COASTAL SYSTEMS AND CONTINENTAL MARGINS

Asia-Pacific Coasts and Their Management

States of Environment

Edited by Nobuo Mimura

Springer

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Coastal Systems and Continental Margins

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Cover Illustrations
Main photo on the left - Mangrove rehabilitation in abandoned shrimp ponds in Southern Thailand (photograph Sanit Aksornkoae).

Smaller photo on top right - A coral community at Mu Koh Chang; a newly developed area for ecotourism in the eastern part of the Gulf of Thailand (photograph Thamasak Yeemin).

Smaller photo at bottom right - Artificial reef constructed by local people in North Sulawesi, Indonesia (photograph Akinori Sato).

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Preface

Coasts are fascinating places that are both beautiful and dynamic. They attract great numbers of people in any country that faces the sea because they have provided a variety of benefits to humankind. In the Asia-Pacific region, coasts stretch from the Arctic to the tropics, and therefore represent a diverse environment. This rich diversity is a source utilized by the region's coasts to support a range of human activities such as fisheries, use of marine resources, transport and trade, marine sports, recreation and everyday life. As a result, coasts have today become home to about half of the region's population.

The benefits that coasts provide are not limited to economic goods and services, but extend to cultural and artistic values. There is a nursery tale in Japan of a small princess who sailed from a country far off to the south in a small coconut boat and arrived on the coast of Japan, which suggests that a connection between Japan and far off countries existed from long ago. We can find similar stories in many countries. This indicates that the sea has been a medium for cultural exchange and the coast acts as the gateway for such exchange. All the environmental, economic and cultural functions are what attract so many people to the coasts, regardless of whether there have also been dangerous natural disasters originating from the sea.

In the latter half of the 20th century, however, adverse phenomena have spread, such as water pollution, the disappearance of mangroves, degradation of coral reefs and coastal erosion, which are the result of coastal development and an increase in the discharge of land-based pollutants. These problems have become increasingly serious, particularly during the past 30 years. Furthermore, the Asia-Pacific region is expected to undergo more intensive urbanization and development. For example, the trend for population growth will continue, and the number of megacities will increase in the region to more than 25 by the middle of this century, which will further increase the destructive pressures along the coasts in the coming decades. In addition, the effects of global environmental change, such as climate change and sea-level rise caused by global warming, are becoming increasingly apparent. To achieve sustainable development in the coastal zones against such multiple stresses, it is fundamentally essential to observe, monitor, and understand the status of the environment.

The International EMECS Center was established in 1994 to promote coastal studies and exchange practices in coastal management among researchers, government officials and citizens, focusing on the environmental protection of semi-enclosed seas and coastal waters. The International EMECS Center organizes international EMECS conferences every two to three years to promote such activities on both a regional and global scale. Since the 5th conference held in 2001 in Kobe, Japan, the EMECS conference has hosted special sessions for the Asia-Pacific region because of the urgent need to find a way to ensure a sustainable future for the region's coasts. The idea of editing a book showing the present status of the environment and costal management was born out of discussions held at these sessions. This book is designed to form the basis upon which to plan a sustainable future for coastal zones in the Asia-Pacific region through summarizing the present status of the coastal environment. During the preparation of the manuscript, we reconfirmed that the region's coasts were vast, and that we still lack sufficient real data on the coastal environment and management practices. However, we believe that this book is a starting point from which to provide an integrated picture of the present status. I shall be more than happy if this book is able to contribute to the improvement of people's understanding of the region's coastal environment.

This book is the fruit of tireless work by a group of some 36 authors and 7 reviewers. As Editor, I would like to express my sincere appreciation to all the authors for their tremendous effort in completing their manuscripts. I also thank Dr. Yoichi Kaya, President, and Mr. Toshizo Ido, Chair, Board of Directors of the International EMECS Center for their continued support of this work and for the great patience they have shown. I am also very grateful to Prof. John Hay for his dedicated work in checking the English and editing the manuscript.

August 1, 2007

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Editor

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1
Introduction: Scope and Objectives of This Book

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1.1 Interaction of the Natural Environment and Human Activities in the Coastal Zones

Coastal zones in Asia and the Pacific are extremely diverse in their characteristics. They range from polar to tropical regions, large areas of which are under the strong influence of Asian monsoons, tropical cyclones, and interannual variability imposed by the El Niño–Southern Oscillation (ENSO). Various geomorphologic features also occur, including deltas formed by large rivers, islands, and rocky coasts. These are often accompanied by valuable ecosystems of mangroves, coral reefs, and sea grass beds. Numerous large rivers in Asia discharge large amounts of freshwater and sediments to the sea, with such sediments accounting for about 70% of the world freshwater flow. Coastal ecosystems are home to a rich biodiversity and a wealth of biological resources that include abundant fishery resources for commercial and subsistence fisheries.

Another distinguishing characteristic of the region's coastal zones is its extremely high degree of interaction with human activities. The Asia and Pacific region accommodates half of the world's population, about 60% of which live on or near the coast. Migration of people from inland areas to the coast is a key factor in this increase because this coastal zone has shown the highest rate of economic growth of any region in the world. Because of such a trend, the majority of the world's largest cities are located on the coast, and most coastal megacities are located in Southeast Asia.

The concentration of population, economic development and related changes in land use has two major effects; one is increased pressure of human activities on the coastal and marine environment. Coastal societies in Asia and the Pacific have been highly dependent on coastal resources in many ways. However, in the last 30 years coastal resources such as mangroves, coral reefs, and fishery resources have become depleted on a large scale. This depletion has become a critical issue for the region. For example, more than 60% of Asia's mangroves have already been converted to aquaculture farms (ESCAP

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and ADB 2000), while coral reefs are threatened by the combined effects of higher temperatures and pollution of sea water. In reality more than 80–90% of coral reefs are threatened in many areas in the region (Burke et al. 2002). The Asia Pacific region is losing its resource bases to support people's everyday lives and future economic development as well as the rich biodiversity in the coastal zones, though this book mainly focuses on East, and Southeast Asia. If such human-induced pressures are exacerbated by, and superposed on global changes, the effects will be devastating for the sustainability of the coastal environment. There is a pressing need to find ways to alter these trends, to protect the coastal ecosystem and return it to a healthy condition.

Populations of human beings and their society are being exposed to natural and human-induced hazards. Global environmental changes, particularly climate change induced by increased atmospheric concentrations of greenhouse gases, will increase threats to the coasts on a wide scale. Higher air and seawater temperatures, and changes in precipitation, tropical cyclones, marine conditions, along with sea-level rise, all exert a variety of pressures on the region's coastal communities. Countries surrounding the Indian Ocean were hit hard by the Indian Ocean Tsunami resulting from the massive earthquake off the island of Sumatra on December 26, 2004. More than 220,000 people died and several million lost their homes, personal assets, and the basis of their socioeconomic livelihoods. Coastal infrastructures were also heavily damaged in these countries. Although the tsunami was too overwhelming for the systems protecting coastal communities, the tragedy symbolically illustrated a number of aspects related to coastal zone management, such as the level of disaster prevention, the preparedness of coastal societies to tackle disasters, the relationship between coastal protection and economic development and land use planning. The coastal zones in the Asia Pacific region have faced, and will continue to face, a variety of natural forces including climate change and variability and other natural hazards. These powerful natural forces, with their high variability, are a major factor in the vulnerability of the coastal zones in the region.

These and other changes in the coastal environment are derived from natural and socioeconomic influences. Past and ongoing changes should be understood by analyzing the changes in those influences. Such knowledge can provide a basis for estimating future trends in the coastal environment. It is a challenge to understand past and ongoing changes, to identify the driving factors of those changes, and to integrate such knowledge in order to provide the necessary information for finding a way to ensure sustainable development of the coastal zone in the region.

1.2 Background and Objectives

This book is an attempt to respond to the above challenges. Its creation was proposed through discussions at the International Conference on the Environmental Management of Enclosed Coastal Seas (EMECS), which is supported by the International EMECS Center. As the EMECS Conferences now boast a history of more than 15 years, it is useful to review this brief history of the Conference in this way provide further background to this book.

Semi-enclosed coastal seas such as bays, inland seas and river estuaries comprise a rich natural environment that has long provided people with space and resources for their livelihood and socioeconomic activities. They have been used for fishing, industrial activity, maritime transport, tourism, and recreation, as well as academic and aesthetic activities. However, as the exchange of seawater in semi-enclosed coastal seas is sluggish, these environments have also been adversely affected by human pressures. As a result, enclosed coastal seas around the world currently suffer from water pollution, reduction in habitats, and declining fish catches. This is especially the case for the Asia and Pacific region, as mentioned above.

Based on recognition of such serious problems, the first International Conference on the EMECS (EMECS '90) was held in 1990 in Kobe, Japan. The conference was attended by over 1,200 people from 42 countries, regions, and international organizations such as the United Nations Environment Program (UNEP), the Organization for Economic Cooperation and Development (OECD) and the Food and Agriculture Organization of the United Nations (FAO). Following the success of the first conference and its subsequent activities, the Second EMECS Conference was held in 1993 in Baltimore, USA, and thereafter the conference has been held every 2 or 3 years, and in locations such as Sweden, Turkey, and Thailand. The most recent conference was held in 2006, in France. In order to support such activities, the International EMECS Center was established in 1994. The Secretariat is located in Kobe, Japan.

In 2001, to celebrate its 10th Anniversary, the 5th ECEMS Conference was again held in Kobe. An Asia Forum was arranged under the joint auspices of the Asia-Pacific Network for Global Change Research (APN), as a special opportunity to discuss the status of the coastal environment, focusing on Asia. The Forum reported that human pressures have been increasing in many respects, mainly due to rapid, major economic development in the developing countries of the region. Those who attended the Forum shared a common concern that threats to the environment would be further exacerbated by the combined effects of human activities and global environmental changes, such as climate change. Following the recognition of a shared need to assess the state of the environment and its changes on a scientific basis, the International EMECS Center commenced a project to undertake such a comprehensive assessment. This included establishing the Editorial Committee for this book. The assessment was based around a framework that comprises three aspects; drivers to environmental change; the state of, and changes in, the environment; and responses to these challenges. Through this framework it is possible to provide a comprehensive overview of the ongoing processes in the Asia and Pacific coastal zones. The objectives of this book are as follows:

1. To summarize the present status of the coastal environment in the Asia and Pacific Region, including its changes
2. To obtain a systematic understanding of the causes and consequences of pressures affecting the coastal environment, and responses of human society to them.
3. To prepare suggestions for future efforts aimed at monitoring, research, and management of the coastal environment.

1.3 Structure of this Book

This book consists of six chapters reflecting the above objectives.

Chapter 1 is an introductory chapter.

Chapter 2 presents an overview of the drivers of environmental changes in the region. First, it looks at the characteristics of natural environments, such as climate and marine conditions, and then summarizes human activities as a major driver of such changes. As population and economic growth is remarkable in the Asia and Pacific Region, trends in population growth, migration of people to the coastal zones, development of both river basins and coastal zones, and pollutant discharge from the land to the sea are highlighted. This chapter also identifies climate change and natural hazards as major drivers.

Chapter 3 is concerned with environmental problems in coastal zones. It presents the current status of the environment and related activities, focusing on the changes in the physical environment and coastal features, beach erosion, water pollution, ecological changes such as those related to mangroves, coral reefs and sea grass, fisheries and tourism. The chapter describes how the coastal environment in the Asia and Pacific Region has been changing rapidly, and on a large scale. This chapter will also provide a comprehensive picture of the strong interactions between the coastal environment and human activities. The potential impacts of global environmental changes, such as climate change and sea-level rise, are also discussed.

Chapter 4 describes responses to these and related changes, focusing on the policy framework provided by integrated coastal management. As a policy response, the importance of integrated coastal management has been widely emphasized. At the same time, an integrated approach always faces challenges of reaching compromises with regard to the interests of different stakeholders as well as with the trade-offs between the different objectives of related policies. This chapter looks at the recent evolution of integrated coastal management in the region, including the lessons already learned.

Chapter 5 provides a summary of the state of the environment for the subregions of East Asia, Southeast Asia, and South Asia. Reports for countries of these subregions give additional details..

Chapter 6 presents conclusions regarding the various themes covered in the book and also proposes future directions regarding the actions needed to ensure sustainable development in coastal zones.

