Bay of Bengal Large Marine Ecosystem Project

Performance in managing marine resources in the Bay of Bengal

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Report to the Bay of Bengal Large Marine Ecosystem Project (*www.boblme.org*) prepared by:

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EXECUTIVE SUMMARY

The eight maritime countries in the FAO Bay of Bengal Large Marine Ecosystem (BOBLME) were assessed as to their sustainable use of the resources within their Exclusive Economic Zones (EEZs), using fourteen indicators of marine living resource management. These indicators assessed MPA investment as well as area coverage, the impact of trawling[1] and other habitat damaging gears[2], mariculture sustainability, the protection of seabirds and marine mammals, ecosystem impacts, economic health, levels of taxonomic reporting of commercially caught species, and compliance with the FAO Code of Conduct for Responsible Fisheries. With the exception of the Marine Trophic Index (MTI) and the Stock Status plots (SSPs), each of the remaining 12 indicators was computed at the EEZ level (or the Bay of Bengal portion of the EEZ when appropriate), and ranked from lowest to highest on a scale of 0 to 10. The MTI and SSPs are presented qualitatively as time-series graphs (1950-2006) and a discussion of the possible implications of the trends is presented. For the 12 ranked indicators, four rankings of the countries are presented, based on the management preferences identified by the Global Environmental Outlook (GEO4) future development scenarios: *Market First*; *Policy First*; *Security First*; and *Sustainability First*.

- **Bangladesh:** Bangladesh received the highest indicator score for the intention to protect seabird species and the second highest score for intention to protect marine mammal species. It also scored well for the trawling effort indicator, as only a small proportion of the catch taken in their EEZ waters was assigned to trawling-type gears using the globally derived taxon-gear associations. However, Bangladesh received the lowest scores for both mariculture sustainability indices (measuring ecological and social impacts of mariculture). This low score is due largely to shrimp mariculture, which has a strong impact on the environment, notably because of the heavy use of antibiotics. Thus, overall, Bangladesh ranked third lowest compared to the other countries in the region, with major strengths in the relatively low proportional use of heavily impacting gears such as trawls and major shortcomings in the sustainability of their mariculture sector.

- **India:** India received the highest scores for the amount of marine protected area (MPA) relative to its EEZ area and for the intention to protect marine mammal species. India also

[1] In areas other than the Bay of Bengal, this indicator may also include dredging, which modifies bottom habitats even more than bottom trawling (Chuenpagdee *et al.*, 2003).
[2] Based on global taxon-gear associations (Watson *et al.*, 2006a, 2006b).

received relatively high scores for investment in MPAs and for the protection of seabird species. Thus, overall, India ranked second highest compared to the other countries in the region, with major strengths in the proportion of MPA coverage and the implementation of protective measures for marine mammals, and major shortcomings in the small economic impact of their fisheries despite extensive coastline, as well as the granting of capacity enhancing subsidies to fisheries.

- **Indonesia:** In general the scores for all indicators were low to medium. Indonesia scored lowest for the ratio of subsidies to landed value, a measure of the economic sustainability of fishing practices of a country. Additionally, its score for the intention to protect marine mammal species was the second lowest of the Bay of Bengal countries. Thus, overall, Indonesia ranked the lowest (together with Myanmar) compared to the other countries in the region, with major strengths in the ecological sustainability of their mariculture practices, and major shortcomings in the use of trawling-type gears (note however that the official ban on trawling gears in Western Indonesia was not considered here)[3], and the use of capacity enhancing subsidies.

- **Malaysia:** Malaysia received the highest scores for both of the mariculture sustainability indices and for its commitment to uphold the FAO Code of Conduct. It had a relatively low score for the intention to protect marine mammals. Thus, overall, Malaysia ranked third compared to the other countries in the region, with major strengths in the ecological and socioeconomic spheres of its mariculture sectors, and major shortcomings in the low proportion of MPA coverage and the use of capacity enhancing subsidies.

- **Maldives:** The Maldives had the highest scores for two of the economic indicators: the economic impact factor relative to GDP, a measure of the importance of fisheries within the overall economy of a country, and the subsidies relative to landed value. Only a small proportion of trawling was assigned to occur in the EEZ waters of the Maldives resulting in a high (good) score for low trawling effort. This suggests that the fisheries of the Maldives may be sustainable in an economic sense. It also had the second highest ranking for the intention to protect marine mammal species. However, the Maldives scored the lowest

[3] Harper, O'Meara, Booth, Zeller and Pauly (2011) Fisheries catches for the Bay of Bengal Large Marine Ecosystem since 1950. Report to the Bay of Bengal Large Marine Ecosystem Project, prepared by the *Sea Around Us* Project, Fisheries Centre University of British Columbia, Vancouver, Canada.

for the area of MPAs within its EEZ waters and for seabird protection. Mariculture could not be evaluated as this activity is not pursued in this country. Thus, overall, the Maldives ranked highest compared to the other countries in the region, with major strengths in the use of sustainable fishing gears, and major shortcomings in the proportion of MPA coverage (although the Maldives is known to protect many areas for tourism and other non-extractive uses) and its intention to protect seabird species.

- **Myanmar:** Myanmar received five of the lowest scores. Myanmar makes a relatively small investment in the establishment of MPAs, a higher proportion of their catch comes from bottom trawling in its EEZ, it ranks fairly low in their commitment to uphold the FAO Code of Conduct and in their intention to protect marine mammal species, and its mariculture sector has a negative social impact. Additionally, Myanmar received very low scores for the low proportional area of MPAs within its EEZ and for the fact that its fisheries have a small economic impact factor relative to GDP. Conversely, it ranked highest for the ratio of ‘good’ to ‘good + bad’ subsidies, indicating that the majority of their subsidies fall in the ‘good’ category. Thus, overall, Myanmar ranked lowest (together with Indonesia) compared to the other countries in the region, with major strengths in the low ratio of capacity enhancing subsidies to total subsidies, and major shortcomings in MPA coverage and investment, the heavy use of trawling gear, marine mammal protection, commitment to uphold the FAO Code of Conduct, and the socioeconomic aspects of the mariculture sector.

- **Sri Lanka:** Sri Lanka received generally high scores across the board, except for the ecological impacts of mariculture and for the economic impact factor relative to GDP. It also received the highest ranking of all the Bay of Bengal countries for the proportion of catch from bottom trawling in its EEZ waters, suggesting that only a small proportion of their catch comes from trawling-type gears. It had one of the lower scores for intention to protect marine mammal species within EEZ waters. Thus, overall, Sri Lanka ranked fourth compared to the other countries in the region, with major strengths in the low proportional usage of trawling gear, and major shortcomings in the ecological sustainability of the mariculture sector.

- **Thailand:** Thailand received the highest score for its investment in MPAs. Despite this investment, it received the lowest score for the ratio of ‘good’ to ‘good + bad’ subsidies, suggesting a very heavy subsidization of the Thai fisheries. Additionally, it ranked second highest of the Bay of Bengal countries for intention to protect marine mammal species. Thus, overall, Thailand ranked fifth compared to the other countries in the region, with major strengths in investment to MPAs, and major shortcomings in the use of capacity enhancing subsidies.

In the work of Alder *et al.* (2010), none of the Bay of Bengal countries ranked amongst the top five with any of the GEO4 scenarios-based weightings. In general, out of 53 countries assessed in Alder *et al.* (2010), the countries that were ranked amongst the top five were developed countries. The top five countries that scored well under the *Market First* scenario were Poland, Senegal, South Africa, the U.S., and Spain and under the *Policy First* scenario were Poland, Senegal, Egypt, Spain, and South Africa. The *Security First* weightings ranked New Zealand, Peru, Iceland, the U.S., and Norway the highest, while Germany, Australia, Sweden, Denmark, and Spain were the highest ranked under the *Sustainability First* scenario.

In contrast, mostly developing countries accounted for the bottom five rankings. Bangladesh ranked fifth amongst the bottom five countries for each of the GEO4 scenario-based weightings. India received the third lowest ranking for the *Security First* scenario, and Myanmar received the second lowest ranking for the *Sustainability First* scenario. This is relatively consistent with the lower overall rankings of these countries when measured amongst the Bay of Bengal countries.

INTRODUCTION

With the state of the world's oceans increasingly perceived as problematic, the need for practical and comprehensive schemes to assess the health of ecosystems has increased (FAO, 2010). Many assessments to date have focused on single-species fisheries and their overall impact on marine resources, including socio-economic implications of such fishing activities (FRDC, 2007; MSC, 2007), but few have assessed the marine ecosystem comprehensively. Also, assessment datasets are rare, leading to a dearth of information for developing countries, where funds and/or technical expertise for such assessments may be lacking.

One region which is in need of such an assessment is the Bay of Bengal Large Marine Ecosystem (BOBLME), which is comprised of part or all of the Exclusive Economic Zone (EEZ) waters of: Bangladesh, India, Indonesia, Malaysia, the Maldives, Myanmar, Sri Lanka, and Thailand, and the High Seas waters north of 2°N (Figure 1)[4]. Over 400 million people in this region are dependent on coastal and marine resources for their food, livelihood and security. Rapid population growth, high dependence on resources, and increased land use has resulted in the overexploitation of fish stocks and habitat degradation, and has led to considerable uncertainty as to whether the ecosystem will be able to support the livelihoods of the coastal populations in the future. Most of the Bay of Bengal's resources are shared by two or more countries and therefore trans-boundary and multi-country collaboration is required to ensure their sustainable management and conservation.

Despite the large number of international, regional and sub-regional bodies and programs operating in the Bay, none have a clear mandate, geographical scope and/or capacity to support a regional initiative that would effectively address the issues confronting the coastal communities of the Bay of Bengal. Furthermore, the existence of many ineffective policies, strategies and legal measures at the national level would likely impede the development of any regional arrangements. Other major constraints include weak institutional capacity at national levels, insufficient budgetary commitments, and lack of community stakeholder consultation and empowerment.

It is in this context that the present study seeks to utilize a framework that was proposed to implicitly address the health of the ecosystem on a country-basis for many developed and

[4] This definition of the BOBLME is slightly larger than defined in other sources (e.g., in Sherman and Hempel, 2008; see also www.seaaroundus.org).

developing countries (Alder *et al.*, 2010). Alder *et al.* (2010) developed fourteen indicators of marine living resource management for 53 countries around the world. The countries that were selected accounted for over 95% of the global reported catch, and the indicators were developed to be reflective of the countries' intent to sustainably use the resource within the Exclusive Economic Zones (EEZs) and the effectiveness of their policies. The ranking of the 53 countries was computed using four different weighting schemes, corresponding to the Global Environment Outlook 4 (GEO4), i.e., *Market First*; *Policy First*; *Security First*; and *Sustainability First*. Rankings differed substantially between the scenarios for developed countries, but showed much less difference for developing countries.

All of the countries within the BOBLME, except for the Maldives, were part of Alder *et al.* (2010). Here, we compute twelve of the initial indicators for the BOBLME with updated information. Additionally, we present the Marine Trophic Index (MTI) and the Fishing-in-Balance (FiB) index. MTI provides a measure of whether 'fishing down the food web' is occurring in the system, and should always be interpreted in conjunction with the FiB index. The FiB index describes whether or not a fishery is expanding or contracting spatially. Finally, stock status plots (SSPs) for each country and for the Bay of Bengal region are presented, which provide a measure of the changes in biodiversity in the area.

The purpose of this work is to provide a baseline assessment of the sustainability of marine resource use within the BOBLME by each of the member countries, highlighting the strengths and weaknesses of each country. The intention is to be able to eventually gauge trends or improvements over time, some of which may be attributed to actions taken by the countries based on the initial assessment conducted here.

METHODS

The countries (and territories) evaluated in the original study by Alder *et al.* (2010) were selected as they jointly account for 95 percent of the world's marine fisheries landings since 1950, and for their assessment of compliance to the FAO Code of Conduct for Responsible Fisheries (Pitcher *et al.*, 2009). Coincidentally, all of the BOBLME countries presented here were part of Alder *et al.* (2010) except for the Maldives. Alder *et al.* (2010) assembled fourteen indicators, covering the period between 2000 and 2004, and assigned these to one of three categories ('biodiversity', 'value', or 'jobs').

For the purposes of the Bay of Bengal study, each of these indicators was reevaluated to determine whether the indicator could be improved or updated based on newly available data or methodologies. When possible, more current data were used to recalculate the indicators. From the original indicator list, two indicators were eliminated: fishmeal consumption by mariculture ($MEAL_{mar}$) and catch relative to fuel consumption ($CATCH_{fuel}$), mainly because it was felt that the relevant data available was too unreliable for the Bay of Bengal area. Hence, twelve of the original indicators, covering the period between 2003 and 2010, were computed for the Bay of Bengal LME region. To these twelve, we added two indicators not used by Alder *et al.* (2010): the Marine Trophic Index & Fishing in Balance Index (a combined index), and stock status plots. These indicators are listed below, and are elaborated on subsequently. In two instances, the indicator was renamed due to significant updates to the computational methodology.

Indicators used here, modified and updated from Alder *et al.* (2010):

Biodiversity-related indicators (b):

1. Marine protected area coverage (MPA_{area});
2. Investment to marine protected areas (MPA_{inv});
3. Proportion of bottom trawling[5] catch to neritic catch *(TRA_{prop})* — formerly change in EEZ area trawled *(EEZ_{trawl})*;
4. Ecological components of mariculture sustainability index (MSI_{ecol});
5. Seabird protection index ($BIRD_{prot}$);
6. Marine mammal protection index (MAM_{prot});
7. Marine Trophic Index and Fishing-in-Balance (MTI_{FiB});
8. Stock status plots (SS_{plot});

Value-related indicators (v):

9. Economic Impact Factor relative to GDP (EIF_{GDP}) — formerly landed value relative to GDP (LV_{GDP})[6];
10. Compliance with the FAO code of conduct ($CODE_{FAO}$);
11. Context-adjusted fisheries statistics indicator ($STAT_{rep}$);
12. 'Good' to 'Good + Bad' subsidies ratio (SUB_{good});

Job-related indicators (j):

13. Subsidies relative to landed value (SUB_{LV}); and
14. Socioeconomic components of mariculture sustainability index (MSI_{soc}).

[5] In areas other than the Bay of Bengal LME, this indicator may also include dredging, which modifies bottom habitats even more than bottom trawling (Chuenpagdee *et al.*, 2003).

[6] Economic Impact Factor relative to GDP (EIF_{GDP}) will be used mainly for temporal comparisons, and not so much for comparisons between countries (i.e., it is included to provide reference to the value of fisheries within a country's overall GDP, but should not really be used to compare between GDPs of different countries).

Marine protected area coverage (MPA_{area})

Marine protected area coverage is expressed as the area of officially designated MPAs relative to the area of that country's claimed EEZ. The relevant MPA data were taken from MPA Global (www.mpaglobal.org; (Wood *et al.*, 2008) and EEZ areas are from the *Sea Around Us* project (www.seaaroundus.org). Substantial updates were made to the MPA Global database prior to completing this report. First, for each country, the database was updated to include all MPAs designated through 2010. Secondly, some previously included reserves that were determined to be entirely terrestrial were removed from the database. Additionally, for every MPA listed, all of the information contained in the database was updated and checked for errors, most importantly with respect to the information available for the area of each MPA[7]. The indicator was ranked from zero to ten, corresponding to a range of zero to ten percent MPA coverage. Ten percent coverage was selected as an anchor in accordance with the CBD-stated conservation goal of protecting at least 10 percent of the world's marine coastal and ecological regions by 2012 (CBD, 2006).

Investment to marine protected areas (MPA_{inv})

Investment to marine protected areas is an index of the total annual expenditures, measured in terms of maintenance costs, of a country's MPAs relative to the value of the fisheries within its EEZ (Balmford *et al.*, 2004; Cullis-Suzuki and Pauly, 2010; McCrea-Strub *et al.*, 2010). The estimates of MPA costs were derived using the MPA data from Wood *et al.* (2008) and updated to 2010 using the methods described above. The values of fisheries landings are derived from the *Sea Around Us* project and represent landed values (Sumaila *et al.*, 2007).

A method for estimating the annual maintenance cost of an MPA, as originally developed by Balmford *et al.* (2004), was modified by McCrea-Strub *et al.* (2010). According to the resultant model, the annual cost of maintenance (MC) is log-linearly related to MPA size (A):

[7] As of May 2011, these updates to the MPA database have not all been included in www.mpaglobal.org.

$$\log_{10}(MC) = 5.25 - 0.21 \times \log_{10}(A) \quad (1)$$

where *MC* is expressed in 2006 USD and *A* is measured in terms of km^2. To determine total annual expenditure on MPAs by a particular country while accounting for the non-linear relationship between these costs and MPA sizes, maintenance cost was estimated for each MPA individually and then summed over all MPAs within the country.

Equation (1) provides approximate costs of MPAs for a developmentally 'average' country and fails to capture the variation in costs owing to the economic status of a country. Therefore, the estimates derived from the equation are improved using a two-step procedure. First, countries are grouped into five categories based on their per capita GDP using year 2006 estimates from the World Bank (www.worldbank.org), the International Monetary Fund (www.imf.org) and the World Factbook (https://www.cia.gov/library/publications/the-world-factbook/index.html). Then, a correction factor (Table 1) was applied to each estimate based on the median costs for developed and developing countries (Balmford *et al.*, 2004).

Proportion of bottom trawling catch to neritic catch (TRA_{prop})

Proportion of bottom trawling catch to neritic catch is an indicator of the amount of trawling effort by country standardized by the shelf area within the EEZ. Alder *et al.* (2010) used an indicator of change in the EEZ area trawled (EEZ_{trawl}) to capture the amount of change of the trawl fisheries within the EEZ. This serves as a proxy for the extent of marine habitat degradation from fishing gear, such as bottom trawls and dredges (hereafter referred to as "trawlers"), which greatly impact sea bottom structures (Chuenpagdee *et al.*, 2003). Alder *et al.* (2010) calculated this indicator as the relative changes in the area trawled from 2000 and 2004, standardized using the proportion of trawlers and dredgers in the total fleet (in Gross Registered Tonnage, GRT) based on the FAO fleet composition data (FAO, 2007). The formula for calculating EEZ_{trawl} was:

$$EEZ_{trawl} = (areatrawled_{2004} / areatrawled_{2000})/(1 - \%fleet_{trawled}/100) \quad (2)$$

This indicator can be biased due to the fact that change in area trawled does not account for the relative size of the shelf area over which trawling occurs, and the amount of trawling effort is not adequately captured by the proportion of trawlers in the fleet. For example, a country with 50%

trawling over 25% of the EEZ area that increases the area by 10% will score lower than a country with 50% trawling over 50% of the area that decreases the area by 10%.

A better proxy for capturing the amount of trawling occurring by country is the ratio of the catch from trawling (shrimp and other bottom trawls), dredging, and raking gears to the total catch of all neritic species (i.e., not including tuna, billfish and other large pelagic species which would not be caught by bottom trawling or similar gears). We calculate this updated indicator, TRA_{prop}, as:

$$TRA_{prop} = (\sum_{2000}^{2004} catch_{trawling} / 3)/(\sum_{2000}^{2004} catch_{neritic} / 3) \quad (3)$$

where $catch_{trawling}$ = the total tonnage of landed catch by trawling and dredging gear and $catch_{neritic}$ = the total tonnage of landed catch of neritic species[8]. Subsequently, the indicator is standardized from zero (worst) to ten (best), using the extreme values as anchors and scoring intermediate values proportionately.

Ecological components of mariculture sustainability index (MSI_{ecol})

The ecological components of mariculture sustainability index is an aggregate of six attributes (Table 2) indicative of the ecological impacts of mariculture (Trujillo, 2008). It is based on scores assessed for each species farmed, per country, aggregated using their relative production as weighting factors. All attributes were designed to be expressed within a range of one to ten. Only brackish water and marine mariculture from the Eastern Indian Ocean[9] and Asian inland waters was used to calculate the MSI_{ecol}. 'Asian inland waters' was included because in many instances, this designation refers to marine species raised in tanks on land (Pablo Trujillo, Fisheries Centre, UBC, pers. comm. May 2011).

Seabird protection index ($BIRD_{prot}$)

[8] Note that this indicator is an average of the last three years for which we have catch data (i.e., 2004-2006).

[9] The Maldives was not scored for this indicator because of the lack of mariculture there.

The seabird protection index is an indicator that quantifies the intention of maritime countries to protect seabird populations breeding in these countries, and gauges the effectiveness of the measures taken for such protection (Karpouzi *et al.*, 2007). Changes in seabird population trends and ecology have been used as indicators of (a) change in marine community structure and composition (Cairns, 1992; Litzgow *et al.*, 2002; Le Corre and Jacquemet, 2005); (b) habitat quality and variability (Springer *et al.*, 1996; Golet *et al.*, 2002); and (c) climate change (Bunce *et al.*, 2002; Weimerskirch *et al.*, 2003; Gaston *et al.*, 2005). This indicator is defined as the aggregate score of two attributes (Table 3): (1) conventions and agreements for seabird protection relevant to each country; and (2) percentage of seabird species with national breeding census data. Conventions are considered relevant to a country if it aims to protect native seabird species and/or the habitats that are used by native seabird species, which may include: The Convention of Biological Diversity (1993), Agreement on the Conservation of Albatrosses and Petrels (2004), RAMSAR Convention on Wetlands (1975), and Convention on Migratory Species (1979).

