Transboundary Diagnostic Analysis

VOLUME 2

BACKGROUND AND ENVIRONMENTAL ASSESSMENT

BAY OF BENGAL LARGE MARINE ECOSYSTEM PROJECT

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Contents

This document was prepared after the Transboundary Diagnostic Analysis (TDA) Confirmation Workshop held in Phuket Thailand from 13 to 14 February 2012. The TDA is published in two volumes. Volume 1 describes the transboundary issues in the Bay of Bengal Large Marine Ecosystem (BOBLME) and their proximate and underlying root causes. These will be used to develop a Strategic Action Programme (SAP). Volume 2 contains background material that sets out the biophysical and socio-economic characteristics of the BOBLME; an analysis of the legal, policy and administrative context in the eight countries that border the Bay of Bengal and an assessment of the status of the marine living resources and the marine environment in the coastal areas of the BOBLME.

Acknowledgements

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- Eight national papers authored by Mohamed Ali (Maldives); Md. M. Maruf Hossain (Bangladesh); Leslie Joseph (Sri Lanka); Kungwan Juntarashote (Thailand); Myint Pe (Myanmar); Ishak Haji Omar (Malaysia); Sri Hartiningsih Purnomohadi (Indonesia); and Varadarajan Sampath (India);
- Five theme reports authored by Charles L. Angell (Mangroves and coral reefs); William Edeson (Legal and enforcement mechanisms); Ursula L. Kaly (Land-based sources of pollution); Garry Leonard Preston (Shared marine resources); and Philip Townsley (Coastal and marine livelihoods and food security);
- Three BOBLME workshops including background papers (BOBLME/REP/1, 2003), (BOBLME/REP/2, 2003) and (BOBLME/REP/2RW, 2004);
- A Preliminary TDA Framework written by Philomene Veerlan (2003); updates of the Preliminary TDA by Ben Cattermoul (Socio-economic characteristics); Michael E. Huber (Pollution); Hugh Kirkman (Critical habitats), Martin Tsamenyi (Legal, administrative and political context); and Derek Staples (Biophysical characteristics, marine living resources and the causal chain analysis). The causal chain analysis was enhanced by the input of John Pernetta.

The process has been guided by national review groups (for the national reports,) and an international scientific review group (for the regional theme papers), National Task Force (NTF) meetings and national workshops. Verification of the TDA was carried out by a thorough national TDA consultation process in 2011. Overall guidance for TDA development was provided by the former BOBLME Project Coordinator, Philomene Verlaan, the current BOBLME Project Regional Coordinator, Chris O'Brien, and the Chief Technical Adviser, Rudolf Hermes.

This publication was compiled and edited by Derek Staples and copy edited by Claire Attwood.

The Bay of Bengal Large Marine Ecosystem Project

In April 2009, the Bay of Bengal Large Marine Ecosystem (BOBLME) Project started work.

This five year project involving Indonesia, Malaysia, Thailand, Myanmar, Bangladesh, India, Sri Lanka and the Maldives, aims to improve the lives of the coastal populations through improved regional management of the Bay of Bengal environment and its fisheries.

The BOBLME countries have a combined total population of 1.78 billion people, equivalent to 25 percent of the world's population. The coastal population of the region is estimated to be 450 million people, equivalent to 50 percent of the world's coastal poor.

The BOBLME is rich in natural resources, including extensive mineral and energy resources; marine living resources that support major fisheries; and forest and land resources.

Fisheries production is six million tonnes per year, more than seven percent of the world's marine catch.

The Bay of Bengal is an area of high biodiversity, with a large number of endangered and vulnerable species

The LME supports a wide range of habitats, including extensive tracts of mangroves (12 percent of the world's mangroves), coral reefs (eight percent of the world's coral reefs) and seagrass beds. It is an area of high biodiversity, with a large number of endangered and vulnerable species.

The LME and its natural resources are of considerable social and economic importance to the countries that border the Bay of Bengal. Activities such as fishing, marine farming, tourism and shipping contribute to food security, employment and national economies. Marine living resources are extremely important to the coastal poor, particularly as a source of food.

There are over 400 000 fishing boats operating in the Bay of Bengal and over 4.5 million people are employed in fisheries and associated activities. But rapid population growth, high dependence on aquatic resources for food, trade and livelihoods, and changing land use patterns are having major impacts on the marine ecosystem. It is not clear how much longer the Bay of Bengal will be able to support the needs and aspirations of the many sectors that use its resources, most notably the large population of coastal poor that depends on them for survival.

The Transboundary Diagnostic Analysis (TDA)

A TDA identifies, quantifies and ranks water-related environmental transboundary issues and their causes according to the severity of environmental and/or socio-economic impacts.

The TDA of the BOBLME draws on numerous studies and extensive regional and national consultations with stakeholders. Importantly, the TDA provides the scientific basis for the development of the Strategic Action Programme that sets out a strategy for the countries to collectively deal with transboundary issues.

Main areas of concern

The TDA of the BOBLME identifies three main transboundary issues:

1. **Overexploitation of marine living resources**
2. **Degradation of mangroves, coral reefs and seagrasses**
3. **Pollution and water quality**

A causal chain analysis was conducted on each of these areas of concern, resulting in the identification of priority issues and their underlying causes. A summary of the three areas is presented here. It should be noted that some important national issues may not be included in this TDA. A transboundary issue is defined as an environmental problem in which either the cause of the problem and/or its impact is separated by a national boundary; or the problem contributes to a global environmental problem and finding regional solutions is considered to be a global environmental benefit.

The TDA also reviews the driving forces at work in the BOBLME, such as the socio-economic, institutional, legal, administrative circumstances and the projected impact of global climate change on the region. These forces all pose a range of constraints and challenges and have the potential to influence the success of actions implemented to address the three main areas of concern. This information is also considered to be important for the development of the Strategic Action Programme.

Overexploitation of living marine resources

The major issues

1. **A decline in the overall availability of fish resources**
2. **Changes in the species composition of catches**
3. **A high proportion of juvenile fish in the catch**
4. **Changes in marine biodiversity, especially through loss of vulnerable and endangered species**

The transboundary nature of the major issues

- Many fish stocks are shared between BOBLME countries, through the transboundary migration of fish, or larvae.
- Fishing overlaps national jurisdictions, both legally and illegally – overcapacity and overfishing in one location forces a migration of fishers and vessels to other locations.
- All countries (to a greater or lesser degree) are experiencing difficulties in implementing fisheries management, especially the ecosystem approach to fisheries.
- BOBLME countries contribute significantly to the global problem of loss of vulnerable and endangered species.

The main causes of the issues

- High consumer demand for fish, including for seed and fishmeal for aquaculture
- Open access to fishing grounds
- Government emphasis on increasing fish catches
- Inappropriate government subsidies provided to fishers
- Increasing fishing effort, especially from trawlers and purse seiners
- Ineffective fisheries management
- Illegal and destructive fishing

Fisheries production in the Bay of Bengal is six million tonnes per year, more than seven percent of the world's catch

Degradation of critical habitats

The major issues

1. **Loss and degradation of mangrove habitats**
2. **Degradation of coral reefs**
3. **Loss and damage to seagrasses**

The transboundary nature of the major issues

- All three critical habitats occur in all BOBLME countries.
- Coastal development for several varying uses of the land and sea are common in all BOBLME countries.
- Trade in products from all the habitats is transboundary in nature.
- Climate change impacts are shared by all BOBLME countries.

The main causes of the issues

- Food security needs of the coastal poor
- Lack of coastal development plans
- Increasing trade in products from coastal habitats
- Coastal development and industrialization
- Ineffective marine protected areas and lack of enforcement
- Upstream development that affects water-flow
- Intensive upstream agricultural practices
- Increasing tourism

Pollution and water quality

The major issues

1. **Sewage-borne pathogens and organic load**
2. **Solid waste/marine litter**
3. **Increasing nutrient inputs**
4. **Oil pollution**
5. **Persistent organic pollutants (POPs) and persistent toxic substances (PTSs)**
6. **Sedimentation**
7. **Heavy metals**

The transboundary nature of the major issues

- Discharge of untreated/partially treated sewage is a common problem; sewage and organic discharges from the Ganges-Brahmaputra-Meghna River are likely to be transboundary.
- Plastics and derelict fishing gear can be transported long distances across national boundaries.
- High nutrient discharges from rivers could intensify large-scale hypoxia; atmospheric transport of nutrients is inherently transboundary.
- Differences between countries with regard to regulation and enforcement of shipping discharges may drive discharges across boundaries; tar balls are transported long distances.
- POPs/PTSs and mercury, including organo-mercury, undergo long-range transport.
- Sedimentation and most heavy metal contamination tend to be localized and lack a strong transboundary dimension.

The main causes of the issues

- Higher consumption, resulting in more waste generated per person
- Increasing coastal population density and urbanization
- Insufficient funds allocated to waste management
- Migration of industry into BOBLME countries
- Proliferation of small industries

With the support of the BOBLME Project, the eight countries are now developing responses to these issues and their causes, for future implementation as the Strategic Action Programme

1. Introduction

This document is Volume 2 of the Transboundary Diagnostic Analysis (TDA) for the Bay of Bengal Large Marine Ecosystem (BOBLME). It describes:

- The scope and characteristics of the BOBLME;
- The legal, administrative and political context and constraints;
- An assessment of marine living resources and the environment (including critical habitats and pollution); and
- The background to the BOBLME transboundary issues.

It provides the background to Volume 1 which focuses on transboundary issues and presents a causal chain analysis that identifies the proximate and root causes of the issues, thereby providing a basis for the development of a Strategic Action Programme (SAP) that identifies the interventions required to address the transboundary issues.

Both volumes are based on a preliminary framework TDA (Verlaan, 2004) that consolidated the results and recommendations of extensive regional and national consultations held with stakeholders, and the reports and comments received between January 2003 and May 2004. Inputs included theme reports by Angell, 2004; Edeson, 2004; Kaly, 2004; Preston, 2004; and Townsley, 2004; and national reports by Ali, 2003; Hossain, 2003; Joseph, 2003; Juntarashote, 2003; Myint, 2003; Omar, 2003; Purnomohadi, 2003 and Sampath, 2003. Also included were the outputs of regional workshops (BOBLME/REP/1, 2003; BOBLME/REP/2, 2003 and BOBLME/REP/2RW, 2004) and national consultations carried out by each country in 2011.

The three main themes that reflect the areas of concern covered in this TDA are:

- Overexploitation of marine living resources;
- Degradation of mangroves, coral reefs and seagrasses; and
- Pollution and water quality.

Volume 1 presents the transboundary issues and their proximate and root causes, describing them under these three themes. Many of the statements in Volume 1 are made without references, data or information; these are presented in considerable detail in this volume.

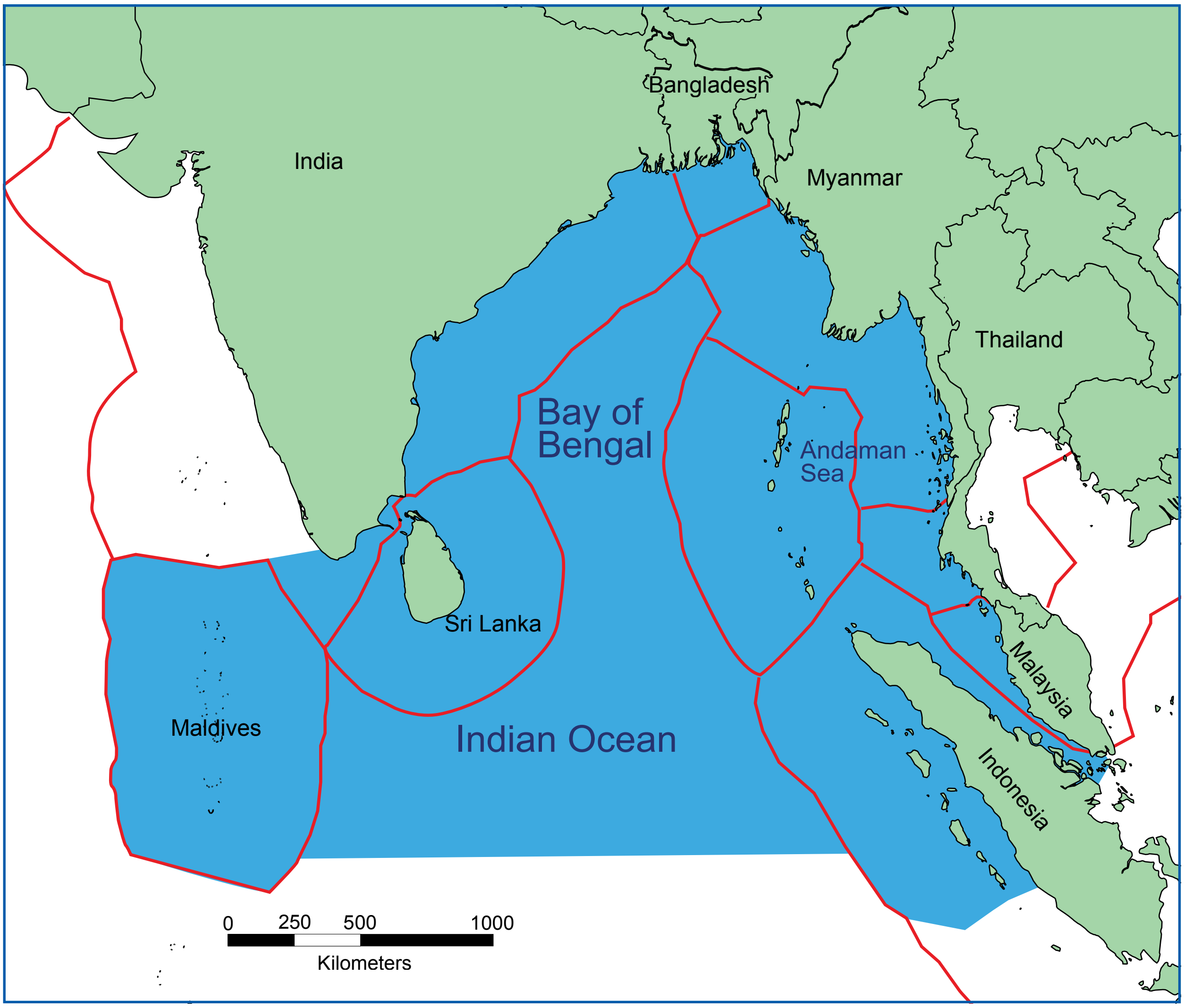
2. Scope and characteristics of the BOBLME

2.1 Boundary and general characteristics of the region

The BOBLME, as defined for the purposes of the BOBLME Project, includes the Bay of Bengal itself, the Andaman Sea, the Straits of Malacca and the Indian Ocean to 2°S (Figure 2.1). As well as the high seas area, it comprises the coastal areas, islands, reefs, continental shelves and coastal and marine waters of the northern part of the Island of Sumatra in Indonesia (Provinces of Aceh, Riau, North Sumatra and West Sumatra); the west coast of Peninsular Malaysia; the west coast of Thailand, Myanmar and Bangladesh; the east coast of India; the Andaman and Nicobar Islands of India; Sri Lanka; and the Maldives. The BOBLME covers an area of about 6.25 million square kilometres. Its boundaries are based on the delineation of the world's LMEs by NOAA,[1] but moved slightly south to include the Maldives and northern Sumatra in Indonesia.

[1] http://www.lme.noaa.gov/

Figure 2.1 BOBLME boundaries and approximate EEZ boundaries[2]. Source: BOBLME Project. Note that the delimitation of the maritime boundaries between Bangladesh, India and Myanmar is subject to ongoing judgements by the International Tribunal for the Law of the Sea. The figure shows the approximate position of the boundaries only.



Source: Sea Around Us Project and the BOBLME RCU.

[2] The designations employed and the material presented in this document do not imply the expression of any opinion whatsoever by the Food and Agriculture Organization (FAO) of the United Nations, or by the author of this document, on the legal status of any country, city, territory or area, or of its authorities, or concerning the delimitation of any frontiers or boundaries.

Table 2.1 Length of coastline and combined EEZ and territorial areas of countries in the BOBLME (Note: these figures pertain only to the area of each country included within the boundaries of the BOBLME.)

Country	Length of coastline (km)	Estimated area of the EEZ (km^2)	Percentage area
Indonesia	**~2 000[1]**	**719 300[1]**	**11.5%**
Malaysia	**1 110**	**68 750**	**1.1%**
Thailand	**740**	**118 600**	**1.9%**
Myanmar	**3 000**	**520 260**	**8.3%**
Bangladesh	**710**	**78 540**	**1.3%**
India	**4 645**	**1 326 510**	**21.2%**
Sri Lanka	**1 770**	**530 680**	**8.5%**
Maldives	**n/a**	**916 190**	**14.7%**
High seas	**–**	**1 972 170**	**31.5%**
Total	**~14 000**	**6 251 000**	

Source: (SAUP, 2010). Note: These estimates also include the territorial waters of each country.
[1] Estimate based on approximate proportion of Indonesian EEZ area and coast.
Note: The delimitation of the maritime boundaries between Bangladesh, India and Myanmar is subject to ongoing judgements by the International Tribunal for the Law of the Sea. The figures cited may change as a result of such judgements.

Just over 68 percent of the BOBLME lies within the EEZs of BOBLME countries, therefore, much of the BOBLME is subject to national jurisdiction. Although several sources of information may be used for determining the EEZ of each country (Table 2.2), the Sea Around Us Project is the source of EEZ data for the BOBLME Project (SAUP, 2010, Table 2.1). Although Table 2.2 refers to the entire EEZ of each country, it is included for the purpose of verifying the SAUP data.

The BOBLME countries with the greatest area of estimated EEZ within the BOBLME as defined are, from largest to smallest: India (both east coast and Andaman and Nicobar Islands), Maldives, Myanmar, Indonesia, Sri Lanka, Thailand, Bangladesh and Malaysia (Table 2.1).

Table 2.2 Combined EEZ and territorial areas of countries in the BOBLME from various sources.

Country	EEZ [SAUP]	EEZ [FAO]	EEZ [Limits in the Seas]	EEZ [VLIZ]	EEZ [Wikipedia]	EEZ [WRI - Earth trends]
Bangladesh	**78 538**	**–**	**76 926**	**79 623**	**86 392**	**80 125**
India	**2 290 268**	**2 200 414**	**2 017 988**	**2 298 674**	**2 305 143**	**2 297 249**
Indonesia	**6 079 377**	**4 500 144**	**5 416 906**	**5 996 571**	**6 159 032**	**6 120 673**
Malaysia	**447 276**	**524 897**	**476 336**	**477 396**	**334 671**	**350 540**
Maldives	**916 189**	**984 858**	**960 571**	**920 372**	**923 322**	**996 481**
Myanmar	**520 262**	**–**	**510 335**	**522 705**	**532 775**	**513 273**
Sri Lanka	**530 684**	**556 336**	**518 234**	**533 058**	**532 572**	**531 294**
Thailand	**306 365**	**–**	**325 227**	**308 042**	**299 397**	**252 416**

Source: SAUP, 2010; FAO Country profiles, 2010; Florida State University, 2012; Vlaams Instituut voor de Zee, 2012; Wikipedia, 2012; WRI, 2012.
FAO country profiles only provide EEZ area outside of territorial waters; territorial water areas were added based on the reported coastal length.

The high seas are open to all states, whether coastal or land-locked. Freedom of the high seas is exercised under the conditions laid down by the United Nations Convention on the Law of the Sea (UNCLOS) and by other rules of international law. States operating in the high seas are afforded freedom of navigation; freedom of overflight; freedom to lay submarine cables and pipelines; freedom to construct installations and artificial islands; freedom to fish; and freedom to conduct scientific research. States can regulate any related activities only by regulating the actions of their own nationals, or vessels under their flags.

A number of conventions relating to high seas areas are consistent with UNCLOS and the International Seabed Authority. The International Maritime Organization (IMO) regulates shipping and a range of IMO conventions relate to activities on the high seas. Fishing in the high seas is covered under the UN Fish Stocks Agreement (Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks) and the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas (FAO Compliance Agreement). Governance gaps surround activities relating to bottom trawling, bio-prospecting, marine scientific research, marine archaeology and deep sea tourism.

The Indian Ocean Tuna Commission (IOTC) is an intergovernmental organization established under Article XIV of the FAO constitution. It is mandated to manage tuna and tuna-like species in the Indian Ocean and adjacent seas and covers both the EEZ and high seas areas. The tuna species currently under the management of IOTC are the yellowfin, skipjack, bigeye, albacore, southern bluefin and longtail tunas; other tuna and tuna-like species are under assessment. With the exception of Myanmar and Bangladesh, all counties of the BOBLME are members of IOTC.

2.2 Regional differences

As noted in Volume 1 (Section 2.3) there are many differences in culture, religion, and political and biological systems, both between and within the countries of the BOBLME. However, this is a regional overview and, as such, the similarities rather than the differences have been highlighted. Where possible, the differences have been noted under each of the major headings, although it was often impractical to separate information into the state/provincial or district level and the TDA national consultations highlighted some of these (Staples *et al.*, 2012). It is clear that generalizations do not necessarily apply uniformly to the whole region and the impact of the issues will also vary depending on national policies and local conditions. The capacity of countries to address the issues successfully will also differ. In the development of the SAP, these differences should be accommodated by the National Action Plans (NAPs) that will support the SAP.

Stakeholders' differing interpretation of scientific assessments is also evident and, given the varying responses to uncertainty and the known diversity of the region, arriving at a consensus on the marine and coastal issues and their causes in the BOBLME is a difficult and complex task.

2.3 Biophysical characteristics

2.3.1 Climate and currents

The BOBLME lies in a high rainfall/monsoonal climate zone and it includes substantial areas of low-lying coastal land. Monsoons blow from the southwest between May and October and from the northeast from November to April. The southwest, or summer monsoon, occurs when warm, moist air from the Indian Ocean flows onto the land. This season is usually characterized by heavy rain. The northeast monsoon occurs when cold, dry winter air flows out of the interior of Asia from the northeast and brings the cool, dry winter weather.

The monsoon influences the wind-driven surface circulation in the BOBLME that changes seasonally, forming a stronger clockwise gyre during the southwest monsoon and a weaker anti-clockwise gyre during the northeast monsoon. Although the monsoon is a recurring event it is characterized by great inter-annual variability in the time of its onset and its intensity. As yet, neither of these variables can be adequately predicted, but the monsoon dynamics are linked with the Indian Ocean Dipole (IOD). The IOD is an irregular oscillation of sea-surface temperatures in which the western Indian Ocean becomes alternately warmer and then colder than the eastern part of the ocean. It interacts with similar phenomena like the "El Nino-Southern Oscillation" (ENSO) in the Pacific Ocean. A significant positive IOD occurred in 1997 and 1998, with another recorded in 2006.

The BOBLME has no true seasonal upwelling. However, in near-shore areas the mixing of nutrient rich bottom waters and warm surface waters creates conditions similar to upwelling. During the northeast monsoon, this phenomenon occurs on the northeast coast of India, the western coast of Thailand and off the south coast of Sri Lanka. And, during the southwest monsoon, the eastward-flowing equatorial current supplies nutrients to the BOBLME from the Somali upwelling in the Arabian Sea. During the season of current reversal, saline water invades the estuaries and lower reaches of coastal rivers. Tides are mostly semi-diurnal and the range is quite large (e.g. from 0.7m in Sri Lanka to 7m in Myanmar during spring tide). Tidal effects are felt up to 130km inland in the northern estuaries of Bangladesh and up to 340km in the north-eastern estuaries.

Many large rivers flow into the BOBLME, e.g. the Ganges, Brahmaputra and Meghna in the north from Bangladesh and India; the Ayeryawady and Thanlwin in the east from Myanmar; and the Mahanadi, Godavari, Krishna and Cauvery in the west from India. The Ganges-Brahmaputra-Meghna Basin, which covers nearly 1.75 million km^2 spread over five countries (Bangladesh, Bhutan, China, India and Nepal), is the second largest hydrologic region in the world. Numerous rivers also flow into the BOBLME from Indonesia, Malaysia, Sri Lanka and Thailand. These rivers introduce huge quantities of fresh water and large amounts of silt into the coastal and marine environment of the BOBLME. As much as 80 percent of the annual discharge enters rivers in the summer, during the southwest monsoon.

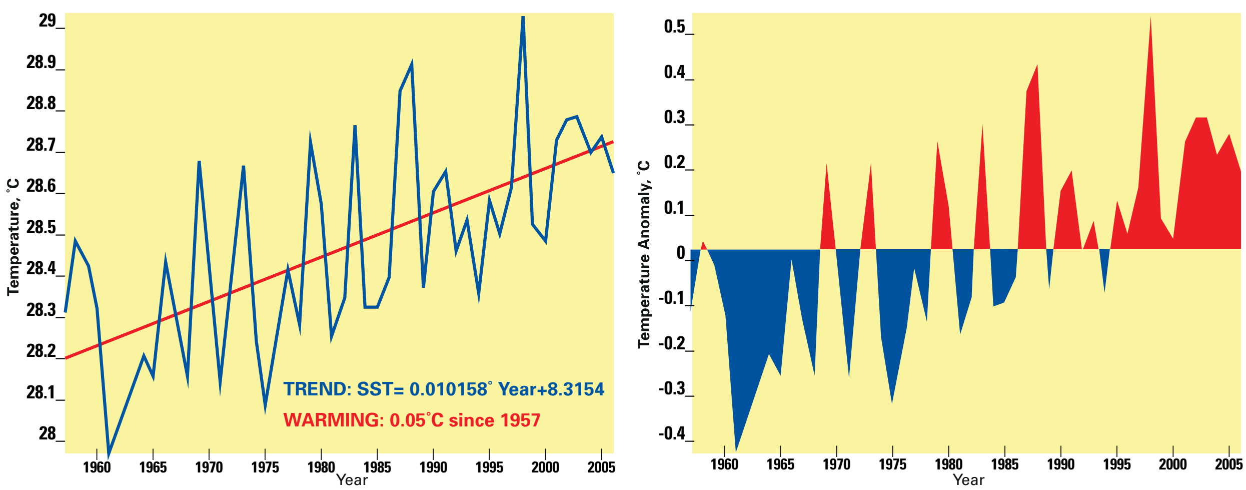
The Intergovernmental Panel on Climate Change (IPCC) predicts an increase in global temperature and an increase in sea surface temperature, rising sea levels, increased precipitation and an increased likelihood of severe weather events for much of Asia (Parry *et al.*, 2007). The effect that climate change is having on sea surface temperatures is shown below, and the impact that climate change is expected to have in the region is discussed in several parts of this publication.

2.3.2 Sea surface temperature and primary productivity

Notwithstanding the wind-driven surface circulation that changes seasonally, the BOBLME shows considerable spatial and temporal variability, particularly in the surface water along the coast. The influx of fresh water from the major rivers affects the salinity and productivity of coastal and estuarine waters and coastal circulation patterns, especially in the north. Monsoon rain and flood waters produce a warm, low-salinity, nutrient- and oxygen-rich layer to a depth of 100 to 150m; this layer floats above a deeper, cooler and more saline layer that does not change significantly with the monsoons (Dwivedi and Choubey, 1998). In the northern area, salinity is perennially low because of the discharge of the Ganges-Brahmaputra River and, as a result, the upper mixed layer is much shallower than it is in the south.

The inter-annual variability of the monsoon also affects the variability of sea surface temperature (SST). In the Bay of Bengal, SST varies with an average magnitude of <0.5°C on a scale of three to five years (decadal variability is not distinct). See Figure 2.2. A positive phase of the IOD results in greater-than-average sea-surface temperatures and greater precipitation in the western Indian Ocean region, with a corresponding cooling of waters in the eastern Indian Ocean. The negative phase of the IOD brings about the opposite conditions, with warmer water and greater precipitation in the eastern Indian Ocean, and cooler and drier conditions in the west. The slow but steady average warming of the Bay of Bengal is also obvious in Figure 2.2. Sea surface temperatures have risen by 0.5°C since 1957.

Figure 2.2 Bay of Bengal LME annual mean SST (left) and SST anomalies (right), 1957 to 2006, based on Hadley climatology.

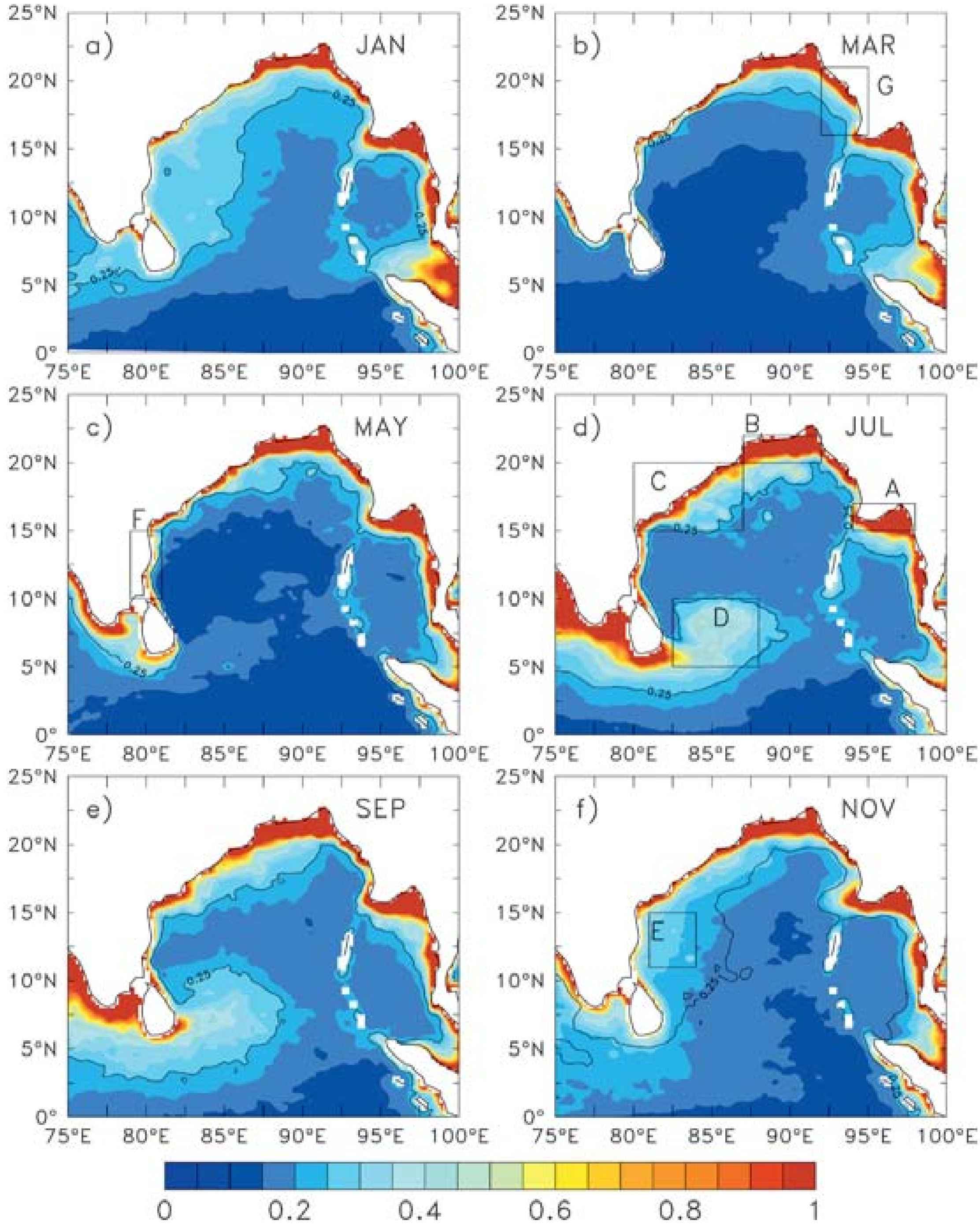


Source: Belkin, 2009.

While the BOBLME was previously considered to be a Class I highly productive ecosystem (>300 gC/m²/y) because of the strong stratification that occurs, the productivity is low when compared with the nearby Arabian Sea (Qasim, 1977; Radhakrishna *et al.*, 1978). As can be seen from SeaWiFS maps (Figure 2.3), for much of the year, high productivity only occurs near the coast and off the mouths of rivers. During the southwest monsoon, local upwelling results in higher productivity around Sri Lanka; during the northeast monsoon, higher productivity occurs in the southwestern bay. Tropical cyclones can also break the strong stratification, thereby injecting nutrients into the euphotic zone, leading to phytoplankton blooms.

The BOBLME is subject to destructive cyclones that form over the open sea and head shoreward in a generally westward direction. The region is also prone to storm surges. Their effects are most severe along the western continental and island coasts. They occur most often just before and after the monsoon rains. Northern Bangladesh, for example, experiences storm surges up to 160 km inland.

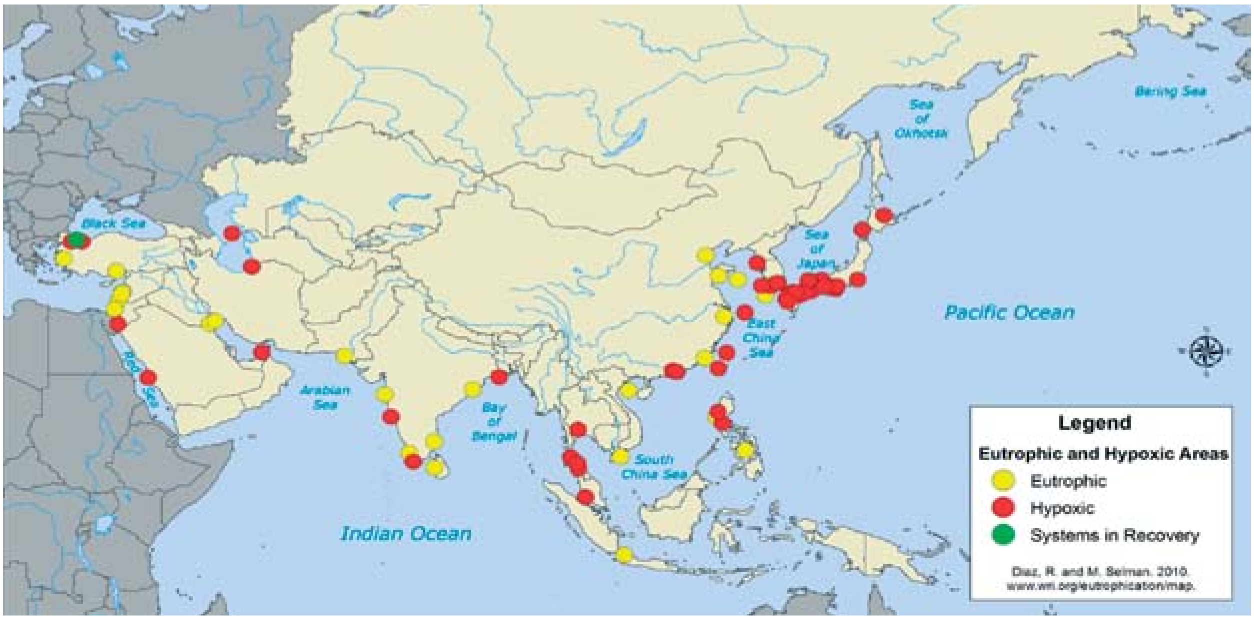
Figure 2.3 Primary productivity of the BOBLME as indicated from SeaWiFS imagery. Red denotes high productivity.



Source: Vinayachandran, 2009.

A number of eutrophic and hypoxic (low oxygen) areas have recently been identified in the BOBLME (Figure 2.4). Coastal hypoxia reduces fisheries production, kills and impairs fish and other marine life, threatens human health and reduces the availability of coastal amenities. As the Bay of Bengal has no physical barriers separating its coastal zone from the open ocean, the rate of exchange between coastal and open ocean water masses will dictate the system's response to the riverine loads (Rabalais *et al.*, 2010). Off east India, in the Bay of Bengal, hypoxic conditions (<1.42 ml per litre) are persistent on the outer shelf beyond 100m and the oxygen minimum zone (<0.5 ml per litre) is present from 150m to about 500m or 600m (Rao *et al.*, 1994; Helly and Levin, 2004).

Figure 2.4 Eutrophic and hypoxia zones in Asia.



Source: World Resources Institute, 2012.

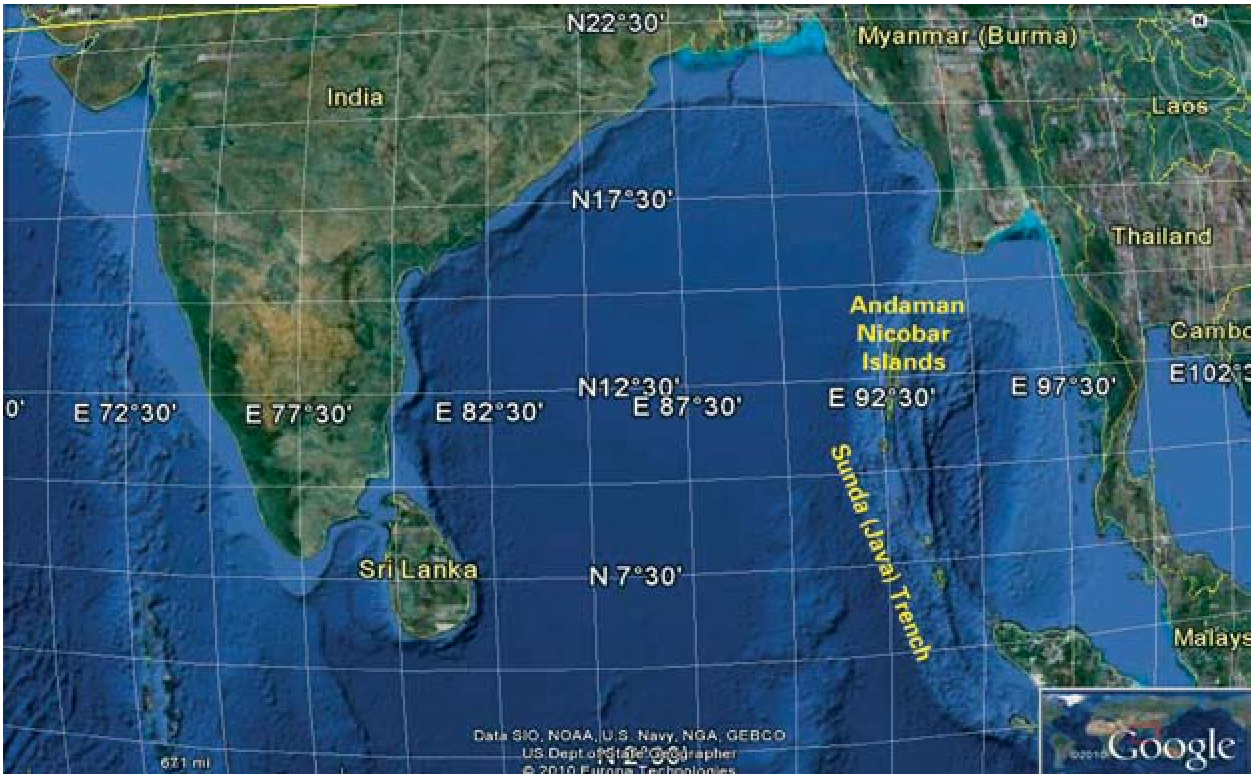
The surface ocean also absorbs carbon dioxide released by vehicles and industries and this changes the surface ocean carbonate chemistry by lowering the pH, through a process called ocean acidification. Increasing vehicular pollution has triggered changes in phytoplankton populations in the Bay of Bengal, upsetting the delicate composition of the surface waters (Biswas *et al.*, 2011). As phytoplankton are a major source of oxygen on the earth and serve as feed for aquatic animals, any disturbance in the phytoplankton community could have severe environmental consequences, including mass kills of marine animals and a drastic lowering of oxygen levels on the earth.

2.3.3 Bathymetry

With the exception of the northern area, the continental shelf of the Bay of Bengal tends to be quite narrow (Figure 2.5). Because of large sediment deposits, the BOBLME is relatively shallow for a large part of its area, including most of the high seas area. However, along the western, oceanic side of the Andaman-Nicobar Islands, the Java Trench stretches south past the western side of Sumatra (and Java) Islands in Indonesia. The Java Trench is seismically active and the only area in the BOBLME where the ocean floor is subducted. The slippage of the tectonic plates caused the December 2004 tsunami that affected most of the BOBLME. In the Andaman Sea east of the Andaman-Nicobar Islands, there is an active spreading centre where new ocean floor is produced and two large seamounts have been noted - more can be expected to exist. However, most of the seamounts that are of interest to fisheries lie to the south of the BOBLME in the Indian Ocean.

Rising sea levels caused by global warming are expected to lead to permanent inundation, drainage congestion, salinity intrusion and frequent storm surge inundation along the coast of the BOBLME. Indian Ocean sea levels are rising unevenly across the region but threatening residents in some densely populated coastal areas, particularly those along the Bay of Bengal, the Arabian Sea, Sri Lanka, Sumatra and Java. It has been estimated that about 11 percent more land will be permanently inundated over the next century in Bangladesh (Mohal *et al.*, 2006). It is also predicted that, by 2100, the Sunderbans Reserved Forest – a Ramsar and World Heritage site – will be lost because of high salinity and the permanent inundation of sea water caused by sea level rise. The Maldives, which consists of a series of low-lying atolls, is believed to be particularly vulnerable to sea level rise.

Figure 2.5 Bathymetry of the BOBLME.



Source: Google Earth and NOAA.

2.3.4 Natural resources and marine biodiversity

The BOBLME is rich in natural resources. These include extensive mineral and energy resources, marine living resources that support major fisheries, and forest and land resources. The LME is the home of three important critical habitats – mangroves (11.9 percent of world mangrove cover), coral reefs (8 percent of the world's reefs) and seagrass beds. It is an area of high biodiversity with a large number of endangered and vulnerable species. The LME and its natural resources are of considerable social and economic importance to the surrounding countries, with activities such as fishing, shrimp farming, tourism and shipping contributing to food security, employment and national economies. These are discussed in more detail below.

2.4 Socio-economic characteristics

The eight countries bordering the BOBLME are characterized by a diverse range of political systems that have evolved out of equally diverse histories. However, in more recent times, as a result of the influence of western European culture, their political and social systems have converged. Colonisation by European countries in most of the BOBLME countries left a legacy of strong public sector institutions and bureaucracies. While the BOBLME nations are following different development paths, they share many challenges in their effort to secure a prosperous and sustainable future for the BOBLME. This section describes the socio-economic factors that underlie many of the management and development challenges. It begins with a description of the people themselves and the challenges posed by growing coastal populations. It then provides an overview of the major economic activities that relate directly to the BOBLME. This overview is followed by a summary of the issues around coastal livelihoods and poverty in the BOBLME, and notably the important role that marine resources have in supporting the livelihoods of millions of coastal people. Some of the key issues relating to governance are then briefly reviewed. The section concludes with a discussion of some key issues pertaining to climate change, and the vulnerability of coastal people to the effects of climate change.

