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A COMPARATIVE ASSESSMENT OF BIODIVERSITY, FISHERIES AND AQUACULTURE IN 53 COUNTRIES' EXCLUSIVE ECONOMIC ZONES

Fisheries Centre, University of British Columbia, Canada

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Edited by
Jackie Alder and Daniel Pauly

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DIRECTOR'S FOREWORD

There are increasing concerns about the sustainability of the seafood we consume and about the environmental impact of fisheries, 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. However, the sustainability of fisheries is not only a matter of how they are managed, but also of the health of the ecosystems in which they are embedded.

There are at present no practical schemes for assessing the health of ecosystems, even if the concept could be defined rigorously. What is proposed in this report, instead, are a set of indicators which may capture how much countries attempt to do towards managing their Exclusive Economic Zones (EEZs; usually including several exploited marine ecosystems) and, to a certain extent, how well they succeed in doing so.

The EEZs of most countries are used for economic, recreational and cultural purposes, and the impacts from these uses vary across countries. The indicators presented here addressed a number of challenges. Foremost among them was to identify the components of the marine ecosystems that needed to, and could be, tracked by indicators. The second challenge was to design, apply and test selected indicators, notably with regard to their ability to produce, when aggregated, an overall indicator of how well individual countries are managing the biodiversity and the living resources within their EEZs.

These challenges could be met, thanks to the dedication of a number of authors, but also because previous work by the *Sea Around Us* Project had generated precursors to several of the indicators presented here, and databases enabling estimation of their values for most countries. The work of Dr. Pitcher and collaborators, on countries' compliance with the FAO Code of Conduct for Responsible Fisheries paved our way, notably regarding the selection of countries to be included in this first analysis. The 53 countries included here represent over 95 % of the world catch. Jointly, they ensure that this report presents more than a pilot study for a sample of countries.

The aggregate indicator presented in the first chapter of this report synthesizes 14 specific indicators, jointly covering the major areas of concern with regard to EEZs: fisheries, coastal aquaculture, seabirds and marine mammals. These 14 indicators were derived from various specific studies that the *Sea Around Us* Project undertook over the last two years, reported upon in the other six chapters in this report.

Seven fisheries indicators, which cover various aspects of fisheries management including subsidies, landed value, compliance with the FAO Code of Conduct for Responsible Fisheries and fuel use are presented by Mondoux *et al.* (this volume). There are two aquaculture indicators covering ecological and socio-economic aspects of the sector (Trujillo, this volume) and an indicator on the quality of countries' fisheries statistics (Pauly and Watson, this volume). Countries' compliance with international conventions for the conservation of seabirds (Karpouzi and Pauly, this volume) and marine mammals (Swartz *et al.*, this volume) are also included in the aggregate indicator, along with an indicator of countries' expenditure on marine protected areas (Cullis-Suzuki and Pauly, this volume).

This is the first report of its kind, and the indicators it presents could be refined, and strengthened through improvements in the quality of the underlying data. Nevertheless, a baseline has been established, which may be used to monitor countries' progress in improving the management of their biodiversity and marine resources in their EEZs.

Daniel Pauly,
Director, UBC Fisheries Centre
August 2008

AGGREGATE PERFORMANCE OF COUNTRIES IN MANAGING THEIR EEZS[1]

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ABSTRACT

Fourteen indicators of resource managements, expressive both of intention and effectiveness, and fully documented in the other contributions included in this report, were used to assess how 53 maritime countries, making up over 95% of the global catch, perform with regard to the resources in their Exclusive Economic Zone. Ranking of the 53 countries are presented for different weightings of the indicators, reflective of four scenarios also used in the Global Environment Outlook 4 (GEO4), i.e., Market First; Policy First; Security First, and Sustainability First. The rankings differed substantially between different scenarios for the top performing countries (New Zealand, Peru, Germany, Netherlands, USA) and less so for the poorer performing countries (Bangladesh, Faeroes Islands, India, Brazil, North Korea).

INTRODUCTION

The requirements of Ecosystem-Based Management of Fisheries (Pikitch *et al*., 2004) have resulted in an increased demand for methods for assessing how well-managed are the marine ecosystems in which fisheries are embedded. In response, criteria for sustainable fisheries practices have been developed, e.g., by the Marine Stewardship Councils (May *et al*., 2003), or in the form of a voluntary 'Code of Conduct for Responsible Fisheries' (FAO, 1995). These approaches are comprehensive in assessing 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 other components of marine ecosystems, such as seabirds and marine mammals, and other sectors such as mariculture. This is a reflection of multiple agencies having partial and overlapping jurisdictions, but none being responsible for the EEZ as a whole. This makes a comprehensive assessment of the effectiveness of these agencies problematic, not to mention the ecosystems in the EEZs thus managed.

Over the last two years the *Sea Around Us* Project has supported a number of initiatives that are now contributing to broad-based assessments of the performance of a number of countries in managing marine resources (Pauly, 2007). A number of these studies are included in this report, and the present contribution is a preliminary synthesis of this work.

MATERIAL AND METHODS

The countries included in this study, and in all other contribution in this report, are listed, by region, in Table 1. These countries, which jointly account for 95% of world fisheries catches, were originally selected by Pitcher *et al.* (2008a) for scoring in terms of their compliance with FAO's Code of Conduct for Responsible Fisheries' (see above). They also represent a range of EEZ sizes, levels of economic development, management regimes and regions, and are thus considered representative of the world as a whole.

[1] Cite as: Alder, J. and Pauly, D. 2008. Aggregate performance of countries in managing their EEZ. p. 3-12 *In*: Alder, J. and Pauly, D. (eds.) A comparative assessment of biodiversity, fisheries and aquaculture in 53 countries' Exclusive Economic Zones. Fisheries Centre Research Reports 16(7). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

Table 1. List of maritime countries (and territories[1]) considered in this study.

Region	Countries (or Territories[1])
Africa	Angola, Egypt, Ghana, Morocco, Namibia, Nigeria, Senegal, South Africa.
Asia	Bangladesh, China, India, Indonesia, Iran, Japan, Korea (North), Korea (South), Malaysia, Myanmar, Pakistan, Philippines, Sri Lanka, Taiwan, Thailand, Turkey, Viet Nam, Yemen.
Europe	Denmark, Faeroes Islands, France, Germany, Iceland, Ireland, Italy, Latvia, Netherlands, Norway, Poland, Portugal, Russian Federation, Spain, Sweden, Ukraine, United Kingdom.
N. America	Canada, Mexico, Contiguous states of the USA.
Oceania	Australia, New Zealand.
S. America	Argentina, Brazil, Chile, Ecuador, Peru.

[1]Used in cases where the ecosystems in the EEZs around the territories have distinct ecological features, differing from those of the core countries, and/or are managed separately.

A total of 14 indicators were assembled for this study, and assigned to one of three broad categories ('Biodiversity' 'Value' and 'Jobs'). They pertain largely to the period 2000-2004, and are briefly described in the following (bracketed acronyms refer to headers in Appendix 1):

Biodiversity-related indicators (b):

1) Marine Protected Area Coverage (MPA_{area}): the area formally protected in the EEZ of each country in Table 1, as assessed by data in www.seaaroundus.org, assembled by Wood *et al.* (2008), relative to the area of its EEZ (see Mondoux *et al.*, this vol.);
2) Investment to Marine Protected Areas (MPA_{inv}) an index of the cost of maintaining MPAs in the various countries, adapted from Balmford *et al.* (2004), relative to the value of their fisheries (Cullis-Suzuki and Pauly, this vol.);
3) Change in EEZ Area Trawled (EEZ_{trawl}), as assessed from trawl catches and related data (in www.seaaroundus.org), relative to the area of its EEZ (see Mondoux *et al.*, this vol.);
4) Ecological components of Mariculture Sustainability Index (MSI_{ecol}; Trujillo, this vol.);
5) Seabird Protection Index ($BIRD_{prot}$), composed of elements reflecting both intention and effectiveness on the ground (Karpouzi and Pauly, this vol.);
6) Marine Mammal Protection Index (MAM_{prot}), composed of elements reflecting both intention and effectiveness on the ground (Swartz *et al*., this vol.);

Value-related indicators (v):

7) Landed Value Relative to GDP (LV_{GDP}), i.e., the ex-vessel value of the total catch of a country (Sumaila *et al*., 2007) relative to Gross Domestic Product of that country (Mondoux *et al*., this vol.);
8) The fishmeal consumption by Mariculture ($MEAL_{mar}$), relative to its mariculture production (Mondoux *et al*., this vol.);
9) Compliance with the FAO Code of Conduct for Fisheries ($CODE_{FAO}$), as assessed by Pitcher *et al.* (2008a), and as reported here in Mondoux *et al.* (this vol.);
10) Context-Adjusted Fisheries Statistics Indicator ($STAT_{rep}$), which measures the effectiveness of countries' fisheries reporting systems (Pauly and Watson, this vol.)
11) 'Good' to 'Good + Bad' subsidies Ratio (SUB_{good}), which measures financial resource allocated to management and surveillance relative to the sum of such 'good' subsidies and 'bad' (capacity enhancing) subsidies (Mondoux *et al*., this vol.).

Job-related indicators (j):

12) Catch Relative to Fuel Consumption ($CATCH_{fuel}$), based on Tyedmers *et al.* (2005; see Mondoux *et al*., this vol.);
13) Subsides Relative to Landed Value (SUB_{LV}), overall subsidies scaled by the value of the catch (Sumaila *et al*., 2007; Mondoux *et al*., this vol.);
14) Socioeconomic Component of Mariculture Sustainability Index (MSI_{soc}), as defined by Trujillo (this vol.).

For seabirds (5), marine mammals (6) and the code of conduct (9), the indicators initially consisted of multiple elements, reflecting a country's intentions to manage the resources and its actual implementation. However, a correlation analysis including these variables suggested strong autocorrelation. Thus, single, combined indicators were used for seabirds, marine mammals and the code of conduct (Appendix 1), which removed the autocorrelation problem. Appendix 1 presents the values of these indicators for the 53 countries and territories.

Aggregate score were computed as the average score of the 14 indicators described above. (But note that Angola, Ghana and Latvia do not have a mariculture sectors, and their aggregate scores are based on 12 indicators instead). Pairwise correlation coefficients were calculated to investigate auto-correlation among the 14 variables. The behavior of the 14 indicators was investigated using a Principal Component Analysis using the STATA statistical package (see www.stata.com).

Other approaches could be taken to derive an aggregate score, e.g., through weighting the indicators. Here, however, the relative weightings to assign are a matter of perception; thus, people concerned with conservation weight indicators for seabirds and marine mammals much higher than people who are interested in managing the fishery industry (see below).

One solution to this problem, elaborated further below, is to make the data from this study (Appendix 1) widely available, including through the *Sea Around Us* Project web site (www.seaaroundus.org) and allow users to determine their own weightings and conduct their own analysis (The FAO Code of Conduct data for the 53 countries of this study can be found in Pitcher *et al.*, 2008b).

The other solution is to use weights reflecting different pre-existing scenarios and, because they include a framework for possible development, constrain the subjective component of assessments (see e.g. Pauly *et al.* 2003). As in Alder *et al.* (2007), we chose here to weight the indicators by mapping them onto the global scenarios used in the Global Environment Outlook 4 (GEO4; UNEP, 2007). The current four GEO4 scenarios represent 4 plausible futures for the world in terms of economic development, social policies, technological advances and ecosystem management.

Table 2. GEO4 scenario weightings (Alder *et al.*, 2007) mapped on 14 indicators of marine resources and ecosystem status in EEZs.

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*
Indicator* (category)				
1) MPA_{area} (b)	2.00	5.00	0.00	10.00
2) MPA_{inv} (b)	2.00	5.00	0.00	10.00
3) EEZ_{trawl} (b)	2.00	5.00	0.00	10.00
4) MSI_{ecol} (b)	2.00	5.00	0.00	10.00
5) $BIRD_{prot}$ (b)	2.00	5.00	0.00	10.00
6) MAM_{prot} (b)	2.00	5.00	0.00	10.00
7) LV_{GDP} (v)	1.00	1.00	0.30	0.10
8) $MEAL_{mar}$ (v)	1.00	1.00	0.30	0.10
9) $CODE_{FAO}$ (v)	1.00	1.00	0.30	0.10
10) $STAT_{rep}$ (v)	1.00	1.00	0.30	0.10
11) SUB_{good} (v)	1.00	1.00	0.30	0.10
12) $CATCH_{fuel}$ (j)	0.33	1.00	0.10	1.00
13) SUB_{LV} (j)	0.33	1.00	0.10	1.00
14) MSI_{soc} (j)	0.33	1.00	0.10	1.00

*The numbers refer to the bulleted definition in the text.

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 a Policy First future, the focus is on the economical and social policies that facilitate development and override 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 for their benefit to do so. Finally, in a Sustainability First scenario, the mix of environmental and social policies are somehow balanced (UNEP, 2007).

RESULTS AND DISCUSSION

The correlation matrix of the 14 variables across the 53 countries indicated 7 of the 91 correlation coefficients (r) were greater than 0.40; the maximum r-value, pertaining to the correlation between the two mariculture indicators (ecological and socio-economic sustainability) was 0.72. The principal component analysis (PCA) of the unweighted scores accounted for more than 50% of the variation of the 14 scores in 3 dimensions. A plot of the country scores in the first two dimensions (Figure 1) illustrates the relative positions of countries along the first and second dimensions of the PCA.

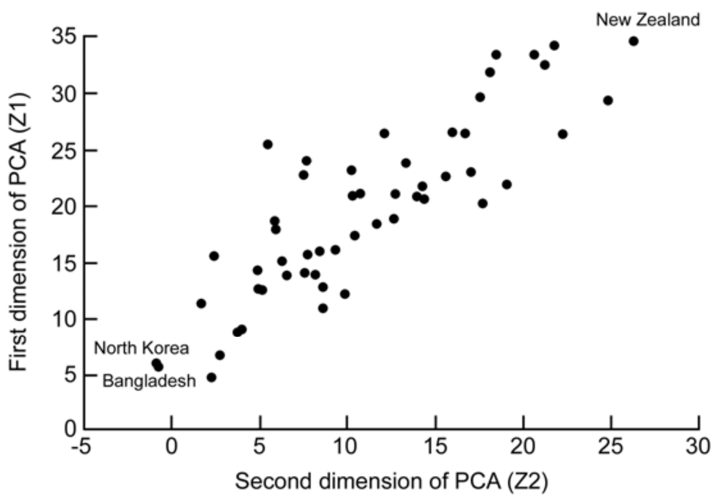

Figure 1. Principal component analysis of the unweighted score of 53 countries, showing the clear separation of countries in a plot of the first dimension (Z1) versus the second (Z2). Two countries characterizing the extreme are shown.

The results of the PCA correspond to the unweighted aggregate score of the 53 countries (Table 3) 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 countries. However, Peru, South Africa and Senegal were in the top 10 scoring countries, while the Faeroes Islands are among the lowest 10 scoring countries.

Table 3. Aggregate scores (unweighted) for marine resources management for 53 maritime countries

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	--	--

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 mariculture tended to have a high overall score, and conversely.

The scores weighted according to the GEO4 scenarios resulted in different rankings from the unweighted analysis (Table 4). 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.

Table 4. The five top, middle, and bottom-ranked countries when the GEO4 weightings for different scenarios are applied.

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
Middle 5	N. Korea	France	Malaysia	Namibia
	France	Namibia	Morocco	Argentina
	UK	UK	Argentina	Canada
	Ireland	Taiwan	Philippines	Peru
	Taiwan	Ireland	Mexico	Malaysia
Bottom 5	Bangladesh	Bangladesh	Bangladesh	Bangladesh
	Iran	Iran	North Korea	Faeroes
	Ukraine	Argentina	India	Iran
	Argentina	Faeroes	Brazil	Myanmar
	Faeroes	Ukraine	Egypt	Iceland

The PCA analysis of the weighted indicators also illustrates the differences in country rankings between the four GEO4 scenarios (Figure 2). The trend in the four scenarios is less well defined than for the unweighted PCA analysis (Figure 1). As well, the PCA trend for Security First (Figure 2C) and Sustainability First (Figure 2D) are orthogonal to the Market First (Figure 2A) and Policy First (Figure 2B) scenarios, and different from the unweighted analysis (Figure 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 (Figure 2).

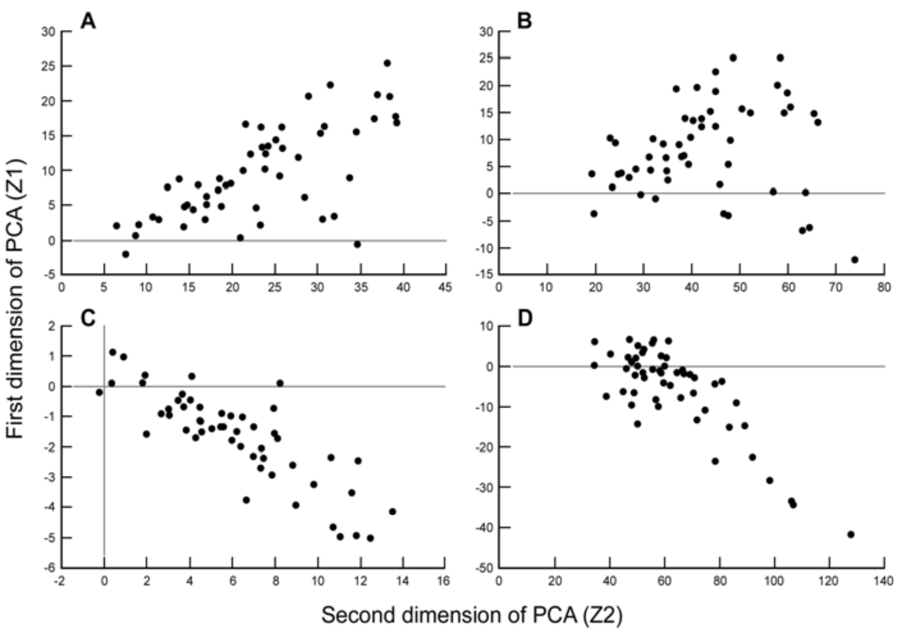

Figure 2. Principal component analysis of weighted scores of 53 countries based on the four GEO4 scenarios represented by 2A) market first scenario; 2B) policy first scenario; 2C) security first scenario; and 2) sustainability scenario.

The distribution of country scores in the PCA unweighted analysis is largely due to SUB_{good} and SUB_{LV} in the first and second dimensions. In the Market First analysis (Figure 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 $STAT_{rep}$ indicators, while in Policy First (Figure 2B) it is EEZ_{trawl} and other ecosystem related indicators and MSI_{ecol} in the second dimension. In the Security First (Figure 2C) analysis it is SUB_{good} and SUB_{LV} dominating the first dimension and the $STAT_{rep}$ in the second dimension, while in Sustainability First (Figure 2D) it is MPAarea and MPAinv 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 Pauly and Watson, this vol.), the indicators, in the aggregate, appear to favor developed countries, which turn out mainly among the top performers. 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 marine protected areas or 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. (See other contributions in this report for details.)

Indeed, the countries that were found here to perform poorly include, at least for some scenarios, developed countries who could be expected to have better scores (e.g., Iceland, see Table 4), in addition to countries which, because of their crushing poverty (Bangladesh), sometimes combined with the stifling of civil society (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 4 is mainly because these countries have been implementing, at least partly, measures to sustainably manage their marine resources, such as establishing networks of marine protected areas 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 (Anon., 2003). Some other countries – for example Peru - show up as top performers in Table 4 not because they are actively implementing 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 2). 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 term 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 Swartz *et al*., this vol.)). This is the reason why lots of indicators exist (see Cury and Christensen, 2005; Cury *et al.,* 2005). It is complex, and fraught with subjective hurdles, because it involves explicit values which are usually implicitly held (Rochet and Rice, 2005). This is why we used scenarios, with explicit emphasis on certain indicators and the consequent de-emphasis of others (Table 4).

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 show, are crucial to the credibility of any ranking schemes.

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. This is clearly seen in the area of MPAs set aside by countries compared to the CBD's interim target of 10% 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% of its EEZ is protected. Similarly, only a few countries give subsidies that are considered beneficial to the sustainability fisheries, despite calls for the elimination of perverse subsidies.

Of the 53 countries of this study, only 4 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 in 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 in managing fisheries, aquaculture development and marine mammals and seabirds. There are a number of initiatives that need to be developed especially in expanding MPA networks, reducing perverse subsidies and reducing areas available for trawling. The socio-economic 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 fisheries of countries that have not been assessed.

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 not to repeat the mistakes of other countries, i.e., by overcapitalizing fisheries and establishing subsidy schemes that contribute to destructive fishing practices or overfishing. The indicators in this study can help these countries track how they are doing against such measures and take corrective action early 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 indictors of this study can assist countries in tracking development in terms of ecological and socio-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 require greater investment and produce larger impacts. However, a range of actions, from reducing perverse subsidies to better reporting of fisheries statistics, will need to be taken eventually if marine resources are to be sustained in the foreseeable future.

Acknowledgements

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Appendix 1: Fourteen indicators used to estimate the aggregate marine resources management performance score. Numbers in the headers refer the bulleted definitions in the text, and to Table 2

Country	(1) MPA area	(2) MPA inv	(3) EEZ trawl	(4) MSI ecol	(5) BIRD prot	(6) MAM prot	(7) LV GDP	(8) MEAL mar	(9) CODE FAO	(10) STAT rep	(11) SUB good	(12) CATCH fuel	(13) SUB LV	(14) MSI soc	Aggregate score
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

Appendix 1 (cont'd).

Country	(1) MPA area	(2) MPA inv	(3) EEZ trawl	(4) MSI ecol	(5) BIRD prot	(6) MAM prot	(7) LV GDP	(8) MEAL mar	(9) CODE FAO*	(10) STAT rep	(11) SUB good	(12) CATCH fuel	(13) SUB tot	(14) MSI soc	Aggregate score
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

*data from: Pitcher et al. (2008b)

RANKING MARITIME COUNTRIES BY THE SUSTAINABILITY OF THEIR FISHERIES[1]

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ABSTRACT

In response to a lack of an international system for assessing marine fisheries, a series of sustainable fisheries management indicators were developed to address the many dimensions of the fisheries sector (social, economic and environmental). A set of eight indicators were used to assess whether 53 maritime countries, accounting for over 95% of the global catch, could be reliably ranked in terms of sustainability of their fisheries and marine ecosystems. The resulting scores, for both developing and developed countries, were evenly distributed across the rankings, without breaks. Overall, the study showed that the maritime countries of the world can be reliably ranked in terms of the sustainability of their fisheries and marine ecosystems.

INTRODUCTION

Fisheries are in crisis throughout the world (Pauly *et al.*, 2002), with most extant fisheries predicted to collapse by the mid century under a business-as-usual scenario (Worm *et al.*, 2006). Most of the world's marine fish stocks are fully or overexploited, or have collapsed. Instead of rebuilding the stocks, however, governments and the fishing industry continue to try to maintain or even increase catches by fishing further offshore and lower down the food chain. These practices not only have the potential to aggravate the state of the resource, but also to further degrade the marine ecosystems that provide a wide range of services to humankind (Balmford *et al.*, 2005; MEA, 2005).

Fisheries management and policy-makers are grappling all over the world with the problem of how fisheries can be made to operate sustainably. Criteria useful for assessing how well countries are doing in managing their marine resources are, however, scarce to non-existent. There are programs that assess the sustainability of fish stocks (MSC, 2002) and there are guidelines on how to sustainably manage fisheries (FAO, 1995). However, there is no system that assesses the overall performance of countries in managing their marine fisheries and ecosystems, and which ranks the performance of countries in a systematic and consistent manner.

In this contribution, we present a set of indicators appropriate for assessing the sustainability of marine fisheries and ecosystems, developed based on explicit criteria and use current and publicly available data. The indicators were developed to address the many dimensions of the fisheries sector (social, economic and environmental), making the indicators multivariate (Rochet *et al.*, 2005). Integrating a number of indicators, that are both relevant and robust, helps to even out those biases which are inherent in some indicators, as well as capture the multifaceted nature of sustainability. Fisheries sustainability indicators that are measurable through time also allow tracking the performance of countries.

The validity of the proposed indicators was tested by assessing a selection of countries, ranking these countries for fisheries sustainability based on the indicator set, and assessing the internal and external coherence of the results. For the purpose of this study, a 'sustainable fisheries indicator' is defined as a

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metric that measures the state of a country's fisheries, and/or reflects how well a country manages its fisheries sector and its impact on the ecosystem(s) within its 200 mile Exclusive Economic Zone (EEZ).

Defining Sustainable Fisheries

Sustainable fisheries can be defined as the result of adequate management of marine species and ecosystems, as described in the FAO Code of Conduct for Responsible Fisheries (FAO, 1995), and by the Marine Stewardship Council Principles and Criteria for Sustainable Fisheries (MSC, 2002). The FAO and the MSC have identified the following components of sustainable fisheries management systems which take into account biological, technical, economic, social, environmental and commercial aspects:

- Conserve and maintain the integrity of aquatic resources;
- Maintain sufficient biomass of targeted species for present and future generations, as well as the biomass of non-target species associated with the target species;
- Base decisions on best scientific evidence available and apply a precautionary approach;
- Develop environmentally safe fishing gear and practices;
- Minimize negative impacts from harvesting to processing and reduce waste;
- Protect and rehabilitate marine fisheries habitat where possible;
- Integrate fisheries interests into coastal management;
- Ensure fleet compliance with conservation and management measures and with relevant local, national and international laws and trade laws.

Also, indicators should be available to inform on the sustainability of the fisheries. Numerous definitions have been given to the term 'indicator'. For the purpose of this study, a 'sustainable fisheries indicator' is defined as a number which quantifies an aspect of the state of a country's fisheries or marine ecosystems, and/or reflects how well or poorly a country manages its fisheries sector. FAO (1999a) defines an indicator as: "…quantitative or qualitative value, a variable, pointer, or index related to a criterion. Its fluctuations reveal the variations of the criteria. A reference point indicates a particular state of a fisheries indicator corresponding to a situation considered as desirable, or undesirable and requiring immediate action".

MATERIAL AND METHODS

A Logical Framework Analysis (BOND, 2003) and the Pressure-State-Response (PSR) Model (OECD, 2003) were used to develop the fisheries indicators presented here. For each indicator, the framework in Table 1 identifies the problem, its stressor, and the objective. The problem identifies an aspect of the fisheries crisis, the stressor shows why the problem exists, and the objective identifies the purpose of the indicator. An indicator, thus, is a number that measures the state of a country's fisheries with respect to an issue (e.g., the state of major fish stocks), a concept or measure (e.g., the setting up of Marine Protected Areas) or set of factors (e.g., income, subsidies), and/or reflects how well or poorly a country manages its fisheries sector.

Table 1. Framework for developing sustainable fisheries indicators.

Indicator	Problem	Stressor	Objective
The indicator is a number that measures the sustainability of a country's fisheries, and/or reflects how well a country manages its fisheries sector.	The problem identifies the crisis.	The stressor identifies the reason for the problem.	The objective identifies the purpose of the indicator.

Identifying Potential Sustainable Fisheries Indicators

The goal of the framework was to help in the identification of indicators that could be used to rank the sustainability of marine fisheries and ecosystems of selected maritime countries. The FAO's Code of Conduct for Sustainable Fisheries and the MSC components of sustainable fisheries also guided this process. There are a number of potential criteria that could be used. However, in this study, only those criteria that reflect sustainability and were 'SMART' (simple, measurable, accessible, relevant, and timely; NORAD, 1999) were selected (Table 2). In Table 2, criteria A to M reflect sustainable fisheries components, while criteria N to X reflect components for SMART data sets. To be selected as a sustainable fisheries indicator, a potential variable had to meet at least 7 out of the 13 criteria in A to M and 6 out of the 11 criteria from N to X. For example, MPA coverage meets 10 of 13 sustainable fisheries criteria (A to M) and all the SMART criteria (N to X).

Using Table 2, a final list of indicators was developed; the indicators it contains are summarized below and discussed in detail in Appendix 1. This list is by no means exhaustive, but is intended to provide a useful inventory for developing sustainable fisheries indicators. The objective of sustainable fisheries indicators is to provide a measuring tool to monitor progress and/or trends of fisheries management practices that address many of the issues of overfishing and habitat degradation.

Table 2. Criteria for selecting sustainable fisheries indicators (the relevance of these criteria to sustainability is covered in Table 3).

Criteria	Description
A	Demonstrates willingness to implement measures and practices aiming to conserve and maintain the integrity of aquatic resources and ecosystems (e.g. through MPAs).
B	Demonstrates fishing practices allowing the persistence of species (high abundances) for present and future generations, and ecosystem well-being.
C	Implements environmentally safe fishing practices and uses environmentally safe fishing gear.
D	Minimizes negative harvesting and processing impacts, and reduces waste.
E	Integrates fisheries interests into coastal management.
F	Demonstrates compliance with laws and enforces conservation and management measures, ensures vessels are in compliance with relevant local and national laws, and encourages compliance with international trade laws; also enables conflict resolution.
G	Measures overfishing (directly or indirectly).
H	Demonstrates change in alternative and/or supplementary sources of income.
I	Demonstrates change in alternative sources of protein other than fish.
J	Demonstrates limited use of aquaculture
K	Demonstrates limited provision of capacity-enhancing fisheries subsidies.
L	Demonstrates low fishing effort (e.g., fleet size and GRT*).
M	Demonstrates low fuel consumption by the fishery sector.
N	Data are available to calculate indicator and evaluate progress against the objective.
O	Methods of data collection and analysis are technically feasible, efficient, comparable, consistent over time, and accessible.
P	Data are scientifically valid, i.e., based on peer-reviewed literature, or issued by organizations that have some sort of internal quality control.
Q	Method is useable today and in the future.
R	Method and indicator are understandable to both decision-makers and other users.
S	Indicator is sensitive to changes in social, economic or environmental conditions.
T	Indicator is internally and externally coherent (i.e., on its own, and compared with other indicators).
U	Synthesized large quantity of information in a single numerical value.
V	Convenient and economically feasible to collect so measures could be carried out frequently.
W	Relevant to fisheries and other elements of sustainability (social, economic and ecological).
X	Indicator is adequately documented.

* Gross Registered Tonnage (GRT) is a standard to define boat size and a proxy for the capacity of a fleet and is based on FAO's fleet statistics for 1995.

Table 3. List of sustainable fisheries indicators (see Table 2 for relevance criteria)

Variable	Objective	Stressor	Problem	Relevance
Marine Protected Area Coverage (MPA_{area}).	Quantifying the attempt by maritime countries to protect some of their marine species and parts of their ecosystems from fishing.	Unrestricted fishing, i.e., lack of designated marine protected areas.	Increased fish mortality, habitat loss, by-catch of non-target species, gear impact on habitat and species.	A, B, C, D, E, F, G, J, L, M, N, O, P, Q, R, S, T, U, V, W,X
Fishmeal Consumption by Mariculture ($MEAL_{mar}$).	Quantifying the consumption of fishmeal per unit of aquaculture production.	Use of fishmeal in aquaculture feed.	Additional stress to often depleted stocks of small pelagic fishes.	A, B, C, D, E, F, G, J, K, M, N, O, P, Q, R, S, T, U, V, W, X
Change in EEZ Area Trawled (EEZ_{trawl}).	Quantifying the impact of trawlers and dredgers on the shelves of maritime countries.	Demersal (bottom) trawl fishing and dredging to catch bottom-dwelling species.	Destruction of marine benthic habitats.	A, B, C, D, F, G, K, L, M, N, O, P, Q, R, S, T, U, V, W, X
Catch Relative to Fuel Consumption ($CATCH_{fuel}$).	Quantifying the fuel consumption of the fleets operating in the EEZ of each maritime country.	Use of energy by the fishing sector.	Increased pressure to already declining fish stocks and continuous habitat degradation.	E, F, G, D, G, L, M, N, O, P, Q, R, S, T, U, V, W, X
Compliance with the FAO Code of Conduct ($CODE_{FAO}$).	Quantifying countries' willingness to work toward sustainable fisheries management.	Lack of voluntary compliance with enforcement and regulations.	Unsustainable fisheries management.	A, B, C, D, E, F, G, L, M, N, O, P, Q, R, S, T, U, V, W, X
Landed Value* Relative to GDP (LV_{GDP})**.	Quantifying the contribution of fishing to the overall economy of countries.	Fishing tends to overexploit fish stocks and wreck its own resource base.	Mismanagement of fisheries.	A, B, C, D, E, F, G, H, I, J, K, L, M, O, P, Q, R, S, T, U, V, W, X
'Good' to 'Good + Bad' Subsidies Ratio (SUB_{good}).	Quantifying efforts towards fisheries management, services and research, thus considered to improve the sustainability of fisheries.	Reduces stress by investing in management programs, services and research.	Fishing overcapacity and overfishing.	A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X
Subsidies Relative to Landed Value (SUB_{LV}).	Quantifying the contribution of subsidies to fisheries.	Funds programs that increase capacity.	Subsidies can contribute to overcapacity, leading to overfishing.	A, B, C, D, E, G, K, L, M,N, O, P, Q, R, S, U, V, W, X

*Landed value: Monetary (ex-vessel) value of fish landed;
**GDP (Gross Domestic Product) is a measure of the goods and services sold in a year in a country, providing a rough measure the size of its economy.