In previous calculations of this indicator, information on fluctuations in seabird population size was included as a measure of seabird health (i.e., a third attribute). We do not include these data on seabird populations in this index due to bias caused by increased sampling efficiency over time.

Marine mammal protection index (MAM_{prot})

The marine mammal protection index is a composite performance index that evaluates the performances of maritime countries based on three components of marine mammal protection: (1) degree of pressure exerted on marine mammal species through human activities (pressure); (2) their conservation status (state); and (3) the response of the government (response) in mitigating or preventing human-induced damages to marine mammal populations (Swartz *et al.*, 2008). It is based on six independent attributes, weighted to represent the three components equally (Table 4), as follows.

Targeted hunts:

The first attribute, targeted hunts, measures the most direct pressure on populations of marine mammals by human activities (Jackson *et al.*, 2001). Wild populations of cetaceans and pinnipeds have historically been reduced drastically by commercial hunting (Christensen, 2006) and targeted hunting continues despite concerns for the vulnerability of marine mammals (Anderson, 2001).

The FAO FishStat database includes data on marine mammal catch. However, the quality of these data is 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). The data on pinniped catches appears to be more reliable, but pinnipeds do not occur in the Bay of Bengal area. Therefore, we have modified this indicator by grouping marine mammals into two categories (small cetaceans and great whales) and scored the Bay of Bengal countries from zero to three for each marine mammal group based on available qualitative and quantitative descriptions of targeted hunting in each country (Table 5).

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

$$TH_c = th_{cetacean,c} + th_{whale,c} \tag{4}$$

where $th_{cetacean,c}$ = 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:

The second attribute, incidental kills, is meant to account for the bycatch of marine mammals, which occurs whenever the distribution of marine mammals overlaps in space and time with fisheries (Swartz *et al.*, 2008). Unlike commercial hunting, incidental kills of marine mammals are less traceable and the magnitude of their impact on marine mammals is harder to quantify. Despite a concerted effort to reduce bycatch, the increases in industrial fishing and proliferation of synthetic fishing gear implies that bycatch remains a significant threat to marine mammals (Reeves *et al.*, 2003; Reeves *et al.*, 2005; Read *et al.*, 2006). However, there is a serious lack of information regarding the amount of bycatch of marine mammals on a global scale. Therefore, the amount of gillnet use is used here as a proxy for the impact of bycatch (Watson *et al.*, 2006a) as it is perceived to have the highest impact on marine mammals among the commonly used gear (Hofman, 1995; Read *et al.*, 2006). In order to compare between countries, catches were expressed as catch per area of the EEZ. Indicator scores of incidental kills, IK_c are expressed as:

$$IK_{\mathrm{c}} = g_c / EEZ_c \qquad (5)$$

where g_c = total estimated gillnet-associated catch for 2006 in the EEZ of country *c*, and EEZ_c = total EEZ area of country *c*.

<u>Species extinction risk</u>:

The conservation status of a marine mammal species, particularly of small cetaceans, within an EEZ is particularly difficult to measure (Mulvaney and McKay, 2003). The IUCN Red List (IUCN, 2011) provides a measure of this risk. However, 40 marine mammal species on this list are still categorized as 'data deficient.' Additionally, many of the assessments have not been updated. Despite these issues, we used the Red List status to score species within the EEZ waters of the Bay of Bengal countries (Table 6).

The proportion of the species distributions that fall within the EEZs (Kaschner, 2004) were used 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. The extinction risk factor for a country, ER_c, is therefore expressed as:

$$ER_c = \sum_{i=1}^{n_c} s_i w_i / \sum_{i=1}^{n_c} w_i \qquad (6)$$

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

Species abundance:

As previously noted, the historical overexploitation of marine mammals has reduced the population size of many marine mammals greatly, and recovery of many of these species has been slow if at all. Therefore a proxy indicator for species abundance was developed from relative abundance estimates of historically exploited marine mammal species (Christensen, 2006). Similarly to the extinction risk indicator, weighting based on the species distributions was used to compute the aggregated species abundance score, SA_c, for each country:

$$SA_c = \sum_{i=1}^{n_c} a_i w_i / \sum_{i=1}^{n_c} w_i \quad (7)$$

where n_c = number of marine mammal species found within the EEZ of country c, a_i = relative abundance of marine mammal species i, and w_i = the proportion of mammal species i's habitat occurring within the EEZ.

It should be noted that the estimates of percent depletion of Christensen (2006) were computed from the reconstructions of historical abundances using reported catches, which tend to be underestimates. Also, Christensen (2006) used, for her population reconstruction, a model which tends to overestimate the growth of formerly depleted populations (Linne Christensen, FC, UBC, pers. comm. 2006). Therefore, the percentage depletions obtained in Christensen (2006) by contrasting present and unexploited populations may have been underestimated. Additionally, the population size of species for which no directed hunts were performed (and/or catches available) were assumed constant, which is also likely to be a conservative assumption.

International treaties:

Because of the widespread nature of most marine mammal species, international mechanisms for the protection of these species have been established. As an indicator of national responses to marine mammal protection, we have assessed the participation of each of the countries in seven international treaties: the International Convention for the Regulation of Whaling (2011e), the

Antarctic Treaty (2011a), the Convention for the Conservation of Antarctic Seals (2011a), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (2011c), the Convention on the Conservation of Migratory Species of Wild Animals (2011d), the Protocol on Environmental Protection to the Antarctic Treaty (2011a), and the Convention on Biological Diversity (2011b). Each of these treaties has relevance to marine mammal conservation 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.

The Antarctic Treaty, the Convention for the Conservation of Antarctic Seals, and the Protocol on Environmental Protection to the Antarctic Treaty jointly represent the Antarctic Treaty System and are included because of the international interest in the 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); and IWC (www.iwcoffice.org).

While participation in international treaties by itself is simply a measure of intent rather than performance, similar use of treaties to gauge ‘environmentalism’ has been used by Dietz (1992), Alder and Lugten (2002) and Roberts *et al.* (2004). The scoring system used here differentiates the signature and ratification of treaties from the objections raised to relevant treaties (Table 7). This is an attempt to better capture the varying degrees of commitments by a country.

No weighting between conventions was applied; however, the three treaties of the Antarctic Treaty System were aggregated so that they were weighted equally to other treaties as a system of treaties. The indicator score for the international treaties, IT_c, is calculated as:

$$IT_c = 10\left[\frac{IT_{CBD,c}}{IT_{CBD,\max}} + \frac{IT_{CITES,c}}{IT_{CITES,\max}} + \frac{IT_{CMS,c}}{IT_{CMS,\max}} + \frac{IT_{ICRW,c}}{IT_{ICRW,\max}} + \frac{IT_{ANT,c}}{IT_{ANT,\max}}\right] \quad (8)$$

where $IT_{X,c}$ = country *c*’s score for participation in treaty *x*, and $IT_{X,max}$ = the maximum possible score for participation in treaty *x* (i.e., 3).

Domestic policies:

Due to the tremendous variation in conservation strategies (e.g., restriction on kills, habitat protection, and pollution control) and the lack of an up-to-date comprehensive compilation of national marine mammal legislation (Marashi, 1986), we use the size of the MPAs with specific protections for marine mammals in each country as a proxy for the willingness to act on conservation domestically. With the number of MPAs rising in recent decades (Wood *et al.*, 2008), they are increasingly used as an essential tool in the conservation of marine mammals (Reeves *et al.*, 2003; Hoyt, 2005). The domestic policies score, DP_c, for a country is expressed as:

$$DP_c = \frac{MPA_c}{EEZ_c} \quad (9)$$

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

Each of the six attributes outlined above was tested for normality using:

$$S = \frac{n}{(n-1)(n-2)} \sum \left(\frac{x_i - \bar{x}}{s} \right)^3 \qquad (10)$$

If considerable skewness in the distribution of indicator variables was observed (|*S*|>2), the extreme values were standardized through the use of a logarithmic transformation. The attributes were then transformed to a common scale comparable to the final scale of the index (Swartz *et al.*, 2008). This method uses the highest (leader) and lowest (laggard) values as benchmarks to standardize the attributes to a scale from zero to ten, from worst performance to best performance, using the 'minimum-maximum' technique:

$$10\left(\frac{actual\,value - \min value}{\max value - \min value}\right) \qquad (11)$$

Therefore, the final MAM_{prot} value is an ordinate score of marine mammal protection performance of a country relative to best and worst performances among the countries evaluated, and will vary between assessments depending on the countries selected. All of the variables were equally weighted for the construction of the composite MAM_{prot} index.

Marine Trophic Index and Fishing-in-Balance (MTI_{FiB})

The marine trophic index was developed, based on the assumption that a decline of the mean trophic level of fisheries catch (mTL = MTI) is generally due to a fisheries-induced reduction of the biomass and hence biodiversity of vulnerable top predators (Pauly *et al.*, 1998). The MTI tracks changes of mean trophic level (mTL), defined for year *k* as:

$$MTI_k = \sum (Y_{ik} \times TL_i) \qquad (12)$$

where Y_{ik} is the catch of species *i* in year *k*, and TL_i the trophic level of species (or group) *i*, the latter usually obtained from the diet composition studies in FishBase (www.fishbase.org).

Usually, MTI declines as the result of fishing pressure being focused on the higher trophic levels at the start of the fishery, which is then replaced by pressure on the lower trophic levels as the abundance of high trophic level species declines. Therefore the MTI is an index of the biodiversity of the top predators. For this reason, MTI is calculated for the trophic levels greater than 3.5, at least in more recent contributions. Furthermore, tunas and billfishes are excluded as well, to ensure that MTI evaluations do not mix ecosystems, such as that exploited by neritic fisheries (the shelf, by definition) and the adjacent oceanic areas, usually exploited by fisheries for large pelagic fishes (see, e.g., Bhathal and Pauly 2008).

The effect of geographic expansion on the trophic level of catch was first analyzed with an index called Fishing-in-Balance (FiB). This index was developed to address the data problem that may occur when the decline in MTI is attributable to the deliberate choice of targeting low trophic level species. In this case, one might assume that fishers may choose to fish lower in the food web because biological production is higher at lower trophic levels (Pauly *et al.*, 2000b). If the choice to fish lower in the food web is deliberate, one would expect there to be a proportional increase in the catch volume that is commensurate with the decline in MTI. This lead to development of the FiB (Pauly *et al.*, 2000a), defined for any year *k*:

$$FIB_k = \log\left[Y_k \times (1/TE)^{TL_k}\right] - \log\left[Y_0 \times (1/TE)^{TL_0}\right] \quad (13)$$

where *Y* is the catch, *TL* is the mean trophic level in the catch, *TE* is the transfer efficiency between trophic levels (generally assumed to be 10%), and 0 refers to the year used as a baseline (generally 1950). This index should:

- remain constant (= 0) if the fishery is ‘balanced’ i.e., all trophic level changes are matched by ‘ecologically equivalent’ changes in catch;
- increase (>0) if there are (a) bottom-up effects (e.g., an increase in primary production), as described in Caddy *et al.* (1998), or (b) geographic expansion of the fishery to new waters which in effect expands the ecosystem exploited by the fishery; or
- decrease (<0) if discarding occurs that is not represented in the catch, or if the ecosystem functioning is impaired by the removal of excessive levels of biomass.

The FiB is an index which is meant to be viewed jointly with the MTI, whose interpretation it is supposed to facilitate. However, few if any authors account for changes in the FiB index when they examine trends in MTI. If they did, they would notice that, generally, MTIs fail to decline in regions where the FiB index increases, suggesting that spatial expansion is causing the maintenance of MTI.

Stock status plots (SS_{plot})

Stock status plots are used to assess the status of stocks by number of stocks and by catch biomass (3-year running average values) since 1950. A review of the development of the SSPs was recently completed (Kleisner and Pauly, 2011). The number of 'stocks' is defined as a catch time series of a given species, genus or family (higher and pooled groups have been excluded) for which the first and last reported landings are at least 10 years apart, for which there are at least 5 years of consecutive catches and for which the catch in a given area is at least 1000 tonnes. Table (8) describes the stock-status categories, which all refer to the maximum catch (i.e., peak catch) or the post-peak minimum in each catch time series.

The SSPs presented here improve on previous versions of the plots in that 'undeveloped' and 'developing' were grouped into a single 'developing' category, and stocks which have a peak in catch in the final year of the time series are classified as 'developing,' thus addressing the previously expressed concern of earlier definitions not having 'undeveloped' or 'developing' stocks in the final year of the time series. Additionally, a new category called 'rebuilding' was created to address criticism that, in cases where stocks have recovered (e.g., through management actions), the stock status plots do not take stock recovery into account (Branch, 2008).

Economic Impact Factor relative to GDP (EIF_{GDP})

The economic impact factor relative to GDP is expressed as the total output in an economy that is dependent (at least partially) on current fisheries output (the economic impact of the fisheries sector of a country) relative to its Gross Domestic Product (GDP). This indicator represents a modification of the landed value relative to GDP (LV_{GDP}) economic indicator used by Alder *et al.* (2010). LV_{GDP} was used previously as earlier studies found a general trend of well-managed fisheries when fisheries are a significant contributor to GDP as seen in developed countries (Hannesson, 1996). However, Dyck and Sumaila (2010) have shown that generally, for many countries, the fishing industry contributes a relatively small amount to GDP, with most countries only reporting fisheries contributions of less than 1%. Because fisheries output affects a number of different resource and employment sectors, the importance of this industry to the economy may be understated when considering only the direct values obtained, for example, landed value

(Sumaila *et al.*, 2007; Willmann *et al.*, 2009). The Economic Impact Factor (EIF) therefore builds on landed value, or the direct economic value of fisheries sector output, and reveals a more complete picture of the contribution of fisheries to the economy of a country. The EIF for each country for 2003 is calculated following the method of Dyck and Sumaila (2010), which is based on the input-output analysis technique (Leontief, 1966). These values are divided by 2003 GDP estimates from the World Bank (www.worldbank.org), the International Monetary Fund (www.imf.org) and the World Factbook (https://www.cia.gov/library/publications/the-world-factbook/index.html).

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

The compliance with the FAO Code of Conduct is an indicator based on a systematic scoring of a country's level of compliance with Article 7 (Fisheries Management) of the FAO Code of Conduct for Responsible Fisheries (Pitcher *et al.*, 2009). The scoring is based on 44 semi-quantitative questions, which have been developed to better cover all of the code's issues and themes while maintaining a balance between the various clauses (Pitcher *et al.*, 2006). The questions fall under six topics: (1) management objectives; (2) framework (data and procedures); (3) precautionary approach; (4) stocks, fleets, and gears; (5) social and economic; and (6) monitoring, control, and surveillance (MCS). Each of the questions is scored on a scale from zero to ten, with the answers to the questions based on published and unpublished literature, and expert opinion (Pitcher *et al.*, 2009). Compilation of the final scores by country is based on a method of ordination analysis using a rapid appraisal technique, Rapfish (Pitcher and Preikshot, 1999). Rapfish is an anchored non-parametric ordination technique for the rapid appraisal of fishery status in relation to some defined goal or norm (Pitcher, 1999).

Context-adjusted fisheries statistics indicator ($STAT_{rep}$)

The context-adjusted fisheries statistics indictor assesses the quality of each country's reporting system in a regional context through the percentage of reported commercial taxa to commercial, but unreported taxa occurring in a country's EEZ (Pauly and Watson, 2008). The ecological distribution range map of a given reported commercial taxon will overlap with the EEZ of at least one country in a particular region, and will often overlap with the EEZs of other countries. The fact that different countries may report the same fish or invertebrates at different taxonomic levels is also accounted for (Pauly and Watson, 2008).

To be counted as a species from a country, at least ten percent of the distribution map must overlap with a country's EEZ, where it may be reported in the catch of that country, or not. The non-reporting of a particular species within a particular EEZ may be due to the fact that the species is caught as unreported bycatch (i.e., not a target species) and/or because there is poor data collection and monitoring of fisheries landings by the country. It is the severity of the latter of these issues that this indicator attempts to capture. The strength of this indicator is that it is 'regional', due to the underlying distributions of the species in a particular area. In other words, a species that occurs in a country within the Bay of Bengal area should show up in the catch of the other countries in the area, if its ecological distribution allows. Data are derived from the spatially allocated *Sea Around Us* catches (Watson *et al.*, 2004) and species distributions outlined in Close *et al.* (2006).

'Good' to 'Good + Bad' subsidy ratio (SUB_{good})

The 'good' to 'good + bad' subsidy ratio indicator measures the financial resources allocated to subsidies that are beneficial (i.e., 'good') for sustainability versus those that are harmful (i.e., 'bad'). Examples of good subsidies are monies allocated to fisheries management, research, and maintenance of MPAs, and which do not contribute to capacity enhancement. Some examples of harmful subsidies (i.e., those which are capacity enhancing) are boat construction, renewal, and modernization subsidies; fishery development and support services; fishing port construction and renovation; marketing support and storage infrastructure; tax exemptions; foreign access agreements; and fuel subsidies. The ratio of good subsidies to the sum of good and bad subsidies represents efforts towards fisheries management, services and research, and therefore can be expected to improve the sustainability of fisheries. The subsidies refer only to marine capture fisheries and were based on both reported and estimated data (Khan *et al.*, 2006). Subsidies data are derived for the year 2003 from Sumaila *et al.* (2010). The index is standardized from zero to ten using the 'minimum-maximum' technique described in equation 5.

Subsidies relative to landed value (SUB_{LV})

Subsidies relative to landed value are computed from total subsidies relative to the value of the catch (Sumaila and Pauly, 2006), expressed on a scale from zero to ten as detailed in Mondoux *et al.* (2008). Countries with higher levels of subsidies relative to the value of the landings have less incentive to manage their fisheries sustainably (Sumaila and Pauly, 2006). Total subsidies data are derived for the year 2003 from Sumaila *et al.* (2010) and landed values for 2003 (expressed in year 2003 USD) from Dyck and Sumaila (2010).

Socioeconomic components of the mariculture sustainability index (MSI_{soc})

Socioeconomic components of the mariculture sustainability index is an aggregate of six attributes (Table 9), which relate to the socio-economic aspects of mariculture as identified and described by Trujillo (2008).

Similar to MSI_{ecol}, only mariculture from brackish water and marine sources from the Eastern Indian Ocean and the Asian inland waters (see above) as reported to FAO were used to calculate MSI_{soc}. The attribute scores are determined for each species, with the aggregate score for a country computed from the relative weight of their annual production of the various farmed species. All attributes were designed to be expressed within a range of one to ten. The Maldives was not scored for this indicator because there is no mariculture in this country.

Aggregate scoring of all indicators

An aggregate score for each country was computed as the average score of the 12 ranked indicators described above (for the Maldives, the aggregate score was computed without MSI_{ecol} and MSI_{soc}). Other approaches could be taken to derive an aggregate score, e.g., through varying weighting schemes of the indicators. However, weighting of indicators is largely subjective. Thus, persons concerned with conservation may weigh indicators associated with seabirds and marine mammals higher than people who are interested in fisheries or mariculture development. To deal with this issue, we weighted the indicators by mapping the global scenarios used in the GEO4 to the 12 ranked indicators in this study (Table 10). The weights used in the GEO4 are based on consensus among country experts participating in the GEO4 process in 2006. The current four GEO4 scenarios represent four plausible futures for the world in terms of economic development, social policies, technological advances and ecosystem management. As the names suggest, the *Market First* future is focused on using economic policies to drive development, including economic incentives to improve environmental management and technology to mitigate impacts. In the *Policy First* future, the focus is on the economic and social policies that facilitate development and on overriding environmental concerns. In the *Security First* future, it is the rich and powerful countries that seek to optimize their economic and social well-being; they support environmental policies only if it is in their benefit to do so. Finally, in the *Sustainability First* future, the environmental and social policies are balanced.