The authors for these chapters are scientists and other experts in coastal issues. They were selected from countries in the Asia and Pacific region, including China, Korea, Japan, Chinese Taiwan, the Philippines, Malaysia, Indonesia, Thailand, Singapore, Bangladesh, India, Pakistan, Sri Lanka, and Fiji.

The book is based on a comprehensive framework of drivers, states and changes in the environment, and responses to these. For these reasons we hope this book not only presents valuable information to all relevant readers but also acts as a trigger to promote further efforts in monitoring, research, management and preservation, leading to improved use of coastal environments in the Asia and Pacific region.

References

Burke L, Selig E, Spalding M (2002) Reefs at risk in Southeast Asia. World Resources Institute, Washington DC, 72pp

ESCAP and ADB (2000) State of the environment in Asia and Pacific 2000. Economic and Social Commission for Asia and the Pacific and Asian Development Bank

2
Drivers for Changes in the Coastal Zone

Chairs: Tetsuo Yanagi and Kwangwoo Cho

2.1 Physical Environment of the Coastal Zone

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The land area of this region is characterized by rain forests, paddy fields, and countless islands, while the coastal area is characterized by its bio-geomorphology such as mangrove forests and coral reefs. Numerous large and small islands subdivide the region into different seas, which are connected with each other by a large number of passages and channels. Deep trenches, high mountain chains, many volcanoes, deep sea basins, and innumerable coral islands form a complexity of phenomena that are not found over such an extended area in any other part of the world.

2.1.1 Monsoon, River Discharge, and Sediment

Monsoon and Surface Currents

The countries in this area are substantially affected by the Asian monsoon climate because they are situated between the land masses of Asia and Australia and the Southeast Asian Waters. The equatorial pressure trough moves according to the position of the sun, crossing the equator twice each year. In the summer hemisphere, a low develops over the continent as a prolongation of the equatorial pressure trough, while in the winter hemisphere a high is formed over the continent, forming part of the subtropical high. Between the high and the low, the monsoons develop. In the boreal summer, hot and humid winds blow from the sea to the continent (Southwest Monsoon), while in the boreal winter cold and dry winds blow from the continent to the sea (Northeast Monsoon) (Fig. 2.1.1.1).

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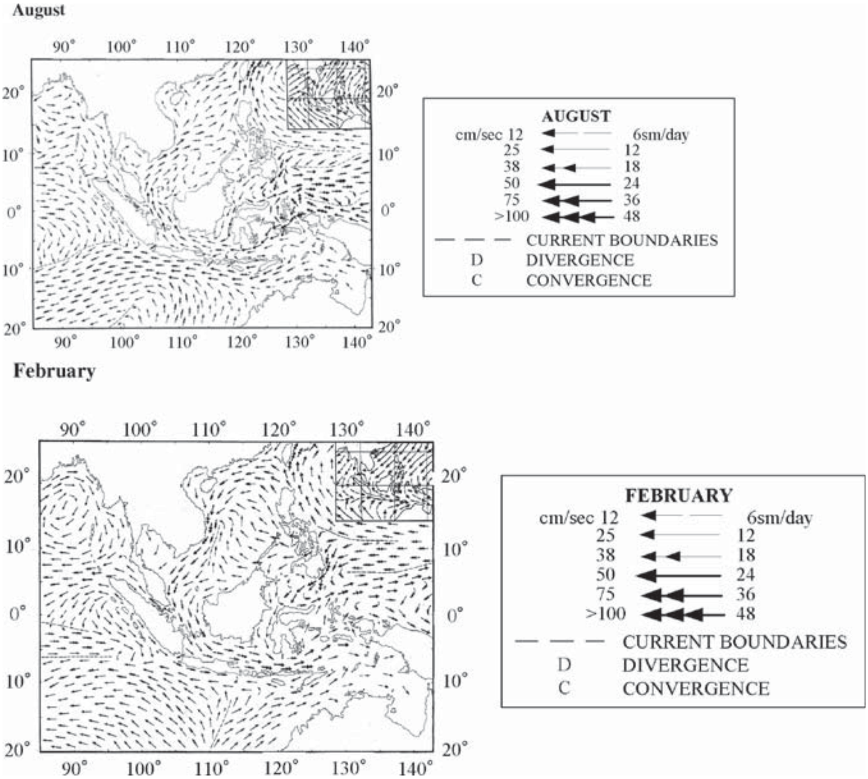

FIG. 2.1.1.1. Sea surface currents in August and February in the South China Sea. Insets show sea surface winds. (From Wyrtki 1961.)

The monsoon system in this area modulates interannual variability imposed by ENSO events. The monsoon in the South China Sea is weak during the period of El Niño, while it is strong during the period of La Niña (Wu et al. 1998).

The sea surface currents in the South China Sea reverse in phase with the Northeast Monsoon and Southwest Monsoon as shown in Fig. 2.1.1.1.

In the boreal summer, there is a northeastward current along the coast of Vietnam and the continental shelf south of China. The speed of this current is about 20 cm s^{-1} in the southern part of the South China Sea and about 5 cm s^{-1} in the northern part. An anticyclonic basin-wide circulation with speeds of 5–10 cm s^{-1} develops in the central part of the South China Sea and there is an anticyclonic circulation with speeds of 10 cm s^{-1} to the southeast of Vietnam.

In the boreal winter, there is a southwestward current along the continental shelf south of China and the coast of Vietnam. The speed of this current is 5 cm s^{-1} in the northern part of the South China Sea and 15–20 cm s^{-1} in the southern part. A cyclonic circulation develops in the central part of the South China Sea (Morimoto et al. 2000).

River Discharge

The dry season and wet season are associated with the monsoons, that is, the wet season along the Vietnam coast, the eastern coast of Peninsula Malaysia and the northern coast of Indonesia occurs during the Northeast Monsoon (from November to March) while the dry season in the area occurs during the Southeast Monsoon (from June to September) (Fig. 2.1.1.2). On the other hand, the wet season along the southern coast of Thailand is during the Southeast Monsoon (from July to October) while the dry season there is during the Northeast Monsoon (from December to March) and results in the seasonal variation in river discharge along the southern coast of Thailand (Fig. 2.1.1.3).

Large rivers such as the Irawaji, Sarwin, Chaopraya, Red River, Changjiang, and Yellow River discharge into shelf waters, supplying large amounts of suspended sediment, causing delta to form and grow at the river mouths.

Annual river discharge throughout the world is shown in Fig. 2.1.1.4. In terms of worldwide water discharge, the world's ten largest rivers account for about 38% of the total fluvial water entering the ocean, slightly greater than the combined percentage of their drainage area. The Amazon River alone contributes over 15% of the world total (about 8,300 km^3/year), more than the combined total of the next 8 largest rivers. Tropical areas with heavy rainfall – specifically, Southern Asia, Oceania, and northern South America – are the prime contributors, about 65% of the global total. Five of the world's largest rivers drain Asia: two in the Eurasian Arctic (Lena and Yenissei) and three in southern Asia (Changjiang, Ganges-Brahmaputra, and Mekong). However, in terms of specific discharge (discharge/drainage basin area), the northern rivers are small, generally less than 0.2 m/year, in accordance with the low net precipitation. In contrast, most rivers in southern Asia drain small basins but reflect very high rainfalls. Several Asian rivers have specific discharge values in excess of 1 m/year, while rivers in Taiwan (whose individual discharges are small) exceed 2 m/year. This is a result of high rainfall, the mountainous terrain and the small river basin area.

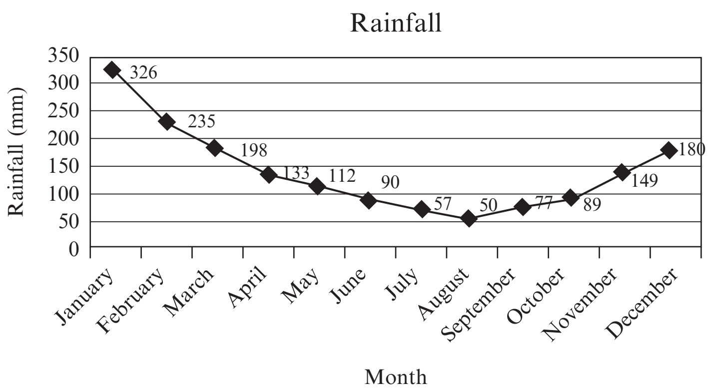

FIG. 2.1.1.2. Seasonal variation in rainfall along the northern coast of Java. (From Sachoemar and Yanagi, 1999.)

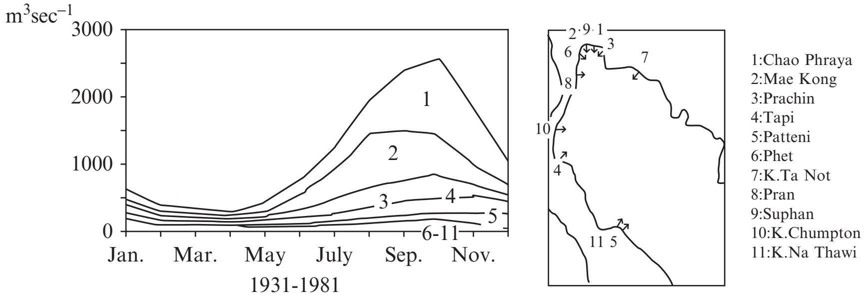

FIG. 2.1.1.3. Seasonal variation in river discharge into the Gulf of Thailand. (From Yanagi et al. 2001.)

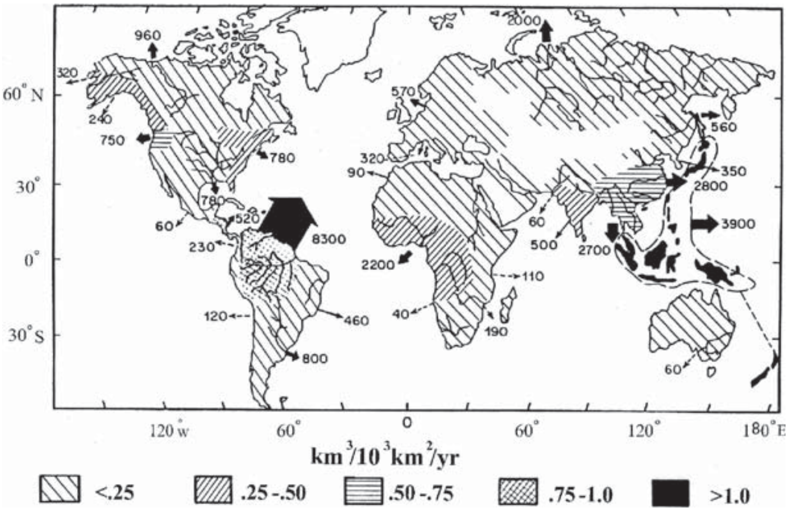

FIG. 2.1.1.4. Annual discharge of fluvial water into the oceans. Numbers in km^3/year; arrows proportional to the numbers. (From Milliman 1991.)

Sediment Flux

The present fluvial suspended sediment flux to the world oceans is approximately 13.5×10^9 t/year, with an additional $1–2 \times 10^9$ t/year coming from flood discharge and bed load sediment. Thus 15×10^9 t/year is a reasonable estimate. With a total drainage basin area accessible to the ocean of about 10^8 km^2, the average sediment yield (sediment discharge/unit area of drainage basin) is 150 t/km^2/year. Southern Asia and Oceania contribute about 70% of the world flux, although they account for only 15% of the land area draining into the oceans. Northeastern South America contributes another 11%. In contrast, rivers draining the Eurasian Arctic, whose basin area is similar in size to southern Asia and Oceania (combined), contribute about two orders of magnitude less sediment (Fig. 2.1.1.5).