Country Selection

The two criteria for selecting maritime countries to be included here were: (1) that data should be available to give values to the indicators, and (2) that the countries selected should jointly account for most of the world's fisheries catches. The second of these criteria was met by using the list of countries (Appendix 2) also used by Pitcher *et al.* (2008) in their study of compliance to the FAO Code of Conduct [see also Alder and Pauly (this volume)]. These countries represent over 95% of the reported world catch. The Faroe Islands were treated as a 'country', because they are a self-governed part of the Kingdom of Denmark, and thus autonomous in their fisheries management practices (FAO, 2001). Of the 53 countries, 32 are developing and 21 are developed countries. Small island states, mainly found in the Caribbean and Oceania, are not represented in Table 2, and Oceania is represented by only two countries, Australia and New Zealand.

Data Sources

Only brief descriptions of the indicators and their sources are given here; see Appendix 1 for more details.

Marine Protected Area Coverage (MPA_{area})

Data from MPA Global (Wood *et al.* 2008; www.mpaglobal.org) were provided by Dr Louisa Wood for the 53 maritime countries listed in Appendix 2 (L. Wood, IUCN, San Francisco, pers. comm.). The data referred to statutory or non-statutory designated MPAs, covering the overwhelming bulk of marine protected area in the world up to 2005. The percentage of MPA in each EEZ (MPA_{area}) was estimated using an aggregate layer of EEZ claims from the Global Maritime Boundaries database (General Dynamics Advanced Information Systems, 2007).

Fishmeal Consumption by Mariculture ($MEAL_{mar}$)

The data on fishmeal consumption per unit of aquaculture production ($MEAL_{mar}$) are documented in Campbell and Alder (2006), and originated from the *Sea Around Us* Project database (www.seaaroundus.org). The fishmeal consumption for the selected countries came from FAO's database of Processed Products, and their aquaculture production was based on FAO's aquaculture production database. Both data sets refer to the year 2000. These 53 countries in Appendix 2 account for more than 90% of the world aquaculture production (marine, brackish and freshwater) and nearly 100% of marine production. Unlike capture fisheries, the levels of miscellaneous species reported is much lower, which reduces uncertainty.

Change in EEZ Area Trawled (EEZ_{trawl})

Four variables are used to calculate this indicator with data derived from various sources: a) the area of a country's EEZ was as described above for MPA_{area}; b) the area within the EEZ that is trawled in 2000 and 2004 was based on Watson *et al.* (2006) and described in detail in Appendix 1; c) the total gross registered tonnage (GRT) which is a proxy for effort is based on FAO's database Global Fishing Fleets (FAO, 2007a); and d) the total catch that was taken using bottom trawls and dredges based on Watson *et al.* (2006). The shelf area trawled is based on associations or gears and catches of reported species and is expressed as a fraction of total EEZ. The ratio of the proportion of area trawled for the year 2000 and 2004 is used. This ratio indicates a country's trend towards either increasing or decreasing trawling activities which are known to have a high impact on marine ecosystems (Chuenpagdee *et al.*, 2003). The proportion of the fleet based on GRT that is bottom trawlers and dredgers is also calculated. The EEZ_{trawl} indicator is then calculated as:

$$(\text{area trawled 2000}/\text{area trawled in2004})/(100\text{-}\%\text{ of fleet}_{\text{trawlers and dredges}}) \qquad \ldots 1)$$

Catch relative to fuel consumption ($CATCH_{fuel}$)

Catch relative to fuel consumption ($CATCH_{fuel}$) for year 2000 was retrieved from the *Sea Around Us* project database (www.seaaroundus.org) and are based on the study by Tyedmers *et al.* (2005). The catch data are explained above (see also (Watson *et al.*, 2004). The indicator involved a log transformation (see Appendix 1).

Compliance with the FAO Code of Conduct ($CODE_{FAO}$)

Compliance with the FAO Code of Conduct ($CODE_{FAO}$) was quantified by Pitcher *et al.* (2008). The data used by Pitcher *et al.* (2008) largely apply to the 2000s. The evaluation of the data was based on an adaptation of the appraisal scheme of 44 questions, each scored on a scale of zero to ten. The scores were based on published and unpublished literature, and expert opinions (Pitcher *et al.*, 2008).

Subsidies-related indicators (SUB_{good} and SUB_{LV})

Two subsidies-related indicators, were derived for the year 2000 from the subsides data in (Khan *et al.*, 2006; Sumaila *et al.*, 2006) and the *Sea Around Us* database (www.seaaroundus.org), respectively, the fraction of 'good' to 'good' + 'bad' subsidies, and total subsidies (adjusted by purchasing power parity per fisher (see Appendix 1 for the purchasing power parity adjustment). 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 (Khan *et al.*, 2006). [Khan *et al.* (2006) also defined 'ugly' subsidies, discussed in Appendix 1.] The landed value data is described below.

Landed value relative to GDP (LV_{GDP})

Landed value and GDP data, whose ratio provided an indicator (LV_{GDP}) were obtained for the year 2000. The landed value data came from the *Sea Around Us* database (www.seaaroundus.org) and consists of ex-vessel prices multiplied with landed weight (Sumaila *et al.*, 2007). The GDP values stem mainly from the World Bank (www.worldbank.org), and are expressed in real 2000 US $.

Data Analysis

The raw indicator scores were computed, standardized between zero and ten, tested for significance, and analyzed to identify the variation amongst the eight indicators for 53 maritime countries (Appendix 2). 'Performance scores' were selected because common units were needed to combine the cumulative results of each indicator for each country. The raw data for each indicator was rescaled to a performance score between zero and ten (bad to good) to convey how well each maritime country ranked against the indicator with respect to sustainable fisheries management and/or practices. Table 4 lists the ranges and values necessary for each indicator to be assigned a performance score between 0 and 10. The performance score for each indicator was plotted as a frequency distribution to show the distribution along the x-axis (score between zero and ten).

Table 4. Ranges used to assign each indicator value a performance score (0 to 10, with 10 indicating practice leading to sustainable fisheries.

SCORE	MPA_{area}	EEZ_{trawl}	$MEAL_{mar}$	$CODE_{FAO}$	$CATCH_{fuel}$	SUB_{good}	SUB_{LV}	LV_{GDP}
0	x≤ 0	x> 15	x≥ 100	x< 1	x≤ 0	x< 10	x≥ 100	x≤ 0
1	0<x≤ 1	10 <x≤ 15	90≤x< 100	1 ≤x< 2	0<x≤ 0.3	10 ≤x< 20	90 ≤x< 100	0 <x≤ 0.01
2	1<x≤ 2	5 <x≤ 10	80 ≤x< 90	2 ≤x< 3	0.3 <x≤ 0.6	20 ≤x< 30	80 ≤x< 90	.01 <x≤ 0.02
3	2 <x≤ 3	2 <x≤ 5	70 ≤x< 80	3 ≤x< 4	0.6 <x≤ 0.9	30 ≤x<40	70 ≤x< 80	.02< x≤ 0.03
4	3 <x≤ 4	1<x≤ 2	60 ≤x< 70	4 ≤x< 5	0.9 <x≤ 1.2	40 ≤x< 50	60 ≤x< 70	.03 <x≤ 0.04
5	4 <x≤ 5	0.8 <x≤ 1	50 ≤x< 60	5 ≤x< 6	1.2<x ≤ 1.5	50 ≤x<60	50 ≤x<60	.04 <x≤ .05
6	5 <x≤ 6	0.6<x≤ 0.8	40 ≤x< 50	6 ≤x< 7	1.5<x≤ 1.8	60 ≤x<70	40 ≤x< 50	0.05 <x≤ 0.1
7	6<x≤ 7	0.4<x≤ 0.6	30 ≤x< 40	7≤x< 8	1.8<x≤ 2.1	70 ≤x< 80	30 ≤x< 40	0.1 <x≤ 0.5
8	7<x≤ 8	0.2<x≤ 0.4	20 ≤x< 30	8 ≤x< 9	2.1<x≤ 2.4	80 ≤x< 90	20 ≤x< 30	0.5 <x≤ 1.0
9	8 <x≤ 9	0<x≤ 0.2	10 ≤x< 20	9≤x<10	2.4 <x≤ 2.7	90 ≤x<100	10 ≤x< 20	1.0 <x≤10
10	x> 9	x≤ 0	x< 10	x≥ 10	x > 2.7	x≥ 100	x< 10	x> 10

Average performance scores were computed for each country, and the countries were ranked. The cross correlations between the performance scores for the 53 countries and eight indicators were computed to determine their relationship and significance. A principal component analysis (PCA) was performed from the standardized scores using the STATA Statistical Software (StataCorp, 2003) to identify the level of variation amongst the eight variables and assess their influence on position of our 53 maritime countries.

RESULTS AND DISCUSSION

The performance score distributions for the 53 countries along the zero to ten scale were either skewed to left (zero) or the right (ten), bimodal, or relatively evenly distributed along a scale (Appendix 3). The indicators that we skewed to the left of the scale were MPA_{area} and SUB_{good}. Those skewed to the right were $MEAL_{mar}$ and SUB_{LV}. $CATCH_{fuel}$ had a bimodal distribution. The indicators evenly distributed along the scale were EEZ_{trawl}, $CODE_{FAO}$ and LV_{GDP} (Figure 1). The average performance score conveyed how each maritime country ranked against the others (Table 6). The highest ranking country was Peru, with a score of 6, while the Faeroes Islands ranked lowest, with a score of 2. The majority of countries had scores between 4 and 5. Interestingly, there was a strong overlap between developing and developed countries.

A PCA, with principal axis Z_1 and Z_2, identified a relatively low level of variation amongst the eight indicators (Table 6). The difference between the highest and the lowest absolute value was not large, indicating that no indicator dominated the analysis (Figure 2; details in Mondoux, 2008).

The fact that some indicators are skewed to the left, and some to the right (see above) had the effect that the aggregated performance scores were not skewed, as indicated in the PCA (with the exception of the

MPAs, which are highly skewed to the left). This confirmed that no particular indicator determines the ranking of countries in Table 7.

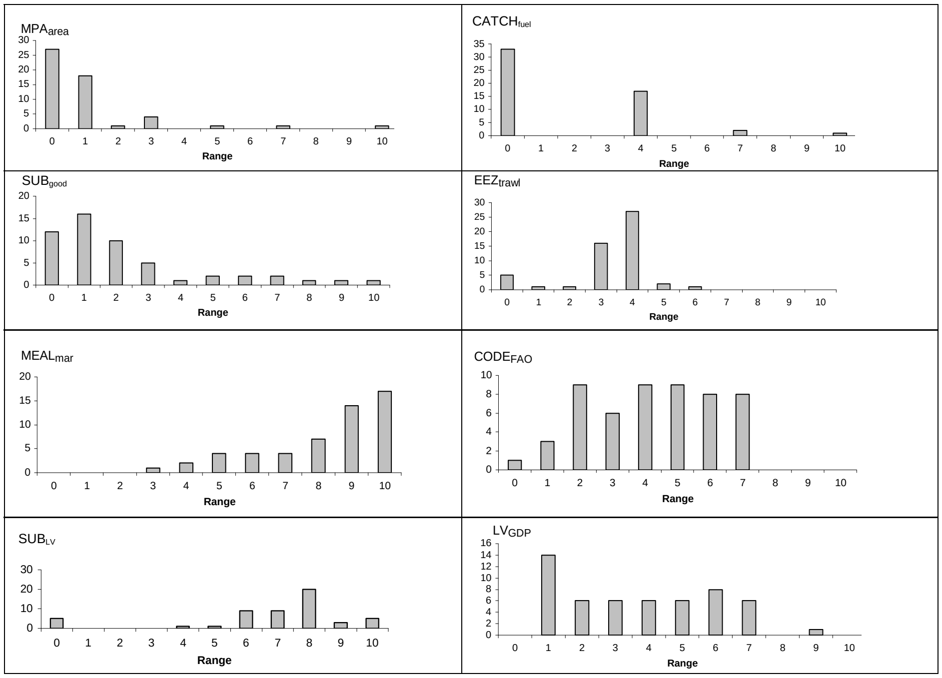

Figure 1. Frequency distributions of the scores of 53 maritime countries for the eight indicators presented here, MPA_{area}, EEZ_{trawl}, $MEAL_{mar}$, $CODE_{FAO}$, $CATCH_{fuel}$, SUBgood, SUB_{LV}, LV_{GDP} (see text for definitions).

The maritime countries of the world can be reliably ranked in terms of the sustainability of their fisheries and marine ecosystem, and the 8 indicators presented here appear plausible and robust. The integration of the indicators, designed to address the many dimensions of the fisheries sector (social, economic, and environmental) also performed as expected.

The data collection and analysis of these eight indicators is technically feasible and efficient because all the data were accessible on-line, through databases that are freely available, and which can be presumed to be maintained in the future. The databases are also from reliable sources because the organizations providing the data are research or science-based institutions (FAO, WRI, the World Bank and the *Sea Around Us* Project). Often the pedigree of data was available along with details on the collection and quality of the data (i.e., metadata).

Table 5. Principal component analysis, ranked from highest degree of association to lowest.

Variable	Scoring coeff	Rank
$CODE_{FAO}$	0.521	1
$MEAL_{mar}$	-0.491	2
SUB_{LV}	-0.473	3
$CATCH_{fuel}$	0.298	4
SUB_{good}	0.281	5
LV_{GDP}	0.228	6
EEZ_{trawl}	0.201	7
MPA_{area}	0.065	8

The ecological aspects of sustainable fisheries indicators assess the environmental conditions of a country's EEZ toward protecting, conserving and sustainably managing their marine ecosystem. The social aspect of sustainable fisheries indicators allow for an understanding of the fisheries sector in terms of community interest or need, and the distribution of benefits gained by the fishing community. For example, compliance with the FAO Code of Conduct for Responsible Fisheries may not be a priority for developing countries because of other perceived social or economic needs. On a global basis, the social aspect of sustainable fisheries indicators may assist in identifying which countries might require international assistance toward achieving sustainable fisheries. The economic aspect of sustainable fisheries indicators touches on the economic dimension of fisheries and their importance to a country's economy, which may be related to a desire to protect the marine resources and ecosystems.

Table 6. Average performance scores for the 53 countries.

Country	Average score	Country	Average score
Peru	6.42	Sweden	3.82
Namibia	5.10	Pakistan	3.81
USA	5.10	Indonesia	3.80
Germany	4.90	Japan	3.78
Poland	4.82	Australia	3.78
Norway	4.71	Spain	3.77
Senegal	4.70	Taiwan	3.75
Chile	4.67	Thailand	3.74
South Africa	4.64	Viet Nam	3.70
Ghana	4.59	Russia	3.67
Netherlands	4.56	Turkey	3.60
New Zealand	4.54	Iceland	3.58
Nigeria	4.45	India	3.57
UK	4.40	Sri Lanka	3.57
Malaysia	4.34	Mexico	3.56
South Korea	4.31	France	3.50
Latvia	4.30	Yemen	3.49
Philippines	4.28	North Korea	3.46
Angola	4.27	Portugal	3.39
Myanmar	4.25	Denmark	3.34
Canada	4.23	Brazil	3.27
Ireland	4.13	Iran	3.12
Italy	4.03	Ecuador	3.00
China	3.96	Bangladesh	2.81
Morocco	3.93	Argentina	2.55
Egypt	3.92	Faroes	2.29
Ukraine	3.90	--------	------

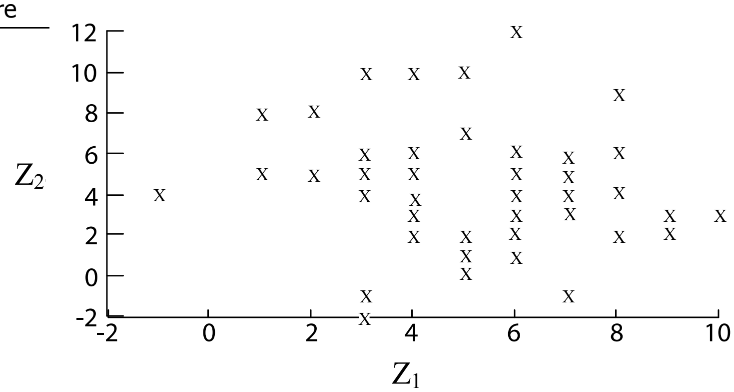

Figure 2. Distribution of 53 countries for the Z_1 and Z_2 of the PCA analysis.

Both developing and developed countries were relatively well distributed in the rankings. However, when the indicators with a skewed distribution were removed from the computation, the only significant pattern was that most of the 53 countries scores declined because many of them scored rather high (good sustainable fisheries practices) in the two skewed indicators (SUB_{LV} and $MEAL_{mar}$). Also, the highly subsidized countries increased their scores when the subsidy-related indicators were removed from the computation.

The study ranked countries along a scale of poor to good sustainability performance, with countries sitting along this spectrum irrespective of their economic development. However, some of the countries performance scores were unexpected. For example, it was expected that New Zealand would score slightly higher that it actually did, because of their reputation for sustainable fisheries practices.

Although there are limitations and shortcomings in the data used here, a set of sustainable fisheries indicators could be developed, which allowed comparisons on the sustainability of marine fisheries in 53 countries. Sustainable fisheries performance can now be tracked with the same rigor, as say, a country's Human Development Index (UNDP, 2000). Nevertheless, the development of sustainable fisheries indicators is still a work in progress, and further research is needed on the relationship between environmental health and human well-being. The series of indicators developed here may help in this.

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APPENDIX 1: DETAILS ON THE EIGHT FISHERIES SUSTAINABILITY INDICATORS

Marine protected area as a fraction of EEZ (MPA_{area})

A Marine Protected Area (MPA) is any marine area specifically designated for the protection, maintenance and management of a part of a marine ecosystem and biodiversity for its natural and cultural resources. The role of a marine protected area is to reduce fishing mortality, reduce by-catch of non-target species and conserve habitats, all positive contributions to sustainability. The indicator is not designed to measure whether conservation objectives are being met. Therefore the effectiveness of the action cannot be identified or used.

This indicator demonstrates an attempt by maritime countries to protect some of their species and parts of their ecosystems from fishing – actions that promote sustainable fisheries. Coverage of protected areas is one of a series of indicators identified by the Convention on Biological Diversity (CBD) listed as available for "immediate testing" and used to assess the progress towards the 2010 biodiversity target (CBD, 2005). MPAs' contribution to sustainable fisheries are that they can contribute to the restoration of species and habitats, address human needs for food and cultural resources, provide economic gain, and possibly increase livelihoods.

Data quality for MPAs is variable because of a lack of data required to update existing information for some countries (Chape *et al.*, 2005; Wood *et al.*, 2008) and a lack of resources (CBD, 2005). However, data were available for the selected 53 maritime countries. In this dataset, two countries, the United States and Australia have large MPAs which skew the data set. However, their large EEZs reduced this potential bias.

As defined, the MPA_{area} indicator naturally corresponded to a range of zero to ten (Table 4). The latter value was selected because the CBD (2006) has set a goal of conserving at least 10% of the world marine coastal and ecological regions by 2012.

Relative use of fishmeal ($MEAL_{mar}$)

Fishmeal consumption is the use of fish capture in the wild such as small pelagic fish for processing into protein-rich meals, used among other things as feed for the raising of carnivorous fish species. Currently, more than 50% of global fishmeal production is used in aquaculture. Whether a country produces its own fishmeal (or fish oil) or imports it, such uses ultimately puts pressure on capture fisheries, especially small pelagic fisheries, thus contributing to unsustainable fishing levels. Fishmeal consumption usually represents a threat to marine biodiversity and ecosystems as small pelagic fish are key prey species for large fish, seabirds and marine mammals (Alder and Pauly, 2006).

Aquaculture presents both advantages and disadvantages to communities. The aquaculture industry contributes to the national economy, provides a source of affordable protein, and creates local employment. The downside of the aquaculture industry is that the production of fishmeal removes a source of cheap protein for many people (Pauly and Alder, 2005), and the fishmeal processing factories are a source of water and air pollution to the communities (Campbell and Alder, 2006).

It is acknowledged that fishmeal consumption, even when standardized by aquaculture production, only imperfectly reflects the level of impact on the fisheries sector, because of inconsistencies and lack of data. For example, some countries may not only use large quantities of fishmeal, but may also use by-catch as direct feed in aquaculture, which is often not recorded in official production statistics (Campbell and Alder, 2006). Campbell and Alder (2006) also report that data on fishmeal consumption by the aquaculture sector are scarce, and that this consumption is usually estimated based on aquaculture production. Also, there are inconsistencies within and between databases and countries with respect to classifications and quantities reported. For example, quantities may be over-estimated due to how the data were categorized in the past, or because of a poor history of reporting.

The following computation from raw data to performance score was computed for the 53 maritime countries. The indicator is computed as fish consumption relative to aquaculture production, in %. The

$MEAL_{mar}$ data were then turned into a performance score (see Table 4), where 10 implies reflects a limited consumption of fishmeal and 0 reflects the maximum range of fishmeal consumed.

Shelf Area Trawled relative to GRT (EEZ_{trawl})

Shelf area trawled refers to an area covered by waters to a depth of 200m, where most fishing activity occurs. For this indicator, only trawls and dredges that are dragged on the sea floor to catch bottom-dwelling species such as flounder and shrimp are considered. The area fished by trawlers and dredgers is based on Watson *et al.* (2006) and described in detail below. It is an indicator of sustainable fisheries in that it quantifies the level of marine habitat degradation from fishing with bottom-impacting gear.

Chuenpagdee *et al*. (2003) report that bottom trawl fishing and dredging to catch bottom-dwelling species is the most destructive fishing gear in use today. The impact from the gear dragging and/or digging into the sediments affects marine habitats, such as coral reefs and seagrass beds, and can change the structure and function of the impacted ecosystems. The destruction of seafloor habitats can last for many years. Usually, trawling and dredging do not allow for a period of recovery.

Fishers who do not use these destructive gears are often impacted since the degraded habitats such as seagrass function as nurseries for a range of commercially important species. The different user groups affect one another depending on the fishing method; particularly, there is competition between small-scale and large-scale fisheries (Chuenpagdee *et al.*, 2006).

Excess tonnage and excess power of fleets result in overfishing (see Brown *et al.*, 2000). Overcapacity is considered one of the most significant reasons for overfishing in global fisheries (FAO, 2007b) and capture-fishery resources and fisheries are under threat with increasing fishing-fleet capacity (Pauly *et al.*, 2002). FAO (2007b) reported that as a result of overcapacity in the mid-1990s, fisheries became economically unsustainable, and as a consequence, many fisheries had to rely on subsidies to continue fishing. Over-capacity results in various problems for fishers, such as low income.

Shelf Area Trawled relative to the GRT of the fleet (EEZ_{trawl}) was derived from:

a. The *Sea Around Us* Project catch database (www.seaaroundus.org) and the work of Watson *et al.* (2006). The catch data (for the year 2000) were based on the global allocation of catch statistics using knowledge of the distribution of the reported taxon on the fishing behavior and access rights of the reporting country. Most of the global catch (~80%) is taken from the productive shelf areas, where most of the fishing occurs, often within 200 miles, which therefore, is the most affected by trawling;
b. The shelf area and the EEZ were estimated by expressing sea surface areas in km^2 and overlaying a global 2-minute cell raster ESRI grid of surface area values with a matching ESRI grid of EEZ (Cimino *et al.*, 2000; Reg Watson pers. comm., 2007). For each EEZ, the intersecting surface areas based on the 2-minute raster cell were extracted and summed. The area for each 'EEZ Shelf' was prepared in a similar way, but was truncated at 200 m depth, i.e., at the shelf edge, based on the United States National Geophysical Data Center's 'ETOPOS GLOBAL 2' bathymetric map data (Cimino *et al.*, 2000; Reg Watson pers. comm., 2007).
c. The trawled area of an EEZ claimed by countries was determined by examining *Sea Around Us* Project's 30-minute spatial cell global catch breakdown (Watson *et al.*, 2004). For each spatial cell, the catch by trawling was established by published associations between trawl gears and the catch of reported species (by countries and years; Watson *et al.*, 2006). In order to establish areas which had more than trivial amounts of trawling, we accepted as trawled only those spatial cells where the reported trawl-associated catch in the year was at least 0.05 tonnes per km^2.
d. The GRT data (for year 1995) came from the Food and Agriculture Organization of the United Nations (FAO, 2007a) through Sylvie Guénette (Fisheries Centre, UBC, pers. comm.).

Limitations of the EEZ_{trawl} data are that the catch mapped may be incomplete, or erroneously mapped (Watson *et al.*, 2004). Also, the catch of different species may have been assigned to the wrong gear (Watson *et al.*, 2006). The major source of this error is due to reporting of 'miscellaneous fish' by a country. Previous studies (Khan *et al.*, 2006) indicate that a high level of reporting miscellaneous catches occurs in both developed and developing countries throughout the world. The data were received and compiled from a variety of sources, including the FAO data set, which does not include all catches landed by countries.

This indicator is based on the area of the EEZ that is trawled, and is adjusted for the size of the fleet (based on the GRT for vessels that are classified as bottom trawlers and dredgers). We use 2000 as the base year. If a country was increasing its area trawled in 2004 then it scores low. If there was no change, it scores in the middle; if the trawled area is decreasing then it scores high. Countries are then adjusted for the intensity of trawling by weighting by the proportion of the fleet that is trawlers and dredgers.

1. (area trawled in 2000/area trawled in 2004)/(1-proportion of fleet GRT that are trawlers and dredges); then
2. The interim score is mapped onto a scale of 0 to 10 to obtain the final score.

Catch per litre of fuel consumed ($CATCH_{fuel}$)

Catch per litre of fuel indicator is the amount of fish caught (kg) per litre (L) of fuel used. 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, where the gear is dragged long distances through the water (e.g. bottom trawl), thereby greatly contributing to fossil fuel consumption and greenhouse gas emissions.

According to the Danish energy consumption study by Thrane (2004), the most energy-intensive fishery is the Norway lobster fishery. The most efficient fisheries in terms of energy are purse seine fisheries for small pelagic fishes (Tyedmers *et al.,* 2005). Overall, in 2000, "fisheries burned almost 50 billion L of fuel in the process of landing just over 80 million t of marine fish and invertebrates, and emitted more than 130 million t of CO_2 into the atmosphere" (Tyedmers *et al.,* 2005).

Fuel studies were not available for all fisheries in the world or all years, possibly resulting in some extrapolation being incorrect for this indicator. Also, as discussed for the above indicators, the catch may not be completely or accurately reported (e.g., wrong species), and the distribution of the species may be erroneous. Here, the logarithm of catch (in kg) per litre of fuel was used as indicator, to provide a better spread among countries with low scores. This was then rescaled to scores ranging from 0, reflecting a high fuel consumption and 10, for the converse (Table 4).

Compliance with FAO Code of Conduct ($CODE_{FAO}$)

The FAO Code of Conduct for Responsible Fisheries (FAO, 1995) is a set of recommendations and guidelines aimed at national policy makers and fisheries managers to voluntarily incorporate aspects of sustainability into their fishery policies. It aims at ensuring management of fishery resources such that they will be available for present and future generations. The $CODE_{FAO}$ as an indicator measures a country's willingness to work toward sustainable fisheries management by voluntary complying with the Code of Conduct's principles (Pitcher *et al.*, 2008).

The limitations of the data and source rest with interpretation and reporting of data. Pitcher *et al.* (2008) report that omissions and errors of interpretation still remain for some countries. Biased conclusions may also be a factor to consider, because the evaluation relied on self-reporting by countries of their own progress, and the uncertainty or levels of accuracy in reporting have not been evaluated. The values of the indicator in Pitcher *et al.* (2008) were re-expressed on a scale from 0 to 10 (see Table 4).

Subsidies-related indicators: SUB_{good} and SUB_{LV}

A subsidy is a financial payment from the government made to a private firm, or household conveying economic benefit to the recipient. The two subsidies-related indicators are discussed jointly in this section. The first is the ratio of good subsidies to good+bad subsidies (SUB_{good}), the second total subsidies (good+bad+ugly) per landed value (SUB_{LV}). Khan *et al.* (2006) argue that three categories of subsidies can be created to capture impacts on the fisheries sector:
1) Good subsidies are investments in management programs, services and research in order to achieve maximum allocation and benefit of natural resources to society and marine conservation; they do not increase fishing capacity and hence do not contribute to overfishing;
2) Bad subsidies develop or support fishing infrastructure (e.g., port facilities), secure access (e.g., to foreign grounds), and cover variable (e.g., bait, insurance) and fixed costs of fishing (e.g., through grants,

loans). They also include price support programs (e.g., government intervention to minimize production cost). These are bad subsidies because they increase fleet capacity, and thus lead to more overfishing;
3) Ugly subsidies, finally, can lead to positive or negative impacts on fleet capacity, depending on the context.

Good subsidies as a fraction of the sum of good and bad subsidies (SUB_{good}) represent efforts towards fisheries management, services and research, and therefore can be considered as initiatives to improve the sustainability of fisheries (Table 4). Total subsidies per landed value (SUB_{LV}) on the other hand, should have the opposite effect (Table 4).

Some of the information available in the literature did not reflect the true extent of the subsidies provided, and the greatest uncertainty regarding subsidies lies in the area of indirect payments (Khan *et al*., 2006). The FAO (1999b) also reports that its estimates of fisher numbers may be inaccurate.

The SUB_{good} indicator was computed from the data of Khan *et al.* (2006), then re-expressed as score, from 0 to 10 (Table 4).

Value of the catch as a fraction of GDP (LV_{GDP})

Landed value as a fraction of the GDP (LV_{GDP}) demonstrates the importance of the contribution of fishing to the overall economy of a country. Countries that rely heavily on fisheries as a contributor to GDP tend to have better sustainable fisheries practices than countries that do not (Hannesson, 1996). The major advantage of the GDP and hence the LV_{GDP} as an indicator of sustainable fisheries and economics is that they can be measured frequently (most countries provide information on the GDP on a quarterly basis), widely (some measure of GDP is available for practically every country), and consistently (the same thing is being measured in each country).

The LV_{GDP} was computed as the landed value of the catch (Sumaila *et al*., 2007; www.seaaroundus.org) divided by the GDP then re-expressed as a score from 0 to 10 (Table 4).

APPENDIX 2: PERFORMANCE SCORED BY COUNTRY FOR THE EIGHT INDICATORS

Table A1. Performance scores between zero and ten, by country, for the eight indicators.