RESULTS

Bangladesh

Biodiversity

- **MPAs:** Bangladesh is fifth in terms of percentage of EEZ area protected, with 0.053% protected (Table 11). A total of 1,394 km^2 is protected, at an estimated annual cost of 3.5 million USD. This is 6.5% of the total expenditure by all Bay of Bengal LME countries on MPAs.
- **Trawling:** Bangladesh has relatively little catch from trawling and dredging relative to the total neritic catch within its EEZ waters, approximately 5% (Table 12). This is reflected in the relatively high score for this indicator (assigned comparatively within the Bay of Bengal countries).
- **Mariculture:** Mariculture production in Bangladesh is mainly for penaeid shrimp species. The score for the production of this species is relatively low because the production has intense effects on the local environment, the origin of the larvae is largely unknown, the use of fishmeal is relatively heavy, the species are not always native, and there are few, if any waste water treatment facilities (Table 13). Bangladesh has the lowest score for MSI_{ecol} of the Bay of Bengal LME countries (Table 14).
- **Seabirds:** Bangladesh receives the highest score for $BIRD_{prot}$ of all the Bay of Bengal LME countries. Bangladesh receives a 10 for the first attribute because it has ratified the CBD, RAMSAR, and CMS, which are the only three treaties relevant for this country (Table 15). Bangladesh also has the highest proportion of seabirds in its national census relative to those appearing on the AVIBASE checklist (Table 16).
- **Marine mammals:** Table 17 displays the scores for each component of the marine mammal protection indicator (MAM_{prot}). There is no recorded targeted hunting (TH) for marine mammals in Bangladeshi waters; therefore Bangladesh received the highest score for this component of MAM_{prot}. The ratio of gillnet catch to total catch was also very low, contributing to the high (good) score for incidental kills (IK). Additionally, Bangladesh has just under 1,400 km^2 of MPAs that have some designation for marine mammal protection, the third largest proportion of marine mammal MPA coverage to EEZ area of the Bay of Bengal countries. Bangladesh has not ratified any of the treaties of the Antarctic treaty system, but has ratified the Convention on International Trade in Endangered Species of Wild Fauna and Flora, the Convention on the Conservation of Migratory Species of Wild Animals, and the Convention on Biological Diversity. Unfortunately, Bangladesh has a very

high proportion of threatened and endangered species and low overall levels of abundance for the marine mammal species within its waters, which acts to drive down the MAM_{prot} score to third within the ranking of the countries.

- **MTI:** The graph of MTI shows a significant decline in trophic level from the mid-1970s where it was greater than 4.0 to the mid-1980s when it was 2.0 (Figure 2). The gap in the graph from 1975 to 1983 occurs because the only fish recorded as caught in the Bangladesh EEZ are from the Bangladesh fleet and recorded as 'Miscellaneous fishes not identified.' Since the mid-1980s, although half of what it was in the 1950s, the trophic level has remained fairly constant. The FiB index shows that there has been little spatial expansion by the Bangladeshi fleet. In fact, according to the catch data recorded, the Bangladeshi fleet has not fished outside its EEZ waters. Therefore, the decline in trophic level displayed by the MTI graph is likely an accurate reflection of what is actually occurring. However, the recent data say little about the 'within country' spatial expansion patterns over time.
- **SSPs:** Stocks within the EEZ waters of Bangladesh were exploited from the 1950s (Figure 10). About 50% of the stocks fished in EEZ of Bangladesh were over exploited in the 1960s, and several stocks were collapsed in the early 1970s. Since the mid-1980s, approximately 20% of the fished stocks are in a collapsed state. The graph of catch by stock status shows a more benign picture in that most of the catch comes from stocks that are developing. Since the late 1990s, approximately 50% of the catch has come from stocks that are considered to be in an exploited stage.

Value

- The economic impact of the fisheries sector is weak in Bangladesh due to the importance of other sectors such as agriculture, therefore the score for EIF_{GDP} is 3rd lowest amongst the Bay of Bengal countries (Table 18). Bangladesh scored 2nd lowest for its compliance with the FAO Code of Conduct (Table 19). This low score stems from a lack of concrete management policy, inadequate infrastructure and monetary allocation to scattered fishing centers, and a need for stricter controls in domestic fisheries through mesh size regulations and banning of destructive fishing practices such as push nets and bag nets. The level of taxonomic reporting is very low in Bangladesh with only 5% of potentially distributed taxa reported at the species level in the catch statistics (Table 20). The proportion of capacity enhancing subsidies (bad subsidies) was relatively low resulting in a higher (better) score (Table 23). This is surprising given that Bangladesh is classified as a Least Developed Country (LDC), and as such is not expected to phase out subsidies as quickly as more developed countries.

Jobs

- The fisheries subsidies relative to landed value indicator was very high indicating a lack of incentive to adequately manage fisheries (Table 24). However, as mentioned previously, given Bangladesh's status as an LDC, fisheries subsidies are unlikely to be phased out quickly. Mariculture production in Bangladesh is mainly for penaeid shrimp species. The score for the production of this species is lower because there is high antibiotic drug use and low traceability (Table 25). Bangladesh and Myanmar have the lowest score for MSI_{soc} of the Bay of Bengal LME countries (Table 26).

India

Biodiversity

- **MPAs:** India protects the most area in terms of overall area protected and percentage of EEZ waters protected. Of its 1,424,000 km^2 EEZ area, 12,276 km^2, or 0.47% is protected (Table 11), at an estimated annual cost of 14.5 million USD. This is 27% of the total expenditure by all Bay of Bengal LME countries on MPAs.
- **Trawling:** India has some of the greatest catch from trawling and dredging gears within its EEZ waters. The proportion of trawling and dredging catch to total neritic catch is 35% (Table 12).
- **Mariculture:** Mariculture production in India is mainly for giant tiger prawns. The score for the production of this species is relatively low because it has intense effects on the local environment, the origin of the larvae is largely unknown, the use of fishmeal is relatively heavy, and there is little use of wastewater treatment facilities. However, this species receives a higher score because it is native (Table 13). Like Bangladesh, India has a relatively low score overall for MSI_{ecol} due to the fact that the mariculture of giant tiger prawns is relatively intense (Table 14).
- **Seabirds:** India received the second highest score for $BIRD_{prot}$. India received a 10 for the first attribute because it has ratified the CBD, RAMSAR, and CMS, which are the only three treaties relevant for this country (Table 15). India also has the second highest proportion (with Sri Lanka) of seabirds in its national census relative to those appearing on the AVIBASE checklist (Table 16).
- **Marine mammals:** India was ranked highest for overall marine mammal protection within their EEZ waters (Table 17). India performs well in terms of international treaties signed and ratified as the only country to have ratified all seven of the applicable treaties. India

has also specified marine mammal protection in 17,235 km^2 of its MPA network, the most of any country. The reporting of some targeted hunting, intermediate numbers of threatened and endangered species, and intermediate levels of abundance of the marine mammal species within their EEZ detract from the lower overall MA_{Mprot} score.

- **MTI:** The graph of MTI for India shows that while trophic level declined until the late 1960s, it steadily increased through the 1980s and has remained relatively constant until the present day (Figure 3). The FiB index highlights the expansion that occurred in the fishery from the mid-1970s through the 1990s and therefore points to the fact that the MTI may have increased due to geographic expansion of the fleet offshore. Bhathal and Pauly (2008) have shown that the geographic expansion of the fisheries have been able to maintain the landings of higher trophic level fish. They point out that until the early 1970s, the Indian fleets exploited only the coastal waters. Now, they are fishing to the edges of the continental shelf and beyond.
- **SSPs:** The stock-status plots for India reveal that, in general, the number of stocks in increasingly more exploited categories has risen (Figure 11). However, since about 2000, these levels have tended to stabilize and since the mid 1980s, there have been a small, but increasing percentage of stocks that are rebuilding. Increasingly the majority of the catch is taken from stocks that are exploited, with the catch of over exploited stocks increasing, but still low (less than 10% of the total catch).

Value

- Fisheries play a major role in the local and national economy with an estimated annual growth rate of around 6% and there are approximately seven million fishermen with one-third depending on marine fisheries for their livelihood. Despite this, the contribution of fisheries is about 1.5% of the GDP and India has a low score for the economic impact of its fisheries relative to its GDP (Table 18). India scored second highest of the Bay of Bengal for their adherence to the FAO Code of Conduct (Table 19). This stems mainly from the fact that the Central Marine Fisheries Research Institute, the leading institution for marine fisheries research in India, regularly assesses the 47 commercially important finfish and shellfish resources, and there have been some attempts to monitor illegal fishing and estimate levels of bycatch and discarding. The level of reporting the highest of the Bay of Bengal countries, with 73% of the potentially distributed taxa present in the reported catch statistics (Table 20). India has a relatively high proportion of capacity enhancing subsidies (e.g., fuel subsidies for motorized vessels quantified by Mathew (2003) indicating that the fleet suffers from overcapacity (Table 23).

Jobs

- Fisheries subsidies relative to landed values are relatively high in India, resulting in the 3rd lowest score for this indicator, and indicating that there may be less incentive overall to manage fisheries and reduce capacity (Table 24). Mariculture production in India is mainly for giant tiger prawns. The score for the production of this species is not higher than five because the production is used mainly for export and there is a high level of antibiotic drug use (Table 25). However, this species receives a high score because it is native. Like Bangladesh, India has a similar score overall for MSI_{soc} due to the mariculture of giant tiger prawns being relatively intense (Table 26).

Indonesia

Biodiversity

- **MPAs:** Indonesia is second in terms of percentage of EEZ area protected, with 0.19% protected (Table 11). A total of 5,000 km^2 is protected, at an estimated annual cost of 6 million USD. This is 12% of the total expenditure by all Bay of Bengal countries on MPAs.
- **Trawling:** Trawling was a commonly used gear type in western Indonesian waters starting in the 1970s. However, a trawl ban was implemented in 1980 due to resource access conflicts between trawl operators and small-scale artisanal fishers (Buchary, 1999; Butcher, 2004). Our presentation of catch by gear type does not take this ban into account, as we use globally derived taxon-gear associations (Watson *et al.*, 2006a2006b). Therefore, the fact that our data suggest that trawling accounts for nearly 40% of the catch landed should be interpreted with caution. Nevertheless, trawling gears are likely still in use in the offshore regions, having moved offshore after the ban to target pelagic species rather than shrimp and their associated inshore fish fauna (Daniel Pauly, pers. observation.). Therefore, Indonesia’s low score for this indicator may somewhat overstate bottom-trawling impacts (Table 12).
- **Mariculture:** Indonesia cultures banana prawns, giant tiger prawns, barramundi, and milkfish, all of which are native species (Table 13). The largest yields are of milkfish, a species whose culture is relatively benign in terms of environmental impacts. The large quantity of milkfish contributes to the relatively high score Indonesia receives overall for MSI_{ecol} (Table 14).
- **Seabirds:** Indonesia received the second lowest score for $BIRD_{prot}$ amongst the Bay of Bengal LME countries. The CBD, ACAP, RAMSAR, and CMS are relevant for Indonesia,

however, only the CBD and RAMSAR were ratified (Table 15). Also, Indonesia records no species in national census data out of 45 relevant species found in AVIBASE (Table 16).

- **Marine mammals:** Indonesia has one of the lowest scores for MAM_{prot} of the Bay of Bengal countries (Table 17). The main drivers of this low score are the fact that it has the highest proportion of gillnet related catch and have no specific MPAs designated to protecting marine mammals. Additionally, it only ratified the Convention on International Trade in Endangered Species of Wild Fauna and Flora and the Convention on Biological Diversity. Indonesia reports (with Sri Lanka) some of the highest levels of targeted hunting of marine mammals within their EEZ. It has intermediate rankings for threatened and endangered species and for levels of abundance of the marine mammal species, which detracts from their overall MAM_{prot} score.
- **MTI:** According to the graph of MTI, the trophic level of fish caught off of western Indonesia declined dramatically in the late 1970s and then increased from the mid 1980s for about a decade (Figure 4). Trophic levels then tended to remain constant through 2006. Like India, Indonesia has greatly expanded the extent of its fishing spatially, mainly through increases in engine horsepower and technological advancements, and this is reflected by the FiB index. However, given the relatively small area of Indonesian EEZ that is included in the Bay of Bengal LME, the present data need to be viewed with caution, as they are derived from *Sea Around Us* project spatial allocation approaches that apply to the entire EEZ (Watson *et al.*, 2004).
- **SSPs:** Similar to India, the number of stocks in increasingly more exploited categories has risen (Figure 12). Since about 2000, the numbers of stocks that are in the exploited category have tended to stabilize. Since the late 1980s, there have been a small, but increasing percentage of stocks that are rebuilding. Increasingly, the majority of the catch is taken from stocks that are fully exploited, with the catch of over exploited stocks increasing since the late 1990s, but still low (just over 10% of the total catch).

Value

- The economic impact of the fisheries sector is weak in Indonesia due to the importance of other sectors such as agriculture; therefore the score for EIF_{GDP} is low (Table 18). Indonesia scored 3rd lowest for its compliance with the FAO Code of Conduct (Table 19). This low score stems from weak fisheries management with no clear recommendations for controlling catches and effort, a lack of enforcement, and a huge proportion of illegal and unreported catches by both foreign and national fishing vessels. Overall the compliance report found that “most Indonesian marine ecosystems exhibit such severe symptoms of over-fishing that the prognosis is poor for seafood security" (Buchary, 1999). Taxonomic reporting is relatively high in Indonesia, with 45% of the potentially distributed taxa reported in the catch statistics (Table 20). Incidentally, it is important to note that although ranked only 7th in annual catch using FAO's official catch statistics, the true Indonesian catch would likely put Indonesia among the top three fishing countries. The proportion of bad, capacity-enhancing subsidies in Indonesia is relatively high resulting in the 3rd lowest score for SUB_{good}.

Jobs

- Like Bangladesh, the fisheries subsidies relative to landed value indicator was very high indicating a lack of incentive to adequately manage fisheries (Table 24). Indonesia raises banana prawns, giant tiger prawns, barramundi, and milkfish. The largest yields from mariculture are of milkfish, which has a low-mid score of 3.8. Overall, milkfish is fairly benign in terms of social impacts (Table 25). The large quantity of milkfish contribute to the second highest score Indonesia receives overall for MSI_{soc} (Table 26).

Malaysia

Biodiversity

- **MPAs:** Malaysia is sixth in terms of percentage of EEZ area protected, with 0.013% protected (Table 11). A total of 345 km^2 is protected, which represents an annual cost of 5.7 million USD, or 8.3 % of the total expenditure by all Bay of Bengal countries on MPAs.
- **Trawling:** Approximately 35% of the catch from Malaysia is from trawling and dredging gear (Table 12). This results in a relatively low score for TRA_{prop} for this country.
- **Mariculture:** Malaysia raises a small amount of banana prawns and cupped oyster species, and a large amount of blood cockles (Table 13). Other species reared are giant tiger prawns and barramundi. The blood cockle and cupped oyster mariculture receive relatively high scores due to low impact on the surrounding environment, low fishmeal usage, and the treatment of the waste from these systems. Because of the large amount of higher scoring blood cockles produced, Malaysia scores the highest for the MSI_{ecol} indicator (Table 14).
- **Seabirds:** Malaysia received a low score for $BIRD_{prot}$. Malaysia ratified the CBD and the RAMSAR treaties, but did not ratify the CMS (Table 15). It records no species in national censuses although at least 39 seabird species occur in this country (Table 16).

- **Marine mammals:** Table 17 displays the scores for each component of the marine mammal protection indicator (MAM_{prot}). Malaysia reports no targeted hunting of marine mammals, and has the lowest ratio of gillnet related catch to catch from other gears. Despite this, Malaysia has a very high proportion of threatened and endangered marine mammal species in its waters and the lowest abundances of these species relative to their distributions. They, like Indonesia, have no specific MPAs designated to protecting marine mammals and only ratified the Convention on International Trade in Endangered Species of Wild Fauna and Flora and the Convention on Biological Diversity.
- **MTI:** Malaysia has fished within its own waters and the waters of Singapore since 1950. In 1982, it began accessing the high seas waters. It is in the early 1980s when the trophic level begins to increase, and this trend has continued through 2006 (Figure 5). General expansion in the fishery begins in the early 1970s, likely in response to the declining trend in trophic level from the mid-1960s. However, given the relatively small area of Malaysian EEZ that is included in the Bay of Bengal LME, the present data need to be viewed with caution, as they are derived from *Sea Around Us* project spatial allocation approaches that apply to the entire EEZ, based on Watson *et al.* (2004).
- **SSPs:** Similar to India and Indonesia, the number of stocks in increasingly more exploited categories has risen (Figure 13). Since about 2000, the numbers of stocks that are in the fully exploited category have tended to stabilize. Since the early 1980s, there have been a small, but increasing percentage of stocks that are rebuilding. Increasingly the majority of the catch is taken from stocks that are exploited, with the catch of over exploited stocks increasing since the late 1990s. However, the catch from over exploited stocks represents just over 10% of the total catch. The catch from collapsed stocks was just under 10% from the early 1980s to the late 1990s. The catch from exploited stocks appears to have been replaced by catch from rebuilding stocks from the late 1990s through 2006.

Value

- The economic impact of the Malaysian fisheries is high (Table 18), which is not surprising given the high level of investment to fisheries management described by the FAO Code of Conduct evaluation (Pitcher *et al.*, 2006). Incidentally, Malaysia scores highest for the FAO_{code} indicator (Table 19), however, this report should be viewed with caution as there are several conflicting viewpoints (i.e., considerable investment to fisheries management and notable attempts to reduce total fishing effort versus the heavy use of destructive fishing methods such as dynamite fishing and trawling). Of the potentially distributed taxa, 32% are reported in the catch statistics, the third best reporting of the Bay of Bengal countries (Table 20). Despite the FAO Code of Conduct evaluation finding that in general Malaysia has attempted to reduce fishing effort, the country does provide relatively large capacity-enhancing subsidies (Table 23).

Jobs

- Malaysia's ratio of subsidies relative to landed value is the second lowest of the Bay of Bengal countries, resulting in a high score for the SUB_{LV} indicator (Table 24), and suggesting that the Maldives has a strong incentive to manage its fisheries, a fact which was reflected in the FAO Code of Conduct evaluation. Malaysia raises a small amount of banana prawns and cupped oyster species, and a large amount of blood cockles (Table 25). Other species reared are giant tiger prawns and barramundi. The blood cockle receives the highest score due to the fact that there is no antibiotic drug use, they are non-GMO, and they have high nutrient protein levels. Because of the large amount of higher scoring blood cockles produced, Malaysia scores the highest for the MSI_{soc} indicator (Table 26).

Maldives

Biodiversity

- **MPAs:** The Maldives have an EEZ area of 916,000 km^2. They currently have the least amount of EEZ area designated as MPA with 92 km^2 currently protected. This represents 0.01% and an annual cost of 5.8 million USD (Table 11). This is a relatively high cost for such a small area of protection. This is 11 % of the total expenditure by all Bay of Bengal LME countries on MPAs.
- **Trawling:** The Maldives have a very low catch of neritic species overall, and only about 2% of this is from trawling and similar gear (Table 12). Therefore the score for the Maldives is very high for TRA_{prop}.
- **Mariculture:** No mariculture industry reported, and hence not valuated.
- **Seabirds:** The Maldives has the lowest overall score for the $BIRD_{prot}$ indicator. The CBD, RAMSAR and CMS are relevant treaties for the Maldives to ratify, however only the CBD has been signed and ratified (Table 15). Therefore, the Maldives receives the lowest score for the first attribute of $BIRD_{prot}$. The Maldives has only recorded one bird species out of 35 possible in national censuses (Table 16), and therefore receives a low score for the second attribute.

- **Marine mammals:** The Maldives has the second highest overall MAM_{prot} ranking of all of the Bay of Bengal countries (Table 17). Their high score is attributed to the fact that it does not have targeted hunting within their EEZ waters (reported), it has the lowest numbers of endangered and threatened species, and relatively high abundances of marine mammals with distributions in their waters. They do report a very high ratio of gillnet catch to total catch from all gears, have less than 100 km^2 of MPA designated with specific marine mammal protections, and only ratified the Convention on Biological Diversity, the fewest number of treaties signed and ratified of all of the Bay of Bengal countries.
- **MTI:** The trophic level of landings from the Maldives decreased from the start of the fisheries in the 1950s to the mid-1960s (Figure 6). Since the mid-1960s, trophic levels have increased, although some of this increase can be attributed to the geographic expansion of the fisheries from coastal waters to deeper waters of the EEZ, as indicated by the increasing trend in the FiB index.
- **SSPs:** The numbers of stocks in the fully exploited and over exploited categories has tended to fluctuate over the time series (Figure 14). There seems to be a spike in the numbers of stocks in the over exploited and collapsed categories since about 2003. Despite this, the majority of the catch is taken from stocks in the developing category, suggesting that the overall picture is generally positive.

Value

- Because of the significance of the fisheries sector in the Maldives, the Maldives score very high for the economic impact of the fisheries relative to the country's GDP (Table 18). Despite this, the evaluation of the country's compliance with the FAO Code of Conduct revealed that management of reef-based fisheries and invertebrate stock could be improved, may be poorly managed with stocks over-exploited in rapid succession leading to closures (Table 19). This finding could be attributed to the giant clam fishery, which opened in 1990-closed in 1991, the sea cucumber fishery, which opened in 1985-closed in 1993), and the shark and grouper fisheries, which are considered to be over-exploited (FAO, 1997). The serial overexploitation of the fisheries of the Maldives is a key component in the lowering of the country's adherence to the FAO Code of Conduct score (to 3rd best), however it is important to note that the tuna fisheries (skipjack, *Katsuwonus pelamis* and yellowfin, *Thunnus albacores*) contribute the most to overall landings, representing 13% of the total catch over the 1950-2006 time period (Harper *et al.*, 2011).[10] Also important to note are the value-enhancing MPA network that the Maldives has in place. Reporting in the Maldives is relatively low at just under 20% of the taxa reported at the species level in the reported catch data (Table 20). The high score for the ratio of good to good+bad subsidies indicates that the government is not heavily subsidizing the fleet, which would lead to excess capacity (Table 23).