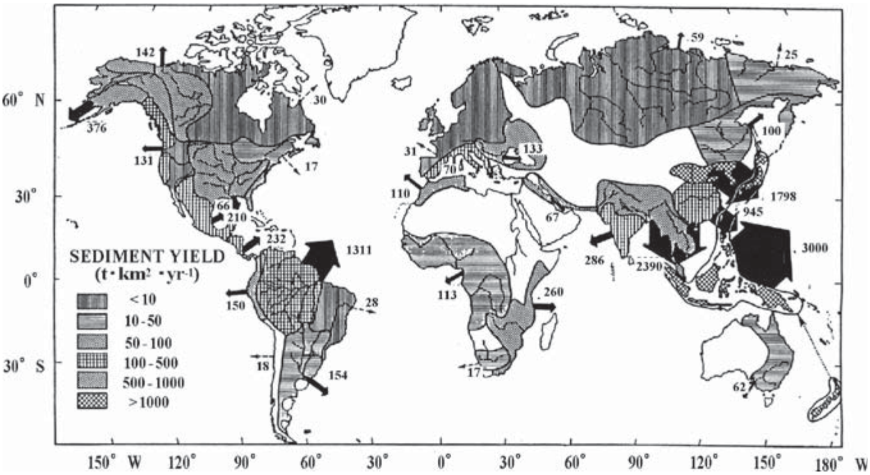

FIG. 2.1.1.5. Annual fluvial sediment flux from large drainage basin areas to the oceans. Numbers represent millions of tons per year; arrows proportional to the numbers. (From Milliman and Meade 1983.)

The Yellow River drains relatively low-lying terrain with low rainfall. The Pleistocene loess hills in northern China provide most of the sediment, with a yield of 1,400 t/year. High values have been documented in rivers in New Guinea, and similarly high values are assumed for many of the high-standing islands in Oceania. Taiwan is perhaps the ultimate example of high sediment yield (greater than 14,000 t/km^2/year, two orders of magnitude greater than the world mean) due to its intensely cultivated lands. The reason for these very high yields also relates directly to the mountainous terrain, heavy rainfall and very small drainage basins. These conditions prevent the accumulation of river-borne sediment.

References

Milliman JD, and Meade RH (1983) World-wide delivery of river sediment to the oceans. J Geol 91:1–21

Milliman JD (1991) Flux and fate of fluvial sediment and water in coastal seas. In: Mantoura RFC et al. (ed) Ocean margin processes in global change. Wiley, pp 69–89

Morimoto A, Yoshimoto K, Yanagi T (2000) Characteristics of sea surface circulation and eddy field in the South China Sea revealed by satellite altimetric data. J Oceanogr 56:331–344

Sachoemar SI, Yanagi T (1999) Seasonal variation in water quality at the northern coast of Karawang-West Java, Indonesia. La mer 37:91–101

Wyrtki K (1961) Naga report, vol. 2. Scripps Institute of Oceanography, The University of California

Yanagi T, Sachoemar SI, Takao T, Fujiwara S (2001) Seasonal variation of stratification in the Gulf of Thailand. J Oceanogr 57:461–470

2.1.2 Coastal Zone, Biodiversity, and Hazards

Mangrove Forest

The coastal ecosystems of Asia and the Pacific, such as mangrove forest and coral reefs, face a grim situation. While 20–30% of coastal areas in Africa, Latin America, and Oceania are under serious potential threat from developments such as port and harbor construction, the figure for Asia is very high at 52% (Burke et al. 2002).

Mangrove forests occupy one fourth of the world's tropical coasts, but they are concentrated in just a few countries. Asian countries in the top ten are Indonesia, Malaysia, and Myanmar (Fig. 2.1.2.1). Mangrove forests from the Indian Ocean to the West Pacific are in crisis as they are being cut down for fuelwood, conversion to shrimp farming, and other purposes. The Philippines has already lost 70% of its old-growth mangrove forests (Burke et al. 2002).

The intensive farming of shrimp in Indonesia, Vietnam, and other countries, mostly for export to Japan, also results in eutrophication from heavy feeding as well as water contamination from antibiotics.

In the seven countries surrounding the South China Sea there has been a recent shift in common coastal land use from mangrove forests to shrimp ponds and other purposes (Table 2.1.2.1).

Coral Reefs

Coral reefs are one of the most diverse ecosystems, and are said to harbor one fourth of all marine species. Fifteen percent of the world's coral reefs are concentrated in the region from the Indian Ocean to the West Pacific. But this coral faces a grim future owing to red soil runoff, the digging of coral for building materials, the catching of fish using dynamite and cyanide, and other causes. Coral bleaching, a phenomenon observed worldwide in recent years,

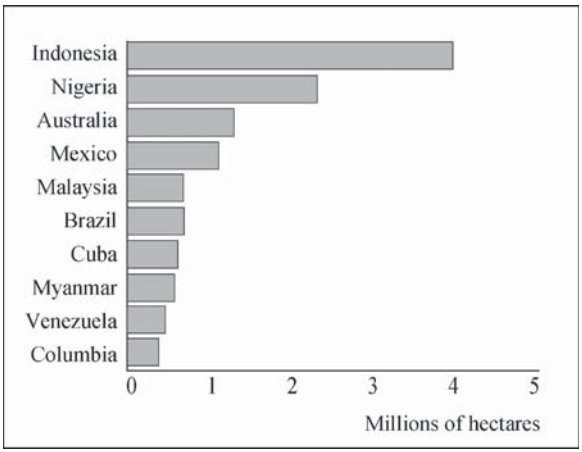

Fig. 2.1.2.1. Top 10 countries for mangrove forests. (From World Resources Institute 1996.)

TABLE 2.1.2.1. Change of mangrove forests in countries surrounding the South China Sea. (From Talaue-MacManus 2000.)

				Causes of mangrove destruction			
Country	Original mangrove area (1,000 ha)	Present mangrove area (1,000 ha)	Area lost (%)	Shrimp culture	Wood chip, pulp, charcoal	Urban develop-ment, Hhuman settlement	Domestic use
Cambodia	170	85	50	•			•
China	42	15	65	•		•	
Indonesia	N/A	936	N/A	•	•	•	
Malaysia	505	446	12	•	•	•	
Philippines	400	160	60	•		•	•
Thailand	280	160	57	•			
Vietnam	400	253	37	•			•
Total		1,852					
Global total		18,108					

is said to occur because of a 1°C rise in seawater temperature and crossing the critical threshold water temperature, and it is likely that coral will face a still bleaker future as global warming continues.

Scientists have found more coral species around a single island in Southeast Asia than have been identified in the entire Caribbean. Figure 2.1.2.2 (Veron and Smith 2000), which shows coral reef diversity world wide, illustrates the high concentration of species in the region, particularly in the broad Indo-Malayan Triangle, stretching from the Philippines to the southern islands of Indonesia and encompassing all of Java east to New Guinea. The region contains more than 600 of the nearly 800 reef-building coral species (Scleractinia) found worldwide (Burke et al. 2002).

The reefs of the Philippines, Vietnam, Singapore, Cambodia, and Taiwan are some of the most threatened in the region, each with over 95% threatened. The reefs of the Nusa Tenggara chain in Indonesia, Okinawa in Japan and Sabah of East Malaysia are also highly threatened (Fig. 2.1.2.3). Malaysia and Indonesia each have over 85% of their coral reefs threatened (Burke et al. 2002).

Biodiversity

Asia has some of the richest biodiversity in the world. East Asia, for example, has 14% of the world's mammal, bird and fish species, about 26% of the ferns, and 40% of conifer species (Birke et al. 2002). Indonesia can boast the world's largest number of mammal species, Malaysia has two of the world's tropical forest hotspots (the Malay Peninsula and Northern Borneo), and the marine region from the Indian Ocean to the West Pacific has the world's most abundant coral reefs and mangrove forests. But Asia also surpasses other world regions in its spiraling population and its economic growth. China, Indonesia, and Malaysia

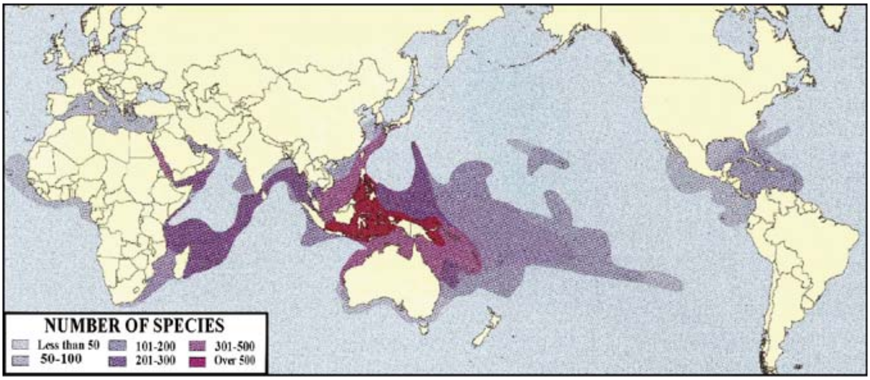

FIG. 2.1.2.2. Patterns of diversity in reef-building scleractinian corals. (From Veron and Smith 2000.)

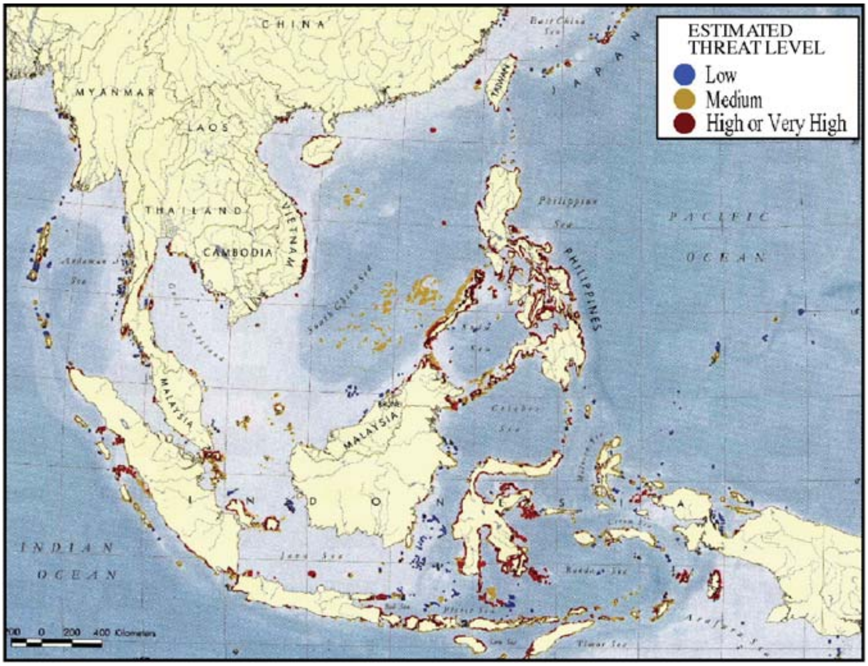

FIG. 2.1.2.3. Coral reefs threatened by human activities. (From Burke et al. 2002.)

are known for their biological mega-diversity, but at the same time they also have very high population densities. People overuse nature there, including the biota for their life (e.g., overfishing). This is why Asia is fast losing its biodiversity.

Marine Protected Areas

Marine Protected Areas (MPAs) are designated for a number of reasons, including fisheries management, tourism promotion, and the maintenance

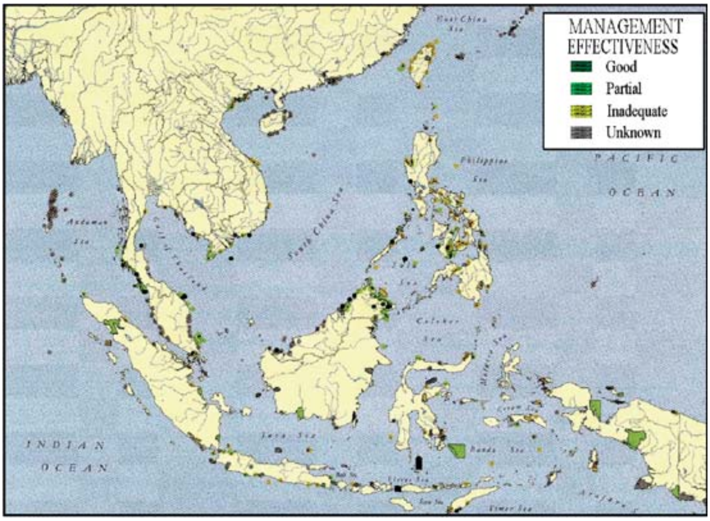

FIG. 2.1.2.4. Marine Protected Areas rated by management effectiveness. (From Burke et al. 2002.)

of biodiversity. Local, provincial, national, and international agreements have established hundreds of MPAs in the Southeast Asia region (Fig. 2.1.2.4, Burke et al. 2002). Most MPAs are managed through central government programs. However, local conflicts and a low capacity for enforcement have made it difficult to manage MPAs in some places, creating a situation in which hundreds of MPAs exist though only a fraction operate in ways that meet their objectives. In some countries, such as the Philippines and Indonesia, governments have been moving toward community-managed MPAs to enhance local support, reduce resource conflict, and bolster enforcement.