Country	MPA_{area}	EEZ_{trawl}	$MEAL_{mar}$	$CODE_{FAO}$	$CATCH_{fuel}$	SUB_{good}	SUB_{LV}	LV_{GDP}
Angola	1	4	10	1	0	2	8	6
Argentina	0	0	8	3	0	1	7	5
Australia	7	3	7	6	0	3	8	4
Bangladesh	0	0	9	1	0	1	6	1
Brazil	1	3	9	3	0	0	0	1
Canada	1	4	6	7	4	4	8	4
Chile	0	4	5	5	7	0	10	6
China	0	4	10	5	0	0	8	3
Denmark	3	3	5	6	4	1	0	5
Ecuador	0	5	8	3	0	2	8	6
Egypt	3	4	10	1	0	2	8	1
Faroes	0	3	3	5	4	1	0	1
France	0	3	9	5	0	1	8	1
Germany	10	2	8	4	4	1	8	1
Ghana	0	4	10	4	4	1	5	4
Iceland	0	4	4	7	4	1	9	9
India	1	3	10	4	0	0	0	1
Indonesia	1	4	9	2	0	1	7	3
Iran	1	0	9	2	0	2	9	1
Ireland	0	3	8	0	4	7	6	3
Italy	1	4	9	4	0	3	6	1
Japan	0	4	8	6	0	6	7	5
Latvia	0	1	10	2	7	2	8	3
Malaysia	1	3	9	5	0	0	8	7
Mexico	1	3	7	4	0	1	8	2
Morocco	0	3	6	3	4	2	7	4
Myanmar	0	4	10	1	0	2	7	7
Namibia	0	3	10	6	4	1	6	7
Netherlands	1	0	10	6	4	1	10	5
New Zealand	0	3	10	6	0	10	10	7
Nigeria	0	4	9	2	0	9	10	3
North Korea	0	4	10	1	0	0	0	4
Norway	0	4	4	7	4	3	8	6
Pakistan	1	4	10	3	0	2	7	2
Peru	0	4	8	4	10	8	9	7
Philippines	1	4	9	3	0	1	6	6
Poland	1	6	9	3	4	5	6	1
Portugal	0	4	6	4	0	2	6	2
Russia	3	4	10	3	0	3	4	3
Senegal	0	5	10	3	4	1	8	7
South Africa	0	4	9	6	4	3	8	1
South Korea	1	4	10	5	0	0	8	5
Spain	1	4	9	5	0	0	6	2
Sri Lanka	0	3	7	2	0	2	8	5
Sweden	3	3	5	5	0	6	8	1
Taiwan	0	4	8	4	0	0	8	4
Thailand	1	3	9	2	0	0	7	6
Turkey	1	4	6	2	4	0	10	2
UK	1	4	5	5	4	5	9	1
Ukraine	2	0	10	2	4	1	6	2
USA	5	4	9	7	0	7	6	1
Viet Nam	0	4	7	2	0	1	8	6
Yemen	0	3	10	1	0	0	7	6

USING A MARICULTURE SUSTAINABILITY INDEX TO RANK COUNTRIES' PERFORMANCE[1]

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ABSTRACT

A global assessment of the sustainability of mariculture in 64 major countries over the 10 year period from 1994 to 2003 was performed, based on 13 indicators covering ecological, economic and social aspects of the industry, and involving 86 farmed species. The suite of indicators were based on a set of criteria meant to be independent of areas, species and time, so that they have wide application and will be applicable for years to come.

The indicators used in the analyses proved to be effective in differentiating levels of sustainability between countries and species and provided a benchmark on which to gauge progress within the industry in the coming decades. A single mariculture sustainability index (MSI), ranging between 1 and 10, was derived by combining the 13 indicators weighted by production to analyze differences between countries and species.

The highest ranking countries for sustainable mariculture are Germany, the Netherlands, Spain, Japan and South Korea. In these countries, the common factor is farming (1) native species, (2) of low trophic levels, (3) under non-intensive conditions, (4) for domestic consumption. The lowest ranking countries were Guatemala, Cambodia, Bangladesh, Honduras and Myanmar, which tend to farm (1) non-native species, (2) with high trophic levels, (3) under intensive conditions, (4) for export, often to countries ranking high for mariculture sustainability.

Based on these analyses, it is suggested that the industry is at the cross-roads of sustainability. There are a number of options for the industry to ensure it is sustainable over the long-term, including the implementation of best management practices. Their implementation will require economic incentives and consumer awareness, expressed as a willingness to pay higher prices for sustainability.

INTRODUCTION

The world's population, and incomes continue to increase, and the resulting demand for food, including fish, is increasing correspondingly. Although, in 2004, only 2.3% of the world's food production originated from capture fisheries and aquaculture (FAO, 2006), fisheries traditionally have been, in many developing countries, important sources of protein and of income.. However, this situation is changing due to current demands for seafood by the developed world and the growing middle class in developing countries.

The increased demand for fish products is partly being driven by the demand for high quality seafood, the lowered prices for many seafood products due to improved technologies, low production costs, increased awareness of the benefits of a seafood-rich diet, and more competitive marketing. However, capture fisheries alone can not meet this demand. Indeed, the recent FAO State of Aquaculture Report (FAO, 2006) highlights the growing importance of aquaculture in meeting the demand for fish for direct human consumption.

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Since 2003, global marine fish landings have recorded no increases and the dismal state of capture fisheries has not improved (Worm *et al.*, 2006). Clearly, if the future demand for fish products is to be met, aquaculture will have to play an increasingly important role. However, development of mariculture is associated with a number of negative environmental and socio-economic impacts, including habitat degradation, lack of waste management, use of antibiotics, displacement of coastal fishers, and the marginalization of coastal communities. On the other hand, mariculture can also create job opportunities for economically depressed coastal communities (Alder and Watson, 2007).

Currently, there are a number of codes of conduct and protocols for improving the sustainability of aquaculture. Implementation of some of these is underway in a number of countries, with differing levels of commitment, especially, in the developed world, e.g., in Europe and Australia. However, no certification schemes exist to allow consumers to determine whether the aquaculture industry in general, and its mariculture subsector in particular, operate in a sustainable manner.

Given the growing awareness of consumers of the long-term benefits of sustainable production, and growing demand by wholesalers to meet the demand based on this awareness, it is imperative that a set of indicators be developed to assess the sustainability of aquaculture, similar to the Marine Stewardship Council's (MSC, 1998) guidelines for the sustainable fishing or the World Wildlife Fund's "*Fish 'Yes' List*" (WWF, 2008).

Existing sustainability indices include the Environmental Sustainability Index (Esty, 2002), the Index of Sustainable Economic Welfare (ISEW) and the Gini Index or HDI Human Development Index (UNDP, 2006). These are based on a suite of indicators that measure and integrate a number of ecological, social and economic parameters. This report presents an aggregated mariculture sustainability index (MSI), based on 6 ecological and 7 socioeconomic indicators (Appendix 1). These indicators were designed, based on a detailed framework to capture the ecological, social and economic dimensions of the mariculture sector. The final suite of indicators also met the 'SMART' criteria, i.e. Specific, Measurable, Achievable, Relevant and Time-bound (GEF, 2005).

METHODS

There are many approaches to assessing the sector's sustainability such as the Pressure-State-Response Model (Linster and Fletcher, 2001) or the Conceptual Framework of the Millennium Ecosystem Assessment (2003). Some approaches are complex and data intensive (e.g., the Conceptual Framework), but provide a comprehensive picture of the state of the system(s) assessed. At the other end of the assessment spectrum is the use of a well-defined, suite of indicators such as the ecological footprint (Wackernagel and Rees, 1996), which requires a number of standardized data sets. The indicators approach is often much simpler to apply and it is easier for policy makers and society to understand how the indicators reflect changes in the system and the significance of changes in the value of the indicators (e.g., declining MTI = declining health of marine ecosystems; Pauly and Watson, 2005).

A search of peer-reviewed and industry-specific literature failed to identify any widely accepted criteria or indicators to assess the sustainability of aquaculture, although Pullin *et al.* (2007) identified criteria, largely overlapping with those presented below, which are broad enough for wide adoption. As noted previously, there are published mariculture guidelines and codes of practices such as those for shrimp (Boyd, 1999) and the Canadian Department of Fisheries and Oceans (DFO, 2001) for salmon farming. Fortunately, work in the fisheries, agriculture and forestry sectors on sustainability indicators provided considerable information, approaches and frameworks upon which to base indicators for the mariculture sector.

The ecological indicators were adapted from on the recommendations and decisions resulting from the Jakarta Mandate (Costa-Pierce, 2001), and from the FAO Code of Conduct (see Pitcher *et al.*, 2008). These studies provided key information on managing ecosystems, and on criteria upon which the indicators can be selected, i.e.:

A. Preserving the form and functions of natural ecosystems;

B. Optimizing trophic level efficiency, i.e., minimize the energetic losses associated with raising high-trophic level animals;
C. Manage nutrients, by reducing discharges, or causing chemical pollution; also, not using chemicals or antibiotics harmful to human or ecosystem health;
D. Using native species/strains, i.e., not contributing to 'biological' pollution. If exotic species/strains are used, ensuring that complete escapement control and recovery procedures are in place;
E. Use indicators that are SMART = Specific, Measurable, Accurate, Realistic and Time-bounded.

The first three criteria are derived from ecology, and considered essential for achieving sustainable aquatic resource management. Since these ecological criteria also provide the basis upon which all current aquatic husbandry practices are based, at least in theory, indicators can be straightforwardly based on them. The fourth criterion (D), identified by Costa Pierce (2001), is based on the fact that introduced species can be pests (Ruesink, 2003; Pullin *et al*., 2007). This subject that becomes contentious in many areas of the world, and which shows how the evolution of criteria and guidelines and technological developments will alter what is considered a requirement for sustainability. Six ecological indicators were developed (Table 1); their properties are summarized in Table 2 (further details in Trujillo, 2007).

Table 1. Ecological indicators and their performance with regards to ecological criteria.

Ecological indicator	Criteria A	B	C	D	E	Main source/references
Native or introduced	√	√		√	√	CBD (2004); Costa Pierce (2001); Pullin *et al*. (2007); Ruesink (2003).
Use of fishmeal and derivatives.		√	√		√	Tacon (1993; 2003).
Stocking density	√		√		√	Bardach (1997).
Larvae & seed provenance	√			√	√	Kautsky and Folke (1991); Folke and Kautsky (1992).
Habitat impacts	√		√	√	√	Costa-Pierce (2001); Folke and Kautsky (1992); Pullin *et al*. (2007).
Waste treatment	√	√	√		√	Costa-Pierce (2001); Rosenthal (1985).

Table 2. Detailed description of ecological indicators for mariculture.

Ecological indicator	Detailed of practice and scoring scheme
Native or introduced	Native species score the highest (10); foreign and introduced species score (1) because of potential impacts to local biodiversity if they escaped. Native, but non-local species were scored using intermediate values. Genetic biodiversity impacts can originate from native species when larvae, spats or seeds are from poorly managed hatcheries, with out-breeding depressions and/or genetic bottlenecks.
Use of fishmeal, and derivatives.	Fish protein and oil inclusion in the diet at any stage of development must be considered; herbivore species score 10, and carnivorous (esp. piscivorous) organisms score closer to 1, depending on the level of feed supplied.
Stocking density	The three intensity levels (intensive, semi-intensive and extensive) score 1, 5 and 10, respectively. Variations due to polyculture or feed requirements at different ontogenetic stages will modify the score accordingly.
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	Farm location and area, impact on 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 in the coastal) scoring low (1).
Waste treatment	Water exchange, output fate, recycling and filtering implementations are considered. Systems that are closed score high (10), while open systems without waste treatments score low (1)

Sustainable production systems do not only consider environmental aspects of the production process, but also its economic and social aspects, especially in the case of 'fair trade'. Based on the concepts and guidelines previously defined and equitable distribution of the economic benefits from developing a mariculture industry, the following criteria were used to evaluate potential performance indicators:

A. Fair trade and equity standards for production and market;
B. Employment standards;
C. Chemical and pharmaceutical use in final product;

D. Code of Practice existence, implementation and degree of impact;
E. SMART = Specific, Measurable, Accurate, Realistic, Time-Bounded.

Seven socio-economic indicators were developed (Table 3) and are summarized in Table 4 and described in detail in Trujillo (2007).

Table 3. Socio-economic indicators chosen for this study and their performance with regards to socio-economic criteria.

Potential indicator	Criteria A	B	C	D	E	Main source/references
Product destination	√	√			√	Naylor *et al.* (1998).
Chemical and pharmaceutical use	√		√	√	√	Folke and Kautsky (1992).
Genetic manipulation			√	√	√	Beardmore and Porte (2003)
Code of practice usage	√	√	√	√	√	FAO (1995; 1999).
Traceability	√			√	√	Moretti *et al.* (2003).
Employment	√	√		√	√	Costa-Pierce (2001); Pullin *et al.* (2007).
Nutrition; protein ratio			√	√	√	Tacon (2004).

Table 4. Socio-economic indicators of the sustainability of mariculture.

Socio-economic criteria	Description of practice and 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, antifoulants, hormones and vaccines (1), or no use of chemicals or pharmaceuticals (10).
Genetic manipulation	Production of genetically modified organisms (e.g. fertile tetraploids) and transgenic species fall low in the scoring scheme (1). Well managed, sterile animals may or may not qualify for better management practices, but score > 1.
Code of practice usage	Certification, up to date set of standards and principles, i.e., FAO Code of Conduct (FAO 1995, 1999), or eco-labeling schemes are scored high; while 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).

The scoring scheme, using a scale from 1 to 10 for each ecological and socio-economic indicator, was developed by examining the range of data values (minimum to maximum), practices (worst to best) and impacts (negative, neutral, and positive) for each indicator based on published literature. A minimum value of 1 was assigned to reflect a completely unsustainable situation, and a maximum value of 10 was used to reflect the ideal case for sustainability. Intermediate values were assigned as seemed appropriated based on the available information.

An overall score of less than 6 or 7 if, of the 13 indicators were less than 6 was considered 'unsustainable', between 6 and 8 as 'approaching sustainability' and greater than 8 'sustainable'. This scheme for rating sustainability is similar to the Marine Stewardship Council approach for scoring capture fisheries (MSC, 1998). The data used applied to the period between 2000 and 2003.

Data from primary sources were preferred since they are generally more reliable, consistent and well documented. When they were insufficient, secondary publications and sources were investigated. However, consistency was maintained to ensure that comparisons across species and countries could be made. If no data were available on a given species/country combination, a similar and adjacent country that produced species in question was used to fill-in the corresponding value. In such cases, the final score could not be inferior to the score determined without the filled-in value.

In the case of 'nei' groups (i.e., fishes or invertebrates, which production statistics are 'not elsewhere identified'), other sources of information were used to determine what would be the likely species in that group and then 50% of the score would be allocated to that group and 50% to the score on the remaining nei groups. This was meant to leave the benefit of doubt to the non-specific group, but, as well, tax the countries that did not specify (as they should) the taxonomic composition of their aquaculture production.

Data Sources

The data used in this study came mainly from primary publications, i.e., official national (e.g. the Canadian Department of Fisheries and Oceans) and international publications (e.g. the Food and Agriculture Organization of the United Nations), internationally recognized websites with databases (e.g. the website of the *Sea Around Us* Project; www.seaaroundus.org) and academic research reported in peer-reviewed journals (Table 5).

The prices used in this study were extracted from the FAO FishStat database for each country-species combination. Some anomalies, i.e., extremely high values, were found in the dataset, and experts in the trade of seafood were queried about these prices (notably A. Tacon, Hawaii Institute of Marine Biology, pers. comm.). The spurious prices often were orders of magnitude higher than the price of related groups, and could be straightforwardly corrected.

Table 5. Type and source of data used to quantify ecological and social indicators.

Indicator	Data description	Sources	Comment
Native or introduced	Two way response (native or none native)	-State of the environment; -FAO publications; -FishBase; -Sea Around Us Project; -Various NGO publications	Country of origin and distribution is readily obtained from these sources; regional or within- region translocations are not.
Fishmeal use	-Use or non-use; and if use, how much of it -Farm diet information; -Industrial feed composition information.	-Anim. nutrition journals. -FAO publications -National syntheses(e.g. SERNAP, Chile) -Field work (in Chile); -Personal comm.	Diet composition usually not readily available; it depends on variable technological and economical factors.
Stocking density	-Stocking capacity Better practice protocols, and maximum production carrying capacity.	-Aquaculture Journals; -Reports on best practices; -NGO reports.	Maximization of production capacity may be unknown. Practices may differ between farms and species
Seed and larvae origin	Origin, provider, hatchery implementation.	-FAO publications; -Aquaculture journals; -FishBase.	Number of hatcheries per farm, unknown importation of larvae from outside
Habitat impacts	Direct and indirect effects on the surrounding environments; biodiversity change biomass changes, eutrophication, etc.	-NGO publications; -FAO publications; -Environmental impact assessments; -Scientific journals.	Full knowledge of the effects is less common in developing and more remote areas.
Waste treatment	Use of filter and waste disposal systems, re-use and recycling systems.	-NGO publications; -Field work (Chile); -Scientific journals.	Updated data are required for accurate estimations
Product destination	Destination market and secondary markets.	-Scientific journals; -FAO publications; -Globefish; -Personal communications	Market watch, scrutiny of market and economic actors and policies, tracking products.
Chemical and drug use	Usage and quantities.	-Scientific journals; -NGO publications.	Seasonal changes in disease outbreaks and control may vary
Genetic manipulation	Use of GMOs, (farmed species and/or feeds.	-Scientific journals; -FAO publications.	Banned in many cases for direct human consumption.
Code of practice	Implemented or not; also: which code and standards	-Scientific journals; -FAO publications.	Reports based on national policy may vary with current practices.
Traceability	Market and product control and monitoring	-Scientific journals; -FAO &NGO publications; -Personal communications.	Problematic in many areas, especially in developing countries.
Employment	Equity, fair trade, number of employees per farm.	-Scientific journals; -NGO publications; -FAO publications; -Personal communications.	Accessibility problems and lack of interest for smaller farms may hide poor working conditions.
Nutrition, protein ratio	Protein content	Nutrition/feed journals.	Protein type of was not considered in this study.

A search of available and reliable data provided a number of datasets to quantify the indicators. The datasets selected were for species that are commercially produced and make up approximately 95% of total global mariculture production; hence, they do not include species with very low production levels. The data were extracted from these datasets on a case-by-case basis and checked to ensure: the information was current and generated within the last 10 years. Consistency was obtained by ensuring that data were within the likely range of possible values; and validity, by comparing the values obtained from other studies or reports.

The 64 countries assessed here include the 53 evaluated in Alder and Pauly (this volume) and jointly account for more than 95% of global reported marine fish landings; these same countries account for more than 95% of the world's mariculture production.

RESULTS AND DISCUSSION

This assessment generated a total of 361 country– species combinations and associated MSI values, covering 64 countries and 86 species or species groups (Appendix 2) for the period from 1950 to 2003, with emphasis on the last 10 years. While possible MSI ranged from 1 (low sustainability) to 10 (high sustainability), the lowest observed score was 1.7 for Whiteleg shrimp farmed in Thailand, and the highest was 8.4 for seaweed grown in Chile. Thirteen cases were greater than or equal to 8 (sustainable), 112 cases were between 6 and 8 (approaching sustainability) and 236 cases were less than or equal to 6 (not sustainable). The average score for each indicator was between 4.5 and 7.6 (Table 6).

Table 6. Summary statistics for the 13 indicators of mariculture sustainability.

Indicator	Average	Std. dev.	Min	Max
Native/introduced	7.3	3.63	1	10
Export levels	4.5	1.87	1	10
Fishmeal use	5.2	3.62	1	10
Stocking intensity	4.8	2.63	1	10
Nutrition	7.6	2.46	2	10
Hatchery use	5.0	1.84	1	10
Antibiotic use	5.2	3.40	1	10
Habitat modification	5.0	2.04	1	10
GMOs use	6.4	1.78	2	10
Code of conduct compliance	5.2	1.44	1	9
Traceability	5.5	1.87	1	10
Employment	5.4	1.26	3	8
Waste management	5.4	3.08	1	10

In approximately 40% of the cases, the data required to compute MSI was lacking. However, it was usually only one indicator that was missing, and in most instances, this was a socio-economic indicator. For these records, the missing score was estimated based on information from adjacent countries, secondary sources or personal communications. The scores for the 13 indicators across the 64 countries are given in Appendix 1.

The ten highest performing countries (Table 7), based on a weighted index (MSI weighted by production), and combining the ecological and socio-economic indicators, were Germany, The Netherlands, Spain, Japan, Russian Federation, North Korea, South Korea, Ireland, France and Argentina (Table 7). Six of these top ten countries are developed and European, while three of the remaining countries are considered to be economies in transition, North Korea being the fourth. There is no consistency between countries scoring high for the ecological indicators and countries scoring high for socio-economic indicators. This illustrated by Iceland which was ranked 13th with an MSI of 6.2 overall, but ranked 22nd for its ecological score (5.4) and 2nd for its socio-economic score (7.1).

The ten lowest scoring countries were Guatemala, Cambodia, Bangladesh, Honduras, Myanmar, Belize, Chile, Norway, Brazil and Faeroe Islands (Table 7). Eight of the 10 countries are developing and spread across Latin America and Asia. The remaining two countries are European. Most of these countries scored low for both ecological and socio-economic indicators.

Table 7. Rankings and mean weighted MSIs of the top and bottom 10 countries, with ecological and socio-economic scores by country; 10 indicates high sustainability and 1 indicates low sustainability of mariculture.

	Rank			Score		
Country	Ecol.	Socio-econ.	MSI	Ecol.	Socio-econ.	MSI
Germany	**1**	1	1	9.0	7.1	8.0
Netherlands	**2**	2	2	9.0	7.1	8.0
Spain	**3**	3	3	8.7	7.1	7.9
Japan	**5**	6	4	7.5	6.5	7.0
Russian Federation	**4**	27	5	8.4	5.4	6.9
Korea, North	**6**	8	6	7.4	6.4	6.9
Korea, South	**10**	9	7	7.1	6.4	6.8
Ireland	**7**	12	8	7.4	6.1	6.8
France	**14**	5	9	6.4	7	6.7
Argentina	**8**	17	10	7.4	5.9	6.6
--	**-**	-	-	-	-	-
India	**54**	39	50	2.8	5.0	3.9
Faeroe Islands	**40**	56	51	4.5	3.0	3.8
Brazil	**57**	46	52	2.5	4.8	3.7
Norway	**50**	53	53	3.5	3.7	3.6
Chile	**53**	51	54	2.9	4.1	3.5
Belize	**56**	52	55	2.7	3.8	3.3
Myanmar	**55**	54	56	2.8	3.7	3.2
Honduras	**52**	57	57	3.2	3.0	3.1
Bangladesh	**58**	58	58	2.3	2.7	2.5
Cambodia	**59**	59	59	2.3	2.7	2.5
Guatemala	**60**	60	60	2.3	2.7	2.5

Four of the top five performing countries, based on a weighted index composed of the six ecological indicators, were European: Germany, Netherlands, Spain, Japan and the Russian Federation (Table 7). Most of the countries scored high because of their limited use of introduced species and fishmeal and their treatment of waste and water. The countries farmed a mix of bivalves and fish, with Russia also farming marine plants.

The majority of the lowest scoring nations (Table 7) for ecological sustainability are highly dependant on aquafeeds that are rich in fishmeal and fish oil, and which were essential for many of the species produced through 1994 to 2003. Low scores for stocking density and insufficient waste treatment were also common for the lowest scoring nations. Low scores of these indicators suggest a higher risk on impacting surrounding habitat, especially, when these farms are open system cultures.

Germany, The Netherlands, Spain, Iceland and France are the five highest scoring countries for socio-economic indicators (Table 7). They all emphasize production of carnivorous species such as finfish and crustaceans, and yet they are also top bivalve producers, which provide high sustainability scores via the socio-economic indicators.

The five lowest scoring countries were Myanmar, Honduras, Bangladesh, Cambodia and Guatemala (Table 7). They are all developing countries which intensively farm shrimps. Low scoring developed countries are European with high tonnage of Atlantic salmon. Pharmaceutical use and the export orientation of these two main species groups were common across developing and developed countries for many of the species cultured.

A principal component analysis (PCA) undertaken following the development of the indicators (Trujillo, 2007) also suggests that the indicators are valid. More than 60% of the variation in the indicator values can be explained by two dimensions, and 77% variation in four dimensions. All the scoring coefficients were less than 0.37 and two had a negative sign. This suggests that the indicators measure different dimensions in the data set, and that no single indicator is driving the assessment. Thus, the indicators are capable of differentiating between high and low sustainability practices.

The species-country combinations used in this assessment represents over 95% of global mariculture production and represents the industry as a whole. The underlying data may, however, bias the results, as much of them were obtained from FAO (2004). While every effort was made to ensure the data was reliable and accurate, there may be reporting biases within specific countries as seen in the capture fisheries sector, where countries such as China have misreported wild capture fisheries landings (Watson and Pauly, 2001). Another other source of inaccuracy is the interpolation procedure for missing data. Nevertheless, the 13 indicators used in this study appear robust; also they are relevant and easily measured for application at the global and regional scales and independent of species and place.

As mentioned above, the top ranking countries for MSI were primarily developed countries (Table 4.3), the exceptions being the Russian Federation and Argentina, which are emerging economies, and North Korea, a developing country. Five of the developed countries are European, which is in part a reflection of the demand by Europeans for sustainable seafood products and their concerns for pollution and GMO-free products (Beardmore and Porte, 2003). Japan and Korea are the other two high-ranking countries and the scores reflect their demand for high quality seafood products (Bridger and Costa-Pierce, 2001). These two countries also produce substantial amounts of mollusks and plants (Table 4.4), which tend to be farmed more sustainably than crustaceans and finfish. However, the rankings of many of these countries would decline if they themselves produced the seafood they import and consume, such as Atlantic salmon and shrimp. For example, Spain is a significant importer of seafood, including salmon and shrimp, much of it from mariculture in developing countries (FAO, 2004).

Of the 10 lowest ranking countries for MSI (Table 4.3), the first five almost exclusively culture shrimp (Table 4.5), while Chile and Norway are the top two producers of Atlantic salmon globally (Ibáñez and Pizarro, 2002). They all score low on sustainability due to their semi-intensive to intensive production practices and use of fishmeal/oil in production. The developing countries in this list also score low for environmental management of waste. Many policy makers promote the expansion of aquaculture for improving the economies of developing countries including the creation of employment opportunities. However, this analysis suggests that this is not a sustainable strategy due to the externalization of environmental costs. The future of the industry in developing countries in the short-term (next 2 to 3 decades) will be a tradeoff between socio-economic development and sustaining ecosystems. However, the impacts of this tradeoff can be minimized implementing best management practices (FAO, 2006).

It is worth noting that USA (ranked 15), Canada (43), Australia (40) and New Zealand (19) were not in the top or bottom ranking countries based on the MSI. The USA and New Zealand are currently not significant mariculture producers by world standards. Much of the US aquaculture production is in freshwater. In New Zealand much of the production is mollusks, and finfish farming is only starting. As in the top ranking countries, if imports were included in the assessment, the rankings of these countries would be lower. Canada and Australia are large producers of finfish, and Australian is also a producer of crustaceans. They culture high-tropic level species requiring fishmeal/oil.

Overall, most mariculture operations are not sustainable using current practices. Those countries ranking high are primarily from the developed world, but only because their imports of unsustainably farmed seafood are not included in an assessment, as they perhaps should. Mariculture in the lowest ranking countries is not sustainable and much of the production consists of crustaceans. In many developing countries, shrimps are the species of choice, which is highly unsustainable and primarily exported by these countries. Some developing countries may be risking their (marine) food security and the long-term sustainability of their marine ecosystem to produce such exports.

Overall, we hope with Pullin *et al.* (2007) "that use of broad biological, ecological and intersectional indicators will contribute to progress towards the sustainability of aquaculture".

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APPENDIX 1: AVERAGE COUNTRY SCORES FOR EACH OF THE 13 INDICATORS.

Table A1. Scores of individual countries on mariculture sustainability indices (ecological & socio-economic).