Jobs

- Subsidies relative to landed value was the only indicator could be used to evaluate the Maldives as there is no reported mariculture industry. The Maldives has the highest score for fisheries subsidies relative to landed value meaning that it does not heavily subsidize the fisheries (Table 24). Countries like the Maldives, that have low subsidies relative to landed value are considered to have more incentive to manage their fisheries.

Myanmar

Biodiversity

- **MPAs:** Myanmar, like Malaysia, is sixth in terms of percentage of EEZ area protected, with 0.013% protected (Table 11). A total of 340 km^2 is protected which represents an annual cost of 1.1 million $, the lowest annual cost of any of the Bay of Bengal countries. This is 2% of the total expenditure by all Bay of Bengal LME countries on MPAs.
- **Trawling:** Myanmar has the highest proportion of bottom trawling with 42% (Table 12). Therefore the score for this country is the lowest for this indicator.
- **Mariculture:** Myanmar has mariculture production for giant tiger prawns, which are native. The score for the production of this species is relatively low because the production has intense effects on the local environment, the origin of the larvae is largely unknown, the use of fishmeal is relatively heavy, and there is little use of wastewater treatment facilities (Table 13). Like India and Bangladesh, Myanmar has a relatively low overall score for MSI_{ecol}, due to the fact that the mariculture of giant tiger prawns is relatively intense (Table 14).
- **Seabirds:** Myanmar received a mid-range score for $BIRD_{prot}$ as it ratified the CBD and the RAMSAR treaties, but did not ratify the CMS treaty (Table 15). Additionally it records 12 species in national censuses out of 44 (Table 16).

[10] Harper, O'Meara, Booth, Zeller and Pauly (2011) Fisheries catches for the Bay of Bengal Large Marine Ecosystem since 1950. Report to the Bay of Bengal Large Marine Ecosystem Project, prepared by the *Sea Around Us* Project, Fisheries Centre University of British Columbia, Vancouver, Canada.

- **Marine mammals:** Myanmar ranked the lowest of the Bay of Bengal countries for the MAM_{prot} indicator (Table 17). This is attributed to low scores for potential kills due to gillnet (i.e., high ratio of gillnet catch to catch by other gears), the extinction risk factor, marine mammal species abundances, and domestic policies (i.e., a low proportion of MPA designated for marine mammal protection). Additionally, it only ratified the Convention on International Trade in Endangered Species of Wild Fauna and Flora and the Convention on Biological Diversity. Myanmar scores well for targeted hunting.
- **MTI:** Myanmar's trophic level decreased steadily from 1970 to the mid-1980s (Figure 7). Since the mid-1980s, the trophic level has increased slightly, probably due to the geographic expansion of Myanmar's fleets since the 1970s. Myanmar fishes predominantly in its own EEZ; note that the large fraction of "miscellaneous fishes" in the reported catches makes any conclusion very tentative.
- **SSPs:** The numbers of stocks in the exploited and over exploited categories has tended to fluctuate over the time series (Figure 15). Overall, however, while the number of stocks that are in the exploited category has tended to increase, the numbers of collapsed stocks has remained fairly constant. Additionally, the majority of the catch is taken from stocks in the developing category, suggesting that the overall picture is generally positive.

Value

- Reporting in Myanmar is relatively low at just over 20% of the taxa potentially distributed reported at the species level in the reported catch data (Table 20). The economic impact factor is low relative to the country's GDP (Table 18). Myanmar has the lowest proportion of capacity-enhancing subsidies resulting in the highest score for SUB_{good} (Table 23).

Jobs

- Overall fisheries subsidies relative to landed value is low, indicating that there is incentive to adequately manage fisheries (Table 24). Myanmar has mariculture production for giant tiger prawns. The score for the production of this species is relatively low because the production is mainly exported, there is high antibiotic drug use, and the traceability of the product is difficult (Table 25). Like India and Bangladesh, Myanmar has a relatively low overall score for MSI_{soc} due to mariculture of giant tiger prawns being relatively intense (Table 26).

Sri Lanka

Biodiversity

- **MPAs:** Sri Lanka protects 2,474 km^2 or 0.094% of its EEZ area (Table 11). This represents an annual cost of 5.6 million $, which is 10.3% of the total expenditure by all Bay of Bengal LME countries on MPAs.
- **Trawling:** Sri Lanka has the lowest proportion of bottom trawling catch relative to neritic catch within its EEZ waters (Table 12). The proportion is just under 2%, therefore Sri Lanka has the highest score for TRA_{prop}.
- **Mariculture:** Sri Lanka produces giant tiger prawns, which are native. The score for the production of this species is relatively low because it has intense effects on the local environment, the origin of the larvae is largely unknown, the use of fishmeal is relatively heavy, and there is little use of wastewater treatment facilities (Table 13). Similar to India, Bangladesh, and Myanmar, Sri Lanka has a relatively low score overall for MSI_{ecol} due to the fact that the mariculture of giant tiger prawns is relatively intense (Table 14).
- **Seabirds:** Sri Lanka scored second highest for $BIRD_{prot}$. Like Bangladesh and India, Sri Lanka receives a 10 for the first attribute because it has ratified the CBD, RAMSAR, and CMS treaties, which are the only three treaties relevant for this country (Table 15). Sri Lanka also has the second highest proportion (with India) of seabirds in its national census relative to those appearing on the AVIBASE checklist. (Table 16).
- **Marine mammals:** Sri Lanka has one of the lowest overall MAM_{prot} scores and like Indonesia has a high reported gillnet catch ratio (Table 17). It protects just over 1,600 k^{m2} of their 530,000 km^2 EEZ waters specifically for marine mammals, one of the lower proportions of area protected. Like Bangladesh, Sri Lanka has not ratified any of the treaties of the Antarctic treaty system, but has ratified the Convention on International Trade in Endangered Species of Wild Fauna and Flora, the Convention on the Conservation of Migratory Species of Wild Animals, and the Convention on Biological Diversity. There is some targeted hunting which occurs in its waters, and although it does not officially report targeted hunting of small cetaceans, there are several reports of commercial hunting available (Reeves *et al.*, 2003). They have intermediate rankings for threatened and endangered species and for levels of abundance of the marine mammal species, which detracts from its overall MA_{Mprot} score.
- **MTI:** The trophic level of Sri Lanka's catch has been steadily increasing until the late 1990s (Figure 8). The decreasing trend in the FiB index and in landings in Sri Lankan waters from

the 1960s to the mid-1970s would suggest that this has been occurring despite a contraction of the fishery. Although Sri Lanka does fish in the high seas waters and within the EEZ area of India, including the Andaman and Nicobar Islands, the amount of catch taken from these waters is relatively small. As the catch reconstruction suggests (see separate report on catches), Sri Lankan data do not properly represent spatially representative catches, as many of the catches taken outside its own EEZ are not declared at all, or are declared as domestically caught.

- **SSPs:** The graph of the number of stocks in a particular category shows that since the early 1980s there have been no major increases in fully exploited, over exploited or collapsed stocks until about 2003, when there is a spike in the number of stocks from the over exploited and collapsed categories (Figure 16). Since the early 1990s, there has been an increase in the number of stocks in the rebuilding category. The graph of catch by stock status is also positive in that the majority of the catch is from stocks, which are classified as rebuilding, while the catch from exploited and over exploited stocks has decreased.

Value

- The fisheries sector contributes to approximately 1% of total GDP, providing livelihood to 250,000 people living in over 2500 fishing villages (Pitcher *et al.*, 2006). Overall, Sri Lanka receives a mid-level ranking for the economic impact of its fisheries sector (Table 18), likely due to the reduction in capacity of many of the country's fisheries due to civil war (see below). Sri Lanka has the 3rd lowest score for compliance with the FAO Code of Conduct amongst the Bay of Bengal countries (Table 19). This is due mainly to the need for substantial reductions in fishing capacity as the fishery resources are predominantly restricted to the narrow continental shelf, the fact that there is significant overfishing in coastal waters, poor monitoring and enforcement, a lack of structural adjustment programs, and a continued reliance on destructive fishing methods even within MPAs. Taxonomic reporting in Sri Lankan fisheries is quite low with less than 10% of the potentially distributed taxa reported in the catch statistics (Table 20). Overall, capacity-enhancing subsidies are relatively low compared to total subsidies (Table 23).

Jobs

- Subsidies relative to landed value are low indicating a strong incentive to manage fisheries (Table 24). Sri Lanka has mariculture production for giant tiger prawns. The score for the production of this species is relatively low because the production is mainly exported and there is high antibiotic drug use (Table 25). Like India and Bangladesh, Myanmar has a relatively low overall score for MSI_{soc}, due to the mariculture of giant tiger prawns being relatively intense (Table 26).

Thailand

Biodiversity

- **MPAs:** Thailand is third in terms of percentage of EEZ area protected, with 0.185% protected (Table 11). A total of 4,550 km^2 is protected which represents an annual cost of 11 million $, the second highest annual cost and 21% of the total expenditure by all Bay of Bengal LME countries on MPAs.
- **Trawling:** Thailand takes 28% of its neritic catch using bottom trawling (Table 12). The score for this indicator is therefore on the lower end: 3.5 compared to countries such as the Maldives, Sri Lanka, or Bangladesh.
- **Mariculture:** Thailand mainly produces giant tiger prawns, which are native. The score for the production of this species is relatively low because it has intense effects on the local environment, the origin of the larvae is largely unknown, the use of fishmeal is relatively heavy, and there is little use of wastewater treatment facilities (Table 13). Other species raised are barramundi, blood cockles, cupped oyster species, and grouper species (Table 13). The blood cockle and cupped oyster mariculture receive relatively high scores due to low impact on the surrounding environment, low fishmeal usage, and the treatment of the waste from these systems. Thailand scores fairly low for the MSI_{ecol} indicator due to the heavy production of giant tiger prawns. Production of other less intensive species such as the blood cockle and cupped oysters slightly boost the score for Thailand (Table 14).
- **Seabirds:** Thailand receives a mid-range score for $BIRD_{prot}$. Thailand ratified the CBD and the RAMSAR treaties, but did not ratify the CMS treaty (Table 15). It records 12 species in national censuses out of 44 (Table 16).
- **Marine mammals:** Thailand has very low reported targeted hunting of marine mammals and it also reports the second highest proportion of marine mammal specific MPA of the Bay of Bengal countries, boosting its overall MA_{Mprot} score (Table 17). The intermediate rankings for threatened and endangered species and for levels of abundance of the marine mammal species detract from its overall MA_{Mprot} score. Additionally, it only ratified the Convention on International Trade in Endangered Species of Wild Fauna and Flora and

the Convention on Biological Diversity and has a high ratio of gillnet catch to catch by other gears.

- **MTI:** The trophic levels of Thailand's landings have been generally increasing, as has the FiB index (Figure 9). Thai fisheries are known to have expanded spatially, and have been fishing extensively in the waters of India, Indonesia, Malaysia, Myanmar, Singapore, and the high seas since 1970.
- **SSPs:** In general, the number of stocks in increasingly more exploited categories has risen (Figure 17). However, since about 2000, these levels have tended to decrease slightly and since the mid 1970s, there have been a small, but increasing percentage of stocks that are rebuilding. Increasingly the majority of the catch is taken from stocks that are fully exploited, with the catch of over exploited stocks decreasing since 2000.

Value

- Fisheries play a substantial role in the economy of Thailand and the EIF_{GDP} score is 3rd highest within in the Bay of Bengal (Table 18). The FAO Code of Conduct compliance assessment reveals that Thai fisheries are intensively exploited and management, monitoring, and enforcement measures are limited. Long-term objectives are not the focus of management plans, when they are in place, and there are few efforts to reduce discard or bycatch levels. However, small-scale fisheries stakeholders are considered in management plans, and MPA areas are believed to be relatively well managed. Overall, the FAO_{code} score is 4th highest of the Bay of Bengal countries (Table 19). Thailand ranks 4th in terms of taxonomic reporting with approximately 23% of the potentially distributed taxa reported in the catch statistics (Table 20). Capacity enhancing subsidies relative to total subsidies are the highest in Thailand, resulting in the lowest score for the SUB_{good} indicator (Table 23).

Jobs

- Subsidies to the fisheries sector are fairly high compared to total subsidies indicating that there may be less incentive to implement effective management strategies in Thailand (Table 24). Mariculture in Thailand has a fairly negative social impact overall. The main production is of giant tiger prawns, which score low because the production is mainly exported and there is high antibiotic drug use (Table 25). Other species raised are barramundi, blood cockles, cupped oyster species, and grouper species. The blood cockle and cupped oyster mariculture receive relatively high scores due to neither using large quantities of antibiotic drugs. Cupped oysters follow relatively strict code of practice guidelines, employ relatively large numbers of people, and the origin of the production is relatively easy to trace. However, Thailand scores fairly low for the MSI_{soc} indicator due to the heavy production of giant tiger prawns (Table 26). Production of other less intensive species such as the blood cockle and cupped oysters slightly boost the score for Thailand.

DISCUSSION

This study provides a baseline for assessing how well the Bay of Bengal countries manage a range of marine resources and issues, and demonstrates the areas where more work is needed to improve performance within the individual EEZs and the Bay of Bengal LME overall. The assessment of the Bay of Bengal countries highlights the fact that even when a country is ranked highest for a particular indicator, it does not imply the country approaches the standards set by international conventions or by consensus among scientists and managers. A clear example of this is the area of MPA designated by countries, compared to the CBD's interim target of 10% of national EEZ areas to be protected by 2010 (CBD, 2006). In the present study, none of the Bay of Bengal countries has designated more than 1% of their EEZ to MPAs. Clearly, countries have not taken the commitments they made to CBD on this matter seriously, and considerably more efforts are required to improve on this poor performance. Similarly, the overall amounts of beneficial or 'good' fisheries subsidies provided by countries are low, despite the calls for the elimination of perverse subsidies {Sumaila, 2006 #220}. It is important to note that an average score likely reflects an approach to marine resource management that should be improved upon (i.e., reducing trawling effort, increasing the area of MPAs within the EEZ, and reducing or eliminating capacity enhancing subsidies). Furthermore, a country scoring average on the range of scores does not necessarily reflect as 'good' or 'average' marine resource management, but rather illustrates that these countries have not begun to tackle bad practices such as reducing/eliminating 'bad' subsidies, developing unsustainable aquaculture ventures, and expanding or developing trawl fisheries. This discrepancy was noted in Alder *et al.* (2010), where it was found that, particularly amongst developing countries, average scores usually reflected the earlier stages of development of certain sectors such as mariculture. We find here that this may be particularly the case for the Bay of Bengal countries, which tend to have developing economies and feel they have fewer resources to allocate to the development of sustainable practices. The indicators presented in this study can help the Bay of Bengal countries track how they are doing against such measures and take corrective action earlier rather than later, when it is more difficult to do so. We present here an overview of the general assessment of marine resource management, alphabetically by country.

Bangladesh

Bangladesh ranks second lowest when the un-weighted scores for the indicators are used. This low ranking reflects the low scores for both of the mariculture sustainability indices (measuring ecological and social impacts of mariculture), which is mainly based on the intensive culturing of shrimp. The bolstering of Bangladesh's ranking among the Bay of Bengal countries under the weightings of *Market First*, *Policy First*, and *Sustainability First* indicates that Bangladesh is somewhat better in terms of biodiversity protection. The weak score under the *Securities First* scenario, a weighting scheme which favors environmental policies only if they contribute first to jobs and secondly to value, is indicative of the high ratio of subsidies to landed values and the low score for the social impacts of mariculture. Both indicators are an indication of inefficiency in the fisheries economic sector. Overall, there is the potential for substantial improvements to marine resource management in Bangladesh. The fisheries data reported for Bangladesh are very poor (Harper *et al.*, 2011)[11] and substantial improvement should be made in the taxonomic reporting of species. The use of bottom trawling gears is reported to be relatively low, however, improvements in the taxonomic reporting would greatly improve the reliability of taxon-gear associations. The heavy use of gillnets likely has a negative impact on the level of incidental kills of marine mammals, however this may be countered by the fact that Bangladesh has designated a relatively large area of their EEZ for marine mammal protection. Economic improvements such as reductions of capacity enhancing subsidies and increased investment in MPA development and enforcement should be encouraged, but may be challenging to implement due to poverty levels in Bangladesh. Agriculture is the main occupation of Bangladeshis, employing around 65% of the labor force, and fisheries represents only about 20% of the agricultural GDP sector, which given the high level of poverty in Bangladeshi households in the agriculture and fisheries sector (Cunningham and Neiland, 2005), makes positive changes all the more challenging.

[11] Harper, O'Meara, Booth, Zeller and Pauly (2011) Fisheries catches for the Bay of Bengal Large Marine Ecosystem since 1950. Report to the Bay of Bengal Large Marine Ecosystem Project, prepared by the *Sea Around Us* Project, Fisheries Centre University of British Columbia, Vancouver, Canada.

India

India ranks second highest when the un-weighted scores for the indicators are used. This relatively high ranking reflects the scale of marine protected area (MPA) relative to its EEZ area and strong mandates for the protection of marine mammal and seabird species. Of note is that the first MPA in India was designated in 1967, before a specific legal framework for protected area designation had been initiated (Singh, 2002). There are over 30 MPAs, designated mainly in the 1980s and 1990s, as well as several MPAs in the Andaman and Nicobar Islands. Most MPAs are relatively small in size. Because larger MPAs are less expensive to maintain (McCrea-Strub *et al.*, 2010), India makes relatively large investments in its MPA network. The ranking of India is strong under the *Market First*, *Policy First*, and *Sustainability First* scenarios, but is low under the *Security First* scenario. Like Bangladesh, the weak score under the *Securities First* scenario, a weighting scheme which favors environmental policies only if they contribute first to jobs and secondly to value, is indicative of the low scores of subsidies to landed values and the social impacts of mariculture. The former indicator is influenced by the fact that India's economy is largely devoted to service and agriculture. Both indicators suggest inefficiency in the fisheries economics sector. Despite the higher ranking within the Bay of Bengal region, India could improve its marine resource management in several ways. First, India takes a substantial portion of its catch using gillnets which are known to have a negative impact on marine mammal species (Hofman, 1995; Read *et al.*, 2006), as well as shrimp trawls and bottom trawls, which can cause extensive damage to the seafloor and benthic habitat (Watling and Norse, 1998). Secondly, the mariculture of giant tiger prawns in India's EEZ waters has been confined mainly to brackish water regions which have a considerable effect on the local environment, receive feed from over 30 domestic feed mills, require the heavy use of antibiotics to counter diseases such as white spot syndrome, and are not well-equipped to treat waste by-products (Bhat and Vinod, 2008). Recently, there have been plans which have promoted the development of mariculture in India (Gospakumar *et al.*, 2007). This work suggests that India could benefit from mariculture if they focus on the development of sustainable and lower impact mariculture as a means to ensure domestic food and nutritional security to its growing population. Reductions in the export of mariculture products would also enhance the availability of important protein sources for Indian people. Finally, an important area for improvement is in the economic development of Indian fisheries. The Indian government provides subsidies to poor fishers to motorize traditional vessels in order to increase the range and frequency of operation. This type of capacity expansion is generally negative as it can enhance the capacity of the fishery and place heavy pressure on stocks whose stock sizes may already be diminished.

Indonesia

Overall, Indonesia ranks (together with Myanmar) as the lowest of the Bay of Bengal countries when the indicators are un-weighted. The ranking of Indonesia remains low under all of the weighted scenarios due to the low scores of the component indicators, indicating that Indonesia performs poorly in many aspects of fisheries and ecosystem management related to fisheries, and should strive for improvements in marine resource management.

Prawns are a very important fisheries item in Indonesia, which can be attributed to the high value of the shrimp species that dominate the landings taken by these gear types. Mariculture of prawns, including the banana prawn (*Fenneropenaeus merguiensis*) and the giant tiger prawn (*Penaeus monodon*), has a large ecological impact. However milkfish (*Chanos chanos*) represents the largest proportion of the mariculture production and is generally considered to be less impacting on the environment and use significantly less fishmeal than shrimp aquaculture. In Indonesia, aquaculture is an important livelihood component for many coastal people. The tsunami in 2008 that affected coastal communities in Indonesia destroyed or damaged more than 50% of all coastal aquaculture ponds, which are the main farming systems for milkfish (*Chanos chanos*) and penaeid shrimps. This had a significant negative effect on the economy in these areas, where mariculture farmers have few opportunities for alternative employment (Suspita, 2006). In general, the fisheries economy in Indonesia is weak and there are constraints and problems related to fishery sector development at a number of levels. In particular, there is overfishing occurring in both marine and inland fisheries waters, the marine fishers and fish farmers have very low incomes and standards of living, there is weak management, and significant degradation of critical marine habitat such as coral reefs and mangroves. Because of the level of poverty associated with the majority of Indonesian fishers, the government heavily subsidizes fisheries, resulting in overcapacity in marine capture fisheries. Indonesia should take steps to protect the biodiversity in their waters, as there are many fishers who rely heavily on subsistence fishing for their livelihoods. In particular, instituting protections for endangered species such as marine mammals and seabirds and substantially increasing the area of MPAs could lead to improvements. Additionally, the majority of the landings in Indonesia seem to be taken with bottom trawling gears, which are among the most destructive fishing gears (Butcher, 2004). However given the difficulties with accurate species-gear associations, especially in light of the trawling ban instituted in the 1980s, we recommend caution when interpreting these results.