2.4.1 Population

The countries surrounding the BOBLME are some of the most populous on earth, with India, Indonesia and Bangladesh being among the world's top ten most populous nations. Collectively, the BOBLME countries are home to some 1.8 billion people, or approximately a quarter of the world's population. This figure has grown rapidly over the last 50 years, tripling from 660 million in 1960.

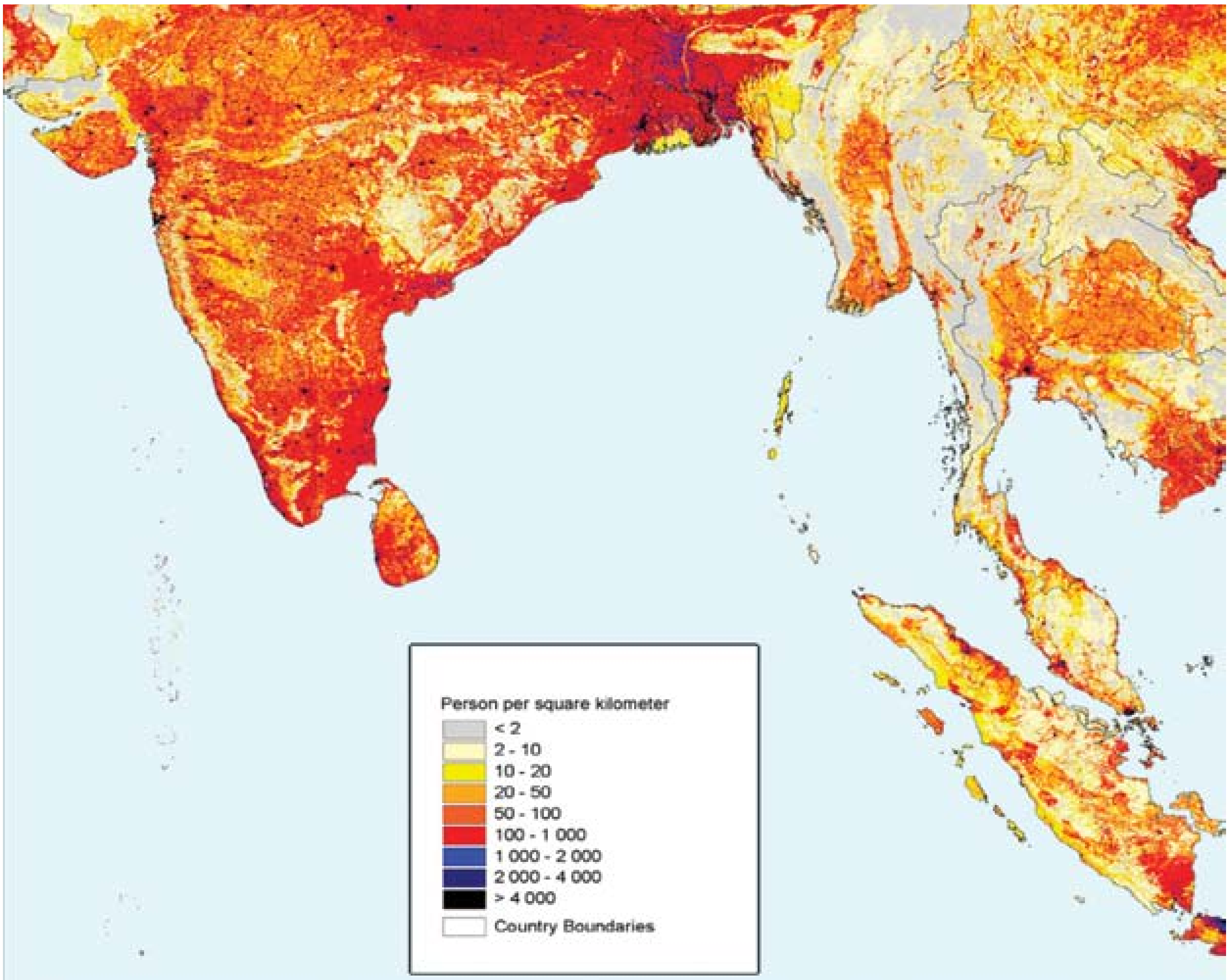
Table 2.3 BOBLME national population statistics in 2011 and projections for 2030 based on 2010 data.

Country	Population (millions) (2011)	Population (millions) (2030)	Population density #/ km² (2011)	Population density #/ km² (2030)	% Urban Population (2011)	Urban growth 2010-2015 (%)
Indonesia	**242.3**	**297.7**	**132**	**153**	**44.6**	**1.72**
Malaysia	**28.9**	**37.3**	**88.0**	**113.0**	**73**	**2.44**
Thailand	**69.5**	**73.3**	**183**	**193**	**34.4**	**1.77**
Myanmar	**59.66**	**54.3**	**72.0**	**81.0**	**34.3**	**2.95**
Bangladesh	**150.5**	**181.9**	**1 042**	**1 263**	**28.6**	**3.13**
India	**1 241.5**	**1 523.5**	**378**	**464**	**30.3**	**2.38**
Sri Lanka	**21.0**	**23.1**	**328**	**361**	**14.3**	**1.06**
Maldives	**0.32**	**0.38**	**1 019**	**1 359**	**41.3**	**4.24**

Source: UNDP, 2011.

Despite having similar land areas (3 497 300 km² in the west and 3 425 000 km² in the east) the total population of the western BOBLME countries is 1.41 billion, compared to 389 million in the east; i.e. about 85 percent live in the western countries (Table 2.3). These populations are projected to increase to 1.73 billion and 460 million, respectively, by 2030, with a total population of over 2.1 billion.

Figure 2.6 Population densities of countries surrounding the BOBLME.



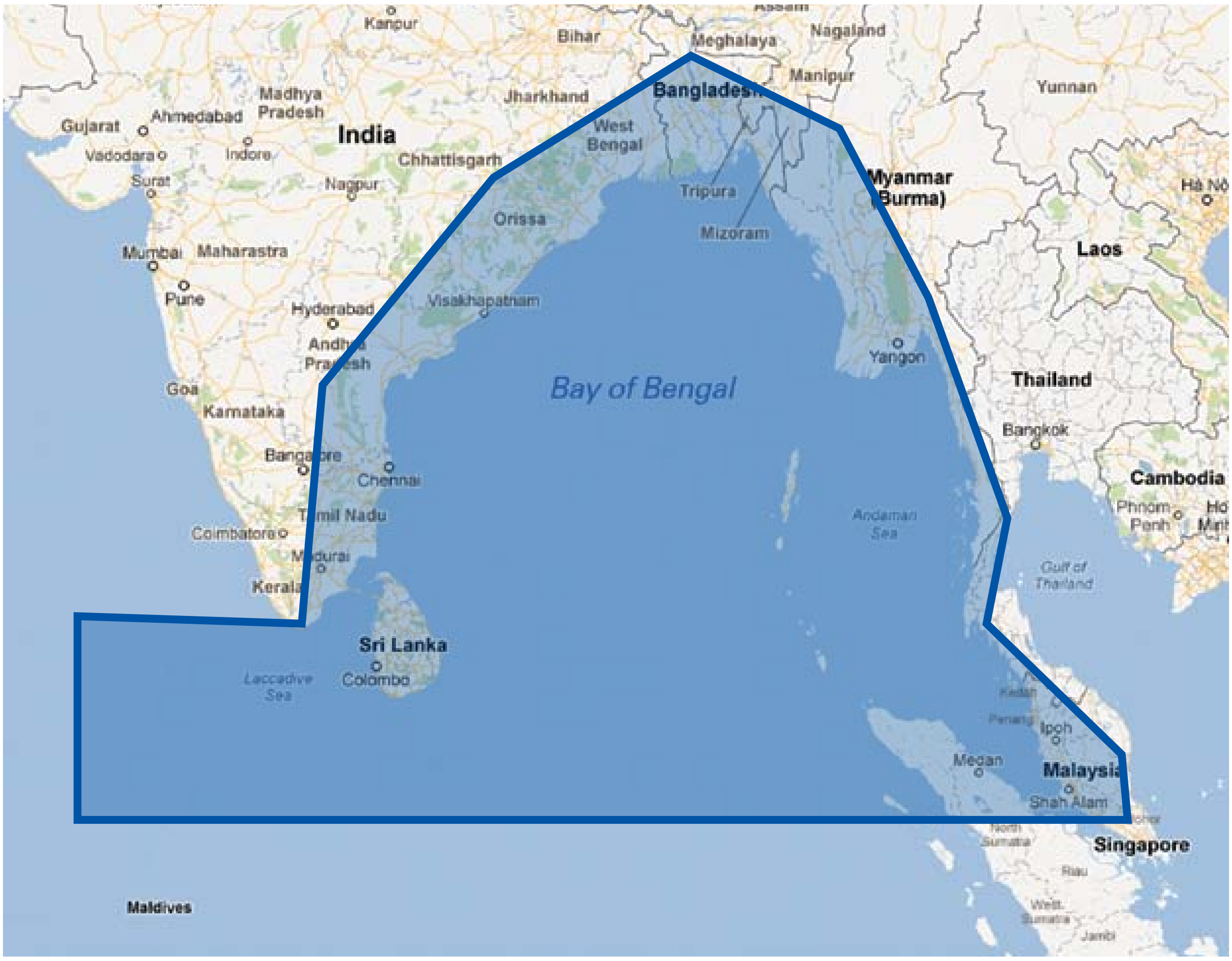
Source: Landscan, 2002.

The large populations are compounded by very high levels of population density (Figure 2.6), particularly in the four western BOBLME countries. Here, population densities are among the highest in the world, with an average of 374 persons/km² in the western countries, compared to a density of 119 persons/km² in the eastern countries, and a world average of 51 persons/km².

The BOBLME countries are still primarily rural in character, but are undergoing a process of rapid urbanization, with average urban population growth rates between 1.06 percent in Sri Lanka, 3.13 percent in Bangladesh and 4.24 percent in the Maldives.

Estimates of the proportion of the total population living in the coastal areas of the BOBLME vary. However, using the Population Estimation Service tool – based on SEDAC Gridded Population of the World Data 2005 – it is possible to make a crude estimate: it is estimated that 424 million people lived in the coastal zone in 2005 (Figure 2.7). Based on the total population growth of the BOBLME region this will have risen to approximately 450 million by 2011, with ongoing urbanization also meaning that the towns and cities in the coastal zone will have continued to expand.

Figure 2.7 Estimates of coastal populations in 2005.



Land area km²: 1 194 847 **Mean unit area km²: 1 333** **Population 2005: 424 284 500**

Source: SEDAC, 2010.

The above estimates are based on physical proximity to the coast and paint only part of the picture in terms of the importance that marine resources play in the livelihoods of the people of the nations adjacent to the BOBLME. The services provided in terms of food, trade and transportation will involve a far larger number of people than just those who live in the coastal zone.

2.4.2 BOBLME economies

Based on the nominal Gross Domestic Product (GDP) – the value of all the goods and services produced within a nation in a given year – and using official exchange rates, India is the largest economy in the BOBLME region. The country is ranked ninth in the world, with three other countries in the region (Indonesia, Malaysia and Thailand) in the top 50 (Table 2.4). When purchasing power parity (an index that takes into account the relative cost of living and the inflation rates of a country, rather than just exchange rates) is taken into account, India's ranking rises to fourth in the world, and Indonesia, Malaysia, Thailand and Bangladesh remain in the top 50.

However, on a per capita basis, the economies of the region are relatively small with no country making the top 50. All BOBLME nations have experienced rapid growth over the past two decades – particularly in the industrial and service sectors. This has resulted in increased levels of industrial development in the coastal zones surrounding the BOBLME. Much of the industry has centred on transforming raw materials into steel, paper, chemicals, paints, plastics and textiles; also important are leather tanning, oil refining and electricity generation (Kaly, 2004). All the economies are reducing their reliance on the agriculture sector (including fisheries) and growth in the industrial and service sectors has been the driving force behind the long-term growth of GDP (Table 2.5).

Between 2005 and 2010, economic growth continued across the countries of the BOBLME, although all have been adversely affected by the global financial crisis (GFC) that began in 2007; by 2012 the effects of the GFC were still being felt and the crisis served to emphasize, yet again, the interconnectedness of the global economy.

Table 2.4 Nominal GDP, purchasing power parity adjusted GDP and per capita GDP for BOBLME countries in 2010. GDP expressed in million USD (2010 value).

	Nominal GDP (rank)	* PPP GDP (rank)	GDP per capita (rank)	Real growth 2005 to 2011
Indonesia	**706 735 (18)**	**1 032 952 (15)**	**4 668 (119)**	**5.6%**
Malaysia	**237 959 (37)**	**416 535 (29)**	**15 469 (58)**	**4.6%**
Thailand	**318 850 (30)**	**589 005 (24)**	**9 693 (84)**	**3.7%**
Myanmar	**42 953 (78)**	**76 839 (76)**	**1 327 (161)**	**3.4%**
Bangladesh	**104 919 (58)**	**260 536 (44)**	**1 697 (152)**	**6.0%**
India	**1 631 970 (9)**	**4 057 787 (4)**	**3 703 (127)**	**8.6%**
Sri Lanka	**49 680 (74)**	**105 460 (66)**	**5 609 (110)**	**6.5%**
Maldives	**1 870 (158)**	**2 514 (164)**	**8 402 (90)**	**5.3%**

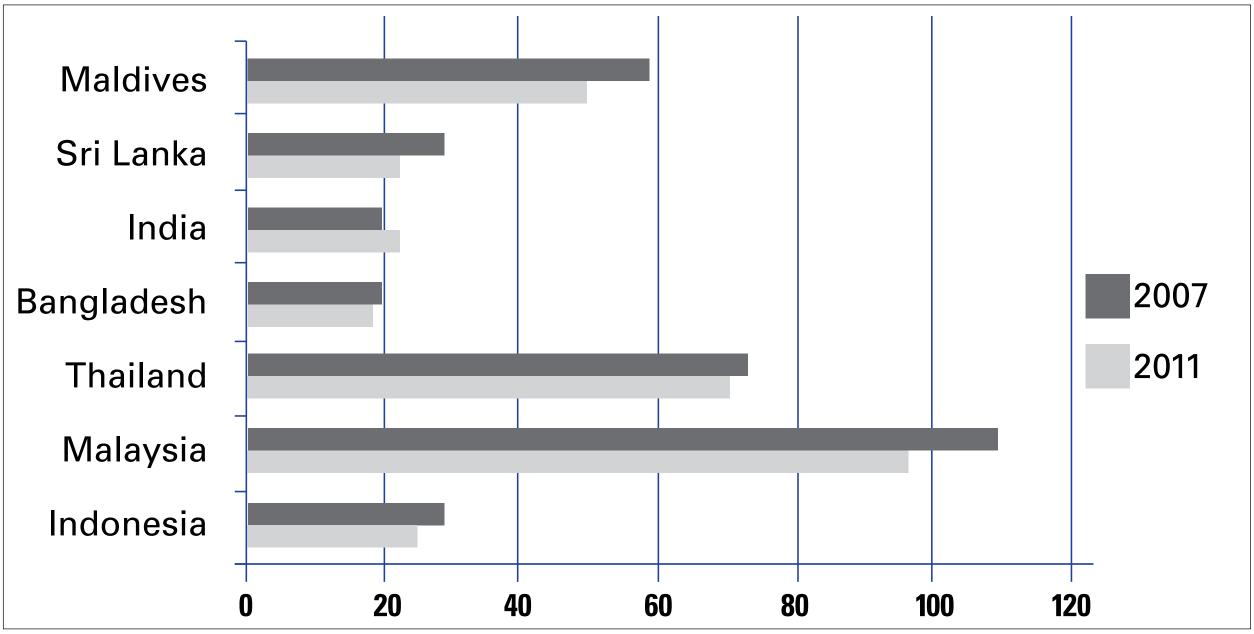
Source: International Monetary Fund, 2012.
** PPP = Purchasing power parity*

Table 2.5 Estimates of percentage contribution of agriculture, industry and services to the GDP, 2009.

	Indonesia	**Malaysia**	**Thailand**	**Myanmar**	**Bangladesh**	**India**	**Sri Lanka**	**Maldives**
Agriculture[1]	**15.3%**	**9.4%**	**11.6%**	**48.0%**	**18.6%[2]**	**17.1%**	**13.8%**	**4.9%**
(Change 2005-2009)	**(2.2%)**	**(1.2%)**	**(1.3%)**	**(1.4%)**	**(-1.5%)**	**(-1.6%)**	**(0.3%)**	**(-4.8%)**
Industry[1]	**47.6%**	**43.6%**	**43.3%**	**16.5%**	**28.6%**	**28.2%**	**31.7%**	**16.8%**
(Change 2005-2009)	**(1.1%)**	**(-5.1%)**	**(-1.0%)**	**(-0.7%)**	**(1.4%)**	**(-0.1%)**	**(-0.5%)**	**(-0.5%)**
Services[1]	**37.1%**	**47.0%**	**45.1%**	**35.6%**	**52.8%**	**54.6%**	**54.5%**	**78.4%**
(Change 2005-2009)	**(-3.3%)**	**(3.9%)**	**(-0.2%)**	**(-0.7%)**	**(0.1%)**	**(1.7%)**	**(0.2%)**	**(5.4%)**

Source [1]: Economic and Social Commission for Asia and the Pacific (ESCAP), 2011.
Source [2]: Bangladesh Bureau of Statistics (BBS), 2010.

Figure 2.8 Exports as a percentage of GDP prior to the global financial crisis in 2007 and 2011.



Source: World Bank, 2012.

Some countries rely heavily on exports. For example, in Thailand, the Maldives and Malaysia, exports account for 71 percent, 50 percent and 97 percent of GDP respectively (Figure 2. 8). Following the GFC, import demand from the advanced economies shrank and many Asian countries faced a sudden drop in exports. This effect is illustrated in Figure 2.8 which compares exports in 2007 with those in 2011.

Fisheries

With the exception of the Maldives and Myanmar where fisheries contribute 6.25 and 9.9 percent respectively, fishing makes a modest contribution to the GDP of the countries bordering the BOBLME (Table 2.6). (It should be noted that these figures are probably underestimates because they do not fully include the contributions of small-scale fisheries.)

Table 2.6 Percentage contribution of fisheries and tourism to GDP.

	% Contribution of capture fisheries to GDP (2006)	% Contribution of tourism (2007)
Indonesia	1.9	1.3
Malaysia	1.1	9
Thailand	1.6	8.4
Myanmar	9.9	
Bangladesh	3.7	0.1
India	0.5	0.9
Sri Lanka	1.3	2.3
Maldives	6.25	55.5

Source: Asia-Pacific Fisheries Commission (APFIC), 2008; ESCAP, 2010; and Maldives Ministry of Planning and National Development, 2010.

Fisheries are nevertheless of major socio-economic importance to BOBLME countries because they generate employment, food security and local revenue. Marine capture fisheries provide direct employment for two million fishers who operate primarily in coastal and inshore waters, and over 5.5 million people directly employed in marine capture fisheries (Table 2.7).

In addition to those involved in direct primary production of fish, there are people involved in ancillary activities, such as processing; net and gear making; ice production and supply; boat construction and maintenance; manufacture of fish processing equipment; packaging; marketing and distribution. Others are involved in research, development and administration. No official data exist on the estimated numbers of people involved in these activities, but some estimates indicate that for each person employed in capture fisheries and aquaculture production, there are about four jobs produced in the secondary activities, including post-harvest (FAO, 2008).

Table 2.7 Number employed and number of active fishers in BOBLME countries.

	Employment in Fisheries[3]		
	Number employed (000s)	Proportion of workforce	Active fishers
Indonesia 2008	**1 775**	**2%**	**536.3**
Malaysia 2008	**122.1**	**1%**	**53.4**
Thailand 2008	**425.6**	**1%**	**92.8**
Myanmar	**797.7**	**n/a**	**326.9**
Bangladesh 2009	**1 280**	**2%**	**259.5**
India 2005	**905.9**	**n/a**	**517.6**
Sri Lanka 2006	**212.5**	**n/a**	**144**
Maldives 2006	**8.3**	**8%**	**n/a**
	5 527.2		**1 930.5**

Source: FAO country profiles, 2010; Central Marine Fisheries Research Institute (CMFRI), 2006; Southeast Asian Fisheries Development Centre (SEAFDEC), 2009; Unpublished reports to APFIC; BBS, 2010.

Fish are also very important for food security and make up a significant proportion of the daily intake of protein in many coastal communities, and in marginalized hill tribes when dried fish is distributed to these areas. The nations around the BOBLME all achieved recent gains in reducing the number of people who are undernourished. To this end, there has been significantly more progress in the eastern countries, with Thailand and Myanmar reducing levels by 40 percent and 60 percent, respectively (FAO, 2009). However, 2009 was a devastating year for the world's hungry, marking a significant worsening of an already disappointing trend in global food security since 1996. The global economic slowdown, following on the heels of the food crisis of 2006 to 2008, deprived an additional 100 million people of access to adequate food.

Fish makes a valuable contribution to a diversified and nutritious diet in many BOBLME countries. Not only does it provide high-value protein, but it supplies a wide range of essential micronutrients, minerals and fatty acids. Globally, fish provides an average of 30 kilocalories per person, per day (FAO, 2008) and in many of the BOBLME countries this figure is significantly higher (Table 2.8). In the Maldives, for example, fish provides up to 368 kilocalories per person, per day, while in Indonesia, Malaysia, Myanmar, Thailand and Sri Lanka, its contribution is well above average. In all the BOBLME countries, with the exception of India, fish and seafood products make a significant contribution to the animal proteins that are consumed. In the Maldives, fish contributes 74 percent of animal proteins and the figures are significant in other countries such as Indonesia (53 percent), Bangladesh (54 percent) and Sri Lanka (53 percent). In all cases the figures are based on national statistics and probably underestimate the importance of fish in the diets of coastal populations. For example, Deya *et al.*, 2005, observed differences in the types of fish consumed by the rich and the poor and also noted that per capita fish consumption was substantially higher in rural areas than in urban areas in countries such as Bangladesh, India, Indonesia and Thailand.

[3] As defined in ILO survey based on category Employment – 2B Total employment, by economic activity (thousands). International Standard Industrial Classification of all Economic Activities (ISIC-Rev.2, 1968). [1]See http://laborsta.ilo.org/

Table 2.8 Per capita seafood consumption (kcal/person/day), total dietary protein (g/person/day) in 2007, seafood dietary protein consumption (g/person/day) in 2007, and meat dietary protein consumption (g/person/day) in 2007.

	Indonesia	Malaysia	Thailand	Bangladesh	Myanmar	India	Sri Lanka	Maldives
Per capita seafood consumption	48.9	89.6	59.1	26.3	43.5	9.2	50.3	368.1
Dietary protein	56.8	78.0	56.2	50.2	70.8	57.4	56.1	111.3
Dietary protein animal	15.3	39.0	24.2	7.8	20.8	10.2	14.4	76.1
Dietary protein fish/seafood	8.0	14.4	9.2	4.2	6.5	1.5	7.7	55.8
Dietary protein consumption meat	3.7	16.3	9.2	1.4	9.3	1.2	2.4	9.6

Source: FAOSTAT, 2011.

Although most fishery production is consumed domestically, there are substantial exports of high-value commodities, especially from Thailand, India and the Maldives. Primary export commodities are shrimp and tuna which may contribute significantly to national foreign exchange earnings. Trading of fish has been a major activity in BOBLME countries for years. Trends in fish trade, however, are now being driven by major fish import economies. To export fish and seafood products to the European Union or United States, for example, the BOBLME economies must comply with various quality and documentation requirements. In addition, major retailers of fish and seafood products are increasingly demanding sustainability and traceability documentation and labels. The United States supermarket chain Wal-Mart, and United Kingdom retailers such as Sainsbury's and Waitrose, prefer to buy fish and seafood products with Marine Stewardship Council and Aquaculture Certification Council accreditation. These labels are earned through extensive processes that examine scientific information and fisheries and aquaculture management plans and activities.

Overexploitation of shrimp resources in coastal waters has reduced the quantity of exports from capture fisheries and there is a growing tendency for exports to come from the aquaculture sector. In the last decade, some countries have developed domestic offshore fisheries for tuna; these species are caught by Indonesian longline fleets, Thai purse seine fleets, Sri Lankan gill-nets and by the pole and line fleets of the Maldives. While the majority of tuna catches continue to come from coastal fisheries, offshore fisheries provide the majority of export-quality tuna. Squid is becoming more important commercially and although production is relatively low, values are high.

Tourism

The tourism industry is evolving in the BOBLME region – growing in importance, expanding geographically and becoming an increasingly important source of wealth (Table 2.6).

The eastern countries of the BOBLME have dominated tourism markets in terms of absolute numbers of visitors, with Malaysia recording over 22 million tourists in 2008 and Thailand over 14.5 million, (Figure 2.9). However, all countries have experienced a growth in tourist numbers. Visitors to Malaysia grew fourfold in the period 1998 to 2008, while tourist numbers doubled in Bangladesh, the Maldives, Thailand and India over the same period.

Figure 2.9 Growth in tourism in the BOBLME countries (millions of visitors), 1998 to 2008.

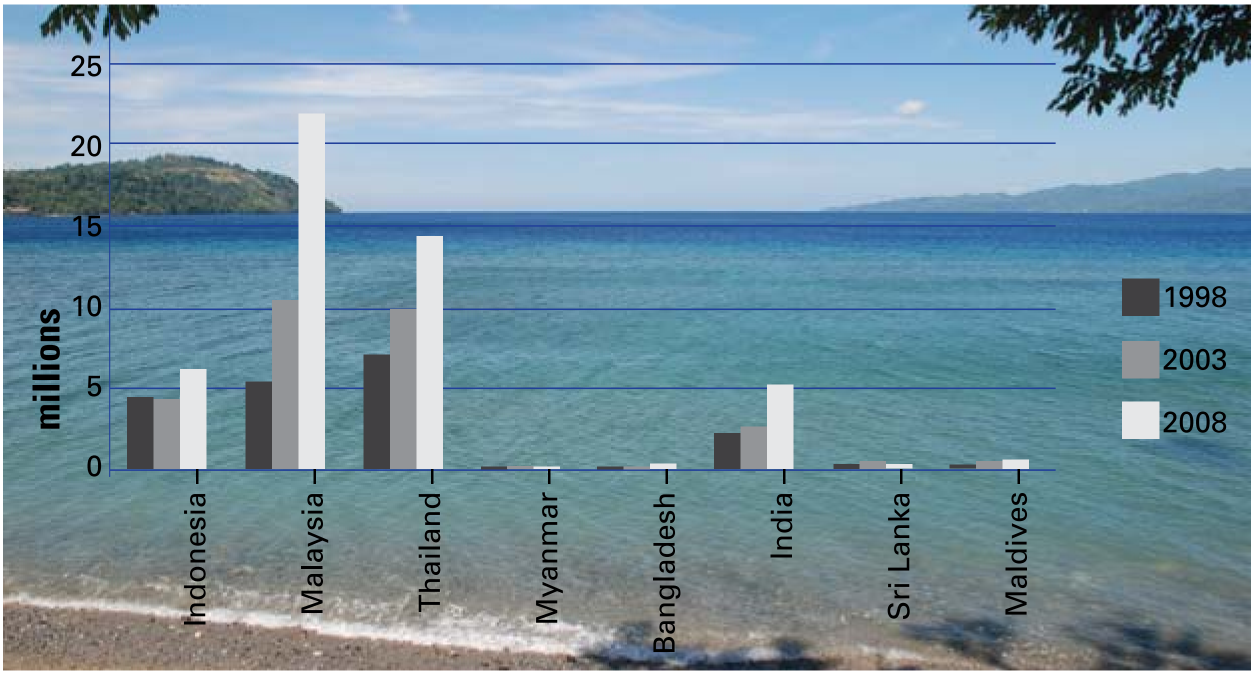


Photo source: BOBP-IGO archives

Source: www.nationmaster.com, 2012.

Oil and gas

The Bay of Bengal is reputed to be one of the hydrocarbon-rich areas of the world, comparable to the Gulf of Mexico, Persian Gulf and Bohai Bay in China. Until recently, it has been poorly explored due to a lack of financial support for exploration, or because of international boundary disputes. However, major discoveries have recently been made. For example, discoveries in the Krishna-Godavari and Mahanadi – the two major basins off the East coast of India – have demonstrated a potential yield of nearly 18 billion barrels of oil equivalent gas (Kumar, 2008). Revenues from oil and gas production have the potential to dwarf those of other sectors in the future.

All the countries surrounding the Bay of Bengal either have done, or are in the process of, auctioning blocks of seabed for exploration. Between the countries there are also varying degrees of boundary disputes, most notably between India, Bangladesh and Myanmar.

Shipping

The main shipping route runs to the south of Sri Lanka, across the Bay of Bengal and into the Straits of Malacca. The Strait is the main shipping channel between the Indian Ocean and the Pacific Ocean, linking major Asian economies such as India, China, Japan and South Korea. Over 50 000 vessels pass through the Strait per year, carrying about one-quarter of the world's traded goods including oil, Chinese manufactures and Indonesian coffee (US Energy Information Administration, 2010).

Along the Indian coastline, there is also intensive shipping traffic and associated oil pollution. This is as a result of the operational discharge of waste, mostly by medium and small ships for which the installation of oil-water separators is not mandatory (Sampath, 2003).

2.4.3 Socio-economic characteristics of coastal communities

Although some coastal areas are relatively wealthy, poverty in coastal communities remains an important issue. Flat, well-watered coastal plains are often focal points for the growth of urban centres; transport by road, rail and sea; and communications networks. Some of the biggest cities in the world surround the BOBLME. These include Kolkata (over 20 million people)[4] and Chennai (7.5 million) in India; Chittagong (five million) in Bangladesh; Yangon (4.4 million) in Myanmar, Medan (two million) in Indonesia and Kuala Lumpur (1.5 million) in Malaysia (DESA, 2011). As these cities grow and expand, many slum areas are created. Agricultural development is also frequently greater in coastal plains.

Poverty in coastal communities

Even when coastal areas are relatively well developed, pockets of "hidden" poverty may occur. But, because they are located amidst relative prosperity, they often remain unseen (IMM/ICC, 2003). Certain features of some coastal areas – the presence of diverse open-access resources and a wide range of livelihood "niches" – often attract the poor who find opportunities along the coast that are not available elsewhere. Many of the people living in the BOBLME's catchment area (particularly in the western countries) are among the world's poorest, subsisting at or below the national poverty level. This is especially true in Bangladesh, India and Sri Lanka where some 81 percent, 76 percent and 40 percent, respectively, of the population has an income less than the equivalent of USD2 per day (UNDP, 2009). Brown *et al.*, (2008) estimate that four BOBLME countries are in the top 10 countries in terms of numbers of coastal poor (Table 2.9) and the BOBLME countries contained over 50 percent of all of the world's coastal poor.

Table 2.9 Numbers of poor people in coastal areas of the world.

Country	Number of coastal poor*	% of world's coastal poor
India	68 226 700	27%
Indonesia	33 768 000	13%
Bangladesh	23 247 500	9%
Vietnam	12 440 000	5%
China	11 730 700	5%
Philippines	11 247 000	4%
Nigeria	8 897 690	4%
Myanmar	6 209 340	2%
Brazil	6 145 760	2%
North Korea	3 899 890	2%

*Data is based on estimates of poverty combined with population density in the 100km coastal strip to provide an estimate of the density and absolute number of coastal poor around the world's poor countries. For a more detailed breakdown see Brown *et al.,* 2008.

[4] Population for city area only

Table 2.10 Education indicators in BOBLME countries.

	Survival rate to last grade of primary level (%)	Adult literacy rate (% aged 15 and over)
	Latest	2005–2009
Indonesia	**80.5 (2007)**	**92.2**
Malaysia	**95.9 (2007)**	**92.5**
Thailand	**–**	**93.5**
Myanmar	**69.6 (2008)**	**92.0**
Bangladesh	**66.6 (2008)**	**59.1**
India	**68.5 (2006)**	**62.8**
Sri Lanka	**88.7 (2008)**	**90.6**
Maldives	**–**	**98.4**

Source: ESCAP, 2011 and BBS, 2010.

Health and education

People's health and education play an important role in their ability to take up and maintain a particular livelihood strategy. They are, of course, critical in respect to people's capacity to change, either in response to a threat (e.g. declining resources or natural disasters) or an opportunity (e.g. seeking new employment or improving an existing strategy).

The key areas of concern for the BOBLME lie in the west where the low rates of educational survival[5] (65.8 percent in India and 54.8 percent in Bangladesh) correlate with low levels of literacy (66 percent in India and 53.5 percent in Bangladesh). See Table 2.10. Therefore, in these countries, people's ability to take advantage of the new opportunities brought about by significant national economic growth may be restricted.

Coastal and marine livelihoods are affected by a range of health risks that are often specific to coastal areas. Sanitation and water supply can be problematic in coastal areas, especially where water tables are affected by saline intrusion. HIV is often very prevalent because of the relative mobility of fishers. Exposure to natural disasters, such as the cyclones and floods that characterize some coastal areas in the BOBLME, can have important long-term impacts on overall health, causing loss of life, epidemics and injury. Access to health services is often affected by the same constraints as those experienced for education. Infrastructure is frequently lacking and staff may be unwilling to travel to remote coastal areas (Townsley, 2004).

Sailing to nowhere – *a Cambodian migrant's tale*

Nang, aged 25, is a Cambodian fisherman from Banteay Meanchey province. He has very little formal education and following the advice of some friends, decided to leave Cambodia in early 2004 to work in neighbouring Thailand to support his family. He was recruited by a Cambodian broker (mekhal) who came to his village and promised him a job in the construction industry in Thailand paying up to THB4 500 (USD128) per month. The broker's fee, payable in advance, was THB3 000 (USD85). Nang borrowed the money for the broker's fee from relatives and he was then taken to the Thailand border where the broker helped him cross the border into Thailand unlawfully for an additional fee of THB200 (USD6).

Once in Thailand, he was taken to Patnam in Samut Prakan Province, where he was kept in a guesthouse for several days before being told that there was no job in construction and that he would have to work on a fishing boat. Nang believes that the broker sold him to the captain of the fishing boat for THB5 000 (USD150). According to Nang, the conditions onboard his boat, which sailed towards Indonesian waters and remained there for six months, were extremely harsh. The crew had to work day and night for three days before having a day to rest and was continually harassed and threatened by the captain. Nang was never allowed to leave the boat.

[5] Education survival – as defined by UN ESCAP as school attendance to the last grade of primary school.

Sailing to nowhere – *a Cambodian migrant's tale*

continued from page 25

Eventually the boat docked in Ranong on the Thai-Myanmar border, where the Cambodian crew was replaced by a crew from Myanmar prior to moving into that country's waters. Nang was paid a total of THB2 000 (USD57) for six months of work. With no travel documents and unable to afford transport back to Cambodia – let alone the sum of THB6 000 (USD171) demanded by a broker to help him return home – Nang realized that it was only a matter of time before he would be picked up by the Thai police as an irregular migrant. On the advice of other Cambodian fishermen stranded in Ranong, he signed up with another Thai fishing boat and was given forged papers identifying him as Thai.

In August 2004, while fishing illegally in Indian waters, the boat was intercepted by the Indian Navy and escorted to Port Blair in the Andaman and Nicobar islands. The entire crew was jailed, but after six weeks the Thai owner of the vessel arrived to stand bail and obtain their release. The Thai crew immediately left India, leaving Nang and the other Cambodians to fend for themselves. Nang was then taken to the Port Blair Immigration Police Centre and held there for three months. When the case was finally heard in court, he pleaded guilty to entering India unlawfully and was sent to an internment camp, where he remained for two years. In March 2007, working with the Cambodian and Indian governments, the International Migration Organization (IMO) was able to at last repatriate Nang from Port Blair to his home province of Banteay Meanchey.

Source: International Migration Organisation, 2008.

Coastal migration

Migration and mobility have always been an integral part of life in the coastal areas of the BOBLME. People living at the coast, and particularly the poor, often have to move in order to adapt to seasonal variations in the availability of resources. Examples of these seasonal migrations include the movement of fishers from the west coast of Sri Lanka to the north and east during the different monsoon seasons, and the migration of fishers from Andhra Pradesh to southern Orissa and Gujarat on the west coast. In other cases, the dynamic nature of the coastal environment, particularly in estuarine areas where land is constantly being formed and washed away by the action of the sea, and by silt deposition from upstream (e.g. the char lands in Bangladesh), means that coastal people are constantly migrating in response to changes in their environment (IMM, 2003).

Increasing industrialization in some of the coastal areas of the BOBLME have attracted new waves of migrants and increased pressure for the development of new residential and industrial zones outside existing towns and cities. An example of this trend can be seen in Orissa in India. Salagrama (2006) observed that competition for space and resources – often involving powerful interest groups – is likely to increase as a result of further liberalization of the economy and new opportunities, such as tourism, emerging in coastal areas. Such developments can create pressure on existing coastal communities, especially where they are made up of groups such as fishers that often have little political influence.

Some migratory movements are not specific to coastal areas and are driven by much wider trends that affect many areas of South and South East Asia. The countries of the BOBLME have experienced growing labour migration over the past two decades. Annual labour migration from Bangladesh – mainly to the Middle East and Malaysia – more than doubled from 103 000 in 1990 to 252 000 in 2005; in 2007 it climbed to over 800 000 people. Migration of labour from India to the Middle East averaged about 355 000 people per year in the decade between 1993 and 2002. Indonesia sent over 712 000 workers abroad in 2006. Between 2000 and 2006, an annual average of 204 000 labour migrants left Sri Lanka, the majority for destinations in the Middle East. It should be noted that the actual number of migrant workers from the region is likely to be greater because there are unknown numbers of workers who migrate without registering with national authorities.

Feminization is an important feature of labour migration in the region because an increasing number of women are crossing borders to gain employment. Female migration has become prominent in terms of both absolute numbers and proportions of the migrant population. For instance, women constitute the large majority of migrant workers leaving Indonesia (79 percent) and Sri Lanka (64 percent), (ESCAP, 2009).

All migrant groups can be vulnerable to a range of issues including HIV, exploitation, lack of representation and lack of access to services. However, where people move across borders illegally they are especially vulnerable.

2.4.4 Government in coastal communities

Agricultural, forestry, fisheries, urban and industrial activities, both in upstream catchments and in the coastal area, all impact on the lives of the people in the coastal zones of the BOBLME. The policies developed for these different sectors by the various institutions and agencies responsible for them, often overlap and conflict with each other and with the strategies developed by people to sustain their livelihoods.

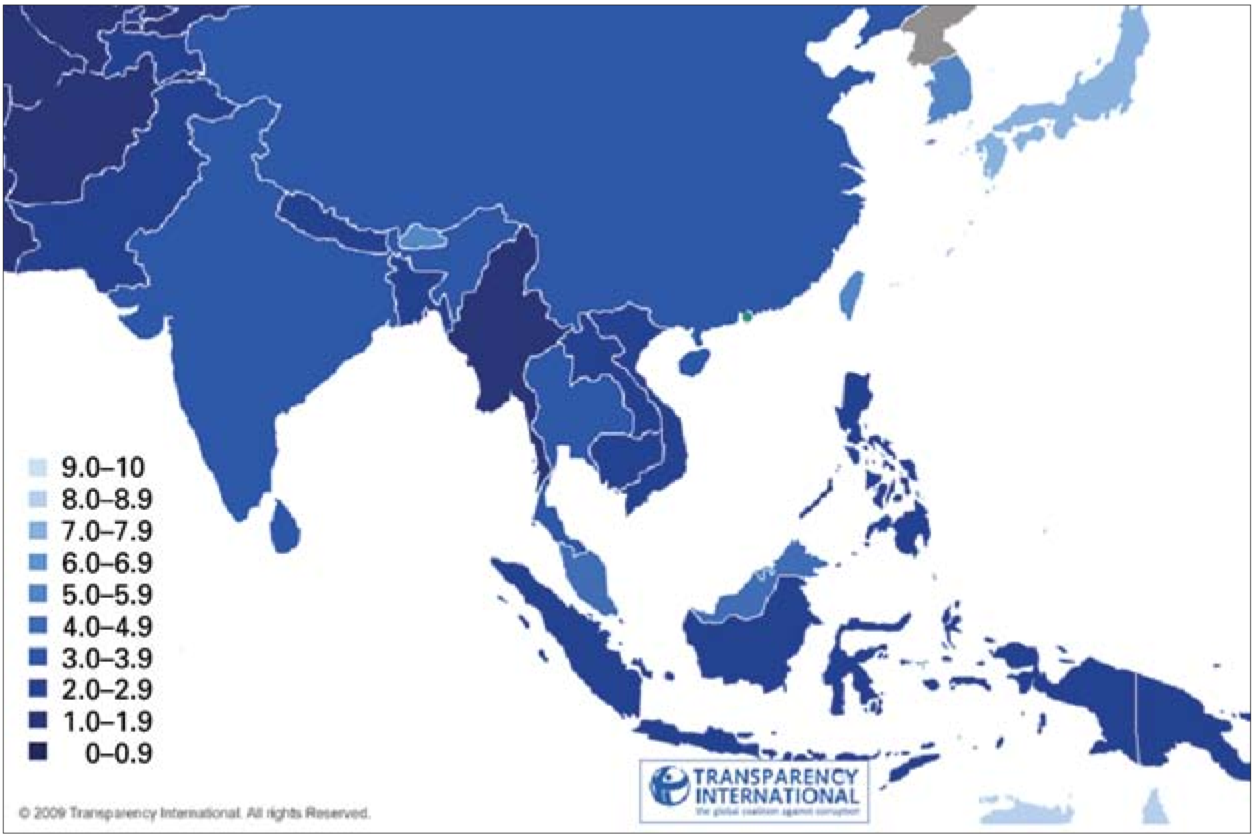
In this TDA it is not possible to cover the nature of all government interventions in coastal communities around the BOBLME and, therefore, four aspects have been selected which are illustrative of the key challenges. These relate to (i) corruption; (ii) take up and implementation of new policies and measures; (iii) subsidies and infrastructure support; and (iv) the social protection services that may be critical for supporting livelihood change.

Corruption

The world's oceans support economic activities on a vast scale and the need to rehabilitate and protect their common wealth and productivity has led the international community to focus intensely on how oceans are used and governed. Intrinsically linked to this recognition is the need to ensure greater responsibility for, and accountability by, all individuals and private companies involved in the exploitation of coastal and marine resources (FAO, 2008).

None of the countries bordering the BOBLME was ranked in the top 50 countries in the world by Transparency International's Corruption Perceptions Index 2011 (Figure 2.10), showing that there is considerable room for improvement. This is a major challenge for improved governance because sustainable management outcomes (including poverty reduction and alleviation; improved food security; stronger economic development and growth; and greater access to public services) depend to a large extent on concurrent improvements in endemic corruption in the management of resource-based and other industries.