Country	Native vs. introduced	Export domestic	Fish meal usage	Intensity level	Nutrition Protein	Hatchery vs wild	Antibiotic Drug use	Habitat alteration	Mol-Biol GMO	Code-practice CoC	Traceability	Employment	Waste water treatment
Argentina	6.7	5.0	10.0	5.8	5.8	6.2	8.2	7.0	7.0	4.6	5.0	7.0	10.0
Australia	3.3	5.8	3.2	3.2	3.2	4.7	3.4	5.2	6.3	5.7	4.5	5.0	4.2
Bangladesh	5.0	5.0	3.0	1.0	1.0	3.0	1.0	1.0	6.0	4.0	1.0	5.0	1.0
Belize	1.0	5.0	3.0	3.0	3.0	5.0	1.0	1.0	5.0	7.0	3.0	5.0	3.0
Brazil	1.2	5.0	3.2	3.1	3.1	5.1	1.3	1.2	5.9	7.0	5.1	5.1	1.3
Cambodia	5.0	5.0	3.0	1.0	1.0	3.0	10.0	1.0	7.0	3.0	5.0	3.0	1.0
Canada	5.4	5.1	4.1	2.8	2.8	4.1	3.2	4.7	6.0	5.1	4.0	4.6	3.7
Chile	3.1	3.0	3.2	3.2	3.2	3.5	3.2	3.2	5.2	4.2	4.7	5.0	3.9
China	2.6	3.4	9.9	6.9	6.9	4.9	9.8	5.2	7.1	6.0	5.8	6.1	1.9
Colombia	10.0	5.0	3.0	3.0	3.0	5.0	1.0	3.0	5.0	3.0	5.0	5.0	3.0
Costa Rica	10.0	5.0	3.0	1.0	1.0	5.0	5.0	3.0	5.0	5.0	5.0	3.0	5.0
Denmark	10.0	7.0	3.3	3.2	3.2	3.2	5.2	6.0	7.1	5.0	5.1	6.9	7.1
Ecuador	9.9	5.0	3.0	5.0	5.0	5.0	1.0	1.0	5.0	3.0	5.0	5.0	3.0
Egypt	9.6	4.8	2.9	4.8	4.8	5.0	3.9	4.9	6.7	5.1	5.1	7.0	4.8
Faeroe	10.0	1.0	3.0	1.0	1.0	5.0	1.0	3.0	7.0	6.0	5.0	5.0	5.0
Finland	10.0	1.0	3.0	2.0	2.0	5.0	1.0	3.0	6.0	7.0	5.0	5.0	7.0
France	3.8	5.5	9.8	9.6	9.6	5.9	9.8	5.6	7.8	7.1	7.7	6.7	3.6
Germany	10.0	7.0	10.0	9.0	9.0	8.0	10.0	7.0	10.0	5.0	7.0	6.0	10.0
Greece	10.0	3.9	1.9	2.7	2.7	3.9	1.9	3.9	4.2	5.0	5.0	6.6	1.0
Guatemala	5.0	5.0	1.0	3.0	3.0	5.0	1.0	5.0	5.0	1.0	1.0	3.0	5.0
Honduras	5.0	5.0	1.0	5.0	5.0	3.0	1.0	1.0	5.0	2.0	2.0	3.0	1.0
Iceland	3.4	5.0	4.6	5.0	5.0	8.0	8.2	6.0	7.4	7.0	10.0	5.0	5.0
India	10.0	1.0	1.0	1.0	1.0	3.0	1.0	1.0	7.0	4.0	5.0	7.0	1.0
Indonesia	10.0	2.6	4.8	6.6	6.6	3.0	3.4	2.4	7.5	4.5	2.9	6.8	2.4
Iran	1.0	1.0	3.0	6.0	6.0	2.0	5.0	6.0	5.0	5.0	6.0	7.0	4.0
Ireland	9.1	4.4	7.3	6.4	6.4	6.5	8.1	6.7	8.5	6.1	6.3	5.6	8.1
Italy	10.0	6.0	3.7	5.4	5.4	5.3	3.9	4.8	5.2	6.1	6.8	6.5	4.8
Japan	10.0	5.0	9.8	6.9	6.9	4.3	9.8	6.2	6.9	7.0	8.3	5.0	8.0
Kiribati	10.0	5.0	7.0	5.0	5.0	1.0	5.0	3.0	8.0	5.0	3.0	7.0	3.0
Korea, N.	7.5	5.0	10.0	7.2	7.2	5.0	10.0	7.0	7.1	7.0	5.4	7.0	5.4
Korea, S.	8.6	5.0	10.0	7.0	7.0	5.0	10.0	7.0	7.0	7.0	7.5	5.0	8.5
Madagascar	10.0	1.0	1.0	3.0	3.0	5.0	1.0	1.0	7.0	3.0	3.0	6.0	1.0
Malaysia	10.0	4.3	8.3	5.9	5.9	2.9	8.3	4.3	9.3	4.6	4.6	5.1	6.0
Mexico	9.5	5.0	3.4	3.4	3.4	4.9	3.4	3.2	5.1	5.0	5.1	3.2	5.3
Morocco	8.3	3.0	4.3	4.6	8.1	5.0	5.2	4.5	5.7	5.0	6.0	7.8	5.9
Myanmar	10.0	1.0	1.0	1.0	10.0	3.0	1.0	1.0	7.0	4.0	3.0	6.0	1.0
Namibia	4.4	1.0	10.0	7.1	3.4	4.0	8.8	7.8	8.0	3.0	5.0	4.6	9.4
Netherlands	9.9	6.9	10.0	8.9	5.0	8.0	10.0	7.1	9.8	5.1	7.0	6.0	10.0

Table A1 (cont'd)

Country	Native vs. introduced	Export domestic	Fish meal usage	Intensity level	Nutrition Protein	Hatchery vs wild	Antibiotic Drug use	Habitat alteration	Mol-Biol GMO	Code-practice CoC	Traceability	Employment	Waste water treatment
New Zealand	1.0	3.0	10.0	10.0	4.0	3.0	10.0	7.0	7.0	8.0	7.0	7.0	10.0
Nicaragua	10.0	5.0	3.0	1.0	10.0	5.0	5.0	3.0	5.0	3.0	5.0	3.0	3.0
Nigeria	5.9	7.4	6.3	3.0	8.5	3.0	4.0	4.0	8.0	3.8	5.0	3.0	3.0
Norway	10.0	1.0	1.0	1.0	9.0	5.0	1.0	3.0	5.0	5.0	5.0	5.0	1.0
Pakistan	4.0	3.0	3.0	5.0	8.0	3.0	4.0	5.0	5.0	5.0	5.0	3.0	3.0
Panama	10.0	5.0	3.0	1.0	10.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Peru	10.0	5.0	3.1	1.1	9.9	5.0	3.1	3.1	3.1	3.1	5.1	5.0	3.1
Philippines	10.0	4.0	5.5	5.5	10.0	1.0	4.0	2.5	7.7	4.5	3.0	6.7	2.5
Poland	5.0	8.0	5.0	5.0	8.0	6.0	4.0	5.0	4.0	5.0	6.0	4.0	5.0
Portugal	8.7	4.3	7.6	5.6	6.3	6.5	6.5	6.6	7.0	6.0	5.7	5.5	7.0
Russian	9.3	3.4	9.7	8.9	3.3	7.3	9.2	7.5	7.9	4.0	5.7	4.2	9.2
Saudi Arabia	9.7	1.5	1.3	1.5	9.9	3.3	1.4	4.9	6.9	3.4	5.0	6.7	1.5
Senegal	7.0	3.2	7.7	5.7	5.3	4.1	6.7	6.0	7.0	4.0	5.1	5.7	6.7
South Africa	2.4	3.4	9.6	6.9	5.2	6.8	8.2	7.1	7.2	6.0	5.3	5.0	9.0
Spain	10.0	6.8	9.6	8.6	5.2	7.7	9.6	6.8	9.8	5.0	6.9	6.0	9.6
Sri Lanka	10.0	1.0	1.0	1.0	10.0	1.0	5.0	1.0	10.0	3.0	1.0	5.0	1.0
Sweden	3.3	5.6	5.6	4.5	8.1	7.6	5.5	5.8	5.8	8.0	5.6	5.0	5.4
Taiwan	6.4	3.9	3.5	5.8	7.8	4.6	5.9	4.2	7.2	5.0	3.9	6.7	5.3
Thailand	9.3	1.9	2.6	2.0	9.5	1.6	2.5	1.8	6.9	3.5	4.1	5.9	2.2
Tonga	10.0	10.0	7.0	10.0	10.0	1.0	5.0	5.0	8.0	5.0	3.0	7.0	3.0
Turkey	6.4	3.0	3.2	3.1	8.9	6.4	4.1	5.1	5.1	4.5	4.2	5.0	6.0
Ukraine	7.7	5.0	9.5	6.2	6.6	5.9	6.4	6.2	6.3	5.0	4.7	5.0	6.9
United Kingdom	9.9	3.4	1.9	2.7	8.6	3.5	1.9	3.5	5.5	5.9	4.3	4.2	5.5
United States	3.7	7.1	7.3	5.1	5.6	6.4	7.3	5.8	6.4	7.0	6.7	4.4	8.4
Venezuela	1.0	5.0	3.0	3.0	10.0	7.0	3.0	3.0	5.0	7.0	5.0	5.0	5.0
Viet Nam	9.7	2.1	2.8	2.8	8.7	2.0	2.4	2.2	7.0	3.6	3.8	7.1	2.7

APPENDIX 2. ECOLOGICAL AND SOCIO-ECONOMIC SCORES AND SUSTAINABILITY INDICES IN EACH COUNTRY-SPECIES COMBINATION.

Table A2. MSI for each country-species and ecological and socio-economic scores

Country	Common name	Native vs. introduced	Fish meal usage	Intensity level	Hatchery vs wild	Habitat alteration	Waste water treatment	Ecological	MSI
Argentina	Blue mussel	10	10	7	5	7	10	8.2	7.1
Argentina	Pacific cupped oyster	3	10	5	7	7	10	7.0	6.4
Argentina	River Plata mussel	7	10	7	5	7	10	7.7	7.0
Australia	Atlantic salmon	1	1	1	3	5	3	2.3	3.7
Australia	Barramundi	5	3	1	5	5	1	3.3	4.0
Australia	Cupped oysters nei	5	10	7	7	9	10	8.0	7.1
Australia	Flat oysters nei	5	10	7	7	7	9	7.5	7.4
Australia	Giant tiger prawn	10	1	1	5	5	1	3.8	4.9
Australia	Giant tiger prawn (br)	10	1	1	5	5	1	3.8	4.9
Australia	Kuruma prawn	10	1	5	4	5	5	5.0	5.0
Australia	Pacific cupped oyster	1	10	10	10	7	10	8.0	7.2
Australia	Pacific cupped oyster (br)	1	10	8	10	7	10	7.7	7.0
Australia	Southern bluefin tuna	10	1	1	1	3	1	2.8	4.1
Bangladesh	Penaeus shrimps nei	5	3	1	3	1	1	2.3	3.5
Belize	Whiteleg shrimp	1	3	3	5	1	3	2.7	3.7
Brazil	Cupped oysters nei	7	10	7	7	7	10	8.0	7.1
Brazil	Groupers nei	9	1	5	5	5	4	4.8	5.2
Brazil	Whiteleg shrimp	1	3	3	5	1	1	2.3	4.0
Cambodia	Penaeus shrimps nei	5	3	1	3	1	1	2.3	3.5
Canada	Atlantic bluefin tuna	10	10	5	1	3	1	5.0	5.0
Canada	Atlantic cod	10	1	3	3	3	3	3.8	4.7
Canada	Atlantic salmon (Atl)	10	1	1	3	5	1	3.5	4.1
Canada	Atlantic salmon (Pac)	1	3	2	3	3	2	2.3	3.4
Canada	Blue mussel	10	10	9	8	8	10	9.2	8.2
Canada	Coho(=Silver)salmon	10	2	1	5	3	3	4.0	4.1
Canada	Pacific cupped oyster	1	10	1	5	7	10	5.7	6.1
Chile	Abalones nei	1	10	1	7	3	3	4.2	3.9
Chile	Atlantic salmon	1	1	1	1	1	2	1.2	2.5
Chile	Coho(=Silver)salmon	1	1	1	5	1	2	1.8	2.8
Chile	Gracilaria seaweeds	10	10	10	7	10	10	9.5	8.4
Chile	Pacific cupped oyster	1	10	7	5	7	1	5.2	5.6
China	Blood cockle	10	10	7	3	5	7	7.0	7.0
China	Groupers nei	9	1	5	5	5	4	4.8	5.3
China	Laver (Nori)	10	10	7	5	7	5	7.3	6.8
China	Pacific cupped oyster	1	10	7	5	5	1	4.8	5.4
China	Red drum	1	1	2	5	4	5	3.0	4.4
China	Whiteleg shrimp	1	3	1	5	3	3	2.7	3.9
Colombia	Cupped oysters nei	5	10	7	7	7	10	7.7	6.9
Colombia	Whiteleg shrimp (Atl)	10	3	3	5	3	3	4.5	4.7
Colombia	Whiteleg shrimp (Pac)	10	3	3	5	3	3	4.5	4.7
Costa Rica	Whiteleg shrimp (Pac) (br)	10	3	1	5	3	5	4.5	5.0
Denmark	Atlantic salmon	10	3	1	5	5	7	5.2	5.5
Denmark	Blue mussel	10	10	9	8	7	10	9.0	8.1
Denmark	European eel	10	3	3	3	6	7	5.3	5.9
Ecuador	Red drum	1	1	3	5	5	5	3.3	4.5

Table A2 (cont'd)

Country	Common name	Native vs. introduced	Fish meal usage	Intensity level	Hatchery vs wild	Habitat alteration	Waste water treatment	Ecological	MSI
Ecuador	Whiteleg shrimp	10	3	5	5	1	3	4.5	4.7
Egypt	European seabass	10	3	5	5	5	5	5.5	5.8
Egypt	European seabass (br)	10	3	5	5	5	5	5.5	5.8
Egypt	Flathead grey mullet	10	3	5	5	5	5	5.5	5.8
Egypt	Flathead grey mullet (Med)	10	3	5	5	5	5	5.5	5.8
Egypt	Gilthead seabream	1	1	1	5	3	1	2.0	3.5
Egypt	Gilthead seabream (br)	1	1	1	5	3	1	2.0	3.5
Egypt	Penaeus shrimps nei	5	1	5	5	3	3	3.7	4.0
Faeroes	Atlantic salmon	10	3	1	5	3	5	4.5	4.7
Finland	Atlantic salmon	10	3	2	5	3	7	5.0	4.9
France	Atlantic salmon	10	3	2	5	5	3	4.7	4.8
France	Blue mussel	10	10	9	8	7	10	9.0	8.1
France	Coho(=Silver)salmon	1	3	1	5	5	3	3.0	3.9
France	European eel	10	3	3	3	6	7	5.3	5.9
France	European flat oyster	10	10	7	5	7	10	8.2	7.3
France	European seabass	10	3	5	7	5	5	5.8	5.7
France	European seabass (br)	10	3	5	7	5	5	5.8	5.7
France	Gilthead seabream	10	1	1	5	3	1	3.5	4.3
France	Kuruma prawn	1	3	5	5	5	5	4.0	4.9
France	Pacific cupped oyster	1	10	10	5	5	1	5.3	6.2
France	Pacific cupped oyster (Med)	1	10	10	5	5	1	5.3	6.2
Germany	Blue mussel	10	10	9	8	7	10	9.0	8.1
Germany	European seabass	10	3	5	7	5	7	6.2	6.2
Germany	Pacific cupped oyster	1	10	10	5	7	1	5.7	6.4
Greece	European eel (br)	10	3	3	3	6	7	5.3	5.9
Greece	European eel	10	3	3	3	6	7	5.3	5.9
Greece	European flat oyster	10	10	7	5	7	10	8.2	7.3
Greece	European seabass (br)	10	3	5	5	5	1	4.8	5.0
Greece	European seabass	10	3	5	5	5	1	4.8	5.0
Greece	Flathead grey mullet (br)	10	3	5	5	5	3	5.2	5.7
Greece	Flathead grey mullet	10	3	5	5	5	3	5.2	5.7
Greece	Gilthead seabream (br)	10	1	1	3	3	1	3.2	4.1
Greece	Gilthead seabream	10	1	1	3	3	1	3.2	4.1
Greece	Kuruma prawn	1	3	5	5	5	5	4.0	4.6
Guatemala	Penaeus shrimps nei	5	1	3	3	1	1	2.3	3.0
Honduras	Penaeus shrimps nei	5	1	5	5	1	2	3.2	3.6
Iceland	Abalones nei	3	7	7	7	7	5	6.0	6.4
Iceland	Arctic char	10	3	5	8	6	5	6.2	6.9
Iceland	Atlantic cod	10	4	5	8	6	5	6.3	7.0
Iceland	Atlantic halibut	10	3	5	8	7	5	6.3	7.0
Iceland	Atlantic salmon (br)	1	5	5	8	6	5	5.0	6.1
Iceland	Atlantic salmon	1	5	5	8	6	5	5.0	6.1
Iceland	Atlantic wolffish	10	3	5	8	7	5	6.3	6.7
Iceland	Blue mussel	7	10	7	8	8	10	8.3	8.0

Table A2 (cont'd).

Country	Common name	Native vs. introduced	Fish meal usage	Intensity level	Hatchery vs wild	Habitat alteration	Waste water treatment	Ecological	MSI
Iceland	European seabass	5		5	8	7	5	5.0	6.2
Iceland	Haddock	10	3	5	8	7	5	6.3	6.9
Iceland	Rainbow trout	10	5	5	8	6	5	6.5	7.0
Iceland	Spotted wolffish	10	3	6	8	7	5	6.5	6.9
Iceland	Turbot	10	3	6	8	7	5	6.5	6.9
India	Giant tiger prawn (East)	10	1	1	3	1	1	2.8	3.9
India	Giant tiger prawn	10	1	1	3	1	1	2.8	3.9
Indonesia	Banana prawn (India)	10	4	4	3	3	3	4.5	4.5
Indonesia	Banana prawn	10	4	4	1	3	3	4.2	4.4
Indonesia	Barramundi (br)	10	3	1	1	3	1	3.2	3.6
Indonesia	Barramundi	10	3	1	1	3	1	3.2	3.6
Indonesia	Giant tiger prawn (India)	10	1	1	3	1	1	2.8	3.8
Indonesia	Giant tiger prawn	10	1	1	3	1	1	2.8	3.8
Indonesia	Groupers nei	9	1	5	5	3	4	4.5	5.0
Indonesia	Milkfish	10	7	10	3	3	3	6.0	5.9
Iran	Indian white prawn	1	3	6	2	6	4	3.7	4.5
Ireland	Atlantic salmon	10	3	3	5	5	5	5.2	5.4
Ireland	Blue mussel	10	10	9	8	8	10	9.2	8.2
Ireland	European flat oyster	10	10	7	5	7	10	8.2	7.3
Ireland	Pacific cupped oyster	1	10	7	5	7	10	6.7	6.8
Italy	Cupped oysters nei (br)	5	10	10	10	9	10	9.0	7.6
Italy	Cupped oysters nei	5	10	10	10	9	10	9.0	7.6
Italy	European eel (br)	10	3	3	3	6	7	5.3	5.9
Italy	European eel	10	3	3	3	6	7	5.3	5.9
Italy	European flat oyster	10	10	7	5	7	10	8.2	7.3
Italy	European seabass (br)	10	3	5	5	5	5	5.5	5.5
Italy	European seabass	10	3	5	5	5	5	5.5	5.5
Italy	Flathead grey mullet (br)	10	3	5	5	5	5	5.5	5.8
Italy	Flathead grey mullet	10	3	5	5	5	5	5.5	5.8
Italy	Giant tiger prawn	1	1	3	5	5	3	3.0	4.6
Italy	Gilthead seabream (br)	10	1	5	5	3	1	4.2	4.9
Italy	Gilthead seabream	10	1	3	5	3	1	3.8	4.7
Italy	Gracilaria seaweeds	10	10	10	7	7	10	9.0	8.2
Italy	Kuruma prawn (br)	1	3	5	5	5	7	4.3	4.8
Italy	Kuruma prawn	1	3	5	5	5	7	4.3	4.8
Japan	Coho(=Silver)salmon	10	1	1	5	3	5	4.2	4.4
Japan	Flathead grey mullet	10	3	5	5	5	5	5.5	5.8
Japan	Kuruma prawn	10	3	5	5	4	7	5.7	5.5
Japan	Laver (Nori)	10	10	7	5	7	7	7.7	7.0
Japan	Pacific cupped oyster	10	10	7	3	5	10	7.5	7.1
Kiribati	Milkfish	10	7	5	1	3	3	4.8	5.5
Korea, N.	Gracilaria seaweeds	5	10	10	5	7	10	7.8	7.4
Korea, N.	Laver (Nori)	10	10	7	5	7	5	7.3	6.8
Korea, S.	Abalones nei	10	5	3	7	5	5	5.8	5.0
Korea, S.	Blood cockle	10	10	7	3	5	7	7.0	7.0

Table A2 (cont'd).

Country	Common name	Native vs. introduced	Fish meal usage	Intensity level	Hatchery vs wild	Habitat alteration	Waste water treatment	Ecological	MSI
Korea, S.	Flathead grey mullet	10	3	5	5	5	5	5.5	5.8
Korea, S.	Groupers nei	9	1	5	5	5	4	4.8	5.2
Korea, S.	Kuruma prawn	10	3	5	5	4	7	5.7	5.5
Korea, S.	Laver (Nori)	10	10	7	5	7	7	7.7	7.0
Korea, S.	Pacific cupped oyster	1	10	7	5	7	10	6.7	6.5
Madagascar	Giant tiger prawn	10	1	3	5	1	1	3.5	4.0
Malaysia	Banana prawn	10	4	3	3	3	2	4.2	4.4
Malaysia	Banana prawn	10	4	3	3	3	2	4.2	4.4
Malaysia	Barramundi (India)	10	1	1	1	3	3	3.2	3.6
Malaysia	Barramundi	10	1	1	1	3	3	3.2	3.6
Malaysia	Blood cockle (India)	10	10	7	3	5	7	7.0	7.0
Malaysia	Blood cockle	10	10	7	3	5	7	7.0	7.0
Malaysia	Cupped oysters nei (India)	5	10	7	5	6	10	7.2	6.7
Malaysia	Cupped oysters nei	5	10	7	5	6	10	7.2	6.7
Malaysia	Giant tiger prawn (India)	10	1	1	3	1	1	2.8	3.6
Malaysia	Giant tiger prawn	10	1	1	3	1	1	2.8	3.6
Mexico	Abalones nei	5	10	1	7	5	3	5.2	4.6
Mexico	Atlantic bluefin tuna	10	5	3	1	3	1	3.8	4.6
Mexico	Flathead grey mullet	10	3	5	5	5	5	5.5	5.8
Mexico	Pacific cupped oyster (Atl)	1	10	10	3	7	10	6.8	6.6
Mexico	Pacific cupped oyster	1	10	10	3	7	10	6.8	6.6
Mexico	Whiteleg shrimp (br)	10	3	3	5	3	5	4.8	5.0
Mexico	Whiteleg shrimp	10	3	3	5	3	5	4.8	5.0
Mexico	Yellowfin tuna	10	1	1	1	3	1	2.8	4.1
Morocco	Clams, etc nei	5	10	8	3	7	10	7.2	6.5
Morocco	European eel	10	3	6	5	4	5	5.5	5.7
Morocco	European flat oyster	10	10	7	3	7	10	7.8	6.9
Morocco	European seabass	10	3	4	5	4	5	5.2	5.4
Morocco	Gilthead seabream	10	3	4	5	4	5	5.2	5.5
Morocco	Marine fishes nei	5	4	5	5	4	5	4.7	5.3
Morocco	Mediterranean mussel	10	10	7	5	6	10	6.3	6.4
Morocco	Pacific cupped oyster	1	10	7	5	7	10	6.7	6.3
Morocco	Pacific cupped oyster (Med)	1	10	7	5	7	10	6.7	6.3
Morocco	Penaeus shrimps nei	5	3	3	5	4	5	4.2	4.9
Morocco	Yesso scallop	1	10	7	7	6	9	6.7	6.5
Myanmar	Giant tiger prawn	10	1	1	3	1	1	2.8	3.7
Namibia	Blue mussel	1	10	8	4	7	9	6.5	5.8
Namibia	Gracilaria seaweeds	10	10	7	4	9	10	8.3	6.7
Namibia	Pacific cupped oyster	1	10	7	4	7	9	6.3	5.5
Netherlands	Blue mussel	10	10	9	8	7	10	9.0	8.1
Netherlands	Cupped oysters nei	5	10	7	7	9	10	8.0	7.1
Netherlands	European flat oyster	10	10	7	5	7	10	8.2	7.3
New Zealand	Abalones nei	5	5	1	5	5	5	4.3	4.2
New Zealand	Pacific cupped oyster	1	10	10	3	7	10	6.8	6.7
Nicaragua	Whiteleg shrimp	10	3	1	5	3	3	4.2	4.8

Table A2 (cont'd).

Country	Common name	Native vs. introduced	Fish meal usage	Intensity level	Hatchery vs wild	Habitat alteration	Waste water treatment	Ecological	MSI
Nigeria	Bagrid catfish	10	9	3	3	4	3	5.3	5.5
Nigeria	Freshwater fishes nei	5	5	5	3	5	3	4.3	5.0
Nigeria	Mullets nei	5	7	3	3	4	3	4.2	4.8
Nigeria	Snappers nei	5	7	3	3	4	3	4.2	4.9
Nigeria	Tilapias nei	5	5	3	3	4	3	3.8	4.8
Nigeria	Torpedo catfishes nei	5	5	3	3	4	3	3.8	4.6
Norway	Atlantic cod	10	1	3	3	3	1	3.5	4.6
Norway	Atlantic salmon	10	1	1	5	3	1	3.5	4.0
Norway	Blue mussel	10	10	9	8	7	10	9.0	8.1
Norway	European flat oyster	10	10	7	5	7	10	8.2	7.3
Norway	Pacific cupped oyster	1	10	7	2	7	10	6.2	6.6
Pakistan	Marine crustaceans nei	4	3	5	3	5	3	3.8	4.3
Panama	Whiteleg shrimp	10	3	1	5	5	5	4.8	5.3
Peru	False abalone	10	10	7	7	7	5	7.7	7.2
Peru	Gracilaria seaweeds	10	10	10	5	10	10	9.2	8.2
Peru	Pacific cupped oyster	1	10	10	5	7	10	7.2	6.5
Peru	Whiteleg shrimp	10	3	1	5	3	3	4.2	4.5
Philippines	Banana prawn (br)	10	4	5	3	3	1	4.3	4.5
Philippines	Banana prawn	10	4	5	1	3	1	4.0	4.3
Philippines	Barramundi	10	1	1	3	3	3	3.5	3.9
Philippines	Giant tiger prawn (br)	10	1	1	1	1	1	2.5	3.5
Philippines	Giant tiger prawn	10	1	1	1	1	1	2.5	3.5
Philippines	Gracilaria seaweeds	10	10	10	5	7	10	8.7	7.8
Philippines	Groupers, seabasses nei (br)	9	1	5	5	6	4	5.0	5.2
Philippines	Groupers, seabasses nei	9	1	5	5	6	4	5.0	5.2
Philippines	Milkfish (br)	10	7	7	1	3	3	5.2	5.7
Philippines	Milkfish	10	7	7	1	3	3	5.2	5.7
Philippines	Penaeus shrimps nei	5	3	5	3	1	1	3.0	3.9
Poland	Freshwater fishes nei	5	5	5	6	5	5	5.2	5.4
Portugal	Atlantic salmon	1	3	3	6	4	3	3.3	4.5
Portugal	Brill	10	5	3	6	4	6	5.7	5.7
Portugal	Common cuttlefish	10	5	5	6	7	7	6.7	6.5
Portugal	Common edible cockle	10	10	7	6	9	6	8.0	6.9
Portugal	Common sole	10	5	3	6	4	5	5.5	5.8
Portugal	European eel	10	5	3	6	4	5	5.5	5.8
Portugal	European flat oyster	10	10	7	6	8	6	7.8	6.9
Portugal	European seabass (br)	10	3	3	6	4	4	5.0	5.2
Portugal	European seabass	10	3	3	6	4	4	5.0	5.4
Portugal	Flat and cupped oysters nei	10	10	7	6	7	9	8.2	7.0
Portugal	Freshwater fishes nei	5	5	5	5	5	5	5.0	5.4
Portugal	Gilthead seabream (br)	10	3	3	6	4	3	4.8	5.1
Portugal	Gilthead seabream	10	3	3	6	4	3	4.8	5.3
Portugal	Grooved carpet shell (br)	10	10	7	7	8	9	8.5	7.2
Portugal	Grooved carpet shell	10	10	7	7	8	9	8.5	7.3
Portugal	Kuruma prawn	1	3	3	6	4	3	3.3	4.6
Portugal	Marine fishes nei	5	5	5	6	4	5	5.0	5.4
Portugal	Marine molluscs nei	5	5	5	6	4	5	5.0	5.3

Table A2 (cont'd).

Country	Common name	Native vs. introduced	Fish meal usage	Intensity level	Hatchery vs wild	Habitat alteration	Waste water treatment	Ecological	MSI
Portugal	Mullets nei	5	5	5	6	4	5	5.0	5.4
Portugal	Octopuses nei	5	5	5	6	8	5	5.7	5.7
Portugal	Pacific cupped oyster	1	10	7	6	8	9	6.8	6.3
Portugal	Pullet carpet shell	10	10	7	6	8	9	8.3	7.0
Portugal	Razor clams nei	5	10	7	6	8	9	7.5	6.5
Portugal	Sargo breams nei	6	3	3	6	4	3	4.2	4.8
Portugal	Sea mussels nei	5	10	7	6	7	8	7.2	6.5
Portugal	Turbot	10	3	3	6	4	5	5.2	5.3
Russian Fed.	Atlantic salmon	1	3	3	6	3	4	3.3	4.1
Russian Fed.	Brown seaweeds	10	10	10	8	8	10	9.3	7.4
Russian Fed.	Brown seaweeds (Pac)	10	10	10	8	8	10	9.3	7.3
Russian Fed.	Flatfishes nei	5	3	4	5	4	5	4.3	4.6
Russian Fed.	Marine fishes nei	5	3	4	5	4	5	4.3	4.7
Russian Fed.	Mediterranean mussel	10	10	7	6	7	8	8.0	6.5
Russian Fed.	Mullets nei	5	5	5	5	4	5	4.8	4.9
Russian Fed.	Sea mussels nei	5	10	7	5	7	8	7.0	6.5
Russian Fed.	Sea mussels nei (Pac)	5	10	7	5	7	8	7.0	6.4
Russian Fed.	Sea trout	10	3	3	6	3	5	5.0	5.2
Russian Fed.	Sea trout (med)	10	3	3	6	3	5	5.0	5.3
Russian Fed.	Sea urchins nei	5	5	7	5	7	5	5.7	5.7
Russian Fed.	Silver carp	10	5	3	6	4	5	5.5	5.5
Russian Fed.	Sturgeons nei	5	5	6	6	4	5	5.2	5.2
Russian Fed.	Yesso scallop	10	10	7	7	7	7	8.0	6.9
Saudi Arabia	Barramundi	5	1	1	3	3	1	2.3	3.5
Saudi Arabia	Flathead grey mullet	10	3	5	5	5	5	5.5	5.7
Saudi Arabia	Giant tiger prawn	10	1	1	3	5	1	3.5	4.2
Saudi Arabia	Groupers nei	9	1	5	5	5	4	4.8	5.2
Senegal	Blackchin tilapia	10	5	3	7	5	5	5.8	5.9
Senegal	Cupped oysters nei	5	10	7	4	7	8	6.0	5.7
Senegal	Gasar cupped oyster	10	10	7	4	7	8	7.7	6.5
Senegal	Giant river prawn	1	3	3	4	4	4	3.2	4.0
Senegal	Nile tilapia	1	5	6	4	5	6	4.5	4.8
Senegal	Pacific cupped oyster	1	10	7	4	7	8	6.2	5.8
South Africa	Aquatic plants nei	7	10	7	6	8	10	8.0	6.9
South Africa	Carpet shells nei	7	10	7	6	7	8	7.5	6.5
South Africa	European flat oyster	1	10	7	7	7	8	6.7	6.1
South Africa	Giant tiger prawn	1	3	3	7	5	5	4.0	4.7
South Africa	Gracilaria seaweeds	10	10	7	6	8	10	8.5	7.3
South Africa	Indian white prawn	1	3	3	7	5	5	4.0	4.6
South Africa	Kuruma prawn	1	3	3	7	5	5	4.0	4.7
South Africa	Mediterranean mussel	1	10	7	7	7	9	6.8	6.2
South Africa	Mullets nei	5	5	4	6	5	6	5.2	5.4
South Africa	Pacific cupped oyster	1	10	7	7	7	9	6.8	6.1
South Africa	Perlemoen abalone	10	5	7	6	7	8	7.2	6.7

Table A2 (cont'd).

Country	Common name	Native vs. introduced	Fish meal usage	Intensity level	Hatchery vs wild	Habitat alteration	Waste water treatment	Ecological	MSI
South Africa	Red bait	1	5	4	7	5	6	4.7	5.0
South Africa	Sea mussels nei	5	10	7	7	7	8	7.3	6.5
South Africa	Smooth mactra	10	10	7	6	7	7	7.8	6.7
Spain	Atlantic salmon	10	1	2	3	3	1	3.3	3.5
Spain	Blue mussel	10	10	9	8	7	10	9.0	8.1
Spain	Cupped oysters nei	5	10	10	7	8	10	8.3	7.2
Spain	European eel	10	3	3	3	6	7	5.3	5.9
Spain	European flat oyster	10	10	7	5	7	10	8.2	7.3
Spain	European seabass	10	3	5	5	5	5	5.5	5.7
Spain	Flathead grey mullet	10	3	5	5	5	5	5.5	5.8
Spain	Gilthead seabream	10	1	1	3	3	1	3.2	4.2
Spain	Kuruma prawn	1	3	5	5	5	7	4.3	4.8
Spain	Pacific cupped oyster	1	10	7	5	7	10	6.7	6.4
Spain	Tuna-like fishes nei	10	1	3	1	5	1	3.5	4.5
Sri Lanka	Giant tiger prawn	10	1	1	1	1	1	2.5	3.8
Sweden	Atlantic salmon	10	3	3	8	5	5	5.7	6.0
Sweden	Blue mussel	7	10	7	7	7	6	7.3	6.7
Sweden	European flat oyster	10	10	7	8	7	8	6.7	6.3
Sweden	Rainbow trout	1	3	3	8	5	5	4.2	5.2
Taiwan	Abalones nei (br)	5	5	1	5	5	3	4.0	3.9
Taiwan	Abalones nei	5	5	1	5	5	3	4.0	3.9
Taiwan	Barramundi (br)	10	1	1	3	3	1	3.2	3.6
Taiwan	Barramundi	10	1	1	3	3	3	3.5	3.9
Taiwan	Blood cockle	10	10	7	3	5	7	7.0	7.0
Taiwan	Flathead grey mullet (br)	10	3	5	5	5	3	5.2	5.5
Taiwan	Flathead grey mullet	10	3	5	5	5	3	5.2	5.5
Taiwan	Giant tiger prawn	10	1	1	1	1	1	2.5	3.5
Taiwan	Groupers nei (Pac) (br)	9	1	5	5	3	4	4.5	5.0
Taiwan	Groupers nei (br)	9	1	5	5	3	4	4.5	5.0
Taiwan	Groupers nei	9	1	5	5	3	4	4.5	5.0
Taiwan	Kuruma prawn (br)	10	3	1	5	1	3	3.8	4.6
Taiwan	Kuruma prawn	10	3	1	5	1	3	3.8	4.6
Taiwan	Laver (Nori)	10	10	7	5	7	5	7.3	7.0
Taiwan	Milkfish (br)	10	7	7	5	3	3	5.8	5.9
Taiwan	Milkfish	10	7	7	5	3	3	5.8	5.9
Taiwan	Pacific cupped oyster (br)	1	1	7	5	7	10	5.2	5.7
Taiwan	Pacific cupped oyster	1	1	7	5	7	10	5.2	5.7
Taiwan	Whiteleg shrimp	1	3	1	5	1	3	2.3	3.6
Thailand	Banana prawn	10	4	4	1	3	1	3.8	4.1
Thailand	Barramundi (Ind)	10	1	1	3	3	1	3.2	3.7
Thailand	Barramundi	10	1	1	3	3	1	3.2	3.7
Thailand	Blood cockle (Ind)	10	10	7	3	5	7	7.0	7.0
Thailand	Blood cockle	10	10	7	3	5	7	7.0	7.0
Thailand	Cupped oysters nei (Ind)	5	10	7	5	6	10	7.2	6.7
Thailand	Cupped oysters nei	5	10	7	5	6	10	7.2	6.7

Table A2 (cont'd).