Maldives

Of the eight countries evaluated within the Bay of Bengal, only the Maldives had an overall score greater than 5 out of 10, and hence ranked best among all evaluated countries. Thus, the Maldives appear to be doing well compared to the other countries. The *Market First* scenario gives the highest weighting to the biodiversity indicators, including MPA investment and coverage, minimum impact from fishing gears and mariculture, and protection of species such as marine mammals and seabirds. Under this scenario, the Maldives scores second highest. This is driven by the fact that the tourism industry is the largest sector in which foreign investment is common. For this reason, the Maldives have a strong incentive to protect their marine resources. Despite the low rankings for the MPA coverage and for their intention to protect seabirds, there were 15 important marine dive sites established as MPAs in 1996, registered in the Ministry of Planning, Human Resources and Environment and managed by the Ministry of Tourism (see http://www.environment.gov.mv/). In 1999, an additional 10 dive sites were declared as protected areas established by the Ministry of Home Affairs, Housing and Environment (see http://www.maldivesbiodiversity.org/). The Maldives also protect certain islands completely from exploitation which are not officially designated as MPAs. These include Hurasdhoo in the North Ari Atoll, Hithaadhoo in the Gaaf Alif Atoll, and Rasfari in the Kaafu Atoll. Additionally, the Maldives have many small MPAs and is therefore protecting a smaller area at a greater cost meaning that it has a low MPA investment ratio. As only officially designated protected areas are included in the indicator, the scores for the MPA related indicators are likely underestimated for the Maldives.

The Maldives have also taken steps to protect specific birds endemic to this region, e.g., the white tern (*Gygyis alba monte*) has been protected since 1996, and have implemented specific bans on exports of all forms of coral (including black, but excluding organ pipe coral), eels, trochus and triton shells, dolphins, whales, turtles, parrot fish, all bait fish, lobsters, and bigeye scad under six inches (AIT-UNEP, 2002) These types of protection indicate that the Maldives is doing more to preserve biodiversity in their waters than the more generalized indicators used here would suggest. The Maldives remain the top ranked country in the present comparison under the Security First scenario mainly because this scenario only considers the value and job related indicators, weighting jobs as most important. Therefore, given that the Maldives are not scored for mariculture, the ratio of subsidies to landed value is the main driver. In the Maldives, fishing provides a livelihood for many people, and is the second largest industry (after tourism). Compared to the other Bay of Bengal countries, fishing in the Maldives is typically practiced using more traditional and less habitat destructive techniques such as pole and line fishing. There is no reported trawling effort within the EEZ. The small amount of trawling allocated to the Maldives is likely due to the taxon-gear associations derived by the spatial catch allocation procedure (Watson *et al.*, 2006a). Pole and line, as well as gillnets, became the dominant gear in the mid-1990s, and a large proportion of the catch comes from pelagic species resulting in less impact on the near shore environment (see Harper *et al.*, 2011). The small boats which comprise the majority of the fishing fleet are typically locally owned and not reliant on large subsidies from the government (as reflected by the low ratio of subsidies relative to landed value). The *Policy First* and *Sustainability First* scenarios down weight the value and jobs indicators to such a degree that the Maldives only receives mid-level rankings. However, when factors such as protection of areas not officially designated as MPAs and specific protection of seabird species are considered, the lower rankings may be underestimates. Overall, the country's high ranking is evidence of relatively good practices in their management of marine resources. In order to maintain and improve high standards of marine resource management, the Maldives should continue to fish using low impact gears, continue to preserve areas from exploitation and other extractive uses, preserve biodiversity by protecting species such as marine mammals, seabirds and corals, maintain the strong economy of their fisheries, and strive to uphold the principles of the FAO Code of Conduct.

Malaysia

Malaysia ranked third highest of the Bay of Bengal countries when all marine management indicators are considered (without weighting). Malaysia's strengths lie in their mariculture sectors and in their commitment to uphold the FAO Code of Conduct, indicating that there are attempts to maintain sustainability in their fisheries. However, Malaysian waters, like other areas of the Bay of Bengal, while rich in biodiversity, are threatened by overfishing. The threat posed by overfishing is reflected by the fact that nearly 15% of the catch is taken by bottom trawls, especially since the 1980s (Harper *et al.*, 2011). With the highest landed values produced by species caught in bagnets and bottom trawls (Harper *et al.*, 2011), the use of bottom trawling gear is unlikely to stop in the near future. Unfortunately, foreign illegal vessels are frequently apprehended in Malaysian waters, adding to the pressures on the fisheries (APFIC, 2007). However, due to increasingly strong measures by fishing authorities, there is hope that some of the illegal fishing can be curbed (Pitcher *et al.*, 2006). Malaysia has been increasing its fishing capacity for several decades. The drivers of this increased capacity are linked to several factors, including the migration of rural people to the coast, the rapid expansion of the trawl fleet in the 1970s, high demand for fish as a source of protein, the encroachment of foreign vessels, and the subsidies provided by the government to encourage growth in the fisheries sector (Morgan *et al.*, 2007). This capacity enhancement should be curbed through the combination of a gradual reduction in trawlers in the coastal zone, a moratorium on the issuance of new licenses, and continued strengthening of monitoring, control and surveillance (MCS) of the fisheries. In this context, the development of alternative livelihood options for the growing coastal population should be assigned highest priority. Much could be done to improve the protection for marine mammal species, including the ratification and enforcement of important protective treaties (especially since a large proportion of the marine mammal species found in Malaysian waters are already highly threatened and at low abundances according to the IUCN Red List) and increasing the number and size of MPAs. Malaysia in general protects only a small proportion of their EEZ waters. Weaknesses in the protection of biodiversity result in the lower relative ranking of Malaysia amongst the other Bay of Bengal countries for the *Market First*, *Policy First*, and *Sustainability First* scenarios, which each give a higher weighting to the biodiversity related indicators. As a final note, the Malacca Strait, one of the busiest shipping lanes in the world, is located off the coast of Malaysia. The impact of shipping traffic is a potential indicator that should be considered in determining the sustainability of Malaysia’s marine resource management in the future.

Myanmar

Myanmar ranked lowest of the Bay of Bengal countries (with Indonesia) when all marine management indicators are considered (without weighting). Fisheries are recognized as an important economic sector for Myanmar. However, many of the current marine resource practices are considered unsustainable. Although Myanmar likely takes the largest proportion of its landings using gillnets, the proportion of landings from trawling-type gears is significant relative to total catch. The likely heavy use of gillnets has a negative effect on the level of incidental kills of marine mammals in the EEZ of Myanmar. A reduction in the use of trawling and focus on marine mammal avoidance strategies for the gillnet fishery would reduce the impact on critically threatened habitats and species. An increase in the MPA coverage would also help to mitigate the effects of heavy fishing pressures, which in turn would entail greater economic allocations in MPA investment. One area with potential for improvement is the mariculture sector, which currently is dominated by giant tiger prawn (*Penaeus monodon*). As mentioned previously, mariculture of shrimp species has a heavy ecological impact. In Myanmar, the majority of the giant tiger prawns produced are exported, resulting in a low socio-economic score as this represents a source of protein that the local people do not have access to. Overall, the fact that Myanmar received the lowest score of the Bay of Bengal countries for their ability to uphold the FAO Code of Conduct reflects the poor condition and unsustainable nature of Myanmar's fisheries management. Due to the fact that Myanmar received low scores for five of the twelve ranked indicators, the overall un-weighted score was the lowest (together with Indonesia). Furthermore, the weightings of *Market First*, *Policy First*, and *Sustainability First* were the lowest of all the countries evaluated. This indicates that Myanmar is clearly not adequately protecting their resources and that there are potentially major threats to biodiversity in the region.

Sri Lanka

Sri Lanka ranked fourth highest of the Bay of Bengal countries when all marine management indicators are considered (without weighting). In terms of biodiversity, Sri Lanka performs well for seabird protection intent and for the low proportion of trawling occurring in their EEZ. Historically, trawling represented a more significant proportion of the Sri Lankan fisheries, however a number of factors changed that pattern, including civil war from1983-2009, which closed much of the productive shrimp trawling fishery in the NW of the island, and the shift of fishing into offshore pelagic waters after the coastal fisheries had been depleted (O'Meara *et al.* in Harper *et al.*, 2011), and are the main reasons for the lack of trawling today. In addition, the most valuable species group in Sri Lanka are the mackerels, tunas and bonitos followed by skipjack tuna (*Katsuwonus pelamis*), narrow-barred Spanish mackerel (*Scomberomorus commerson*), and yellowfin tuna (*Thunnus albacares*), all pelagic species taken predominantly with gillnets and hooks. The heavy use of gillnets indicates that incidental kills of marine mammals may be high in Sri Lankan waters. The Indian Ocean tsunami which struck on the 26th of December 2004 directly affected the livelihoods of at least one million people in Sri Lanka, with the bulk of the damage in the underdeveloped regions of the northeast, east, south, and southwest coastline. Estimates of up to 100,000 fishers unemployed and 18,500 fishing vessels lost or damaged highlight that fishing pressures subsequently may have been temporarily suppressed, and that care should be taken to prevent unrestrained growth within the fisheries sector.

Although several MPAs of substantial size and investment exist in Sri Lanka, they have been shown to be poorly managed, and resource extraction and habitat degradation continue unabated (Perera and de Vos, 2007). In this context, the evaluation of MPA coverage and investment may not achieve the desired measurement of biodiversity protection. A better indicator would be an evaluation of MPA effectiveness. However, the study of Perera and de Vos (2007) is unique within the Bay of Bengal. Therefore, the MPA area and MPA investment indicators should eventually be enhanced as more and better information on the quality of MPAs within particular countries becomes available. A major area of improvement is in both the ecological and socio-economic aspect of the mariculture sector in Sri Lanka. It has been noted that development of the mariculture sector in Sri Lanka is one area of economic growth that has not been tapped as a means to improve food security (Sivasubramaniam, 2000). A precautionary approach would call for both the emphasis on the development of sustainable mariculture opportunities for domestic consumption (rather than export) and a review of the current aquaculture situation (the giant prawn industry), which points to existing unsustainable ecological and economic practices. In particular, improvements to the treatment of waste products, reduction in habitat alteration, fishmeal usage, and the use of antibiotics would ensure that mariculture development is sustainable and that impacts are minimized.

Thailand

Thailand ranked fourth lowest of the Bay of Bengal countries when all marine management indicators are considered (without weighting). Shrimp represent a valuable commodity in both the marine capture and mariculture sectors for Thailand. The majority of the shrimp from the marine capture fisheries are landed with shrimp trawling gear, although the majority of overall landings are likely from gillnet gear (Harper *et al.*, 2011). The large proportion of landings assigned to gillnet gear results in Thailand ranking better than many of the other Bay of Bengal countries with respect to the amount of trawling occurring within their EEZ. Thailand was the world's largest producer of farmed shrimp until 1996, when a combination of problems led to the gradual decline following the rapid expansion in productivity that had commenced in the 1980s (Smith, 1996). In this study, Thailand scores very low for mariculture despite the production of other finfish and bivalve species, because the majority of the mariculture production is of giant tiger prawn, which has a heavy ecological impact and relies on the intense use of antibiotics to combat the outbreaks of new shrimp viral diseases in many parts of Thailand (Smith, 1996). In terms of biodiversity protection, Thailand seems to be doing a relatively good job when compared to the other Bay of Bengal countries. In particular, it preserves the third largest proportion of MPA within the Bay of Bengal, although it is still well below the CBD-stated conservation goal of protecting at least 10 percent of EEZ waters by 2012 (CBD, 2006). The west coast of Thailand has only about 1400 km^2 of MPAs compared to the nearly 5000 km^2 in the Bay of Bengal region. Unfortunately, little or no data are available on the management effectiveness of Thailand's MPAs. Thailand received the highest score for its investment in MPAs. Despite this investment, it received the lowest score for the ratio of 'good' to 'good + bad' subsidies, suggesting a heavy subsidization of Thai fisheries. This has lead to massive overcapitalization of Thai fishing fleets. Because of the relative strength of its ranking in their commitment to protect marine mammal and bird species, its investment in and coverage of their MPA network, and the low relative proportion of their trawl fisheries to total landings, Thailand performs relatively well in the *Market First*, *Policy First*, and *Sustainability First* scenarios. This is mainly due to the fact that these scenarios weigh the biodiversity indicators more than the value or job-related indicators. Thailand ranked lowest when the Security First scenario was considered, due to the fact that the biodiversity indicators are not included under this weighting scheme. Therefore, Thailand would best improve the state of its marine resource management by focusing on a reduction of capacity enhancing fisheries subsidies and on improving the socioeconomic and environmental aspects of their mariculture industry.

The Bay of Bengal in a global perspective

In general, Alder *et al.* (2010) found that developing countries scored lower than developed countries. This seemed especially true for the Bay of Bengal countries as evaluated by Alder *et al.* (2010), which all scored in the bottom 20, except Malaysia (which ranked 23 out of 53). Of the 53 countries evaluated by Alder *et al.* (2010), only four (New Zealand, Peru, Germany, and the

Netherlands) had an un-weighted score of more than 5 out of 10. These countries are considered to be incorporating best practices into their management. Interestingly, the Maldives, a country that was not evaluated in Alder *et al.* (2010), scored more than 5 out of 10 in the present evaluation, indicating that it could be considered a leader in marine resource management within the Bay of Bengal. The Maldives' position and ranking, however, is likely influenced by its unique situation, in being the only small-island country in the Bay of Bengal, with a relatively low human population and a major source of national income (tourism) that is relatively independent of resource-extraction but highly dependent on biodiversity and ecosystem health. Notably, Bangladesh was the lowest ranked country in the Alder *et al.* (2010) study, followed by India. While Bangladesh also had a low ranking in this study (although not the lowest), India performed relatively well in this study, possibly due to a refining of the individual indicators evaluated here (e.g., updated MPA coverage data). Similar to Alder *et al.* (2010), the suite of 12 indicators, when aggregated to a single (un-weighted) score, appear to be consistent in identifying high, average, and low performers across the eight Bay of Bengal countries. For example, countries that scored well on upholding the FAO Code of Conduct and mariculture tended to have higher overall scores, and conversely. Alder *et al.* (2010) suggested that as many developing countries have only relatively recently begun to develop their mariculture sectors, the two mariculture indicators might assist countries in tracking development in terms of ecological, social, and economic sustainability. In general, and also supported by Alder *et al.* (2010), there is no single action that can be prescribed to improve marine resource sustainability; this will vary between countries, as they have different priorities, resources and values. However, the indicators presented here assist in the prioritization of goals and actions, which need to be implemented to ensure the health of marine resources.

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TABLES

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

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

Table 2. Attributes used for assessing the ecological impacts of mariculture

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

Table 3. Attributes and scoring schemes used in $BIRD_{prot}$

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	**Percentage of native seabird species with national breeding census data**	**Score**
	None of the native species are in the census	0
	Half of the native species are in the census	5
	All of the native species are in the census	10

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

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

Table 5. Scoring of participation in targeted hunting by each country

Score	Small cetaceans	Great whales
3	No hunting	No hunting
2	Participation in 'opportunistic' hunting of single species	Hunting of a single species with average annual catch (2000-2006) < 10
1	Participation in '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	Participation in 'regular' hunting noted for multiple species	Hunting of multiple species with average annual catch ≥ 10

Table 6. 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

Table 7. Scoring for participation in international treaties

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

Table 8. Algorithm used to interpret the status of fishery resources based on time series of catch.

Status of fishery	Criterion applied
Developing	Year of landing < year of max. landing AND landing is ≤50% of max. landing OR year of max. landing = final year of landing
Exploited	Landing > 50% of max. landing
Over exploited	Year of landing > year of max. landing AND landing is between 10-50% of max. landing
Collapsed	Year of landing > year of max. landing AND landing is < 10% of max. landing
Recovering[a]	Year of landing > year of post-max. min. landing AND post-max. min. landing < 10% of max. landing AND landing is 10-50% of max. landing

[a] This requires the definition of a 'post-maximum minimum' (post-max. min.): the minimum landing, which occurs after the maximum landing.

Table 9. Socioeconomic attributes used for the computation of MSI_{soc}

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

Table 10. GEO4 scenario-based weightings used in computing the aggregated scores of country performance.

Criteria 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
Biodiversity (b)	2.00	5.00	0.00	10.00
Indicators				
$\mathbf{MPA_{area}}$	2.00	5.00	0.00	10.00
$\mathbf{MPA_{inv}}$	2.00	5.00	0.00	10.00
$\mathbf{TRA_{prop}}$	2.00	5.00	0.00	10.00
$\mathbf{MSI_{ecol}}$	2.00	5.00	0.00	10.00
$\mathbf{BIRD_{prot}}$	2.00	5.00	0.00	10.00
$\mathbf{MAM_{prot}}$	2.00	5.00	0.00	10.00
$\mathbf{EIF_{GDP}}$	1.00	1.00	0.30	0.10
$\mathbf{CODE_{FAO}}$	1.00	1.00	0.30	0.10
$\mathbf{STAT_{rep}}$	1.00	1.00	0.30	0.10
$\mathbf{SUB_{good}}$	1.00	1.00	0.30	0.10
$\mathbf{SUB_{LV}}$	0.33	1.00	0.10	0.10
$\mathbf{MSI_{soc}}$	0.33	1.00	0.10	0.10

Table 11. MPA investment costs for the Bay of Bengal Large Marine Ecosystem region and the individual BOBLME countries (dollar amounts are expressed in 2006 USD).

Area	Total area (km^2)	MPA Area (km^2)	% Area	Annual cost	Cost in perpetuity
Bay of Bengal	6,251,000	26,195.00	0.00419	$54,226,758	$526,926,572

Country	MPA Area (km^2)	% MPA Area of EEZ	% MPA Area of LME	MPA_{area} Score	Annual Cost ($)	% Annual Cost	Cost in Perpetuity ($)	% Cost in Perpetuity	MPA_{inv} Score
Bangladesh	1,394.36	0.053	0.00022	1.1	3,513,092	0.065	23,250,115	0.044	1.0
India	12,276.38	0.469	0.00196	10.0	14,543,494	0.268	121,195,780	0.230	7.0
Indonesia	5,050.81	0.193	0.00081	4.1	6,567,893	0.121	41,049,329	0.078	2.1
Malaysia	344.83	0.013	0.00006	0.3	5,676,786	0.105	43,667,584	0.083	2.2
Maldives	92.04	0.004	0.00001	0.0	5,833,681	0.108	41,169,238	0.078	2.1
Myanmar	340.51	0.013	0.00005	0.2	1,100,473	0.020	7,336,485	0.014	0.0
Sri Lanka	2,473.82	0.094	0.00040	2.0	5,607,085	0.103	80,101,212	0.152	4.5
Thailand	4,850.11	0.185	0.00078	3.9	11,384,255	0.210	169,156,830	0.321	10.0

Table 12. The proportion of average catch (2004-2006) from trawling and dredging gears to the average catch of neritic species (2004-2006) and the TRA_{prop} score by country.

