by 2010. In this study, only one country, Germany, stood above the rest with a score of 2 out of a possible 10, indicating that approximately 2 percent of its EEZ is protected.[3] Similarly, only a few countries give subsidies that are considered beneficial to fisheries, despite calls for the elimination of perverse subsidies.

[3] Turkey has not declared its EEZ in the Mediterranean as of 2008. However, our assessment of Turkey's performance includes the management of areas in the Mediterranean that would be inside the Turkish EEZ, if one existed see www.seaaroundus.org for the description of such areas.

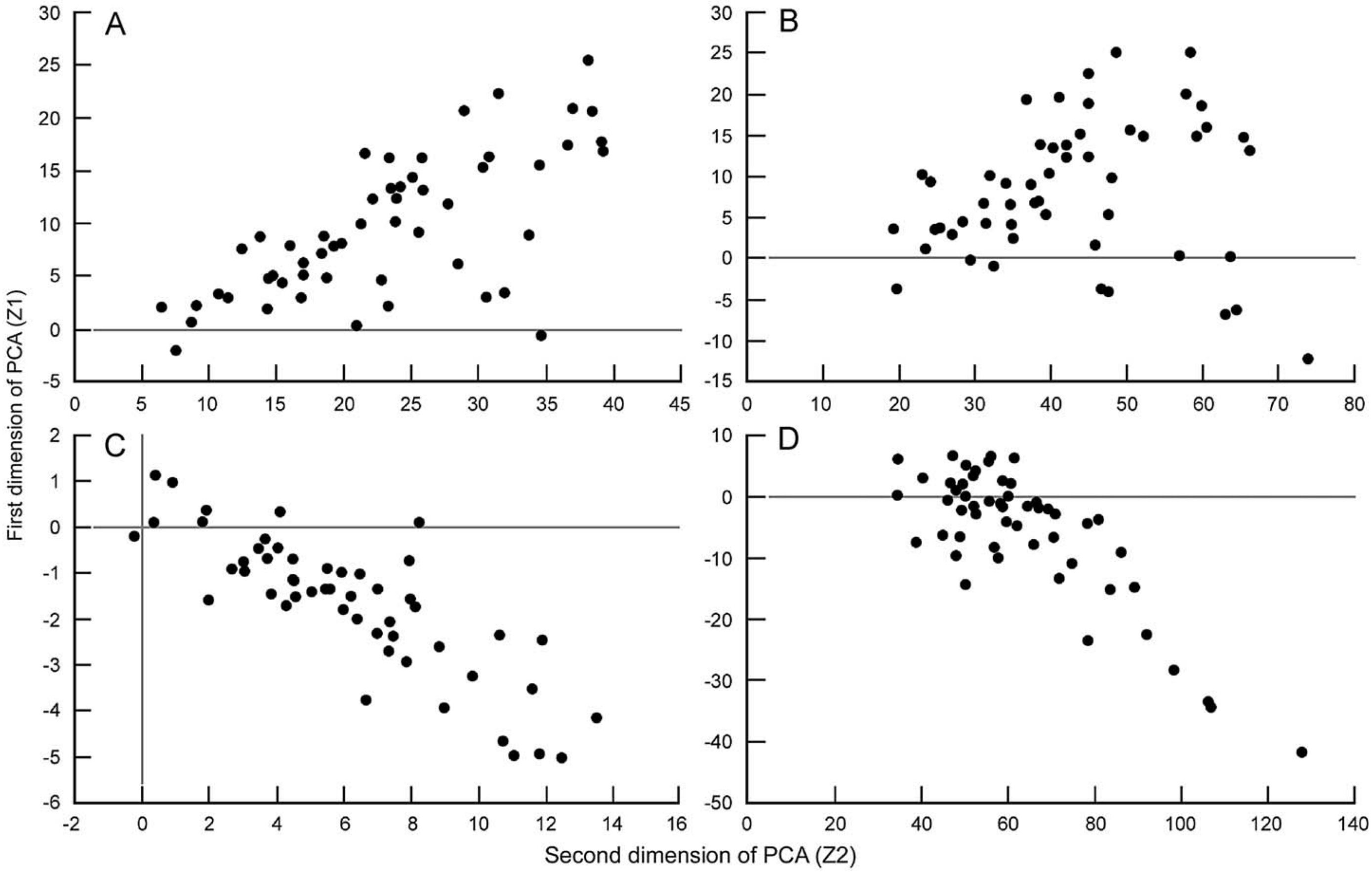

Fig. 2. Principle component analysis of weighted scores of 53 countries based on the four GEO4 scenarios (A—Market First; B—Policy First; C—Security First; D—Sustainability First).