Country	Common name	Native vs. introduced	Fish meal usage	Intensity level	Hatchery vs wild	Habitat alteration	Waste water treatment	Ecological	MSI
Thailand	Giant tiger prawn (Ind)	10	1	1	1	1	1	2.5	3.5
Thailand	Giant tiger prawn	10	1	1	1	1	1	2.5	3.5
Thailand	Groupers nei (Ind)	9	1	5	5	3	4	4.5	5.0
Thailand	Groupers nei	9	1	5	5	3	4	4.5	5.0
Thailand	Penaeus shrimps nei	5	3	1	3	1	2	2.5	3.5
Thailand	Whiteleg shrimp	1	3	1	3	1	1	1.7	3.0
Tonga	Milkfish	10	7	10	1	5	3	6.0	6.4
Turkey	Atlantic salmon	1	3	3	8	5	5	4.2	4.7
Turkey	Com.2-banded seabream	10	3	3	7	5	6	5.7	5.3
Turkey	Gilthead seabream	8	3	3	7	5	6	5.3	5.1
Turkey	Mediterranean mussel	10	10	7	6	7	8	8.0	6.6
Turkey	Natantian decapods nei	5	5	5	6	5	5	5.2	5.1
Turkey	Seabasses nei	5	3	3	6	5	6	4.7	4.8
Turkey	Trouts nei	5	3	3	5	5	5	4.3	4.8
Ukraine	Baltic prawn	10	3	3	6	5	5	5.3	5.2
Ukraine	Flatfishes nei	5	3	3	6	5	6	3.8	4.4
Ukraine	Gobies nei	5	5	3	5	5	6	4.0	4.5
Ukraine	Mediterranean mussel	10	10	7	6	7	8	8.0	6.9
Ukraine	Mullets nei (br)	5	10	5	5	5	5	5.8	5.6
Ukraine	Mullets nei	5	10	5	5	5	5	5.8	5.6
Ukraine	Silversides nei	10	5	5	6	5	6	6.2	6.0
Ukraine	So-iuy mullet	1	5	5	8	5	6	5.0	5.3
Ukraine	Sturgeons nei	5	5	5	6	5	7	5.5	5.6
United Kingdom	Atlantic cod	10	1	3	3	3	1	3.5	4.6
United Kingdom	Atlantic salmon	10	1	2	3	3	5	4.0	4.3
United Kingdom	Blue mussel	10	10	9	8	8	10	9.2	8.2
United Kingdom	Cupped oysters nei	5	10	7	6	8	10	7.7	6.9
United Kingdom	European flat oyster	10	10	7	5	7	10	8.2	7.3
United Kingdom	European seabass	10	3	5	7	5	5	5.8	6.0
United Kingdom	Pacific cupped oyster	1	10	7	5	7	10	6.7	6.7
U.S. of America	Abalones nei	10	5	1	5	5	5	5.2	5.6
U.S. of America	Atlantic salmon	10	1	1	5	3	5	4.2	4.5
U.S. of America	Blue mussel	10	10	8	8	7	10	8.8	7.9
U.S. of America	Coho(=Silver)salmon	10	1	1	5	3	5	4.2	4.4
U.S. of America	Cupped oysters nei	5	10	7	10	8	10	8.3	7.2
U.S. of America	European flat oyster	1	10	7	5	7	10	6.7	6.5
U.S. of America	Flat oysters nei	5	10	7	7	7	9	7.5	7.4
U.S. of America	Pacific cupped oyster	1	10	7	7	7	10	7.0	7.0
U.S. of America	Whiteleg shrimp	1	3	1	5	5	5	3.3	4.7
Venezuela	Whiteleg shrimp	1	3	3	7	3	5	3.7	4.7
Viet Nam	Banana prawn	10	4	3	3	3	3	4.3	4.5
Viet Nam	Giant tiger prawn	10	1	1	1	1	1	2.5	3.5
Viet Nam	Gracilaria seaweeds	10	10	10	5	7	10	8.7	7.9
Viet Nam	Whiteleg shrimp	1	1	7	3	1	3	2.7	3.8

Table A2 (cont'd).

Country	Common name	Export domestic	Nutrition Protein	Antibiotic Drug use	Mol-Biol GMO	Code-practice CoC	Traceability	Employment	Socio-eco	MSI
Argentina	Blue mussel	5	5	10	7	3	5	7	6.0	7.1
Argentina	Pacific cupped oyster	5	4	7	7	5	5	7	5.7	6.4
Argentina	River Plata mussel	5	5	10	7	5	5	7	6.3	7.0
Australia	Atlantic salmon	7	9	1	5	5	3	5	5.0	3.7
Australia	Barramundi	1	10	1	5	5	6	5	4.7	4.0
Australia	Cupped oysters nei	5	4	10	3	7	7	7	6.1	7.1
Australia	Flat oysters nei	10	4	10	6	7	8	6	7.3	7.4
Australia	Giant tiger prawn (br)	5	10	1	7	7	7	5	6.0	4.9
Australia	Giant tiger prawn	5	10	1	7	7	7	5	6.0	4.9
Australia	Kuruma prawn	5	9	3	5	5	5	3	5.0	5.0
Australia	Pacific cupped oyster (br)	5	4	10	7	6	7	6	6.4	7.0
Australia	Pacific cupped oyster	5	4	10	7	6	7	6	6.4	7.2
Australia	Southern bluefin tuna	5	10	3	10	7	3	3	5.9	4.1
Bangladesh	Penaeus shrimps nei	5	10	1	6	4	1	5	4.6	3.5
Belize	Whiteleg shrimp	5	10	1	5	7	3	5	5.1	3.7
Brazil	Cupped oysters nei	5	4	10	3	7	7	7	6.1	7.1
Brazil	Groupers nei	5	9	3	7	5	5	5	5.6	5.2
Brazil	Whiteleg shrimp	5	10	1	6	7	5	5	5.6	4.0
Cambodia	Penaeus shrimps nei	5	10	1	6	4	1	5	4.6	3.5
Canada	Atlantic bluefin tuna	5	10	10	7	3	5	3	6.1	5.0
Canada	Atlantic cod	7	9	1	10	5	4	3	5.6	4.7
Canada	Atlantic salmon (Atl)	7	9	1	5	5	3	3	4.7	4.1
Canada	Atlantic salmon (Pac)	3	9	1	5	5	3	5	4.4	3.4
Canada	Blue mussel	7	5	10	10	5	7	6	7.1	8.2
Canada	Coho(=Silver)salmon	5	9	1	3	3	5	3	4.1	4.1
Canada	Pacific cupped oyster	5	4	10	7	7	7	6	6.6	6.1
Chile	Abalones nei	3	7	3	3	5	5	5	4.4	3.9
Chile	Atlantic salmon	1	9	1	5	3	3	5	3.9	2.5
Chile	Coho(=Silver)salmon	3	9	1	3	3	3	4	3.7	2.8
Chile	Gracilaria seaweeds	7	2	10	8	8	10	6	7.3	8.4
Chile	Pacific cupped oyster	3	4	10	7	6	6	6	6.0	5.6
China	Blood cockle	5	9	10	10	5	5	5	7.0	7.0
China	Groupers nei	5	9	3	7	5	5	6	5.7	5.3
China	Laver (Nori)	5	3	10	7	7	5	7	6.3	6.8
China	Pacific cupped oyster	3	4	10	7	6	6	6	6.0	5.4
China	Red drum	5	10	4	5	6	5	6	5.9	4.4
China	Whiteleg shrimp	5	10	1	5	3	5	7	5.1	3.9
Colombia	Cupped oysters nei	5	4	10	3	7	7	7	6.1	6.9
Colombia	Whiteleg shrimp (Atl)	5	10	1	5	3	5	5	4.9	4.7
Colombia	Whiteleg shrimp (Pac)	5	10	1	5	3	5	5	4.9	4.7
Costa Rica	Whiteleg shrimp (Pac) (br)	5	10	5	5	5	5	3	5.4	5.0
Denmark	Atlantic salmon	3	9	5	6	7	6	5	5.9	5.5
Denmark	Blue mussel	7	5	10	10	5	7	6	7.1	8.1
Denmark	European eel	7	9	5	7	5	5	7	6.4	5.9
Ecuador	Red drum	5	10	5	6	4	5	5	5.7	4.5

Table A2 (cont'd).

Country	Common name	Export domestic	Nutrition Protein	Antibiotic Drug use	Mol-Biol GMO	Code-practice CoC	Traceability	Employment	Socio-eco	MSI
Ecuador	Whiteleg shrimp	5	10	1	5	3	5	5	4.9	4.7
Egypt	European seabass (br)	5	9	5	3	7	7	7	6.1	5.8
Egypt	European seabass	5	9	5	3	7	7	7	6.1	5.8
Egypt	Flathead grey mullet (Med)	5	9	4	7	5	5	7	6.0	5.8
Egypt	Flathead grey mullet	5	9	4	7	5	5	7	6.0	5.8
Egypt	Gilthead seabream (br)	1	9	1	5	5	6	8	5.0	3.5
Egypt	Gilthead seabream	1	9	1	5	5	6	8	5.0	3.5
Egypt	Penaeus shrimps nei	5	10	3	5	3	2	3	4.4	4.0
Faeroes	Atlantic salmon	1	9	1	7	6	5	5	4.9	4.7
Finland	Atlantic salmon	1	9	1	6	7	5	5	4.9	4.9
France	Atlantic salmon	1	9	4	5	5	5	5	4.9	4.8
France	Blue mussel	7	5	10	10	5	7	6	7.1	8.1
France	Coho(=Silver)salmon	3	9	4	3	5	5	5	4.9	3.9
France	European eel	7	9	5	7	5	5	7	6.4	5.9
France	European flat oyster	5	4	10	7	7	5	7	6.4	7.3
France	European seabass (br)	5	9	3	5	5	7	5	5.6	5.7
France	European seabass	5	9	3	5	5	7	5	5.6	5.7
France	Gilthead seabream	1	9	1	5	5	7	7	5.0	4.3
France	Kuruma prawn	7	9	4	5	5	7	3	5.7	4.9
France	Pacific cupped oyster	5	4	10	7	8	8	7	7.0	6.2
France	Pacific cupped oyster (Med)	5	4	10	7	8	8	7	7.0	6.2
Germany	Blue mussel	7	5	10	10	5	7	6	7.1	8.1
Germany	European seabass	5	9	5	5	7	7	5	6.1	6.2
Germany	Pacific cupped oyster	5	4	10	7	9	9	6	7.1	6.4
Greece	European eel (br)	7	9	5	7	5	5	7	6.4	5.9
Greece	European eel	7	9	5	7	5	5	7	6.4	5.9
Greece	European flat oyster	5	4	10	7	7	5	7	6.4	7.3
Greece	European seabass (br)	5	9	3	3	5	5	6	5.1	5.0
Greece	European seabass	5	9	3	3	5	5	6	5.1	5.0
Greece	Flathead grey mullet (br)	5	9	4	7	5	7	7	6.3	5.7
Greece	Flathead grey mullet	5	9	4	7	5	7	7	6.3	5.7
Greece	Gilthead seabream (br)	3	9	1	5	5	5	7	5.0	4.1
Greece	Gilthead seabream	3	9	1	5	5	5	7	5.0	4.1
Greece	Kuruma prawn	6	9	1	5	5	7	3	5.1	4.6
Guatemala	Penaeus shrimps nei	5	10	1	5	1	1	3	3.7	3.0
Honduras	Penaeus shrimps nei	5	10	1	5	2	2	3	4.0	3.6
Iceland	Abalones nei	1	8	7	9	7	10	5	6.7	6.4
Iceland	Arctic char	5	9	9	9	7	10	5	7.7	6.9
Iceland	Atlantic cod	5	9	8	9	7	10	5	7.6	7.0
Iceland	Atlantic halibut	5	9	8	9	8	10	5	7.7	7.0
Iceland	Atlantic salmon (br)	5	9	8	7	7	10	5	7.3	6.1
Iceland	Atlantic salmon	5	9	8	7	7	10	5	7.3	6.1
Iceland	Atlantic wolffish	1	7	10	9	7	10	5	7.0	6.7
Iceland	Blue mussel	10	5	8	7	8	10	5	7.6	8.0
Iceland	European seabass	5	9	8	8	7	10	5	7.4	6.2

Table A2 (cont'd).

Country	Common name	Export domestic	Nutrition Protein	Antibiotic Drug use	Mol-Biol GMO	Code-practice CoC	Traceability	Employment	Socio-eco	MSI
Iceland	Haddock	5	8	8	9	7	10	5	7.4	6.9
Iceland	Rainbow trout	5	10	8	7	7	10	5	7.4	7.0
Iceland	Spotted wolffish	5	7	8	9	7	10	5	7.3	6.9
Iceland	Turbot	5	8	8	8	7	10	5	7.3	6.9
India	Giant tiger prawn (East)	1	10	1	7	4	5	7	5.0	3.9
India	Giant tiger prawn	1	10	1	7	4	5	7	5.0	3.9
Indonesia	Banana prawn (India)	5	9	2	6	3	2	5	4.6	4.5
Indonesia	Banana prawn	5	9	2	6	3	2	5	4.6	4.4
Indonesia	Barramundi (br)	1	10	1	5	3	3	5	4.0	3.6
Indonesia	Barramundi	1	10	1	5	3	3	5	4.0	3.6
Indonesia	Giant tiger prawn (India)	1	10	1	7	4	3	7	4.7	3.8
Indonesia	Giant tiger prawn	1	10	1	7	4	3	7	4.7	3.8
Indonesia	Groupers nei	5	9	3	7	5	3	6	5.4	5.0
Indonesia	Milkfish	3	10	5	8	5	3	7	5.9	5.9
Iran	Indian white prawn	1	9	5	5	5	6	7	5.4	4.5
Ireland	Atlantic salmon	1	9	5	7	7	5	5	5.6	5.4
Ireland	Blue mussel	7	5	10	10	5	7	6	7.1	8.2
Ireland	European flat oyster	5	4	10	7	7	5	7	6.4	7.3
Ireland	Pacific cupped oyster	5	4	10	7	8	8	6	6.9	6.8
Italy	Cupped oysters nei (br)	5	4	10	3	7	7	7	6.1	7.6
Italy	Cupped oysters nei	5	4	10	3	7	7	7	6.1	7.6
Italy	European eel (br)	7	9	5	7	5	5	7	6.4	5.9
Italy	European eel	7	9	5	7	5	5	7	6.4	5.9
Italy	European flat oyster	5	4	10	7	7	5	7	6.4	7.3
Italy	European seabass (br)	5	9	3	3	7	5	7	5.6	5.5
Italy	European seabass	5	9	3	3	7	5	7	5.6	5.5
Italy	Flathead grey mullet (br)	5	9	4	7	5	7	6	6.1	5.8
Italy	Flathead grey mullet	5	9	4	7	5	7	6	6.1	5.8
Italy	Giant tiger prawn	10	10	1	7	5	5	5	6.1	4.6
Italy	Gilthead seabream (br)	5	9	1	5	5	7	7	5.6	4.9
Italy	Gilthead seabream	5	9	1	5	5	7	7	5.6	4.7
Italy	Gracilaria seaweeds	10	2	10	8	7	10	5	7.4	8.2
Italy	Kuruma prawn (br)	7	9	1	5	5	7	3	5.3	4.8
Italy	Kuruma prawn	7	9	1	5	5	7	3	5.3	4.8
Japan	Coho(=Silver)salmon	7	9	1	3	5	4	3	4.6	4.4
Japan	Flathead grey mullet	5	9	4	7	5	7	5	6.0	5.8
Japan	Kuruma prawn	7	9	1	5	5	7	3	5.3	5.5
Japan	Laver (Nori)	5	3	10	7	7	8	5	6.4	7.0
Japan	Pacific cupped oyster	5	4	10	7	7	9	5	6.7	7.1
Kiribati	Milkfish	5	10	5	8	5	3	7	6.1	5.5
Korea, N.	Gracilaria seaweeds	5	2	10	8	7	10	7	7.0	7.4
Korea, N.	Laver (Nori)	5	3	10	7	7	5	7	6.3	6.8
Korea, S.	Abalones nei	5	8	5	2	4	5		4.1	5.0
Korea, S	Blood cockle	5	9	10	10	5	5	5	7.0	7.0

Table A2 (cont'd).

Country	Common name	Export domestic	Nutrition Protein	Antibiotic Drug use	Mol-Biol GMO	Code-practice CoC	Traceability	Employment	Socio-eco	MSI
Korea, S.	Flathead grey mullet	5	9	4	7	5	7	5	6.0	5.8
Korea, S.	Groupers nei	5	9	3	7	5	5	5	5.6	5.2
Korea, S.	Kuruma prawn	7	9	1	5	5	7	3	5.3	5.5
Korea, S.	Laver (Nori)	5	3	10	7	7	8	5	6.4	7.0
Korea, S.	Pacific cupped oyster	5	4	10	7	7	7	5	6.4	6.5
Madagascar	Giant tiger prawn	1	10	1	7	3	3	6	4.4	4.0
Malaysia	Banana prawn	5	9	2	5	3	3	5	4.6	4.4
Malaysia	Banana prawn	5	9	2	5	3	3	5	4.6	4.4
Malaysia	Barramundi (India)	1	10	1	5	3	3	5	4.0	3.6
Malaysia	Barramundi	1	10	1	5	3	3	5	4.0	3.6
Malaysia	Blood cockle (India)	5	9	10	10	5	5	5	7.0	7.0
Malaysia	Blood cockle	5	9	10	10	5	5	5	7.0	7.0
Malaysia	Cupped oysters nei (India)	5	4	10	3	7	7	7	6.1	6.7
Malaysia	Cupped oysters nei	5	4	10	3	7	7	7	6.1	6.7
Malaysia	Giant tiger prawn (India)	1	10	1	7	3	3	6	4.4	3.6
Malaysia	Giant tiger prawn	1	10	1	7	3	3	6	4.4	3.6
Mexico	Abalones nei	3	7	5	3	5	5	5	4.7	4.6
Mexico	Atlantic bluefin tuna	5	10	10	7	1	5	3	5.9	4.6
Mexico	Flathead grey mullet	5	9	4	7	5	5	7	6.0	5.8
Mexico	Pacific cupped oyster (Atl)	5	4	10	7	6	6	6	6.3	6.6
Mexico	Pacific cupped oyster	5	4	10	7	6	6	6	6.3	6.6
Mexico	Whiteleg shrimp (br)	5	10	3	5	5	5	3	5.1	5.0
Mexico	Whiteleg shrimp	5	10	3	5	5	5	3	5.1	5.0
Mexico	Yellowfin tuna	5	10	3	10	1	3	5	5.3	4.1
Morocco	Clams, etc nei	3	3	8	9	5	6	7	5.9	6.5
Morocco	European eel	3	9	4	7	5	6	7	5.9	5.7
Morocco	European flat oyster	3	4	8	8	5	7	7	6.0	6.9
Morocco	European seabass	3	9	4	5	5	6	8	5.7	5.4
Morocco	Gilthead seabream	3	9	5	5	5	6	8	5.9	5.5
Morocco	Marine fishes nei	3	8	5	7	5	6	7	5.9	5.3
Morocco	Mediterranean mussel	3	5	8	9	5	7	8	6.4	6.4
Morocco	Pacific cupped oyster	3	4	8	8	5	6	7	5.9	6.3
Morocco	Pacific cupped oyster (Med)	3	4	8	8	5	6	7	5.9	6.3
Morocco	Penaeus shrimps nei	3	10	4	5	5	6	7	5.7	4.9
Morocco	Yesso scallop	3	7	8	9	5	7	6	6.4	6.5
Myanmar	Giant tiger prawn	1	10	1	7	4	3	6	4.6	3.7
Namibia	Blue mussel	1	5	8	8	3	5	6	5.1	5.8
Namibia	Gracilaria seaweeds	1	2	10	8	3	5	6	5.0	6.7
Namibia	Pacific cupped oyster	1	4	8	8	3	5	3	4.6	5.5
Netherlands	Blue mussel	7	5	10	10	5	7	6	7.1	8.1
Netherlands	Cupped oysters nei	5	4	10	3	7	7	7	6.1	7.1
Netherlands	European flat oyster	5	4	10	7	7	5	7	6.4	7.3

Table A2 (cont'd).

Country	Common name	Export domestic	Nutrition Protein	Antibiotic Drug use	Mol-Biol GMO	Code-practice CoC	Traceability	Employment	Socio-eco	MSI
New Zealand	Abalones nei	3	8	5	3	4	6	5	4.9	4.2
New Zealand	Pacific cupped oyster	3	4	10	7	8	7	7	6.6	6.7
Nicaragua	Whiteleg shrimp	5	10	5	5	3	5	5	5.4	4.8
Nigeria	Bagrid catfish	8	9	4	8	3	5	3	5.7	5.5
Nigeria	Freshwater fishes nei	7	8	4	8	4	5	3	5.6	5.0
Nigeria	Mullets nei	6	9	4	8	3	5	3	5.4	4.8
Nigeria	Snappers nei	6	9	4	8	4	5	3	5.6	4.9
Nigeria	Tilapias nei	8	8	4	8	4	5	3	5.7	4.8
Nigeria	Torpedo catfishes nei	6	8	4	8	4	5	3	5.4	4.6
Norway	Atlantic cod	7	9	1	8	5	7	3	5.7	4.6
Norway	Atlantic salmon	1	9	1	5	5	5	5	4.4	4.0
Norway	Blue mussel	7	5	10	10	5	7	6	7.1	8.1
Norway	European flat oyster	5	4	10	7	7	5	7	6.4	7.3
Norway	Pacific cupped oyster	5	4	10	7	8	8	7	7.0	6.6
Pakistan	Marine crustaceans nei	3	8	4	5	5	5	3	4.7	4.3
Panama	Whiteleg shrimp	5	10	5	5	5	5	5	5.7	5.3
Peru	False abalone	5	8	7	7	7	8	5	6.7	7.2
Peru	Gracilaria seaweeds	5	2	10	10	7	10	6	7.1	8.2
Peru	Pacific cupped oyster	3	4	10	7	5	5	7	5.9	6.5
Peru	Whiteleg shrimp	5	10	3	3	3	5	5	4.9	4.5
Philippines	Banana prawn (br)	5	9	2	6	3	2	5	4.6	4.5
Philippines	Banana prawn	5	9	2	6	3	2	5	4.6	4.3
Philippines	Barramundi	3	10	1	5	3	3	5	4.3	3.9
Philippines	Giant tiger prawn (br)	1	10	1	7	3	3	6	4.4	3.5
Philippines	Giant tiger prawn	1	10	1	7	3	3	6	4.4	3.5
Philippines	Gracilaria seaweeds	3	2	10	10	7	10	7	7.0	7.8
Philippines	Groupers, seabasses nei (br)	5	9	3	7	5	3	6	5.4	5.2
Philippines	Groupers, seabasses nei	5	9	3	7	5	3	6	5.4	5.2
Philippines	Milkfish (br)	5	10	5	8	5	3	7	6.1	5.7
Philippines	Milkfish	5	10	5	8	5	3	7	6.1	5.7
Philippines	Penaeus shrimps nei	5	10	3	5	3	2	5	4.7	3.9
Poland	Freshwater fishes nei	8	8	4	4	5	6	4	5.6	5.4
Portugal	Atlantic salmon	5	9	4	5	6	7	4	5.7	4.5
Portugal	Brill	5	8	4	8	6	5	4	5.7	5.7
Portugal	Common cuttlefish	5	8	8	8	6	6	4	6.4	6.5
Portugal	Common edible cockle	5	8	4	8	6	6	4	5.9	6.9
Portugal	Common sole	5	9	4	8	6	6	4	6.0	5.8
Portugal	European eel	5	9	4	8	6	6	4	6.0	5.8
Portugal	European flat oyster	5	4	8	8	6	7	4	6.0	6.9
Portugal	European seabass (br)	5	9	4	5	6	5	4	5.4	5.2
Portugal	European seabass	5	9	4	5	6	5	6	5.7	5.4
Portugal	Flat and cupped oysters nei	3	4	8	8	6	7	5	5.9	7.0
Portugal	Freshwater fishes nei	5	8	4	8	6	5	4	5.7	5.4
Portugal	Gilthead seabream (br)	5	9	4	5	6	5	4	5.4	5.1

Table A2 (cont'd).

Country	Common name	Export domestic	Nutrition Protein	Antibiotic Drug use	Mol-Biol GMO	Code-practice CoC	Traceability	Employment	Socio-eco	MSI
Portugal	Gilthead seabream	5	9	4	5	6	5	6	5.7	5.3
Portugal	Grooved carpet shell (br)	4	5	8	8	6	6	4	5.9	7.2
Portugal	Grooved carpet shell	4	5	8	8	6	6	6	6.1	7.3
Portugal	Kuruma prawn	3	9	4	8	6	7	4	5.9	4.6
Portugal	Marine fishes nei	5	8	4	8	6	5	4	5.7	5.4
Portugal	Marine molluscs nei	5	7	4	8	6	5	4	5.6	5.3
Portugal	Mullets nei	5	9	4	8	6	5	4	5.9	5.4
Portugal	Octopuses nei	5	8	4	8	6	5	4	5.7	5.7
Portugal	Pacific cupped oyster	3	4	8	8	6	7	4	5.7	6.3
Portugal	Pullet carpet shell	3	5	8	8	6	5	4	5.6	7.0
Portugal	Razor clams nei	3	4	8	8	6	5	4	5.4	6.5
Portugal	Sargo breams nei	5	9	4	5	6	5	4	5.4	4.8
Portugal	Sea mussels nei	5	5	8	8	6	5	4	5.9	6.5
Portugal	Turbot	5	8	4	5	6	5	5	5.4	5.3
Russian Fed.	Atlantic salmon	5	9	3	5	3	5	4	4.9	4.1
Russian Fed.	Brown seaweeds	3	2	10	8	4	6	5	5.4	7.4
Russian Fed.	Brown seaweeds (Pac)	3	2	10	8	4	6	4	5.3	7.3
Russian Fed.	Flatfishes nei	3	8	4	5	4	5	5	4.9	4.6
Russian Fed.	Marine fishes nei	5	8	4	5	4	5	5	5.1	4.7
Russian Fed.	Mediterranean mussel	5	5	4	8	4	5	4	5.0	6.5
Russian Fed.	Mullets nei	3	9	4	5	4	5	5	5.0	4.9
Russian Fed.	Sea mussels nei	5	5	10	8	4	5	5	6.0	6.5
Russian Fed.	Sea mussels nei (Pac)	5	5	10	8	4	5	4	5.9	6.4
Russian Fed.	Sea trout	5	10	4	5	4	6	4	5.4	5.2
Russian Fed.	Sea trout (med)	5	10	4	5	4	6	5	5.6	5.3
Russian Fed.	Sea urchins nei	3	7	8	8	4	5	5	5.7	5.7
Russian Fed.	Silver carp	5	8	8	5	4	5	4	5.6	5.5
Russian Fed.	Sturgeons nei	3	9	4	6	4	7	4	5.3	5.2
Russian Fed.	Yesso scallop	3	7	8	8	4	5	5	5.7	6.9
Saudi Arabia	Barramundi	1	10	1	5	5	5	5	4.6	3.5
Saudi Arabia	Flathead grey mullet	5	9	4	7	5	5	6	5.9	5.7
Saudi Arabia	Giant tiger prawn	1	10	1	7	3	5	7	4.9	4.2
Saudi Arabia	Groupers nei	5	9	3	7	5	5	5	5.6	5.2
Senegal	Blackchin tilapia	8	8	4	6	4	6	6	6.0	5.9
Senegal	Cupped oysters nei	3	4	8	8	4	6	5	5.4	5.7
Senegal	Gasar cupped oyster	3	4	8	8	4	5	6	5.4	6.5
Senegal	Giant river prawn	3	8	4	5	4	5	5	4.9	4.0
Senegal	Nile tilapia	3	8	4	6	4	5	6	5.1	4.8
Senegal	Pacific cupped oyster	3	4	8	8	4	6	5	5.4	5.8

Table A2 (cont'd).

Country	Common name	Export domestic	Nutrition Protein	Antibiotic Drug use	Mol-Biol GMO	Code-practice CoC	Traceability	Employment	Socio-eco	MSI
South Africa	Aquatic plants nei	5	6	10	9	6	6	5	6.7	6.9
South Africa	Carpet shells nei	3	3	8	8	6	6	5	5.6	6.5
South Africa	European flat oyster	3	4	8	8	6	5	5	5.6	6.1
South Africa	Giant tiger prawn	3	10	3	5	6	6	5	5.4	4.7
South Africa	Gracilaria seaweeds	3	2	10	9	6	7	5	6.0	7.3
South Africa	Indian white prawn	3	9	3	5	6	6	5	5.3	4.6
South Africa	Kuruma prawn	3	9	3	5	6	7	5	5.4	4.7
South Africa	Mediterranean mussel	3	5	8	7	6	5	5	5.6	6.2
South Africa	Mullets nei	5	9	4	6	6	5	5	5.7	5.4
South Africa	Pacific cupped oyster	3	4	8	7	6	5	5	5.4	6.1
South Africa	Perlemoen abalone	3	8	8	7	6	7	5	6.3	6.7
South Africa	Red bait	3	8	4	6	6	5	5	5.3	5.0
South Africa	Sea mussels nei	5	5	8	6	6	5	5	5.7	6.5
South Africa	Smooth mactra	3	5	8	7	6	5	5	5.6	6.7
Spain	Atlantic salmon	1	9	1	5	3	4	3	3.7	3.5
Spain	Blue mussel	7	5	10	10	5	7	6	7.1	8.1
Spain	Cupped oysters nei	5	4	10	3	7	7	7	6.1	7.2
Spain	European eel	7	9	5	7	5	5	7	6.4	5.9
Spain	European flat oyster	5	4	10	7	7	5	7	6.4	7.3
Spain	European seabass	5	9	3	5	5	7	7	5.9	5.7
Spain	Flathead grey mullet	5	9	4	7	5	7	5	6.0	5.8
Spain	Gilthead seabream	3	9	1	5	5	7	7	5.3	4.2
Spain	Kuruma prawn	7	9	1	5	5	7	3	5.3	4.8
Spain	Pacific cupped oyster	3	4	10	7	6	7	6	6.1	6.4
Spain	Tuna-like fishes nei	5	10	5	10	3	1	5	5.6	4.5
Sri Lanka	Giant tiger prawn	1	10	1	7	4	5	7	5.0	3.8
Sweden	Atlantic salmon	7	9	4	5	8	6	5	6.3	6.0
Sweden	Blue mussel	5	5	8	7	8	5	5	6.1	6.7
Sweden	European flat oyster	5	4	8	7	8	5	5	6.0	6.3
Sweden	Rainbow trout	6	10	4	5	8	6	5	6.3	5.2
Taiwan	Abalones nei (br)	5	8	3	3	4	4	5	4.6	3.9
Taiwan	Abalones nei	5	8	3	3	4	4	5	4.6	3.9
Taiwan	Barramundi (br)	1	10	1	5	3	3	5	4.0	3.6
Taiwan	Barramundi	3	10	1	5	3	3	5	4.3	3.9
Taiwan	Blood cockle	5	9	10	10	5	5	5	7.0	7.0
Taiwan	Flathead grey mullet (br)	5	9	4	7	5	5	6	5.9	5.5
Taiwan	Flathead grey mullet	5	9	4	7	5	5	6	5.9	5.5
Taiwan	Giant tiger prawn	1	10	1	7	3	4	6	4.6	3.5
Taiwan	Groupers nei (Pac) (br)	5	9	3	7	5	3	6	5.4	5.0
Taiwan	Groupers nei (br)	5	9	3	7	5	3	6	5.4	5.0
Taiwan	Groupers nei	5	9	3	7	5	3	6	5.4	5.0
Taiwan	Kuruma prawn (br)	5	9	1	5	3	7	7	5.3	4.6
Taiwan	Kuruma prawn	5	9	1	5	3	7	7	5.3	4.6
Taiwan	Laver (Nori)	5	3	10	7	7	8	7	6.7	7.0
Taiwan	Milkfish (br)	5	10	5	8	4	3	7	6.0	5.9
Taiwan	Milkfish	5	10	5	8	4	3	7	6.0	5.9

Table A2 (cont'd).