Country	Mean (t + d)	Mean (neritic)	Effort	TRA_{prop} Score
High Seas	1422.05	4825.50	0.29	3.1
Bangladesh	10817.68	237041.28	0.05	9.3
India	268673.62	771379.51	0.35	1.8
Indonesia (Western)	122012.54	310558.09	0.39	0.7
Malaysia (West Pen.)	85974.29	247486.20	0.35	1.8
Maldives	80.14	3976.25	0.02	9.9
Myanmar	77668.58	185352.40	0.42	0.0
Sri Lanka	228.42	13129.46	0.02	10.0
Thailand	24373.63	88104.56	0.28	3.5

Table 13. Average production (1993-2004) by species-country and scores for each of the ecological components of mariculture sustainability for each species by BOBLME country

Country	Common Name	Average Production	Native vs. introduced	Fish meal usage	Intensity level	Hatchery vs. wild	Habitat alteration	Waste water treatment	Average
Bangladesh	Penaeus shrimps nei	49232.40	5	3	1	3	1	1	2.3
India	Giant tiger prawn	75259.00	10	1	1	3	1	1	2.8
Indonesia	Banana prawn	23696.80	10	4	4	3	3	3	4.5
Indonesia	Barramundi	3350.70	10	3	1	1	3	1	3.2
Indonesia	Giant tiger prawn	80690.00	10	1	1	3	1	1	2.8
Indonesia	Milkfish	185277.30	10	7	10	3	3	3	6.0
Malaysia	Banana prawn	9.85	10	4	3	3	3	2	4.2
Malaysia	Barramundi	2549.70	10	1	1	1	3	3	3.2
Malaysia	Blood cockle	75569.10	10	10	7	3	5	7	7.0
Malaysia	Cupped oysters nei	18.20	5	10	7	5	6	10	7.2
Malaysia	Giant tiger prawn	5694.90	10	1	1	3	1	1	2.8
Maldives	*	*	*	*	*	*	*	*	*
Myanmar	Giant tiger prawn	4855.80	10	1	1	3	1	1	2.8
Sri Lanka	Giant tiger prawn	4662.40	10	1	1	1	1	1	2.5
Thailand	Barramundi	116.60	10	1	1	3	3	1	3.2
Thailand	Blood cockle	4380.95	10	10	7	3	5	7	7.0
Thailand	Cupped oysters nei	1372.50	5	10	7	5	6	10	7.2
Thailand	Giant tiger prawn	43435.50	10	1	1	1	1	1	2.5
Thailand	Groupers nei	507.90	9	1	5	5	3	4	4.5

Table 14. Scores for each of the ecological components of mariculture sustainability for each of the BOBLME countries and the final weighted MSI_{ecol} score, which was weighted by the average production. Maldives was not scored, as no mariculture is occurring in this country.

Country	Native vs. introduced	Fish meal usage	Intensity level	Hatchery vs. wild	Habitat alteration	Waste water treatment	MSI_{ecol}
Bangladesh	5.0	3.0	1.0	3.0	1.0	1.0	0.0
India	10.0	1.0	1.0	3.0	1.0	1.0	1.2
Indonesia	10.0	5.1	6.9	3.0	2.4	2.4	6.3
Malaysia	10.0	9.1	6.4	2.9	4.7	6.5	10.0
Maldives	*	*	*	*	*	*	*
Myanmar	10.0	1.0	1.0	3.0	1.0	1.0	1.2
Sri Lanka	10.0	1.0	1.0	1.0	1.0	1.0	0.5
Thailand	9.9	2.0	1.7	1.3	1.5	1.8	1.6

Table 15. Attribute 1—Conventions and agreements signed and ratified by the BOBLME countries. R indicates that the convention or agreement was signed and ratified, N indicates a relevant convention or agreement for that country that was not signed or ratified, and N/A is not relevant

Country	CBD[a]	ACAP[b]	RAMSAR[c]	CMS[d]	Total ratified	Relevant	Attribute score
Bangladesh	R	N/A	R	R	3	3	10.0
India East	R	N/A	R	R	3	3	10.0
Indonesia	R	N	R	N	2	4	5.0
Malaysia	R	N/A	R	N	2	3	6.6
Maldives	R	N/A	N	N	1	3	3.3
Myanmar	R	N/A	R	N	2	3	6.6
Sri Lanka	R	N/A	R	R	3	3	10.0
Thailand	R	N/A	R	N	2	3	6.6

[a] Convention of Biological Diversity (1993)

[b] Agreement on the Conservation of Alabtrosses and Petrels (2004)

[c] Convention on Wetlands (1975)

[d] Convention on Migratory Species, aka Bonn Convention (1979)

Table 16. Attribute 2—Percentage of native seabird species with national breeding

census data for the FAO Bay of Bengal LME countries. Species are considered native if they appear on the national checklist available at http://avibase.bsc-eoc.org/checklist.jsp?lang=EN

Country	Number of seabird species in census	Number of native seabird species (Avibase checklist)	Attribute score	$BIRD_{prot}$ score
Bangladesh	13	29	4	10.0
India East	12	38	3	9.1
Indonesia	0	45	0	1.5
Malaysia	0	39	0	3.0
Maldives	1	35	0	0.0
Myanmar	12	44	3	5.8
Sri Lanka	16	47	3	9.1
Thailand	12	47	3	5.8

Table 17. Composite scores for the Bay of Bengal LME countries on their marine mammal protection performance. 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}
Bangladesh	10.0	7.2	0.1	0.6	3.3	6.4	4.9
India East	7.1	2.8	3.5	3.9	10.0	10.0	10.0
Indonesia	5.7	0.0	6.5	6.5	1.7	0.0	1.1
Malaysia	10.0	10.0	0.0	0.0	1.7	0.0	1.8
Maldives	10.0	0.1	10.0	10.0	0.0	0.1	6.3
Myanmar	10.0	0.2	3.4	2.8	1.7	0.1	0.0
Sri Lanka	5.7	0.0	5.6	6.0	3.3	1.1	1.8
Thailand	10.0	1.2	3.1	2.8	1.7	8.6	4.8

Table 18. Score of Economic Impact Factor of fisheries relative to GDP by country.

Country	Economic Impact	GDP 2003	EIF_{GDP}
Bangladesh	719.74	51913.67	0.03
India	3598.91	599461.00	0
Indonesia	3250.58	234772.00	0.03
Malaysia	4244.24	110202.00	0.14
Maldives	1631.41	692.42	10
Myanmar	667.7	74530.00	0.01
Sri Lanka	551.74	18881.77	0.10
Thailand	4406.58	142640.00	0.11

Table 19. Scores for each BOBLME country assessing compliance with the FAO Code of Conduct, where 0 is low and 10 is high

Questions	Bangladesh	India	Indonesia	Malaysia	Maldives	Myanmar	Sri Lanka	Thailand
Field 1: Management objectives								
Are formal reference points for fish stocks in fisheries identified using best science?	2.0	6.0	2.0	6.0	4.5	1.0	2.5	3.0
Is present fleet capacity calculated and are there plans to reduce it?	3.0	4.5	1.0	7.5	4.5	2.5	4.5	2.0
Are small-scale fishers considered in plan and are there institutional structures for ongoing consultation?	3.0	6.0	3.0	8.0	5.0	2.5	5.0	6.0
Impacts of fishery on biodiversity allowed for in plan and are mitigation measures in place?	3.5	4.0	2.0	6.5	1.5	0.5	2.0	2.0
Does the management plan aim to restore depleted stocks in this fishery?	2.0	3.0	2.5	5.0	1.5	0.0	2.5	1.0
Are human impacts (pollution, waste) on the fishery habitat identified and mitigated?	3.5	4.5	2.0	6.0	2.5	1.0	3.5	2.0
Is fishing gear mandated by the management plan to avoid by-catch of non-target species, environmental and habitat damage?	0.0	4.5	3.0	5.0	1.5	1.5	2.5	2.5
Are ecosystem linkages with this fishery made explicit in the management plan and are adverse effects minimized?	0.0	4.5	1.5	5.0	0.0	0.0	0.0	0.0
Are environmental influences on this fishery made explicit in the management plan and are adverse effects minimized?	1.0	4.0	4.0	4.0	1.5	0.0	0.0	1.0
Average Field 1	**2.0**	**4.6**	**2.3**	**5.9**	**2.5**	**1.0**	**2.5**	**2.2**
Field 2: Framework (data and procedures):								
Are total and complete removals from the stocks over the whole stock area and over whole life cycle accounted for in assessment?	0.0	5.5	3.0	6.0	3.5	1.0	1.0	3.0

Table 19. Scores for each BOBLME country assessing compliance with the FAO Code of Conduct, where 0 is low and 10 is high

Questions	**Bangladesh**	**India**	**Indonesia**	**Malaysia**	**Maldives**	**Myanmar**	**Sri Lanka**	**Thailand**
Are management measures compatible with those of other jurisdictions concerned with the stocks?	0.0	3.5	3.5	5.0	1.5	0.0	3.0	1.0
Does the management plan have clearly stated long-term objectives?	1.0	5.5	5.5	8.0	2.0	0.0	2.0	3.0
Are all the stakeholders in this fishery resource identified and considered?	2.0	5.0	3.0	8.0	4.5	3.0	5.5	4.0
Are data, management processes and decision-making open and transparent, including any international aspects?	2.0	4.5	3.0	9.0	2.5	0.0	0.0	2.0
Are timely, complete and reliable statistics collected and verified?	2.0	5.0	3.0	7.0	3.5	2.0	1.0	3.0
Are social, economic and institutional factors related to sustainability evaluated with data?	2.0	5.5	4.0	4.0	4.5	1.0	3.5	2.5
Average Field 2	**1.3**	**4.9**	**3.6**	**6.7**	**3.1**	**1.0**	**2.3**	**2.6**
Field 3: Precautionary approach:								
Is precaution explicitly enshrined in legislation, and is it applied to management of fishery stocks?	0.0	1.0	2.5	1.5	0.5	1.0	5.0	1.0
Is uncertainty, including lack of appropriate information, quantified and used to restrain fishing that might otherwise occur?	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Are stock-specific target reference points estimated and employed?	0.0	3.5	3.5	4.5	3.5	0.0	2.5	2.5
Are stock-specific limit reference points estimated and employed?	2.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0
Are there viable contingency plans to restrict fishing in the event of an environmental emergency?	0.0	4.0	1.5	0.0	1.0	0.0	0.0	0.0
Are there viable contingency plans to restrict fishing in the event of an unforeseen emergency caused by fishing?	0.0	0.0	0.0	4.0	1.5	0.0	0.0	0.0

Table 19. Scores for each BOBLME country assessing compliance with the FAO Code of Conduct, where 0 is low and 10 is high

Questions	Bangladesh	India	Indonesia	Malaysia	Maldives	Myanmar	Sri Lanka	Thailand
Are management instruments under continuous review?	1.5	5.5	4.0	7.0	1.5	2.0	3.0	3.0
Are no-take areas of sufficient size to work, policed and monitored as insurance?	2.0	3.0	3.5	5.0	1.5	1.5	0.5	4.0
Are plans in place to restrict fishing if species linked through the ecosystem to the target(s) of this fishery become threatened?	0.0	3.5	1.0	2.0	2.0	1.5	0.0	0.0
Average Field 3	**0.6**	**2.3**	**1.8**	**2.7**	**1.5**	**0.7**	**1.2**	**1.2**
Field 4: Stocks, fleets and gear								
Is excess fleet capacity being reduced?	0.0	3.0	0.0	4.0	3.5	0.0	0.0	1.5
Are fishing methods known to be harmful to habitats, to create by-catch problems, or whose high fishing capacity is difficult to control, being phased out?	0.0	1.0	1.0	3.5	4.5	0.0	0.0	2.0
Is by-catch of non-target species minimized?	1.0	1.0	2.5	3.0	2.5	1.0	0.5	2.0
Are discards minimized?	0.0	3.0	3.0	4.0	5.5	1.0	3.0	3.0
Is gear designed to minimize ghost fishing if lost?	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Is the fishing of juveniles and spawners restricted to safe levels?	0.0	1.0	0.0	2.5	0.0	1.0	0.0	1.0
Are depleted stocks being rebuild?	0.0	0.5	0.0	0.0	2.5	0.0	0.0	0.5
Average Field 4	**0.1**	**1.4**	**0.9**	**2.4**	**2.6**	**0.4**	**0.5**	**1.4**
Field 5: Social and economic								
Is the fishery managed so as to minimize conflict among different sectors?	2.0	4.5	0.0	8.0	5.0	0.0	3.0	0.0
Are Indigenous Peoples rights and needs in fisheries being met?	5.0	9.0	2.5	6.0	5.0	0.0	0.0	1.0
Are the needs of local fishing communities being met?	3.5	4.5	3.0	5.0	6.5	1.0	3.5	1.5

Table 19. Scores for each BOBLME country assessing compliance with the FAO Code of Conduct, where 0 is low and 10 is high

Questions	**Bangladesh**	**India**	**Indonesia**	**Malaysia**	**Maldives**	**Myanmar**	**Sri Lanka**	**Thailand**
When a change to the management of a fishery is made, is its cost-effectiveness evaluated?	3.5	0.0	0.0	3.0	1.5	0.0	2.5	3.0
When a change to the management of the fishery is made, is its social impact evaluated?	4.0	3.0	2.0	7.0	4.5	0.0	2.0	1.5
Is funding for the research and the MCS programme obtained by cost recovery from the industry?	0.0	0.0	3.5	0.0	0.0	1.0	0.0	0.0
Average Field 5	**3.0**	**3.5**	**1.8**	**4.8**	**3.8**	**0.3**	**1.8**	**1.2**
Field 6: Monitoring, control and surveillance (MCS)								
On a ten-point scale, how effective is the observer scheme?	1.0	0.0	1.0	0.0	0.0	0.0	0.5	0.0
On a ten-point scale, how effective is the catch inspection scheme?	1.5	4.5	3.5	6.0	4.5	3.0	1.0	1.5
On a ten-point scale, how effective is the vessel monitoring scheme?	0.0	3.0	4.0	6.0	3.5	1.5	0.0	2.5
Are vessels fishing illegally in fisheries?	2.5	4.0	1.0	4.0	5.0	0.0	2.0	0.0
On a ten-point scale, how effective is control of access in stopping illegal fishing?	0.0	3.5	3.5	4.0	2.5	2.0	2.5	2.0
Are vessels that really derive from this jurisdiction reflagged in states of convenience, generally to avoid reporting or other fishery regulations?	10.0	10.0	6.0	7.0	8.0	4.0	10.0	10.0
Average Field 6	**2.5**	**4.2**	**3.2**	**4.5**	**3.9**	**1.8**	**2.7**	**2.7**
$CODE_{FAO}$	**1.8**	**7.1**	**3.8**	**10.0**	**5.3**	**0.0**	**2.7**	**2.8**

Table 20. Ratios of reported species to total reported within the BOBLME and scores for $STAT_{rep}$.

Country	Taxa Reported	Taxa Distributed	Percent Reported	$STAT_{rep}$
Bangladesh	18	353	0.05	0.0
India	254	349	0.73	10.0
Indonesia	155	346	0.45	5.9
Malaysia	109	337	0.32	4.0
Maldives	48	249	0.19	2.1
Myanmar	73	355	0.21	2.3
Sri Lanka	29	335	0.09	0.5
Thailand	80	354	0.23	2.6

Table 21. Breakdown of subsidies by ‘good’, ‘bad’ and ‘ugly’ designations for Bangladesh, India, Indonesia, and Malaysia.

	Bangladesh		**India**		**Indonesia**		**Malaysia**	
	Amount USD	**Source**	**Amount USD**	**Source**	**Amount USD**	**Source**	**Amount USD**	**Source**
Beneficial (good)								
Fisheries management and services	-10,611	FAO profile	152,247	(Salagrama, 2004)	84,546	(APEC, 2000)	1,723	(APEC, 2000)
Fishery research and development	-8,888	FAO profile	124,395	FAO profile	-	-	521	(APEC, 2000)
Maintenance of MPAs	345	(Cullis-Suzuki and Pauly, 2008)	1,198	(Cullis-Suzuki and Pauly, 2008)	18,100	(Cullis-Suzuki and Pauly, 2008)	25,831	(Cullis-Suzuki and Pauly, 2008)
Subtotal	**19,843**		**277,840**		**102,646**		**28,075**	
Percent of landed value	**11.2**		**11.2**		**6.5**		**1.7**	
Harmful (bad)								
Boat construction, renewal and modernization	-11,767	(Khatun *et al.*, 2004)	164,688	(Salagrama, 2004)	-	-	11,720	(APEC, 2000)
Fishery development and support services	-39,366	FAO profile	26,489	FAO profile	36,677	(APEC, 2000)	-373,433	FAO profile
Fishing port construction and renovation	-	-	121,259	(Salagrama, 2004)	91,200	(APEC, 2000)	-	-
Marketing support and storage infrastructure	-7,516	(Khatun *et al.*, 2004)	22,219	(Salagrama, 2004)	98,200	(APEC, 2000)	1,456	(APEC, 2000)
Tax exemption	-7,589	(Khatun *et al.*, 2004)	284	(Salagrama, 2004)	-	-	-71,994	FAO profile
Foreign access agreements	-	-	-	-	-	-	-	-
Fuel subsidies	8,000	(Khatun *et al.*, 2004)	221,710	(Salagrama, 2004)	171,000	Antara news	116,000	BERNAMA
Subtotal	**74,238**		**556,648**		**397,077**		**574,604**	
Percent of landed value	**42.0**		**22.5**		**25.2**		**34.2**	
Ambiguous (ugly)								
Fisher assistance	-	-	-	-	-	-	-	-

Table 21. Breakdown of subsidies by 'good', 'bad' and 'ugly' designations for Bangladesh, India, Indonesia, and Malaysia.

Vessel buyback	-	-	-	-	-	-	-	-
Rural fisheries community development	-13,661	FAO profile	191,203	FAO profile	-121,654	(APEC, 2000)	-	-
Subtotal	**13,661**		**191,203**		**121,654**		**-**	
Percent of landed value	**7.72**		**7.72**		**7.72**			
Total Percentage of Landed Value	**60.89**		**41.42**		**39.43**		**35.91**	
Grand total:	**107,742**		**1,025,690**		**621,377**		**602,678**	

Table 22. Breakdown of subsidies by 'good', 'bad', and 'ugly' designations for the Maldives, Myanmar, Sri Lanka, and Thailand

	Maldives		Myanmar		Sri Lanka		Thailand	
	Amount USD	**Source**	**Amount USD**	**Source**	**Amount USD**	**Source**	**Amount USD**	**Source**
Beneficial (good)								
Fisheries management and services	-23,601	FAO profile	40,121	FAO profile	34,609	FAO profile	24,625	(APEC, 2000)
Fishery research and development	200	FAO profile	33,606	FAO profile	28,989	FAO profile	2,379	(APEC, 2000)
Maintenance of MPAs	3,552	(Cullis-Suzuki and Pauly, 2008)	1,926	(Cullis-Suzuki and Pauly, 2008)	1,743	(Cullis-Suzuki and Pauly, 2008)	3,517	(Cullis-Suzuki and Pauly, 2008)
Subtotal	**27,353**		**75,652**		**65,342**		**30,521**	
Percent of landed value	**7.0**		**11.3**		**11.3**		**1.4**	
Harmful (bad)								
Boat construction, renewal and modernization	-	-	44,491	FAO profile	-	-	67,254	(APEC, 2000)
Fishery development and support services	-87,563	FAO profile	148,850	FAO profile	6,967	FAO profile	-	-
Fishing port construction and renovation	1,623	FAO profile	-	-	-	FAO profile	-	-
Marketing support and storage infrastructure	1,870	FAO profile	28,418	FAO profile	1,480	-	66,960	(APEC, 2000)
Tax exemption	-	-	-	-	-	FAO profile	-94,170	(Ahmed *et al.*, 2002)
Foreign access agreements	-	-	-	-	-	-	-	-

Table 22. Breakdown of subsidies by 'good', 'bad', and 'ugly' designations for the Maldives, Myanmar, Sri Lanka, and Thailand

Fuel subsidies	-	-	-	-	41,700	Govt. press release	241,000	Bangkok Post
Subtotal	**91,056**		**221,759**		**50,147**		**469,384**	
Percent of landed value	**23.1**		**33.2**		**8.7**		**21.4**	
Ambiguous (ugly)								
Fisher assistance					-	-	-	-
Vessel buyback	-	-	-	-	-	-	-	-
Rural fisheries community development	-	-	51,654	FAO profile	-	-	-169,506	(Ahmed *et al.*, 2002)
Subtotal	**-**		**51,654**		**-**		**169,506**	
Percent of landed value			**7.7**				**7.7**	
Total Percentage of Landed Value	**30.1**		**52.2**		**20.0**		**30.5**	
Grand total:	**118,409**		**349,066**		**115,489**		**669,411**	

Table 23. Scores for the ratio of 'good' to 'good + bad' subsidies.

Country	**Landed Value**	**SUB_{good}**
Bangladesh	242.03	7.5
India	2637.98	1.9
Indonesia	1952.79	1.8
Malaysia	1647.86	0.7
Maldives	548.5	9.9
Myanmar	786.27	10
Sri Lanka	544.44	7.6
Thailand	2080.11	0

Table 24. Scores for the ratio of subsidies to landed values

Country	**Landed Value**	**SUB_{LV}**
Bangladesh	242.03	0.0
India	2637.98	3.4
Indonesia	1952.79	0.0
Malaysia	1647.86	8.1
Maldives	548.5	10.0
Myanmar	786.27	7.9
Sri Lanka	544.44	6.8
Thailand	2080.11	6.2

Table 25. Average production (1993-2004) by species-country and scores for each of the socio-economic components of mariculture sustainability for each species by BOBLME country.