Figure 2.10 Corruption Perceptions Index 2011. 10 = least corrupt (light blue); 0 = most corrupt (dark blue).



Source: Transparency International, 2012.

Implementation of laws and policies

The countries of the BOBLME are governed by a range of different political systems, but in spite of their differences, all the governments of the region are eager to promote economic growth and development and embrace the increased exploitation of living resources. As a result, all the region's governments have encouraged increased marine and freshwater fishery production (including aquaculture) and have expended considerable funding in an attempt to make this happen. Most countries have legislation and policies in the different sectors (see next section for details), but these are often not harmonized across sectors. Most government services are applied in a multi-layered system (national, provincial/state and local) without clear roles and responsibilities acknowledged by the different players. Many countries now have "decentralization" policies that are aggravating these problems.

The complexity of the coastal area and the government bureaucracies often results in decision-making structures being inadequate or inappropriate to deal with problems in a coordinated and effective manner. Implementation of policies can also be constrained by weak governance – especially at the local level – and insufficient human capacity and government funding for enforcing laws and regulations.

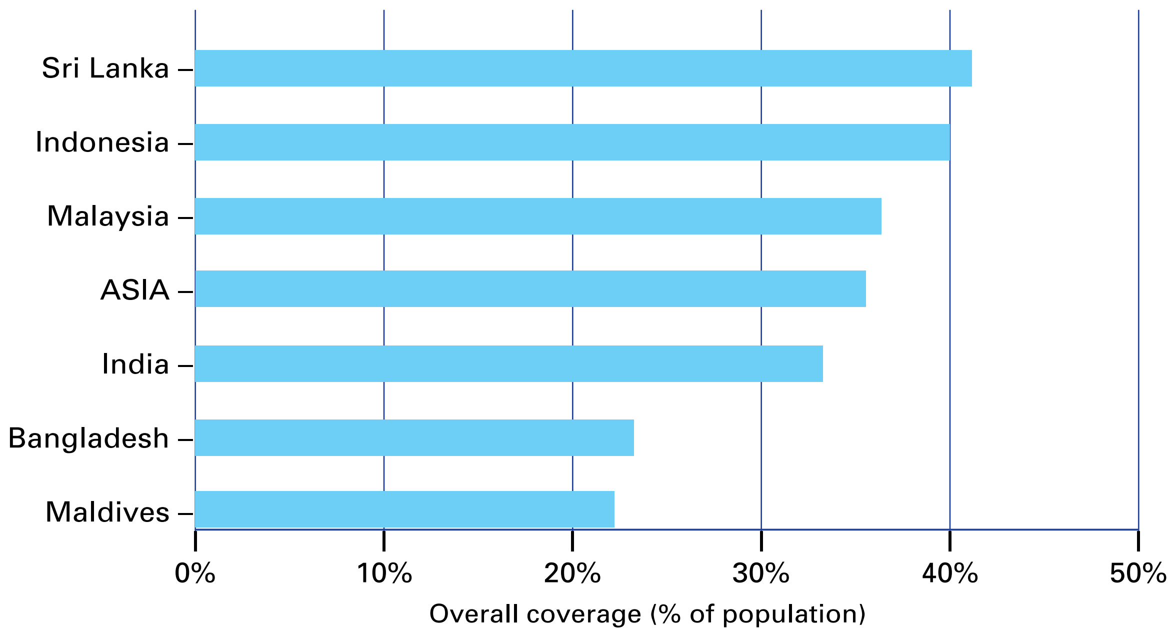
In instances where the existing legislation and regulations are adequate, enforcement is impeded by a number of factors, including weak institutions; varying interpretation of the law; lack of funds to enforce laws and regulations; a lack of consultation with stakeholders; and a lack of accessibility by numerous stakeholders to the ever-increasing number of rules and regulations that are developed. A related problem is that generally inadequate penalties are imposed for violations of marine living resource and critical habitat laws. The inadequacy of penalties arises partly from the fact that in many of the BOBLME countries, laws have not been updated since the 1980s and they need to be improved, revised and amended.

In a policy environment that is often confused, the services provided to coastal communities can be limited. This is particularly so along the western and northern shores of the Bay of Bengal, where an absence of supportive institutions increases the vulnerability of coastal fishing communities to changes, such as illness and natural disasters (Townsley, 2004).

Subsidies and infrastructure support

Public funding of the fisheries sector has taken the form of subsidies and grants; construction of infrastructure (ports, ice machines, etc.); establishment of government-owned fishing companies; and concessions to foreign fishing vessels. Much of this funding has come from aid organizations or in the form of concessionary loan finance from multilateral banks (Preston, 2004).

Figure 2.11 Proportion of BOBLME population covered by social security.



Source: ADB, 2010.

One of the most striking features of "fisheries development" in some BOBLME countries (particularly Sri Lanka and India) is the extent to which the government subsidizes fishers, including industrial, commercial and artisanal operators. Cheap gear and equipment, artificially inflated product prices, credit facilities and cash subsidies are incorporated into subsidized boatbuilding and marketing operations, and welfare schemes aimed at fishers and fishing communities (Preston, 2004). Commercial and industrial fishing fleets, in particular, are overcapitalized, and subsidizing fishers or fishing operations allows them to keep on fishing even when catches have declined to very low levels, thereby increasing the occurrence of serious overfishing and consequent stock collapse.

Table 2.11 Social protection in the BOBLME countries.

	Sickness	Poverty	Health	Education	Employment	Transfers	Child
Indonesia	X					X	X
Malaysia	X	X			X	X	X
Thailand	X	X	X		X	X	X
Bangladesh	X	X	X	X	X	X	
India	X	X	X	X	X	X	
Sri Lanka	X	X	X	X	X	X	
Maldives	X	X		X		X	

Source: ADB, 2010.

Social protection measures

Formal social protection measures – such as providing additional income to the poor and maintaining their food intake and access to education and health services – can play a key role in the sustainable development of coastal communities. Such measures also have the potential to benefit aquatic resources by removing the need for poor people to move into fisheries as a last resort in tough times; by giving people the confidence and certainty to make longer term investment decisions and take up opportunities to move out of fisheries. The BOBLME countries offer a range of social protection measures which are shown in Table 2.11. However, in many cases these measures are not sufficiently funded, coherent or extensive enough to protect vulnerable populations. Indeed, the rates of coverage are among the lowest in the world (Figure 2.11)[6].

For example, the index shows that less than a quarter of the target population for social protection in Bangladesh and the Maldives actually have access to those benefits. Often, where social safety nets do exist, they are biased towards the formal government sector, leaving many without basic services and rights (ADB, 2010).

2.4.5 Vulnerability to change in coastal communities

An important feature of coastal and marine livelihoods in the Bay of Bengal – especially on the western and northern shores of the region – is acute vulnerability to major shocks from natural disasters. Poverty tends to increase vulnerability and reduce resilience and longer term adaptive capacity. As is demonstrated in Table 2.9, over 50 percent of the world's coastal poor live in the countries that border the BOBLME.

People's livelihoods are complex and the livelihood strategies they adopt are influenced by many factors. When considering the vulnerability of people in coastal communities it is important to recognize that their livelihood strategies are influenced by many changing factors such as health; education; land tenure; wider environmental issues; relationships with government and support agencies; and food security. These are often of greater significance than immediate natural resource related concerns – especially after a disaster – but they will often impact on the ways in which people are able to utilize natural resources in their livelihood strategies.

A FAO regional consultation on disaster risk management in fishing and fish farming communities in Asia and the Pacific identified some of the key elements of the vulnerability of the coastal communities of the BOBLME (Campbell, 2010). They include inherent vulnerability, hazards and disasters and climate change. These elements are further influenced by a range of social and economic changes that are affecting the BOBLME countries.

[6] Social Protection Coverage indicator (SPCOV) has been formulated to represent the coverage of social protection. It is based on assessments related to each different type of social protection measure and then combined to give a figure that is indicative of the percentage of targeted people actually receiving the benefits of social protection. See Baulch *et al.*, 2008.

Inherent vulnerability

The coastal zone of the BOBLME is a very dynamic environment. Daily tidal changes and seasonal weather patterns are essential parts of this dynamism, but the region is also subject to changing patterns of river flow and surface water run-off from the land, both of which may affect the state of near-shore ecosystems and the services they provide. The impacts of these regular and expected changes are exacerbated by long-term trends such as resource degradation, pollution and climate change. Ironically, very often it is the hostile nature of coastal and marine environments that creates opportunities for the poor. Their remote and inhospitable nature, coupled with poor communications and poor market access, make for a less than welcoming environment. This may be tolerated by the poor but be unacceptable to better-off operators who may prefer to seek opportunities in lower risk and higher return environments (Campbell *et al*., 2006).

Hazards and disasters

Coastal communities in the BOBLME are exposed to a variety of hazards and disasters. They are most directly impacted by events such as tsunamis, storm surges and coastal flooding. More indirectly, droughts and other events can cause mass migration of people into areas normally occupied by fishing and fish farming communities, creating competition for resources. Biological disasters, such as the colonization of non-local species in coastal areas – for example crown-of-thorns starfish on reefs, or diseases in farmed fish and shrimp – can have devastating effects on local resources and livelihoods.

Asia has the highest number of disasters of any region. In recent years, major events have included the Orissa super cyclone in India in 1999; the Indian Ocean Tsunami of 2004; Cyclone Sidr in Bangladesh in 2007; Cyclone Nargis in Myanmar in 2008; and the floods in Pakistan in 2010. Although the Annual Disaster Statistical Review (2009) has shown no evidence that the number of disasters is increasing significantly (Vos *et al.*, 2010), more people are exposed to natural hazards because populations in the coastal zone are increasing (Figure 2.6).

Climate change

The impacts of climate change on the ecosystem services provided by the BOBLME are likely to affect people in many different ways. Some examples identified by Campbell (2010) include:

- Changes in fish abundance and distribution are likely to affect their availability to local fisheries and may result in the migration of fishers;
- Changes in the distribution of bait fish will compromise people's abilities to participate in commercial fisheries (such as fisheries for tuna);
- For some people, traditional knowledge will become redundant because species compositions will change; for others, traditional knowledge will provide the means to adapt and survive;
- Storms are likely to damage fishing boats, fish cages, fish drying racks, landing infrastructure and houses;
- Changes in weather patterns will affect traditional fish processing methods, especially where sun is used to dry fish. In some locations this may be of benefit to processors, in others poor weather in fish landing seasons will affect drying rates with the potential for substantial losses; and
- Changes in roads to markets where unusual flooding or heavy rains occur.

In the case of fisheries and aquaculture, Sriskanthan and Funge-Smith (2011) point out that because fisheries systems in Asia are poorly managed and overstressed (e.g. overfishing, pollution, water abstraction and habitat alteration) their capacity to recover from the additional stressors that climate change will present may be reduced. There are wide-spread implications, including a direct impact on species composition and distribution; an impact on catch potential and aquaculture production; and indirect impacts through changes to biophysical characteristics and the impact on other sectors. Any observed changes in fisheries systems will be a result of complex interactions between direct anthropogenic impacts and climate change related impacts; any attempts to mitigate impacts or adapt fisheries systems in response to climate change therefore require a more holistic understanding of important variables at the site-level.

According to the IPCC (2001), the vulnerability of fisheries- and aquaculture-dependent communities and economies to climate change will be based on several factors, namely:

- The exposure of the system to climate change "the nature and degree to which a system is exposed to significant climatic variations";
- The sensitivity of the system to climate change ("the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli"); and
- The adaptive capacity of ecosystems and human societies that are going to experience these impacts ("the ability of a system to adjust to climate change [including climate variability and extremes], to moderate the potential damage from it, to take advantage of its opportunities, or to cope with its consequences.")

Social and economic changes

The vulnerability of coastal communities in the BOBLME is further exacerbated by a number of social and economic pressures, both global and local. Examples of these pressures are provided here:

Fuel price fluctuations: oil prices more than trebled between 2002 and 2008 when they soared to nearly USD150/barrel in July 2008 and fell again to USD50/barrel in November 2008. Such fluctuations not only affect major investment decisions on a global scale, they also affect the costs of harvesting and marketing marine and coastal resources. Such uncertainty can be very difficult to manage.

Oil exploration and exploitation: the Bay of Bengal is reputed to be one of the hydrocarbon-rich areas of the world. While oil is expected to bring a wealth of opportunities to the nations surrounding the BOBLME, it also creates many risks to both the coastal communities and the environment. Experiences from other parts of the world have shown that oil exploitation can lead to a wide range of issues, including conflicts with fishers and coastal communities; transboundary conflicts between governments; diversion of government focus from all other uses; and an influx of job seekers to coastal areas.

Increased coastal development: poor communities are often at risk of being displaced from the coastal spaces they have occupied to make way for tourism activities and facilities, ports, urban growth, industry, intensive aquaculture, airports, special economic zones (SEZs) and top down conservation projects. Where people do not have clearly defined land rights or the right of access to coastal and marine resources, their ability to resist - or at least be compensated for - such changes is greatly compromised.

The Global Financial Crisis: while many of the impacts of this crisis may not yet have filtered down to the coastal communities of the BOBLME, the slowdown in growth and contraction of exports could have adverse consequences for the development of the coastal zone. In past crises, increased levels of industrial unemployment led to workers moving into agriculture and possibly fisheries (ADB, 2009). Falling remittances as unemployment grows in developed countries, and pressure on aid budgets, may either reduce aid flows or change their nature (ODI, 2010).

3. Legal, administrative and political context and constraints

3.1 Introduction

The implementation of the BOBLME Project's activities and reform agenda needs to be assessed against the overall legal, administrative and political context, and the constraints experienced by the countries of the region and the BOBLME as a whole. The regional context is particularly important because the BOBLME countries share the same marine environment and, consequently, national activities may be expected to have a transboundary impact.

There is considerable variance in the legal, administrative and political situation across the eight BOBLME countries. Some countries have federal systems of government while others are unitary states. Some are republics and some are monarchies. Despite these differences, administrative structures and legislation pertaining to marine conservation and utilization share similar characteristics and constraints.

In recent years, many of the BOBLME countries have made significant progress towards improving national policies and legal and institutional frameworks with a view to achieving the goal of the sustainable management of the BOBLME. However, the effectiveness of these efforts has been hampered by a number of constraints. These can be arranged into four broad categories, namely (a) legal and policy; (b) institutional; (c) fiscal; and (d) community participation and public awareness.

In most of the BOBLME countries, the lack of institutional capacity to implement policies and enforce regulations is strongly linked to financial constraints and the failure to mobilize grassroots participation. The effective enforcement and implementation of the best of laws and policies necessitate substantial fiscal resources which most of the BOBLME countries are not in a position to muster. The effort required to deal with the immense transboundary issues that impact on the BOBLME is beyond the means of any one country, all of which experience weighty domestic social and economic concerns. Therefore, there is a need to strengthen institutional capacity and improve integration and coordination between national and local government units, and tap into community-based participation with the goal of achieving conservation and management objectives.

3.2 International and domestic legal context

3.2.1 International agreements

First and foremost, the effectiveness of the BOBLME Project's activities and reform agenda needs to be analysed against the standards and principles of international marine conservation and sustainable resource use. Some international instruments are legally binding and require ratification and legislation at the national level, while others are non-binding policy documents that require domestic policy or legal compliance. Tables 3.1 and 3.2 provide a list of the major international instruments whose implementation at the national level will support the achievement of the BOBLME Project's objectives. The tables also evaluate the status of these instruments in the BOBLME countries.

Of particular importance is the FAO Code of Conduct for Responsible Fisheries (Code of Conduct) which provides principles and standards applicable to the conservation, management and development of all fisheries, including the capture, processing and trade of fish and fishery products; fishing operations; aquaculture; fisheries research; and the integration of fisheries into coastal area management. The Code of Conduct is supported by the FAO Compliance Agreement and specific International Plans of Action that require the development and implementation of corresponding national plans of action.

Collectively, these binding and non-binding international instruments provide the framework for the implementation of sustainable and responsible fishing practices and sound marine environmental management, including better management of fisheries; protection of migratory and threatened species; ecosystem and biodiversity protection; and the prevention of marine pollution.

Table 3.1 Status of major environmental treaties of BOBLME countries.

	Indonesia	Malaysia	Thailand	Myanmar	Bangladesh	Sri Lanka	India	Maldives
United Nations Convention on the Law of the Sea (UNCLOS)	✔	✔	✔	✔	✔	✔	✔	✔
Convention on Biological Diversity (CBD)	✔	✔	✔	✔	✔	✔	✔	✔
Convention on International Trade in Endangered Species (CITES)	✔	✔	✔	✔	✔	✔	✔	✘
Convention on Migratory Species (Bonn Convention)	✔	✔	✔	✔	✔	✔	✔	✘
Ramsar Convention on Wetlands of International Importance (Ramsar)	✔	✔	✔	✔	✔	✔	✔	✘
Stockholm Convention on Persistent Organic Pollutants	✔	✔	✔	✔	✔	✔	✔	✔
UN Framework Convention on Climate Change (FCCC) and Kyoto Protocol	✔	✔	✔	✔	✔	✔	✔	✔
Basel Convention on the control of Transboundary Movements of Hazardous Wastes and their Disposal	✔	✔	✔	✘	✔	✔	✔	✔
UN Fish Stocks Agreement	✘	✘	✘	✘	✘	✔	✔	✔
FAO Compliance Agreement	✘	✘	✘	✘	✘	✘	✘	✘
Fund Convention	✘	✔	✘	✘	✘	✘	✔	✔
International convention for the prevention of pollution from ships (MARPOL 73/78)	✔ (Annex I–II)	✔ (Annex I, II, V)	✔ (Annex I & II)	✔ (Annex I & II)	✔ (Annex I–VI)	✔ (Annex I–V)	✔ (Annex I–V)	✔ (Annex I, II, V)

✔ State party ✘ Non-state party

Most of the BOBLME countries are party to major international agreements pertaining to biodiversity and protection of ecosystems (Table 3.1). These include the United Nations Convention on the Law of the Sea[7]; the Convention on Biological Diversity[8]; and the Cartagena Protocol on Biosafety to the Convention on Biological Diversity[9]. With the exception of the Maldives, all BOBLME member countries are party to the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention)[10]; and the Convention on International Trade in Endangered Species of Wild Fauna and Flora[11]. All BOBLME countries are party to key international instruments concerning the protection of the atmosphere, such as the United Nations Framework Convention on Climate Change[12] and the Kyoto Protocol to the United Nations Framework Convention on Climate [13].

[7] United Nations Convention on the Law of the Sea, concluded on 10 December 1982, entered into force on 16 November 1994, 1833 UNTS; 21 ILM 1261 (1982).

[8] Convention on Biological Diversity, concluded on 05 June 1992, entered into force on 29 December 1993, 1760 UNTS 79; 31 ILM 818 (1992).

[9] Cartagena Protocol on Biosafety to the Convention on Biological Diversity, concluded on 29 January 2000, entered into force on 11 September 2003, 2226 U.N.T.S. 208; 39 ILM 1027 (2000).

[10] Convention on Wetlands of International Importance especially as Waterfowl Habitat, concluded on 29 January 2000, entered into force on 11 September 2003, 2226 U.N.T.S. 208; 39 ILM 1027 (2000).

[11] Convention on International Trade in Endangered Species of Wild Fauna and Flora, concluded on 03 March 1973, entered into force on 01 July 1975, 27 UST 1087; TIAS 8249; 993 UNTS 243.

[12] United Nations Framework Convention on Climate Change, concluded on 09 May 1992, entered into force on 21 March 1994, 1771 UNTS 107; S. Treaty Doc No. 102-38; U.N. Doc. A/AC.237/18 (Part II)/Add.1; 31 ILM 849 (1992).

[13] Kyoto Protocol to the United Nations Framework Convention on Climate, concluded on 11 December 1997, entered into force on 16 February 2005, UN Doc FCCC/CP/1997/7/Add.1, Dec. 10, 1997; 37 ILM 22 (1998).

Table 3.2 Adoption of International and National Plans of Action by BOBLME countries.

	Indonesia	Malaysia	Thailand	Myanmar	Bangladesh	Sri Lanka	India	Maldives
IPOA – seabirds	✔	✔	✔	✔	✔	✔	✔	✔
NPOA – seabirds	✘	✘	✘	✘	✘	✘	✘	✘
IPOA – sharks	✔	✔	✔	✔	✔	✔	✔	✔
Sharks – plan	✔	✔	✘	✘	✘	✘	✘	✘
IPOA – capacity	✔	✔	✔	✔	✔	✔	✔	✔
NPOA – capacity	✔	✘	✘	✘	✘	✘	✘	✘
IPOA – IUU	✔	✔	✔	✔	✔	✔	✔	✔
NPOA – IUU	✘	✘	✘	✘	✘	✘	✘	✘

✔ for the IPOA columns indicate participation in the 23rd and 24th FAO committee on fisheries meetings when the IPOAs were adopted.

Only a few of the BOBLME countries have ratified the UN Fish Stocks Agreement[14] and none have accepted the FAO Compliance Agreement (Table 3.2)[15]. Only a few BOBLME countries have developed national plans of action to implement the various FAO International Plans of Action, namely on capacity, seabirds, sharks and illegal, unreported and unregulated (IUU) fishing.

A major shortfall is the lack of widespread ratification of international agreements pertaining to the prevention of marine pollution. None of the BOBLME countries are party to the Convention for the Prevention of Marine Pollution from Land-Based Sources[16], nor the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Convention) [17]. Among the BOBLME countries, only Malaysia is party to the International Convention on Civil Liability for Bunker Oil Pollution Damage[18], and only India, Malaysia and the Maldives have ratified the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (Fund Convention)[19].

The Participation by BOBLME countries in many relevant international instruments, as shown in Tables 3.1 and 3.2, demonstrates significant commitment to address cross-cutting issues of transboundary concern. However, many of these international commitments are yet to be incorporated into domestic policies and legislation.

The Environmental Performance Index (EPI, 2010) provides a benchmark of the environmental performance of a country's policies. The 2010 EPI ranks 163 countries on 25 performance indicators tracked across 10 well-established policy categories covering both environmental public health and ecosystem vitality. The performance of the BOBLME countries in the 2010 EPI was very poor, with the highest-ranked BOBLME country being the Maldives at 48 and the lowest-ranked being Bangladesh at 139. Despite the comprehensive scope of the EPI, there is still the need for a study to assess how BOBLME member countries meet their national environmental objectives and how these objectives fulfil the country's international obligations and commitments.

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[14] United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, concluded on 04 August 1995, entered into force on 11 December 2001, 34 ILM 1542 (1995); 2167 UNTS 88.

[15] The Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, unanimously approved, subject to acceptance, at the 27th Session of the Conference of the FAO in November 1993, entered into force on 24 April 2003.

[16] Convention for the Prevention of Marine Pollution from Land-Based Sources, concluded on 04 June 1974, entered into force on 06 May 1978, 1546 UNTS 119; 13 ILM 352 (1974); UKTS 1978, No. 64.

[17] Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, concluded on 29 December 1972, entered into force on 30 August 1975, 26 UST 2403, 1046 UNTS 120, 11 ILM 1294 (1972).

[18] International Convention on Civil Liability for Bunker Oil Pollution Damage, concluded on 23 March 2001, entered into force on 21 November 2008, IMO LEG/CONF.12/19; OJ 2002 L 256/7.

[19] International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, Brussels, 1971.

3.2.2 Domestic legislation

While there is considerable variance across the BOBLME countries with regard to their respective political, legislative and administrative structures, they have all enacted a number of laws that seek to regulate activities in the BOBLME and ensure that marine living resources and critical habitats of the region are afforded a degree of protection. The existing legal and policy frameworks dealing with coastal and marine resource management and sustainable use of the BOBLME are, in general, comprehensive in their content and coverage. However, they are fragmented, sectoral in scope and not effectively implemented. Table 3.3 provides a summary of the relevant national legislation of the BOBLME countries. The laws can be classified into three broad categories, namely: fisheries management and development, marine biodiversity protection and marine pollution.

An analysis of the laws of individual BOBLME countries in the context of the objectives of the BOBLME Project reveals that many laws do not embody modern management concepts of international instruments and sustainable marine environmental management practices. Major gaps relate to the objectives of long-term sustainable use, the precautionary approach and the ecosystem approach.

There is a complex suite of laws and regulations on, for example, aquaculture, coastal zone management, environment, capture fisheries, forests, pollution, critical habitats and certain defined commercially attractive and/or endangered species. However, the domestic legal and administrative structures are largely sectoral, uncoordinated and need to be simplified, streamlined and harmonized in order for national and regional efforts to manage the BOBLME to be effective. Other major constraints are inadequate budgetary commitments and a lack of stakeholder consultation and empowerment at the community level.

Some legislation exists to protect the BOBLME from the main forms of pollution, but it is largely in the form of controls on effluent discharges. Even if these controls are rigorously enforced (which they tend not to be; see also institutional root causes), controlled discharges can still destroy an ecosystem if there are enough of them. The effluent control approach also does not take into account the effect of pollutants on ecosystems, or whether ecosystems are already polluted, physically damaged or otherwise stressed (e.g. by floods). A further failure of pollution-specific legislation in the region is the absence of the “polluter-pays” principle and other penalties severe enough to ensure that breaking the law is a serious economic cost of doing business (i.e. it is more expensive to break the law than to comply with it).

At the local level, where community-based management or co-management is being developed, specific devolution of power and authority from higher levels of government down to locally constituted bodies is necessary. These bodies may range from local authorities or communities, to committees made up of a representative selection of stakeholders according to the resources utilized or the habitats impacted. This, in turn, requires enabling legislation at the national or state level, coupled with appropriate local by-laws that give effect to the co-management arrangements and adequate consultation and participation.

In a number of critical areas, there is an absence of any legislation, policies or strategies. For example, there is inadequate legislation to protect the BOBLME from principal forms of land-based pollution, a key transboundary environmental problem and identified as a priority area by the BOBLME Project. This shortfall needs to be addressed in a coordinated manner across national and supra-national institutions. Another noticeable common trend in the BOBLME region is that in many instances where legislation is in place, it has ambiguous, overlapping, or conflicting provisions. There are often no enabling subsidiary rules or regulations to implement the laws.

Table 3.3 Marine-related legislation of the BOBLME countries.

Country	Laws, acts and regulations
Myanmar	• Law Relating to the Fishing Rights of Foreign Fishing Vessels, 1989 • Aquaculture Law, 1989 • Myanmar Marine Fisheries Law, 1990 • Freshwater Fisheries Law, 1991 • Law Amending the Myanmar Marine Fisheries Law, 1993 • Law Amending the Law Relating to Fishing Rights of Foreign Fishing Vessels, 1993

Country	Laws, acts and regulations
Indonesia	• Act concerning Indonesian Waters (No. 4 of 1960), 1960 • Fisheries Act, Act No. 9/1985 • Fisheries Law No. 31/2004, 2004 • Act No. 9/concerning Tourism, 1990 • Law 23/regarding Environmental Management, 1997 • Act on the conservation of biological resources and their ecosystems (Act No. 5 of 1990) • Law No. 24/regarding Spatial Planning, 1992 • Presidential Decree No. 196/1998 regarding the Agency for the Control of Environmental Impact • Environmental Impact Act No. 21/1992 regarding Maritime Transportation • Government Regulation No. 60/2007 regarding the Conservation of Fishery Resources, 2007 • Regulation of the Minister of Finance No. 113/PMK.04/2007 regarding the exemption from import duty on the import of sea products caught by permitted catching instruments, 2007 • Regulation of the Minister of Finance No. 105/PMK.04/2007 regarding the exemption from import duty on the import of parent stocks and seeds for the establishment and development of farming, breeding, or fishery industry, 2007 • Law No. 16/2006 on Agricultural, Fishery and Forestry Extension System, 2006 • Government Regulation No. 15/2002 concerning fish quarantine, 2002 • Decree of the Minister of Agriculture No. 646/KPTS/KP.150/7/1996 re. establishment of a team for fostering and controlling the supply of fishing vessels, 1996 • Joint Decree of the Minister of Agriculture and the Minister of Communications No. 492/Kpts/IK.120/7/1996 and No. SK.1/AL.003/PHB-96 of 4 July 1996 re. the simplification of licensing for fishing vessels, 1996 • Joint Decree of the Minister of Agriculture and the Minister of Communications No. 493/KPTS/IK.410/7/96 and No. SK.2/AL.106/PHB-96 of 4 July 1996, re. the operation of fishing ports as fishing infrastructures, 1996 • Decree of the Minister of Agriculture No. 805/Kpts/IK.120/12/95 on the stipulation on the use of fish-carrying vessels, 1995 • Decree of the Minister of Agriculture on appointing a port as a fishing base for chartered foreign flag fishing vessels for fishing in the EEZ (No. 144 of 1993), 1993 • Decree relative to Licenses for any Foreigner or Foreign Corporate Body to Catch Fish in Indonesian Exclusive Economic Zone (No. 475/Kpts/IK.120/7/1985), 1985 • Decree of the Minister of Agriculture on the Determination of Total Allowable Catch in the Indonesian Exclusive Economic Zone (No. 473a/KPTS/IK 250.6/1985), 1985. Fisheries Law (No. 9 of 1985), 1985 • Regulations on Fishery Resource Management in the Indonesian Exclusive Economic Zone (EEZ) (Government Decree No. 15 of 1984), 1984 • Presidential Decree regarding Seafarming Development in Indonesian Waters (No. 23 of 1982), 1982. • Decree No. 608/Kpts/Um/9/1976 on the delimitation of fishing lanes for vessels owned by state fishing entities, 1976 • Decree No. 607/Kpts/Um/9/1976 on Fishing Lanes, 1976. Decree of the Minister of Agriculture on the Fishing Areas for Sea-bed Trawlers (No. 609 of 1976), 1976 • Decree No. 123/Kpts/Um/3/1975 establishing the size of mesh in the purse seine nets used for fishing certain fish species, 1975 • Decree No. 1 of the Minister of Agriculture on the Conservation of the Riches of the Fish Resources of Indonesia, 1975 • Decree No. 561 of the Minister of Agriculture on the Utilization of the By-products of Fisheries, 1973 • Foreign Ships - Innocent Passage in Indonesian Waters (Govt Decree No. 36 of 1962), 1962

Country	Laws, acts and regulations
Malaysia	• Malaysian Maritime Enforcement Agency Act, 2004 • Environmental Quality Act, 1974 • Exclusive Economic Zone Act, 1984 • Merchant Shipping Ordinance, 1952 • Merchant Shipping (Amendment and Extension) Act, 2007 • Protection of Wildlife Act, 1972 • Fisheries Act 1985 (No. 317 of 1985), 1985 • Waters Act, 1920 (as amended 1989) • Fisheries (Prohibited Areas) Regulations, 1994 • Fisheries (Riverine) Rules, 1990 • Fisheries (Maritime) (Licensing of Local Fishing Vessel) Regulations, 1985 • Fisheries (Prohibition of Method of Fishing) Regulations, 1980
Thailand	• The Fisheries Act (1947, as amended in 1953 and 1985 and currently being updated) • Wildlife Conservation and Protection Act (1992) • Enhancement and Preservation of Natural Environmental Quality Act (1992) • Regulation of the Department of Fisheries on the Application and Permission for Aquaculture in Public Fishing Grounds (1990) • National Park Act (1961, as amended) • Navigation in Thai Waters Act (1913, as amended) • Regulation of the Fisheries Department on the application for a license for overseas fisheries B.E. 2532, 1989 • Act Governing the Right to Fish in Thai Fishery Waters B.E. 2502 (1939) • Act Organizing the Activities of the Fish Market B.E. 2496 • Wildlife Reservation and Protection Act B.E. 2535 (1992) • The Thai vessel Act was established in B.E. 2481 (1938) • The National Reserved Forest Act B.E.2507 • Forestry Act B.E.2484 • National Parks Act B.E. 2504 of 1961 (impacting on marine parks and their licensing of or management of these parks) • Enhancement and Conservation of National Environmental Quality Act, 1992 • Animal Feed Quality Control Act B.E.2525 • Food Act B.E.2522 • Drug Act B.E. 2510 • Endemic Animal Act B.E.2499 • Foreign Business Act B.E.2542 • Dangerous Substance Act B.E.2535
Maldives	• Maritime Zones of Maldives Act No. 6, 1996 • Navigation Act (Law No. 69/78) • Mandate of the Ministry of Transport, Environment and Construction-138/2009/34 (2009) • Customs Control over International Ships in Ports Act (Law No. 62/78) • Police Act (Law No. 5/2008) (2008) • Levy of Fees of Maritime Vessels Act (Law No. 19/83) • National Security Service and Coast Guard Act (Law no. 1/2008) • Navigational Lights Act (Law No. 65/78) • Outwards Clearance Permit for Ship Embarking on International Voyage Act (Law No.61/78) • Port Dues Act (Law No. 66/78) • Regulation for Vessels Navigating within the Maritime Zones, (1999) • Ship Levies Act (Law No: 19/83) • Ship Station License Act (Law No. 36/78) • Ship Wrecks and Collision within Maritime Zones of Maldives Act (Law No:7/96) • Ships Engaged in International Import/ Export Trade other than Ships Granted Diplomatic Immunity Act (Law No. 63/78) • Fisheries Law of the Maldives (Law No. 5/87), 1987 • Environment Protection Law of 1993 • Law No. 1/74 relating to Fishing in the Lagoons of Maldives (enacted 1374 Hejira, amended by laws 19 of 1971 and 22 of 1975), 1975 • Regulations for Issuing the License to Fish in the Exclusive Economic Zone of the Republic of Maldives, 1986

Country	Laws, acts and regulations
Bangladesh	• Territorial Waters and Maritime Zones Act, 1974 (Act No. XXVI), 1978 • The Bangladesh Environment Conservation Act, 1995 • The Bangladesh Wild Life (Preservation) Order, 1973 • The Embankment and Drainage Act, 1952 (East Bengal Act) • The Environment Conservation Rules, 1997 • The Environment Court Act, 2000 • The Environment Pollution Control Ordinance 1977 • The Ground Water Management Ordinance, 1985 • Water Development Board Act, 2000 • The Marine Fisheries Ordinance, 1983 • The Marine Fisheries Rules, 1983 • The Private Fisheries Protection Act, 1889 • The Protection and Conservation of Fish Act, 1950 • The Fish and Fish Products Ordinance, 1983 • The Tanks Improvement Act, 1939 • Bangladesh Merchant Shipping Ordinance, 1983 (No. XXVI of 1983) • Protection and Conservation of Fish Act, 1950 (East Bengal Act XVIII of 1950) • Fisheries Research Institute Ordinance, 1984 (Ordinance No. XVL of 1984), 1984 • Protection and Conservation of Fish Rules, 1985 • Bangladesh Fisheries Development Corporation Act, 1973 • Government Fisheries (Protection) Ordinance, 1959 (E.P. Ordinance No. XXIV of 1959), 1959 • The Inland Shipping Ordinance, 1976
India	• Territorial Waters Continental Shelf Exclusive Economic Zone and other Maritime Zones Act, 1976 • Environment (Protection) Act, 1986 • Environmental Impact Assessment Notification, 1994 • Water (Prevention and Control of Pollution) Act, 1974 (as amended) • Water (Prevention and Control of Pollution) Cess Act, 1977 (as amended) • Guidelines for Sustainable Development and Management of Brackish Water Aquaculture, 1995 • Hazardous Wastes (Management and Handling) Rules (1989, as amended) • Wildlife (Protection) Act (1972, as amended in 2003) • Biological Diversity Act, 2002 • The Air (Prevention and Control of Pollution) Act 1981, amended 1987 • Coastal Aquaculture Authority Rules, 2005 • Marine Products Export Development Authority Act, 1972 (Act No. 13 of 1972), 1972, 1986 • Maritime Zones of India (Regulation of Fishing by Foreign Fishing Vessels) Rules, 1982 • Maritime Zone of India (Regulation of Fishing by Foreign Vessels) Act, 1981 (Act No. 42), 1981 • Coastal Regulation Zone Notification 2011 • Coastal Zone Management Act • Comprehensive Marine Fishing Policy • Wetlands (Conservation and Management Rules 2010)
Sri Lanka	• Aquaculture (Monitoring of Residues) Regulations 2002 • Aquaculture Management (Disease Control) Regulations 2000 • National Institute of Fisheries and Nautical Engineering Act (No. 36 of 1999) • National Aquaculture Development Authority of Sri Lanka Act, No. 53 of 1998 • Fish Products (Export) Regulations, 1998 • Export and Import of Live Fish Regulations, 1998 • Fish Processing Establishments Regulations, 1998 • Aquaculture Management Regulations of 1996 • Fishing Operations Regulations of 1996 • Inland Fisheries Management Regulations of 1996 • Fisheries and Aquatic Resources Act 1996 (No. 2 of 1996) • Madel (Beach Seine) Fishing Regulations 1984 • National Aquatic Resources Research and Development Agency Act 1981 (No. 54 of 1981)

Country	Laws, acts and regulations
Sri Lanka (continued)	• Foreign Fishing Boat Regulations, 1981, 1981 • Sri Lanka Ports Authority Act (No. 51 of 1979), 1979 Inland Water Fishing Regulations, 1978, 1978 • Proclamation of the President delimiting the breadth of the maritime zones (unofficial title), 1977 • Spiny Lobster and Prawn (Shrimp) Regulations, 1973 • Fisheries Regulations, 1941, 1968 • Fish Landing Regulations (Amendment) 2011 • Fishing (Import and Export) Regulations, 2010 • Department of Coast Guard Act, No.41 of 2009 • Declaration of Prohibited Time Period of Lobster Fishing Operations, 2009 • Fishing Boat Safety (Design, Construction and Equipment) Regulations, 2009 • Fish Landing Regulations (Amendment), 2008 • Fish Products (Export) Regulations, 2007 • Fishing Boat Regulations (Amendment), 2006 • Monofilament Nets Prohibition Regulations, 2006 • Fishing Operation Regulations (Amendment), 2005 • Export and Import of Live Fish Regulations (Amendment), 2003 • Chank Fishery Management and Export Regulations, 2003 • Fish Processing Establishment Regulations, 1998, 2003 • Lobster Fisheries Management Regulations, 2000 • Fish Product (Export) Regulations (Amendment), 2000 • Fish Product (Export) Regulations (Amendment), 2002 • Aquaculture (Monitoring of Residues) Regulation, 2002 • Seashells Fisheries Management and Export Regulations, 2001 • Handling and Distribution of Fish Regulations (Amendment), 2001 • Fisheries Committee Regulations (Amendment), 1999 • Export and Import of Live Fish Regulations (Amendment), 1999 • National Institute of Fisheries and Nautical Engineering Act (No. 36 of 1999) • Aquaculture Management (Disease Control) Regulations, 2000 • Export and Import of Live Fish Regulations, 1998 • National Aquaculture Development Authority of Sri Lanka Act, No. 53 of 1998 • Fish Products (Export) Regulations, 1998 • Landing of Fish Regulations, 1997 • Fisheries Committee Regulations, 1997 • Handling and Distribution Regulations, 1997 • Registration of Fishing Boat Regulations, 1996 • Aquaculture Management Regulations of 1996, 1996 • Fishing Operation Regulations,1996 • Inland Fisheries Management Regulations, 1996 • Aquaculture Management Regulations, 1996 • Fisheries and Aquatic Resources Act, No. 2 of 1996 • Fauna and Flora Protection Ordinance (cap469) as amended especially by Act No 49 of 1993 • Forest Ordinance (Cap 453) • North western Provincial Environmental Statutes no 12 of 1990 • Madel (Beach Seine) Fishing Regulations 1984 • Marine Pollution Prevention Act 59 of 1981 • Coast Conservation Act No 57 of 1981 • National Aquatic Resources Research and Development Agency Act No. 54 of 1981 • Foreign Fishing Boat Regulations, 1981 • National Environmental Act No 47 of 1980 • Sri Lanka Ports Authority Act , No. 51 of 1979 • Inland Water Fishing Regulations, 1978 • Proclamation of the President delimiting the breadth of the maritime zones (unofficial title), 1977 • Maritime Zones Law, No.22 of 1976

3.3 Institutional arrangements

In each of the BOBLME countries, a number of institutions with the authority to implement the objectives of the BOBLME Project exist at the national and provincial levels. However, the form and type of institutional arrangement varies widely. Table 3.4 shows the institutional arrangements in each country with actual or potential responsibility for environmental protection and the management of coastal and marine resources of the BOBLME.

As a result of the many different institutions that exist with overlapping mandates and jurisdiction, responsibility and accountability between different levels of government is not always clearly assigned or delineated. This may lead to conflict between agencies and confusion among stakeholders with a resultant negative impact on the management of the resources of the BOBLME. At the grassroots level, the lack of local community stakeholder consultation and involvement in planning, decision-making, implementation and enforcement undermine effective implementation by responsible agencies. There is thus a need for continuous coordination and collaboration between agencies, and between the central government and the various sub-national units in order to ensure sustainable conservation and management of the BOBLME. In order to be effective, it is necessary that institutions assign enforcement powers to clearly identified agencies, specify fines and other penalties that act as deterrents, and promote monitoring and compliance with legislation.

The lack of clarity with regard to responsibility and accountability resulting from overlapping institutional mandates also gives rise to corruption. The performance of the BOBLME countries in the Corruption Perception Index which measures the perceived level of public-sector corruption is indicative of the need to address wider issues of governance, including corruption. (See Section 2.3 for more detail).

Table 3.4 Ministries, departments and agencies with marine and environment functions among BOBLME countries.