Country	Common name	Export domestic	Nutrition Protein	Antibiotic Drug use	Mol-Biol GMO	Code-practice CoC	Traceability	Employment	Socio-eco	MSI
Taiwan	Pacific cupped oyster (br)	3	4	10	7	7	5	7	6.1	5.7
Taiwan	Pacific cupped oyster	3	4	10	7	7	5	7	6.1	5.7
Taiwan	Whiteleg shrimp	5	10	1	5	3	3	7	4.9	3.6
Thailand	Banana prawn	5	9	2	5	3	2	5	4.4	4.1
Thailand	Barramundi (Ind)	3	10	1	5	3	3	5	4.3	3.7
Thailand	Barramundi	3	10	1	5	3	3	5	4.3	3.7
Thailand	Blood cockle (Ind)	5	9	10	10	5	5	5	7.0	7.0
Thailand	Blood cockle	5	9	10	10	5	5	5	7.0	7.0
Thailand	Cupped oysters nei (Ind)	5	4	10	3	7	7	7	6.1	6.7
Thailand	Cupped oysters nei	5	4	10	3	7	7	7	6.1	6.7
Thailand	Giant tiger prawn (Ind)	1	10	1	7	3	4	6	4.6	3.5
Thailand	Giant tiger prawn	1	10	1	7	3	4	6	4.6	3.5
Thailand	Groupers nei (Ind)	5	9	3	7	5	3	6	5.4	5.0
Thailand	Groupers nei	5	9	3	7	5	3	6	5.4	5.0
Thailand	Penaeus shrimps nei	5	10	1	5	4	1	5	4.4	3.5
Thailand	Whiteleg shrimp	5	10	1	4	4	1	5	4.3	3.0
Tonga	Milkfish	10	10	5	8	5	3	7	6.9	6.4
Turkey	Atlantic salmon	3	9	3	5	5	6	5	5.1	4.7
Turkey	Com.2-banded seabream	3	9	4	5	4	5	5	5.0	5.3
Turkey	Gilthead seabream	3	9	4	5	5	3	5	4.9	5.1
Turkey	Mediterranean mussel	3	5	8	7	4	5	5	5.3	6.6
Turkey	Natantian decapods nei	3	9	4	5	5	4	5	5.0	5.1
Turkey	Seabasses nei	3	9	4	5	4	5	5	5.0	4.8
Turkey	Trouts nei	3	9	4	5	5	6	5	5.3	4.8
Ukraine	Baltic prawn	3	9	3	5	5	6	5	5.1	5.2
Ukraine	Flatfishes nei	3	8	4	5	5	5	5	5.0	4.4
Ukraine	Gobies nei	3	8	4	5	5	5	5	5.0	4.5
Ukraine	Mediterranean mussel	5	5	8	7	5	5	5	5.7	6.9
Ukraine	Mullets nei (br)	5	9	4	5	5	4	5	5.3	5.6
Ukraine	Mullets nei	5	9	4	5	5	4	5	5.3	5.6
Ukraine	Silversides nei	5	9	4	6	5	7	5	5.9	6.0
Ukraine	So-iuy mullet	5	9	4	6	5	5	5	5.6	5.3
Ukraine	Sturgeons nei	3	9	4	7	5	7	5	5.7	5.6
United Kingdom	Atlantic cod	7	9	1	8	5	7	3	5.7	4.6
United Kingdom	Atlantic salmon	3	9	1	5	6	4	4	4.6	4.3
United Kingdom	Blue mussel	7	5	10	10	5	7	6	7.1	8.2
United Kingdom	Cupped oysters nei	5	4	10	3	7	7	7	6.1	6.9
United Kingdom	European flat oyster	5	4	10	7	7	5	7	6.4	7.3
United Kingdom	European seabass	5	9	5	5	7	7	5	6.1	6.0
United Kingdom	Pacific cupped oyster	5	4	10	7	8	8	5	6.7	6.7

Table A2 (cont'd).

Country	Common name	Export domestic	Nutrition Protein	Antibiotic Drug use	Mol-Biol GMO	Code-practice CoC	Traceability	Employment	Socio-eco	MSI
U.S. of America	Abalones nei	7	8	5	2	7	7	6	6.0	5.6
U.S. of America	Atlantic salmon	7	9	1	5	5	4	3	4.9	4.5
U.S. of America	Blue mussel	7	5	10	10	5	7	5	7.0	7.9
U.S. of America	Coho(=Silver)salmon	7	9	1	3	5	4	3	4.6	4.4
U.S. of America	Cupped oysters nei	5	4	10	3	7	7	7	6.1	7.2
U.S. of America	European flat oyster	5	4	10	7	7	5	7	6.4	6.5
U.S. of America	Flat oysters nei	10	4	10	6	7	8	6	7.3	7.4
U.S. of America	Pacific cupped oyster	7	4	10	7	8	8	5	7.0	7.0
U.S. of America	Whiteleg shrimp	10	10	5	3	7	5	3	6.1	4.7
Venezuela	Whiteleg shrimp	5	10	3	5	7	5	5	5.7	4.7
Viet Nam	Banana prawn	5	9	2	5	3	2	7	4.7	4.5
Viet Nam	Giant tiger prawn	1	10	1	7	3	3	7	4.6	3.5
Viet Nam	Gracilaria seaweeds	3	2	10	10	7	10	8	7.1	7.9
Viet Nam	Whiteleg shrimp	5	10	1	5	3	3	7	4.9	3.8

ADJUSTING FOR CONTEXT IN EVALUATING NATIONAL FISHERIES STATISTICS REPORTING SYSTEMS[1]

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ABSTRACT

Fisheries management requires detailed catch time series. Thus, the effectiveness of countries' reporting system can be, in part, evaluated by the taxonomic resolution of the data they submit to annually to Food and Agriculture of the United Nation (FAO). However, the fish and invertebrate faunas in the Exclusive Economic Zones (EEZs) of these countries differ widely, as do the species that are exploited and considered important enough to be reported in fisheries statistics.

To adjust for the difference, an index of reporting performance was devised which is based, for each country, on the ratio of the reported taxa (numerators) relative to the number of commercial taxa whose distribution overlaps with at least 10% of its EEZ (denominator). Commercial marine taxa of fish or invertebrates are here defined as species, genera, families or higher group reported in the catch of at least one country in the FAO database, for any year from 1950 to the present. The result is a new Context-Adjusted Fisheries Statistics Indicator ($STAT_{rep}$).

Using the $STAT_{rep}$, New Zealand, Portugal and the US are the three countries that are performing best, while the worst performing countries are a group of mainly developing countries much of their catches as 'miscellaneous fishes', e.g., Myanmar. However, the $STAT_{rep}$ appears to overcome the developed *vs.* developing country dichotomy, with e.g., Senegal, in West Africa, ranking 12th of 53.

The $STAT_{rep}$ also appears to be suitable for tracking changes in the effectiveness of national fisheries reporting systems, except perhaps for countries with very small EEZs. This should, however, not affect the 53 countries that are being compared here, and which jointly account for 95 % of the world marine fisheries catch.

INTRODUCTION

In the early 1980s, maritime countries assumed the responsibility of managing their 200-nautical mile Exclusive Economic Zones (EEZ). One of their major tasks is managing the fisheries operating in their EEZs. Such management requires, among other things, that catches (= landings and discards) should be documented at the finest possible taxonomic scale (i.e., at the level of species) and, given the international nature of most fisheries, submitted to the Food and Agriculture Organization of the United Nations (FAO; www.fao.org). The contribution presents an approach to measure and compare the performance of countries, i.e., members of FAO, in accomplishing this.

Directly comparing the number of low-level taxa (e.g., species or genera) that countries report, while instructive[2], would not be a fair measure of their efforts to monitor and report on fisheries catches, as the number of species that can potentially be caught varies enormously between latitudes and ocean basins (Cheung *et al*., 2005; Mora *et al*., 2007).

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[1] Cite as: Pauly, D. and Watson, R. (2008) Adjusting for context in evaluating national fisheries statistics reporting systems. p. 57-61. *In*: Alder, J. and Pauly, D. (eds.) A comparative assessment of biodiversity, fisheries and aquaculture in 53 countries' Exclusive Economic Zones. Fisheries Centre Research Reports 16(7). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

[2] As shown by the 'Spread-in-Catch Index' (SiC) of D. Pauly and D. Zeller (unpublished data; presented at the 5th ICEF: Environmental Future of Aquatic Ecosystems, Zürich, 23-29 March 2003).

A solution to the problem caused by variations of the underlying taxonomic diversity is to divide, for any given year, the number of taxa reported by a given country by the number of 'commercial taxa' available in that country's EEZ, the problem then being one of defining what 'commercial taxa' are in an operational sense.

One definition used earlier by Palomares and Pauly (unpublished data[3]) was to use the fish identified as 'highly commercial', 'commercial', 'minor commercial', etc. in FishBase (Froese and Pauly, 2000, p. 81). This did lead to a usable index. Ultimately, this approach was not followed up, because the definitions in FishBase lacked rigor, and were replaced by an assignment of market value, based on Sumaila *et al.* (2006; see www.fishbase.org). Also, using FishBase to define commercial taxa left invertebrate taxa undefined.

However, the FAO landings database itself can be used to obtain an operational definition: we can define 'commercial' taxa as any species, genus, family or higher category that is officially reported as part of fisheries catch to FAO by at least one of its member countries. The *Sea Around Us* Project maps reported catches as reported to FAO (Watson *et al.,* 2004), and thus it has drawn distribution range maps for all commercial fish and invertebrate taxa (see Close *et al.,* 2006). Each of these distribution range maps, corresponding to a specific taxon, overlaps with the fisheries of at least one country, which then reports it to FAO (because otherwise, it would not be counted among the commercial taxa, see definition above).

METHODOLOGY

In addition to overlapping with the EEZ of at least one country that reports on it, the distribution range of mapped taxa will generally overlap with the EEZs of other countries. (We used an overlap of at least 10 % of the EEZ area of a given country for a taxon to be considered to occur 'in' that country). We assume here that these other countries catch that these taxa as well, but do not report them (e.g., because they are not targeted, and they appear only in the by-catch, and/or because these countries do no monitor their fisheries adequately).

This led to our new Context-Adjusted Fisheries Statistics Indicator ($STAT_{rep}$), which assesses the quality of each country's reporting system in a regional context (defined by shared taxa) through the ratio (expressed as percentage) of reported commercial taxa to commercial, but unreported taxa occurring in a country EEZ.

Table 1. Illustrating how the same 3 species (belonging to the same genus, and hence family, order, etc) would score on the $STAT_{rep}$ of various countries (A-F), depending on the taxonomic level they are reported in. A country's overall $STAT_{rep}$ score will depend on how it reports all components of it catch.

Reporting level	A	B	C	D	E	F
Species	3	-	-	-	-	-
Genus	1	1	-	-	-	-
Family	1	1	1	-	-	-
Order	1	1	1	1	-	-
Class	1	1	1	1	1	-
ISSCAP*	1	1	1	1	1	1
Component of $STAT_{rep}$ score (numerator)	8+	5+	4+	3+	2+	1

*International Standard Classification of Aquatic Animals and Plants

We built into the design of the $STAT_{rep}$ the fact different countries may report the same target for fish or invertebrate at different taxonomic levels. Thus, for example, a country may report catch of groupers by their species name, (say *Epinephelus* species a, b, and c), another country by their generic name, "*Epinephelus* spp" and yet another by their family names ("Serranidae"), or even as "Perch-like fish" (Percoidae). Since it is better to report catches at the lowest possible level, a country reporting such catch is given not only a score for a species, but also for the genus to which it belong (so far it is also a commercial taxon), and correspondingly for families and higher taxa (Table 1). The example illustrates how six countries (A-F) reporting the same 3 species at various levels (from species to ISSCAP) would score on the $STAT_{rep}$.

[3] Palomares, M.L.D. and Pauly, D. (2004) A biodiversity-based data quality indicator for fisheries catch statistics. Presentation at the International Symposium on Quantitative Ecosystem Indicators for Fisheries Management, 30 March to 4 April 2004, Paris, France.

Data Sources

Data were derived from the *Sea Around Us* Project's landings and species distribution databases (www.seaaroundus.org), and FishBase (www.fishbase.org).

Results and Discussion

We report $STAT_{rep}$ scores for a list of 53 countries contributing over 95 % of the world catch (Alder and Pauly, this vol.), although all countries reporting to FAO were used to compute these scores.

Table 2. The 10 countries with the highest $STAT_{rep}$ (for 2000-2004 inclusive), based on the number of taxa reported versus those that occur in their EEZs.

Country	Numerator	Denominator	$STAT_{rep}$
New Zealand	149.2	204.0	73.1
Portugal	110.0	157.2	70.0
USA	72.4	104.4	69.3
Spain	268.0	396.8	67.5
France	446.4	702.4	63.6
Chile	62.0	99.6	62.2
UK	288.0	474.0	60.8
Russian Fed	118.4	210.0	56.4
Norway	131.2	245.6	53.4
South Africa	75.2	141.6	53.1

Of these 53 countries, the top 10, i.e., those with the highest mean level of $STAT_{rep}$ in the last 5 years (Table 2) generally report between 53 and 73 % of the commercial taxa occurring in their waters. These countries together report about 23% of the total global reported catch. This relatively low figure is still an overestimation of their performance, as hundreds of species may be caught regularly, by the trawlers and other fishing vessel of such countries which, however, fail to be reported by any country, and thus not defined as commercial taxa (i.e., not including in the denominator).

Table 3 gives the 10 countries that have the lowest $STAT_{rep}$. As might be seen, in spite of the $STAT_{rep}$ adjusting for the high taxonomic diversity in low latitudes (by comparing countries with shared, and hence similar faunas), the list contains mainly low latitude developing countries. The only exceptions are North Korea and Poland, which occurs at middle latitudes. While the position of North Korea is not surprising, that of Poland is. Perhaps it is due to its small EEZ, i.e., to the fact that the distribution range map of many commercial species overlap with the Polish EEZ, although the taxa they represent being, in the central Baltic, at the edge of their distribution, do not support fisheries, and thus are not there to be recorded. We will investigate this possibility in a future contribution, in conjunction with a number of countries with even smaller EEZs (Iraq, Slovenia, etc).

Table 3. The 10 countries with the lowest $STAT_{rep}$ (for 2000-2004 inclusive), based on number of taxa reported versus those that occur in their EEZs.

Country	Numerator	Denominator	$STAT_{rep}$
Poland	65.2	403.6	16.2
India	112.8	716.4	15.7
Egypt	103.2	662.4	15.6
China	114.0	755.2	15.1
Yemen	94.0	808.4	11.6
Sri Lanka	58.0	761.2	7.6
Korea (North)	24.0	582.4	4.1
Bangladesh	18.0	818.4	2.2
Viet Nam	12.0	810.8	1.5
Myanmar	2.0	140.0	1.4

The 53 countries that are considered in other contributions in this volume are ranked in Table 4 in terms of their mean $STAT_{rep}$ score for the years 2000 to 2004. The list shows that the $STAT_{rep}$, at least in part, overcomes the developed *vs.* developing country dichotomy that hobbles many other indicators. Rather, the $STAT_{rep}$ succeeds at detecting countries, including developing ones, that give attention to their fisheries data. Thus, Senegal, a developing country, ranked 12th (of 53), confirming what was previously known of the detailed nature of fisheries statistics maintained by that country (Gulland and Garcia, 1984; Ferraris *et al.,* 1994).

Finally, we want to highlight the potential of the $STAT_{rep}$ to identify changes in the quality of the reporting system of a given country, relative to the other countries' systems. Figure 1 illustrates this for a selection of 5 countries with low and 5 countries with high values of the $STAT_{rep}$.

Table 4. Mean $STAT_{rep}$ score for 2000-2004 for 53 countries jointly contributing about 95% of the world catch.

Rank	Country	% reported	Rank	Country	% reported
1	New Zealand	73.1	28	Taiwan	27.5
2	Portugal	70.0	29	Sweden	27.5
3	USA	69.4	30	Angola	27.4
4	Spain	67.5	31	Indonesia	27.0
5	France	63.6	32	Germany	26.9
6	Chile	62.2	33	Ukraine	26.4
7	UK	60.8	34	Philippines	26.0
8	Russian Fed.	56.4	35	Australia	26.0
9	Norway	53.4	36	Italy	23.1
10	South Africa	53.1	37	Iran	22.6
11	Ireland	51.1	38	Thailand	22.1
12	Senegal	46.8	39	Malaysia	20.6
13	Brazil	45.8	40	Latvia	20.2
14	Mexico	44.1	41	Ghana	20.1
15	Denmark	41.6	42	Pakistan	17.7
16	Faeroe Isl.	40.7	43	Nigeria	17.4
17	Korea (South)	39.8	44	Poland	16.2
18	Namibia	38.0	45	India	15.8
19	Canada	37.4	46	Egypt	15.6
20	Japan	36.8	47	China Main	15.1
21	Argentina	36.7	48	Yemen	11.6
22	Peru	36.0	49	Sri Lanka	7.6
23	Iceland	35.7	50	Korea (North)	4.1
23	Ecuador	34.6	51	Bangladesh	2.2
25	Netherlands	31.8	52	Viet Nam	1.5
26	Morocco	29.3	53	Myanmar	1.4
27	Turkey	28.0	--	--	--

As might be seem, the performance of the high- $STAT_{rep}$ countries, particularly France, increased in recent decade, despite the overall 'standard' (number of commercial species reported in denominator) doubling from an average of 35 in 1950 to 73 in 2004. Contrariwise, the low- $STAT_{rep}$ countries failed to improve their lot during the entire period considered here.

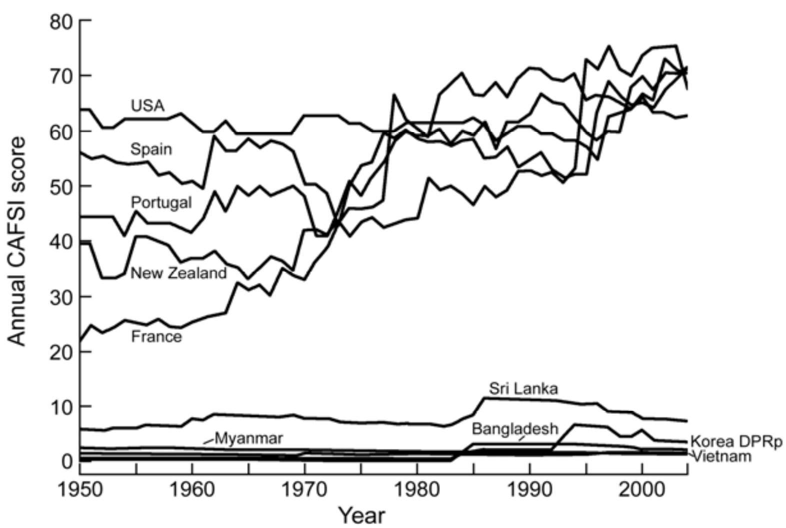

Figure 1. Time series of the STATrep for 10 selected countries (5 with high, 5 with low scores), showing changes in the performance of their fisheries statistical reporting systems.

Overall, the $STAT_{rep}$ thus appears useful for tracking the relative performance of countries in time, and for performing comparisons between countries. However, the validity of the $STAT_{rep}$ rests entirely on the assumption that a commercial fish or invertebrate taxon (i.e., a taxon reported caught to FAO by at least on country) will also be caught in all the other country in which it also occur, whether these countries target it or not. This implies that the $STAT_{rep}$, at least in part, measures countries' reporting of landed by-catch.

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A FRAMEWORK FOR EVALUATING NATIONAL SEABIRD CONSERVATION EFFORTS[1]

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ABSTRACT

Marine biodiversity is increasingly under threat particularly through fisheries. The conservation of marine biodiversity requires the development of methods for monitoring and assessing marine ecosystem structure and ecological processes. In this paper we attempted to evaluate the performance of 55 countries, jointly accounting for over 95 % of the world's fisheries catches, on conservation and management efforts of seabird populations that breed within their Exclusive Economic Zone. We considered: (a) conventions and agreements relevant to each country, as an indicator of the country's intention to engage in conservation actions; and (b) trends of breeding seabird populations for each country. We calculated a mean index of performance for each country, also taking into account the quality of the seabird population data that influence trends through time. Scores, which potentially ranged from 0 (no protection for seabirds) to 10 (effective protection), ranged from 1.59 for Taiwan, to 5.94 for France. More than 72 % of the countries evaluated scored from 1 to 4.

INTRODUCTION

Fisheries have dramatically expanded in the last few decades (Myers and Worm, 2003; Pauly *et al.*, 2002) and now extract from the world's oceans well over 120 million tonnes of resources annually (Pauly *et al.*, 2002). Global fishing operations reduce populations of target and non-target species and compromise ecosystem integrity (Pauly *et al.*, 1998; Jennings *et al.*, 2001), and threaten marine biodiversity. Thus, it has become imperative that scientists, stakeholders, as well as public policy makers commit to conservation of natural resources and to understanding the implications of resource management.

This, however, implies the development of methods for monitoring and assessing ecosystem structure and ecological processes, i.e., indicators of ecological change (Dale and Beyeler, 2001). Indicators are valued for their ability to integrate large amounts of information into easily understood formats for a general audience; they may also be used as starting points for further analysis. Ecological indicators, in particular, may be used to: (a) assess the condition of the environment; (b) monitor trends in condition over time; (c) provide warning signals of environmental change; and (d) evaluate and rank performance of a country's efforts to avert environmental change (Cairns *et al.*, 1993; Dale and Beyeler, 2001).

In this paper, we attempt to evaluate the performance of maritime countries on conservation and management efforts of seabird populations breeding within their Exclusive Economic Zone (EEZ). Seabirds have been proposed as useful indicators of change in marine ecosystems; particularly, seabird population trends and aspects of seabird ecology have been used as indicators of: (a) change in marine community structure and composition (e.g., Cairns, 1992; Litzow *et al.*, 2002; Le Corre and Jaquemet, 2005); (b) habitat quality and variability (e.g., Springer *et al.*, 1996; Golet *et al.*, 2002); and (c) climate change (e.g., Bunce *et al.*, 2002; Weimerskirch *et al.*, 2003; Gaston *et al.*, 2005).

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Protection of seabirds has long been an important issue in the development of conservation policies. The world's first legislation to protect wild populations was the Seabirds Preservation Act of 1869, which called against over-exploitation of seabird colonies in Britain (Doughty, 1975; Monaghan, 1996). More recently, in the 1992 Convention for the Protection of the Marine Environment of the Northeast Atlantic (OSPAR Convention), Ecological Quality Objectives (EcoQOs) were proposed as an important tool for identifying ecosystem change and implementing management goals, with seabirds as one of the elements of ecological quality. Also, seabird population trends were proposed as an index of seabird community health.

This paper is an attempt to evaluate countries' performance on conservation efforts for seabird populations. First, we considered conventions and agreements relevant to each country, in order to assess the country's intention to engage in conservation actions for the protection of biodiversity. Next, we estimated trends of breeding seabird populations for each country. Last, we calculated a mean index of performance for each country, also taking into account the quality of the seabird population data that influence trends through time.

MATERIALS AND METHODS

Scoring methods

In order to evaluate a countries' performance on conservation efforts for seabird populations, we considered the following three attributes (Table 1): (a) conventions and agreements for the protection of seabird populations relevant to each country; (b) estimated trends of breeding seabird populations for each country; and (c) quality of seabird population data. Overall, we evaluated 55 countries (Table 2), with two countries (Mozambique and Tanzania) added to the 53 evaluated by Alder and Pauly (this volume), in terms of their compliance to the United Nations Food and Agriculture Organization (FAO) Code of Conduct for Responsible Fisheries, and which jointly contribute to over 95 % of the world's fisheries catches. For the purpose of this study, performance of countries was evaluated for a 25-year period (from 1976 to 2000).

Table 1. The three attributes used to evaluate the performance of conservation efforts for seabird populations of 55 maritime countries.

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

In order to assess a country's intention to engage in conservation actions for the protection of its seabirds, we considered five conventions and agreements. Conservation actions entail species and habitat protection, management of human activities, research and monitoring, capacity building and environmental education. The following conventions and agreements that implicitly or explicitly pertain to seabirds were considered here: (a) Convention on Biological Diversity (CBD, 2007); (b) Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR, 2007); (c) Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention, 2007); (d) Agreement on the Conservation of Albatrosses and Petrels (ACAP, 2007); (e) Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA, 2007); (f) the RAMSAR Convention on Wetlands (RAMSAR, 2007); and (g) the Convention on Migratory Species (CMS, 2007).

We assigned to each country a number of conventions and agreements for the protection of seabirds relevant to them (Table 2). Relevance of a convention and agreement depends, among others, on whether the geographic area it encompasses includes the seabird species that breed within a country's EEZ (Table 2). Each country was given a score according to the number of conventions and agreements signed and ratified in relation to the overall number of relevant agreements. A zero score was given to countries that were signatories to no conventions and agreements (Tables 1 and 2). In contrast, countries that signed and ratified all relevant conventions and agreements were given a score of 10 (Tables 1 and 2). Moreover, the score given to each country was multiplied with a weighting factor (ranging from 0 to 1, with 1 applying to countries that have participated as signatories to all conventions and agreements considered in this study), which essentially draws attention to all countries that have fully committed to seabird conservation. EXAMPLE: If a country was assigned only one relevant agreement that was signed and ratified, original score was 10. Equally, if a country was a signatory of all seven agreements considered in this study, the score was also 10. However, the score of the first country was multiplied with a weighing factor of 1/7=0.143 (1 relevant agreement over 7 overall agreements considered here). Similarly, the weighing factor for the second country was 7/7=1. Thus, final scores were modified to 1.43 and 10 respectively. This implies a higher commitment to conservation for those countries that have engaged in many agreements.

For each country, we estimated the % annual change in the population size of all breeding seabirds combined. Countries where seabird populations exhibited no change in time were given a score of 5 (Table 2). Countries with declining seabird population sizes were given scores between 0 and 5 (Table 2), depending on the strength of the decline. Conversely, countries with increasing seabird population sizes were given scores greater than 5 and up to 10 (Table 2). In the absence of data, we assumed that no change has occurred in seabird population size over time. Thus, each of the above-mentioned countries was given an optimistic score of 5 (moderate field performance).

Lastly, each country was given a score based on the availability and quality of the information on population sizes of seabirds breeding within a country's EEZ. For each country, data quality was assessed for all seabird species combined. It was expressed as the ratio of the number of years for which seabird population size data were available over the 25 years considered (Table 2). Quality scores were normalized and ranged from 0 (no data available) to 10 (best literature coverage throughout the 25-year period). Zero score was given to five countries for which no seabird population information was available, as well as to those countries with information extra- or interpolated throughout the 25-year period. All other countries were given scores based on the quality ratio estimated (Table 2). Each sub-score (i.e., agreement, trend, and quality scores) was weighted equally, which implies that each component considered was believed to have the same impact on the performance being measured. The final score was calculated as the mean of the three sub-scores. It ranged from 0 (worst performance) to 10 (best performance) (Table 2). Finally, each country was ranked based on their final score (a ranking of 1 indicates the highest level of commitment to conservation of seabirds) (Table 2).

Data sources

To assess national trends in seabird populations by countries, the data compiled by Karpouzi *et al.* (2007) were used. Karpouzi *et al.* (2007) compiled information for 351 marine bird species (belonging to four orders and 14 families) in a Microsoft Access database. The database contains information on seabirds' taxonomy, population dynamics, diet composition, and foraging ecology of seabirds. In particular, the population size table in the database covers the years from 1950 to 2003. It contains population sizes expressed as breeding pairs (bp) in the original studies. They are also re-expressed as numbers of individuals, using the following equations to account for non- and pre-breeders present in colonies: (a) for single-egg laying species (bp×0.6)+(bp×0.7); and (b) for multi-egg laying species (bp×0.6)+(bp×1.0) (Karpouzi *et al.*, 2007). For years when population sizes were not available, data were interpolated, assuming a linear relationship between the available counts. Data were also extrapolated from the first available count back to 1950, as well as from the last available count to 2003, assuming no change in the population size (Karpouzi *et al.*, 2007). For the purpose of this study, national trends in seabird populations by countries were assessed for a 25-year period (from 1976 to 2000). For five out of 55 countries (Bangladesh, Iran, North Korea, Malaysia, and Myanmar; Table 2), no seabird population information was available.

Table 2. Ranking of 55 countries by evaluating their performance on seabird conservation efforts.

Country	Relevant conventions and agreements[1]	Score	% Trend[2]	Score	Data quality[3]	Score	Final score	Rank
Angola	ACAP, CBD, AEWA, RAMSAR, CMS	2.86	0.00	5.00	0.00	0.00	2.62	50
Argentina	ACAP, CBD, CCAMLR, RAMSAR, CMS	6.43	– 0.21	4.88	0.06	0.60	3.97	21
Australia	ACAP, CBD, CCAMLR, RAMSAR, CMS	7.14	+ 1.41	6.76	0.08	0.80	4.90	6
Bangladesh	CBD, RAMSAR, CMS	4.29	0.00	5.00	0.00	0.00	3.10	41
Brazil	ACAP, CBD, CCAMLR, RAMSAR, CMS	4.43	– 8.50	0.00	0.06	0.64	1.69	54
Canada	CBD, AEWA, RAMSAR, CMS	2.86	+1.76	7.20	0.23	2.30	4.12	17
Chile	ACAP, CBD, CCAMLR, RAMSAR, CMS	7.14	+ 0.35	5.44	0.06	0.56	4.38	9
China	CBD, RAMSAR, CMS	3.29	+ 1.43	6.79	0.09	0.92	3.67	31
Denmark	Bern, CBD, AEWA, RAMSAR, CMS	7.14	– 0.75	4.56	0.11	1.12	4.27	11
Ecuador	ACAP, CBD, RAMSAR, CMS	5.71	+ 0.24	5.30	0.09	0.85	3.95	22
Egypt	CBD, AEWA, RAMSAR, CMS	5.71	+ 4.03	10.00	0.08	0.76	5.49	2
Faeroe Islands[4]	Bern, CBD, AEWA, RAMSAR, CMS	2.86	+ 0.80	6.00	0.14	1.37	3.41	37
France	ACAP, Bern, CBD, CCAMLR, AEWA, RAMSAR, CMS	10.00	+ 1.20	6.50	0.13	1.32	5.94	1
Germany	Bern, CBD, AEWA, RAMSAR, CMS	7.14	+ 0.65	5.81	0.28	2.80	5.25	4
Ghana	CBD, AEWA, RAMSAR, CMS	5.71	+ 0.99	6.24	0.06	0.60	4.18	14
Iceland	Bern, CBD, AEWA, RAMSAR, CMS	4.29	– 5.27	1.90	0.13	1.30	2.50	52
India	CBD, RAMSAR, CMS	4.29	+ 0.87	6.09	0.11	1.09	3.82	25
Indonesia	CBD, RAMSAR, CMS	3.29	0.00	5.00	0.00	0.00	2.76	44
Iran	CBD, AEWA, RAMSAR, CMS	3.29	0.00	5.00	0.00	0.00	2.76	45
Ireland	Bern, CBD, AEWA, RAMSAR, CMS	7.14	– 1.46	4.14	0.12	1.15	4.14	16
Italy	Bern, CBD, AEWA, RAMSAR, CMS	7.14	+ 0.31	5.39	0.18	1.80	4.78	8
Japan	CBD, CCAMLR, RAMSAR, CMS	3.71	+ 0.79	5.99	0.08	0.81	3.50	34
Korea, N.	CBD, RAMSAR, CMS	1.14	0.00	5.00	0.00	0.00	2.05	53
Korea, S.	CBD, RAMSAR, CMS	2.86	0.00	5.00	0.04	0.40	2.75	48
Latvia	Bern, CBD, AEWA, RAMSAR, CMS	5.71	– 2.31	3.64	0.14	1.40	3.58	32
Malaysia	CBD, RAMSAR, CMS	2.86	0.00	5.00	0.00	0.00	2.62	51
Mexico	CBD, RAMSAR, CMS	2.86	+ 3.18	8.98	0.08	0.77	4.20	13
Morocco	CBD, AEWA, RAMSAR, CMS	5.00	– 0.18	4.89	0.04	0.40	3.43	35
Mozambique	ACAP, CBD, AEWA, RAMSAR, CMS	2.86	0.00	5.00	0.04	0.40	2.75	49
Myanmar	CBD, RAMSAR, CMS	3.29	0.00	5.00	0.00	0.00	2.76	46
Namibia	ACAP, CBD, CCAMLR, AEWA, RAMSAR, CMS	3.71	– 2.79	3.36	0.16	1.64	2.90	43
Netherlands	Bern, CBD, AEWA, RAMSAR, CMS	7.14	– 1.09	4.36	0.15	1.45	4.32	10
New Zealand	ACAP, CBD, CCAMLR, RAMSAR, CMS	7.14	– 0.77	4.55	0.08	0.76	4.15	15
Nigeria	CBD, AEWA, RAMSAR, CMS	5.71	0.00	5.00	0.04	0.40	3.70	28
Norway	Bern, CBD, CCAMLR, AEWA, RAMSAR, CMS	7.14	– 2.51	3.52	0.13	1.28	3.98	20
Pakistan	CBD, RAMSAR, CMS	4.29	+ 0.72	5.90	0.14	1.37	3.85	24
Peru	ACAP, CBD, RAMSAR, CMS	5.71	– 2.62	3.46	0.30	3.03	4.07	19
Philippines	CBD, RAMSAR, CMS	4.29	+ 1.22	6.53	0.14	1.42	4.08	18
Poland	Bern, CBD, AEWA, RAMSAR, CMS	5.71	+ 0.02	5.03	0.05	0.47	3.74	27
Portugal	Bern, CBD, AEWA, RAMSAR, CMS	7.14	– 5.60	1.71	0.12	1.17	3.34	39
Russian Federation	Bern, CBD, CCAMLR, AEWA, RAMSAR, CMS	3.71	+ 0.59	5.74	0.07	0.70	3.38	38
Senegal	CBD, AEWA, RAMSAR, CMS	5.71	– 0.14	4.92	0.05	0.48	3.70	29

Table 2 (cont'd).