Increasing Fish Catch

A rapid increasing fish catch is one of the problems facing the coastal zone of East Asia because it destroys the ecosystem in the coastal sea. The world fish catch in 2004 was about 140 million tons and is approaching nature's production limit (Fig. 2.1.2.5).

China has rapidly increasing fish catch and becomes the largest fish catch country over the world (Fig. 2.1.2.6).

Its share of the total world catch rose from 4% in 1970 to 17% in 2004. Other than China, Indonesia, Japan and Thailand are among the top ten countries with the highest catches (Fig. 2.1.2.6). Reasons for the rising catch of these four countries are increased effort and more efficient fishing practices in their coastal and inshore fisheries, and expanding aquaculture production. From 1970 to 2004 marine aquaculture production in China surged 18-fold and increased the aquaculture share of their total catch (Fig. 2.1.2.7).

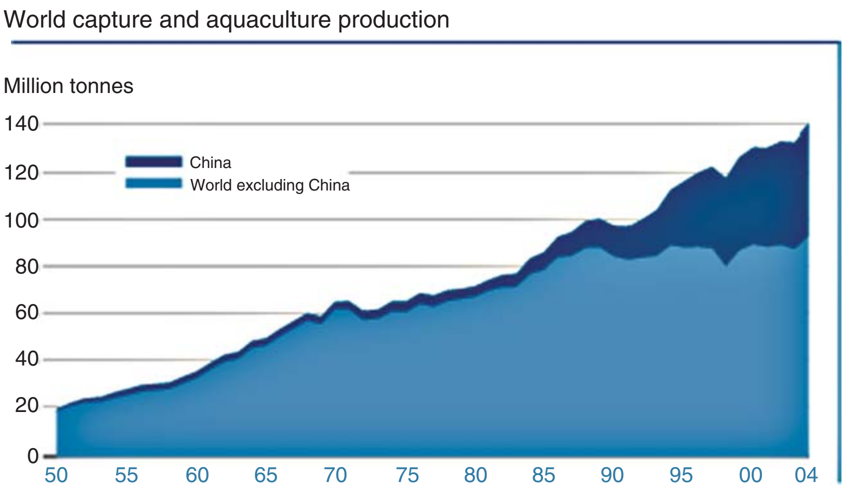

Fig. 2.1.2.5. World fish catch from 1950 to 2004. (From FAO 2006.)

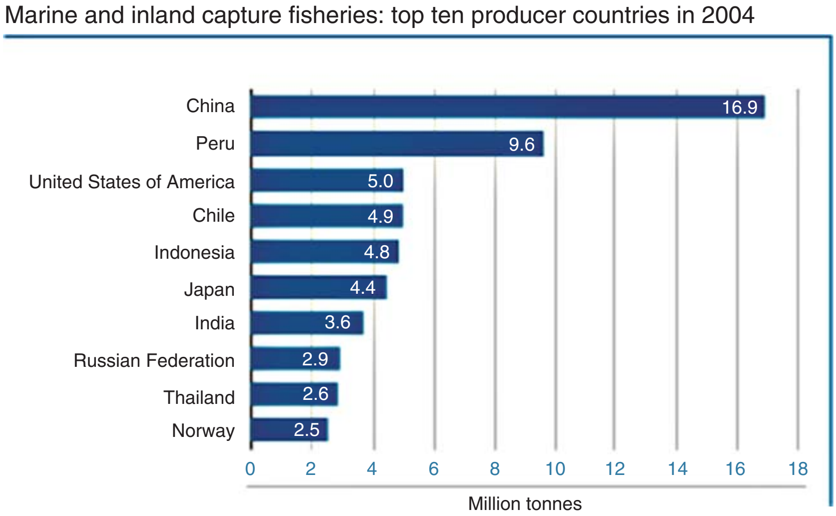

Fig. 2.1.2.6. Top ten fish catch countries in 2004. (From FAO 2006.)

A number of problems are brought about due to such a rapid increase in the fish catch. First, Asia's coastal fishery resources are suffering from overfishing. Second, aquaculture results in problems such as environmental damage caused by cutting mangrove forests when building aquaculture ponds and polluting water. Especially in the Asia-Pacific, the growth of aquaculture is said to be the largest cause of mangrove forest destruction. There are adverse effects on biodiversity due to introduction of exotic species, as well as competition with other sectors for land and water and a waste of food resources through heavy fish feeding.

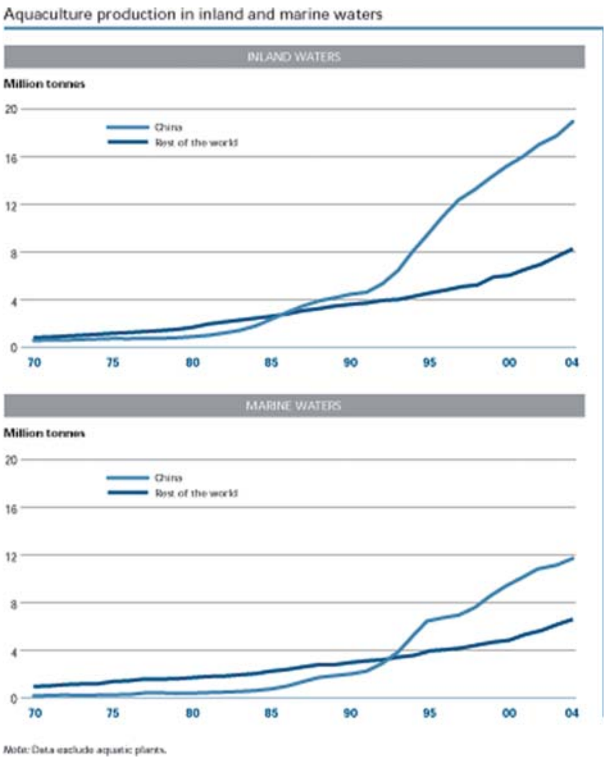

FIG. 2.1.2.7. Aquaculture production in inland and marine waters. (From FAO 2006.)

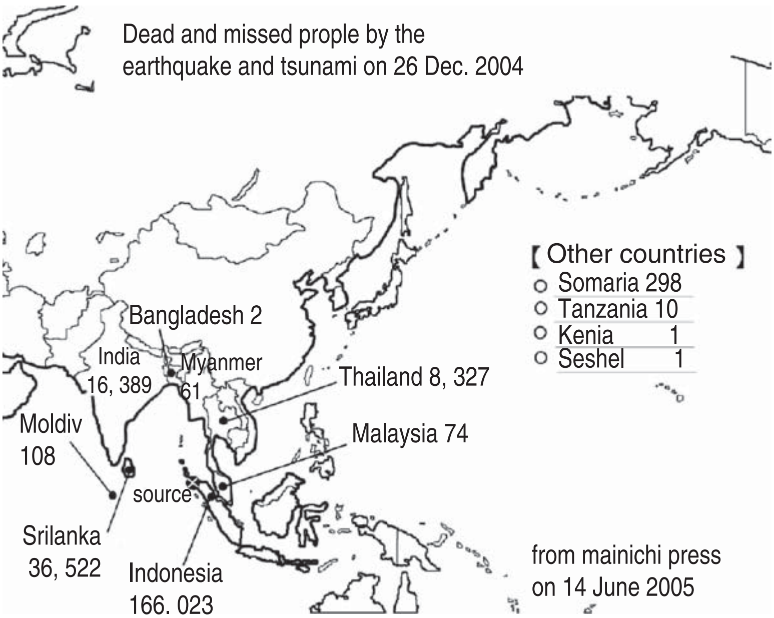

FIG. 2.1.2.8. Center of the massive earthquake on 26 December 2004, and the number of dead and missing following the tsunami disaster. (From Mainichi Newspaper, 14 June 2005.)

Reclamation

Reclamation for waste disposal and other aims has increased in recent years. This results in the loss of areas with considerable water purification capabilities, and therefore worsens water quality. Moreover the shallow seas, which are lost by such reclamation, play a very important role as nursery grounds for juveniles. This means that reclamation may result in a decrease in fish resources.

Natural Disasters

Natural disasters, such as typhoons, volcanic eruptions, earthquakes, tsunami, floods, storm surges, drought are common in this region. The natural disasters are associated with severe damage to the coastal environment in the East and South Asia. For example, more than 220,000 people died or went missing, 50 million people were injured, and 5 million people lost their homes as a result of the tsunami disaster following the massive earthquake of M 9.0 that occurred on 26 December 2004 off Sumatra, Indonesia (Fig. 2.1.2.8).

References

Burke L, Selig E, Spalding M (2002) Reefs at risk in Southeast Asia. World Resources Institute, 72 p

FAO (2006) The state of world fisheries and agriculture 2006.

Talaue-McManus L (2000) Transboundary diagnostic analysis for the South China Sea. EAS/RCU Technical Report Series No.14, UNEP, Bangkok

Veron JEN, Stafford-Smith M (2000) Corals of the world. Cape Ferguson, Australian Institute of Marine Science

World Resources Institute (1996) World Resources 1996–1997

2.2 Natural Environment Change

2.2.1 Climate Change

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It is expected that anthropogenic global warming due to increasing atmospheric concentrations of greenhouse gases will result in large changes in Asia's climate, including changes in surface temperature and changes in monsoon intensity and duration over South Asia, Southeast Asia, and East Asia. An increase in greenhouse gases will lead to increased surface air temperature and precipitation in the global mean sense, but its geographical distribution is not easy to project, in particular with respect to precipitation. IPCC (2001) projects that the globally averaged, annual mean surface air temperature will increase by 1.4–5.8°C over the period 1990–2100. In the atmosphere–ocean general circulation model (AOGCM) projections, six marker scenarios (A1B, A1T, A1FI, A2, B1, B2) described in the Special Report on Emission Scenarios (SRES) (IPCC 2000) are widely used. In these scenerios atmospheric CO_2 concentrations for 2100 are estimated at about 717, 582, 970, 856, 549, and 621 ppm, respectively. These values can be compared to a value of 369 ppm for the year 2000. The global average annual mean surface air temperature is expected to rise by 3.0°C at the end of the 21st century (2071–2100) compared to 1961–1990. This is for the A2 scenario. The range in projected temperature increase is from +1.3 to +4.5°C. For the B2 scenario the mean temperature change is +2.2°C, with a range of +0.9 to +3.4°C. It is also considered very likely that nearly all land areas will warm more rapidly than the global average, particularly those in northern, high latitudes in the winter season. IPCC (2001) also assessed regional and seasonal mean precipitation changes due to global warming, using several models. Most tropical areas will have increased mean precipitation while most of the subtropical areas will have decreased mean precipitation by the end of the 21st century. This is due to anthropogenic influence. Also noted were an increase in summertime precipitation in East Asia and South Asia, and a mean El Niño-like response in the tropical Pacific, with a corresponding eastward shift of precipitation.

Since the IPCC report various modeling groups have performed new simulations, including the 20th century historical runs and future climate simulations based on a diverse set of scenarios. These model data are collected and archived by the Program for Climate Model Diagnosis and Intercomparison (PCMDI), and have been analyzed from various aspects by many scientists. Here, we summarize the results in terms of seasonal mean changes in surface air temperature, mean sea-level pressure and total precipitation.