Of the 53 countries of this study, only four had an unweighted score of more than 5 out of 10, and the maximum score was 5.5. These four countries are incorporating best practices into their management of marine resources, but with room for considerable improvement. The remaining countries have considerably more work to do in improving their practices and policies to manage fisheries, marine mammals and seabirds, and setting their mariculture industry on a sustainable course. There are a number of initiatives that need to be developed, notably in expanding MPA networks, reducing perverse subsidies and reducing areas available for trawling. The socioeconomic impacts of these initiatives can be offset, especially in developed countries, by creating new opportunities in other sectors such as marine tourism and post-harvest processing to add value and jobs in existing fisheries, and in the remaining fisheries.

It was also noted that many developing countries scored around the average; this is not necessarily a reflection of good marine resource management, but of the fact they cannot afford to undertake bad practices such as subsidizing fisheries, developing unsustainable aquaculture ventures and expanding trawling fleets. These countries are in the position to avoid the mistakes of other countries, i.e., overcapitalizing fisheries and establishing subsidy schemes that contribute to destructive fishing practices and overfishing. The indicators in this study can help these countries track how they are doing against such measures and take corrective action earlier rather than later, when it is more difficult to do. Many developing countries are also just beginning to develop their aquaculture sector. The two aquaculture indicators of this study can assist countries in tracking development in terms of ecological, social and economic sustainability.

This study has set the baseline for measuring how well countries manage a range of marine resources and issues, and demonstrated that much more work needs to be done to improve performance among the 53 countries assessed. There is no single recommendation on what are the priority actions to improve these scores; this will vary between countries, as they have different priorities, resources and values. Some actions will require few resources and have minimal impact on communities, either socially or economically, while others will be more costly and have higher impacts. However, a range of actions, from reducing perverse subsidies to better reporting of fisheries statistics, will need to be taken soon if marine resources remain sustainable.

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Appendix A

Fourteen indicators used to estimate the aggregate marine resources management performance score are presented in Table A1.

Table A1
Fourteen indicators used to estimate the aggregate marine resources management performance score.