Country	Relevant conventions and agreements[1]	Score	% Trend[2]	Score	Data quality[3]	Score	Final score	Rank
South Africa	ACAP, CBD, CCAMLR, AEWA, RAMSAR, CMS	8.57	– 0.25	4.85	0.14	1.44	4.95	5
Spain	Bern, CBD, AEWA, RAMSAR, CMS	7.14	+ 1.04	6.30	0.11	1.09	4.84	7
Sri Lanka	CBD, RAMSAR, CMS	4.29	+ 0.15	5.19	0.18	1.75	3.74	26
Sweden	Bern, CBD, AEWA, RAMSAR, CMS	7.14	– 1.59	4.06	0.14	1.41	4.20	12
Taiwan	CBD, RAMSAR, CMS	0.00	– 2.43	3.57	0.12	1.20	1.59	55
Tanzania	ACAP, CBD, AEWA, RAMSAR, CMS	4.29	– 1.50	4.12	0.04	0.36	2.92	42
Thailand	CBD, RAMSAR, CMS	3.29	+ 0.70	5.88	0.06	0.63	3.27	40
Turkey	Bern, CBD, AEWA, RAMSAR, CMS	4.29	+ 0.43	5.54	0.04	0.42	3.42	36
Ukraine	Bern, CBD, AEWA, RAMSAR, CMS	7.14	– 4.02	2.64	0.13	1.31	3.70	30
UK	ACAP, Bern, CBD, CCAMLR, AEWA, RAMSAR, CMS	10.00	– 0.58	4.66	0.12	1.24	5.30	3
USA	ACAP, CBD, CCAMLR, RAMSAR, CMS	4.00	+ 0.03	5.04	0.26	2.62	3.89	23
Viet Nam	CBD, RAMSAR, CMS	3.29	+ 0.98	6.23	0.12	1.20	3.57	33
Yemen	CBD, RAMSAR, CMS	2.86	+ 0.02	5.03	0.04	0.38	2.76	47

[1] Conventions and agreements for the protection of seabird species relevant to each country:
ACAP: Agreement on the Conservation of Albatrosses and Petrels;
CBD: Convention on Biological Diversity;
CCAMLR: Convention on the Conservation of Antarctic Marine Living Resources;
Bern: Bern Convention, Convention on the Conservation of European Wildlife and Natural Habitats;
AEWA: Agreement on the Conservation of African-Eurasian Migratory Waterbirds;
RAMSAR: The RAMSAR Convention on Wetlands.

The agreements that a country signed are in bold characters. The agreements also ratified are in bold italics. The agreements in which countries simply participate with Memoranda of Understanding are underlined.

[2] % Trend: annual % change [i.e., (+) increase, (–) decrease] of seabird populations breeding within a country's Exclusive Economic Zone.

[3] Data quality: ratio of number of years for which population sizes were available over the overall number of years considered.

[4] Faeroe Islands: Not covered by the Bern Convention (IUCN, 1992), but responsible of implementing CBD and AEWA as a self-governing overseas administrative division of Denmark.

RESULTS AND DISCUSSION

Overall, we considered 55 countries (Table 2). More than 65 % of the countries evaluated (36 out of 55 countries; 65.5 %) scored between 1 and 4 (Table 2). Final scores ranged from 1.59 for Taiwan, to 5.94 for France (Table 2). Taiwan's lowest ranking in the performance evaluation may be attributed predominantly to the fact that Taiwan is not a signatory to any major international conventions and agreements (Table 2), even if participation in international nature conservation activities is one of the objectives of the Taiwan Nature Conservation Strategy (CPA, 1985). Also, seabird populations have been declining at an annual rate of 4.25 % since the mid-1980s (Table 2). Taiwan is home to a number of vulnerable to critically endangered seabird species, which are most likely affected by the loss of coastal wetlands (e.g., reclamation of tidal flats and salt marshes), and egg-collection for food mainly by Taiwanese fishermen (BirdLife International, 2007a, b).

Other countries that ranked low in the evaluation performance are Brazil and North Korea. Brazil's seabird populations exhibited the greatest declining annual rate of 8.5% decline (Table 2). Moreover, Brazil has displayed low to moderate intention in protecting seabird diversity. Brazil has signed and ratified only the CBD and RAMSAR, and thus committed to actions that promote the conservation, sustainable use and equitable sharing of benefits of the country's wetlands and biological diversity. Also, in the late 1990s, Brazil completed a National Biodiversity Strategy Action Plan to meet the CBD objectives. In addition, a National Plan of Action was also completed in 2004, in order to implement the recommendations of FAO's International Plan of Action for reducing incidental catch of seabirds in longline fisheries (FAO IPOA-Seabirds).

In the case of North Korea, information on seabird populations was not available; thus, the country scored zero in the data quality (Table 2). In addition, North Korea is not a signatory to any of the conventions and agreement considered in this paper (Table 2). Nevertheless, the government of North Korea has passed a number of legislations to establish protected areas. These include: nature protection areas, animal protection areas, breeding seabird protection areas, aquatic resources protection areas, strict nature reserves, forest reserves, experimental and scientific reserves, and protected landscapes (Scott, 1989). In the late 1980s, there were six breeding seabird protection areas and four aquatic resources protection areas, established to protect populations of marine invertebrates and fish (IUCN, 1992). However, the need for agricultural land, has led to reclamation of large areas. In addition to the damage this may be causing to coastal wetlands, it has been reported that the rocks being used for the reclamation are obtained by blasting offshore rocky islets of great conservation value (Poole, 1991).

The countries that ranked highest in the performance evaluation were France, Egypt, and the UK (Table 2). For France and the UK, these results were highly influenced mainly by the countries' participation in all seven relevant conventions and agreements (Table 2). Indeed, both countries have shown strong commitment towards the protection of seabirds and their habitat, by: (a) preparing and implementing management plans for habitat protection and restoration, (b) creating and updating inventories of Important Bird Areas, (c) evaluating trends of wintering and breeding birds, and (d) raising awareness, at the European Union and national levels, by networking and exchanging of expertise. However, the above-mentioned actions have not been fully reflected in the seabird population trend analysis undertaken in this study. Although breeding seabirds in France have exhibited an increasing trend, conversely in the UK, seabirds are declining with an annual rate of 0.58 % (Table 2). As a result, both countries achieved a moderate score not higher than 6 (Table 2).

In the case of Egypt, the score was highly driven by the country's participation in four out of seven agreements, and also by the high annual increasing rate of 4.03 % for the country's seabird populations (Table 2). Egypt has a long coastline, which extends along two seas (the Mediterranean and the Red Seas). In the Mediterranean Egypt, five major important seabird sites are found, four of which belong to the complex of the Nile Delta lakes (Sultana, 1993). These wetlands are partly protected areas and RAMSAR sites, however they are largely unprotected from fishing, pollution, land reclamation, and disturbance (Sultana, 1993). These wetlands are important sites mostly for migratory tern and gull species that winter in the area (Sultana, 1993). On the other hand, along the Red Sea coast of Egypt, a large network of marine protected areas exists, which protects important breeding, roosting, and feeding seabird habitat (i.e., mangroves, tidal flats, coral reefs) (PERSGA/GEF, 2003). Although little is known about the population status of seabirds breeding in Egypt before 1970s (Cooper *et al*., 1984), recent studies show an increasing trend in seabird populations in the area (PERSGA/GEF, 2003). Seabird population trends are mainly driven by those of four tern and gull populations (i.e., the White-cheeked, *Sterna repressa*, Lesser crested, *S. bengalensis*, and Bridled terns, *S. anaethetus*, and the White-eyed gull, *Larus leucophthalmus*) that breed in the Red Sea. Among these species, the White-eyed gull is endemic in the area and the Egyptian Red Sea islands hold the largest known breeding population in the world (Cooper *et al*., 1984; PERSGA/GEF, 2003).

With regards to national seabird population trends, for five out of 55 countries, analysis of trends showed no change in the seabird population sizes (Table 2). For 25 out of 55 countries, population sizes have increased since 1975 (Table 2). On the other hand, for 16 out of 55 countries seabird populations have been declining since 1975, with an annual rate higher than 0.5 % (Table 2). This is worth mentioning, because when reference levels were set for EcoQOs to be met, 0.5 % annual decline in seabird populations was decided as the limit reference point (i.e., LPR: a value of a property of a resource that, if violated, is taken as evidence of conservation concern). Any other value below the LPR should raise conversation concerns for the health of seabird communities breeding within a country's EEZ. Thus, such decline in the size of seabird populations should trigger further research to investigate the causes of change, as well as management by drafting and implementing species action plans.

When assessing national population trends, a few issues were identified. Firstly, the % annual change in the population size for each country was estimated after combining all breeding seabirds combined. This would satisfy a number of criteria for a biodiversity indicator (summarized in Table 2 in Gregory *et al*., 2003, 2005). However, by taking this inclusive approach, there is the potential for the declines among threatened species to be counterbalanced by population increases among more common, opportunistic, 'less desirable' species (Gregory *et al*., 2003, 2005). Nevertheless, it is a simple approach that does not require deciding on species-specific conservation status, population targets or reference periods. Indeed, selecting priority areas for protection of just threatened species may be a first step towards an effective conservation plan. However, it does not guarantee conservation of the overall species diversity (Bonn *et al*., 2002), which is an explicit goal in the CBD.

Secondly, in some cases, information for a country's breeding seabirds may have been dependent on a single source. In the case of India, for instance, annual waterbird censuses for the region initiated in the late 1990s and were documented by Wetlands International (e.g., Li and Mundkur, 2007). In particular, Li and Mundkur (2007) suggest a dramatic increase in three major seabird populations breeding in India (i.e., the Whiskered tern, *Chlidonias hybridus*, the Little tern, *Sterna albifrons*, and the Indian cormorant, *Phalacrocorax fuscicollis*) at an annual rate of about 50 % since 1997. This has influenced our estimate of the overall trend (Table 2). A similar situation also became obvious for other countries, such as China and Pakistan. Zuo Wei and Mundkur (2004) suggest a major increase in a few gull and cormorant populations breeding in both Pakistan and China at an annual rate of about 20 % since 1997. This information also influenced our estimates of the overall trends (Table 2). Indeed, recent dramatic changes in the population size of species with opportunistic feeding behaviour and multiple clutch size may have masked historical changes and consequently distorted our results.

When assessing the quality of the seabird population data, it became apparent that for all countries considered here the percentage of data extrapolated was greater than 69 %. This indicated that time series and historical data on seabird population sizes were not accessible to us due to the language barrier or did not exist. Given the nature of the indicators' computation, continuing problems of missing data may result in distorted findings on country performance. In order to be able to set conservation targets of population levels, it is essential to continue building a picture of what the seabird populations were like before the beginning of commercial fishing and humans impacting on marine ecosystems and how they have changed over time. The establishment of contact with regional authorities and the local scientific communities should be encouraged in an attempt to share seabird information that is not published in English. However, in the absence of local information, the use of other available methods may help assess trends in seabird populations. For instance, a method has been proposed that quantifies qualitative information on abundance of marine organisms from narratives of early expeditions, and finally uses it to map trends of observed abundances in a specific locality over time (Palomares *et al*., 2006).

This effort is work in progress to depict a more accurate picture of the status of seabird populations and how countries respond and act towards conservation of marine biodiversity. The same is also underway for other taxa (e.g., marine mammals, sea turtles), biomes, and other aspects of marine biodiversity, and will also cover other countries of the world. Composite population trend indicators, as we have described in this paper, will provide a solid basis for measuring a country's performance and progress towards the biodiversity targets set at global and regional scales.

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THE MARINE MAMMAL PROTECTION INDEX: RANKING COUNTRIES' CONSERVATION PERFORMANCE[1]

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ABSTRACT

This paper presents a composite performance index, Marine Mammal Protection Index (MAM_{prot}), 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; their conservation status; and government response in mitigating or preventing human-induced damages to marine mammal populations.

Computation of MAM_{prot}, as an aggregated relative score of six independent indicators, enables maritime countries to be ranked based on their performance in protecting marine mammals. A composite league table presented in this paper shows Australia, followed by four European countries, Germany, UK, Sweden and the Netherlands, as the top five countries, while three countries that participate in commercial hunting of marine mammals, Canada, Japan, and Iceland, ranked amongst the bottom five. While severe data gaps at the global level, difficulties in attributing country performance to the status of highly migratory species and conceptual concerns inherent to composite indices limit the MAM_{prot}'s suitability as a definitive measure of marine mammal protection, the index is, nevertheless, a first attempt at a multi-dimensional comparison of marine mammal protection performance across maritime countries.

INTRODUCTION

A composite index is a powerful communication tool with which to present clear and simple "executive summaries" (Jesinghaus, 1999) of complex systems. Through aggregation of multiple parameters or indicators, each of which is representative of a dimension of the system in question, composite indices condense information into a single value that can be presented to non-experts requiring an overview of the system without the need for further interpretation. Because of this ability to integrate large amounts of disparate information into an easily understood format, composite indices are increasingly being used as benchmarks in comparing and ranking performances of various entities, ranging from hospital to universities to governments.

While a number of composite indices on environmental sustainability have been developed in recent years (e.g Environmental Performance Index see Esty and Levy, 2006), none has focused exclusively on management of the oceans, or parts thereof. Yet, management of the oceans, or of at least those parts of the marine realm within the Exclusive Economic Zones of maritime countries (40%), could benefit from such an index. Unsustainable expansion of global fisheries in the latter half of the 20th century and the perilous state of marine living resources of the world is well documented (Jackson *et al.,* 2001; Myers and Worm, 2003; Pauly *et al*., 2002; Worm *et al.*, 2006). While the intricacy of the marine environment implies that the state of world's oceans is a global responsibility, the current ocean management regime based on the principal of national jurisdiction up to 200 nautical miles out from a coast (i.e., within EEZs) dictates that coastal countries must ultimately be held accountable for addressing the conservation issues in their waters. A composite index, as a mean to tracking management performance and a benchmark for comparative cross-national assessment, thus, may serve as a

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useful tool in monitoring ocean (and EEZ) governance and the periodic publication of a composite league table should raise public awareness and recognition of the need for better governance.

Thus, the objective of this study is to construct a composite index that can serve as an indicator of marine mammal protection for an aggregated ocean management index. The index, named Marine Mammal Protection Index (MAM_{prot}), was designed based on the Pressure-State-Response (PSR) model of environmental indicators developed by the OECD (2002) and is an aggregated score of six proxy indicators representing, for each country:

- The existence of targeted hunting of marine mammals;
- The potential marine mammal bycatch within its EEZ;
- The extinction risk of marine mammals inhabiting its EEZ;
- The abundance of marine mammals inhabiting its EEZ;
- Its participation in international conservation treaties; and
- The willingness to act domestically on marine conservation.

This study presents a league table of countries based on their MAM_{prot} scores, which can be evaluated separately, or aggregated with the other indicators presented in this volume to derive and aggregated EEZ protection score.

METHODOLOGY

Theoretical framework

A composite index comprising multiple dimensions, in general, will take the form (Freudenberg, 2003):

$$I = \sum_{i=1}^{n} w_i X_i \qquad \text{...1)}$$

where I = composite index, X_i=underlying indicators or variables, w_i=weight of the X_i, Σw_i=1 and $0 \le w_i \le 1$.

In principle, variables selected should each represent a core component of the system being analysed and weights should reflect their relative importance in the overall composite. However, in practice, it is difficult to identify a set of individual variables and integrate them in manner that accurately reflects reality. Even if such a theoretically ideal set of variables were to be identified, the non-availability of suitable data presents a major constraint in its implementation (Niemeijer, 2002). This constraint is most strongly visible when attempting to construct an index that will allow a broad cross-national comparison, as is the case with the MAM_{prot}, where data gaps and inconsistencies from one country to another are severe.

While there is no consensus on how environmental indices should be framed, the use of PSR-based models has been increasing, particularly for designing the MAM_{prot}. The OECD (2002a) model is based on the concept of causality, with an emphasis on identifying a set of indicators that represent:

- The pressure exerted on the environment through human activities ('pressure' indicators);
- Changes in the quality and quantity of the environment resulting from this pressure ('state' indicators);and
- Social response to mitigate or prevent human-induced damage on the environment ('response' indicators).

Applying this model to marine mammal protection, three questions must be addressed:

- What are the human-induced threats faced by marine mammals?
- What is the current status of marine mammal populations?
- What are governments doing to protect and conserve these species?

In selecting and aggregating individual variables, these three questions were used as our guidelines.

Variable selection

In constructing a composite index, variable selection represents the major source of uncertainties and bias. Ideally, variables should be selected based on their analytical soundness, measurability, and relevance to the system in question (OECD, 2002b). Moreover, they must reflect changes over time and should periodically be updated to sufficiently reflect the current state of the system (Hammond *et al.*, 1995). As noted above, the greatest constraint in constructing a composite index is the lack of relevant data. A composite index can only be based on existing data. Consequently, many theoretically ideal indicators were abandoned in the course of completing this contribution. For example, the use rate of by-catch reduction devices, both as an indicator of pressure on marine mammal populations and of government management policies, would constitute a valuable measurement of marine mammal protection performance. However, such assessments are generally limited to regional case studies and currently do not exist on a global scale.

In the end, six variables were selected for the MAM_{prot}, representing obvious and easily accessible aspects of marine mammal protection:

Targeted Hunts (Pressure)

Exploitation of marine mammals for consumption is the most direct pressure on populations from human activities (Jackson *et al.,* 2001). Historically, excessive commercial hunting has led to massive reductions in wild populations and such declines are well documented for both cetaceans and pinnipeds (Christensen, 2006). Despite concerns over the inherent vulnerability of marine mammals to human exploitation (Anderson, 2001), targeted hunting for marine mammals continues, including for species protected by a moratorium on commercial whaling by the International Whaling Commission (e.g. see Mulvaney, 1996 for summaries of targeted hunting of small cetaceans). Perceived conflicts between marine mammals and fisheries also lead to targeted culling and are expected to intensify with the increasing demand for seafood (Levigne, 2003).

A global database of marine mammal catch does exist, i.e., the FishStat database of the Food and Agricultural Organization of the United Nations (FAO). However, the quality of data is highly questionable, particularly for the catch of small cetaceans, with zero catch recorded for countries (e.g., Sri Lanka and the Philippines) known to participate in commercial hunting (Reeves *et al.,* 2003). However, catches for pinnipeds appear to be consistent with various qualitative assessment of pinniped exploitation. With no alternative source of small cetacean catches with a global scope, we have instead grouped marine mammals into three categories (pinnipeds, small cetaceans and great whales) and scored countries from zero to three for each marine mammal groups based on available qualitative and quantitative description of targeted hunting in a country (Table 1).

Table 1. Scoring of participation in targeting hunting by maritime countries.

Score	Pinnipeds	Small cetaceans	Great whales
3	No hunting	No hunting	No hunting
2	Hunting of a single species with average annual catch (2000-2005) <100	Participation in an 'opportunistic' hunting of a single species	Hunting of a single species with average annual catch (2000-2005) <10
1	Hunting of a single species with average annual catch ≥100 OR Hunting of multiple species with average annual catch <100 per species	Participation in a 'regular' hunting noted for a single species OR Participation in 'opportunistic' hunting noted for multiple species	Hunting of a single species with average annual catch ≥10 OR Hunting of multiple species with average annual catch >10 per species
0	Hunting of multiple species with average annual catch ≥ 100	Participation in 'regular' hunting noted for multiple species	Hunting of multiple species with average annual catch ≥10

For each country, its indicator score for targeted hunting, TH_c, equals:

$$TH_c = th_{pinniped,c} + th_{cetacean,c} + th_{whale,c} \quad \text{...2)}$$

where $th_{pinniped,c}$=country's score for participation in hunting of pinnipeds, $th_{cetacean,c}$=country's score for participation in hunting of small cetaceans, and $th_{whale,c}$=country's score for participation in hunting of great whales.

Incidental Kills (Pressure)

Wherever the distribution of marine mammals overlaps in space and time with fisheries, there is a potential for them to be caught and killed as bycatch. Unlike commercial hunting, such incidental kills of marine mammals are less traceable and the magnitude of their impact on marine mammal populations is only beginning to be fully understood (a first global estimate, based on the US bycatch data, places the figure in the hundreds of thousands; Read *et al.*, 2006). Concerted efforts by the international community have succeeded in reducing the level of bycatch in some fisheries (e.g. eastern tropical tuna fisheries; detailed in Hall, 1998). Nevertheless, the proliferation of synthetic fishing gear and the intensification of industrial fisheries imply that bycatch remains a serious, if not the gravest, threat to marine mammals (Reeves *et al.*, 2003; Reeves *et al.*, 2005; Read *et al.*, 2006).

Regrettably, the lack of reporting of marine mammal bycatch on a global scale and the difficulty in obtaining useful estimates render any direct comparison of bycatch across countries unfeasible. Therefore, we have adopted as our proxy indicator the relative use of gillnets as measured by gillnet-associated catch (Watson *et al.*, 2006). While we recognize the potential impact of bycatch from gear such as mid-water trawls and longlines, we have focused on the use of gillnet as its marine mammal bycatch rate is perceived to be highest among commonly used gear (Hofman, 1995; Read *et al.*, 2006). In order to facilitate cross-national comparison, catches were re-expressed as catch per are; of EEZ. Indicator score of incidental kills, IK_c, is expressed as:

$$IK_c = \frac{g_c}{EEZ_c} \qquad \text{...3)}$$

where g_c=total estimated gillnet-associated catch for 2004 in the EEZ of country *c*, and EEZ_c=total EEZ area of country *c*.

Species Extinction Risk (State)

While the conservation status of marine mammal species in its EEZ is an excellent measure how a country fares with regards to marine mammal protection, the status of marine mammal species, in particular of small cetaceans, is difficult to assess (Mulvaney and Mckay, 2003). Moreover, while, of the 115 species of marine mammals considered in this study, extinction risk for 111 species has been assessed by the IUCN Red List (2007), 40 species are still classed as 'data deficient,' and many of the assessments have not been updated since 1994. While aware of these issues, we developed a scoring system based on the Red Book status of marine mammal species (Table 2).

Table 2. Species scoring of the IUCN Red List status.

Status	Score
Of least concern	10
Near threatened or conservation dependent	6
Vulnerable or data deficient	4
Endangered	2
Critically endangered	0

The highly migratory nature of many marine mammal species, and the fact that their distributions often encompass multiple national jurisdictions and high seas, imply that the contribution of maritime countries to the status of marine mammal populations will vary between species and countries. We have, therefore, applied the proportion of species distribution[2] that falls within the EEZs as weighting for the aggregated score of Red List status. The weighting assumes that the status of endemic species better represents the management performance of a country. Species with w<0.01 (i.e., less than 1% of its habitat falling within an EEZ) were not considered. The extinction risk indicator for a country, ER_c, is thus expressed as:

[2] The distribution ranges of marine mammal species are estimated based on the Relative Environmental Suitability model of Kaschner *et al.* (2006), using RES threshold of 0.2 and are available online at www.seaaroundus.org.

$$ER_C = \frac{\sum_{i=1}^{n_C} s_i w_i}{\sum_{i=1}^{n_C} w_i} \quad \ldots 4)$$

where n_c = number of marine mammal species found with in the EEZ of c, s_i = status score of marine mammal species I, and w_i = proportion of i's habitat occurring within the EEZ..

Species Abundance (State)

As noted above, historical overexploitation of marine mammals has reduced many populations to fractions of their previous abundance and in many cases these species have yet to recover despite conservation measures implemented by national governments. Therefore, relative abundance estimates of historically exploited species (from Christensen, 2006), originally presented as % depletion, were used as our second indicator of species health. Again, weighting based on the species distribution was used to compute the aggregated species abundance score, SA_c, for each country:

$$SA_C = \frac{\sum_{i=1}^{n_C} a_i w_i}{\sum_{i=1}^{n_C} w_i} \quad \ldots 5)$$

where nc = number of marine mammal species found with in the EEZ of c, ai = relative abundance of marine mammal species i ,and wi = proportion of i's habitat occurring within the EEZ.

It must be noted here that the estimation of percent depletion of Christensen (2006) was computed from reconstruction of historical abundances using reported catches, which tend to be underestimates. Also, Christensen (2006) used a model for population reconstruction which tended to overestimate the growth of formerly depleted populations. For these reasons, the percentage depletion she obtained by contrasting present and unexploited populations may have been underestimated. As well, the population size of species for which no directed hunt were performed (and/or catches available) were assumed constant, which is likely to also be a conservative assumption. Finally, in cases where no estimates were available for all marine mammal species found within the EEZ of a country, no *SA* score for that country was estimated.

International Treaties (Response)

Extensive distribution of many marine mammal species necessitates mechanisms for protection on an international level, and the United Nations Convention on the Law of the Sea (UNCLOS) explicitly requires countries to work through "appropriate international organizations for their (marine mammals) conservation, management and study" (Article 65). As our indicator of national responses to marine mammal protection, we have, therefore, assessed the participation of countries in selected international treaties (Table 3). While participation in international treaties, by itself, is simply a measure of intent rather than performance, similar use of treaty ratification as a measure of countries 'environmentalism' has been made by Dietz and Kalof (1992), Alder and Lugten (2002) and Roberts *et al.* (2004).

Table 3. Scoring for participation in international treaties.

Degree of commitment	Score
Full ratification, acceptance or approval with no objection or reservation	3
Ratification, acceptance or approval with objections or reservations[3]	2
Signature, subject to ratification, acceptance or approval	1
Non-party	0

[3] Countries were assigned a score of 2 for ICRW, if they entered an objection against the moratorium on commercial whaling (Paragraph 10(e) of the Schedule) and for CITES, if they have entered a reservation against listing of marine mammal species in either of the Appendices.

Moreover, our scoring system, which differentiates signature and ratification of, and objections, to relevant treaties, should capture the varying degrees of commitments by a country. Whilst we recognize the sovereign right of countries to enter objections, we have nonetheless assigned a lower value to ratification with objections, as such a response denotes deviation from the international conservation norm.

Four treaties and one system of treaties were selected for our assessment (their relevance to marine mammal conservation are noted in Appendix 1) based on three criteria:

- The treaty must be open for accession by any state;
- The scope of the treaty must be global; and
- The treaty must explicitly or implicitly address the issue of marine mammal protection.

We have, however, included the Antarctic Treaty System in our assessment as an exception, recognizing the international interest in management of Antarctica. Lists of parties for each treaty were obtained via their respective websites (Antarctic Treaty Secretariat (www.ats.aq); CBD (www.cbd.int); CITES (www.cites.org); CMS (www.cms.int); IWC (www.iwcoffice.org).

No weighting between conventions was applied in our assessment, except for the three instruments of the Antarctic Treaty System[4] (Antarctic Treaty, Environment Protocol and Antarctic Seal Convention) which were aggregated (represented as $\Sigma IT_{ANT,c}$ below) so that they weigh equal to other treaties as a system of treaties, not as individual instruments:

$$IT_c = 10\left[\frac{IT_{CBD,c}}{IT_{CBD,\max}} + \frac{IT_{CITES,c}}{IT_{CITES,\max}} + \frac{IT_{CMS,c}}{IT_{CMS,\max}} + \frac{IT_{ICRW,c}}{IT_{ICRW,\max}} + \frac{\sum IT_{ANT,c}}{\sum IT_{ANT,\max}}\right] \quad ...6)$$

where IT_c=indicator score for international treaties; $IT_{X,c}$ = country's score for participation in Treaty X, and $IT_{X,max}$= maximum possible score for participation in X (i.e., 3).

Two points to note: for the Faroe Islands, scores were assigned based on the participation in the treaties by Denmark, and Taiwan was omitted from the assessment of international conservation due to its lack of representation in the United Nations, and hence its restricted participation in international treaties.

Domestic Policies (Response)

Variation in conservation strategies (e.g., restriction on kills, habitat protection and pollution control) and need for management schemes to be tailored to particular local or regional conditions make broad comparison of national policies difficult. Moreover, the last comprehensive compilation of national marine mammal legislation is over 20 years old (Marashi, 1986), and likely does not reflect the current policies of the listed countries. We have, therefore, selected the size of marine protected areas (MPAs) as our proxy for willingness to act on conservation domestically. The number of national MPAs has been rising in recent decades (Woods *et al.* 2008), and they are increasingly being regarded as an essential tool in the conservation of marine mammals (Hoyt, 2005; Reeves *et al.*, 2003). More importantly, a global database of MPAs has recently been updated and is readily available online (MPA Global www.mpaglobal.org). As was the case in the use of gillnet-associated catch, the sizes of marine protected areas were re-expressed as a fraction of the total EEZ area. Hence, the domestic policies score, DP_c, for a country is expressed as:

$$DP_c = \frac{MPA_c}{EEZ_c} \quad ...7)$$

[4] Participation to the Convention on the Conservation of Antarctic Marine Living Resources was not included as a part of the Antarctic Treaty System for this study, as the Convention specifically excludes provisions for marine mammals (Art. VI).

where MPA_c=total size of MPAs in country c, and EEZ_c = total size of EEZ in country c.