Surface Air Temperature

Figure 2.2.1.1 shows the changes in 14 model averaged December–February (DJF) and June–August (JJA) mean surface air temperatures between the 1981–2000 averages of the respective 20th century history runs (20C 3M) and the period 2081–2100, The results are for the A1B scenario experiments. The models used are listed in Table 2.2.1.1. It can be seen that the higher latitudes have greater warming than the lower latitudes, and the land surface warms more than over the oceans. These findings are thus consistent with those reported in IPCC (2001). In the northern winter, greater warming is found over the Arctic Ocean and the eastern parts of Eurasian and North American continents. In summer, on the other hand, greater warming occurs over semi-arid regions of Middle East, western China, and western USA, where drier conditions are projected (see below). Annual, JJA and DJF mean changes in surface air temperature averaged for the world as a whole, East Asia (20° –50° N, 100°–145° E), and Japan (30–45° N, 130–145° E) are shown in Table 2.2.1.2a for the A1B and B1 scenarios. Projected annual mean temperature changes over East Asia are around 3°C and 2°C for the A1B and B1

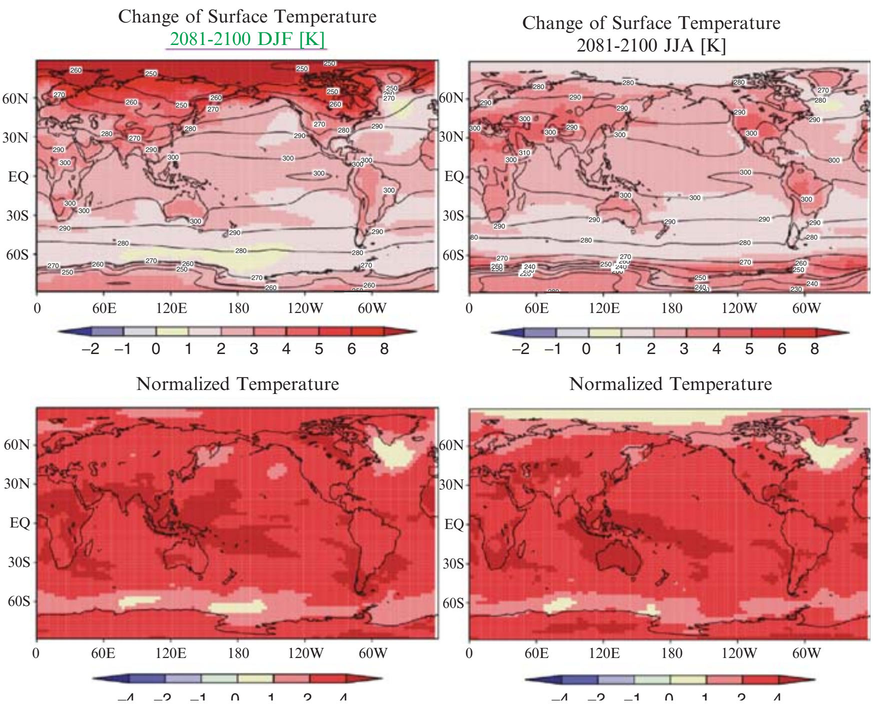

FIG. 2.2.1.1. (left top) Multi-model ensemble mean DJF (December–February) surface air temperature in the present-day model climate (1981–2000) (contours) and its changes for 2081–2100 compared to 1981–2000 (shading). (left bottom) Model consistency as calculated by the ratio of (left top) to inter-model standard deviations. (right) As for (left) except for JJA (June–August) season.

TABLE 2.2.1.1. List of AOGCM experiments based on the IPCC SRES A1B and 20C3M. (See http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php for more details.)

Model name	Originating group
CNRM-CM3	Meteo-France/Centre National de Recherches Météorologiques, France
CSIRO-Mk3.0	CSIRO Atmospheric Research, Australia
GFDL-CM2.1	US Department. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory, USA
GISS-AOM	NASA / Goddard Institute for Space Studies, USA
GISS-EH	NASA/Goddard Institute for Space Studies, USA
GISS-ER	NASA/Goddard Institute for Space Studies, USA
INM-CM3.0	Institute for Numerical Mathematics, Russia
MIROC3.2(hires)	Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan
MIROC3.2(medres)	Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan
ECHAM5/MPI-OM	Max Planck Institute for Meteorology, Germany
MRI-CGCM2.3.2	Meteorological Research Institute, Japan
NCAR-CCSM3	National Center for Atmospheric Research, USA
NCAR-PCM	National Center for Atmospheric Research, USA
UKMO-HadCM3	Hadley Centre for Climate Prediction and Research / Met Office, UK

TABLE 2.2.1.2. Annual/JJA/DJF mean (a) surface air temperature (°C) and (b) precipitation (mm/day) changes between 2081–2100 and 1981–2000 for global, East Asia (20°–50° N, 100°–145° E), and Japan (30°–45° N, 130°–145° E). Multi-model ensemble mean and range among models are shown.

Scenario	Season	Global	East Asia	Japan
(a) Surface air temperature (°C)				
A1B	Annual	2.60 (1.80~4.17)	3.07 (2.01~4.55)	2.99 (1.86~4.45)
	JJA	2.49 (1.71~4.17)	2.95 (1.67~4.40)	2.83 (1.44~4.62)
	DJF	2.72 (1.91~4.27)	3.36 (1.74~4.82)	3.27 (1.70~4.63)
B1	Annual	1.75 (1.07~3.07)	2.05 (1.24~3.33)	2.01 (1.18~3.21)
	JJA	1.68 (1.05~3.05)	2.00 (1.00~3.20)	1.97 (1.00~3.27)
	DJF	1.83 (1.09~3.15)	2.22 (1.34~3.55)	2.13 (1.25~3.36)
(b) Precipitation (mm/day)				
A1B	Annual	0.121 (0.045~0.197)	0.195 (0.023~0.403)	0.154 (−0.364~0.564)
	JJA	0.118 (0.035~0.198)	0.424 (0.076~0.935)	0.456 (−0.358~1.266)
	DJF	0.126 (0.070~0.200)	0.048 (−0.127~0.411)	−0.057 (−0.778~0.457)
B1	Annual	0.093 (0.046~0.158)	0.133 (0.008~0.302)	0.121 (−0.012~0.457)
	JJA	0.092 (0.041~0.162)	0.278 (0.027~0.644)	0.293 (−0.048~1.139)
	DJF	0.130 (0.070~0.200)	0.051 (−0.127~0.411)	−0.026 (−0.305~0.457)

scenarios, respectively, and are about 20% higher than the respective global average values.

Model consistency can be seen in the bottom panels of Fig. 2.2.1.1, which shows the ratio of the ensemble mean temperature difference to the inter-model standard deviations of temperature changes. The fact that the value is greater than 2 almost everywhere in these diagrams means that these temperature increases are robust among all models. Relatively larger values in low latitudes and smaller values in high latitudes suggest that quantitative projection of temperature is more difficult in high latitudes. However, as is shown in Table 2.2.1.2a, the projected absolute value of the temperature increase is large.

Mean Sea-Level Pressure

Figure 2.2.1.2 shows the changes in multi-model averaged DJF and JJA mean sea-level pressure (SLP) for 2081–2100 for the A1B scenario, relative to 1981–2000 averages. Generally in both seasons SLP falls over land and rises over the ocean. In DJF, SLP falls in northern high latitudes and rises in the subtropics. The cold anticyclone over the eastern Eurasian continent becomes weaker, which is consistent with greater warming there. Large falls in SLP occur over the Bering Sea area while the increases over the central north Pacific indicate a northward shift of the Aleutian cyclone. In the southern hemisphere a poleward shift of the subtropical anticyclone belt and surface westerly zone is noted. Based on the normalized SLP field, the increases in SLP south of Japan and over the Mediterranean region, and the decreases over Arctic North America are significant.

In JJA, the models are consistent in indicating that SLP falls over the Canadian Archipelago and over and around the Mediterranean region. A lowering of pressure over the Sahara was noted in IPCC (2001). Centers of the subtropical

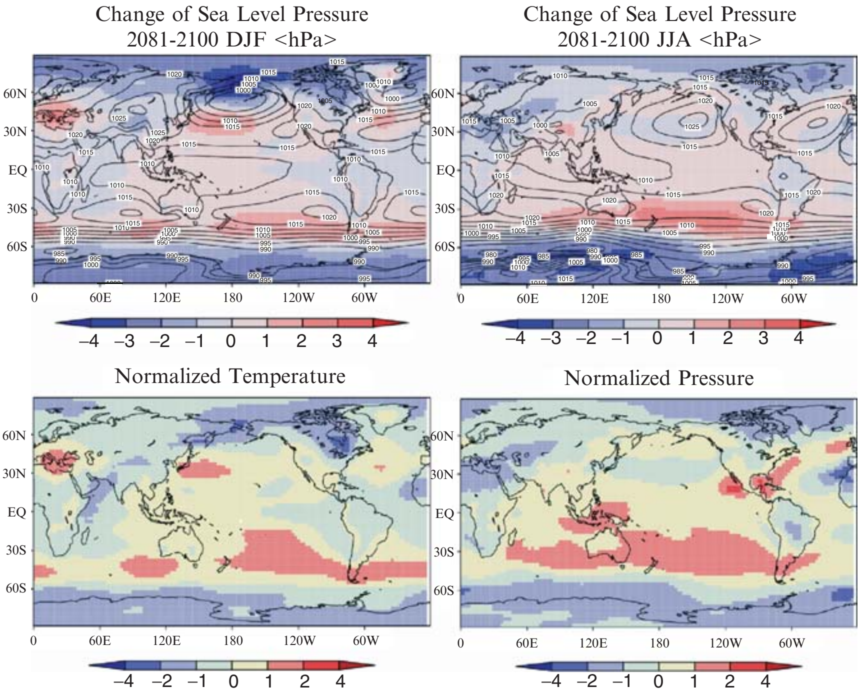

FIG. 2.2.1.2. As in Fig. 2.2.1.1 except for mean sea-level pressure.

anticyclones over the North Pacific and North Atlantic tend to shift northward, while southwestward extension of the North Pacific high is also seen. Over Central America, an extension of subtropical highs from both the Pacific and the Caribbean Sea is significant.

Precipitation

As stated earlier, models exhibit larger uncertainties in the projections of precipitation, particularly in the regional patterns. Generally models are consistent in projecting increased precipitation in the tropics and in mid- and high-latitudes, and decreased precipitation in the subtropics (IPCC 2001). With respect to model consistency, Giorgi et al. (2001) found that models run with an SRES-A2 scenario are consistent with respect to increased precipitation over the South Asia and East Asia region in JJA, but are inconsistent in DJF. Lal and Harasawa (2001), based on the results of four relatively skillful models, show a general increase in precipitation over most of Asia except for a decrease in summertime precipitation over Central Asia. Min et al. (2004) reported that in East Asia precipitation increases in the warmer season (April–September) while it decreases in the colder season (November–February). They also note that wintertime inter-model uncertainty is larger than the signal.

Figure 2.2.1.3 shows the changes in averaged DJF and JJA mean total precipitation for 2081–2100 for the A1B scenario, relative to 1981–2000

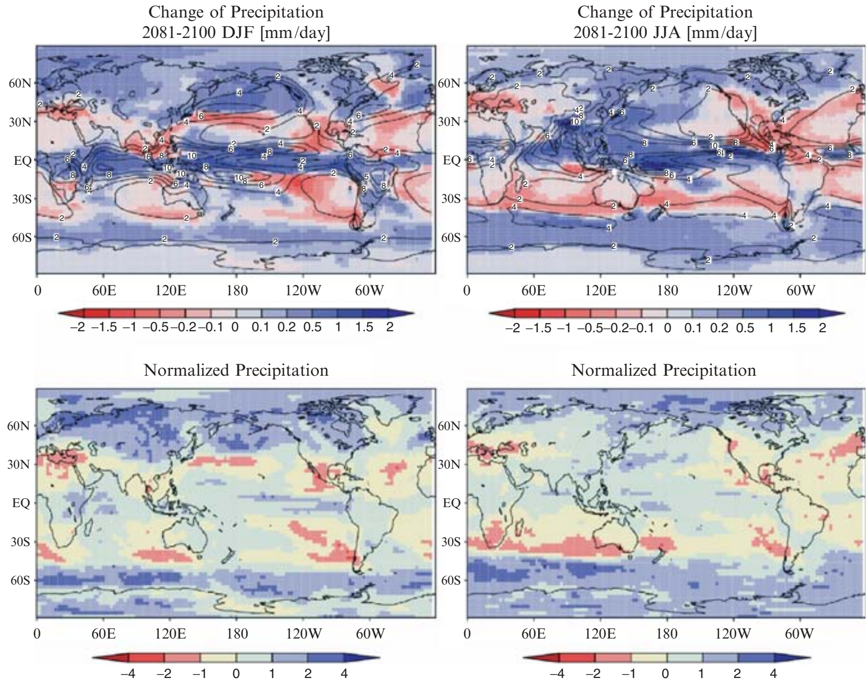

FIG. 2.2.1.3. As in Fig. 2.2.1.1 except for total precipitation.

averages. The results are based on new 14-model analyses. In DJF the overall pattern of precipitation change is similar to that of ensemble means of several models, as reported in IPCC (2001). There is a large increase in the tropics, an increase in the mid- and high-latitudes and a decrease in the subtropics, particularly over the north Pacific subtropical region and the Mediterranean region. These features are generally found in each model, as seen from normalized values exceeding one. Over the North Pacific, a poleward shift in the precipitation zone is clearly seen. This is associated with a northward shift of SLP fields in that area. Model consistency is relatively small in the tropics, but there is indication of a positive precipitation anomaly to the east of the present-day precipitation area, that is, a mean El Niño-like response in the tropical climate.