Country	Ministries, Departments and Agencies
Indonesia	• Ministry of Marine Affairs and Fisheries • Agency for Marine and Fisheries Research, Ministry of Marine Affairs and Fisheries • Ministry of Environment • Department of Agriculture • Department of Forestry • National Coordinating Agency for Survey and Mapping (BAKOSURTANAL) • Meteorological and Geophysics Institute of Indonesia (BMG) • Agency for the Assessment and Application of Technology (BPPT) • Defense and Maritime Police

Malaysia	• Federal Department of Fisheries
	• Ministry of Agriculture and Agro-Based Industry
	• Fisheries Development Authority of Malaysia
	• Fisheries Research Institute Malaysia
	• Fisheries Development Authority of Malaysia
	• Ministry of Natural Resources and Environment
	    • Department of Marine Parks
	    • Department of Environment
	• National Oceanography Directorate
	• Coast Guard

Bangladesh	• Ministry of Fisheries and Livestock
	    • Department of Fisheries
	    • Bangladesh Fisheries Research Institute
	    • Bangladesh Fisheries Development Corporation
	    • Marine Fisheries Academy
	• Ministry of Environment and Forest
	    • Department of Environment
	• Ministry of Water Resources
	• Ministry of Defense
	    • Coast Guard
	• Ministry of Science and Technology

Country	Ministries, Departments and Agencies

Myanmar	• Ministry of Livestock and Fisheries
	  • Department of Fisheries
	    • Marine Fisheries Resources Survey and Research Unit
	• Hotel and Tourist Department
	• Ministry of Environment Conservation and Forestry
	  • Department of Forestry

Maldives	• Ministry of Fisheries and Agriculture • Marine Research Centre • Ministry of Housing and Environment • Ministry of Tourism Arts and Culture • Environmental Protection Agency • Maldives Meteorological Services
India	• Department of Agriculture and Cooperation • Department of Animal Husbandry, Dairying and Fisheries • Department of Agricultural Research and Education • Ministry of Food Processing Industries • Department of Ocean Development • Department of Bio-Technology • Indian Council of Agricultural Research • Central Institute of Brackishwater Aquaculture • Central Inland Fisheries Research Institute • Central Institute of Freshwater Aquaculture • Central Institute of Fisheries Technology • Central Marine Fisheries Research Institute • Central Institute of Fisheries Education • National Bureau of Fish Genetic Resources • National Research Centre on Coldwater Fisheries • Fishery Survey of India • National Institute of Fisheries Post Harvest Technology and Training • Central Institute of Fisheries, Nautical and Training • Central Institute of Coastal Engineering for Fisheries • Coastal Aquaculture Authority • Marine Product Export Development Authority • National Fisheries Development Board • National Institute of Oceanography • Coast Guard • Ministry of Environment and Forest

Sri Lanka	• Ministry of Fisheries and Aquatic Resources Development
	  • Department of Fisheries and Aquatic Resources
	  • National Aquatic Resources Research and Development Agency
	  • Ceylon Fisheries Harbours Corporation
	  • National Aquaculture Development Authority
	• Ministry of Environment
	  • Central Environment Authority
	  • Department of Wildlife
	  • Department of Forests
	  • Marine Environment Protection Authority
	• Ministry of Tourism
	• Ministry of Science and Technology
	• Ministry of Plantation, Infrastructure and Construction
	• Ministry of Irrigation and Water Management
	• Ministry of Provincial Councils and Local Government
	• Provincial Ministry of Local Government, Education, Industries and Environment
	• Ministry of Defense and Urban Development
	  • Coast Conservation Department
	  • Department of Sri Lanka Coast Guard

Country	Ministries, Departments and Agencies

Thailand	• Ministry of Agriculture and Cooperatives
	  • Department of Fisheries
	  • Land Development Department
	• Ministry of Natural Resources and Environment
	  • Department of Marine and Coastal Resources
	  • Department of National Parks, Wildlife and Plant Conservation
	  • Department of Water Resources
	  • Office of the Natural Resources and Environmental Policy and Planning
	  • Department of Environmental Quality Promotion
	  • Pollution Control Department
	  • Royal Forestry Department
	• Ministry of Transportation
	  • Marine Department
	• Ministry of Tourism and Sport
	  • Office of Tourism Development
	• Ministry of Interior
	  • Department of Disaster Prevention and Mitigation
	• Royal Thai Navy
	• Port Authority of Thailand
	• Six Andaman Provincial Offices
	• Tourism Authority of Thailand

3.3.1 Decentralized governments

A noticeable trend in the BOBLME member countries is a move towards decentralized administrations. The exercise of administrative authority is complicated because of the overlapping and uncoordinated powers and functions of national, state and local government bodies. Moreover, central, state and local governments are often hampered by poor planning and inadequate communication, including poor information exchange. While there is, by and large, inadequate capacity at all levels; this is most serious at the local government level, which generally lacks the capacity for managing multiple-use, multiple-stakeholder activities in the BOBLME region. Table 3.5 presents the sub-national administrative mechanisms in place in the BOBLME member countries.

Decentralized and participatory models of governance ensure local cultural and political autonomy; bring the government closer to the people; mobilize local resources; enhance sub-national units and institutions; and encourage grassroots community citizen participation in public administration. The move to decentralized governance across the BOBLME countries also provides unique opportunities for states/provinces to implement and enforce legislation and policies in the BOBLME.

However, at the same time, decentralized administration creates a number of administrative, fiscal and logistical constraints and complicates the delivery of public services. Decentralized administration raises important questions about the capacity of the sub-national units to enforce rules and regulations decided at the national level. By and large, the success of decentralization depends on the skills, education and motivation, equipment and financial resources of the local government units.

3.3.2 Traditional systems and customary rights

The recognition of traditional systems and customary rights through, for example, customary marine tenure and community-based management, have proved to be successful in managing marine living resources, improving the livelihoods of traditional fishers and the management and conservation of marine resources. In the BOBLME countries, local customary management practices that regulate the use, access, and transfer of resources have been developed over many generations of humans interacting with the environment. Such practices are often distilled from indigenous ecological knowledge and are culturally embedded in customary institutions responsible for land and sea tenure.

Table 3.5 Sub-national government systems in BOBLME countries.

Country	Local government
Indonesia	• Four out of 33 provinces (Aceh, North Sumatra, West Sumatra and Riau) are part of the BOBLME. • Provinces are subdivided into regencies (*kabupaten*) and cities (*kota*), further divided into subdistricts (*kecamatan*) and into village groupings (either *desa* or *kelurahan*) which all have their own local governments and parliamentary bodies. • The modern administration is supported by the traditional *gotong royong*, or mutual responsibility and cooperation system, based on village councils led by a headman.
Malaysia	• Eight out of 11 peninsular states (Perlis, Kedah, Pulau Pinang, Perak, Selangor, Sembilan, Melaka and Johor) are on the BOB. • Nine states have hereditary rulers and four are led by governors appointed by the hereditary rulers. Each state also has a state parliament. • All states except Perlis (which is too small) are divided into varying numbers of districts, each headed by a district officer. • Beneath this are local, municipal and city councils.
Thailand	• 77 provinces, called *changwat*, are each under the control of a governor appointed by the national government. • 877 districts, called *amphoe*, are controlled by appointed district officials. • More than 7 255 communes, called *tambon*, and 69 307 villages, known as *muban.*
Myanmar	• 14 regions, seven of which are states of ethnic minority groups; and seven administrative divisions occupied by the Burmese majority – Kachin State, Kayah State, Kayin State, Chin State, Sagaing Division, Tanintһayi Division, Bago Division, Magway Division, Mandalay Division, Mon State, Rakhine State, Yangon Division, Shan State, Ayeyawady Division. • Division, township, and village law and order restoration councils control local government. • Regional commanders have considerable autonomy over their districts.
Maldives	• Seven provinces – Upper North, North, North Central, Central, South Central, Upper South and South. • Local councils and island administrations.
Bangladesh	• Seven administrative divisions, three of which are adjacent to the BOB (although all are linked to it via the river and the coastal watershed). • Divisions are subdivided into districts (*zila*), which are further divided into subdistricts (*upazila* or *thana*).
India	• Four states (West Bengal, Orissa, Andrha Pradesh, Tamil Nadu) are on the BOB. • Two Union Territories (Andaman and Nicobar Islands, Pondicherry) are in or adjacent to the BOB. These are administered collectively by a governor appointed by the head of state. • Various urban and rural administrative bodies.
Sri Lanka	• Nine provinces each headed by a directly elected provincial council – Central, Eastern, North Central, Northern, North Western, Sabaragamuwa, Southern, Uva and Western. • 25 administrative districts, which are further divided into divisional secretariats. • Other local government units include 12 municipal councils and 39 urban councils.

The implementation of customary marine tenure, practices and traditional knowledge is demonstrated in a variety of ways in the BOBLME. For example, particular areas may be closed to fishing, (e.g. temporary closures to provide supplies of fish for a feast, or permanent closures in areas where spirits are believed to reside); limits may be placed on who can harvest certain species, using certain gears and in certain areas; and the size of a harvest may also be limited. However, with colonization and adoption of Western cultures, community-based management and co-management schemes have weakened. Where they still exist, the integration of such approaches into the domestic legal framework and resource management practices of the BOBLME countries should be encouraged and promoted as a positive step towards ensuring the sustainable management of the BOBLME.

3.3.3 Community participation and public awareness

Community participation of one form or another in coastal and marine living resource management is generally accepted as a fundamental and practical way to promote compliance with laws and regulations and ensure the sustainability of marine living resources.

At present, the opportunities for stakeholder participation in the BOBLME are limited by existing laws, regulations and policies, and by the relatively low level of capability of the stakeholders themselves. There is a need to strengthen, improve and expand opportunities for participation by all major stakeholders at the regional, national and local levels, both in coastal habitats and resources conservation and the management of the BOBLME. In order to strengthen the participation of community stakeholders, appropriate policies, laws and regulations need to be put in place. Building the capacity of the stakeholders themselves should be made a separate goal that could be achieved by the development of training and information transfer projects and institutional arrangements which allow for routine participation by stakeholders. The involvement and participation of stakeholders in establishing a transparent and practical management mechanism for the BOBLME should be ensured, and not merely limited to perfunctory consultation.

At the regional level, broad and enduring partnerships between and within the BOBLME countries, and with key regional/international agencies and donors, should be built so as to achieve a coordinated implementation process that will harness the unique contributions of the respective co-financing institutions. In light of the size and complexity of the BOB, achieving a high degree of regional cooperation with a large number of government agencies – many of which would likely be directly involved in project implementation – will ensure the long-term viability of BOBLME projects and activities.

4. Assessment of marine living resources and the environment

4.1 Overexploitation of marine living resources

In the context of this TDA, the term "marine living resources" describes (i) fish[20] that support important fisheries in the BOBLME; (ii) marine biodiversity; and (iii) vulnerable and endangered species. In all the consultations with BOBLME countries that led to the development of the TDA, the impact of fishing on the marine living resources was a common concern. "Fishing" in this context comprises the harvesting or other extractive use(s) of naturally occurring marine living resources, irrespective of their phylogenetic classification and includes, *inter alia*, adults, juveniles, eggs and miscellaneous parts of fish, invertebrates, plants and other organisms that rely on the marine environment for some part of their lifecycle.

As described in Section 2.3, the fisheries of the BOBLME are of great socio-economic importance to the countries of the region and provide for direct employment of over two million fishers. A wide range of species are landed, including sardine, anchovy, scad, shad, mackerel, snapper, emperor, grouper, tuna, shark, ornamental reef fish, shrimp, bivalve shellfish and seaweed (Preston, 2004).

4.1.1 Current production and value

In 2009, the estimated fisheries production of the BOBLME was approximately six million tonnes valued at USD4 billion (SAUP, 2010 and FAO FishStat, 2011). It should be noted that there are a number of organizations responsible for compiling production figures. These include the Food and Agriculture Organization of the United Nations (FAO), the Sea Around Us Project (SAUP), and individual country statistics. All present the data in different ways and it is difficult to derive a definitive figure, although an analysis of the different data all produced an estimate of around five million tonnes in 2006[21] (Table 4.1). In countries where only part of the marine and coastal environment is included in the BOBLME, it is difficult to identify a portion of the catch that is landed only in those areas; rough estimates were necessary as is explained in Table 4.1.

Table 4.1 Estimates of marine production and value for each country of the Bay of Bengal, 2006.

	Indonesia*	Malaysia	Thailand	Myanmar	Bangladesh	India**	Sri Lanka	Maldives	Total*
FAO statistics									
Tonnes (10^3)	561.9	586.0	733.4	1 373.7	479.8	991.5	238.7	184.3	5 151
Country statistics									
Tonnes (10^3)	571.1	640.0	891.4	1 380.0	514.6	919.9	216.0	184.2	5 317
Sea around us Project (Production in BOBLME country EEZs)									
Tonnes (10^3)	365.3	465.4	206.8	1 838.2	555.0	1 183.2	144.0	40.2	4 798
USD (10^6)	159	572.0	175.0	1 270.0	127.0	993.9	131.0	74.5	3 581

*Indonesia, FAO and SAUP figures based on 50 percent of FAO fishing area 57 landings. National landings based on Fishery Management Area (FMA) 571 plus 50 percent of 572

** SAUP data for India's Andaman and Nicobar Islands corrected from 2001-06 from India's National Yearbook statistics

Source: SAUP, 2010; FAO FishStat, 2011; and Country statistics and yearbooks, 2007.

[20] Fish includes finfish, crustaceans, molluscs and any aquatic animal which is harvested

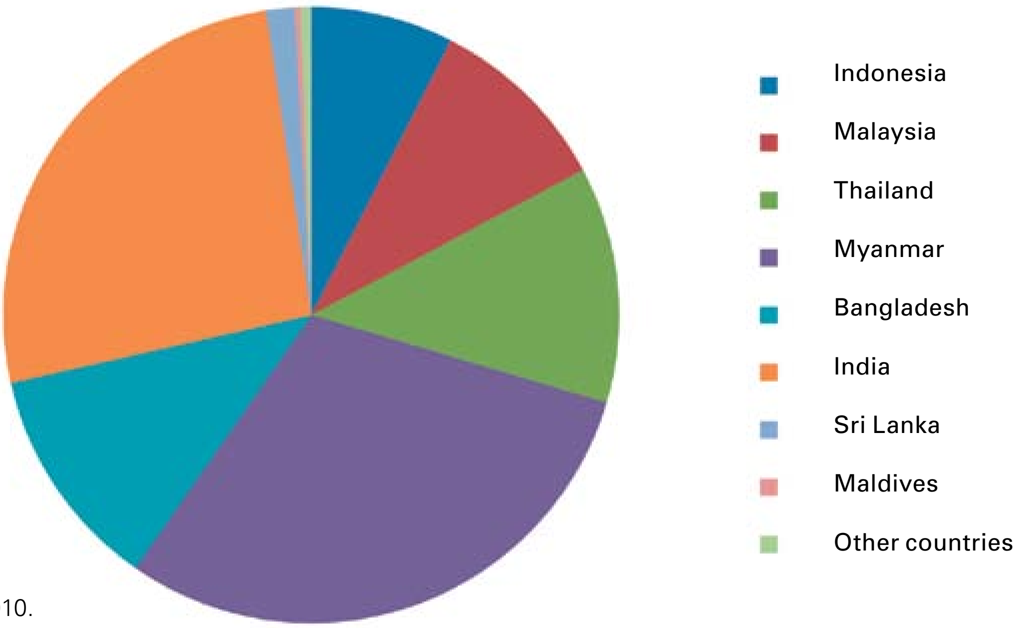
[21] SAUP data are only available up to 2006 so comparisons are not possible for later years

The national statistics, and the FAO records derived from these, refer to landings recorded by each of the BOBLME countries. SAUP estimates differ in that they are (i) allocated to fishing ground at capture, not the place of landing; (ii) based on best available data sets; and (iii) in the case of India, based on "reconstructed" catches that include missing data and discards.

For example, although Thailand recorded a total catch of about 850 000 tonnes, much of this figure is not caught in Thailand, but fished in the EEZs of other countries; according to SAUP (2010), only 200 000 tonnes is taken from the Thailand EEZ (Andaman Sea). SAUP and FAO also point out that the catch recorded in each country is probably an underestimate because it often does not include (i) the catch taken by the small-scale fisheries; (ii) IUU catch; and (iii) discarded catch. Thus, the total catch and value of the BOBLME is probably considerably larger than is reported here.

In addition to estimating the amount of fish actually caught in each EEZ, SAUP (2010) also estimates the catch of each fishing country in the BOB, regardless of where the fish is caught. Myanmar is the top fishing nation with a total catch of 1.472 million tonnes in 2006. India was second, followed by Thailand and Bangladesh (Figure 4.1).

Figure 4.1 Catches by fishing nation in the Bay of Bengal, 2006.



Source: SAUP, 2010.

4.1.2 Catch and fleet characteristics

Catch profile

Fisheries in the BOBLME target a wide range of species, including sardines, anchovies, scads, shads, mackerels, snappers, emperors, groupers, congers, pike-eels, tunas, sharks, ornamental reef fish, shrimps, crabs, lobsters, octopus, gastropod and bivalve shellfish, sea cucumbers and seaweeds.

Almost 70 percent of the 2009 catch of the BOBLME in the FAO FishStat information system is not broken down to species or species groups – 42.8 percent is designated as "marine fish not elsewhere identified" (or "nei" based on International Standard Statistical Classification of Aquatic Animals and Plants). This standard divides commercial species into 50 groups on the basis of their taxonomic, ecological and economic characteristics. The imprecise nature of the data introduces considerable unreliability into any conclusions that may be drawn from them. However, it is apparent that pelagic fish make up a large proportion of the catch (Table 4.2). Of the properly defined species categories, "tunas, bonitos and billfishes"and "herrings, sardines, anchovies" are the most important, making up about 57 percent of the identified catch. (It is likely that a significant proportion of the tuna catch is taken outside the BOBLME proper, for example by Indonesian vessels fishing in the wider Indian Ocean.)

Table 4.2 Major species groups contributing to fishery production in BOBLME countries (percentage), 2009, based on international Standard Statistical Classification of Aquatic Animals and Plants.

	Indonesia[1]	Malaysia[1]	Thailand[1]	Myanmar[1]	Bangladesh[2]	India[1]	Sri Lanka[1]	Maldives[1]	BOBLME
Marine fish “nei”	15.9	29.7	38.5	98.07	17.0	15.0	4.5	11.8	28.8
Herrings, sardines, anchovies	16.0	1.8	8.9	–	–	16.2	23.5	–	13.3
Miscellaneous pelagic fishes	21.7	32.4	20.7	–	12.8	12.1	10.7	–	18.4
Miscellaneous demersal fishes	1.7	0.9	0.8	–	–	3.0	5.3	–	2.3
Miscellaneous coastal fishes	14.0	10.9	13.3	–	19.3	26.1	–	–	16.7
Shrimps, prawns	5.8	8.9	2.6	1.9	10.2	12.4	–	–	7.0
Squids, cuttlefish, octopus	1.7	5.4	6.2	–	–	1.1	0.2	–	2.9
Shads	0.2	1.7	–	–	39.4	1.5	–	–	10.7
Tunas, bonitos, billfish	15.2	3.3	4.7	–	–	5.2	50.2	87.7	27.7
Sharks, rays, chimaeras	2.0	1.0	0.9	–	0.8	4.0	–	0.4	1.5
Others	5.8	2.5	3.3	0.1	–	4.9	4.3	0.1	3.0

Source [1]: FAO FishStat, 2011.
Source [2]: Fisheries statistical year book of Bangladesh, 2010.

There are considerable differences between countries, both in terms of detailed reporting and in major groups caught. Countries closer to the open Indian Ocean, especially Sri Lanka and the Maldives, catch more tunas, bonitos and billfish, (Table 4.3). Hilsa shad (mainly *Tenualosa ilisha*) dominates the catch of Bangladesh and is the most important single species identified in the statistics; the species is probably also an important component of the catch in Myanmar. On the eastern coast of the LME (Indonesia, Malaysia and Thailand), Indian mackerels (mainly *Rastrelliger kanagurta*) and Indian scad (*Decapterus russelli*) are the most abundant species identified, while on the western coast (India, Sri Lanka and the Maldives), skipjack tuna (*Katsuwonus pelamis)* is the most important single species identified.

The Indian Ocean in general, and the BOBLME within it, differs from other oceans of the world in that production from artisanal, small-scale fisheries equals or exceeds that of industrial, large-scale fisheries. In Bangladesh, for example, less than five percent of marine landings are estimated to come from industrial fishing activities, with the remainder being produced by artisanal fishers (Hossain, 2003). In Thailand, although the quantity of fish caught by the small-scale sector is only about 15 percent of the catch, it is of much higher value than that landed by larger vessels, especially trawlers whose catch includes a high proportion of low value small or trash fish. The Maldives is an exception; the country has a modern fleet of relatively large pole-and-line tuna vessels.

A characteristic of artisanal fisheries in the BOBLME countries is the low volume of discards. Almost every part of the catch is consumed or used for animal feed. Fish constitutes a generally affordable source of protein in the BOBLME countries and most of the inshore catch is used for local or domestic consumption, contributing significantly to dietary health and food security, particularly in coastal areas.

Table 4.3 Major species and species groups contributing to fishery production in the eastern, middle and western BOBLME.

Eastern BOB		Middle BOB		Western BOB	
Marine fishes nei	577 425	Marine fishes nei	1 822 987	Marine fishes nei	320 029
Indian mackerels nei	176 410	Hilsa shad	200 100	Clupeoids nei	96 992
Indian scad	64 124	Marine crustaceans nei	53 206	Skipjack tuna	81 335
Threadfin breams nei	37 258	Bombay-duck	36 980	Penaeid prawns	62 277
Croakers, drums nei	35 619	Natantian decapods nei	33 000	Croakers, drums nei	62 110
Anchovies etc. nei	30 197	Sea catfishes nei	20 534	Sea catfishes nei	61 203
Sardinellas nei	30 120	Sharks, rays, skates, etc. nei	4 767	Sharks, rays, skates, etc. nei	57 655
Natantian decapods nei	29 321	Jellyfishes	2 410	Ponyfishes (=Slipmouths) nei	47 800
Torpedo scad	28 973	Seerfishes nei	1 559	Percoids nei	45 605
Sergestid shrimps nei	25 851	Indian threadfin	1 040	Yellowfin tuna	43 118

Source: FAO FishStat, 2010.

In 2010, the Sea Around Us Project made an effort to increase the range of species identified by extrapolating from countries where better statistics are available and also inferring catches from gear type used. According to data from the year 2000, medium-sized pelagic fish (39 to 89cm) were the dominant group in all countries, thereby supporting the findings of FAO FishStat[22].

Table 4.4 Best estimate of the number of fishing vessels operating in the BOBLME countries. Trawlers are included in the total.

	Year	Inboard	Outboard	Non-motorized	Total	Trawlers
Indonesia* [1]	**2008**	**30 320**	**14 900**	**24 895**	**70 115**	**-**
Malaysia [2]	**2008**	**7 865**	**10 027**	**98**	**19 998**	**3 098**
Thailand [3]	**2007**	**1 744**	**17 954**	**1 458**	**21 156**	**n/a**
Myanmar [4]	**2008**	**2 087**	**14 289**	**15 219**	**31 595**	**1 615**
Bangladesh [5]	**2006**	**21 433****		**22 527**	**43 236**	**141**
India[6]**	**2005**	**21 450**	**46 182**	**77 563**	**145 195**	**9 391**
Sri Lanka [5]	**2010*******	**4 525**	**21 450**	**20 165**	**46 138**	**n/a**
Maldives [5]	**2008**	**907**	**–**	**24**	**931**	**–**
Total		90 555	142 456	142 738	412 521	

* Indonesia statistics refer to FMA 571 plus 50 percent of FMA 572.

** Both inboard and outboard combined.

*** India classifies boats as (i) mechanised, (ii) motorized and (iii) non-motorized. For convenience, categories (i) and (ii) were re-classified as "inboard" and "outboard", respectively.

*** Both outboard and non-motorized combined.
**** MFARD, 2012 www.Fisheries.gov.lk

Source [1]: SEAFDEC, 2009. Source [2]: Abu Talib (pers. comm). Source [3]: Panjarat, 2008. Source [4]: Country update, BOBLME Project. Source [5]: FAO Country profiles, 2010. Source [6]: CMFRI, 2006.

[22] SAUP 2010 data sets contain an error after 2001 (which is currently being addressed) – the Indian production was incorrectly entered, distorting many extrapolations after this date.

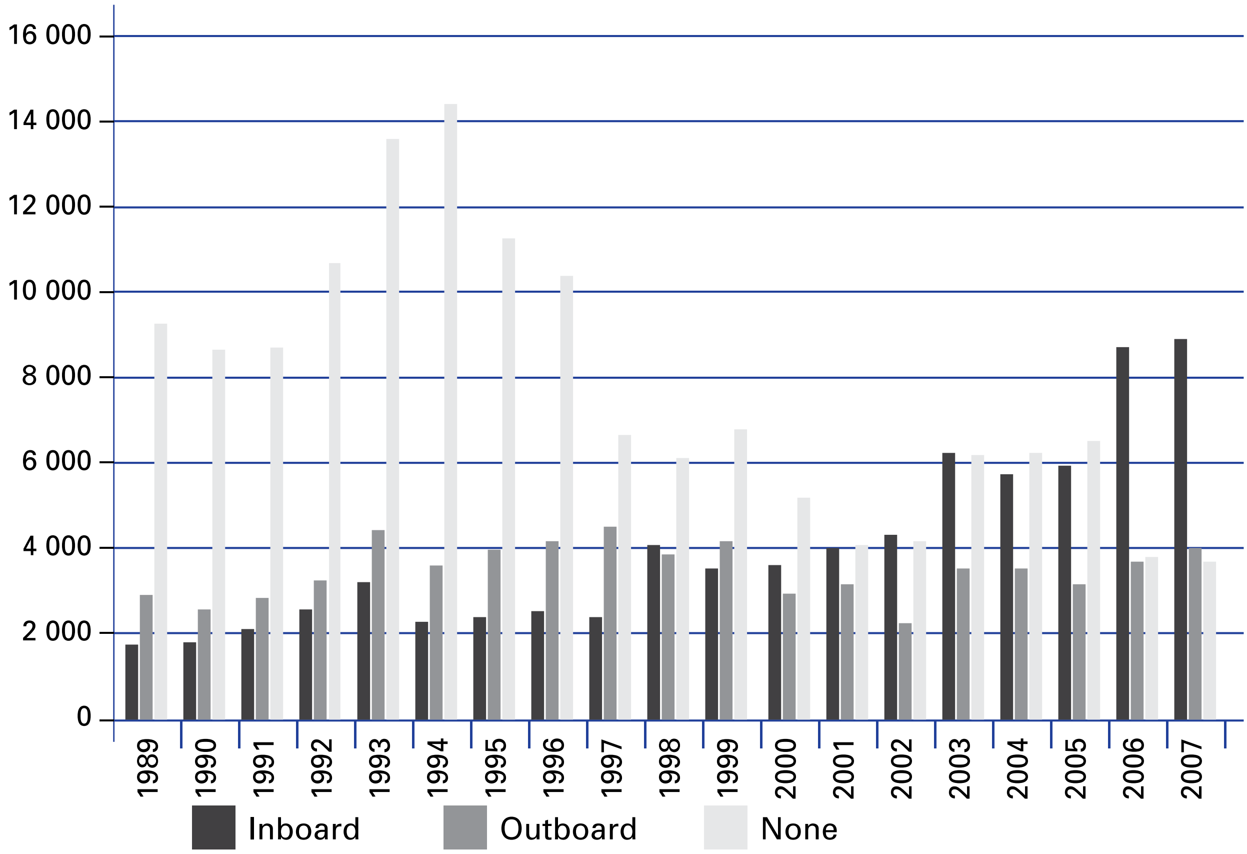
Fishing fleet profile

There are at least 377 000 fishing vessels operating in the BOBLME (Table 4.4). This is probably an underestimate because many countries only report registered vessels and many small vessels are unregistered. Of the 377 000 vessels, about 42 percent are non-motorized (for example, small-scale dugout canoes), and 32 percent are powered by outboard motors (including long-tail powered boats and modern outboards). Inboard driven fishing vessels range from <5 GRT to in excess of 200 GRT, although most are in smaller categories.

The fishing vessels in BOBLME countries are mostly small-scale in nature but there has been a significant increase in the number of various categories of trawlers targeting primarily shrimp and demersal fish by-catch, and purse seiners targeting pelagic fish. Some countries provide statistics on the catch by different fishing gear. Small-scale fisheries in the region use gill nets, trammel nets, purse-seines, beach seines, push-nets, various kinds of fixed nets and traps, troll lines, pole-and-line gear and longlines (not to mention dynamite and cyanide) to target a wide range of species. In Aceh, Indonesia, where trawling has been banned since 1980, the main gears used are gill nets and hook and lines, but some illegal trawling still occurs. In other BOBLME countries, a much larger portion of the catch comes from trawling and purse seining (for example, about 80 percent in West Coast Malaysia in 2006 [Anon, 2007] and 95 percent in the Andaman Sea, Thailand [SEAFDEC, 2009]. Again, the Maldives is an exception, with most of the country's catch coming from pole-and-line fishing for tuna, mainly skipjack.

Despite predictions to the contrary, and significant subsidies provided to support larger-scale activities, the importance of the region's small-scale fisheries has continued to increase in recent years and artisanal craft are ranging over progressively larger areas. Over time, the size and number of motorized vessels has increased, while that of non-motorized vessels has either declined or remained static. An example of this trend is given for the Province of Aceh in Indonesia (Figure 4.2).

Figure 4.2 Trends in the number of non-motorized vessels, vessels powered by outboard and inboard motors, Aceh Province, Indonesia 1998 to 2007.



4.1.3 Status of marine living resources – inshore

Increasing numbers of fishers and fishing vessels, their greater fishing capacity (including the widespread adoption of fish aggregating and attracting devices in concert with purse seines) have all contributed to a dramatic increase in fishing pressure on limited fishery resources.

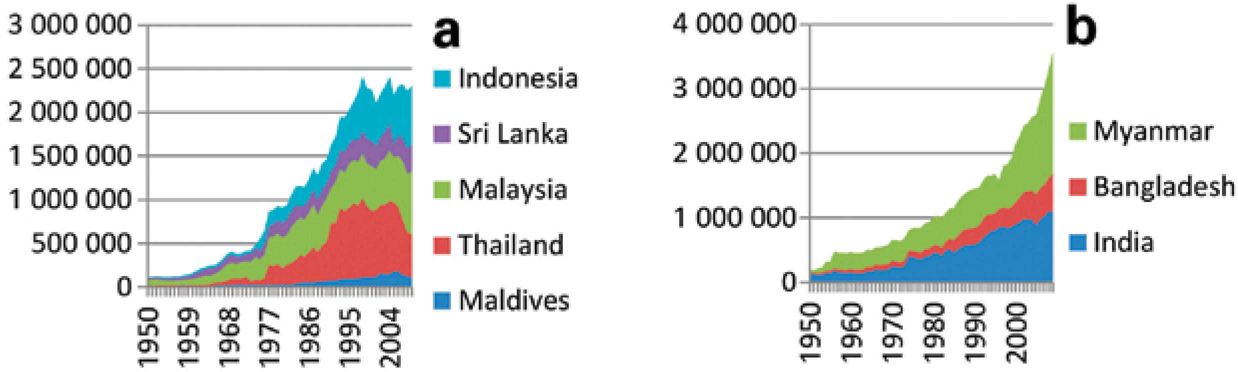
A number of indictors point towards overexploitation of marine living resources, especially in coastal inshore waters. These indicators include:

1. Stagnating production from marine waters in many of the BOBLME countries;
2. Changes in species composition and "fishing down the food chain";
3. Catches equal to, or greater than, estimated potential yields;
4. Assessments of exploitation of major fish groups and selected stocks;
5. Quantities of juvenile fish taken; and
6. Anecdotal information from fishers on catch and profit trends.

Stagnating catches in many BOBLME countries

The catch of marine fish in five of the eight BOBLME countries has either remained static or declined over the past decade (Figure 4.3a), although there are recent signs of renewed growth in Malaysia. The most obvious decline has been in Thailand's Andaman Sea where landings declined from 904 000 tonnes in 1998 to 489 360 tonnes in 2009. In Malaysia, catches levelled off as early as 1990 and remained static until 2007 when a slight increase was recorded. On the western side of the BOB, India's catch has shown a recent small increase, similar to that seen in Malaysia. Most of the tsunami affected countries (Indonesia, Thailand, India and Sri Lanka) showed a decreased catch in 2005 and a quick rebound to previous catch levels in 2006.

Figure 4.3 Catches of marine fish from BOBLME countries, 1950 to 2009.
a. All countries except India, Bangladesh and Myanmar. **b.** India, Bangladesh and Myanmar.



Source: FAO FishStat, 2011.

The exceptions to the stagnating trend require comment (Figure 4.3b). The increased catch taken on India's east coast seems to be associated with recent increases in the catch of small pelagic species, especially oil sardine. However, it is difficult to pinpoint a particular group because the recent improvements in Indian reporting systems, although excellent, make time series analyses difficult. As the level of detail of reporting has improved, so the proportion of miscellaneous and unidentified fish has decreased and the proportion of other species and species groups has increased, thereby masking any real increases or decreases in catch. The catch from the west coast of India has stagnated at around two million tonnes since 1994.

Both Bangladesh and Myanmar provide the least detailed statistics to FAO, so it is difficult to examine which fish are contributing to the increases. The increase in Myanmar is particularly spectacular, increasing from 681 000 tonnes to 1 864 800 tonnes over the last decade.

Harper *et al.*, (2011) recently provided a detailed description of the fisheries catches in the BOBLME, based on reconstructed catch data. Their analysis increased the total catch estimate by including previously unreported subsistence fisheries and IUU catches and discards for Myanmar and Sri Lanka. Unfortunately, the results are presented as the accumulated total catch from 2000 to 2006, and comparisons with previous estimates of the 2006 catch are not possible. The authors also note the large reported increase in catches by Myanmar, but found that inshore catches were declining, while total reconstructed catches have levelled off or are even beginning to decline. Their findings are in contrast to the reported data, which suggests continued growth in landings.

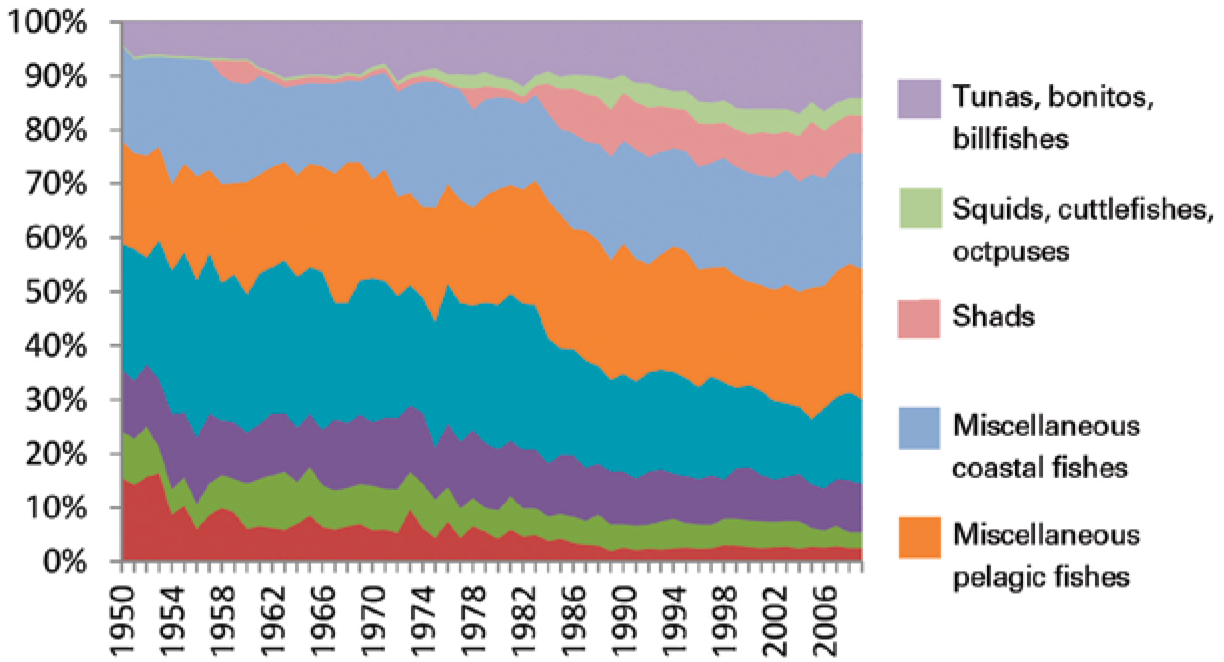
Changes in species composition and "fishing down the food chain"

Although difficult to detect from gross statistics where many species are grouped as "nei", all the evidence points towards considerable shifts in the species composition of landings from BOBLME countries. This is evident in Figure 4.4 that shows the changes in major ISCAAP groups (International Standard Statistical Classification of Aquatic Animals and Plants) over time. The proportion of demersal fish; sharks, rays and chimaeras; shrimps and prawns; and herrings, sardines and anchovies declined, while that of shads (mainly hilsa shad); squids, cuttlefish and octopuses; and tunas, bonitos and billfishes increased.

Along with these changes in catch, fishers have been fishing further away from their homeports and landing places. This is expressed as a "Fishing in Balance" ("FIB") index by SAUP (2010) and shows a steady increase throughout most of the BOBLME fishery (Figure 4.5). Interestingly, the index for the past five years has been relatively flat, suggesting that the trend may have ended.

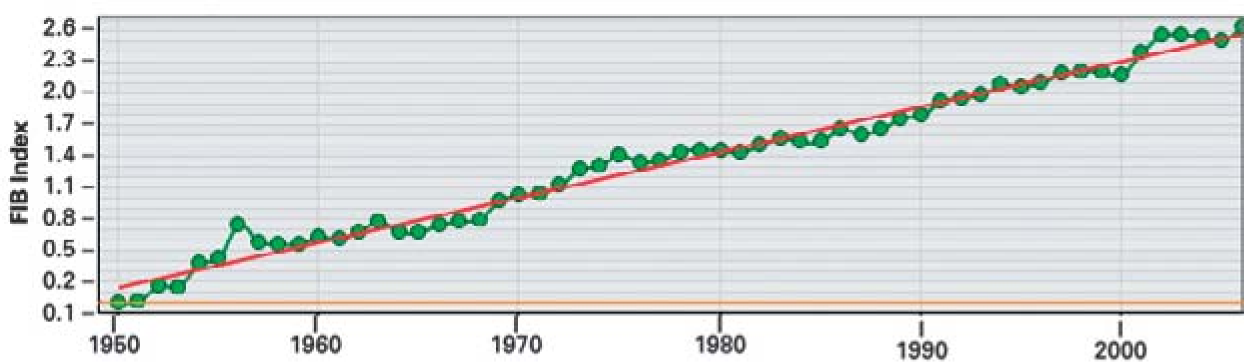
Changes in species composition are often associated with a change in the underlying ecosystem. When larger, longer-lived predators are removed (for example sharks and rays) the overall trophic level of the system declines as the proportion of prey species increases. SAUP (2010) demonstrates this trend by a decline in the mean trophic level for the BOBLME over the time span of the fishery (Figure 4.6).

Figure 4.4 Changes in the composition of landings from the BOBLME from 1950 to 2009.



Source: FAO FishStat, 2011.

Figure 4.5 FIB index that demonstrates the offshore expansion of the fisheries in the BOBLME.



Source: SAUP, 2010.

Figure 4.6 Changes in the mean trophic level of the BOBLME as calculated from changes in the species composition of catches, 1950 to 2006.

Source: SAUP, 2010.

Actual catches versus potential yield estimates

A comparison between actual yields and "potential yields" is commonly used to indicate the status of marine living resources in BOBLME countries. However, this comparison can be misleading because the potential yield is often calculated from different sources of data and often based on a number of assumptions that are not clearly identified or substantiated. For example, early "potential yields" were often based on research surveys where the biomass of fish was calculated from the swept area of the survey and extrapolated for the EEZ as a whole. The potential yield was estimated as a proportion of the biomass (often 0.5). More recently, acoustic surveys have been used to estimate pelagic biomass. Some BOBLME countries updated their "potential yield"estimates by modelling the trends in the catch and effort for major species and species groups and calculating the maximum sustainable yield (MSY) from production models. With the expansion of fishing grounds (as demonstrated in Figure 4.5), catches and catch rates can increase, but this does not necessarily indicate a change in the MSY. However, because this indicator is commonly used, an attempt was made to find the most recent estimate of the potential yield and compare that with past and current maximum catches (Table 4.5).

Across all BOBLME countries, the current yield exceeds the sum of the potential yields, indicating that the regional fishery is overexploited. Within this overall assessment, however, there are many country and species differences and it appears that some resources and areas may still have room for development (e.g. small pelagic resources off the coast of Sumatra). However, these are the exceptions rather than the rule. It is also difficult to see how certain target fisheries can be developed without adding to the problem of excess fishing effort and fishing capacity.

The outliers in the magnitude of the potential yield can also be seen. The potential yield/km^2 of the different EEZs averages 2.6 tonnes/km^2 with Bangladesh's estimate of 5.73 tonnes/km^2 lying well outside this average. This may indicate the difference in methods used to estimate potential yields, as described above. However, when these potential estimates are compared with the estimated primary production of the waters of each country, it is Indonesia that is an outlier, with a very high potential yield compared to its primary productivity.

Stock assessments

Some BOBLME countries, notably Malaysia and India, conduct routine stock assessments to guide fisheries management, while others, notably Myanmar, have very little information on the status of their stocks.

In 2011, the APFIC collated stock assessments at the species group level (e.g. large demersals, small pelagics) from scientists in each country. These show that a large number of the groups in the region are either overfished or fully fished, especially in eastern BOBLME countries (Table 4.6 and Figure 4.7). There is also a large number of groups that are scored as moderately fished (i.e. little room for development).

Underfished stocks are mainly confined to Bangladesh, but given the lack of assessments in that country, these claims are questionable. Both large and small demersal fish are overfished in the majority of areas where assessments have been carried out. The status of large and small pelagic stocks is more variable, with most recorded as overfished or fully fished, although some are still moderately fished. The stocks of anchovies and sardines are fully fished in the majority of assessed fisheries in the BOBLME.

Table 4.5 Estimates of the potential yield (PY) (1 000 tonnes), PY per area of EZZ (PY/km²), PY per unit of primary productivity (PY/mgC) and actual yield (both peak landings and 2008 estimates) and the difference between current landings and PY for BOBLME countries.

	Potential yields (PY)				Landings				
	Demersal	Pelagic	Others	Total	PY/ km²	PY/ mgC	Peak landing	Landings 2008	Difference
Indonesia[1]	235.4	1 067.8	29.7	1 332.9	2.72	2405	887.6	830.3	-502.6
Malaysia[2]	155.5	62.0		217.5	3.16	159	677.1	669.7	452.2
Thailand[3]	159.2	200.8		360.0	4.04	507	909.6	753.3	393.3
Myanmar[4]	800 000	550 000		1 050.0	2.02	1 117	1 679.0	1 679.0	629.0
Bangladesh*[5]			939.5	939.5	5.73	550		497.6	-441.9
India[6]	413.6	500.5	263.0	1 177.1	0.92	1 163	1 085.9	1 085.9	-91.1
Sri Lanka[7]	80.0	170.0		250	0.48	411	303.2	285.0	35.0
Total				5 327.0				5 800.8	

Source [1]: Duta (pers. comm.) Source [2]: Abu Talib (pers. comm.) Source [3]: Panjarat, 2008. Source [4]: FAO Country profiles, 2010. Source [5]: APFIC, 2011. Source [6]: GOI, 2000. Source [7]: Blindheim & Forn, 1980.