Country	Common Name	Average Production	Export vs. Domestic	Antibiotic Drug Use	Mol-Biol GMO	Code-practice CoC	Traceablilty	Employment	Nutrition Protein	Average
Bangladesh	Penaeus shrimps nei	49232.40	5	1	6	4	1	5	10	4.6
India	Giant tiger prawn	75259.00	1	1	7	4	5	7	10	5.0
Indonesia	Banana prawn	23696.80	5	2	6	3	2	5	9	4.6
	Barramundi	3350.70	1	1	5	3	3	5	10	4.0
	Giant tiger prawn	80690.00	1	1	7	4	3	7	10	4.7
	Milkfish	185277.30	3	5	8	5	3	7	10	5.9
Malaysia	Banana prawn	9.85	5	2	5	3	3	5	9	4.6
	Barramundi	2549.70	1	1	5	3	3	5	10	4.0
	Blood cockle	75569.10	5	10	10	5	5	5	9	7.0
	Cupped oysters nei	18.20	5	10	3	7	7	7	4	6.1
	Giant tiger prawn	5694.90	1	1	7	3	3	6	10	4.4
Maldives	*	*	*	*	*	*	*	*	*	*
Myanmar	Giant tiger prawn	4855.80	1	1	7	4	3	6	10	4.6
Sri Lanka	Giant tiger prawn	4662.40	1	1	7	4	5	7	10	5.0
Thailand	Barramundi	116.60	3	1	5	3	3	5	10	4.3
	Blood cockle	4380.95	5	10	10	5	5	5	9	7.0
	Cupped oysters nei	1372.50	5	10	3	7	7	7	4	6.1
	Giant tiger prawn	43435.50	1	1	7	3	4	6	10	4.6
	Groupers nei	507.90	5	3	7	5	3	6	9	5.4

Table 26. Scores for each of the socio-economic components of mariculture sustainability for each of the BOBLME countries and the final weighted MSI_{soc} score, which was weighted by the average production.

Country	**Export vs. domestic**	**Antibiotic Drug Use**	**Mol-Biol GMO**	**Code-practice CoC**	**Traceablilty**	**Employment**	**Nutrition Protein**	**MSI_{soc}**
Bangladesh	5.0	1.0	6.0	4.0	1.0	5.0	10.0	0.0
India	1.0	1.0	7.0	4.0	5.0	7.0	10.0	1.4
Indonesia	2.6	3.6	7.5	4.5	2.9	6.8	9.9	3.8
Malaysia	4.6	9.1	9.6	4.8	4.8	5.1	9.1	10.0
Maldives	*	*	*	*	*	*	*	*
Myanmar	1.0	1.0	7.0	4.0	3.0	6.0	10.0	0.0
Sri Lanka	1.0	1.0	7.0	4.0	5.0	7.0	10.0	1.9
Thailand	1.5	2.1	7.1	3.3	4.2	5.9	9.7	1.0

Table 27. Aggregated score (unweighted) of marine resources management performance.

Country	**MPA_{area}**	**MPA_{inv}**	TRA_{prop}	**MSI_{ecol}**	**$BIRD_{prot}$**	**MAM_{prot}**	**EIF_{GDP}**	**$CODE_{FAO}$**	**$STAT_{rep}$**	**SUB_{good}**	**SUB_{LV}**	**MSI_{soc}**	**Average Score**	**Standardized Score**
Bangladesh	1.1	1	9.3	0	10	4.9	0.03	1.8		7.5	0	0	3.2	2.6
India	10	7	1.8	1.2	9.1	10	0	7.1		1.9	3.4	1.4	4.8	6.9
Indonesia	4.1	2.1	0.7	6.3	1.5	1.1	0.03	3.8		1.8	0	3.8	2.3	0.0
Malaysia	0.3	2.2	1.8	10	3	1.8	0.14	10		0.7	8.1	10	4.4	5.7
Maldives	0	2.1	9.9	*	0	6.3	10	5.3		9.9	10	*	5.9	10.0
Myanmar	0.2	0	0	1.2	5.8	0	0.01	0		10	7.9	0	2.3	0.0
Sri Lanka	2	4.5	10	0.5	9.1	1.8	0.1	2.7		7.6	6.8	1.9	4.3	5.4
Thailand	3.9	10	3.5	1.6	5.8	4.8	0.11	2.8		0	6.2	1	3.6	3.6

Table 28. Rankings for Bay of Bengal countries when indicators are aggregated using the GEO4 scenario-based weightings.

Country	***Market First***	***Policy First***	**Security First**	**Sustainability First**
Bangladesh	5.7	5.6	1.4	6.0
India	10.0	10.0	1.8	10.0
Indonesia	1.9	2.2	0.5	2.7
Malaysia	4.5	4.5	4.0	3.8
Maldives	8.3	6.3	10.0	4.7
Myanmar	0.0	0.0	2.5	0.0
Sri Lanka	6.8	6.7	2.8	6.5
Thailand	6.1	6.7	0.0	7.0

FIGURES

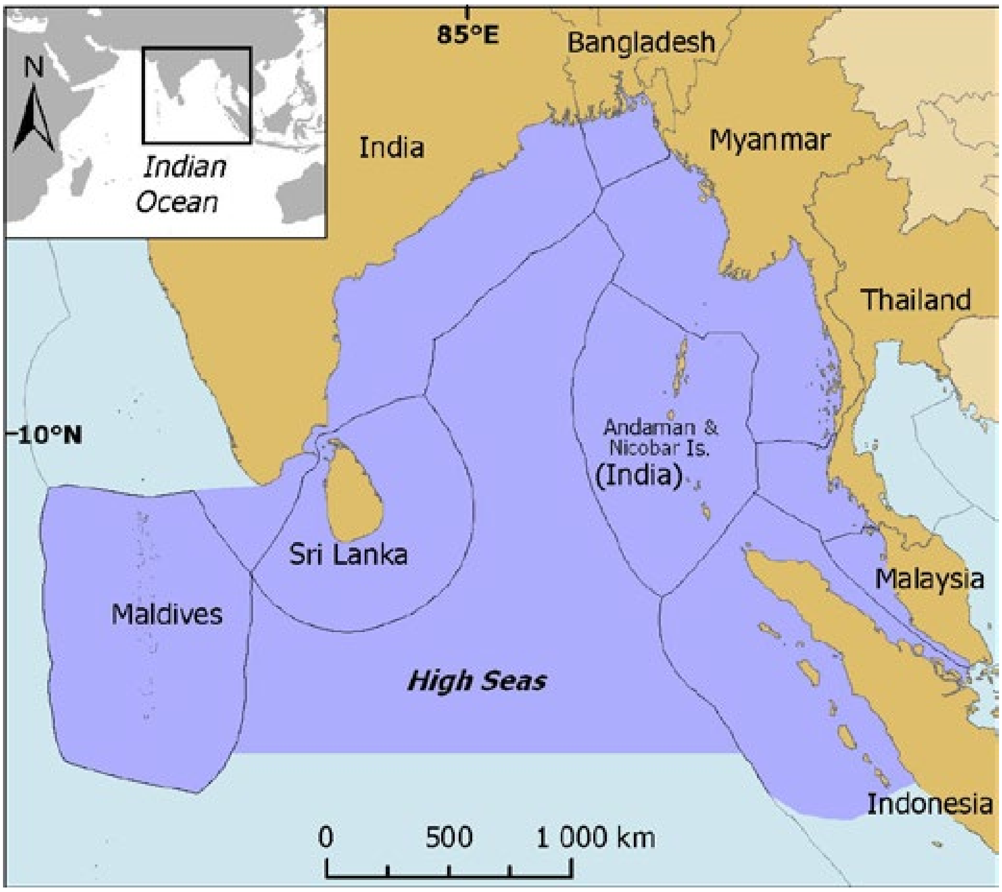

Figure 1. Map of the Bay of Bengal Large Marine Ecosystem (shaded region), including the eight countries, their EEZs, and the high seas area that lie within this area.

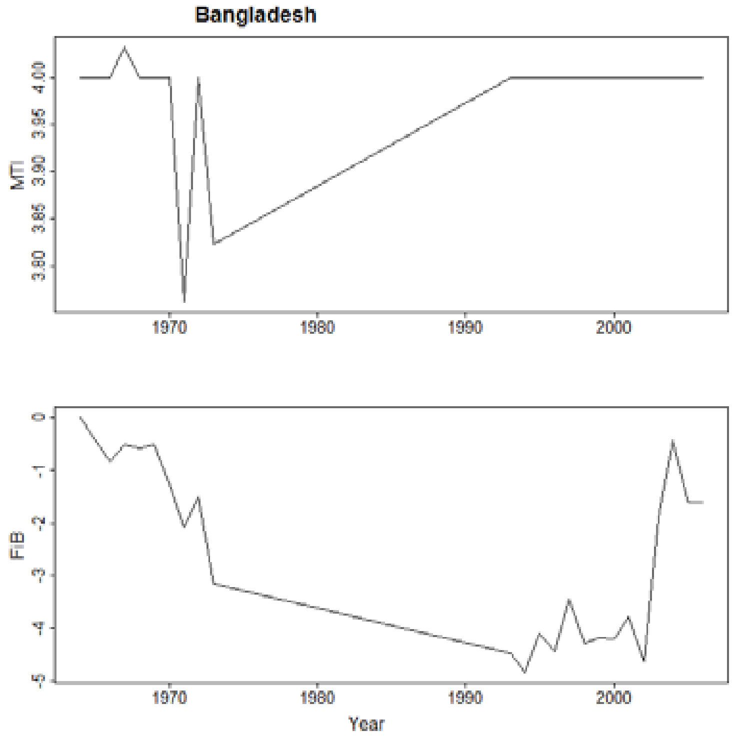

Figure 2. MTI and FiB for Bangladesh

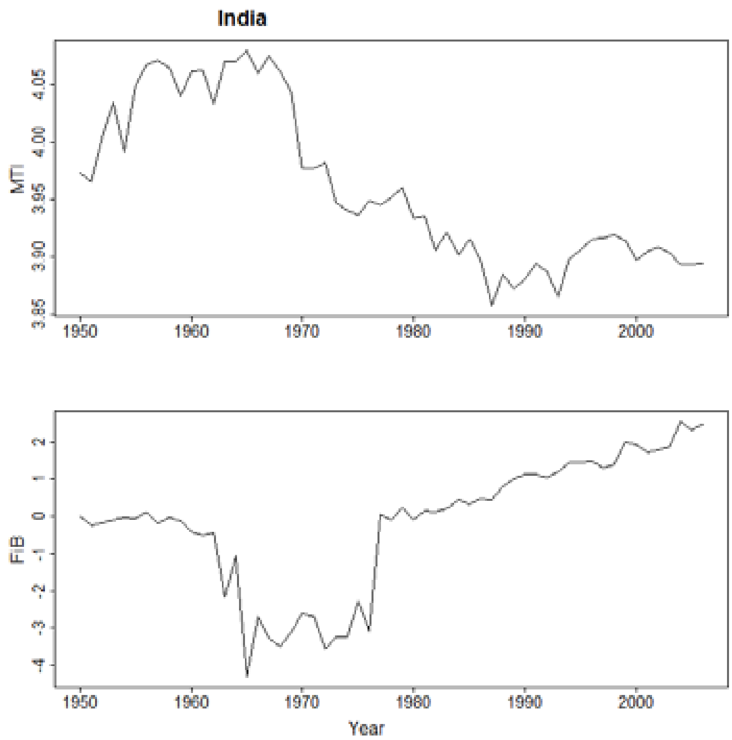

Figure 3. MTI and FiB for India

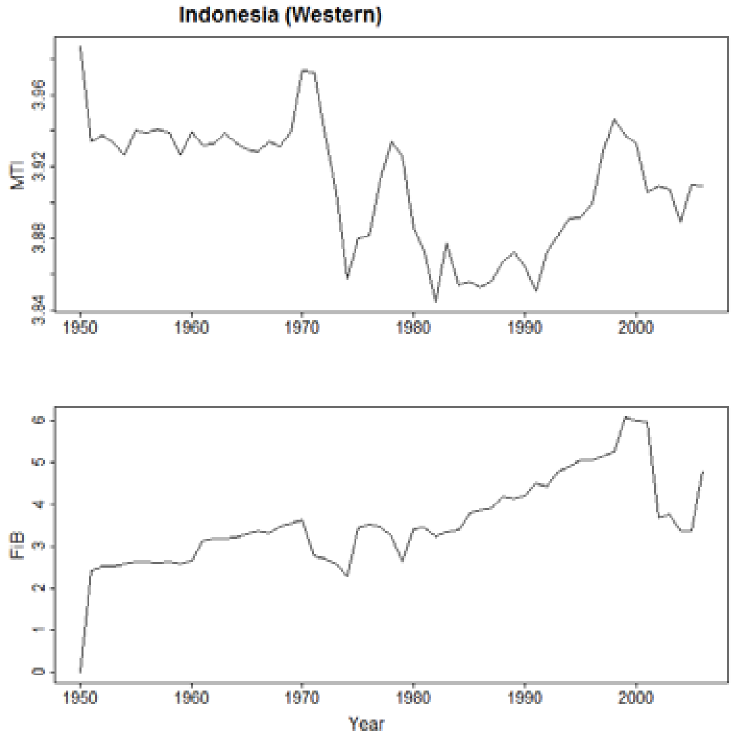

Figure 4. MTI and FiB for Indonesia

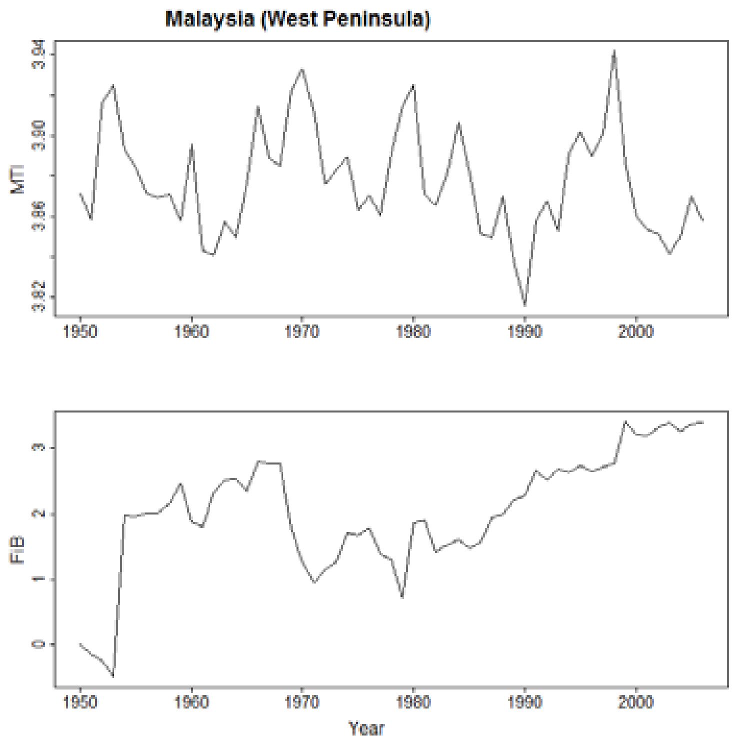

Figure 5. MTI and FiB for Malaysia

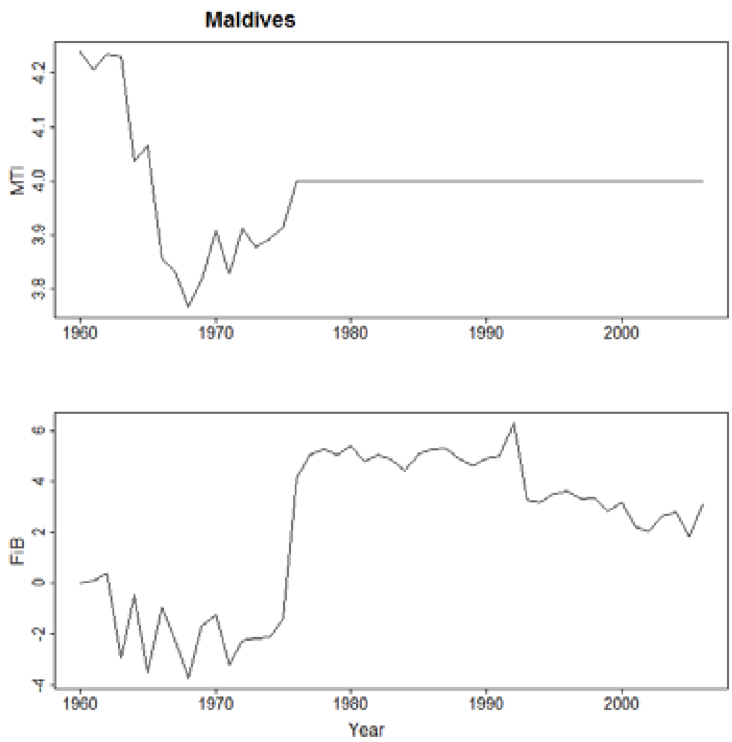

Figure 6. MTI and FiB for the Maldives

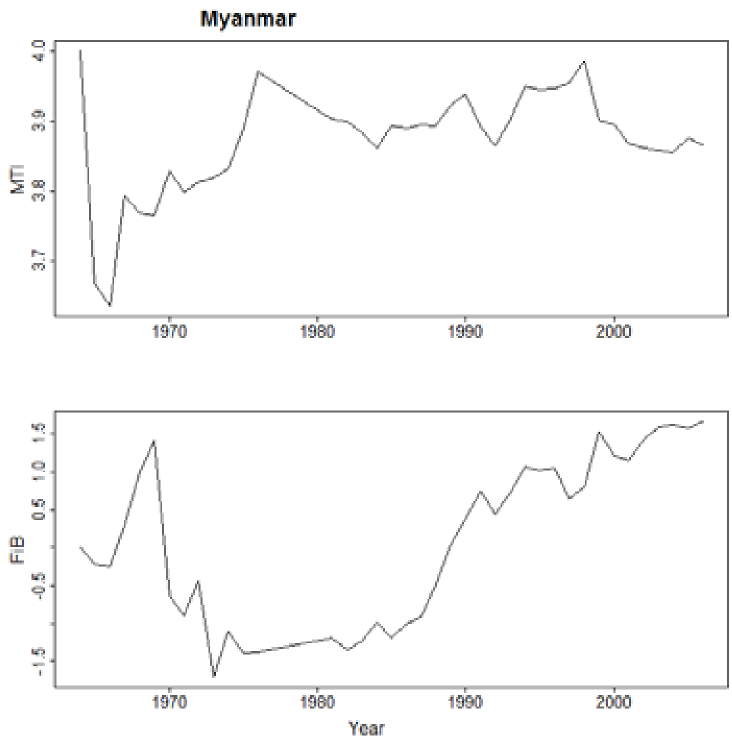

Figure 7. MTI and FiB for Myanmar

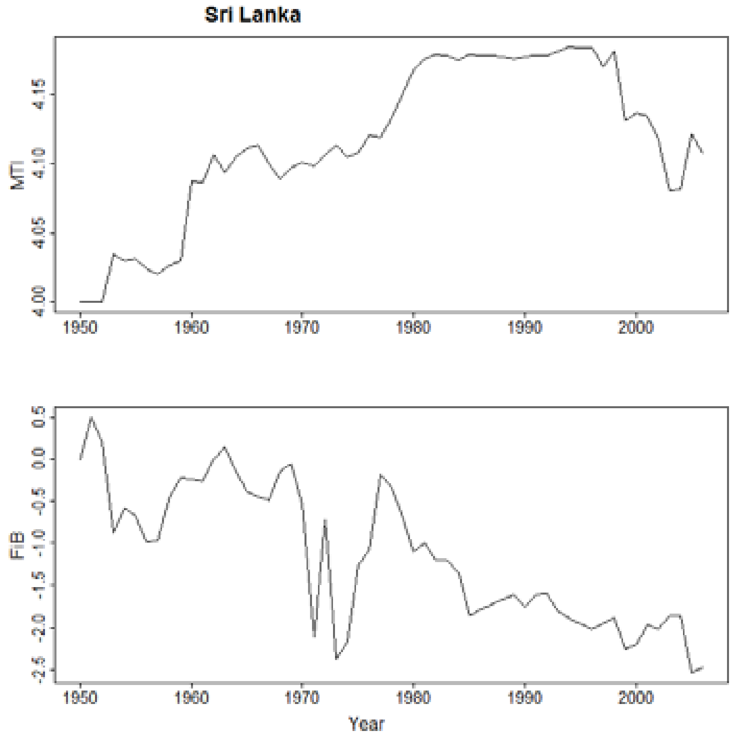

Figure 8. MTI and FiB for Sri Lanka

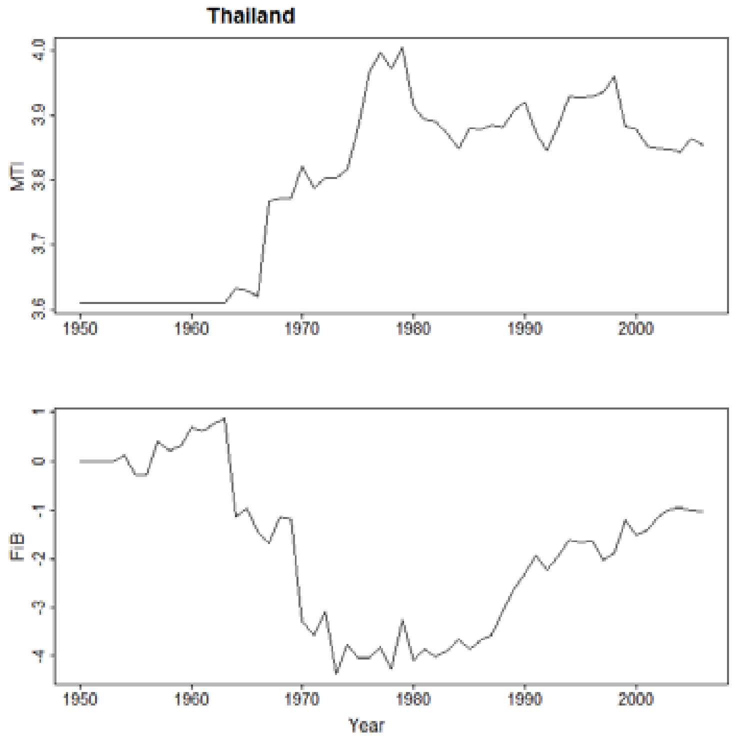

Figure 9. MTI and FiB for Thailand

Figure 10. Stock status plots for Bangladesh, showing percentage of stocks in numbers (top panel) and percentage catch by stock status (bottom panel).