In JJA the model ensemble mean shows a large increase in precipitation over Asia and the western Pacific region, an increase in high latitudes and a decrease over Central America and the Mediterranean region. There are many studies of the South Asian monsoon showing that a moisture buildup due to a global-scale temperature increase is responsible for increasing moisture flux convergence. This is the case even if dynamical convergence becomes weaker (e.g., Kitoh et al. 1997; Ashrit et al. 2005). It is interesting to note that the models are generally consistent in simulating an increased precipitation around Japan. This implies a more active or more prolonged Baiu rainy season (Uchiyama and Kitoh 2004). Decreased precipitation over western coastal North America is noted where increased winter precipitation is projected, resulting in a larger seasonal contrast in precipitation. On the other hand, an all-year-round decline in precipitation is projected over southwest USA and Mexico.

Annual, JJA and DJF mean changes in precipitation averaged for the world as a whole, East Asia, and Japan are shown in Table 2.2.1.2b for the A1B and B1 scenarios. Projected annual precipitation changes over East Asia are around 70 mm and 50 mm for the A1B and B1 scenarios, respectively. The change is dominated by an increase in summertime precipitation. Wintertime precipitation changes are more model dependent, and even the signs of the change are not certain. When the spatial average is taken in smaller domains, such as Japan, model-to-model inconsistency becomes even larger, with the projected range of precipitation change spanning negative to positive values.

Global warming would result not only in changes in mean precipitation but also increases in the amplitude and frequency of extreme precipitation events (e.g., Zwiers and Kharin 1998; Kharin and Zwiers 2000; Semenov and Bengtsson 2002; Watterson and Dix 2003). This would lead to more frequent floods and landslides, with enormous socioeconomic consequences. On the other hand, a general drying of the mid-continental areas would lead to increases in summer droughts. Kitoh et al. (2005) found from the MRI CGCM results that, for one third of the globe the number of rain days has decreased while the intensity of precipitation has increased. This suggests a shift of precipitation distribution by global warming toward more intense events. They also showed that South China is an example of a region where the summertime frequency of wet-days is decreasing while precipitation intensity is increasing. Further studies of extreme rainfall events and temperatures are required, including using estimates based on multi-model projections.

Summary

Projected temperature changes over the next 100 years for East Asia are around 3°C and 2°C for the A1B and B1 scenario, respectively. These increases are about 20% higher than the respective globally averaged increases for the same time period. An increase in summertime precipitation is projected over East Asia by all models, but precipitation change in winter is more model-dependent, and even the sign of the change is uncertain.

Acknowledgments. We thank the international modeling groups for providing their data for analysis, as well as the Program for Climate Model Diagnosis and Intercomparison (PCMDI) for collecting and archiving the model data, the JSC/CLIVAR Working Group on Coupled Modelling (WGCM) and their Coupled Model Intercomparison Project (CMIP) and the Climate Simulation Panel for organizing the model data analysis activity, and the IPCC WG1 TSU for technical support. The IPCC Data Archive at Lawrence Livermore National Laboratory is supported by the Office of Science, US Department of

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References

Ashrit R, Kitoh A, Yukimoto S (2005) Transient response of ENSO-monsoon teleconnection in MRI-CGCM2.2 climate change simulations. J Meteor Soc Jpn 83:273–291

Giorgi F, Coauthors (2001) Emerging patterns of simulated regional climatic changes for the 21st century due to anthropogenic forcings. Geophys Res Lett 28:3317–3320

IPCC (2000) In: Nakicenovic N, Swart R (eds) Special report on emissions scenarios. Cambridge University Press, 612pp

IPCC (2001) In: Houghton JT et al. (eds) Climate change 2001: the scientific basis. Contribution of working group I to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press, 881pp

Kharin VV, Zwiers FW (2000) Changes in the extremes in an ensemble of transient climate simulations with a coupled atmosphere-ocean GCM. J Climate 13:3760–3788

Kitoh A, Yukimoto S, Noda A, Motoi T (1997) Simulated changes in the Asian summer monsoon at times of increased atmospheric CO_2. J Meteor Soc Jpn 75:1019–1031

Kitoh A, Hosaka M, Adachi Y, Kamiguchi K (2005) Future projections of precipitation characteristics in East Asia simulated by the MRI CGCM2. Adv Atmos Sci 22:467–478

Lal M, Harasawa H (2001) Future climate change scenarios for Asia as inferred from selected coupled atmosphere-ocean global climate models. J Meteor Soc Jpn 79:219–227

Min SK, Park EH, Kwon WT (2004) Future projections of East Asian climate change from multi-AOGCM ensembles of IPCC SRES scenario simulations. J Meteor Soc Jpn 82:1187–1211

Semenov VA, Bengtsson L (2002) Secular trends in daily precipitation characteristics: greenhouse gas simulation with a coupled AOGCM. Clim Dyn 19:123–140

Uchiyama T, Kitoh A (2004) Changes in Baiu-Changma-Meiyu rain by global warming in MRI-CGCM. Proceedings of the international conference on high-impact weather and climate, March 22–24, 2004, Seoul, Korea, 218–221

Watterson IG, Dix MR (2003) Simulated changes due to global warming in daily precipitation means and extremes and their interpretation using the gamma distribution. J Geophys Res 108(D13):4379, doi:10.1029/2002JD002928

Zwiers FW, Kharin VV (1998) Changes in the extremes of the climate simulated by CCC GCM2 under CO2 doubling. J Climate 11:2200–2222

2.2.2 Sea-level Rise and its Impact

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Sea levels fluctuate on a variety of spatial and temporal scales. Long-term changes in sea level in the coastal zone is due to vertical land movement and changes in the level of the ocean's surface, as shown in Fig. 2.2.2.1. The changes in the level of the ocean's surface can further be divided into factors affecting seawater volume, such as thermal expansion, and sea surface shape, such as ocean currents.

Recent global warming is known to induce sea level rise. The Intergovernmental Panel on Climate Change (IPCC) reported that global mean sea level rose in the range of 10–20 cm during the 20th century, based on tide gauge data. Analysis of several long tide gauge datasets indicates that the sea level rose faster in the 20th century than in the 19th century. Within the 20th century, an acceleration in sea-level rise was not reported in tide gauge data. However, recent satellite altimeter observations suggest that the sea-level rise during the 1990s was higher than the mean sea-level rise in the 20th century (Nerem 1999). It is unclear whether this discrepancy is the result of recent acceleration, the difference in the two observational methods, or the short duration of the satellite observation (IPCC WGI 2001).

The sea-level rise in the 20th century is affected by many factors, including thermal expansion of the ocean, melting of glaciers and ice caps on land, melting and limited disintegration of glaciers and ice sheets in Greenland and Antarctica, thawing of permafrost, sediment deposition on the sea floor, and terrestrial water storage by dams and reservoirs. Details are listed in Table 2.2.2.1 (IPCC WGI 2001). This table suggests that global warming in the 20th century has contributed significantly to the global mean sea-level rise, mainly through thermal expansion of seawater and widespread loss of land ice. The contribution of other factors is either small or unclear.

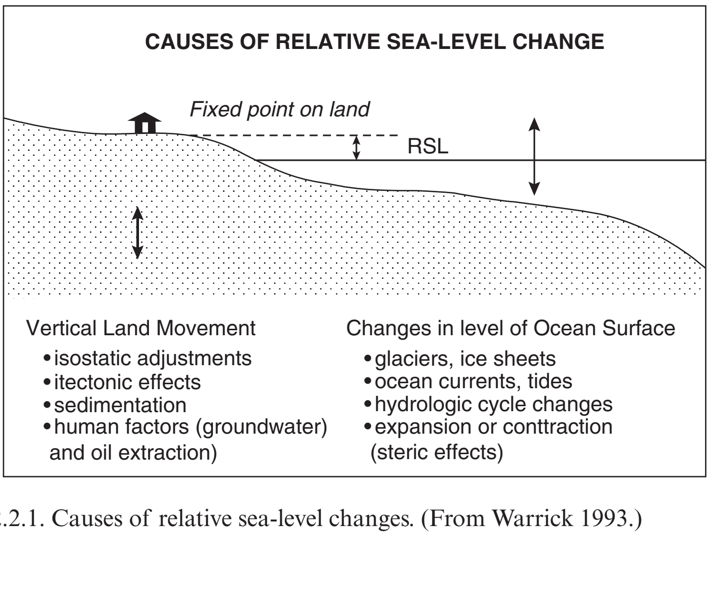


Fig. 2.2.2.1. Causes of relative sea-level changes. (From Warrick 1993.)

TABLE 2.2.2.1. Estimated rates of change in sea level rise components from observations and models (mm/yr) averaged over the period 1910 to 1990 (IPCC WGI 2001).

	Minimum (mm/year)	Central value (mm/year)	Maximum (mm/year)
Thermal expansion	0.3	0.5	0.7
Glaciers and ice caps	0.2	0.3	0.4
Greenland – 20th century effects	0.0	0.05	0.1
Antarctica – 20th century effects	−0.2	−0.1	0.0
Ice sheets – adjustment since LGM	0.0	0.25	0.5
Permafrost	0.00	0.025	0.05
Sediment deposition	0.00	0.025	0.05
Terrestrial storage	−1.1	−0.35	0.4
Total	−0.8	0.7	2.2
Estimated from observations	1.0	1.5	2.0

Studies on the regional distribution of sea-level rise due to global warming are very limited due to the sampling problem of tide gauge data (Douglas et al. 2001). In spite of this, Douglas (1997) attempted to determine a 20th-century rate of sea-level rise based on tide gauge records with several restrictions. The criteria imposed on the tide gauge records were that the records must be longer than 60 years, free of vertical crustal movements due to plate tectonics, correctable for glacial isostatic adjustment, and have trends insensitive to small changes in their record length. Only 21 usable records complied with these criteria. They were divided into 9 groups worldwide. The data indicated a mean trend for a global sea-level rise of 1.8 mm/year +/−0.1, with a postglacial rebound correction (ICE-3G). In the Asia-Pacific region, the only record that meets the criteria is for Honolulu (1905–1997). The trend shown by this record is 1.9 mm/year.

In the 21st century, the global mean sea-level rise is expected to accelerate due to the acceleration of global warming. Based on the 35 SRES scenarios (IPCC 2000), IPCC estimated that the sea level rise in the 21st century would be in the range of 9–88 cm, with a median value of 48 cm (Fig. 2.2.2.2). The projected range of the sea-level rise is 2.2–4.4 times higher than that of the 20th century. The regional distribution of future sea-level change will be complex because of factors such as the regional distribution of thermal expansion, heat transport into ocean interiors, ocean circulation changes caused by the change of density structure with temperature and salinity changes, horizontal heat transport changes due to the ocean circulation changes, and wind field changes due to climate change. It is projected that the regional variation will be large when compared to the global mean value. Climate model predictions in the regional distribution of the 21st sea-level change show little similarity between models except for the maximum sea level rise in the Arctic Ocean and the minimum rise in the Southern Ocean. This implies that confidence is low with regard to predicting the regional distribution of sea-level change (Gregory et al. 2001).

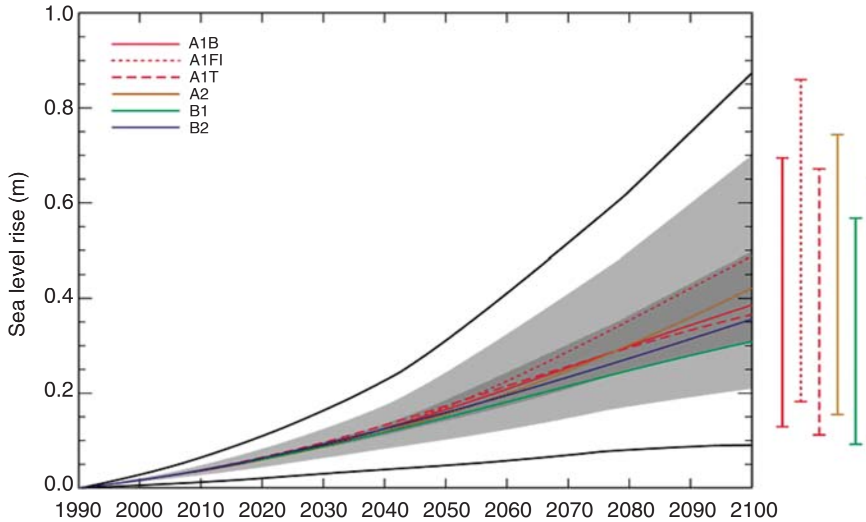


Fig. 2.2.2.2. Global sea-level rise from 1990 to 2100 for SRES scenarios. (From IPCC WGI 2001.)