Surimi is becoming a more important product in the region and is based on catches of species that previously had little commercial value such as threadfin bream (*Nemipterus spp.*), big eye (*Priacanthus spp.*) and lizardfish (*Saurida spp.*). These species are assessed as overfished in Malaysia and the east coast of Sumatra and fully or moderately fished in India and the west coast of Sumatra. The stocks of crustaceans are scored as fully fished in the majority of the assessed fisheries, whereas squids/cuttlefish are fully fished in some areas and moderately fished in others. Interestingly, scientists assess small low value/trash fish as overfished in waters <40m in Bangladesh and fully to overexploited in Indonesian waters (Table 4.6).

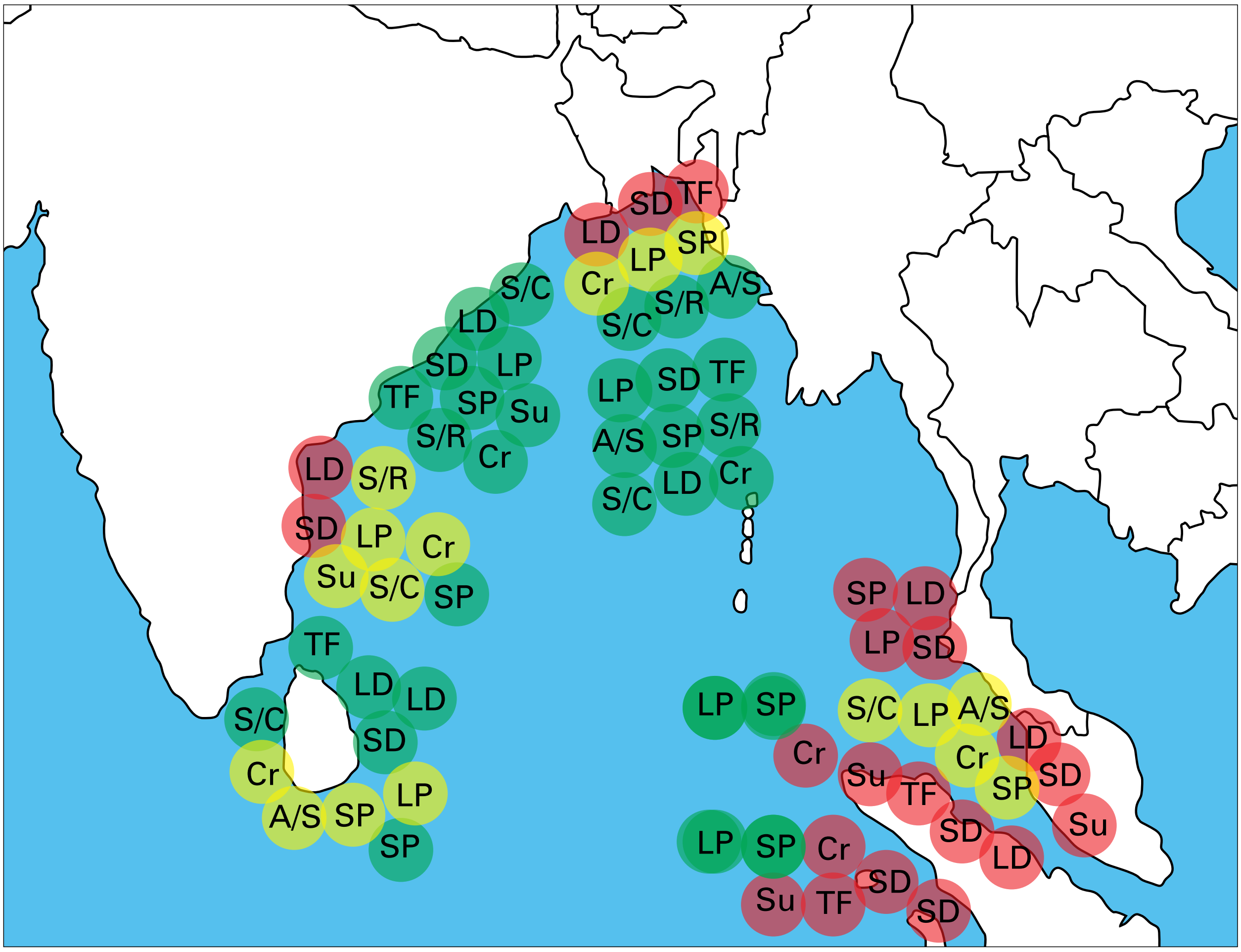
Table 4.6 Fishery/stock assessments for the assessed Bay of Bengal fisheries areas: Depleted (**D**); Overfished (**O**); Fully (**F**), Moderately (**M**); Underfished denotes no data available (**U**). Several values indicate range of reported values (e.g. several sub-areas).

	Indonesia		Malaysia	Thailand	Bangladesh		India		Sri Lanka	
	FMA 571	FMA 572			Inshore	Offshore	SE	NE	South	North
Large demersal	F/O	F/O	O	O	O	F	O/F	M	M	U
Small demersal	F/O	F/O	O	O	O	M	O	M	M	M
Large pelagic	M	M	F	O	F	U	F	M	F	F
Small pelagic	M	M	F	O	F	M	M	M	F	M
Anchovy/Sardine			F		M	U			F	F
Trash fish /low value fish	F/O	F/O			O	U	nd	M	M	M
Surimi species	F/O	F/O	O				F	M		
Shark/rays					M	U	F	M		
Squids/cuttlefish			F		U	U	F	M	M	M
Crustaceans	F/O	F/O	F		F	M	F	M	F	F

Note: This table presents indicative status for species groupings. Terminologies for level of exploitation vary between countries as do the methods of assessment, date of last assessment and the geographic scope of those assessments.
Source: APFIC, 2011.

Figure 4.7 Indicative fishery/stock assessments for the assessed fisheries areas.

Green = underfished **yellow = fully fished** **red = overfished**



Source: APFIC, 2011.

LD	Large demersals	**TF**	Trash fish/low value fish	Depleted/overfished
SD	Small demersals	**Su**	*Surimi* species	
LP	Large pelagics	**S/R**	Sharks/rays	Fully fished
SP	Small pelagics	**S/C**	Squid/cuttlefish	Moderately/underfished
A/S	Anchovy/sardine	**Cr**	Crustaceans	

Trawl surveys

India, Malaysia and Thailand (Andaman Sea and Gulf of Thailand) undertake regular surveys with dedicated research vessels. In Thailand (Andaman Sea), trawl surveys have been conducted since 1966. The catch rate declined steadily between 1966 and 1972 (Figure 4.8), indicating an early decline in the abundance of demersal fish during a period of heavy fishing pressure. This coincided with the introduction of trawling to Thailand from the Philippines by a joint Thai-German government initiative in the early 1960s. Parallel industrial-scale developments were also initiated at this time, most notably in Indonesia and the Malay Peninsula.

In Malaysia, the average catch rate in the coastal zone of the northern area of the west coast decreased from 74.5 kg/hr in 1971-72 to only 22.7 kg/hr in 1991. This was followed by a further decrease to 18.6 kg/hr in 1997, a reduction of 75 percent. Further south, the average catch rate of 67.2 kg/hr in 1971-72 decreased to 21.0 kg/hr by 1991 – a reduction of 69 percent (Abu Talib *et al*., 2003).

India began to conduct fisheries surveys in 1946 and currently several vessels are deployed for the purpose of undertaking regular surveys along the east coast. Unfortunately, no long-term time series has been compiled, but such records would no doubt provide very interesting perspectives on the status of marine resources in India.

Table 4.7 Percentage juveniles caught in a survey of commercial trawlers, purse seiners and ring seiners in Mangalore-Malpe, Orissa, India 2005.

Trawlers	Total catch kg	Juvenile catch kg	Percent
Hairtails	11 970 434	5 314 873	44.4
Groupers	4 641 669	3 717 683	80.1
Threadfin bream	11 44 722	915 777	80.0
Tongue sole	1 340 807	474 109	35.4
Herring, scads and hilsa	625 265	393 492	62.9
Oil sardine	717 544	171 493	23.9
Lizard fishes	206 967	82 787	40.0
Drums and croakers	239 892	81 329	33.9
Pony fishes	103 207	35 489	34.4
False trevally	1 108 998	26 815	2.4
Mackerel	58 212	19 431	33.4
Anchovy	667	217	32.5
	22 158 384	**11 233 495**	**50.7**
Purse seiners			
Oil sardine	4 617 881	2 664 517	57.7
Torpedo scad	1 161 987	730 890	62.9
	5 779 868	**3 395 407**	**58.8**
Ring seiners			
Oil sardine	957 643	316 980	33.1
Indian mackerel	8 330	1166	14.0
	965 973	**318 146**	**32.9**

Source: CMFRI, 2006.

High proportion of juvenile fish

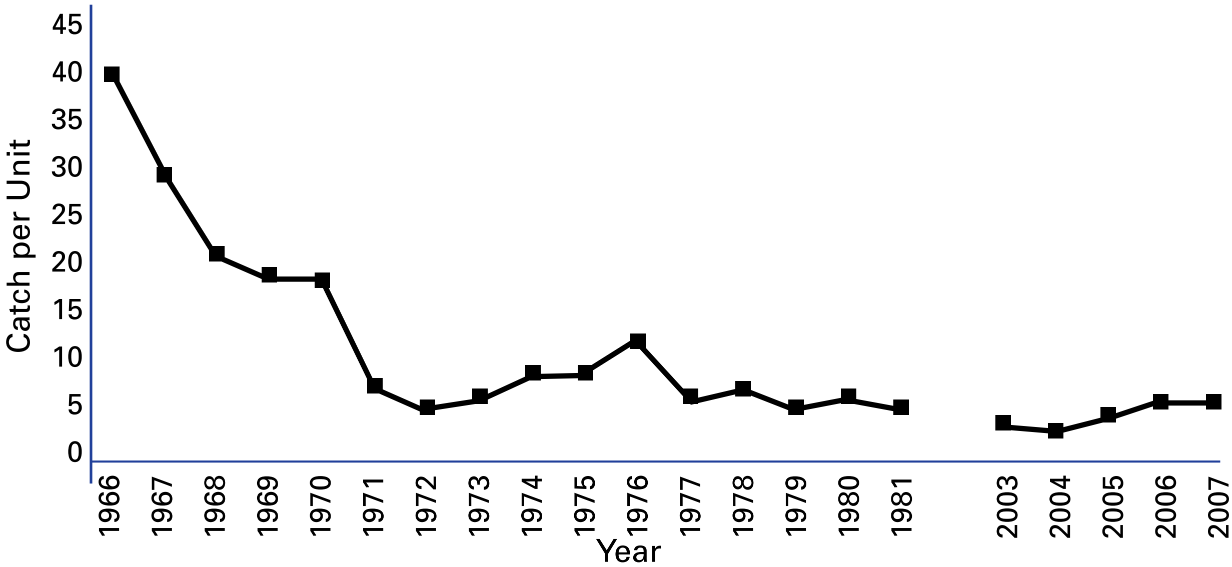
In many fisheries of the region, there is little control over the mesh size of fishing nets and the proportion of juvenile fish in the catch is generally very high. Juveniles of more highly-priced fish species would fetch much higher prices in the market if they were allowed to grow before they were caught. The catch of low value/trash fish taken mainly by trawlers in the BOBLME consists of an assortment of juveniles of commercial and non-commercial fish species; and small, more productive fish species. In Thailand, between 18 and 32 percent of low value/trash fish are actually juveniles of commercially important fish species. Between 1995 and 1999, low value/trash fish production in the trawl fisheries comprised at least 35 species, nine of which were small species; the remaining 26 species were juveniles of high value fish (nine pelagic species and 17 demersal species). Other aquatic species such as cuttlefish, shrimp (including sergestid shrimp) and crab are also taken. In the push net fisheries, 14 species of low value/trash fish were caught – three species of small fish and 11 species of juvenile fish of high value species (five pelagic species and six demersal species). See Kaewnern and Wangvoralak, 2004. Large volumes of low value/trash fish are taken in Thailand, Malaysia, India, Bangladesh, and presumably Myanmar.

In India, detailed studies have been carried out on the catch of trawlers discharging fish in Mangalore-Malpe (CMFRI, 2006 and Table 4.7). Over 50 percent of the trawl catch, nearly 60 percent of the purse seine catch, and over 30 percent of the fish taken by ring seines were juvenile fish.

Quite apart from demersal trawling, other types of fishing gears are also non-selective. In Bangladesh, for example, bag net fisheries trap a large number of juvenile fish on the tidal flows of estuaries (Mazid and Rahman, 2005). Lift net fishing gear, which is used in Indonesia, also catches large numbers of juvenile fish, especially the mobile lift net that can be operated from a fishing vessel (Purnomohadi, 2003).

No detailed analyses of the impact that non-selective fishing is having on the resources – either in terms of growth overfishing that is affecting the economics of the fisheries, nor recruitment overfishing that is damaging to the stocks – has been undertaken in the BOBLME. However, based on studies elsewhere, killing fish before they have a chance to breed is very detrimental.

Table 4.8 Catch rate (kg/hr) of the total fish taken in the standard bottom trawl of the research vessel in the Andaman Sea from 1966 to 1981 and 2003 to 2007.



Source: Praulai Nootmorn, pers. comm.

Anecdotal evidence from fishers

Fishers consistently report that catches, catch rates and profits are declining; that they must travel increasingly greater distances to fill up their boats; and that there is a need to adopt more effective and destructive gears such as ring seines. These trends have been accompanied by a diversification of fishing effort to focus on low value species; migration of fishers from their homes to other places to fish (e.g. fishers from Andhra Pradesh migrating seasonally to Gujarat in India); and increasing dependence on cheap foreign labour for fishing crews, as happens in Thailand, for example. Along many coastlines and in many ports, one may observe idle boats and idle fishing crews, the deteriorating state of the vessels and the scrapping of some boats.

There is also increased competition for fish by buyers, especially at landing sites, and increased conflicts between the different vessel and gear types.

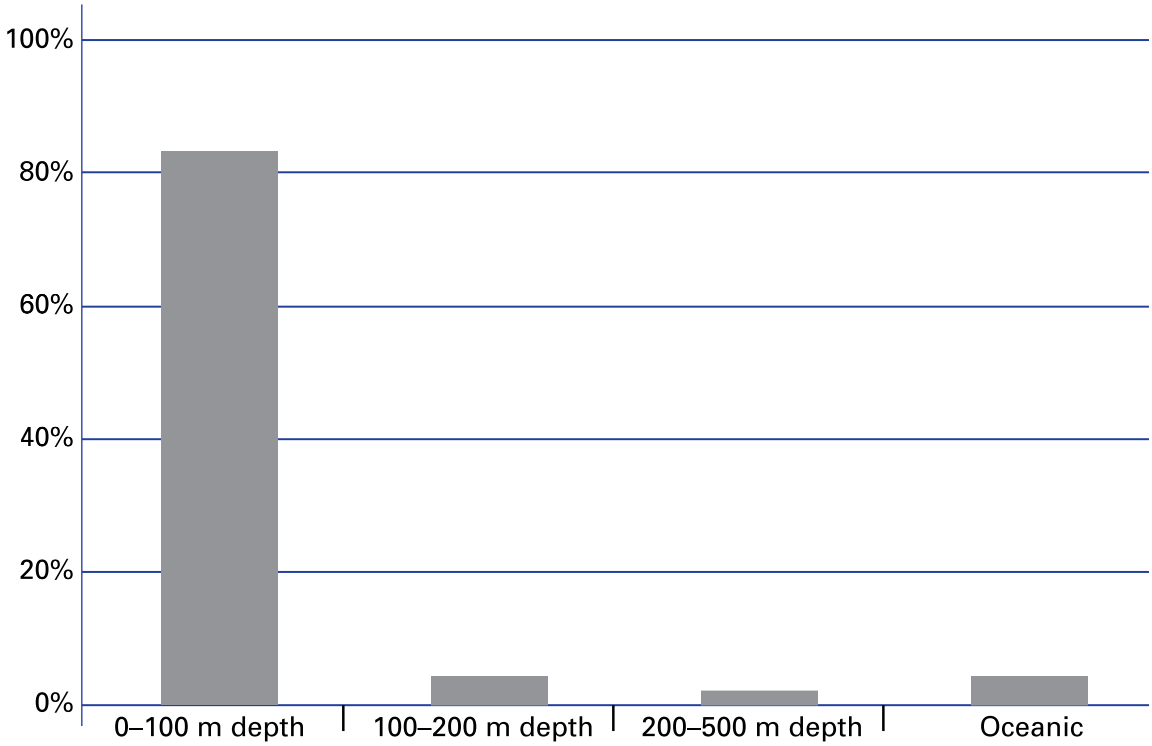
4.1.4 Status of marine living resources – offshore

Most BOBLME countries have policies to promote and expand fishing in offshore areas (APFIC, 2009). The main policy drivers for this development are (i) overfishing in inshore areas; (ii) attempting to realize the potential of offshore fishing (iii); building up catch history records in preparation for negotiations at regional fisheries management organizations (RFMOs); and (iv) ensuring full utilization so that other nations cannot fish under the provisions of the UN Convention on the Law of the Sea (UNCLOS). Governments are providing a number of incentives to facilitate this move.

Catches for the high seas area of the BOBLME were published by Harper *et al.*, in 2011. Taxon-specific landings were dominated by skipjack tuna (*Katsuwonus pelamis*), representing approximately five percent of total high seas landings and USD753 million of landed value. Landings from the high seas were dominated by fleets from countries bordering the Bay of Bengal, with Malaysia, Thailand, Indonesia and Sri Lanka representing 32, 26, 22 and ten percent of total high seas landings, respectively. The landed value was highest for Malaysia (USD1.7 billion). According to the present tax-on-gear associations used, landings were mainly from gillnet (74 percent by weight, USD2.7 billion by value) and tuna longline gears (10 percent by weight, USD2 billion by value).

While it is known that there are resources that could be exploited in the offshore waters of the BOBLME – including tunas, small pelagic resources, oceanic squid and some economically important demersal species, such as snapper, grouper and deep-sea shrimp – the extent of the potential remains unknown. However, indications are that these resources are limited (APFIC, 2009). This is consistent with the low productivity of the offshore waters described in Section 2.2.

Figure 4.9 Gradient of distribution of resources in the EEZ (percentage of potential yield estimates). Oceanic = tunas and tuna-like species.



Source: GOI, 2011.

Figure 4.9 shows the gradient of distribution of resources in the Indian EEZ.

There is some concern that, if not managed effectively, the policy to move offshore could be detrimental to the overall fisheries resources of the BOBLME and increase fishing capacity even further. If the potential has been overestimated, and the costs of fishing in offshore areas are too high relative to the revenue gained, vessels could return to inshore areas and increase fishing pressure even further.

APFIC (2009) advises that a precautionary approach should be adopted when considering the development of these fisheries. The number of vessels should be built up slowly as more information and data from the fishery and from research activities become available. The fishery development should be carefully monitored and the status of offshore fisheries, at national and regional levels, should be reviewed regularly, preferably annually.

Table 4.9 Status of highly migratory tuna in the Indian Ocean.

Species	Status	Comment
Albacore	Overfished	Catches > MSY
Bigeye tuna	Fully fished	Catches ~ MSY
Skipjack tuna	Uncertain	Recent low catches in some locations e.g. Maldives
Yellowfin tuna	Fully fished	Catches ~ MSY
Swordfish	Overfished in western IO	
Other billfish and tunas	Uncertain	

Source: IOTC, 2011.

Oceanic tuna are already heavily fished in both the Pacific and the Indian Ocean. Large, migratory tuna need to be assessed at the regional level because assessments at the country or province/state level do not allow for movement and migrations and may give erroneous estimates of potential yield. The Indian Ocean Tuna Commission (IOTC) provides regular status reports based on national inputs. In 2011, the Scientific Committee of IOTC assessed that albacore was overfished, yellowfin tuna and bigeye tuna were fully fished, and skipjack tuna were showing signs of possible overfishing in some areas (IOTC, 2011 and Table 4.9). There are no quantitative assessments for billfish or coastal tunas.

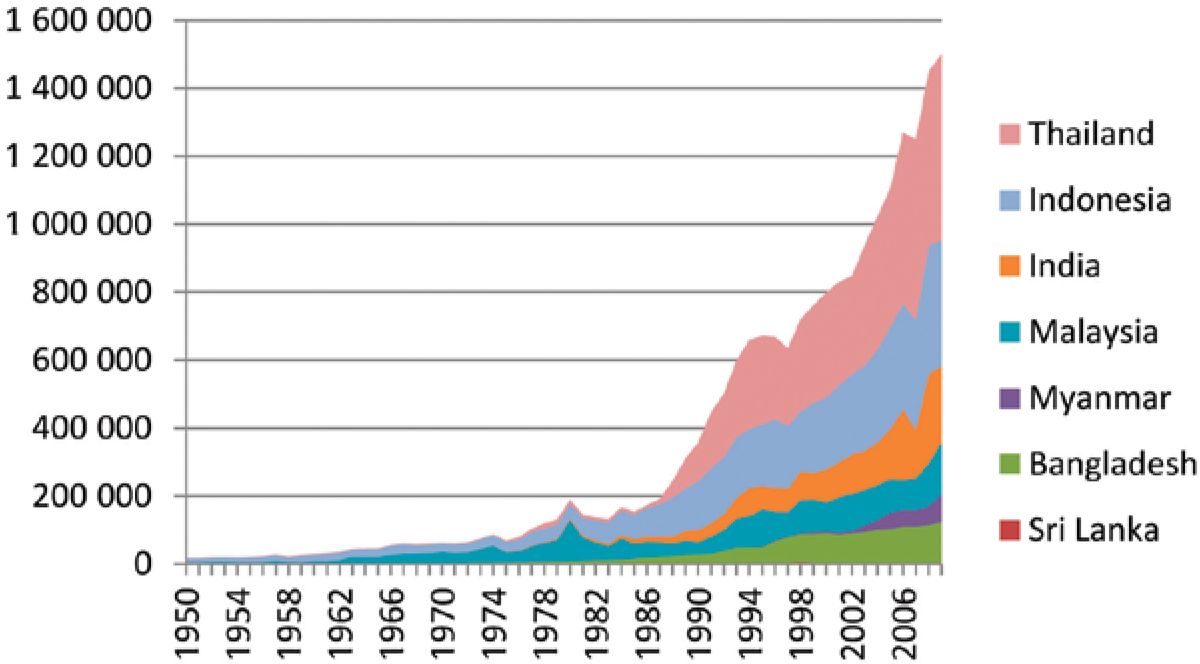
4.1.5 Status of coastal aquaculture

Shrimp farming has been practiced by the coastal people of certain Asian countries, such as Indonesia and Thailand, for more than a century. The giant tiger prawn was originally harvested with other shrimp species from traditional trapping-growing ponds, or as a significant by-product of extensive milkfish ponds. Following on from research into breeding in Taiwan Province of China (POC), extensive and semi-intensive farms were established on a commercial scale in Thailand in the early 1970s. This occurred, after the first successful breeding of giant tiger prawns took place at Phuket Fisheries Station in 1972. Taiwan POC was the leading producer of giant tiger prawns for several years, but after a viral disease wiped out the industry there, Thailand – encouraged by extremely high prices in the Japanese market – became the world's leading producer of farm-raised giant tiger prawns in 1988. Later, the culture of this species, which grows to a large size and is highly valued in the international market, spread throughout southeast and south Asia.

Commercial aquaculture started rather slowly in the BOBLME region in the 1970s and 1980s, but took off rapidly in the 1990s and early 2000s (Figure 4.10). The largest production for the region as a whole was recorded in 2008. In 2009, the estimated total marine and brackish water aquaculture production was 1.46 million tonnes valued at USD4.8 million (about 25 percent of capture fisheries production).

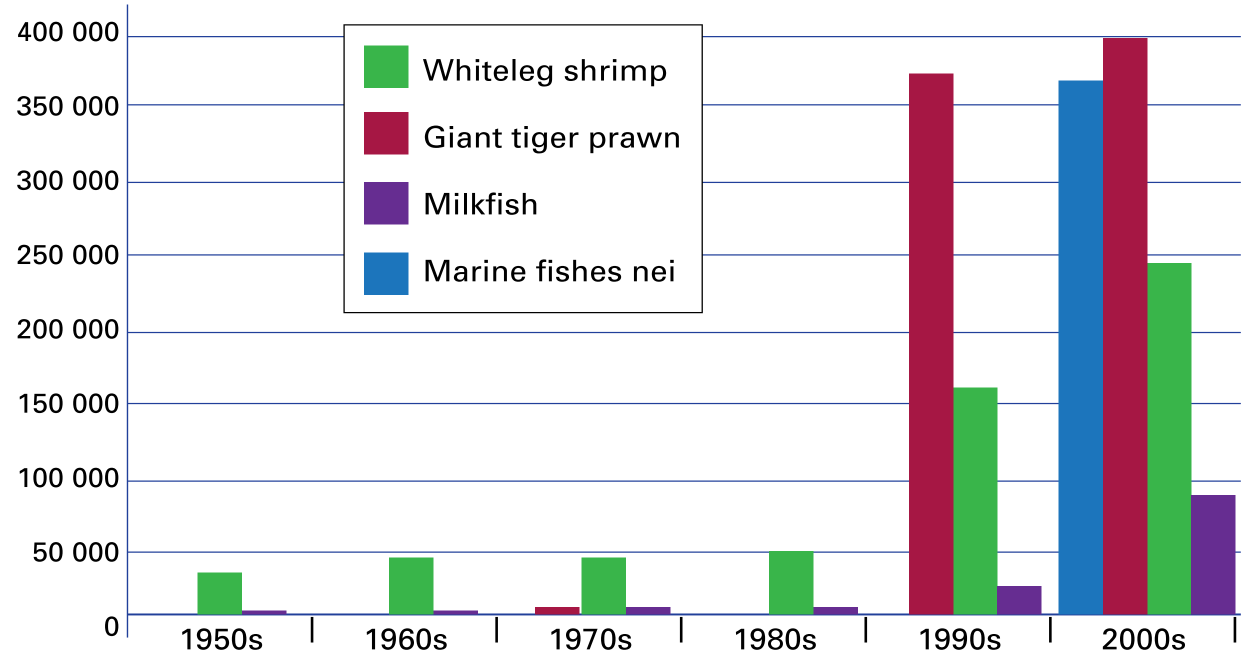
Myanmar, Thailand and Indonesia have all experienced rapid growth in aquaculture production, with the greatest growth recorded by Myanmar which increased production from 5 000 tonnes in 2000 to 81 000 tonnes in 2009. India, Bangladesh and Malaysia have all shown a steady overall increase in production, while in Sri Lanka output peaked in 1998 and has since declined. The decades from 1950 to 1980 were dominated by milkfish culture, especially in Indonesia (Figure 4.11), and extensive prawn culture based on wild-caught seed.

Figure 4.10 Trends in brackish water and marine aquaculture production in the BOBLME, 1950 to 2009.



Source: FAO FishStat, 2011.

Figure 4.11 Changes in the major species cultured in BOBLME countries.



Source: FAO FishStat, 2011.

The 1990s saw the introduction of giant tiger prawns, while in the 2000s it was the culture of whiteleg shrimp that had an enormous impact on aquaculture production. Whiteleg shrimp culture began in Thailand in 2002 and in Indonesia in 2004. The species was introduced (both legally and illegally) from South America because it was found to be highly resistant to disease. In Thailand, whiteleg shrimp is now the major aquaculture product – 535 000 tonnes were produced in 2009. Blood cockles have been a major crop of Malaysia and are still dominant, although there has been a major shift to banana prawns in recent years. Fish culture is still relatively small but is becoming increasingly important in Thailand, Malaysia and India.

Aquatic diseases have plagued the aquaculture industries of most countries in the BOBLME for the past 20 years. Successive waves of fish and shrimp viruses, e.g. white spot syndrome virus (WSSV); viral nervous necrosis virus (VNNV); and more recently infectious myonecrosis virus (IMNV); have caused varying degrees of economic impact. It is well known that the transboundary spread of infectious diseases is aided by the trade in live animals and, as a consequence, the pathogen broadens its host range to new species (Rodgers *et al.*, 2011). As the aquaculture industry continues to expand and globalize, the transfer and movement of aquatic animals will become more difficult to control.

The movement of live shrimps by the aquaculture industry presents the greatest risk to the BOBLME countries; if shrimps carry pathogens, the potential for these pathogens to spread to wild stocks and establish themselves in endemic species is high. However, there is no evidence that disease will cause significant losses to the natural fishery; natural carriers are a perpetual threat to aquaculture because diseases cause intermittent mortalities, slow growth or increased operational costs as a result of prevention or treatment regimes. Generally, crustaceans that recover from a disease remain infected, often for life without showing any gross signs of disease. Therefore, their transboundary movement might eventually cause havoc in the shrimp farming industry because once infection is transferred, it might become established.

The continuous importation of certified and non-certified SPF (Specific Pathogen Free) stocks (e.g. whiteleg shrimp) is also a concern because asymptomatic shrimps might carry pathogens that can facilitate the spread of disease among and between the countries of the BOBLME. Coupled to this is the problem of misdiagnosis of diseases or pathogens which presents a risk to trading activities between disease-free and disease-affected BOBLME countries. Misdiagnosis may result in ineffective treatment procedures and aquatic animal health management which can compromise the health status of the cultured animals.

4.1.6 Key marine species

Sharks

Sharks are either targeted by commercial and artisanal fisheries, or caught as bycatch, in all BOBLME countries. Many of the larger species are slow growing, reaching sexual maturity after a number of years, and produce relatively few offspring. There is widespread concern among biologists and fisheries managers that the shark resource is easily overfished; many species are already considered to be threatened. In response to global concerns about the conservation status of sharks, member countries of the FAO adopted an International Plan of Action (IPOA) in 1999. The objective of the IPOA is to ensure the conservation and management of sharks and their long-term sustainable use. Part of the IPOA was a request for countries to develop National Plans (NPOAs) and Regional Plans, where appropriate. This has been achieved by Malaysia and Indonesia and a draft NPOA has been developed by Thailand. To assist the countries to develop these plans, the Bay of Bengal Intergovernmental Organisation (BOBP-IGO) organised two Regional Consultations on the Preparation of a Management Plan for Shark Fisheries; the most recent taking place in the Maldives in August 2009. At this meeting, the Maldives, Sri Lanka, India and Bangladesh all proposed a “road map” for completing national plans. A draft regional Plan of Action was also discussed.

Detailed statistics on shark catches are poor in the BOBLME countries. No data are available for Myanmar but the total catch of all sharks recorded for the other seven countries in 2008 was 100 031 tonnes. Peak catches of around 120 000 tonnes occurred in the late 1990s and early 2000s. Species details are only available for Indonesia; records have been kept in that country since 2005.

Despite the fact that three of the BOBLME countries are among the world’s largest shark fishing nations, management of shark fisheries within the region is almost non-existent. Most countries have regulations pertaining to general fishing (e.g. registration of vessels), but have no specific regulations for elasmobranchs, or elasmobranch fisheries. The exceptions are India, Myanmar and the Maldives. Nine species of sharks and rays, including the whale shark *Rhincodon typus*, are protected in India and the landing of these species is banned. Myanmar established shark protected areas in 2004 and reportedly also protects the whale shark from fishing and trading. The Maldives restricts exports of sharks, bans the export of ray products, has established protected areas and specifically protects the whale shark. In 2010, the country introduced a total ban on shark fishing.

While many exploited shark species move across national boundaries, there are no mechanisms in place for joint management of stocks. The IOTC has agreed to act as a regional data repository for oceanic shark catch data; however, this relies on national authorities to submit the data and at the moment this is not taking place as it should be.

Hilsa

Hilsa shad has been chosen by the BOBLME Project as a key species because of its importance to the eastern countries (it is the national fish of Bangladesh), and because hilsa is a single stock that is probably shared by India, Bangladesh and Myanmar.

Annual hilsa landings in Bangladesh ranged between 144 000 and 290 000 tonnes – with an average of 211 000 tonnes – between 1983-84 and 2007-08. The average landings from inland and marine sectors were 79 152 and 131 371 tonnes during this period. Total hilsa landings from Bangladesh’s waters did not decrease over this period and production increased substantially in recent years as a result of the adoption of different management interventions after 2003. In the past two decades, hilsa production from inland waters declined by about 12 percent, with an almost two-fold increase in production from the marine sector. There has been an approximate four-fold increase in the number of marine fishing boats and gears since 1984-85, resulting in tremendous fishing pressure in the marine sector. In addition, the intensity of marine catches increased following the introduction of nylon twine and mechanized boats. In India, the marine catch of hilsa is around 35 000 tonnes per year. The marine catch of Myanmar has increased significantly in recent years, but data are lacking.

The BOBP-IGO is assisting BOBLME countries with the management of hilsa and held a regional consultation on preparation of a management plan for hilsa fisheries in February 2010. Moreover, scientists have undertaken several stock assessments of hilsa in Bangladesh’s waters. Their findings are based on the analysis of large samples of fish length frequencies. Although only one of these analyses adjusted the data for net selectivity, they all point to the hilsa population in Bangladesh being overexploited and suggest that fishing mortality needs to be reduced by at least ten percent if the overall objective is to maximize biological yield; or be reduced to as little as 33 percent of the existing levels if the objective is to maximize economic yield (Mome and Arnason, 2007).

However, none of these stock assessments have led to a change in the Department of Fisheries' policies, or to improved management of fishing effort in Bangladesh. Further assessments and the expansion of the current approach of restricting catches during critical spawning periods, and spatial closures for juvenile fish (*jatka*), are required. In India, there is currently no control on fishing effort. Nets with a small mesh size are widely used to catch *jatka* and similar-sized juveniles of many species. Limited studies on Indian hilsa stocks suggest they are overexploited. India has proposed a management plan that outlines a number of very valuable management actions, but many of the timelines advocated in the proposed management plan have already lapsed.

There is very little information on the hilsa fishery in Myanmar and there appear to have been no scientific studies of hilsa in that country. Therefore, the knowledge base and technical resources required to manage the fishery in Myanmar are probably less available than they are in other BOBLME countries.

Indian mackerel

Indian mackerel (mainly *Rastrelliger kanagurta*) occurs along the coast of all BOBLME countries. However, detailed catch data are not available for Myanmar or Bangladesh. Catches are usually recorded as *Rastrelliger spp.* and combined with *R. brachysoma*. Total landings of *Rastrelliger spp.* for the BOBLME countries – excluding Myanmar and Bangladesh – were 195 000 tonnes, while catches reported separately as *R. kanagurta* were 45 500 tonnes in 2008. The largest catches were taken by Malaysia and Thailand (FAO FishStat, 2010). The Sea Around Us Project (2010) estimated that in 2006, the catch of *R. kanagurta* was 71 800 tonnes and that of mackerels other than *R. kanagurta* was 129 200 tonnes (total of 231 000 tonnes).

Little is known about the current status of Indian mackerel. One study carried out in India (Noble *et al*., 1992) indicated that *R. kanagurta* was overexploited on the east coast in the late 1980s, and recommended a reduction of fishing effort of 38 percent. However, Joseph and Jayaprakash (2003), concluded that for the east coast of India, the problem was not as severe as for the west coast, where large numbers of juveniles are taken indiscriminately by large seine gear. In the Java Sea (to the south of the BOBLME), Cardinale *et al.,* (2009) assessed that the biomass of Indian mackerel had been reduced to levels of between three and 19 percent of the maximum observed biomass in the 1990s.

4.1.7 Biodiversity, endangered and vulnerable species

Marine ecosystems across the globe are experiencing declining biodiversity, with largely unknown consequences. Recent studies have suggested that these declines are increasingly impairing the ocean's capacity to provide food, maintain water quality and recover from perturbations (Worm *et al*., 2006). Tropical oceans typically enjoy high diversity and it is this characteristic that has allowed these ecosystems to provide more services with less variability than more temperate systems in the past.

The global and regional importance of the rich coastal and marine genetic, species, ecosystem and process biodiversity of the BOBLME is well recognized (see, for example Kelleher *et al*., 1995). Table 4.10 shows the wide range of species that contribute to the biodiversity of the BOBLME and which are currently at risk. (Note that this is not an exhaustive list).

The list of species recently declared to be extinct in the Sunderbans includes mammals, birds and reptiles (Hossain, 2003). That list is unlikely to be exhaustive because knowledge of the full extent of diversity in the Sunderbans is poor.

4.1.8 Restoration of marine living resources

If resources are managed better, the fisheries sector has the potential to contribute much more to the BOBLME economy, especially to pro-poor growth and improved livelihoods. Fisheries currently trap millions of people into a downward spiral of low profits, few assets, marginalization, increased poverty, poor health and a lack of any viable alternatives.

However, current policies and management objectives frequently focus on increasing production. Rather than improving the situation, these objectives are often the main cause of the poor state of the sector. A paradigm shift towards increasing the social and economic benefits of fishing, especially pro-poor growth, is needed.

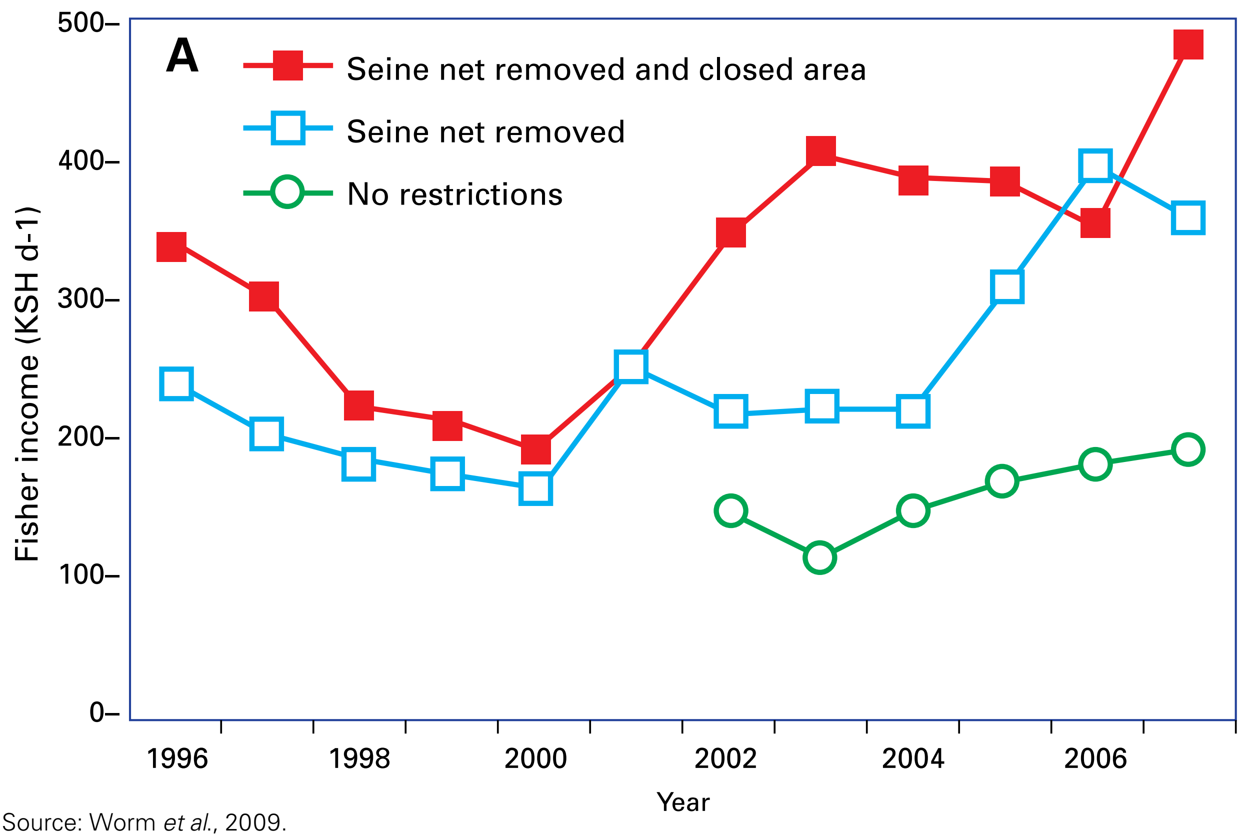
Table 4.10 Examples of threatened or endangered species in the BOBLME.

	Common name	Scientific name
Fish	Horseshoe crab	*Tachypleus gigas*
	Whale shark	*Rhincodon typus*
	Marine catfish	*genus Tachysurus* and *genus Osteogrenousus*
	White fish	*Lactarius lactarius*
	Flat head	*Platycephalus maculipinna*
	Threadfin	*Polynemus indicus and P. heptadactylus,*
	Sciaenid	*Pseudosciaena diaqcanthus* and *Otolithoides brunneus,*
	Perch	*Pomadasys hasta*
	Eel	*Muraenosox spp.*
	Seahorse	*Hippocampus spp*
	Bêche-de-mer	*Holothuria scabra*
Molluscs		*Xancus pyrum, Cypraea talpa, C. serpentis, Pinctada fucata, Chicoreus ramosus, C. virgineus, Conus amadis, C. textile, Strombus canarium, Murex adustus, M. haustellum, Velluta lapponica*
Marine worm	Enteropneust	*Ptychodera flava (Balanoglossus)*
Mammals	Dugong	*Dugong dugon*
	Gangetic dolphin	*Platanista gangetica*
	Irrawaddy dolphin	*Orcaella brevirostris*
	Finless porpoise	*Neophocaena phocaenoides*
	Royal Bengal tiger	*Panthera tigris*
	Fishing cat	*Felis viverrina*
	Jungle cat	*Felis chaus*
Reptiles	Loggerhead turtle	*Caretta caretta*
	Green turtle	*Chelonia mydas*
	Leatherback turtle	*Dermochelys coriacea*
	Hawksbill turtle	*Eretmochelys imbricata*
	Olive ridley turtle	*Lepidochelys olivacea*
	River terrapin	*Batagur baska*
	Estuarine crocodile	*Crocodilus porosus*
	Marsh crocodile	*Crocodilus palustris*
	Water monitor	*lizard Varanus salvator*
Birds	Oceanic teal	*Anas gibberfrons albogularis*
Mangroves		*Sonneratia caseolaris, S. apetala, Avicennia marina, A. officialis, Suaeda maritima, S. monoica, Rhizophora apiculata, R. annamalayana, Bruguiera cylindrica, Ceriops decandra, Aegiceros corniculatum, Acanthus ilicifolius, Lumnitzera racemosa*

Source: Preston, 2004.

A recent analysis of the world's fisheries, including 10 LMEs, shows that many fisheries have been overexploited (Worm *et al.*, 2009), but some are rebuilding as a result of improved management. For small-scale fisheries in a developing country, the example of depleted fish stocks on Kenyan coral reefs is cited. According to Worm *et al.*, a network of closed fishing areas and the banning of highly unselective beach seines were introduced in cooperation with local communities. This led to a recovery in the abundance of fish and the size of fish on the reefs, translating into steep increases in fisher's income, particularly in areas that had both gear restrictions in place (Figure 4.12).

Figure 4.12 Increase in fisher's income in a small-scale reef fishery in Kenya following management interventions.