Transformation of variables

Because the six variables identified above do not have the same dimension, it is necessary to transform them into a common scale comparable with the final scale of the index (OECD, 2002b). Transformation of two variables, gillnet catch and MPA coverage, relative to EEZ areas of countries, have already been noted. It is also necessary to remove any substantial skewness in variables prior to their aggregation in order to avoid distortion of the final index (Gilthorpe, 1995). Distortion of the aggregated index due to skewness in underlying variables is of serious concern, particularly when standardization of variables is heavily dependent on two extreme values as is the case with the MAM_{prot} (see below). Therefore, each variable was tested for normality of distribution using:

$$S = \frac{n}{(n-1)(n-2)} \sum \left(\frac{x_i - \bar{x}}{s} \right)^3 \qquad \text{...8)}$$

If a considerable skewness in the distribution of indicator variables was observed ($|S|>2$), the extreme values were standardized through the use of a logarithmic transformation.

In order to standardize variables on a scale of zero to ten, from worst performance to best performance, the 'minimum-maximum' technique was used. This method, which uses highest (leader) and lowest (laggard) values as benchmarks, positions values in relations to the global maximum and minimum:

$$10\left(\frac{\textit{actual value - minimum value}}{\textit{maximum value - minimum value}} \right) \qquad \text{...9)}$$

Therefore, the final MAM_{prot} score is an ordinate score of marine mammal protection performance of a country relative to best and worst performances among the countries evaluated. It is not an absolute, cardinal score and consequently the valuation will vary from one assessment to another.

<u>Weighting and aggregation</u>

The final step in the construction of a composite index involves the weighting of variables before aggregating them into a final score. Assimilation of multiple variables into a single composite value implicitly implies substitutability of variables, while the weighting used to represent the relative importance of underlying variables is often viewed as a major source of subjectivity (OECD, 2002b; Freudenberg, 2003). The weights given to different variables heavily influence the outcomes of an index, particularly if there is polarity in variables.
Largely for reasons of simplicity and the lack of viable alternatives, all variables were given equal weight in MAM_{prot}.

$$MMPI_c = wTH_c + wIK_c + wER_c + wSA_c + wIT_c + wDP_c \qquad \text{...10)}$$

where w=1/6.

It should, however, be noted that by selecting two variables per each component of the PSR framework, three components are equally represented in the final MAM_{prot} score.

Choice of countries

The 53 countries assessed here are those evaluated in Alder and Pauly (this volume) and jointly account for about 95% of global reported landings. Boundaries of EEZ are limited to waters around countries' 'mainland' (except for the EEZs off Alaska and Hawaii which were included as a part of the US EEZ) and do not include EEZs off overseas territories[5].

Data Sources

Pinnipeds were scored based on FishStat (FAO, 2007), small cetaceans based on the qualitative descriptions in the IUCN Conservation Action Plans (Reeves *et al.,* 2003) and great whales based on the catch statistics from the International Whaling Commission (IWC, 2007). Scoring is detailed in Table 1. The levels of gillnet use as a proxy for incidental kills was obtained from Watson (2006) while data on species extinctions were from IUCN's Red List (IUCN, 2007). The estimates of species abundance were based on Christensen (2006). Data on country participation in international treaties were derived from relevant convention websites and data on MPAs were from the MPA Global website (www.mpaglobal.org).

Results and Discussion

Of the six variables assessed, substantial skewness occurred in variables related to incidental kills and domestic policies (S=5.6 and S=4.3, respectively); these variables were log-transformed. Significant skewness (S=-1.9) was also observed in the variable for targeted hunting, though it was below the pre-determined threshold, and, indeed, was expected, considering that a large majority of countries assessed do not currently participate in hunting of marine mammal at all.

A composite league table, ranking maritime countries based on their MAM_{prot} score, is presented in Table 4. The MAM_{prot} scores ranged from 4.0 (North Korea) to 8.9 (Australia) with an average score of 6.2. Australia, followed by four European countries, Germany, UK, Sweden and the Netherlands ranked the top five in the table while countries that participate in commercial hunting of marine mammals, Canada, Japan and Iceland ranked among the bottom five.

At a sub-index level, Canada, with its participation in hunting for pinnipeds (harp seals and ringed seals), small cetaceans (white-beaked dolphin, beluga and narwhal) and great whales (bowhead) scored zero, while Bangladesh scored lowest in the incidental kills for its high use of gillnet (with nearly half of the reported landings in its EEZ associated with gillnet). Italy and Turkey scored lowest in the extinction risk indicator, due to the 'critically endangered' status of Mediterranean monk seals, the only marine mammal species with over 1% of its distribution falls within the EEZs of these countries, while Germany scored highest based on the low extinction risk assessed for gray seals and harbour seals. Extremely low relative abundance of North Atlantic right whales was the main factor in the low species abundance score for Canada. Again, the relatively healthy state of gray seals and harbour seals resulted in high scores for Poland and Germany. In the international treaties, nine countries that have ratified all treaties assessed scored 10, while North Korea, which has only ratified the Antarctic Treaty and CBD, scored lowest. As for the domestic policies indicator, Germany, with close to 15% of its EEZ protected, scored highest while countries with no MPAs (Faroes, Ghana and Nigeria) scored lowest.

Table 4. Composite league table of 53 maritime countries on their marine mammal protection performance (ranking based on MAM_{prot} scores). TH=standardized score for targeted hunt, IK=incidental kills, ER=extinction risk, SA=species abundance, IT=international treaties and DP=domestic policies.

Country	TH	IK	ER	SA	IT	DP	MAM_{prot}
Australia	10.0	10.0	7.3	6.7	10.0	9.2	8.9
Germany	10.0	3.2	10.0	9.9	10.0	10.0	8.8
UK	10.0	2.6	8.6	8.3	10.0	8.3	8.0
Sweden	10.0	2.8	8.9	9.0	9.1	8.0	8.0
Netherlands	10.0	3.9	9.1	9.0	9.1	6.2	7.9
Denmark	10.0	2.4	9.1	9.0	8.2	8.3	7.8
South Africa	10.0	7.7	5.8	7.3	10.0	5.7	7.7

[5] EEZ boundaries are available online at www.seaaroundus.org; for Germany. Japan, Malaysia, Russia and Turkey, these boundaries are presented as regional 'sub-EEZ'.

Table 4 (cont'd).

Country	TH	IK	ER	SA	IT	DP	MAM_{prot}
Poland	10.0	2.0	10.0	10.0	7.3	6.3	7.6
Portugal	0.0	6.6	6.4	8.8	7.3	5.5	7.4
France	10.0	4.4	6.7	8.3	10.0	5.0	7.4
Argentina	7.1	8.5	6.1	5.0	10.0	5.9	7.1
Latvia	10.0	2.8	10.0	9.6	4.5	5.5	7.1
Spain	10.0	5.5	4.0	8.8	9.1	5.0	7.1
Brazil	10.0	7.5	4.9	6.2	7.3	6.2	7.0
Chile	7.1	6.8	5.3	4.6	10.0	8.0	7.0
Mexico	10.0	8.0	4.7	6.8	4.5	7.4	6.9
New Zealand	10.0	8.5	5.2	1.6	9.4	5.5	6.7
Ireland	10.0	4.3	8.0	7.8	7.3	1.9	6.6
Ukraine	10.0	7.0	4.0	4.4	6.4	7.0	6.5
Ecuador	7.1	6.7	4.0	n.a	9.1	5.0	6.4
Italy	10.0	5.5	0.0	n.a	10.0	6.5	6.4
Peru	5.7	7.1	4.7	5.5	9.1	5.8	6.3
Thailand	10.0	6.4	4.0	8.2	1.8	7.3	6.3
Senegal	10.0	4.5	4.0	n.a	7.3	5.7	6.3
Namibia	7.1	7.1	5.4	8.3	1.8	7.8	6.3
Viet Nam	10.0	6.3	4.1	8.7	1.8	5.9	6.1
India	7.1	3.0	4.2	7.7	9.1	5.4	6.1
Yemen	10.0	7.0	4.0	n.a	4.5	4.7	6.0
Taiwan	7.1	7.4	4.7	7.3	n.a	3.4	6.0
Angola	10.0	7.0	4.0	n.a	1.8	7.0	6.0
Egypt	10.0	5.3	1.3	n.a	4.5	8.5	5.9
Pakistan	10.0	4.5	4.0	n.a	4.5	6.4	5.9
Sri Lanka	5.7	7.1	4.0	8.2	4.5	5.5	5.9
Morocco	10.0	4.5	1.9	n.a	7.3	5.4	5.8
Philippines	5.7	5.0	4.8	7.3	4.5	7.2	5.7
Myanmar	10.0	2.2	4.0	8.2	1.8	6.8	5.5
Korea (South)	10.0	2.3	4.9	1.3	6.4	7.0	5.3
Iran	10.0	3.7	4.0	n.a	1.8	6.9	5.3
Russian Fed	1.4	5.9	6.6	2.5	6.4	8.2	5.2
Faroes	5.7	3.6	8.1	5.4	8.2	0.0	5.2
China Main	10.0	3.1	4.6	2.7	6.4	4.1	5.1
Malaysia	10.0	3.1	4.0	n.a	1.8	6.6	5.1
Bangladesh	10.0	0.0	4.0	n.a	4.5	6.9	5.1
Norway	2.9	3.0	8.3	4.3	8.2	3.8	5.1
Indonesia	5.7	4.2	4.4	6.3	1.8	7.4	5.0
USA	0.0	7.4	5.5	2.7	5.5	8.8	5.0
Ghana	10.0	6.1	4.0	n.a	4.5	0.0	4.9
Turkey	10.0	5.2	0.0	n.a	2.7	6.6	4.9
Iceland	7.1	2.9	8.3	3.6	2.7	3.2	4.6
Nigeria	10.0	4.3	4.0	n.a	4.5	0.0	4.6
Japan	1.4	3.8	5.3	1.9	6.4	7.4	4.4
Canada	0.0	7.6	7.1	0.0	4.5	6.8	4.4
Korea (North)	10.0	4.6	4.3	1.8	0.0	3.1	4.0

MAM_{prot} is by no means a definitive measure of a country's performance in marine mammal protection. As mentioned in relation to variable selection, an ideal set of indicators would extend beyond the six incorporated into the index. Considering human induced pressures to marine mammals, for example, the IUCN Conservation Action Plans identified many other threats to marine mammal conservation, including ship strikes, habitat degradation and pollution (Reeves *et al.,* 2003). In data-rich countries like the US and Australia, in-depth examination of marine mammal protection performance that incorporate wider dimension of conservation drivers is possible and undoubtedly, such examination would yield more comprehensive assessment of country performance. However, in the context of the study, that is, to provide an indicative measurement of country performance for a broad group of maritime countries, it was necessary to sacrifice precision of assessment for few countries in order to maintain equal evaluation standards for all countries. Improvements in data availability and coverage on a global scale should greatly enhance the breadth of the index in future.

Moreover, the indicators selected have inherent weaknesses and biases. Lack of reliable global databases for targeted and incidental kills of marine mammals has already been noted, and scoring based on the qualitative description of hunts is susceptible to criticism of their subjectivity. The use of number of species hunted as an additional criterion was an attempt to reduce the potential bias in the scoring of targeted kills. It is also likely that the reports of targeted hunting cited in the IUCN Conservation Action Plans were not exhaustive and may be biased toward countries with better reporting infrastructures. Nevertheless, we believe the selection of targeted kills as an underlying indictor of the MAM_{prot} is critical, not only as an indicator of the threat to conservation, but also as an identifier of countries' positions in the sustainable use-preservation spectrum. Similarly, relative gillnet use estimated from gear associated catch data, applied in the model as a proxy indicator for bycatch, implicitly assumes a constant bycatch rate for the gear and ignores regional variations in the utilization of bycatch reduction devices. The indicator was, nonetheless, incorporated in the index in recognition of bycatch as a significant direct and immediate threat to marine mammals.

It must be noted, however, that the assumption of substitutability of variables inherent to composite indices implies that an increase in a number of parameters could possibly weaken the diagnostic feature of an index, by diluting the effect of individual parameters. We believe, therefore, the six sub-indicators selected in MAM_{prot}, though limited in scope, represent a set of indicators most closely associated with marine mammal conservation and should sufficiently encapsulate country performance.

Standardization of the indicators using the 'minimum-maximum' approach denotes that MAM_{prot} scores are ordinal values beneficial for ranking but their valuation is susceptible to change and do not provide information as to absolute performance. A possible solution is to anchor each indicator using a defined policy target and standardize variables based on their proximity to the target (e.g. the Environmental Performance Index: www.yale.edu/epi/). The stated goal of protecting "at least 10% of each of the world's ecological regions [by 2010]" of the Eighth Ordinary Conference of the Parties to the CBD in 2006, for example, could be used as anchoring value (i.e., score of 10) for our domestic policies indicator. Consultation with experts should help identify a target value for each variable.

Lastly, when interpreting the composite league table of MAM_{prot}, it must be noted that there is still no global consensus on 'marine mammal conservation.' The schism within the International Whaling Commission (IWC) between those who contend that certain species of whales, provided that they have sufficiently recovered from historical overexploitation, can be subjected to sustainable exploitation and those who maintain that whales should be permanently protected from commercial exploitation, is well documented (Friedheim, 2001). This fundamental debate between using and preserving natural resource, or whether marine mammal should even be seen as a 'resource', is beyond the scope of the present study. The MAM_{prot} presented in this study is strictly a measurement of marine mammal protection. Despite its various shortcomings, the index is, nevertheless, a first attempt at a multi-dimensional comparison of marine mammal protection performance across maritime countries. As such, it may also serve as an indicative measure of marine mammal conservation for a comprehensive EEZ management index presented elsewhere in this report.

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APPENDIX 1: LIST OF INTERNATIONAL TREATIES CONSIDERED FOR THE MARINE MAMMAL PROTECTION INDEX (IN CHRONOLOGICAL ORDER, DATE OF ADOPTION IN PARENTHESES AND NUMBER OF CONTACTING PARTIES AS OF NOVEMBER 2007).

International Convention for the Regulation of Whaling (02/12/1946)

Contracting Parties: 77

For protection of all species of whales from over-exploitation and for establishment of a "system of international regulation for the whale fisheries to ensure proper and effecting conservation and development of whale stocks." Since 1986, a moratorium on the commercial whaling has been put in place through enforcement of zero catch limits for all whale stocks (Paragraph 10(e) of the Schedule).

Antarctic Treaty (01/12/1959)

Contracting Parties: 46

For peaceful use of Antarctica with preservation and conservation of its living resources (Art. IX 1(f)).

Convention for the Conservation of Antarctic Seals (01/07/1972)

Contacting Parties: 17

For 'the objectives of protection, scientific study and rational use of Antarctic seals, and to maintain a satisfactory balance within the ecological system.' Conservation measures include permissible catch limits and designation of protected species[6] (Art. III).

Convention on International Trade in Endangered Species of Wild Fauna and Flora (03/03/1973)

Contracting Parties: 104

For 'the protection of certain species of wild fauna and flora against over-exploitation through international trade.' All cetacean listed under appendix I, which includes all species threatened with extinction which are or may be affected by trade, and Appendix II which include all species which although not necessarily threatened may become so unless trade is regulated. *Monachus* spp., *Arctocephalus* spp. and *Mirounga leonina* are listed in Appendices I & II, and *Odobenus rosmarus* in Appendix III.

Convention on the Conservation of Migratory Species of Wild Animals (23/06/1979)

Contracting Parties: 101

Parties 'should endeavour to provide immediate protection for migratory species included in Appendix I' and to 'conclude agreements covering the conservation and management of migratory species included in Appendix II' (Article II 3). 12 cetacean species and one pinnipeds species of pinniped listed in Appendix I and 38 cetacean species and 5 pinniped species in Appendix II.

Protocol on Environmental Protection to the Antarctic Treaty (04/10/1991)

Contracting Parties: 32

For 'comprehensive protection of Antarctic environment and dependent and associated ecosystems' (Art. II). Protection of native marine mammals designated in Annex II, including prohibition on the taking of Specially Protected Species without a permit[7].

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[6] Prohibition on killing or capturing of *Ommatophoca rossii, Mirounga leonine,* and *Arctocephalus* spp. as well as adult *Leptonychotes weddelli* during the breeding season (1 Sep to 31 Jan).

[7] Specially Protected Species under the Protocol originally defined as all species of the genus *Arctocephalus*, and *Ommatophoca rossii*. *Arctocephalus* spp. de-listed effective June, 2007.

Convention on Biological Diversity (22/05/1992)

Contracting Parties: 190

Although no explicit reference to marine mammal protection in the Convention, conservation of coastal and marine biodiversity has been identified as one of its seven thematic areas (Decision II/10).

PRELIMINARY ESTIMATES OF NATIONAL AND GLOBAL COSTS OF MARINE PROTECTED AREAS[1]

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ABSTRACT

Marine Protected Areas (MPAs) are widely seen as an important part of the solution of the global crisis of fisheries, characterized by overcapacity, habitat degradation, and declining stocks. A relevant factor in the establishment of MPAs is that of cost. This contribution estimates, based, among other things, on an empirical model linking costs and area protected, and a global database of MPAs within the EEZs of the world's maritime countries, the annual maintenance cost of the current global network of MPAs, covering 0.7 % of the world's ocean, and 1.5 % of EEZs. Results reveal a global cost estimate of about 870 million US$ for the year 2000, corresponding to about 1% of the ex-vessel value of global landings. A larger area than the present MPA coverage (e.g., 20-30 %), as targeted by various institutions, would probably be cheaper on a per area basis, as it would benefit from economies of scale.

INTRODUCTION

The most commonly used definition of a Marine Protected Area (MPA) is that established by IUCN:

> "any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (Kelleher, 1999).

Clearly, the MPA concept is quite broad. Indeed, Agardy (2000) points out that it can encompass parks, ecologically focused reserves and areas designated off limits to certain fishing gears. In the past, there have always been areas of the ocean that people could not access, be they too far from shore, too deep, or too remote i.e., because we did not have the technology to exploit them (Pauly *et al.,* 2002). Such 'default' protection guaranteed that some areas remained sanctuaries for sea life (Agardy *et al.,* 2003).

Things are very different today. Dramatic advances in echolocation, catching and on-board processing technologies, along with a general increase in the size of vessels enable fishing to be conducted far offshore, and in deep waters and remote areas, such that fish are exploited anywhere they occur, and there is no more default protection. Thus, explicit MPAs have become necessary (Roberts and Hawkins, 2000; Jones, 2003), notwithstanding residual uncertainty as to their precise effects in some specific conditions (Gell and Roberts, 2003; Sale *et al.*, 2005).

A number of targets for global MPA coverage have been set by the international community. Thus, in 2002, the delegates to the World Summit on Sustainable Development (WSSD) agreed that by 2012, "representative networks of MPAs" must be established (United Nations, 2002), and

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the World Conservation Union's (IUCN) 5th World Parks Congress (WPC) in 2003 echoed the advocate for such networks by 2012 (IUCN, 2003). These targets, and the exceedingly slow pace toward achieving them (or not) are reviewed in Wood *et al.* (2008).

One essential aspect of MPAs is the costs associated with their creation and maintenance. Such costs are clearly connected with socio-economic factors which, to date, have been given little emphasis (Stewart and Possingham, 2005; Sumaila and Charles, 2002). If MPAs are to play a vital role in the conservation of our oceans, we must acknowledge, as with any conservation technique, that MPAs generate, on an annual basis, costs for enforcement, management, and research, to name a few. On the other hand, MPA costs can be seen as an investment into the future of fisheries, ensuring the continuation of the resource and overall sustainability of the industry (Roberts and Hawkins, 2000). It is for this reason that the costs associated with MPAs have been categorized by Khan *et al.* (2006) as "good" subsidies to fisheries (although they were not included in their evaluation of global subsidies to fisheries).

This study aims to estimate the running costs in the year 2000 (and in 2000 US$) of the MPAs in the Exclusive Economic Zone (EEZ) of 192 maritime countries (and territories) of the world, with emphasis on the 53 countries, jointly contributing 95 % of the world catch, and which are the focus of the other contributions in this volume (Alder and Pauly, this volume).

Materials and Methods

The three main sources of data used for this contribution were the global database of MPAs assembled and described by Wood *et al.* (2008)[2], the global fisheries catch and value database of the *Sea Around Us* Project (Pauly, 2007; Sumaila *et al.*, 2007; see also www.seaaroundus.org), and the study of Balmford *et al.* (2004) on the projected costs of future MPA networks.

Balmford *et al.* (2004) gathered their MPA cost data from approximately 500 informants working on, or otherwise connected with, MPAs. From the quotes below, we can gather that the type of MPA sampled in their study was diverse, and the size of MPAs, varied. Thus, their questionnaire focused on "information on MPA area, protection type, and goals, staffing, recurrent income and expenditure, and how much (if any) extra expenditure and staff were required for minimum effective protection."

Balmford *et al.* (2004) obtained data for 83 MPAs: "12 from Africa, 12 from Asia, 10 from Australasia and Oceania, 13 from Europe, 13 from Latin America and the Caribbean, and 23 from North America, and ranging in size from <0.1 km² to >300,000 km². As well as encompassing a broad geographic and size range [their] sample included a wide spectrum of management types (run by government agencies, nongovernmental organizations, and local communities; zoned and not zoned), objectives (e.g., biodiversity protection, recreation, conflict reduction, and fishery enhancement), and resources protected (e.g., coral reefs, whales, and coastal scenery). Of the 76 MPAs that reported their purpose, 75 (98.7%) listed habitat and species protection (the remaining MPA was solely for research), and protection was the primary purpose for 58 (76.5%)." Thus, they concluded that their sample was "broadly representative of the range of MPAs in use worldwide and should produce a meaningful approximation of the costs of running a global MPA system". However, there was one caveat: "questionnaires were only distributed to MPAs for which [they] could obtain contact details, and only 16% responded; [thus, their] figures are probably biased toward relatively well managed and funded MPAs" (Balmford *et al.*, 2004).

Balmford *et al.* (2004) derived a number of multiple regression models from their data, and concluded that "just three variables could predict nearly all of the variation in total MPA running costs." These variables were the size of MPAs (i.e., their area in km²), the distance of MPAs from inhabited land (in km), and purchasing power parity. In this preliminary study, we use the simplest of their models:

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[2] MPA Global is accessible via www.seaaroundus.org

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

where C is the annual cost per km², in 2000 US$, and A the MPA area in km², and which explained almost 80% of the variance in the dataset ($r^2 = 0.79$).

Equation (1) being logarithmic in both variables (i.e., highly non-linear), the cost of the MPAs of a given country must be calculated for each MPA separately, then added up (rather than adding up the MPA areas beforehand, then applying Equation (1) only once). The huge differences due to this effect, also discussed in Pauly and Ingles (1999) in connection with the relationships between shrimp catches and coastal mangrove area, are illustrated in Table 1.

Table 1. Hypothetical example of correct and incorrect applications of Equation (1) to data from a country with four MPAs of very different sizes.

MPA	Area (km²)	Cost per area ($·km^{-2})	Estimated cost (US$)
Little one	2.3	4.74	123,151
Larger one	57.4	3.61	235,348
Big one	149.6	3.28	285,098
Very big one	462.1	2.89	357,222
Total (correct)	-	-	1,000,819
Incorrect total	671.3	2.76	384,928

Equation (1) provides us with a method for approximating the cost of MPAs for a developmentally 'average' country. However, Balmford *et al.* (2004) do mention a difference in costs between developing and developed countries: the median cost of MPAs for 43 developing countries was stated as US$ 1,584·km^{-2}, while it was US$ 8,976·km^{-2} for 40 developed countries.

We used this information to correct the output of Equation (1) based on a two-step procedure: (i) we used the Gross Domestic Product per capita (GDP) of countries to slot them into one of five GDP classes; and (ii) we assigned to each country a GDP correction factor (F), based on the above medians and the GDP classes, and which was used to increase or reduce the initial cost estimates produced by Equation (1).

The GDP estimates used here originate from the World Bank (www.worldbank.org) and the International Monetary Fund, (IMF, www.imf.org), and pertain to the year 2000. Of the 192 territorial entities that have MPAs, and which are covered here, 57 lacked GDP per capita information, mainly small island states or dependent territories. The 135 countries with such GDP estimates were arranged in order of GDP per capita value, and grouped into five classes (see Table 2), with 25-29 countries per class. Given the MPA costs in developed and developing countries given above, a deviation from the mean cost (as predicted by Equation 1) of 1.7 for developed countries, and 0.3 for developing countries was calculated (which appears justified as the number of MPAs sampled from developed and developing countries were similar - 43 and 40, respectively). We then applied these multipliers to our country classes I and V, respectively, and interpolated the F-values for classes II and IV, class III having, by definition, a correction factor of 1 (i.e., we expect average costs). Table 2 presents the data involved here.

Table 2. Derivation of correction factor (F) for adjusting the output of Equation (1) to the GDP per caput (US$·10^3) of countries in 2000.

Country	GDP·caput^{-1}	F
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

The 57 countries or territories lacking GDP per capita information from the World Bank or the IMF were subsequently assigned an F-factor of 1. It should be noted that these countries or territories have few MPAs, and that any subjective bias will have a limited influence on our global cost estimate. Also, in order to allow for comparison of the costs of MPAs in countries with small EEZs with those of countries with large EEZs, the MPA costs were divided, for each country and territory, by the ex-vessel value (in year 2000) of the fisheries catches in their EEZ, as given on the website of the *Sea Around Us* Project (see www.seaaroundus.org). The resulting dimensionless ratio is our proposed 'Investment to Marine Protected Areas', or MPA_{inv}, expressed in percent in Table 3. In assessing which countries are performing well in terms of running costs relative to the value of the fisheries catches, we considered an investment of 10% or more the target investment for all countries as demonstrated by Australia which is considered to be one of the most advanced countries in managing its marine protected areas, with just over 10% of its running costs. A score of 10 was assigned to those countries achieving the target investment, while countries with no investment or a low investment (i.e. MPA_{cost} = <0.5%) score zero and investments of 5% score 5.

For 55 countries, of which only one (Sweden) is included in Table 3, the method detailed above produced MPA cost estimates above 15 % of the value of their fisheries catches. In such cases, MPA_{costs} were set at 15 %; this corresponds to assuming that beyond this value, MPAs do not benefit fisheries. This does not have any impact on our scoring (see above).

Table 3. Estimates of the costs of running MPAs (in year 2000) for 53 countries jointly contributing 95% of the world marine fisheries catch, and estimates for the rest of the world (MPA costs are in US$·$10^3$; MPA_{cost} = Fisheries Protection by MPA Cost Index; see text).

Rank	Country	Costs for MPA	MPA Cost Index	Score	Rank	Country	Costs for MPA	MPA Cost Index	Score
1	Sweden	30,046	15.0	10	29	Indonesia	18,100	0.7	1
2	Germany	12,610	12.3	10	30	Japan	33,046	0.7	1
3	Australia	111,893	11.5	10	31	Norway	6,195	0.6	1
4	Denmark	21,100	8.6	8	32	Iran	1,647	0.5	1
5	UK	70,685	5.8	5	33	Ireland	1,971	0.5	1
6	Egypt	2,969	5.5	5	34	Morocco	1,248	0.5	1
7	Ukraine	1,053	4.0	4	35	Chile	2,005	0.4	0
8	Canada	141,275	3.9	3	36	Iceland	2,412	0.3	0
9	Italy	19,258	3.6	3	37	Russia	7,925	0.3	0
10	Netherlands	4,335	3.2	3	38	Myanmar	1,926	0.2	0
11	*USA	119,162	3.2	3	39	Angola	474	0.2	0
12	Spain	13,780	2.7	2	40	Senegal	322	0.2	0
13	South Africa	5,226	2.5	2	41	Bangladesh	345	0.2	0
14	Thailand	3,517	2.3	2	42	Pakistan	391	0.1	0
15	Malaysia	25,831	2.1	2	43	Viet Nam	1,880	0.1	0
16	Poland	980	1.9	1	44	Peru	635	0.1	0
17	France	8,616	1.8	1	45	Korea (South)	2,250	0.1	0
18	Brazil	16,300	1.7	1	46	India	1,198	0.1	0
19	Taiwan	3,214	1.5	1	47	Yemen	123	0.1	0
20	Sri Lanka	1,743	1.2	1	48	China	4,136	0.0	0
21	Portugal	2,602	1.1	1	49	Faeroe Islands	0	0.0	0
22	Philippines	14,182	1.0	1	50	Ghana	0	0.0	0
23	New Zealand	6,375	1.0	1	51	Korea (North)	0	0.0	0
23	Argentina	6,813	0.8	1	52	Namibia	0	0.0	0
25	Latvia	216	0.8	1	53	Nigeria	0	0.0	0
26	Mexico	6,967	0.8	1	-	--	--	--	--
27	Turkey	3,262	0.8	1	-	**All others**	**126,108**	**-**	--
28	Ecuador	376	0.8	1		**Total**	**868,722**	**-**	--

* USA includes Alaska and Hawaii

RESULTS AND DISCUSSION

Table 3 gives our MPA cost estimate for the world, and for the 53 countries which are the focus of this volume. (Detailed information for the other countries can be found, for each of the other countries and territories at www.seaaroundus.org). Globally, the estimate of MPA cost is nearly 900 million US$ for the year 2000, or about 1 % of the value of global catches. As a subsidy to fisheries, this would add about 3 % to the global estimate of 30-34 billion US$ (Khan *et al.*, 2006; Sumaila and Pauly, 2006), but in the form of 'good' subsidies, i.e., not adding to fleet capacity. As far as the 53 countries selected for comparison (Table 3), they contribute 81.1 % of the cost of MPAs in the world, below their contribution to world fisheries catches at 95 %.

The preliminary nature of these estimates cannot be overemphasized. The problems range from deficiencies in the underlying databases of MPAs, catch values and GDP, to the uncertainly in Equation (1) and its underlying database. Further, we do not believe that our attempt to correct for GDP per capita difference between countries, and hence in the cost of their MPAs, was optimal in any sense. However, not performing some type of correction would have certainly led to cost overestimates in developing, and underestimates in developed, countries. It should also be noted that Balmford *et al.* (2004) include only MPAs whose total area is at least 50 % marine; this differs from MPAs used in this research: MPA Global includes MPAs based on the IUCN definition noted previously, and incorporates MPAs that range from 0.03 % marine in area to 100% marine.

Balmford *et al.* (2004) mention other possible bias: the data from which Equation (1) was derived were from those individuals who responded to their survey, i.e., persons for the most part involved in MPAs easier to access or more responsive to the public. They also remark that upon collection of MPA data, if there was any ambiguity between terrestrial and marine reserve costs, they tended to ascribe all costs to the marine component, which could potentially contribute to an overestimation of MPA cost.

The data generated in this study shows a high percentage of the countries have low MPA_{cost} scores. This is in part a reflection of the dominance of small, relatively expensive to operate MPAs. Only three countries, which are already known to have large MPAs, scored the highest (i.e. 10) – Sweden, Germany and Australia, are all developed and relatively wealthy countries.

Although Balmford *et al.* (2004) do not give an annual cost estimate for the current global MPA system (as reflected in www.mpaglobal.org), they suggest an annual cost for 20-30 % coverage of global oceans of US$5-19 billion. Given that current MPAs cover only 0.7 % of the entire ocean (Wood *et al.*, 2008), but cost nearly US$900 million to maintain, one could assume that it would cost US$27-40 billion annually to protect 20-30 % of the global oceans. This value is much higher than the cost estimate in Balmford *et al.* (2004) because it is affected by the many small (and relatively costly) MPAs in MPA Global, which comprises over 4400 entries. Balmford *et al.* (2004), on the other hand, base their projections on 83, generally larger MPAs. The mean size of an MPA in MPA Global is 544 km^2, but the median is 4.6 km^2. This vast disparity between mean and median values is a result of the ten largest MPAs, which make up 68% of the world's cumulative MPA area (Wood *et al.*, 2008).

However, a high percent coverage of MPAs, i.e., the 20-30 % figure used above, is not achievable, within the next decades, by projecting present trends in number and cumulative coverage of MPAs (Wood *et al.*, 2008). Indeed, the CBD and WSSD target (see above) can be reached only by the rapid creation of a great number of very large MPAs. These are very 'cheap' on a per area basis (see Table 2), and hence both of the above cost estimates, ours and that of Balmford *et al.* (2004), are likely to be far too high. In any case, it would be a useful expense, given present trends of degrading fisheries resources and marine biodiversity.

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