Country	MPA_{area}	MPA_{inv}	EEZ_{trawl}	MSI_{ecol}	$BIRD_{prot}$	MAM_{prot}	LV_{GDP}	$MEAL_{mar}$	$CODE_{FAO}$	$STAT_{rep}$	SUB_{good}	$CATCH_{fuel}$	SUB_{LV}	MSI_{soc}	Aggregate
Angola	1	0	4	–	2.6	6.0	6	10	1.2	27.4	2	0	8	–	**3.6**
Argentina	0	1	0	7.4	4.0	7.1	5	8	3.4	36.7	1	0	7	5.9	**3.8**
Australia	1	10	3	3.9	4.9	8.9	4	7	6.2	26.0	3	0	8	5.1	**4.8**
Bangladesh	0	0	0	2.3	3.1	5.1	1	9	1.4	2.2	1	0	6	2.7	**2.3**
Brazil	1	1	3	2.5	1.7	7.0	1	9	3.1	45.8	0	0	0	4.8	**2.8**
Canada	1	3	4	4.1	4.1	4.4	4	6	6.8	37.4	4	4	8	4.6	**4.4**
Chile	0	0	4	2.9	4.4	7.0	6	5	5.4	62.3	0	7	10	4.1	**4.4**
China	0	0	4	5.2	3.7	5.1	3	10	4.7	15.1	0	0	8	6.1	**3.7**
Denmark	1	8	3	5.5	4.3	7.8	5	5	5.7	41.6	1	4	0	6.5	**4.4**
Ecuador	0	1	5	4.5	4.0	6.4	6	8	3.0	34.6	2	0	8	4.9	**4.0**
Egypt	1	5	4	5.4	5.5	5.9	1	10	1.4	15.6	2	0	8	6.0	**4.0**
Faroes	0	0	3	4.5	3.4	5.2	1	3	5.3	40.7	1	4	0	3.0	**2.7**
France	0	1	3	6.4	5.9	7.4	1	9	5.0	63.6	1	0	8	7.0	**4.4**
Germany	2	10	2	9.0	5.3	8.8	1	8	4.2	26.9	1	4	8	7.1	**5.2**
Ghana	0	0	4	–	4.2	4.9	4	10	3.7	20.1	1	4	5	–	**3.6**
Iceland	0	0	4	5.4	2.5	4.6	9	4	6.6	35.7	1	4	9	7.1	**4.3**
India	1	0	3	2.8	3.8	6.1	1	10	3.6	15.8	0	0	0	5.0	**2.7**
Indonesia	1	1	4	4.9	2.8	5.0	3	9	2.4	27.0	1	0	7	5.3	**3.5**
Iran	1	1	0	3.7	2.8	5.3	1	9	2.0	22.6	2	0	7	4.8	**3.0**
Ireland	0	1	3	7.4	4.1	6.6	3	8	0.0	51.1	7	4	6	6.1	**4.4**
Italy	1	3	4	5.3	4.8	6.4	1	9	4.2	23.1	3	0	6	5.9	**4.0**
Japan	0	1	4	7.5	3.5	4.4	5	8	6.3	36.8	6	0	7	6.5	**4.5**
Latvia	0	1	1	–	3.6	7.1	3	10	2.4	20.2	2	7	8	–	**3.9**
Malaysia	1	2	3	5.1	2.6	5.1	7	9	4.7	20.7	0	0	8	4.9	**3.9**
Mexico	1	1	3	4.9	4.2	6.9	2	7	4.5	44.1	1	0	8	5.2	**3.8**
Morocco	0	1	3	5.5	3.4	5.8	4	6	3.5	29.3	2	4	7	5.8	**3.9**
Myanmar	0	0	4	2.8	2.8	5.5	7	10	1.0	1.4	2	0	7	3.7	**3.3**
Namibia	0	0	3	7.2	2.9	6.3	7	10	5.8	38.0	1	4	6	4.8	**4.4**
Netherlands	1	3	0	9.0	4.3	7.9	5	10	5.5	31.8	1	4	10	7.1	**5.1**
New Zealand	0	1	3	5.7	4.1	6.7	7	10	6.4	73.1	10	0	10	6.1	**5.5**
Nigeria	0	0	4	5.3	3.7	4.6	3	9	1.6	17.4	9	0	10	5.7	**4.1**
North Korea	0	0	4	7.4	2.0	4.0	4	10	0.7	4.1	0	0	0	6.4	**2.8**
Norway	0	1	4	3.5	4.0	5.1	6	4	6.7	53.4	3	4	8	3.7	**4.2**
Pakistan	1	0	4	3.8	3.9	5.9	2	10	2.5	17.7	2	0	7	4.2	**3.4**
Peru	0	0	4	4.3	4.1	6.3	7	8	4.3	36.0	8	10	9	4.9	**5.2**
Philippines	1	1	4	4.7	4.1	5.7	6	9	3.2	26.0	1	0	6	5.8	**3.9**
Poland	1	1	6	5.2	3.7	7.6	1	9	2.5	16.2	5	4	6	5.2	**4.2**
Portugal	0	1	4	6.8	3.3	7.4	2	6	4.1	70.0	2	0	6	5.7	**4.0**
Russia	1	0	4	8.7	3.4	5.2	3	10	3.4	56.4	3	0	4	5.4	**4.1**
Senegal	0	0	5	6.6	3.7	6.3	7	10	2.6	46.8	1	4	8	5.3	**4.6**
South Africa	0	2	4	7.0	5.0	7.7	1	9	6.1	53.1	3	4	8	5.5	**4.8**
South Korea	1	0	4	7.1	2.8	5.3	5	10	5.5	39.8	0	0	8	6.4	**4.2**
Spain	1	2	4	8.7	4.8	7.1	2	9	5.2	67.5	0	0	6	7.1	**4.5**
Sri Lanka	0	1	3	2.5	3.7	5.9	5	7	1.5	7.6	2	0	8	5.0	**3.2**
Sweden	1	10	3	5.4	4.2	8.0	1	5	4.5	27.5	6	0	8	6.2	**4.6**
Taiwan	0	1	4	5.0	1.6	6.0	4	8	4.0	27.5	0	0	8	5.7	**3.6**
Thailand	1	2	3	3.3	3.3	6.3	6	9	2.0	22.1	0	0	7	4.9	**3.6**
Turkey	1	1	4	5.0	3.4	4.9	2	6	1.8	28.0	0	4	10	5.0	**3.6**
UK	1	5	4	4.5	5.3	8.0	1	5	5.2	60.8	5	4	9	4.2	**4.8**
Ukraine	1	4	0	6.2	3.7	6.5	2	10	2.2	26.5	1	4	6	5.5	**3.9**
USA	1	3	4	6.1	3.9	5.0	1	9	6.8	69.4	7	0	8	6.1	**4.8**
Viet Nam	0	0	4	3.7	3.6	6.1	6	7	1.6	1.5	1	0	8	5.0	**3.3**
Yemen	0	0	3	3.7	2.8	6.0	6	10	0.9	11.6	0	0	7	5.0	**3.3**

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