Source: Worm *et al.*, 2009.

Fisheries management is very weak in the BOBLME, with very few viable co-management systems in place. Major stakeholders should be more involved in introducing responsible fisheries management and there ought to be better links to wider government initiatives and policies aimed at improved social welfare and support. Partnerships between governments (at all levels) and major stakeholders, hold the key to improving the management of the resources and securing the potential social and economic benefits that are available. This will require human capacity building at all levels, development of institutions that engender trust, and true participation of all stakeholders in the development and implementation of new policies and reforms.

4.2 Degradation of critical habitats

In the context of the sustainable management of a LME, Angell (2004) defined a critical habitat as one in which services are necessary to the LME's sustainability. Some examples of services are: providing centres of biodiversity and sources of food; serving as breeding, feeding, nursery and refuge areas; moderating the influence of nutrients, sediments and pollutants from land; supporting coastal and offshore productivity; and protecting the coast from the effects of storms and floods. The assessment of whether a habitat is critical or not would include a consideration of the habitat's exceptional ecological value and/or its being at risk from imminent threats, inherent vulnerability, and/or rarity. The three critical habitats – mangroves, coral reefs and seagrasses – all satisfy the criteria for critical habitats, both locally and regionally, and have already been formally recognised as habitats of global significance. They are all highly productive and often interdependent, such that degradation of one may adversely affect the status of the other two.

Several other coastal wetland habitats are recognised as being important in the BOBLME. These include mudflats, estuaries and salt marshes. Such habitats are especially important because of the ecological products and services that they generate (see Volume 1), but they are not included in the following analysis of the critical habitats in the BOBLME. Mudflats, estuaries and salt marshes are associated with the three critical habitats identified in the TDA, therefore the issues and causes that pertain to them can be considered along with those that apply to critical habitats.

4.2.1 Mangroves

Importance of mangroves

Mangroves occur in all BOBLME countries and collectively account for 11.9 percent of the world's mangroves. Few assessments of the economic value of mangroves have been conducted in the BOBLME. One study showed that converting mangroves to aquaculture in southern Thailand resulted in a net loss when the value of timber, charcoal, non-timber forest products, offshore fisheries and storm protection were taken into account (Conservation International, 2008).

Mangroves form an ideal habitat for the life stages of many animals and are critical for supporting offshore fish populations and fisheries (Blaber, 2009). Above the water, mangrove trees and canopy provide important habitat for a wide range of species. Below the water, plants and animals such as algae, tunicates, sponges and bivalves grow on mangrove roots. The soft substratum in the mangrove forests provides a habitat for a wide variety of species, while the space between roots provides shelter and food for motile fauna such as shrimps, crabs, and fishes. Mangrove litter supports an intricate food web, together with plankton, algae and microphytobenthos.

Nagelkerken *et al.*, (2008) reviewed the habitat function of mangroves. The authors concluded that evidence for linkages between mangroves and offshore habitats by animal migrations is scarce but highly necessary for conservation and management purposes. Some examples do exist in the literature but more studies are needed. Many of the fish caught for sustenance, or commercial purposes in Malaysia for example, spend part of their life cycle in the Matang mangroves (Sasekumar *et al.*, 1994). There were 119 species of fish and nine species of shrimp captured in mangrove inlets and creeks in Selangor, Malaysia, and the majority of these were juveniles. Many of the juvenile fish and shrimp species moved out of the mangroves and became commercially important, clearly demonstrating that mangroves support fisheries by providing habitat and food. It is well known that mangroves in Australia are used as nursery areas for postlarval and juvenile banana prawn (*Penaeus merguiensis)* (Vance *et al.*, 1990) and that fish move into mangrove areas at high tide (Vance *et al.*, 1996). Laedsgaard and Johnson (2001) found that there were more juvenile fish in artificial mangrove structures with fouling algae than in seagrass beds, artificial mangrove structures without fouling algae or bare sand. As the fish grew they moved to more open areas in response to changes in diet, foraging efficiency and vulnerability to predators.

Although mangroves have been widely promoted for the purpose of reducing the impact of large storm surges and tsunami (Danielson *et al.*, 2005) this perspective is a controversial one. A recent review (Feagin *et al.*, 2010) suggests that it should not be assumed that the science on short-period wave attenuation supports the conclusion that vegetation can reduce the effects of storm surges or tsunamis. Mangroves grow in areas of relatively low energy and are, by definition, protected from high-energy impacts.

A significant percentage of the people living in coastal communities are traditionally dependent on mangroves for their domestic needs and livelihoods, including firewood and timber and for catching fish, shrimp, crabs and worms. Aquaculture practices in BOBLME countries still rely on stock collected from the wild. Not only are brood stock routinely gathered, but trash fish is used for feeding cultured animals. Many of these resources are associated with mangroves and it is estimated that the exploitation of prawns, crabs and molluscs with links to mangroves amounts to a total global figure of about USD4 billion per year.

Status of mangroves

The most recent analysis of the status of mangroves in the BOBLME was carried out by Giri *et al.*, 2008. In 2005 there were approximately 16 500km^2 of mangrove forest remaining in the region (compared with 157 000km^2 in the South China Sea). The largest percentage of the remaining mangrove areas was located in Myanmar, followed by Bangladesh, India, Thailand, Malaysia, Indonesia and Sri Lanka (Table 4.11). Mangroves in the Maldives occur mainly on the northern atolls of this island chain (Spalding *et al.*, 2010). The species composition and vegetation structure are unique and these are the only atoll islands with mangroves in the world.

Table 4.11 Area of mangroves in the countries of the BOBLME.

	% World	km^2	% BOBLME
Indonesia	**0.5%**	**682**	**4.1%**
Malaysia	**0.5%**	**706**	**4.3%**
Thailand	**1.2%**	**1 689**	**10.2%**
Myanmar	**4.0%**	**5 514**	**33.5%**
Bangladesh	**3.2%**	**4 388**	**26.7%**
India	**2.5%**	**3 377**	**20.5%**
Sri Lanka	**0.1%**	**104**	**0.6%**
Maldives	**<0.1%**	**0.95**	**0.01%**
Total	11.9%	16 460	

Source: Giri *et al.*, 2008.

The largest expanse of mangrove forests is in the Sunderbans (along the border between Bangladesh and India); the Ayeyarwady Delta, Rakhine and Tahinthayi (Myanmar); Phang Nga and Krabi (Thailand); and Matang (Malaysia).

Over 4 500km^2 of mangrove have been lost in the region over the last 30 years, with the majority being lost in Myanmar. In that country, the total area lost (3 001km^2) exceeds the sum of all losses in the other countries (Table 4.12). Net loss of mangroves peaked at 1 374 km^2 between 1990 and 2000, increasing from 976km^2 in the period 1975 to 1990, and declining to 139 km^2 between 2000 and 2005. The main reason for the decline is the leveling off of aquaculture expansion in all the countries, except Myanmar and Indonesia. Losses in India and Bangladesh occurred during the earlier part of the period and the present areas of mangrove in those countries have remained comparatively unchanged over the past five years.

A similar situation occurred in Thailand where mangroves are no longer cleared as extensively as before. Mangrove losses on the Thailand Andaman coast – where 80 percent of the original mangrove cover remains – are not as great as along the coast of the South China Sea where losses amounted to more than 80 percent of the original area. The mangroves in those areas of Indonesia and Malaysia that border the Bay of Bengal are relatively small when compared to the areas of mangroves bordering the South China Sea (6 758km^2 in Indonesia and 5 321km^2 in Malaysia). In the case of Malaysia, some 400km^2 of mangrove are contained in the Matang forest in Perak State; this amounts to 57 percent of Malaysian mangrove in the BOBLME. This area is managed as production forest on a 30 year cycle with a consequent reduction in diversity of both the flora and fauna. *Rhizophora* now dominates much of the cropped area, which has been sustainably harvested for over 100 years.

Table 4.12 Change in mangrove cover from 1975 to 2005 in BOBLME countries.

	1975	Present	Area lost	% loss	Annual rate (km^2/year)
Indonesia	**1 012**	**682**	**330**	**32.6%**	**11**
Malaysia	**929**	**706**	**223**	**24.0%**	**7**
Thailand	**2 095**	**1 689**	**406**	**19.4%**	**14**
Myanmar	**8 515**	**5 514**	**3 001**	**35.3%**	**100**
Bangladesh	**4 481**	**4 388**	**93**	**2.1%**	**3**
India	**3 718**	**3 377**	**341**	**9.2%**	**11**
Sri Lanka	**240**	**104**	**136**	**56.7%**	**5**
Maldives	**n/a**	**0.95**	**n/a**	**n/a**	**n/a**
Total	21 008	16 460	4 530	21.6%	151

Source: Giri *et al.*, 2008.

It can be seen from Table 4.13 that the major cause of loss of mangrove has been conversion to agriculture (82 percent) and aquaculture (12 percent). It is important to recognize that conversion of mangrove to agricultural land generally occurs on the landward side of mangrove habitats where the soil salinity is usually lower than on the seaward side. Mangrove that has already been converted for agricultural purposes is generally unavailable for mangrove replanting. This is because of the continuing growth of human populations in the countries of the BOBLME that place food security high on the national policy agenda.

In contrast, conversion to aquaculture tends to occur in the more brackish reaches on the seaward side of mangrove ecosystems. This is because the waterlogged, typically acid sulphate soils in the lower zones of mangrove communities tend to require extensive treatment and large inputs of freshwater if they are to be used productively for agriculture. With both causes of mangrove conversion it is important to distinguish between losses as a result of production for national consumption; and losses caused by production for export. The two different production types have distinctive underlying drivers and are generally undertaken by different sectors of society, with consequent differences in terms of the accrual of costs and benefits. Production for subsistence and national use is generally in accordance with national policies aimed at achieving food security. Moreover, the units of production tend to be small. In contrast, commercial production for export markets is usually on a much larger scale, requires substantial capital investment and local communities are often not the beneficiaries of production.

At the local level, both deforestation and forest regeneration have occurred with varying intensities, and with localized "hotspots" of rapid change. Major reforestation and aforestation areas are located on the south-eastern coast of Bangladesh, and in Pichavaram, Devi Mouth, and Godavari in India.

Table 4.13 Causes of mangrove conversion (area converted km^2) by country, 1975-2005.

	Aquaculture	Agriculture	Urban	Other
Indonesia	**209.6**	**106.3**	**14.2**	**0**
Malaysia	**16.1**	**96.1**	**45.3**	**65.6**
Thailand	**168.2**	**203.0**	**7.1**	**27.5**
Myanmar	**68.7**	**2 930.4**	**0.7**	**1.3**
Bangladesh	**10.7**	**71.9**	**0**	**10.5**
India	**75.5**	**171.8**	**1.7**	**91.8**
Sri Lanka	**1.3**	**125.6**	**0.3**	**9.0**
Total	550.0	3 704.9	69.2	205.5
Total (percent)	12%	82%	2%	5%

Source: Giri *et al.*, 2008.

In addition to the loss of mangrove habitat as a consequence of land use changes, degradation of remaining mangrove habitat is occurring as a consequence of a number of anthropogenic activities occurring at both the subsistence and commercial levels of exploitation. Even when they enjoy some form of nominal protection, mangroves are a source of timber, fuel-wood, charcoal, thatching materials and food (including fish and shrimp). More recently, the capture of shrimp and fish fry for aquaculture ponds has increased and the harvest of crabs for small scale commercial purposes is widespread. The impact of subsistence and small scale commercial exploitation of mangrove resources increases with the continuing growth of coastal populations, and the resulting increase in demand for fuel and food. The importance of this cause of degradation varies considerably from location to location and reflects local population densities, the extent of the mangrove areas and demands from outside the area.

In addition to direct anthropogenic drivers of mangrove degradation, indirect causes are found in cases where the flow of freshwater into mangrove ecosystems is reduced or stopped altogether, usually as a consequence of dams and barrage construction and diversion of water for irrigation. Such reductions in fresh water flow result in an increased intrusion of saline wedges into inland areas and a resultant alteration of species composition in the landward zone of the mangrove system. Extensive saline intrusion combined with high evapo-transpiration rates, result in degradation of the mangrove and the formation of salt flats which can be, and often are, used for salt production.

Table 4.14 Major mangrove forests in the BOBLME (Modified from Angell, 2004).

Country		Area, km^2	Status	Condition
Indonesia	Aceh	594		70% to shrimp ponds
	North Sumatera	868		Threatened
	Riau	2 399		Threatened
	West Sumatera	365		53% destroyed
Malaysia	Perlis	1		
	Kedah	80	99% forest reserve	Degraded
	Penang	6		
	Perak	435	78% forest reserve	Sustainable harvesting
	Selangor	151	76% forest reserve	Degraded
	Negri Sembilan	2		
	Melaka	2		
	Johor	167	68% forest reserve	Degraded
Thailand	Ranong, Pangnga, Phuket	707	15% protected, 82% under management	Recovering
	Krabi, Trang, Setun	1 058		
Myanmar	Rakhine	229	Nominally protected	Threatened
	Ayeyarwady	275	Nominally protected	10.6% reserved forest, remainder threatened
	Tanintharyi	224	Nominally protected	Threatened. Rate of decrease 2.4% per annum.
Bangladesh	Sunderbans	4 016	Reserved forest	Threatened
	Chokaria	182	Converted to shrimp farms	≈ 100% destroyed
	Aforestation/ reforestation	1043	Plantation	575 km^2 in good condition
India	Sunderbans[1]	9 630 of which 4 263 km^2 are mangroves	Biosphere Reserve	Threatened
	Bhitarkanika	675	Sanctuary	Now 25% of sanctuary[7]
	Coringa	101	Reserve Forest	Threatened
	Pichavaram	11	Reserve Forest	Stable
	Vedharanyam Mangrove Swamp	17.3	Wild life sanctuary[2]	Threatened. 40% degraded
	Nicobar Islands	2 450		
	Andaman Islands	966	Timber extraction banned	Threatened
Sri Lanka	Batticaloa	16		Undisturbed
	Mullaitivu	10		
	Jaffna	11	52% reduction	
	Puttalam	5	85% reduction	
	Other, Kipparatota, Hikkadawee	19	Degraded	
Maldives	Scattered	Not available	Not protected	Threatened

[1] Includes core area, manipulation zone and restoration zone. Core area is 1692 km^2 (Sampath, 2003).
[2] Sampath, 2003. [3] Only a small portion is protected, but the entire area has been proposed as a Ramsar site.
Sources: National reports; Kumar; Choudhury, 2003. www.indianjungles.com; Jagtap, 1992.

Alteration of freshwater inputs causes changes in the zonation and species composition of the mangrove community, with the more salt tolerant species replacing those dependent on low salinity. In addition to altering the input of water to mangrove systems, dams and barrages trap sediment (and nutrients) which also has consequences for the mangrove community. Where depositional shorelines are sinking relative to mean sea level, mangrove communities help to maintain coastal stability by trapping sediments in and around their prop roots and pneumatophores. By trapping sediment the mangrove soil surface accretes vertically, and where sufficient sediment inflows occur the mangrove community may prograde seaward. In cases were sediment inputs are reduced or cut off altogether, the relative sea level may continue to rise and seaward mangrove communities may die as a consequence of the "drowning" of the breathing roots. This is accompanied by landward saline intrusion and a shift in the zonation of the mangrove communities reflecting new tidal inundation regimes. Clearly, under conditions of a continuing rise in global mean sea level, the maintenance of sediment inflows is vitally important if the mangrove community is to continue to exist. The mangroves of the Sunderbans are considered severely degraded (Wilkie *et al.*, 2003) with significant reduced forest cover and it seems likely that changes in freshwater and sediment flux have played a part in the process.

In India, although the main cause of mangrove loss is the conversion to agriculture that took place between 1975 and 2005, a dramatic example of clear-felling of mangroves occurred in the Vellar estuary, located in the northernmost end of the Cauvery delta. Between 1935 and 1975 about 500 ha of mature mangrove forest in the Pichavaram wetland was clear-felled by the government management agencies to generate revenue. The agencies believed that mangrove plants would regenerate naturally in the clear-felled areas. The clear-felling and subsequent exposure of the mangrove wetland caused subsidence of sediment in the clear-felled areas, causing the topography to become trough-shaped. As a result, tidal water entering into the trough-shaped portion became stagnant. Evaporation of stagnant tidal water increased the soil and groundwater salinity to a level which was lethal to mangrove species. This was the main cause of the degradation of the Pichavaram mangrove wetland (Selvam *et al.*, 2003).

Angell (2004) provided more in-country detail, mainly from information provided in the national reports (Table 4.14). Note that some of the estimates of mangrove areas differ from those estimated by Landsat imagery by Giri *et al.*, 2008). This is because of a difference in definitions and the techniques used to estimate areas.

Most of the mangrove forests in the BOBLME are either already degraded or threatened. However, in all the BOBLME countries, some mangroves are under various forms of government protection. The Maldives is the exception, but, as is pointed out by Ali (2004), the importance of the country's mangroves is recognized.

Arguably, the Maldives has the most to lose if the islands' mangroves are lost. Particularly the northern atolls have luxuriant mangroves but the islanders are unaware of their value to the islands' ecosystems, in preventing erosion and enhancing sedimentation. Island reclamation, particularly on Male atoll, has resulted in considerable erosion due to the removal of mangroves (Jagtap and Untawale, 1999).

Restoration and management of mangroves

Total mangrove ecosystem management entails managing mangroves for silviculture (forestry), aquaculture, and ecosystem services, such as coastal protection. The broader context in which mangroves and their diverse benthos are managed is reviewed by Ellison (1998). The author reassesses the relative merits of management focused on short term economic gains, and suggests that managing for ecosystem services may ultimately preserve benthic biodiversity in mangrove ecosystems.

The Matang Mangrove Forest Reserve in Perak State, Malaysia, is of considerable economic importance. Its management provides an example that could be followed by other BOBLME countries. In 1906, legislation was passed to establish the Matang Mangrove Forest Reserve and it has been managed sustainably ever since. The area is a major supplier of seafood to the local and international market. Revenue from forestry was about USD12 million in the late 1990s and the value of the shrimp and fishing industry in the area was at least USD48 million and USD60 million, respectively, in 1994 (Sasekumar, 1994).

Of the three critical habitats described here, mangroves are the easiest to restore. Abandoned shrimp farms can best be restored by opening the walls and allowing mangrove propagules to settle in the bare areas (Lewis, 1998). Remote sensing techniques have been used to assess and monitor the effectiveness of mangrove restoration and conservation programmes where physical monitoring is difficult (Selvam *et al.*, 2003) and to monitor conversion of mangrove to shrimp ponds and abandoned ponds back to mangrove (Jayanthi *et al.*, 2007).

Restoration should be carried out where substrates and other conditions are suitable. Care should be taken that intertidal mudflats that never carried mangroves are not used as mangrove planting areas because they appear to be easy to plant. These mudflats themselves are important coastal habitats (Ertemeijer and Lewis, 1999) and restoration of mangroves should not be at the expense of intertidal mudflats. The consequences of indiscriminant mangrove planting on the sedimentation and hydrology of estuaries and lagoons, and the fisheries of these areas, have been recently documented in Sri Lanka (IUCN, 2011).

Community groups are ideal for providing the labour for planting mangroves and large areas may be planted with many seedlings (Ertemeijer and Bualuang, 1998). Unfortunately, it is usual to plant single species (Figure 4.13), which results in the function and form of the mangrove forest not being returned. Practical guidelines for mangrove restoration are given in Giesen *et al*., (2006) and Field (1996).

In the Pichavaram mangrove in India, remote sensing has shown that mangrove cover increased by 90 percent between 1986 and 2002 after a process of revegetation began and some channels were dug to assist water flow (Table 4.15).

There are many examples of restoration projects in BOBLME countries. In Thailand, the Ecological Mangrove Restoration (EMR) Project is managed by Mangrove Action Project (MAP) which has developed a unique mangrove rehabilitation method. Ecological Mangrove Restoration (EMR) supports the idea of returning the natural forest biodiversity that was lost, rather than creating a tree plantation of one or several species. EMR results in a higher biodiversity in re-vegetated mangrove forests.

Table 4.15 Change in Pichavaram mangrove before and after restoration.

Class	1986 ha	2002 ha	Change ha
Dense mangrove	325	411	+86
Young mangrove more than 3 years old	0	117	+117
Young mangrove less than 3 years old	0	90	+90
Degraded	375	65	–310

Source: Selvam *et al*., 2003.

Despite these successes, a number of coastal mangrove restoration projects, undertaken in the aftermath of the December 2004 tsunami, failed. This was as a result of planting of inappropriate species, in inappropriate locations, and a lack of understanding of the restoration site itself. However, the Mangrove Action Programme has a number of projects underway to restore mangroves in BOBLME countries (MAP, 2010).

Figure 4.13 Starting mangrove rehabilitation.

Photo source: BOBP-IGO archives

The shrimp ponds at Lampung, Southern Sumatra.

Source: Google Earth.

Degradation of mangroves

Although it is located outside the boundary of the BOBLME, the largest shrimp farm in the world in Lampung, southern Sumatra is a good case study. Approximately 1 860km^2 of mangrove was converted to ponds. The ponds stretched along the coast for 60 km and reached about 4 km inland (see photo). In 1996 the farm produced 19 854 tonnes of shrimp worth USD167 million.

The farm was supported by the BDNI, World Bank and Export-Import Bank of Japan. The company was the sole supplier of feed, fry, power and other basics and took a huge cut from the farmers' income. Farmers had to borrow to stay afloat and account status for farmers was refused. However, shrimp proved to be temperamental to grow. Early harvests were poor and even when harvests were good the company took more from the farmers. Clashes between the company and farmers have been common and the overall future of the venture is in doubt.

Source: Far Eastern Economic Review, 30 May 2000. www.gtenterprise.com.dipasena

4.2.2 Coral reefs

Importance of coral reefs

Like mangroves, coral reefs also occur in all the countries of the BOBLME. Globally, coral reefs are well known for high productivity and rich biodiversity, and as a source of beauty. They also provide many services to the communities that live on coral reefs or nearby. Coral reefs support a variety of human needs and are important for subsistence and commercial fisheries, tourism, shoreline protection, and they may have the potential to yield compounds for the development of new medicines. Economic valuations of coral reefs in the BOBLME are not available, but globally coral reefs are estimated to be worth USD29.8 billion, based on tourism (32 percent), fisheries (19 percent), coastal protection (three percent) and biodiversity (18 percent), according to Cesar *et al.*, (2003). Although coral reefs cover less than one percent of the earth's surface, they are home to 25 percent of all marine fish species.

Large river flows, monsoonal runoff from the land and strong currents that cause turbidity render much of the BOBLME unsuitable for corals. Therefore, corals are limited in distribution and are usually found offshore where it is shallow enough for them to establish, or in shallow inshore waters that do not have large rivers flowing nearby. Although their distribution is limited in the region, the reefs are vitally important for the communities that depend on them.

Status of coral reefs

The major coral reefs of the BOBLME occur in the Maldives, the Andaman and Nicobar Islands, Myanmar and the Andaman Sea area of Thailand. There are also extensive reefs in the Gulf of Mannar, and fringing and patch reefs elsewhere in India, Sri Lanka, Malaysia and Indonesia. Limited coral communities occur around St Martin's Island in Bangladesh.

Table 4.16 Area of coral reefs in countries around the BOBLME.

	% World	km^2	% BOBLME
Indonesia	**0.7%**	**1 848**	**8.2%**
Malaysia	**0.1%**	**284**	**1.3%**
Thailand	**0.3%**	**853**	**3.8%**
Myanmar	**0.9%**	**2 559**	**11.3%**
Bangladesh	**–**	**–**	**0.0%**
India	**2.6%**	**7 392**	**32.7%**
Sri Lanka	**0.3%**	**853**	**3.8%**
Maldives	**3.1%**	**8 813**	**39.0%**
Total	8.0%	22 602	

Note: Andaman and Nicobar Islands account for 88 percent of India's coral reefs.

Source: Percentages from SAUP, 2010; areas from UNEP, 2007.

The total area of reef has been estimated at 22 600km^2, with the largest area in the Maldives, followed by India (mainly the Andaman and Nicobar Islands), Myanmar, Indonesia, Sri Lanka, Thailand, Malaysia and Bangladesh (Table 4.16).

In 1998, the coral reefs of South Asia suffered a large scale bleaching event that caused an enormous reduction in coral cover. Up to 90 percent mortality was observed on certain coral reefs in the Maldives, but there was much less bleaching in the Gulf of Mannar and the Andaman and Nicobar Islands (Wilkinson, 2008). Some recovery has occurred, but further damage will occur with sea temperature rises. One of the major problems of coral bleaching is that after an event, alga turfs and macroalgae grow back faster than the zooxanthellae. This causes the coral to die. The growth of coral turfs is often encouraged by high levels of nutrients that enter the marine environment in runoff from the land, and by the overfishing of herbivore species that previously controlled coral turf growth.

The coral reef recovery that followed the 1998 bleaching event was variable. Some areas show relatively good recovery, whereas in other areas there are indications of a phase shift, with algal growth smothering corals. Minor coral bleaching was also observed in 2003 and 2004 in the Maldives, Sri Lanka, on the Indian side of the Gulf of Mannar and on St. Martin's Island in Bangladesh, with almost 100 percent recovery within months. In mid-2010, a new massive coral bleaching event, possibly linked to the late onset of the southwest monsoon, occurred.

By 2004, many of the reefs of the region were yet to recover from the mass bleaching event of 1998, partly as a result of a number of other stresses. Although reefs that were not affected by the bleaching are in relatively better health, they are also under threat from human activities. There are clear signs of over harvesting of fish and other reef resources, such as sea cucumbers, chanks and spiny lobsters. The effects of over-fishing and the use of destructive methods to collect reef resources, e.g. dynamite fishing and mining, are clearly evident on reefs close to larger human settlements, resulting in reduced coral cover and ecosystem productivity. New or rapidly growing activities, including tourism and marine aquarium fish collection, also affect the reef resources, e.g. reef fish and lobster populations. Reefs in the Maldives and Sri Lanka were mostly recovering well from earlier plagues of crown-of-thorns starfish (COTS). There were no obvious signs of large-scale perturbations.

Table 4.17 shows that most coral reefs in the BOBLME are either degraded or threatened, despite the fact that many are under some form of government protection. Ocean acidification, higher than normal sea surface temperatures, and human impacts such as declining water quality and over fishing, are reducing coral reef resilience to environmental change, changing reef structure, coral abundance and community composition.

With the loss of coral cover, the biodiversity supported by coral reefs is at risk. The productivity of the coastal fisheries supported by coral reefs is thought to be declining as the reefs deteriorate. Bait fish for commercial tuna pole-and-line fishing are caught over coral reefs (Blaber, 2009; the author also describes the relationship between coral reef fish, larvae and pelagic reef-associated fish.)

Table 4.17 Summary of coral reef status in the BOBLME (Modified from Angell, 2004.)

Country	Site	Area km^2	% live coral cover	Major threats
Indonesia	Riau	521 km^2	67% to 98% of reefs have been degraded	Mining, sedimentation, destructive fishing methods
	Central Tapanuli including Karang Island	12 km^2	12%–69% good to poor condition	Trawling, blasting, Thai fishing in 1998
	Nias and South Nias	10 km^2 fringing and patch	Good to poor	Blasting, cyanide, trawling, fish traps, mining
	Mentawai	240 km^2 Fringing, patch and shoal	3%–52%	Blasting, cyanide, trawling, overfishing
Malaysia	P. Langkawai, P. Sembilan, P. Pangkor, Port Dickson (P. Segantang, P.Lembu, P.Kaca) in the P. Payar Marine Park	Fringing Fringing Fringing Fringing Fringing Fringing	Threatened 61% Threatened Degraded Degraded 74% 12–18%	Destructive fishing, land reclamation, shipping accidents Boats and shipping Protected area, but potential threat from tourist development
Thailand	BOBLME area of Andaman Sea, Similan Islands, Surin Islands	Fringing 78.6 km^2	Good, 12%; fair,34%; poor,27%; very poor 23%	Destructive fishing, crown-of-thorns, bleaching, sedimentation, storms, tourist development
Myanmar	Mergui Archipelago Burma Banks Rakine area Tanintharyi	Fringing 1 700 km^2 Barrier Fringing	Unknown Supposed to be good. Unknown	Blast fishing Tangled nets, blast fishing, coastal pollution, poor fishing practices
Bangladesh	St. Martins Island (Narikel Jinjira)	Patch	7.6% coverage on SE coast	Coral mining, sedimentation, overfishing, pollution from sewage and waste

Country	Site	Area km²	% live coral cover	Major threats
India	Gulf of Mannar Marine Biosphere Reserve Mahatma Gandhi Marine National Park, Andaman and Nicobar Islands	Fringing and patch 66.5 km^2 Fringing and patch	3–52% 17.5 km^2 10% to 85%, varies between park islands	Intensive trawling, coral mining, blast fishing, overfishing of reef resources Siltation
Sri Lanka	Bar Reef Marine Sanctuary Kapparatota Talawila in NW Aranwala & Kirawella in S Jafna Peninsula	Patch Fringing Fringing Fringing Fringing	Almost 100% mortality from coral bleaching, well recovered by 2008	Bleaching, destructive fishing, anchoring, sediment and coral rubble
	Kandakuliya	Fringing	New growth after bleaching, but destroyed by Halimeda	Bleaching, destructive fishing, anchoring, quarrying for lime
	Hikkadua Marine Sanctuary	Fringing	Decreased from 47% live coral coverage to 12% after bleaching	Sedimentation, anchoring, pollution, uncontrolled tourist activity, mining
	Weligama	Fringing	Decreased from 92% to 54% after bleaching	Sedimentation, pollution, uncontrolled tourist activities, anchoring
	Rumassala	Fringing	Decreased from 45% to 23% after bleaching. Some restoration efforts	Blasting
	Great Basses and Little Basses Reef Marine Sanctuaries in south east	Barrier	Un-degraded	Overfishing
Maldives	Nation wide	26 atolls, 1200 coral islands, 202 inhabited	High coverage up to 70% but coral bleaching caused losses up to 90% in 1998, recovering now	Coral mining, oil pollution, tourist and domestic waste, overfishing, bleaching, sea level rise

Source: National reports; Spalding *et al.*, 2001; Wilkinson, 2008; Bayu, 2009. Mollah, 1997; Haida, 2008; Lim, 1990; Hoon, 1997.

Corals in most shallow reef areas of Sri Lanka were destroyed in 1998 as a result of bleaching caused by high water temperatures associated with the *El Nino* Southern Oscillation (ENSO) effect. Coral reefs at depths of between three and five metres lost most of their live coral from the northwest to the east coast, except near Trincomalee. Since then, coral species at different locations have shown varied levels of impact and recovery. Bleached corals were even recorded at 42m depth off the east coast, although almost all bleached corals at depths below 10 or 15m recovered after about six months. A cause for concern is that, at many locations, dead corals in shallow waters have been covered by rapidly growing algae, tunicates and invertebrates such as corallimorphs. This may inhibit the re-establishment of live coral (Rajasuriya *et al.*, 2000).

The coast of Thailand's Andaman Sea is a coral reef area that falls within the Bay of Bengal region. It has a total area of 78 km^2 of primarily fringing reefs ranging from near shore to offshore areas (Changsang *et al.*, 1999). The 1998 bleaching event did not appear to affect reefs in the Andaman Sea (Spalding *et al.*, 2001). These reefs are an important resource for tourism in Thailand. However, rapid coastal development on the Thai Andaman Sea coast over the past three decades has led to degradation of coastal resources. Although development has boosted the country's economic growth and the population's income, it has also affected the physical environment and the socio-economic condition of coastal communities.

Myanmar has some of the region's most pristine reefs, but reef status is difficult to determine because of a lack of baseline information. The country's reefs probably typify the past experience of most other reefs in the BOB. The consensus is that the coral reefs of Myanmar are generally in very good to excellent condition. However, there are growing concerns that destructive fishing practices, such as trawling and longline fishing near reefs, and blast fishing, are on the increase. There is also evidence of damage by fishing gear, such as tangled nets. There are many reports of illegal and destructive fishing by foreign fishers and the harvest of reef invertebrates for the ornamental and aquarium trade, and sea cucumbers for food and export, is increasing. The coral reefs of Myanmar are currently threatened for the following reasons: there is a lack of legislation; local government enforcement and scientific capacity is weak; many NGOs cannot operate coral reef programs in Myanmar; and over-exploitation of reef resources and coastal developments are increasing. Urgent action is needed to prevent the coral reefs of Myanmar from declining to unsustainable levels.

St Martin's Island (Narikel Jinjira) is the only place where coral grows in Bangladesh but the area is afflicted by the same problems common to other parts of the BOBLME. Its total area is only 12 km^2, yet corals are affected by runoff of market and domestic waste including sewage; exposure to sedimentation; and the collection of benthic animals such as sea cucumbers and molluscs and corals for tourists. Boat moorings damage seagrass and coral- and rock-weighted gill nets also take their toll on the reefs. More information about the corals of St Martin's Island and their connectivity to corals of Myanmar and the mainland of Bangladesh is required.

In western Sumatra there are two protected areas that include coral reefs: Pulau Weh near Aceh has fringing reef and there is about 85km of barrier reef located 20km off the west coast of Aceh and Kepulauan Banyak. There is also the Mentawai Island chain and barrier reefs with a combined length of 660km along the west coast of Sumatra. These have been rarely studied or mentioned in reviews (Spalding *et al*., 2001).

Among the major findings of Wilkinson *et al*., (2006) was that damage to BOBLME coral reefs caused by the tsunami of 2004, was patchy, site dependent and heavily influenced by environmental conditions. Most of the damage was caused by sediment and coral rubble and from debris washed from the land into the sea. The Indian Ocean tsunami caused very limited damage to the coral reefs of western Thailand, with negative impacts being greater in the north than in the south. The major damaging effects included overturning of massive corals, broken branching corals and the smothering of coral tissues by sediment in Aceh. Most of the coral reefs in the BOBLME escaped serious damage and are expected to recover in five to ten years. The damage at Aceh in northern Sumatra was the greatest, but even here, debris from the land was the main cause of damage. In the northwest of Simeuleu Island, corals were lifted one to two metres above sea level. The greatest impacts of the 2004 tsunami on coral reefs in Sri Lanka were observed on the shallow coral habitats of the east coast, while the north-western coastal reefs were undamaged (Rajasuriya, 2005).

In Myanmar, prior to the tsunami, the best accounts of the coral reefs were from anecdotal reports by recreational divers visiting the Burma Banks and the Myeik Archipelago on live-aboard dive boats operating out of Thailand. After the tsunami Tun and Heiss (2006) reported that the tsunami caused minimal or no damage to the coastline of Myanmar, or to the coral reefs in the Myeik (Mergui) Archipelago.

Baseline quantitative data for reefs in northern Sumatra, Indonesia is comparatively limited, both before and after the Indian Ocean tsunami. In the aftermath of the tsunami, long term reef monitoring was recognized as a priority and monitoring was carried out on Pulau Weh and Aceh Islands. Natural coral recruitment was observed to take place two years after the tsunami, especially on rocky substrates in shallow waters. However, rubble substrates in deeper waters prevented recruitment because of the post settlement mortality of the recruits (Rudi *et al*., 2008).

Long-term monitoring studies in Thailand suggest that coral reefs that were not affected by the tsunami are in good condition and currently show the same degree of coral cover as recorded during the past 25 years. Such background conditions, together with sustained coral growth rate and high regeneration potential, should aid the recovery of most damaged locations over the next three to five years (Satapoomin, 2006).

Management and restoration of coral reefs

Certain coral reefs in Thai waters (Surin Islands National Park, Similan Islands and the Adang Rawi Islands of Tarutao National Park) have been monitored under a long term monitoring programme (Phongsuwan *et al.*, 2008). Results indicate that reefs in the Andaman Sea are resilient to natural stress and damage; the reefs did not suffer extensive damage from the bleaching event in 1998 in comparison to reefs in, for example, the Maldives (Zahir and Rasheed, 2005) and Sri Lanka (Rajasuriya, 2002). However reefs close to tourist development areas show signs of degradation (Phongsuwan *et al.*, 2008). Throughout the region there are tourist operators who are diligent in their control of clients diving on coral reefs, but tourists often do not consider the impacts of their activities.

Thailand and the Maldives are probably the leaders in controlling and managing the activities of tourists on the coral reefs of the BOBLME. In Thailand, "Green Fins" asks a network of dive operators to offer tours according to a set of environmentally-friendly guidelines. The dive operators will assist in surveying and keeping track of information on their customers' knowledge of, and behaviour in, the sea. In addition, the dive operators may help with monitoring coral reefs when they take customers on dive trips. The Green Fins initiative will strengthen the involvement and role of dive operators as an important stakeholder and partner in the protection, conservation and sustainable use of coral reefs, and will help to raise awareness of the problems and issues that impact coral reefs. To support the Green Fins initiative, capacity building activities and training workshops will be organized as needed. Green Fins is sponsored by Thomson Reuters, Siam Cement Group and the Siam Commercial Bank. This is a good example of private-public partnership and is supported by UNEP and the Thai Department of Marine and Coastal Resources. For more information see www.greenfins-thailand.org

Many attempts have been made to restore coral reefs in the BOBLME countries. For example, in Indonesia an experiment compared three different low-cost, locally available treatments: rock piles, cement slabs pinned to the rubble, and fishing net pinned to the rubble. Significantly greater recruitment occurred on the rock and cement experimental treatments compared to the bare, untreated rubble (Fox *et al*., 2000). Many of these experimental methods have been considered successful, but they have been shown to be less successful when implemented on a wide scale. Other important concerns are, of course, the cost per area restored.

4.2.3 Seagrass

Importance of seagrass

Seagrass beds and meadows are areas of great biodiversity and are especially important as nursery areas for many commercial fish and crustacean species. They support adult fish, molluscs and crustaceans, which are fished or gathered by local communities across the BOBLME, and well known as the feeding grounds of green sea turtles (*Chelonia mydas*) and dugongs (*Dugong dugon*). Seagrasses are also known to stabilise coastal sediments and trap and recycle nutrients. Like coral reefs, they are important sources of food and income for some coastal communities. Gleaning on seagrass beds by local communities is for molluscs, seahorses and sea cucumbers, some of which are destined for the export market.

Status of seagrass

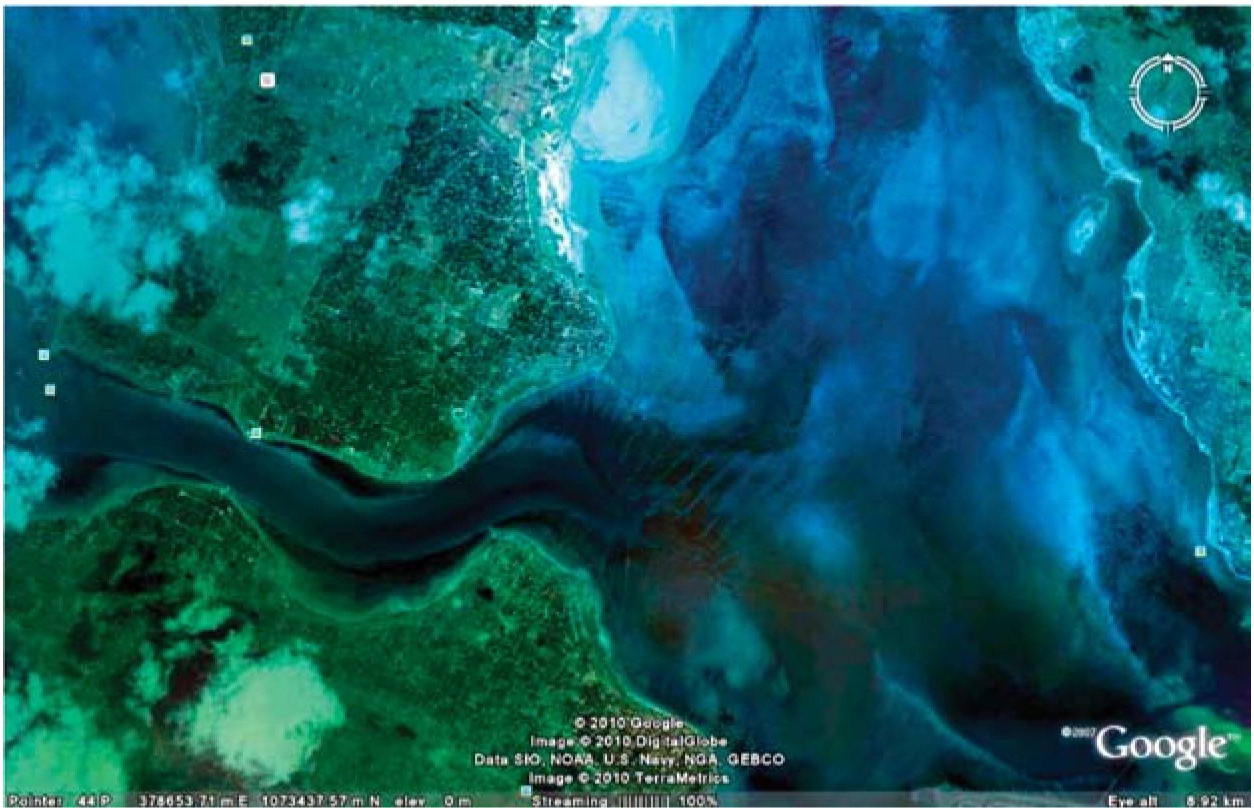
Very little is known about seagrass abundance and distribution in the tropical Indo-Pacific region. Few regional maps exist and there is little information about the great biological diversity living within them. According to Waycott *et al*. (2009) the BOBLME region has the highest number of seagrass species. In their global review of seagrasses, the authors refer to a global loss of seagrasses, but not specifically to the BOBLME region, nor do they show any evidence for seagrass loss in this region. They do, however, correctly state that "given the rapid population growth and development pressures in the Indo-Pacific, there is a pressing need to acquire more data on seagrass extent in this important region to aid in evaluating the status of seagrasses".

The information provided in this section is based on the information from the World Atlas of Seagrasses (Green and Short, 2003) and the country reports and national reports. It appears that seagrass beds remain the least well-studied of the three critical habitats addressed here, as noted earlier by Holmgren (1994).

Many of the BOBLME region's seagrass beds are known to be either already degraded or threatened. The biodiversity supported by the seagrass beds is also known to be at risk, especially with regard to endangered species such as marine turtles, dugongs and seahorses, although little quantitative information is available (Table 4.18). The productivity of the coastal fisheries supported by seagrass beds is also thought to be declining as the seagrass beds degrade and disappear.

Of all the countries in the BOBLME, Thailand has conducted the most research on seagrass. This was probably as a result of the seagrass beds at Trang supporting the largest number of dugong in the region and the interest in this endangered mammal (Mukai *et al*., 1999). The area of seagrass along the Andaman Sea coast was described by Changsang and Poovachiranon (1994). In Thailand, as in other BOBLME countries, because of the poor knowledge of seagrass ecology and distribution, seagrass beds suffer many serious abuses, five of which are common to global seagrass resources. These are overexploitation; physical modification; nutrient and sediment pollution; introduction of non-native species; and global climate change. It should be noted, however, that there is currently very little information available about the impact of invasive species on the seagrass resources of the BOBLME.