Table 2.2.2.2. Predictions of sea level rise due to global warming in the 21st century by HadCM3 climate model for A2 and B2 emission scenarios. Asia covers 100° – 160° E longitude 0° – 60° N latitude.

Region/Year	2030	2060	2090
Global–A2	7.0	17.0	34.0
Asia– A2	6.0	17.9	39.8
Global–B2	7.1	20.5	45.7
Asia– B2	5.3	18.4	43.2

In spite of this low level of confidence in the regional projections of sea-level rise, one GCM (HadCM3, Hadley Centre, UK) is used here to estimate future sea-level trends near the Asian region and compare these with the global trend. HadCM3 includes components of sea-level change due to thermal expansion, ice melting and the mass balance of the Greenland/Antarctica ice sheet (Gregory and Lowe 2000). Table 2.2.2.2 represents the projections for sea-level change in Asian waters relative to the global mean in 2030, 2060, and 2090 for the A2 and B2 emission scenarios (IPCC 2000). The estimated sea-level changes represent 10-year averages relative to 1990. As seen in Table 2.2.2.2, sea-level rise near Asia in 2060, and 2090, and for both scenarios, is likely to be higher than the global average. In the northwestern Pacific, the HadCM3 model indicates that a large rise in sea level occurs in the region of Kuroshio. This same large increase in sea level also appears in other climate models such as NCAR CSM (Choi et al. 2001). The indication that sea level will undergo large increases in the 21st century suggests serious impacts on the region.

The impacts of sea-level rise are widespread in the coastal environment. Biophysical impacts can include increased coastal erosion, more extensive coastal inundation, higher storm-surge flooding, and landward intrusion of seawater in estuaries and aquifers (IPCC WGII 2001). These biophysical impacts will in turn induce a variety of socioeconomic impacts. These can include increased loss of property and coastal habitats, increased flood risk and potential loss of life, damage to coastal protection and other infrastructure, loss of tourism and transportation functions, and impacts on agriculture and aquaculture through a decline in soil and water quality. However, the impacts of sea-level rise will be highly variable in time and space due to the wide variety of coastal environments, such as regional differences in sea-level rise, the resilience of the coastal system, and the adaptive capacity of natural and socioeconomic systems (Klein and Nicholls 1999).

There are about 10 deltas with an area of more than 10,000 km^2 in the coastal zone of Asia (Coleman and Wright 1975). Sea-level rise will have an impact on the deltas through inundation, erosion, increased wave action, saltwater intrusion, and ground subsidence. Low-lying deltas, in particular, are more vulnerable to sea-level rise (Walker 1998). In the case of China, low-lying deltas occupy 22% of the total coast. Coral reefs are more vulnerable to an increase in atmospheric CO_2 concentration and water temperature than to sea-level rise. Indeed, a moderate rate of sea-level rise can actually stimulate the growth of coral reef.

Mangrove forests exhibit high biological productivity and form a coastal buffer zone. The world's largest mangrove forest exists in the Asia-Pacific region at the Sundarbans in Bangladesh and adjacent areas in India, which covers 6,000 km^2 (Allison 1998). The depletion of mangrove forest has already occurred in countries such as Thailand, Philippines, and Indonesia. Sea-level rise will change the salinity distribution in the coastal zone and hence the productivity of mangrove forests in the region. A lack of sediment supply and discontinuation of alongshore sediment transport already means that beach erosion is widespread along the coasts of Asia in countries such as China, Japan, Indonesia, Korea, Sri Lanka, Thailand, Bangladesh, and Malaysia (IPCC WGII 2001). When coupled with sea-level rise, the situation will lead to accelerated erosion along such coasts. As one example, Mimura et al. (1995) estimated the future erosion rate of Japanese sandy beaches using the Bruun rule (Bruun 1962). The study revealed that 57%, 82%, and 90% of the areas of existing sandy beaches in Japan would be eroded due to a sea-level rise of 30, 65 and 100 cm, respectively. As noted earlier,

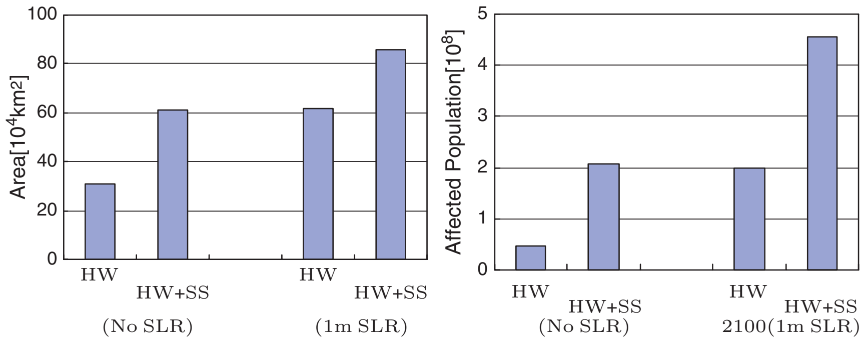
Asia-Pacific coasts are undergoing high socioeconomic development in parallel with global trends such as urbanization, industrial development, trade and transport demands, and lifestyle changes. Currently, more than half of Asia's population (1.7 billion) lives in the coastal zone. It is expected that the future sea-level rise will have a great impact on the socioeconomic activities of Asia-Pacific coasts. IPCC WGI (2001) issued a vulnerability assessment for Asian countries, as shown in Table 2.2.2.3, which represents the

TABLE 2.2.2.3. Potential land loss and population exposed in Asian countries to sea -level rise under no adaptation measures. (From IPCC WGII 2001.)

	Sea-level rise	Potential land loss		Population exposed	
Country	(cm)	(km^2)	(%)	(millions)	(%)
Bangladesh	45	15,668	10.9	5.5	5.0
Bangladesh	100	29,846	20.7	14.8	13.5
India	100	5,763	0.4	7.1	0.8
Indonesia	60	34,000	1.9	2.0	1.1
Japan	50	1,412	0.4	2.9	2.3
Malaysia	100	7,000	2.1	>0.05	>0.3
Pakistan	20	1,700	0.2	n.a.	n.a.
Vietnam	100	40,000	12.1	17.1	23.1

potential land loss and population exposure in Asian countries as a result of a given rise in sea level, and without a rise under no adaptation measures (IPCC WGII 2001). In general, Asian countries will be vulnerable to future sea-level rises. Among the countries listed, the vulnerability of Bangladesh and Vietnam is particularly high. In a scenario where there is a 1-m sea-level rise, about one fifth of Bangladesh's land will be inundated, and 15 million people will be vulnerable. This represents around 13% of the nation's population. In Vietnam, land loss will be 12% of the total area while the population exposed will amount to 23% (17.1 million) of the total population.

In order to develop a more comprehensive understanding of the vulnerability to sea level rise in the Asia and Pacific region, Mimura (2000) performed a region-wide assessment of sea-level rise and storm surges, using global datasets of climatic, environmental, and societal information. The Asia-Pacific region considered in the analysis covers an area from 30° E to 165° E, and 90° N to 60° S. The population in 1994 was about 3.8 billion, but is estimated to increase to 7.6 billion by 2100. Results of the study are summarized in Fig. 2.2.2.3. Even today, the areas below the high tide level and storm surge level, i.e., inundated and flooded areas, amount to 311,000 km^2 or 0.48% of the total area and 611,000 km^2 or 0.94%, respectively. These increase to 618,000 and 858,000 km^2 (0.98% and 1.3%) with a 1 m sea-level rise. The area flooded by sea-level rise would therefore increase by 247,000 km^2. With regard to the people affected, today, about 47 million, or 1.2% of the total population, live in the area below the high tide level, while 270 million people or 5.3% live below the storm surge level. These figures show that the Asia-Pacific region is already vulnerable to flooding by storm surge. If the mean sea level rises by 1 m and the population growth by 2100 is taken into account, the numbers of people affected increase and the above populations come to about 200 and 450 million people, respectively. The number of people in the population in the flooded areas rises to some 249 million. The areas that may be seriously affected are distributed in the deltas of the Mekong, Ganges and Brahmaputra Rivers, the Yangtze River, and the southern part of Papua New Guinea. Countries and areas where more than 10% of the national population



(a) Inundated and flooded areas (b) Affected population

Fig. 2.2.2.3. Affected area (a) and population (b) for present (no SLR) and 2100 (1 m) in the Asia Pacific region (from Mimura 2000). HH, SS, and SLR represent high water, storm surge, and sea-level rise, respectively.

is affected include Vietnam, Taiwan, Cambodia, Brunei, Bangladesh, and Guam.

References

Allison MA (1998) Geological framework and environmental status of the Ganges-Brahmaputra Delta. J Coast Res 14(3):794–825

Bruun P (1962) Sea-level rise as a cause of storm erosion. Proc ASCE, J Waterway Harbors Div 88:117–130

Choi BH, Kim DH, Kim JW (2001) Regional responses of climate in the northwestern Pacific Ocean to gradual global warming for CO_2 quadrupling. J Meteor Soc Jpn 80(6):1427–1442

Coleman JM, Wright LD (1975) Modern river deltas: variability of processes and sand bodies. In: Brousard ML (ed) Deltas. Houston Geological Society, pp 99–149

Douglas BC (1997) Global sea level rise: a redetermination. Surv Geophys 18:279–292

Douglas CD, Kearney MS, Leatherman SP (2001) Sea level rise. History and consequences. International Geophysics Series 75, 232pp

Gregory JM, Church JA, Boer GJ, Dixon KW, Flato GM, Jackett DR, Lowe JA, O'Farrel SP, Roeckner E, Russell GL, Stouffer RJ, Wintern M (2001) Comparison of results from several AOGCMs for global and regional sea level change 1900–2100. Climate Dyn 18:225–240

Gregory JM, Lowe JA (2000) Predictions of global and regional sea level rise using AOGCMs with and without flux adjustment. Geophys Res Lett 27:3069–3072

IPCC (2000) IPCC special report on emissions scenarios. Cambridge University Press, Cambridge, 599pp

IPCC WGI (2001) Climate change 2001: the scientific basis. Cambridge University Press, Cambridge, 881pp

IPCC WGII (2001) Climate change 2001: impacts, adaptation, and vulnerability. Cambridge University Press, Cambridge, 1032pp

Klein RJT, Nicholls RJ (1999) Assessment of coastal vulnerability to climate change. Ambio 28(2):182–187

Mimura N, Kiyohashi M, Kawaguchi E (1995) Response of coastal landform to sea level rise: focusing on sandy beaches amd river mouths. Preprints of 3rd symposium on global environment, committee on global environment, JSCE, 97–102
Mimura N, Satoh K, Machida S (2000) Asian and Pacific vulnerability assessment: an approach to integrated regional assessment. Proceedings of the Thai-Japanese geological meeting: comprehensive assessment on impacts of sea-level rise.
Nerem RS (1999) Measuring very low frequency sea level variations using satellite altimeter data. Global Planet Change 20:157–171
Walker HJ (1998) Arctic deltas. J Coast Res 14(3):718–738

2.3 Human Activities

2.3.1 Population and Economic Growth

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Population

Human activities within the coastal zone are diverse and include industry, urban and residential development, tourism and recreation, transport, fisheries/aquaculture and agriculture (Rigg et al. 1997). Because they are a center of various human and other urban economic activities, coastal areas are among the most crowded and developed in the world. Recent studies have shown that the overwhelming bulk of humanity is concentrated along or near coasts on just 10% of the earth's land surface (Hinrichsen 1998). Recent data (Population Reference Bureau 2004) show that the Asia-Pacific region has half of the world's largest countries in terms of population, and this situation will continue in the 21st century (Table 2.3.1.1). In fact, more than half of all Asian people live in the coastal zone. Close to 60% of China's 1.3 billion people live in coastal provinces.