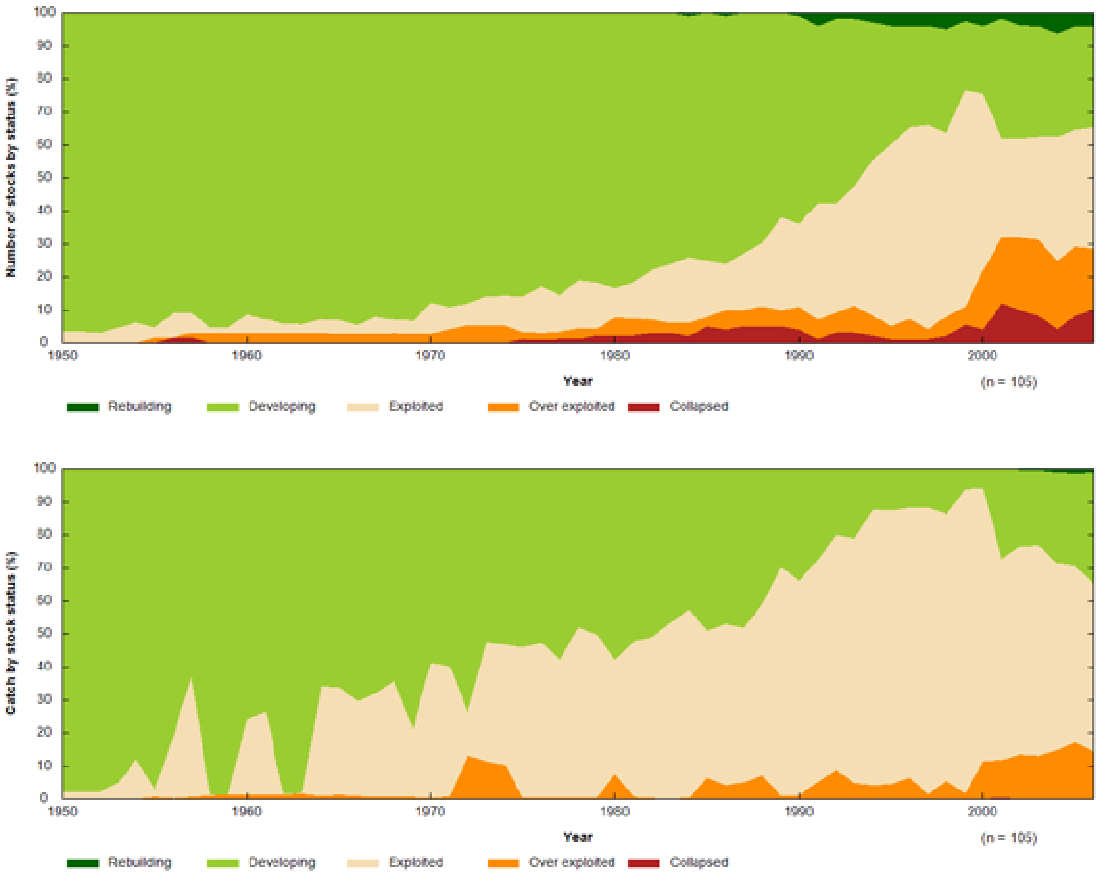

Figure 11. Stock status plots for India, showing percentage of stocks in numbers (top panel) and percentage catch by stock status (bottom panel).

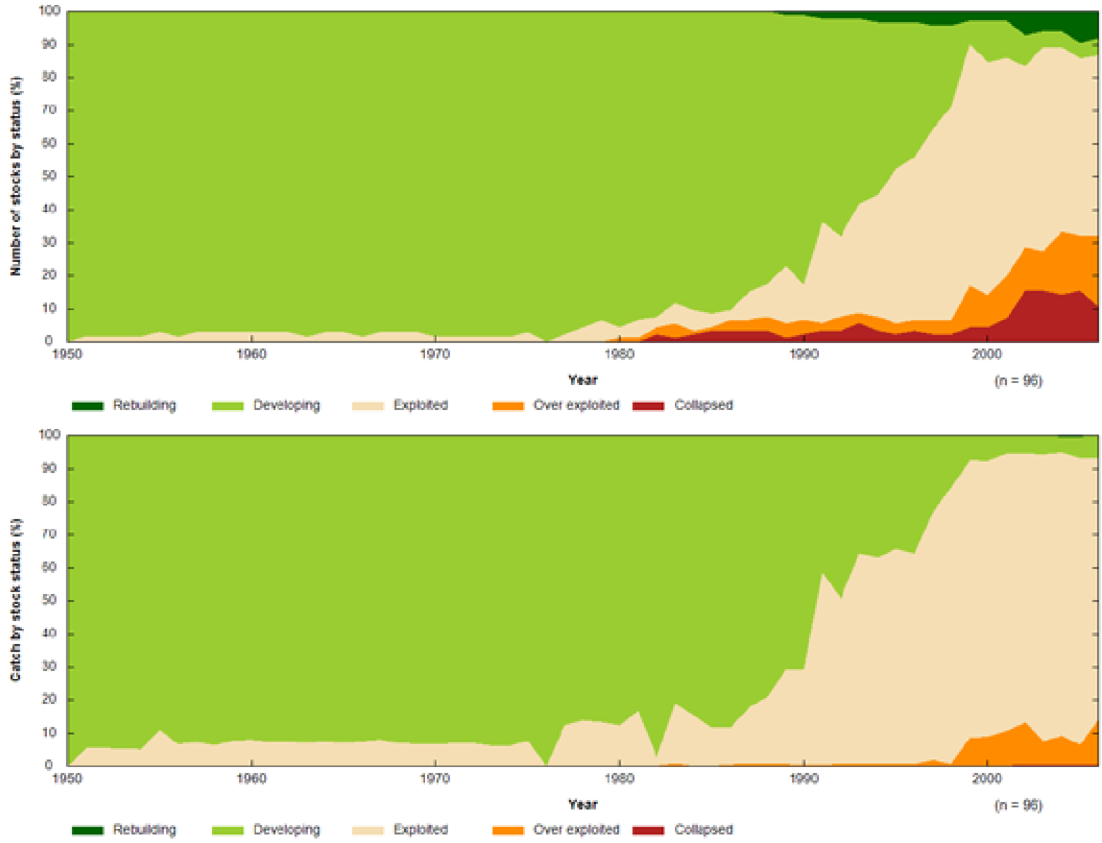

Figure 12. Stock status plots for Indonesia, showing percentage of stocks in numbers (top panel) and percentage catch by stock status (bottom panel).

Figure 13. Stock status plots for Malaysia, showing percentage of stocks in numbers (top panel) and percentage catch by stock status (bottom panel).

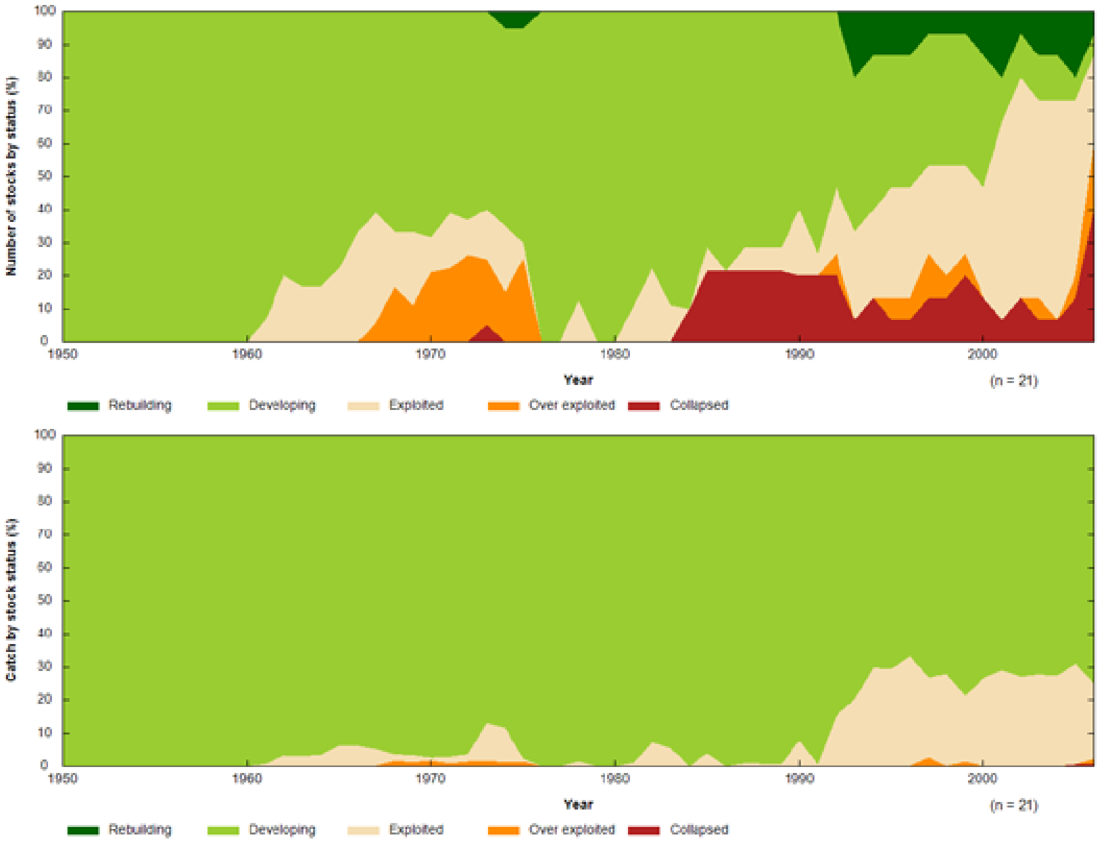

Figure 14. Stock status plots for Maldives, showing percentage of stocks in numbers (top panel) and percentage catch by stock status (bottom panel).

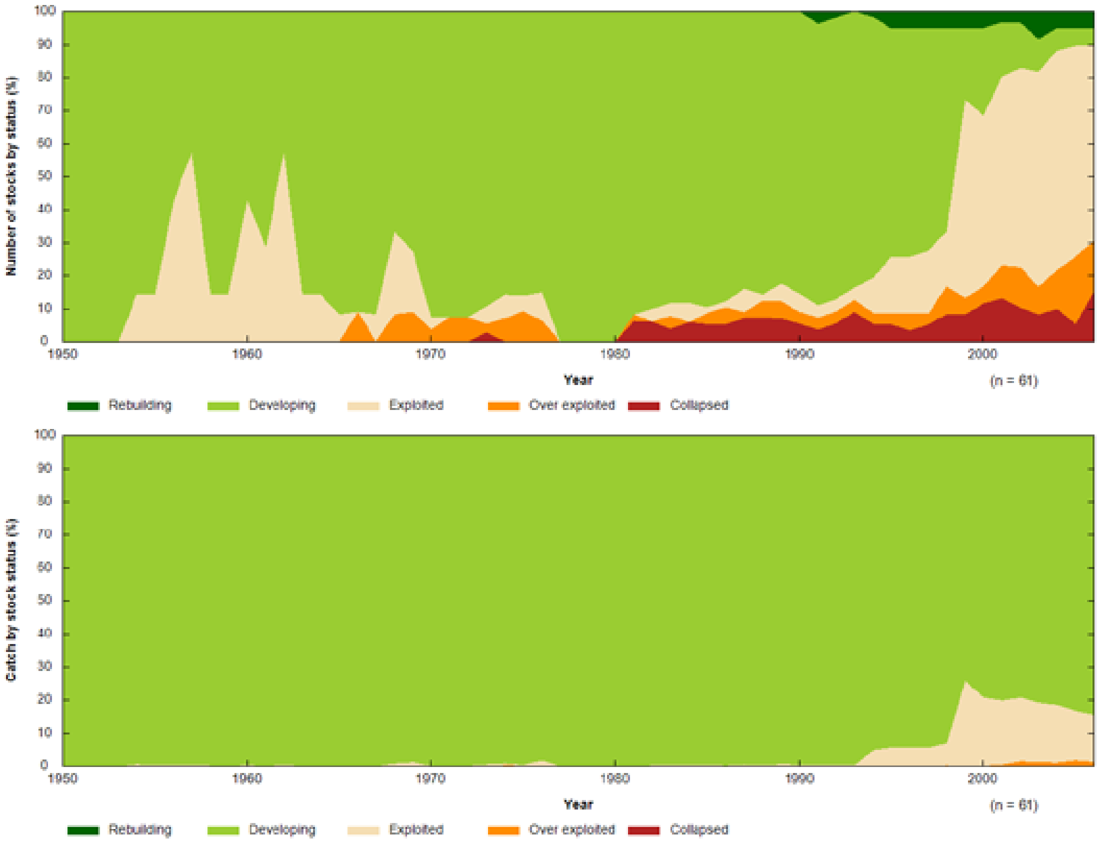

Figure 15. Stock status plots for Myanmar, showing percentage of stocks in numbers (top panel) and percentage catch by stock status (bottom panel).

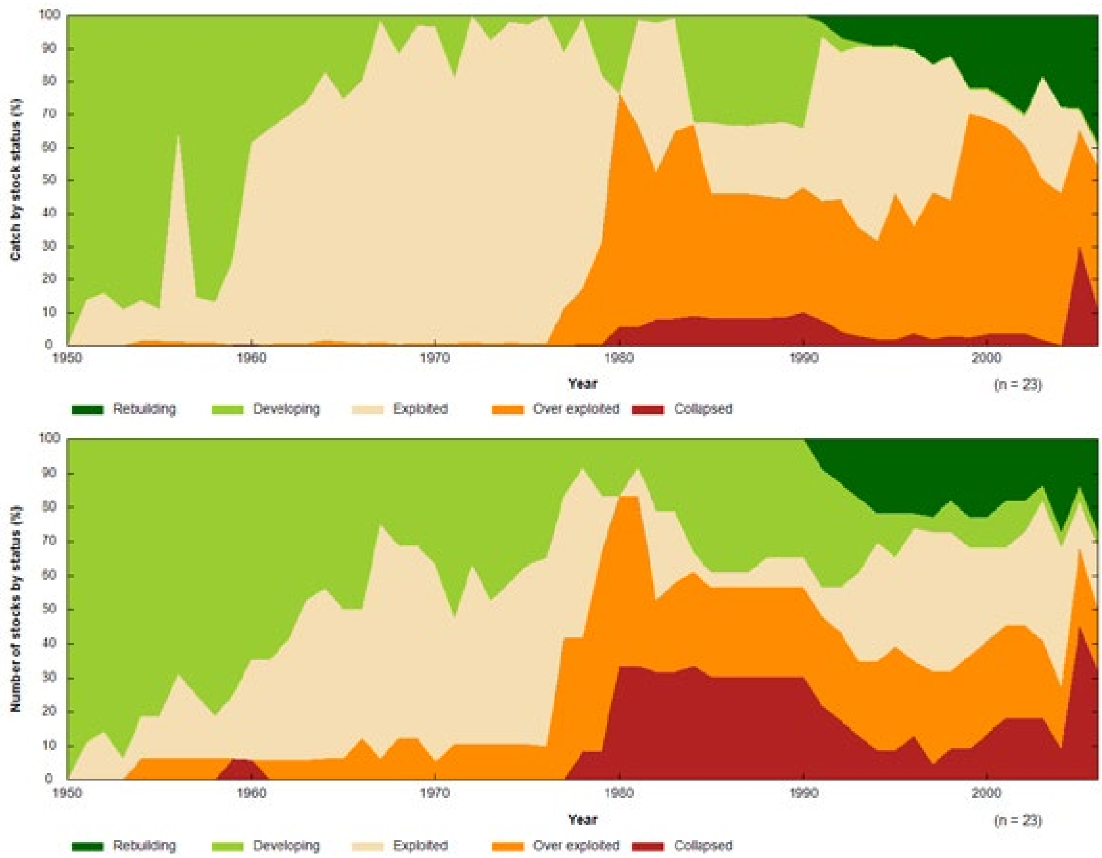

Figure 16. Stock status plots for Sri Lanka, showing percentage of stocks in numbers (top panel) and percentage catch by stock status (bottom panel).

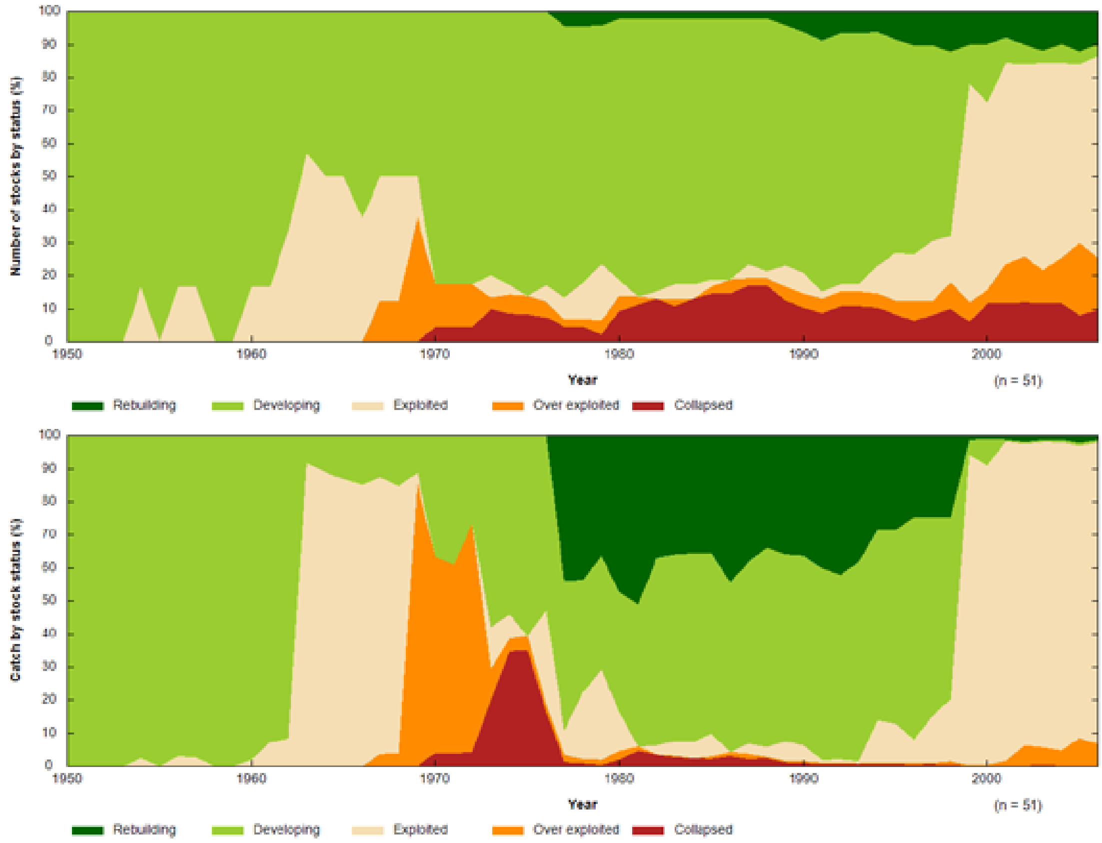

Figure 17. Stock status plots for Thailand, showing percentage of stocks in numbers (top panel) and percentage catch by stock status (bottom panel).

Bangladesh, India, Indonesia, Malaysia, Maldives, Myanmar, Sri Lanka and Thailand are working together through the Bay of Bengal Large Marine Ecosystem (BOBLME) Project and to lay the foundations for a coordinated programme of action designed to improve the lives of the coastal populations through improved regional management of the Bay of Bengal environment and its fisheries.

The Food and Agriculture Organization (FAO) is the implementing agency for the BOBLME Project.

The Project is funded principally by the Global Environment Facility (GEF), Norway, the Swedish International Development Cooperation Agency, the FAO, and the National Oceanic and Atmospheric Administration of the USA.

For more information, please visit www.boblme.org