Figure 4.14 Trawler marks in seagrass bed at Karainagar on Hunativu Island at Jaffna, Sri Lanka.



Source: Google Earth.

Pushnet and trawler fishing (Figure 4.14) tear up underground rhizomes, while gleaning by local communities for molluscs, seahorses and sea cucumbers reduces biological diversity and can damage the seagrass by trampling. Details of known seagrass beds and their status are given in Table 4.18.

Table 4.18 Status of seagrass beds in the BOBLME.

Country	Site	Status	Major threats
Indonesia [1]	Palau Weh, Sunda Strait	Patches offshore islands of west Sumatra	Runoff, siltation, poor fishing gear
Malaysia [2]	Langkawi Port Dickson to Malacca Tanjung Piai (west coast of Johor)	Patches in sheltered silt free areas	Tourists, runoff, Sand mining, oil spills
Thailand [3]	Trang Ko Talibong Ranong	18 km^2 7 km^2 1.2 km^2	Push nets, mining, land development, destruction of mangroves
Myanmar [4]	Myeik Archipelago Rakhine Tanintharyi	Good condition, areas not known	Blast fishing, siltation
Bangladesh [5]	Bakkhali estuary	Areas not known	Siltation, overfishing
India [6]	Andaman and Nicobar Islands Gulf of Mannar and Palk Bay	8.3 km^2 patchy and mixed 30 km^2	Siltation Dredging, pollution, siltation
Sri Lanka [7]	Estuaries, Kalitiya to end of Jaffna Peninsular	Degraded Good	Eutrophication, siltation, poor fishing gear
Maldives [8]	Most atolls on lee side	No real survey done	Tourists, building sand

Source: [1,2,3,7,& 8]: Green & Short, 2003. Source [4]: Novak *et al.*, 2009. Source [5]: Abu Hena, 2007; Kanal & Short, 2009. Source [8]: Jagtap & Untawale, 1999.

Restoration of seagrass

Seagrass is generally difficult to restore, but it will grow from seeds or vegetative propagules. Much work has been carried out on seagrass restoration in temperate areas of Australia and the United States, but little is reported from the BOBLME. Community groups in this region are the most likely to attempt to restore seagrass in this region and reports on their work are not often available in a public forum. Community groups have tried to restore seagrass beds, usually using *Enhalus acoroides* as this is a large plant and easily cut from donor beds. The problem with getting vegetative propagules from donor beds is that the donor beds are then damaged and themselves take time to recover. Another problem is that the seedlings and vegetative propagules do not rapidly stretch out their rhizomes to attach successfully to the substrate and they are often washed out to sea. Success is usually gauged on coverage or density and function is often ignored. The economics of seagrass restoration is discussed in Fonseca *et al*. (2000) who describe a way of calculating the ecological function value compared to the restoration cost and the intrinsic recovery value. Once the countries of the BOBLME realize the importance of seagrass, it is likely they will investigate restoration techniques, build the knowledge base of coastal communities and promote seagrass restoration and conservation.

4.3 Pollution and water quality

Pollution can be defined as the human introduction into the environment of substances or energy resulting in adverse environmental impacts. Contaminants, on the other hand, are substances or energy introduced into the environment by human activities that may or may not have adverse effects on the environment.

The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) – agreed to by governments to prevent the degradation of the marine environment as a result of marine activities on land – identifies eight major categories of contaminants (not listed in priority order):

- Sewage
- Persistent organic pollutants (POPs)
- Radioactive substances
- Heavy metals
- Oils (hydrocarbons)
- Nutrients
- Sediment mobilization
- Litter

Sewage is a complex and variable mixture that can contain all other contaminant categories identified by the GPA; as a result it can be problematic to treat it as an individual contaminant. The analytical framework used in the TDA has, therefore, been modified to consider separately two types of contaminants that are invariably associated with untreated or inadequately treated domestic sewage: sewage-borne pathogens and biodegradable organic matter, or organic load.

Other contaminants that can occur in domestic or industrial wastewater are considered under the respective GPA contaminant category. Radioactive substances are not included in the TDA because available information does not indicate that contamination of the marine environment with radioactive substances is a significant problem in the BOBLME. Thus, the TDA of pollution and water quality in the BOBLME is based on the following contaminant categories:

- Sewage-borne pathogens
- Organic load
- Solid waste/marine litter
- Nutrients
- Oils (hydrocarbons)
- Sediment mobilization
- Persistent organic pollutants (POPs) and persistent toxic substances (PTSs)
- Heavy metals

GESAMP (1990), in the first global estimate of sources of marine contaminants, estimated that 77 percent of all contaminants reaching the global ocean are produced by land-based activities (44 percent via runoff and land-based discharges, and 33 percent via atmospheric transport and deposition). It is now widely accepted that up to 80 percent of anthropogenic contaminants entering the marine environment are derived from human activities on land. Table 4.19 summarizes the relative importance of land- and sea-based sources in the BOBLME and this is discussed under the individual contaminants below. It is clear that, with the exception of oil, land-based sources dominate pollutant inputs in the BOBLME.

4.3.1 Sewage-borne pathogens

"Sewage" is a generic term that in different contexts may be used to refer specifically to human waste or more broadly to include other types of wastewater, or even any form of liquid effluent, domestic, agricultural, or industrial. In the framework of the GPA, "sewage" refers to domestic wastewater, or domestic sewage. Shipping and small vessels may discharge sewage but sea-based sources of domestic sewage in the Bay of Bengal are insignificant relative to land-based sources.

Sewage is the main source of human parasites and disease-causing microorganisms, or pathogens, in the marine environment, as well as a major source of organic matter, nutrients, and suspended solids. Excreted pharmaceuticals such as antibiotics and endocrine disrupting compounds derived from oral contraceptives are of concern in some parts of the world. Available information does not allow for the evaluation of the significance of these contaminants in the BOBLME region.

Domestic sewage may also contain significant amounts of POPs, metals and oil. This is usually the case when industrial wastewater, urban runoff, and/or agricultural waste streams are mixed with the domestic wastewater stream.

Table 4.19 Relative importance of land-based and sea-based sources of the contaminant categories considered in the TDA.

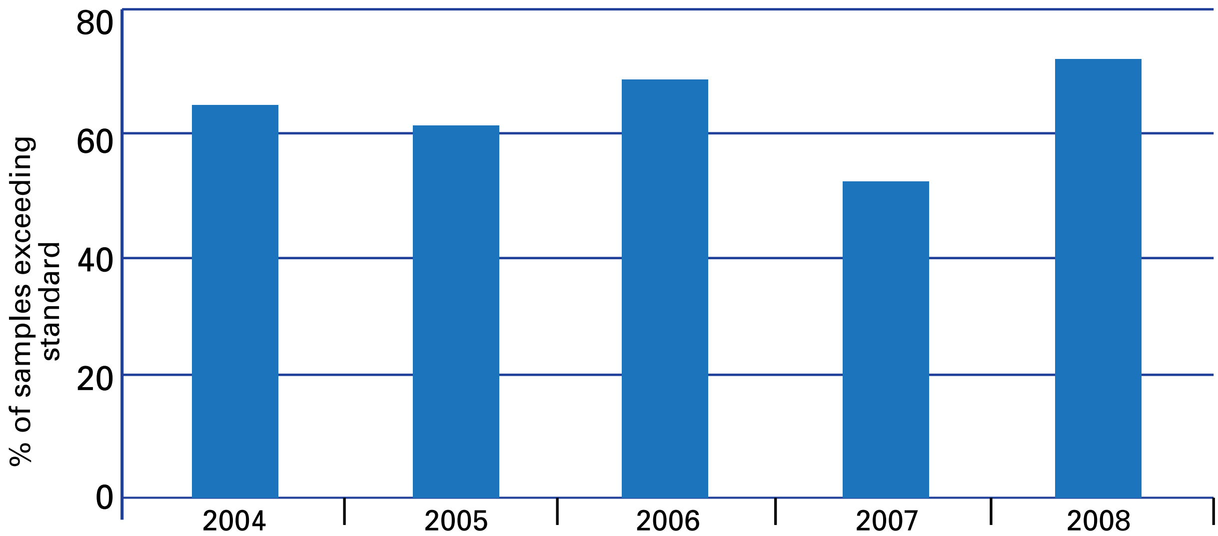
Contaminant category	Relative importance of land-based sources	Relative importance of sea-based sources
Domestic sewage (pathogens and organic load)	Overwhelmingly dominant	Minor
Solid waste/marine litter	Overwhelmingly dominant for solid waste in general Unknown for marine litter	Unknown for marine litter Discarded fishing gear a particular concern
Nutrients	Overwhelmingly dominant	Minor
Oil	Uncertain, likely to be 20–50%	Uncertain, likely to be 50–80%
Sedimentation	Essentially a land-based issue	Insignificant, dredging for navigation can be locally significant
Persistent organic pollutants (POPs)	Overwhelmingly dominant	Minor
Heavy metals	Overwhelmingly dominant	Minor, except for organotins

The level of sewage treatment is poor in all the BOBLME countries (Kaly, 2004) and most domestic sewage is discharged with no, or ineffective, treatment. An estimated 90 to 95 percent of domestic sewage in South Asian countries is discharged untreated (UNEP/DA, 2009). Almost all domestic sewage in Sumatra is discharged without treatment (Purnomohadi, 2003) and a large volume of sewage is also discharged untreated, or partially treated, in the other Southeast Asian countries bordering the BOBLME (UNEP/COBSEA, 2009). Despite investment in sewage treatment facilities in the 1990s, only about 53 percent of the population of Malaysia was serviced by sewage treatment by the mid-1990s, and this figure has declined since (Omar, 2003). Even when sewage treatment is available, it is often inadequate. Effluent from sewage treatment plants is still the main source of organic loading in Malaysian rivers, for example (see Section 2).

Sewage has been assessed as the highest-priority contaminant in the marine environment globally (GESAMP, 2001). Not surprisingly, given the large human populations and low levels of treatment in the region, sewage is a high, if not the highest, priority in the BOBLME countries. Kaly (2004) ranked sewage as the number one pollution priority on the basis of the BOBLME national reports; domestic sewage has also been identified as a major pollution problem by recent assessments of the South Asian Seas and East Asian Seas (UNEP/COBSEA, 2010).

All of India's major rivers are polluted (UNEP/DA, 2009) and high biological oxygen demand (BOD) and coliform bacteria counts show that sewage is the main source of pollution in both Indian rivers and coastal waters (CPCB, 2008; Sampath, 2003). Coastal impacts from urban waste – dominated by sewage – are very important in most of the major river basins of South Asia flowing into the Bay of Bengal, including the Mahanadi, Godavari, Krishna, and Cauvery systems of Peninsular India; the Ganges-Brahmaputra-Meghna (GBM) system shared by India and Bangladesh; the Karnafuli in Bangladesh; and the Ayeyarwadi in Myanmar (Ramesh *et al.*, 2009). Ramesh *et al.* (2009) assessed water pollution from municipal waste in the Walawe system in Sri Lanka to be of minor importance and confined to local urban areas. Nonetheless, sewage pollution is a problem in Sri Lankan coastal waters near cities and tourist areas (Joseph, 2003). Despite the relatively high proportion of the population serviced by some level of sewage treatment in Malaysia, more than half of water quality samples from coastal waters in the Andaman Sea and Straits of Malacca exceed Malaysian standards for contamination by sewage bacteria (Figure 4.15), and effluent from sewage treatment plants remains the largest source of organic loading in Malaysian rivers (see Section 2). Although Thai waters in the Andaman Sea are generally relatively clean, bacterial pollution from sewage is a problem in concentrated tourist areas (Juntarashote, 2003).

Figure 4.15 Percentage of marine water quality samples from the west coast of peninsular Malaysia exceeding the Malaysian Interim Marine Water Quality Standard for coliform bacteria of 100 MPN/100ml from 2004 to 2008.



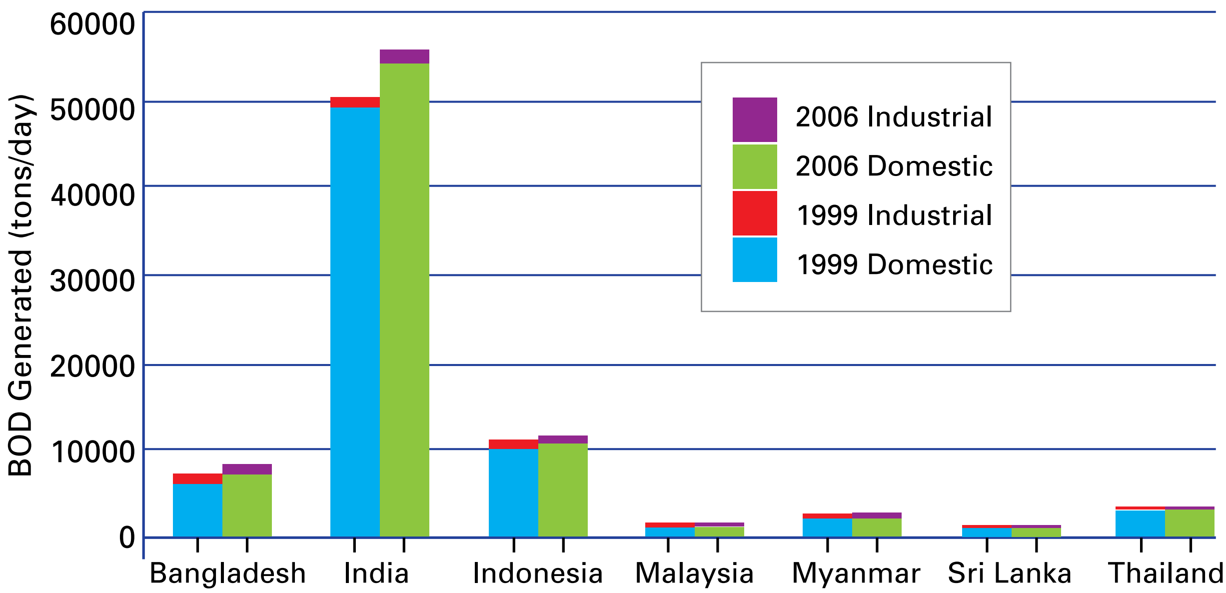
Source: DoE, 2005 to 2009.

Domestic sewage contains a broad range of disease-causing organisms, including viruses, bacteria, protozoans and worms (Chia, 2000). Sewage pollution in marine waters results in an estimated global burden of disease from respiratory and gastrointenstinal infections, as well as hepatitis, of about three million disability-adjusted life years (DALYs), comparable to the disease burden from major diseases including syphilis, trachoma, schistosomiasis, and nematode infections (Shuval, 2003; WHO, 2008). Although reliable data are not available for the BOBLME region, the impacts of sewage pollution of coastal waters on human health are likely to be substantial given widespread sewage pollution and the large coastal population. High levels of sewage bacteria in estuaries and coastal waters near concentrated urban areas are reported in the national reports of Bangladesh (Hossain, 2003); India (Sampath, 2003); Malaysia (Omar, 2003); Sri Lanka (Joseph, 2003); and Thailand (Juntarashote, 2003). Food poisoning is often associated with cultured bivalves in Malaysia (Omar, 2003), and a high proportion of the offshore marine catch in Sri Lanka is contaminated with sewage bacteria (Joseph, 2003).

4.3.2 Organic Load

Domestic sewage, industrial effluents, agricultural waste and aquaculture all contribute loads of biodegradable organic matter – causing biochemical oxygen demand (BOD) - to the environment, but sewage is probably the dominant contributor in the BOBLME. BOD is an accepted indicator of organic loading on aquatic environments. Sewage probably far outweighs industrial effluents in terms of BOD generation. Figure 4.16 shows estimated BOD generated by domestic sewage and industrial effluents based on the World Bank's World Development Indicators (World Bank, 2001, 2006, 2010). In terms of the initial generation of organic load, domestic sewage clearly dominates industrial generation.

Figure 4.16 Estimated daily generation of BOD from domestic sewage and industrial effluents in BOBLME countries in 1999 and 2006.

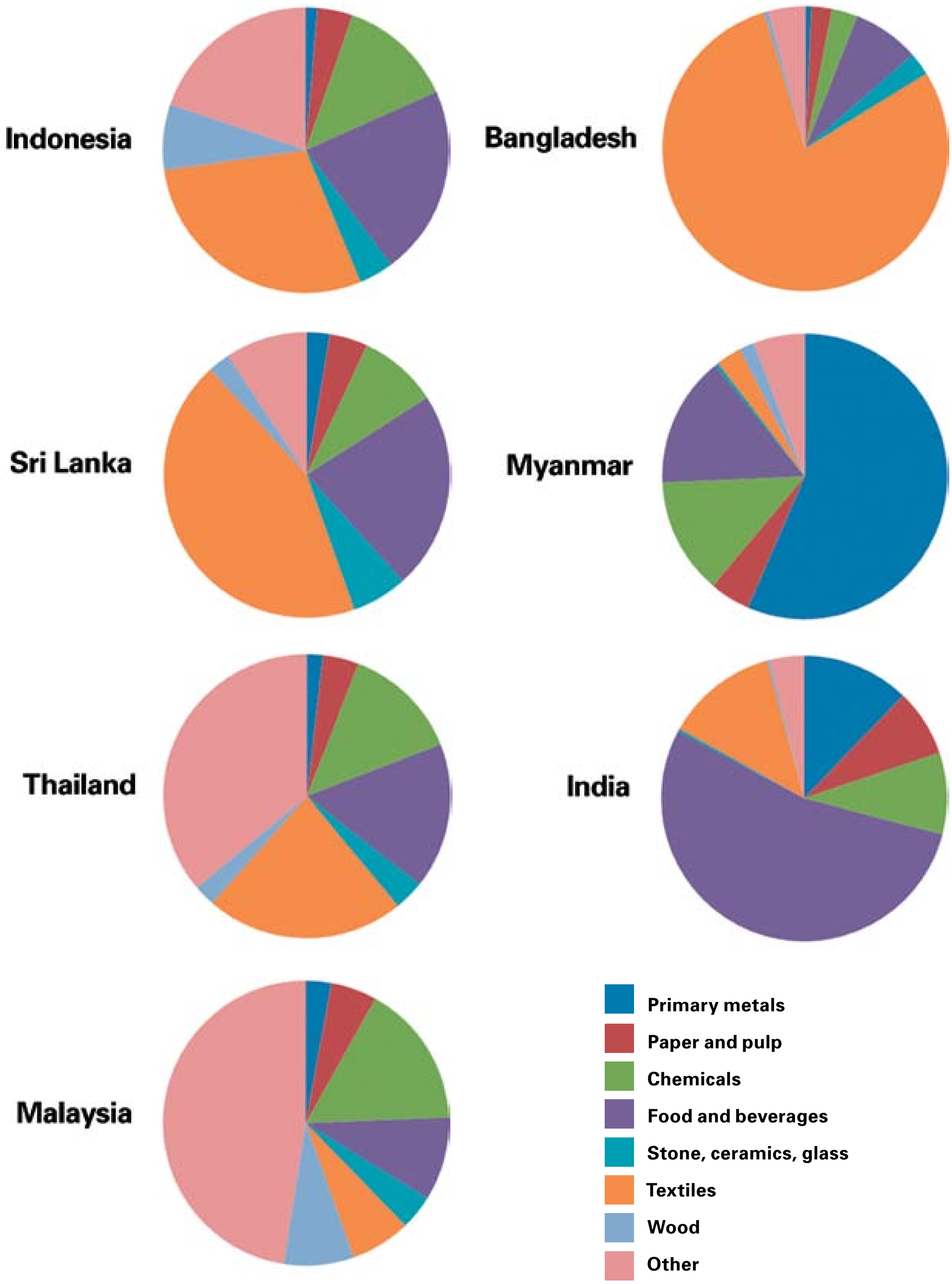


Source: Domestic sewage generation is estimated using the World Health Organization estimate of 0.05 kg/d/person (Economopoulous, 1993). Estimates of population and industrial BOD generation are from World Bank, 2001, 2006, 2010. Data are not available for the Maldives.

The relative contribution of different sectors to the industrial component of BOD generation varies markedly between countries (Figure 4.16). These data are national estimates and not specific to catchments in the BOBLME and they reflect waste generation rather than inputs to the marine environment. Nonetheless, the figure is likely to be generally indicative of the situation in the BOBLME. If anything, the relative contribution of industrial effluents may be reduced by a somewhat higher level of treatment in comparison to domestic sewage. Large industries often have waste treatment systems, as is the case in India (Sampath, 2003). An estimated 25 percent of industrial effluent in South Asian countries is treated before discharge, compared to five percent of domestic sewage (UNEP/DA, 2009). Nonetheless, treatment of industrial wastewater is minimal in some countries, such as Indonesia (Purnomohadi, 2003) and Sri Lanka (Joseph, 2003), and even with treatment industrial sources of BOD can be locally dominant because the effluent concentrations and volumes of these point sources can be high.

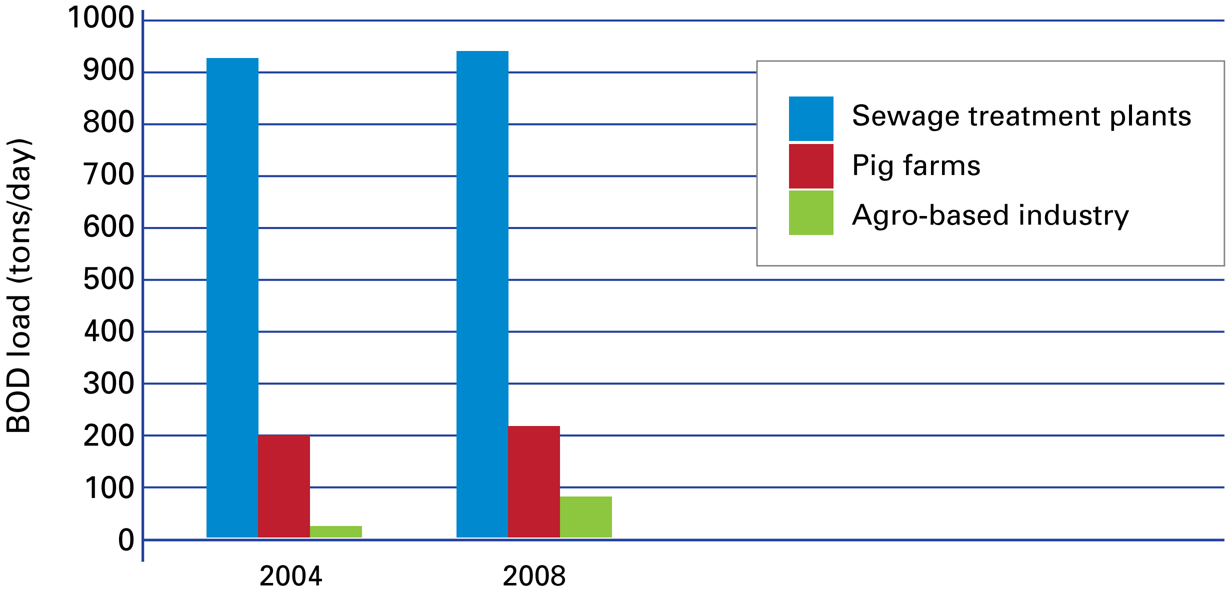
Agriculture is a significant contributor to organic pollution in some BOBLME countries, for example through runoff of animal wastes and discharges from agricultural processing industries. Regional statistics on the agricultural contribution to organic load are not available, but it is higher than the industrial contribution at least in Malaysia, where pig farms and agro-based industry are the second and third largest sources of BOD discharge into rivers, even though they represent a much smaller number of individual sources than manufacturing industries (Figure 4.17, Figure 4.18 and Figure 4.19). Nevertheless, BOD discharges of treated and partially treated sewage from sewage treatment plants far outweigh the contribution from agriculture. It should be noted that the sewage contribution represented in Figure 4.19 includes only sewage treatment plant effluents, and not discharges of untreated sewage.

Figure 4.17 Percent contribution of different industry sectors to industrial BOD generation in 2006.



Source: World Bank, 2010.

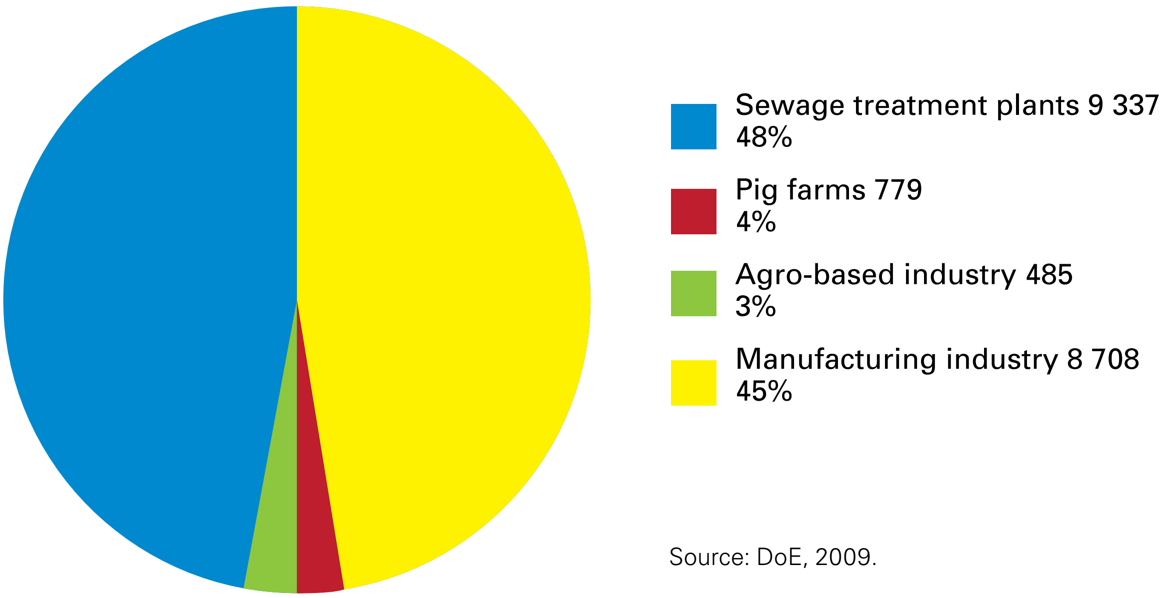
Figure 4.18 BOD discharges from sewage treatment plants, animal farms (pig farms), and agro-based industry in Malaysia in 2004 and 2008. BOD discharges from manufacturing industries were less than from agro-based industry.



Source: DoE, 2005, 2009.

In addition to sewage and agriculture, aquaculture facilities have been identified as a significant local source of BOD in Bangladesh (Hossain, 2003), India (Sampath, 2003), Malaysia (Omar, 2003), and Sri Lanka (Joseph, 2003).

Figure 4.19 Number of individual sources of BOD discharges to Malaysian rivers and coastal areas by source category in 2008.



Source: DoE, 2009.

Low levels of dissolved oxygen have been observed in proximity to large BOD sources in several BOBLME countries, generally in estuaries, lagoons, and near-shore coastal waters, with impacts decreasing offshore (Hossain, 2003; Sampath, 2003). Hypoxia from organic loading may be acute, but in general is probably localised around sources. However, it might also contribute to the risk of increasing basin-scale hypoxia driven primarily by agricultural and other sources of excess nutrients (see Section 4).

4.3.3 Solid waste/marine litter

The national reports of all countries ranked solid waste from domestic (including medical waste) and industrial sources as a high priority. In the Maldives, this was ranked as the highest priority (Ali, 2003). Urban areas and industries generate large amounts of solid waste, but reliable statistics on the quantities generated are unavailable. Much of the solid waste is not managed but is dumped haphazardly, including into waterways. Solid waste management systems that do exist are often unable to deal with the waste load. Dhaka is able to manage only about 55 percent of its municipal solid waste, for example (Hossain, 2003), and only 60 percent of domestic solid waste in India is collected. Even when solid waste is managed, waste from landfills often reaches the environment as a result of inadequate management or landfill capacity, or flooding (Kaly, 2004; UNEP/GPA, 2006). Landfills may also leach toxic substances and other pollutants.

Solid waste includes a very wide variety of materials. Much of municipal solid waste is food waste and other degradable material (UNEP/GPA, 2006), and industries such as jute, fish and shrimp processing, and slaughter houses, also generate large amounts of organic waste that may cause oxygen depletion of the water column and sediments, as well as health hazards. Medical wastes such as used hypodermic syringes and dressings are also a health risk. Industry generates large amounts of inorganic solid waste. Some 65 percent of industrial solid waste in India is inorganic material such as blast furnace slag and fly ash, for example (Sampath, 2003), and about a third of the solid waste generated in Male is construction waste (Ali, 2003). The textile industry generates large amounts of solid waste, in the form of fabric offcuts, in Sri Lanka (Joseph, 2003). Ship breaking is a significant source in India and Bangladesh (UNEP, 2009) adding to other pollutant categories. Non-degradable solid waste often causes severe habitat damage through burial and smothering.

Many components of solid waste are relatively immobile, so that impacts are localised, although they can be severe and widespread. Plastic waste is of particular concern because plastics persist in the environment for long periods and are transported for long distances in the ocean. Plastics are the main component of marine litter and have widespread effects on fauna that consume or become entangled in plastic litter (UNEP, 2009).

The relative importance of land-based and sea-based sources of marine litter is unknown, both in the BOBLME and globally. A 1995 assessment (NRC, 1995) concluded that shipping is the source of almost 90 percent of marine litter. Studies in Australia and the Republic of Korea, on the other hand, indicate that up to 80 percent comes from land-based sources. There are almost no reliable data regarding the sources, quantities in the environment, distribution, composition, or impacts of marine litter in the BOBLME (UNEP, 2008, 2009).

Derelict fishing gear is one component of marine litter and debris that is of concern in the BOBLME; this is unquestionably from sea-based sources. Abandoned, lost, or otherwise discarded fishing gear (ALDFG) causes damage through physical damage to coral reefs, seagrass beds and other habitats; through entanglement of marine fauna; and through "ghost fishing"; in which derelict nets or traps continue to capture and kill fish and other marine fauna. Thailand identifies ALDFG as the component of marine litter with the most serious impacts (UNEP, 2008).

4.3.4 Nutrients

Excessive inputs of nutrients to marine systems can lead to eutrophication, or excessive primary production that can result in overgrowth of coral reefs by algae; harmful algal blooms (HABs); the formation or expansion of low-oxygen (hypoxic) zones when phytoplankton biomass decays and consumes oxygen; and other problems. Nitrogen is usually the nutrient of most concern because nitrogen availability typically limits primary productivity in coastal marine systems.

Domestic sewage, runoff of fertilizers and animal manure from agriculture and some industrial effluents all contribute to anthropogenic nutrient inputs to the BOBLME. Aquaculture is an important source in some areas (Hossain, 2003; Omar, 2003; Joseph, 2003; Sampath, 2003). Large amounts of nitrogen also enter the BOBLME from the atmosphere as a result of fossil fuel combustion and industrial and agricultural atmospheric emissions. Fertilizers are the largest source of dissolved inorganic nitrogen (DIN) in the GBM system and most east Indian watersheds (Dumont *et al.*, 2005). In most other areas bordering the BOBLME, natural nitrogen fixation remains a dominant source (Dumont *et al.*, 2005), but human activities still contribute large amounts (Kaly, 2004). Sea-based sources do contribute nutrients via waste discharge and atmospheric emissions from fuel combustion, but it can safely be assumed that sea-based sources of nutrients are negligible in comparison to land-based sources.

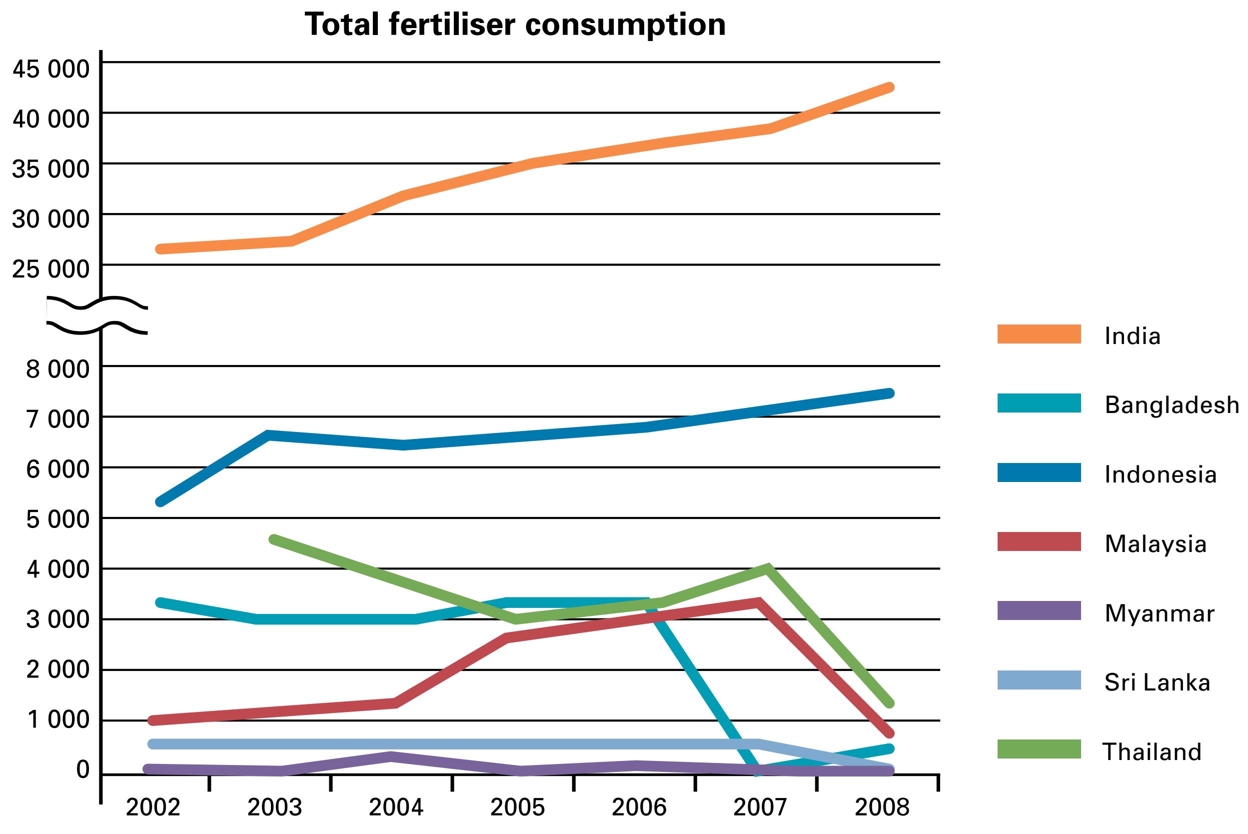
Despite high levels of anthropogenic nitrogen generation in watersheds linked to the BOBLME and enormous river discharge, river inputs of DIN remain relatively low (Naqvi *et al.*, 2006, 2010). The effects of anthropogenic nutrient inputs on the BOBLME are poorly studied (Hossain, 2003; Kaly, 2004). All the BOBLME national reports recognize risks associated with increasing nutrient inputs, and several identify problems of eutrophication in coastal wetlands and estuaries.

Many countries in the BOBLME experience HABs, sometimes referred to as "red tides", when dinoflagellates color the water. In Malaysia, HAB events are reported to be increasing, not only in frequency and severity, but also in terms of the occurrence of species with no prior record (Lim *et al.*, 2006). Lim *et al.* (2011) document several bloom events caused by dinoflagellate species, including shellfish poisoning events. Paralytic Shellfish Poisoning (PSP) is no longer restricted to Sabah coasts, with blooms reported for Peninsular Malaysia; on one occasion six persons were hospitalized after consuming contaminated benthic clams. There was one fatality associated with this case.

Mass fish-kill incidents around the BOBLME are thought to be related to changes in physical and chemical conditions in the marine environment: algal blooms, viral or bacterial infections, or a combination of these factors (BOBLME, 2010). Mass mortality of shrimps in coastal shrimp farms occurs almost every year in Bangladesh, costing the industry millions of dollars (BOBLME, 2011). HABs have been documented along the coasts of India, with the ill effects felt by society at large. Most of these reports are from the Arabian Sea, west coast of India, whereas its counterpart, the Bay of Bengal – with its large amount of riverine fresh water discharges, monsoonal clouds, rainfall, and weak surface winds that make the area strongly stratified – is different. The presence of frequently occurring HAB species in low abundance (≤ 40 cell L(-1) in stratified waters of the BOB may play a significant role in the development of pelagic seed banks, which can serve as inocula for blooms if coupled with local physical processes like eddies and cyclones (BOBLME, 2011).

However, the available data do not demonstrate that there are widespread increases in the frequency or severity of HABs in coastal or offshore areas, or that the naturally occurring hypoxic zone in the Bay of Bengal (see below) is expanding or intensifying.

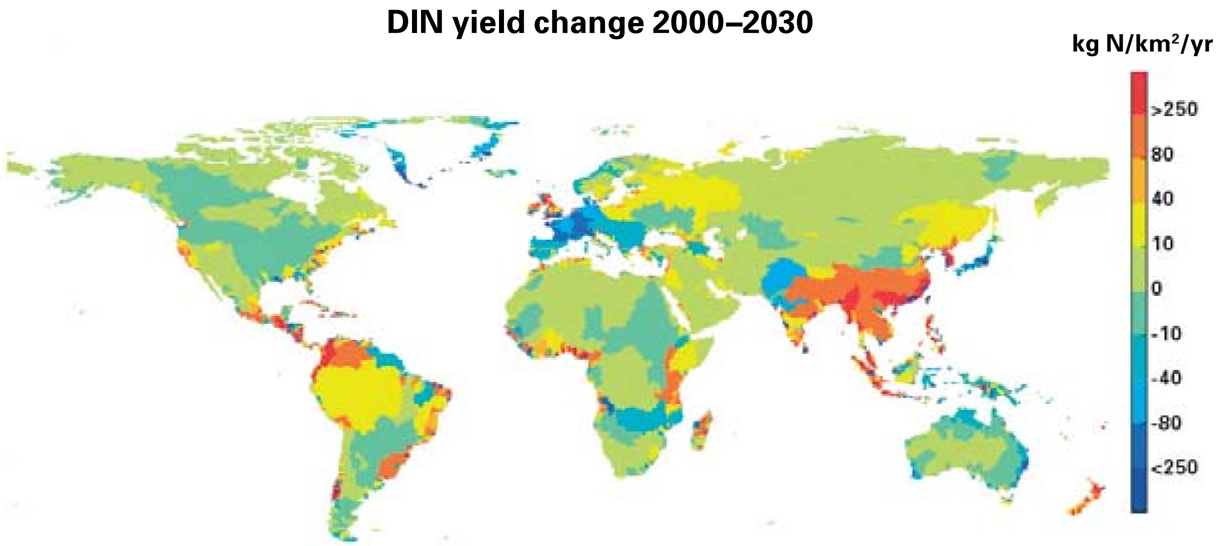
Figure 4.20 Trends in total fertilizer consumption 2002 – 2008 in the BOBLME countries, except the Maldives. The apparent declines in Thailand and Malaysia in 2008, and in Bangladesh in 2007 and 2008, may reflect changes in reporting rather than in actual fertilizer use.



Source: FAOStat statistical database.

Nutrient inputs are, however, increasing. Fertilizer use appears to be generally increasing regionally (Figure 4.20) and inputs from sewage will also increase with population growth if there is no compensatory improvement in sewage treatment. The Global Nutrient Export from Watersheds (Global NEWS) model projects the northern Bay of Bengal to be one of the areas of the world where the greatest increase in dissolved inorganic nitrogen (DIN) export could be expected between 2000 and 2030 (Figure 4.21) in one of the scenarios used (Seitzinger *et al.*, 2010). However, the predicted increase is less under other scenarios (Seitzinger *et al.*, 2010). The north-western BOBLME is also expected to experience among the world's greatest increases in atmospheric inputs of nitrogen from 2000 to 2030 (Duce *et al.*, 2008), Figure 4.22.

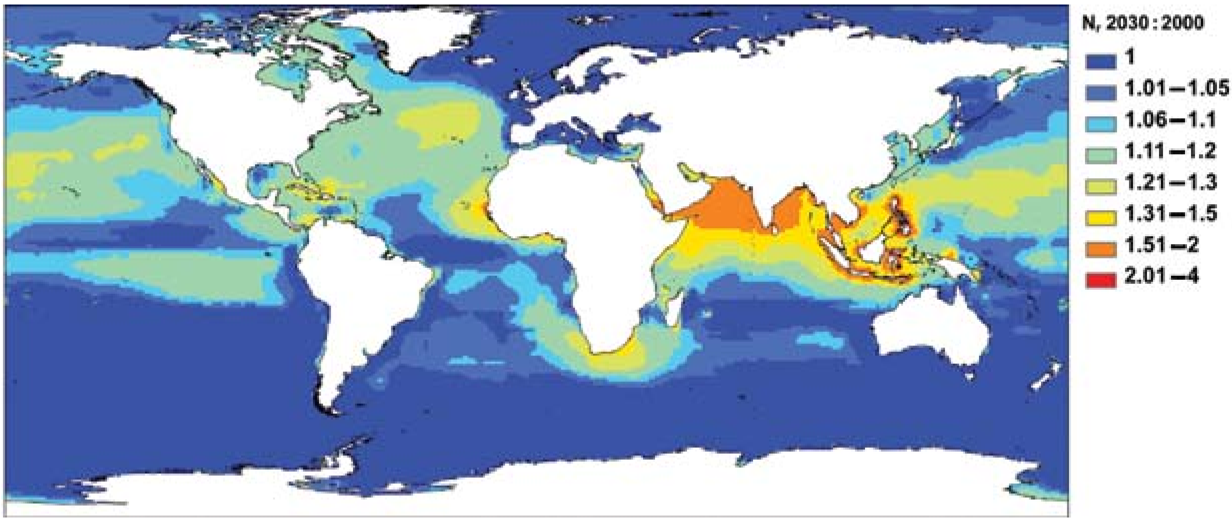
Figure 4.21 Predicted change in the generation of dissolved inorganic nitrogen (kg N/km^2/yr) in watersheds between 2000 and 2030 (adapted from Seitzinger *et al.*, 2010)



There is scientific consensus that anthropogenic increases in nutrient inputs to coastal areas are associated with increases in the frequency, severity, and duration of HABs (Heisler *et al.*, 2008; Rabalais, 2010) but present understanding is inadequate to predict the effects of the expected increases in nutrient inputs on HABs in the BOBLME. Hypoxia is often defined as a dissolved oxygen concentration of less than 2 ml/L, below which physiological and behavioural effects in fishes and invertebrates are observed (Diaz and Rosenberg, 1995). The Bay of Bengal has a persistent offshore oxygen minimum zone (OMZ) with less than 0.5 mg/L dissolved oxygen between about 100 and 600m depth (Helly and Levin, 2004), and dissolved oxygen levels below 1 ml/L are reached at a depth of 80 to 100 m in the northern Bay of Bengal (Hossain, 2003). The entire outer continental shelf of the Bay of Bengal is subject to hypoxic conditions from the OMZ (Levin *et al.*, 2009). The OMZ is considered to be a natural feature of the Bay of Bengal, as opposed to the coastal hypoxia due to eutrophication that has occurred in many other ocean areas (Helly and Levin, 2004; Diaz and Rosenberg, 2008). It is thought that hypoxia has not developed on the inner shelf in association with large rivers such as the GBM and Ayeyarwadi because of the relatively limited input of DIN and a lack of upwelling (Naqvi *et al.*, 2006, 2010). Hypoxic deep water is, however, known to seasonally intrude onto the continental shelf of Myanmar (Myint, 2003).

The continued resilience of the BOBLME with regard to hypoxia in the face of continued increases in nutrient inputs is uncertain. Rabelais *et al.* (2008) note that the Bay of Bengal is an open system compared to other ocean areas that receive high nutrient inputs, lacking physical features such as shallow sills or narrow entrances that restrict water exchange and the replenishment of oxygen. This exchange will determine the system's response to increased nutrient inputs (Rabelais *et al.*, 2008). The development of coastal hypoxic zones or a shoaling of the deep-water OMZ that leads to widespread intrusion of hypoxic water onto the shallow shelf (as has been observed on the Oregon shelf of the northeast Pacific in recent years [Chan *et al.*, 2008]), could have significant impacts on ecosystems and fisheries of the BOBLME. It should be noted in this regard that global warming may lead to a general decline in marine dissolved oxygen concentrations (Keeling and Garcia, 2002; Levin *et al.*, 2009). Furthermore, the development of coastal hypoxic zones due to eutrophication in other parts of the world has typically lagged behind increased nutrient inputs by a decade (Diaz and Rosenberg, 2008), so even present nutrient inputs could still lead to increasing hypoxia in coming years.

Figure 4.22 Increase in atmospheric nitrogen deposition between 2000 and 2030, shown as the ratio of predicted deposition in 2030 to deposition in 2000.



Source: Duce *et al.*, 2008.

4.3.5 Oil

All of the BOBLME national reports identify coastal oil pollution as a problem, with the Maldives considering oil pollution the top national priority (Ali, 2003). Oil is the third most common pollutant in Malaysian coastal waters, with 35 to 49 percent of coastal monitoring sites exceeding the Malaysian water quality standard for oil and grease over the period 2004 to 2008 (DoE, 2005, 2006, 2008), but in general there is little available information on the extent or impacts of oil pollution in the BOBLME.

Land-based sources of oil pollution in the BOBLME include municipal runoff and spills and operational discharges from coastal refineries and other petroleum infrastructure. Sea-based sources include tanker spills; operational discharges of bilge and ballast water; dumping of waste oil; spills during transfer and handling of oil cargoes; and operational discharges and spills from offshore oil and gas extraction. In Bangladesh and India, ship breaking is also a significant source of oil pollution in the vicinity of ship breaking activities (Hossein, 2003; Sampath, 2003).

Globally, estimates of the relative contributions of land-based and sea-based sources of oil pollution in the marine environment vary considerably. GESAMP (1993), for example, estimated that land-based runoff accounts for some 56 percent of oil inputs to the oceans (excluding natural seeps), while NRC (2002) estimated this contribution at 21 percent. In the BOBLME, the sea-based contribution could be toward the higher end of the global estimates given the high shipping traffic and large number of small vessels operating in coastal waters, but quantitative estimates of the relative importance of land-based and sea-based sources of oil pollution are not available.

Of the sea-based sources, routine operational discharges are almost certainly more important than catastrophic oil spills, even though the risk of such spills is high due to the high volume of tanker traffic, particularly in the Straits of Malacca. Operational discharges account for about 80 percent of sea-based oil inputs to the marine environment in India, for example (Sampath, 2003). Some of these operational inputs come from large ships, in particular oily ballast water from tankers. Bangladesh allows the direct discharge of tanker ballast (Hossain, 2003). Where there are restrictions on oil discharge from ships they may be ineffective. For example, the Port of Colombo has receiving facilities for waste oil from ships, but the final disposal of this oil is unregulated (Joseph, 2003).

Sea-based oil discharges from small vessels are probably very important relative to discharges from large ships. This is owing to the vast number of small vessels operating in BOBLME coastal and river waters and a general lack of controls or waste oil reception facilities. At least 50 percent of oil entering the marine environment in India and Bangladesh comes from river craft and small steamers (UNEP/GPA, 2006), and it is highly likely that small vessels, particularly the dumping of waste oil from such vessels, is a major source of oil pollution in most other BOBLME countries.

Land-based sources of marine oil pollution are also probably mainly operational, such as the dumping of waste oil from vehicles, workshops, manufacturing facilities, and routine small spills at refineries and transfer facilities (Hossain, 2003; Joseph, 2003; UNEP/DA, 2009).

4.3.6 Sedimentation

The Bay of Bengal receives a huge sediment load from the GBM system, the Ayeyarwady and several rivers in eastern India (Ramesh *et al.*, 2009; UNEP/GPA, 2006). The high natural sediment load into the BOBLME has been increased greatly by human activities. This is primarily a result of agriculture, forestry, and other changes in land use, although sewage and other waste discharges can contribute large amounts of suspended solids at a local scale (Kaly, 2004; Ramesh *et al.*, 2009). Dredging for port development and navigation channels can also re-mobilise sediments at a local scale.

Elevated sedimentation can adversely affect sensitive ecological communities through a reduction of light penetration through the water column and smothering of benthic communities when suspended solids settle on the bottom. Coral reef and seagrass communities are particularly sensitive to these effects. Given the very high natural sediment loads in the BOBLME, the ecological communities in areas subject to large river inputs are generally sediment-tolerant. The effects of increased sedimentation are generally localized in areas where sediment inputs are naturally relatively low but have been increased by land-use change.

4.3.7 Persistent organic pollutants/persistent toxic substances

The term "persistent organic pollutants" (POPs) is often used in a broad sense to refer to organic compounds that persist for long periods of time and undergo long-range transport in the environment, and are toxic to and tend to accumulate in the tissues of organisms. In recent decades, "POPs" has increasingly tended to refer specifically to compounds regulated under the Stockholm Convention on Persistent Organic Pollutants. The terms "persistent toxic substances" (PTSs) and "persistent, bioaccumulating, and toxic (PBT) substances" are often used to refer to organic compounds with the characteristics of environmental persistence, tendency for bioaccumulation, and toxicity, without reference to their status with regard to the Stockholm Convention. The TDA has been conducted in the context of PTSs.

The major sources of PTSs in the marine environment are agricultural pesticides, industrial processes, landfills, and waste burning. PTSs may also be present in sewage, sometimes from discarded household chemicals, but more often when industrial waste streams are mixed with domestic sewage. This is likely to be common in BOBLME countries where separation of waste streams is unusual, especially from small industries. Domestic sewage treatment is often ineffective in removing PTSs.

Little information is available on the quantities and trends of PTS emissions, levels in the environment, and ecological and human health impacts in the BOBLME region. Measurements of PTS concentrations in water, sediments, and organisms in the region are sparse, in large part because of limited capacity for laboratory analysis (UNEP Chemicals, 2002, 2003).

Organochlorine pesticides used for agricultural and domestic purposes are one important source of PTSs in the environment, and moderate to high levels of organochlorine pesticides have been observed in the BOBLME (UNEP Chemicals, 2002, 2003). BOBLME countries have banned the use of most of these pesticides, although DDT (dichlorodiphenyltrichloroethane) is still used for malaria control. Although little quantitative information is available, levels of PTS pesticides in the region generally appear to be declining (Ramesh *et al.*, 2009; Sampath, 2003; UNEP Chemicals, 2002, 2003). Some stockpiles remain (UNEP Chemicals, 2003) and organochlorine pesticides may still be in use in some areas. Ramesh *et al.* (2009) report that 79 percent of pesticides used in the Godavari basin are organochlorines, for example.

The levels and effects of PTSs produced as industrial chemicals are also poorly known, but considerable progress has been made in banning or regulating many of these chemicals. Industrial emissions of at least some PTSs, however, could be increasing, given the growth of industry in the region, particularly the chemical industry.

Polychlorinated dibenzo-p-dioxins (PCDDs) and Polychlorinated dibenzofurans (PCDFs), often referred to simply as "dioxins" and "furans", have been identified as the PTSs of most concern to countries in the region. Dioxins and furans are unintended by-products of some industries including chloralkali, pulp and paper, and some plastics and chemicals manufacturing, as well as from the combustion of waste and biomass. The widespread open burning or low-temperature incineration of solid waste in the region is considered a potential major source of dioxins and furans (UNEP Chemicals, 2002, 2003).

PTSs are an issue of concern for the BOBLME countries given their persistence in the environment and potential impacts on organisms and human health. The lack of information regarding the levels and impacts of POPs in the environment is regarded as a serious information gap.

Minor amounts of PTSs are generated from sea-based activities, including shipping and offshore oil and gas production, but land-based sources are overwhelmingly dominant.

4.3.8 Heavy metals

Major anthropogenic sources of heavy metals in the marine environment include tanneries, fertilizer production, chloralkali plants and the paint and textile industries. Ship-breaking activities can also be a source of heavy metals. As with PTSs, high levels of heavy metals may be present when industrial waste streams are mixed with sewage.

Heavy metal pollution associated with industrial areas was identified in the national reports of Bangladesh, India, Indonesia, Malaysia and Sri Lanka, but the extent of heavy metal contamination in the BOBLME is not known (Kaly, 2004). In most cases, heavy metal contamination is probably localized near the source, because most metals are not transported long distances in the marine environment (GESAMP, 2001). The exceptions are the volatile metals lead and mercury, which can be transported long distances in the atmosphere. Lead contamination of the marine environment is a decreasing concern because leaded fuels, a dominant source, are being phased out. Both lead and mercury are of particular concern in terms of toxic effects when complexed in organic form. Lead is added to fuels in organic form, and organomercury compounds are formed through biological transformation in sediments.

Data on the distribution, levels, or effects of organolead and organomercury compounds in the BOBLME are not available (UNEP Chemicals, 2002, 2003). Organolead compounds are probably of decreasing concern given the phase-out of leaded fuels, but there is increasing international concern about anthropogenic mercury contamination.

The sources of heavy metal contamination of the marine environment are overwhelmingly land-based, with the exception of tributyl tin (TBT), which has been widely used in antifoul coatings for ships and maritime infrastructure. The status of organotin contamination in the BOBLME has not been assessed regionally (UNEP Chemicals, 2002, 2003), but tributyl tin is being removed from use globally, so that organotin contamination can be expected to decline in future.

5. Transboundary nature of the issues

5.1 Overexploitation of marine living resources

5.1.1 Transboundary nature of fish

Many of the living marine resources on which the BOBLME's fisheries are based traverse the international boundaries of adjacent, and sometimes non-adjacent, countries and many of them are targeted by several BOBLME countries.

Table 5.1 lists several important fishery species/species groups that range across BOBLME country borders. Large pelagic species, such as tunas and billfishes, range over large ocean spaces and pass through the EEZs of many countries both inside and outside the BOBLME.

Smaller pelagic species, such as anchovies, herrings and shads are not as mobile, but usually migrate through the coastal waters of two or more neighbouring countries. Some small pelagic species, e.g. the rainbow sardine (*Dussumieria acuta*), are distributed along the coasts of all BOBLME countries; their range may extend well beyond the BOBLME.

Resources that appear to be sessile or only locally mobile, such as reef fish, lobsters, sea cucumbers and corals, often have patterns of larval dispersal that give their distribution a transboundary dimension. Tropical lobsters (*genus Panulirus*), for instance, have a pelagic larval lifespan that may last from four to 12 months, during which period the larvae may travel thousands of kilometres from the place of birth to the place of adult settlement. Some demersal species, such as the sea catfish (family *Ariidae*) are also transboundary.

Unsustainable fisheries based on these shared or straddling stocks, and unsustainable activities based on the critical habitats that support these stocks in one country, may adversely affect recruitment that originates in another country but replenishes the stocks in the first country, or vice-versa.

5.1.2 Transboundary nature of fishing

The Sea Around Us Project (2010) has estimated the origin of each country's landings, based on known access agreements (both formal and informal) (Table 5.2). This does not include IUU fishing in other countries' EEZs. According to SAUP, most BOBLME countries fish to some degree in other countries' EEZs. The most wide-ranging fleet is that of Thailand which fishes in Indonesia, Malaysia, Myanmar, Bangladesh, India (including Nicobar and Andaman Islands) and Sri Lanka. According to SAUP, only a small percentage of Thailand's catch is taken in the Thailand EEZ – much more is taken in Myanmar and Malaysian waters. This figure may overestimate the catch outside the Thailand EEZ but a well-researched study published by the United Nations (Panjarat, 2008), also highlighted the spread of Thai fishing vessels throughout the BOBLME: 4 000 large Thai vessels operate in the EEZs of other coastal states (mainly Myanmar and Malaysia) and only half of these have licenses.

The least wide-ranging fleet is that of the Maldives which fishes almost exclusively inside its own EEZ. Other distant water fleets (mainly Japan, South Korea, China and Taiwan [Province of China], Singapore, European Union [Spain and France]) have all been active in the BOBLME (Table 5.1). As in other parts of the world, foreign access was encouraged by many BOBLME countries, but fishing activity has changed over time. Japan was the most active player in early years.

In recent years, foreign access has been allowed in Myanmar, the Maldives and India under joint venture arrangements. Most foreign fishing reported by SAUP in 2006 occurred in the Maldives by "other" countries.

Crews are also often shared across boundaries. This is particularly prevalent on Thai fishing vessels where many of the crew (apart from the Skipper and senior crew) are from Myanmar and some from Cambodia. The Asia Foundation has reported the results of a survey (Anon, 2010) that identified and interviewed more than 60 Cambodian men who were trafficked onto Thai fishing boats since 2007.

IUU fishing has been identified by BOBLME countries as a major problem and highlighted in many regional and international fora (e.g. APFIC, 2007). The general conclusion has been that IUU fishing is costing the region significant amounts in lost revenue and is resulting in overexploited fisheries and adverse social consequences. It is important to separate IUU fishing into different categories because a range of regulatory and enforcement regimes apply to each situation. These categories are:

- national vessels in national waters
- foreign vessels in national waters
- vessels fishing on the high seas

Table 5.1 Examples of transboundary species/species groups in the BOBLME.

Common name	Scientific name	Countries primarily concerned
Migratory tunas		All
e.g. Skipjack tuna	*Katsuwonus pelamis*	
Yellowfin tuna	*Thunnus albacores*	
Bigeye tuna	*T. obesus*	
Coastal tunas		All
e.g. Frigate tuna	*Auxis thazard*	
Kawa kawa	*Euthynnus affinis*	
Indian mackerel	*Rastrelliger kanagurta*	All
Short mackerel	*Rastrelliger brachysoma*	Indonesia, Malaysia, Thailand, Myanmar and Sri Lanka
Spanish mackerel/seerfish	*Scomberomorus spp.*	All
Oil sardine	*Sardinella longiceps*	India, Indonesia and Sri Lanka
Hilsa	*Tenualosa ilisha/toli*	All except Maldives
Bali sardinella	*Sardinella lemuru*	Thailand and Indonesia
Rainbow sardine	*Dussumieria acuta/elopsoides*	All, especially southern India/Sri Lanka
Indian pellona	*Pellona ditchella*	All except Maldives
Goldstripe sardinella	*Sardinella gibbosa/fimbriata*	All except Maldives
Indian scad	*Decapterus russelli*	All
Indian halibut	*Psettodes erumei*	India, Indonesia, Malaysia, Myanmar, Sri Lanka and Thailand
Bombay duck	*Harpodon nehereus*	India, Bangladesh, Indonesia, Malaysia and Myanmar
Black pomfrets	*Parastromateus niger*	India, Indonesia, Malaysia, Sri Lanka and Thailand
Sea catfish	*Arius maculates, A. thalassinum*	All except Maldives

Source: modified from Preston, 2004.

Table 5.2 Origin of catches by countries fishing in the BOBLME.

	Country fishing								
Country's EEZ	Indonesia	Malaysia	Thailand	Myanmar	Bangladesh	India	Sri Lanka	Maldives	Others
Indonesia	71.0	26.3	9.1	–	–	2.2	2.7	–	3.3
Malaysia	17.1	61.9	23.3	–	–	–	–	–	57.6
Thailand	7.5	9.9	15.2	3.4	–	0.8	0.2	–	0.1
Myanmar	–	0.2	47.8	93.3	11.0	8.4	2.4	–	0.5
Bangladesh	–	–	1.7	3.0	83.3	1.6	0.7	–	–
India	3.8	1.0	2.5	0.4	5.8	77.0	63.7	–	3.0
Sri Lanka	0.5	0.6	0.5	–	–	8.7	30.3	–	1.9
Maldives	–	–	–	–	–	1.3	–	100.0	33.6

Source: SAUP, 2010.

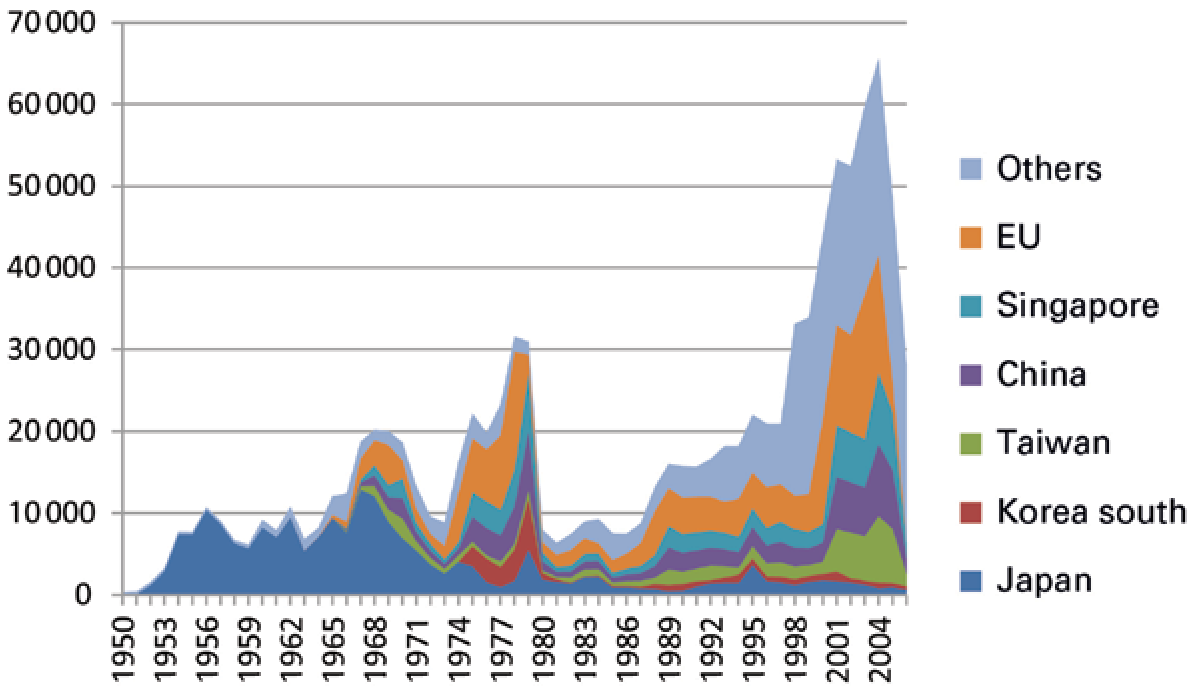
Both the first two categories are transboundary issues in the BOBLME. The first category is common to all countries, causing a major loss of revenue from fishing, depletion of resources and conflict. The second category is a problem pertinent to all BOBLME countries and the major IUU issues identified are reasonably consistent across the countries.

In the national category, nationals using prohibited gears or methods are the main problems. In terms of foreign fishing, unauthorized incursions into the countries' EEZs by foreign fishing vessels – either commercial or industrial vessels from distant-water fishing nations, or artisanal or commercial fishers from one BOBLME country fishing in the waters of another – is similarly a concern shared by all countries.

A large proportion of the national fleets is not registered and although in some countries there is no legal requirement for registration, and so this does not strictly constitute IUU fishing, it is of regional concern. A robust and enforceable vessel registration and licensing system is a cornerstone of any fisheries management programme; it is vital for measuring, and therefore managing fishing effort and fishing capacity.

IUU fishing by foreign vessels in national waters has been repeatedly raised as an issue that should be addressed. IUU fishing by foreign fleets is particularly common on the borders between India and Sri Lanka, Myanmar and Thailand and Thailand and Malaysia.

Figure 5:1 Catches of fish by distant water fishing nations in the Bay of Bengal.



Source: SAUP, 2010.

5.1.3 Transboundary nature of markets

Despite its perishable nature, fish is the most traded commodity in the world (Figure 5.2). World exports of fish and fishery products reached USD85.9 billion in 2006 (FAO, 2008).

In real terms (adjusted for inflation), exports of fish and fishery products increased by 32.1 percent in the period 2000 to 2006. Exports of fish for human consumption have increased by 57 percent since 1996. The fishery net exports of developing countries (i.e. the total value of their exports less the total value of their imports) continue to be of vital importance to the economies of many fish-exporting developing countries, including many BOBLME countries. They have increased significantly in recent decades, growing from USD1.8 billion in 1976 to USD24.6 billion in 2006. Growth is predicted to continue, but mainly in developing countries (Delgado *et al.*, 2002). Developing countries have gone from being net importers of fisheries products to large net exporters over the past 30 years. World food fish consumption is projected to grow 0.5 percent faster than the population worldwide, with 36 percent of food fish consumption growth in 2020 coming from China, a near neighbour of BOBLME countries, and 61 percent from other developing countries.

A major driver is the expansion of large retail chains cashing in on the demand for fish. In the United States for example, the top 20 retailers have captured 52 percent of food sales, and in Germany and the United Kingdom, 82 percent and 60 percent of fresh seafood sales, respectively.

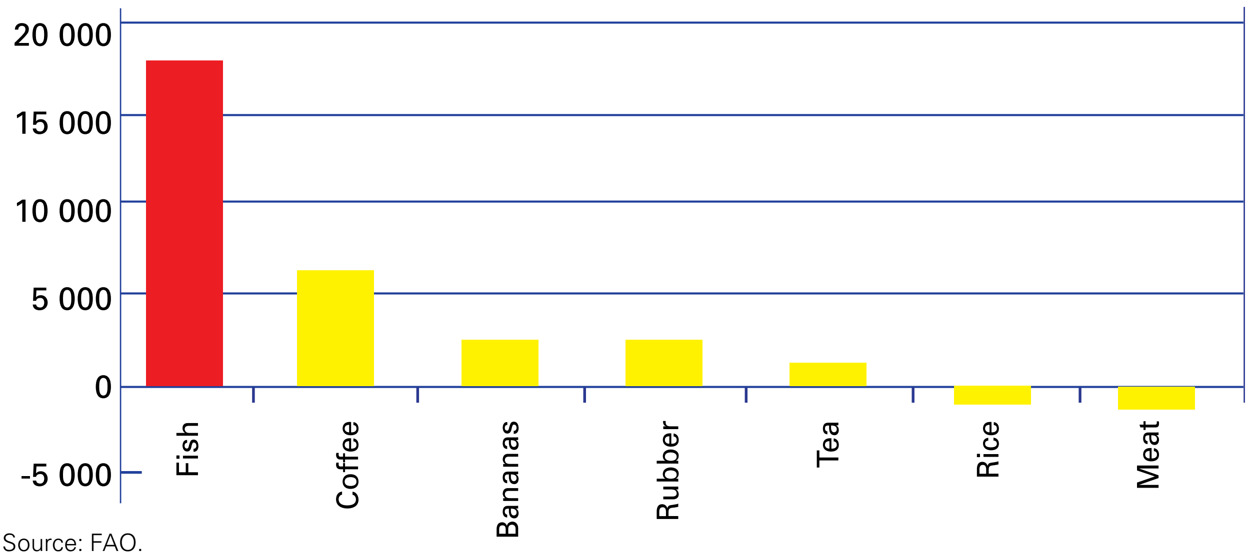
This globalization presents many advantages for developing countries in terms of their supply of natural resources, their cost of production and flexibility in small-scale enterprises. However, it is also putting increasing pressure on already stretched limits of fisheries production and is providing incentives for governments to insist on "increased production", rather than a more thorough consideration of the limits to growth and the need for "increased value".

Emerging markets for fishmeal and *surimi* are also encouraging the capture of small, low value/trash fish. The total production of trash fish is around 900 000 tonnes in the BOBLME (interpolating for countries where no data are available). Percentage composition of low value/trash fish ranges from 5.6 percent in Indonesia, where trawling is banned, to as much as 34.7 percent in Thailand where trawling is a very common fishing method (APFIC, 2011). In Thailand, low/value trash fish constitute as much as 64 percent of the otter trawl catch.

In countries where the demand for aquaculture feed is high, many of the small, low value/trash fish are either converted to fishmeal and included in formulated aquaculture diets, or fed directly into fish cages. Because of the demand and large quantities that the market can absorb, the incentive to fish with non-selective small-mesh fishing gear is high. Increasing demand from the growing aquaculture industry in the Bay of Bengal could begin to drive direct targeting and mesh size reductions, as seen in the South China Sea region.

Threadfin bream, lizard fish, bigeye, croaker and goatfish are becoming more economically important demersal fishes as they are now commonly used as raw materials for surimi manufacture in the region. The total production for the region is growing and is roughly estimated at 75 000 tonnes, requiring approximately 262 500 tonnes of raw material (APFIC, 2011). Many countries in the Bay of Bengal region do not produce *surimi* in significant quantities, implying that the facilities to produce *surimi* are not yet established (there is a technological lag). It may also be that fish is utilized directly for consumption and thus there is less pressure to process fish into surimi and improve utilization for human consumption (especially products of trawl fisheries). In countries where the facilities for *surimi* manufacturing exist, surimi species make up between five percent (Thailand) and 16 percent (India) of the total catch.

Figure 5:2 Global trade in commodities from developing countries (10^{-3} tonnes).



Source: FAO.

Figure 5:3 Estimates of the catch of low value/trash fish and its percentage of the total catch in BOBLME countries.

	Tonnes	% total catch
Indonesia	**34 500**	**5.6%**
Thailand	**215 571**	**34.7%**
Malaysia	**206 105**	**30.7%**
Myanmar	**No data available**	
Bangladesh	**85 843**	**17.6%**
India	**347 862***	**14-32%****
Sri Lanka	**No data available**	
Maldives	**No data available**	

* Estimate for whole of India, ** Percentages for east coast of India. Source: APFIC, 2011.

5.1.4 Transboundary constraints to better management

All the countries of the BOBLME are experiencing difficulties in implementing better fisheries management. Despite relatively good fisheries legislation and policies, best practice fisheries management is difficult to find. Malaysia and the Maldives, because of their smaller populations and greater economic development probably lead the field, but here too there are problems. The main constraint is that the fisheries have either been controlled by traditional customary practices that have been eroded by the introduction of western-style government and bureaucracies, or inadequately managed by central governments in an ineffective "top-down" approach. The "open access" nature of fishing has reached a point where countries have been hindered by an unwillingness or inability to bear the short-term social and economic costs of reducing fishing. Some local success is apparent in certain localities where co-management has been trialed (usually supported by foreign aid), but co-management is yet to be mainstreamed into national systems.

All countries of the region face similar challenges in terms of lack of government resources; lack of human capacity; and social and market systems that provide perverse incentives to good management. This transboundary dimension of overexploitation of marine living resources sends a strong signal to the countries of the BOBLME to cooperate and share experiences in meeting these challenges. The BOBLME project will be focusing on three key fisheries – sharks, hilsa and Indian mackerel.

5.2 Degradation of critical habitats

5.2.1 Transboundary nature of mangroves, coral reefs and seagrass

Mangrove forests are found in all the BOBLME countries and, in some, their coverage is of global importance. Moreover, the Sunderbans, shared by India and Bangladesh, is the largest mangrove system in the world. This area has been declared a Biosphere Reserve by the government of India.

Similarly, coral reefs are found in all the BOBLME countries and some are of global significance. For example, the Mannar coral reef system is shared by India and Sri Lanka and the Indian part of the system has been designated a UNESCO Biosphere Reserve.

Seagrass is usually found on mud/sand flats or between coral reefs and mangroves and, in some cases is considered a nuisance, e.g. outside hotels in the Maldives. Seagrass beds are found in all the BOBLME countries, but information on their regional areal extent and current status is unavailable.

Of major transboundary significance are losses in biodiversity and fisheries productivity that are associated with the degradation of critical habitats. The threatened (and extinct) species of the BOBLME are closely associated with at least one of the three habitats identified as being of critical importance in their own right to the maintenance of the BOBLME region's biodiversity. In the BOBLME region at least six areas have been identified as having regional priority: the Sunderbans, Palk Bay and the Gulf of Mannar, Marine Wandur National Park in the Andaman and Nicobar Islands, the Maldives Atolls and Mu Ko Similan and Mu Ko Surin National Parks in Thailand. In the Sunderbans, there is a worrying number of endangered species of amphibians, birds, mammals and reptiles and the area has already experienced species extinctions.

5.2.2 Coastal development

In all the BOBLME countries industrialization is increasing rapidly. Industrial activities are centred on transforming raw materials into steel, paper, chemicals, paints, plastics and textiles; also important are leather tanning, oil refining, and electricity generation. These resource-intensive activities produce large quantities of toxic and hazardous wastes. Raw material extraction (e.g. mining and logging) is environmentally damaging, both in situ and downstream (through, for example, ecosystem disturbance and destruction, erosion and sedimentation). Where ports and harbours include industrial facilities, they should be included in the category of industry. (Kaly, 2004).

Tourism is a source of substantial foreign earnings, but the resultant damage to critical habitats has usually not been considered. Resorts, roads and whole towns are being developed close to the sea without taking into account erosion and sea level rise. Tourists are often from other countries and are able to inject local economies with funds, but in many instances they do not realise the damage their requirement for services and infrastructure does to the environment.

Tourist activities and the consequences of operating a tourism industry can have deleterious effects on reefs. Without the education of divers and the enforcement of regulations, the damage to coral will increase far beyond repair. Boat anchors are very destructive and moorings are often badly placed. The Thai Government has rules for mooring at dive sites in the Andaman Sea and it provides non-destructive moorings which volunteers and National Park wardens distribute in sensitive places. This is a good practice that might be followed by other countries of the region. Trampling, touching and collecting curios from coral reefs are also highly damaging.

Deforestation and the resultant runoff after monsoon rains may impact other countries, particularly where rivers are large. Upstream dams have been built on large rivers in many countries causing less scouring by floods and therefore more silt in down-river areas. This silt has, in turn, caused more flooding downstream which may increase water turbidity and affect the three critical habitats. For example, the Sunderbans mangroves are decreasing in area, partly as a result of rising sea level, but also because deposition of silt is occurring in the delta of the Ganges River. India and Bangladesh share the problem of mangrove degradation and this is an important transboundary issue. The Sunderbans in West Bengal are designated a UNESCO Biosphere Reserve and wetland of international importance under the Ramsar Convention. Loss of mangrove habitat and the corresponding loss of fish nursery area will be felt in both Bangladesh and India. In the Sunderbans, the Maldives and elsewhere in the BOBLME, mangroves provide vitally important protection against erosion and storm waves.

5.2.3 Transboundary trade

One of the common drivers of critical habitat degradation is the desire to boost export earnings and trade in the BOBLME countries. The best example of this is the export of cultured shrimp that caused the concurrent destruction of mangroves, especially in the past. As the demand for shrimp and fish increases both locally and internationally, the temptation to exploit mangrove land by clearing and installing in shrimp farms increases. Once the shrimp farms have failed – often as a result of acid sulphate soils, disease and overuse of antibiotics – they are turned into salt farms, abandoned or taken over by local people for a very basic form of rearing fish.

There are many less well-known impacts on critical habitats caused by transboundary trade. For example, trade in mangrove products (shrimp, charcoal, wood, honey, etc.) with countries nearby, or globally, is having a major impact on the sustainability of mangroves. The aquarium and live fish trade also encourages local people to dynamite or poison reefs to capture fish. As China becomes more affluent this trend will increase unless strict regulations are enforced and alternative means of obtaining coral fish (both live food fish and aquarium fish) can be developed. Destructive fishing practices are also widespread across the BOBLME. One example is the stunning of fish by cyanide or blasting. The fish are caught and then revived for the live fish trade or aquarium trade, a lucrative practice for local people and consequently difficult to curtail. Other destructive fishing methods impact the habitats. For example, foreign fishers working for one night on a seagrass bed may wipe out the livelihoods of local people for weeks. Inappropriate fishing gear tears up underground rhizomes and push nets damage seagrass beds and also remove many – often juvenile and immature – animals.

The Marine Stewardship Council (MSC) and the Marine Aquarium Council (MAC) are dedicated to introducing sustainable fishing on coral reefs and with the aid of experts have developed standards for sustainable fishing and seafood traceability. MSC-labeled seafood comes from, and can be traced back to, sustainable fisheries.

Gleaning by local communities for molluscs, seahorses (for Chinese medicine) and sea cucumbers reduces biological diversity and can damage the seagrass by trampling. As the value of these products rises, more and more are taken from the seagrass beds. Even trade in sea urchins and starfish is taking its toll and trophic relationships may be broken.

Building materials such as lime, coral blocks and sand are taken from reefs and used illegally. Sometimes these building materials are taken to other countries that would not allow such practices. Trade in coral has been reduced by awareness campaigns and enforcement of regulations, but it continues in many regions. Dredging channels so that international ships can more easily approach the coast or make shorter voyages, is also an issue of transboundary concern. For example, the Sethu Samudram Ship Canal Project on the coast of Tamil Nadu, entails the dredging of a canal to enable faster sea travel between the east and west coasts, saving ships a journey of 1 100 km around Sri Lanka. The canal will require constant dredging to maintain a depth of between 10 and 14m. Aside from the immediate area of the sea bed, the consistent churning of sediment may also smother adjacent coral reefs and seagrass meadows in the ecologically critical Gulf of Mannar. The increase in shipping traffic could also result in an increase in oil spills and marine pollution.

5.2.4 Pollution and introduced pests

Other transboundary threats come from pollution and introduced marine pests. Pollution from sea could come from ships unloading ballast water, which might contain exotic species or oil. Oil spills are obvious transboundary sources of pollution. Abandoned, lost, or otherwise discarded fishing gear (ALDFG) is also a problem because it smothers coral and causes ghost fishing. Herbicides enter coastal waters from spray drift, leaching, run-off and accidental spills. Macinnis-Ng and Ralph (2003) found that Atrazine, Diuron and Irgarol 1051 impacted seagrass, but that Iragarol 1051 and Diuron severely affected plants although they recovered after exposure to Atrazine. The likelihood of oil spills is very high in the BOBLME but the contingency plans are unknown. Not much is known about introduced marine species. They are brought into countries on the hulls of ships, as ballast water or when exotic species are brought in for culture. It is difficult to decide whether a species is an exotic if a comprehensive inventory is not available for indigenous species.

5.2.5 Climate related events

Climate change brings an important transboundary dimension to the issue of critical habitat degradation. Although there will be many local differences in the impact that global climate change has on the the BOBLME, in the region as a whole it is predicted to result in (i) ocean acidification; (ii) sea level change; (iii) rising sea surface temperatures; (iv) changes in rainfall (decrease in some areas and increase in others); and (v) possible increased frequency of storms and cyclones.

Relative sea level rise may be a threat to mangroves, especially in areas where sediment surface elevation is not keeping pace with sea level rise and there is limited area for landward migration. More research is needed to assess the likely impacts, although better management of mangrove resources, restoration programmes and increases in strategically designed protected area networks that include mangroves will help to mitigate any deleterious effects (Gilman *et al*., 2007).

Global climate change may have a number of deleterious effects on corals. Sea level rise may cause lack of light at deeper levels and sea temperature rise is associated with coral bleaching with dire consequences for coral reefs, especially if corals are smothered by algal turf and zooxanthellae are prevented from re-growing. Acidification causes an increase in dissolved bicarbonate and a decrease in the available carbonate in seawater. Thus, as dissolved carbonate concentration rises it will become more difficult and energy consuming for coral and reef animals and plants to make skeletons.

Global climate change will also affect seagrass beds (Bjork *et al*., 2008). Rising sea levels may adversely impact seagrass communities as a result of increases in water depths above present beds. The depth limit of seagrass is usually governed by light and sea level rise will reduce light at the limiting edge and plants will die. It is possible that seagrass beds may move towards the shore, as long as there are no impediments to their expansion. Changed currents causing erosion and increased turbidity and seawater intrusions higher up on land, or into estuaries and rivers, will also favour land-ward seagrass colonisations. Changing current patterns can either erode seagrass beds or create new areas for seagrass colonization. Increased acidification of the sea (Doney *et al*., 2009) may also be beneficial for seagrass. Most seagrass species use HCO_3 inefficiently but photosynthesis increases with increased dissolved CO_2 concentration.

5.3 Pollution and water quality

5.3.1 Transboundary nature of pollution

Pollution is potentially a transboundary issue, but two conditions need to be met before it may be considered strictly transboundary: (i) the impacts of the contaminant/pollutant occur within the waters of a country that is not generating the contaminant or pollutant; and (ii) that there is a basin scale impact. With the possible exception of the long-term issue of expansion of bottom water anoxia in the upper Bay of Bengal, the threat from plastics and fishing gear, and the Ganges-Brahmaputra-Meghna system where sewage and other forms of organic contamination are likely to be transboundary between India, Bangladesh, and Myanmar, most pollution issues in the BOBLME are likely to be more of local concern.

However, these issues can be included as transboundary issues if the ecosystem degradation/loss contributes to a global environmental problem and finding regional solutions is considered a global environmental benefit. Some of the issues fall into this category.

Although some pathogenic bacteria and viruses can remain viable for up to several months in the marine environment, they are generally unlikely to be transported long distances from their point of discharge, especially when the organisms are deposited in sediments and relatively immobile sewage-borne pathogens (Ashbolt, 1995). The effects of high organic loads are also likely to be localized near the source due to the rapid degradation of the organic matter and the mixing and dilution that typically accompany transport by currents. The exception is the Ganges-Brahmaputra-Meghna system, where pollution from sewage and other organic contaminants is likely to be shared by India, Bangladesh and Myanmar because of high river discharge and ocean circulation patterns.

Therefore, sewage-borne pathogens and organic load from sewage and other discharges are probably not major transboundary issues in the sense of the contaminants or their effects being transported across national boundaries. Discharges of untreated or inadequately treated domestic sewage and high organic loads from other sources, are, however, transboundary in that successful measures to address these issues can be transferred from one country to another within the region.

Plastic litter and derelict fishing gear can be transported long distances in the marine environment and are clearly a major transboundary issue. Other components of solid waste tend to remain localized near their source in the marine environment.

Increasing nutrient inputs from rivers have the potential to lead to inner-shelf hypoxic zones near rivers, which could expand or be carried across borders, or adversely affect transboundary fish stocks. Increasing river and atmospheric nutrient inputs could also intensify the natural oxygen minimum zone in deeper waters offshore, potentially leading to increasing incursions of hypoxic deep water onto the shelf.

Shipping and associated sea-based discharges of oil are inherently transboundary. Disparities between the countries in regulation and enforcement around operational discharges could be acting to drive such discharges from one country to another, particularly into Bangladesh where discharges of oil ballast water are unregulated (Hossain, 2003). Residual oil in the form of tar balls is known to be transported long distances across national boundaries.

Many PTSs undergo long-range transport in the atmosphere or via other pathways. Therefore, PTSs are likely to have a transboundary distribution, both within and outside the BOBLME. Because of the potentially serious consequences of these compounds, the lack of information regarding the levels and effects of PTSs in the BOBLME is a concern.

The bulk of riverine sediment inputs to the ocean settle out near the river mouth, so the effects of sedimentation are generally localized; even in the Ganges-Brahmaputra-Meghna system that is subject to high natural sediment inputs. Sedimentation, therefore, may not have a strong transboundary dimension, in the strict sense. Most heavy metals also remain localized near their source, the exceptions being mercury and lead. Lead inputs are expected to decline with the phasing out of leaded fuels, but the status of mercury contamination, including organomercury contamination, in the BOBLME is not known and is a priority gap in knowledge.

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Abbreviations and Acronyms

ADB	Asian Development Bank
APFIC	Asia-Pacific Fishery Commission
BOB	Bay of Bengal
BOBLME	Bay of Bengal Large Marine Ecosystem
BOD	Biochemical Oxygen Demand
BBS	Bangladesh Bureau of Statistics
CBM	Community-Based Management
CPI	Corruption Perceptions Index
DIN	Dissolved Inorganic Nitrogen
DDT	**D**ichloro**d**iphenyl**t**richloroethane
EEZ	Exclusive Economic Zone
ESI	Environmental Sustainability Index
ESCAP	Economic and Social Commission for Asia and the Pacific
EVI	Environmental Vulnerability Index
EU	European Union
FAO	Food and Agriculture Organization
GBM	Ganges-Brahmaputra-Meghna (river system)
GDP	Gross Domestic Product
GEF	Global Environment Facility
GFC	Global Financial Crisis
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
HAB	Harmful Algal Bloom
HDI	Human Development Index
IOTC	Indian Ocean Tuna Commission
IW	International Waters
LME	Large Marine Ecosystem
NGO	Non-Governmental Organization
NPK	Nitrogen, Phosphorus, Potassium
OMZ	Oxygen Minimum Zone
PBT	Persistent, Bioaccumulative and Toxic
PCDD	**P**oly**c**hlorinated **d**ibenzo-p-**d**ioxins
PCDF	**P**oly**c**hlorinated **d**ibenzo**f**urans
PDF	Project Development and Preparation Facility
POP(s)	Persistent Organic Pollutant(s)
PTS	Persistent Toxic Substances
SAP	Strategic Action Programme
SEDAC	Socioeconomics Data and Applications Centre
TBT	Tributyl Tin
TDA	Transboundary Diagnostic Analysis
UN	United Nations
UNDP	United Nations Development Programme
UN ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNSD	United Nations Statistics Division
USD	United States of America Dollar
VLIZ	Flanders Marine Institute, Belgium (Maritime Boundaries Geodatabase)
WRI	World Resources Institute, Washington
WWF	Worldwide Fund for Nature

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Eight countries connected by one ecosystem, working together to secure its future

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