In Asia-Pacific countries, populations in coastal areas are growing faster than those in non-coastal areas. Migration is a key factor affecting population growth in coastal zones. Indonesia and Vietnam are two typical examples of Asia's population shift from the hinterlands to coastal areas. In Indonesia, 65% of people live on the main island of Java, on just 7% of country's land area. Similarly in Vietnam, coastal populations are growing two tenths of a percentage point faster than the rest of the country. Around 1,000 people arrive in China's large coastal cities each day, and similar numbers move to the coasts in Vietnam and the Philippines (Hinrichsen 1998). Many of the world's coasts are becoming increasingly urbanized. In fact, 14 of the world's 17 largest cities are located along coasts, and 11 of these cities, including Bangkok, Jakarta, and Shanghai, are in the Asia-Pacific region (John 2002, Fig. 2.3.1.1).

TABLE 2.3.1.1. The world's 10 largest countries.

	2004		2050	
Rank	Country	Population (millions)	Country	Population (millions)
1	China	1,300	India	1,628
2	India	1,087	China	1,437
3	United States	294	USA	420
4	Indonesia	219	Indonesia	308
5	Brazil	179	Nigeria	307
6	Pakistan	159	Pakistan	295
7	Russia	144	Bangladesh	280
8	Bangladesh	141	Brazil	221
9	Nigeria	137	Congo, Dem. Rep. of	181
10	Japan	128	Ethiopia	173

FIG. 2.3.1.1. Main cities and their population in Asian-Pacific area.

Fertility levels globally are expected to decline and the world population will stabilize in 40 years. In the 1960s many newly independent countries believed their large and growing population was a major asset. However, over the last 50 years, the world has slowed population growth, raised life expectancy, lowered mortality and improved quality of life. The last century saw the total population more than triple to 6.1 billion in 2000, growing annually at 1.2% – lower than the 2% in the late 1960s. The number of children per woman has reduced from 5 in the 1950s to less than 3 currently, and the annual increase in the population fell from 87 million in 1987 to 77 million in 2004. The increase has been falling since the 1980s and is expected to fall to 29 million by 2050, when there will be stabilization, attributed to lower fertility.

China has 21% of the world's population and has been working to curb the rise in its population. Lower population growth remains a top priority for the Chinese government. Its policy of controlling population and improving quality of life has made outstanding progress.

Japan is undergoing a redefinition of gender roles as women enter the workforce. The change is cited as a factor for the birthrate declining to 1.29 children, which is among the lowest rates in the world. Japan's population is expected to peak at 128 million in 2 years and then decrease to 120 million by 2026 and 100 million by 2050 (Washington Post 2004).

In Korea, to end the poverty and the baby boom that followed the 1950–1953 Korean War, a family planning program was instituted in 1961. This was aimed at persuading Koreans to "stop at two children". In the 1960s, the average Korean woman gave birth to six children. By 1970, the number dropped to four. The number of children continued to decrease and eventually reached its current level of 1.42 births per woman. Within four decades, Korea has transformed itself to a country with a very low birth rate.

Vietnam has reduced its population growth. Its baby-boom generation is approaching the peak of its child-bearing years. The country has managed to bring the birth rate down from 3.8 children in 1989 to 2.28 children in 2003 (Vietnam News Agency 2003).If the country keeps following the voluntary two-child policy, the population will reach 100 million people by 2025, 15 years later than past estimates.

In Bangladesh, family planning was launched in 1962. The total fertility rate was brought down from 6.3 in 1976 to 3.3 in 1996. The current population of 140 million has doubled from 75 million in 1971. The Bangladeshi Cabinet has approved the draft of Policy 2004 (NPP 2004) that focuses on reducing the population growth rate to 1% by 2010 from the present 1.54%. It also aims to stabilize Bangladesh's population at 216 million by 2060.

While education, economic development, and government support for family planning programs are all important, there is not a single "silver bullet solution" that triggers rapid and sustained fertility decline in every country, every time. According to Amartya Sen, author of "Development as Freedom," and recipient of the Nobel Memorial Prize in Economic Science in 1998, women's empowerment, through such initiatives as employment, education, and property rights, can lead to a reduction in the fertility rate. The Indian states of Kerala, Tamil Nadu, or Himachal Pradesh have experienced speedy fertility declines that can be linked to the rapid enhancement of female education, employment opportunities, and other forms of empowerment of young women. The states of Uttar Pradesh, Bihar, and Rajasthan, on the other hand, provide few economic and educational opportunities to young women and experience high fertility rates. It is notable that China, where coercive one-child policies were employed, fertility rates fell from 2.8 to 2.0 from 1979 to 1991, while in Kerala, where fertility decline was freely chosen, fertility rates fell much faster, from 3 to 1.8 in the same period.

Economic Growth

There is uneven economic growth among the world's major regions resulting from global restructuring. The Asia-Pacific area has come out strongly as a leading growth region. The ASEAN countries and coastal areas of China are experiencing rapid economic growth, and are forming the focus of the world's current economic growth. This rapid economic growth is bringing about increased mutual dependence between the countries of the region in terms of resources, trade and so on. Over the last 30 years the region has gradually moved from a subsistence lifestyle towards a consumer society, with rapid rates of urbanization and westernization, as well as population increases. Some scholars suggest that the 21st century will be the Pacific Century (e.g., Linder 1986). In China's push for modernization and economic reforms, its coastal cities are assigned vital catalytic roles. These include Special Economic Zones and Open Coastal Areas that have special incentives for international investors. These areas are scattered along China's coast and now include Hong Kong and also China's largest city, Shanghai (Fig. 2.3.1.2). By 1996, with economic growth averaging 8% for over a decade, a number of countries in the Asia-Pacific region – in particular the newly industrialized economies such as Hong Kong, the Republic of Korea, Singapore, Taiwan and China – had been able to reduce poverty to nonexistent levels, while Indonesia, Malaysia, and Thailand also had made impressive strides.

With the financial and economic crisis starting in Asia in 1997, annual GDP growth rates decreased from a high of 9.76% in 1970 to 2.54% in 1999, with a negative growth of −1.04% in 1998. Overall, however, between 1972 and 1999 real per-capita income nearly doubled in Northwest Pacific and East Asia, growing by an average of 2.4% annually (Fig. 2.3.1.3). In South Asia, the growth rate also exceeded 2%. However, growth was very low in the Pacific Islands (World Bank 2001).

Impact of Population and Economic Growth on Coastal Environments

The high concentration of people combined with rapid economic growth in coastal regions has produced many economic benefits, including improved transportation links, industrial and urban development, revenue from tourism,

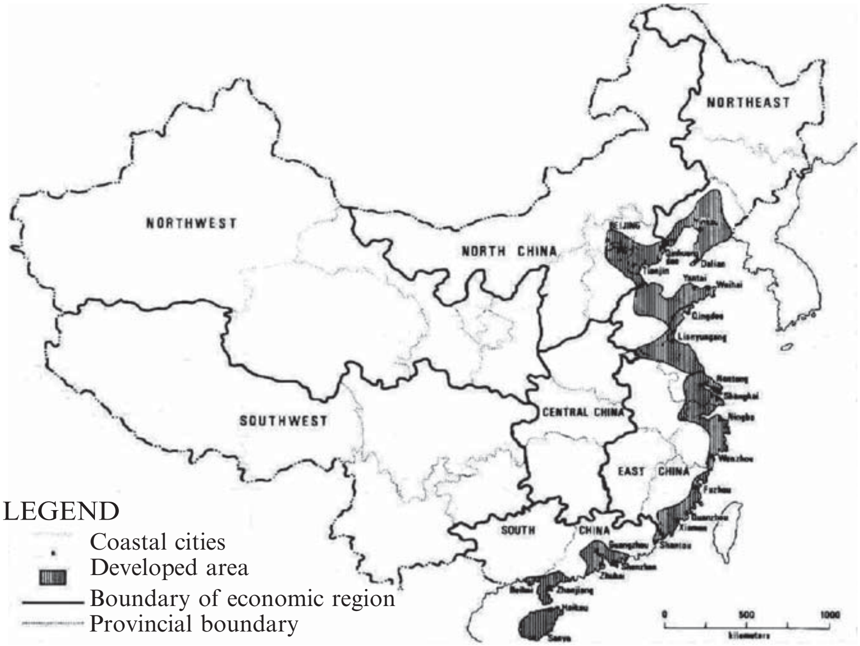

FIG. 2.3.1.2. Developed areas in China.(From Yeung and Hu 1992.)

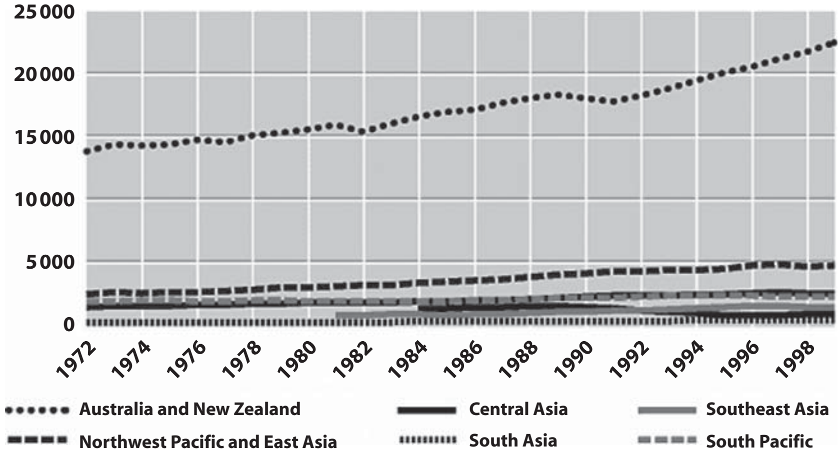

FIG. 2.3.1.3. GDP per capita (US $1995) by region in Asian-Pacific area.

and food production. However, the combined effects of a booming population growth and economic and technological development are threatening the ecosystems that are critical to providing these economic benefits. Coastal regions are undergoing environmental decline. The problem is particularly acute in Asia-Pacific countries (Table 2.3.1.2).

TABLE 2.3.1.2. Relative significance of resource and environmental issues in selected Asian-Pacific countries. (From ADB data.)

	Land & soil resources	Pesicide & fertilizer	Deforestation	water resources	Industrial pollution	Acid rain	Marine & coastal degradation	Sea level rise	urban congestion & pollution	waste disposal
Bangladesh	□	▨	▨	■	□		□	▨	▨	
China	□	▨	■	□	■	■	□	▨	■	□
India	■	▨	■	■	■	▨	▨	□	■	□
Myanmar	▨	□	▨					□		
Nepal	■	□	■	□			n.a.	n.a.	□	
Pakistan	■	▨	▨	▨	□		□	□	■	□
Sri Lanka	▨	□	■	▨	□		■		□	
Cambodia	▨		■	□	□		▨		□	□
Indonesia	▨	▨	■	■	▨		▨	▨	■	□
Lao PDR	▨		■	▨			n.a.	n.a.		
Malaysia	□	□	■	□	▨		▨	□	▨	
Philippines	■	▨	■	▨	▨		▨	▨	■	□
Thailand	▨	▨	■	■	▨	□	▨	▨	■	□
Vietnam	▨	□	■	▨	▨		▨	□	▨	□
Pacific Islands	▨	□	▨	■	□		■	■	▨	■

■ High priority
▨ Meduim Priority
□ Low Priority
n.a. not applicable

The reasons for environmental decline are complex, but population factors play a significant role. Changes in the size, composition, and distribution of human populations affect coastal regions by changing land use and land cover. Fishing or harvesting, the destruction of mangroves, and pollution and sedimentation from human activities can all affect the coastal environment.

Managing population pressures in coastal zones is difficult because these regions encompass many physical, social and regulatory divisions. Governments usually manage each sector separately. Consequently, many coastal nations have experienced rapid uncontrolled development along their coastlines. Integrated coastal management (ICM), an internationally accepted approach to managing resources that is based on the United States' 1972 Coastal Zone Management Act, allows policymakers and planners to take population issues into account when looking at the pressures, threats, and opportunities facing coastal areas. ICM attempts to forge a balance between users of water and natural resources while ensuring that long-term environmental health and productivity are not compromised (NOAA 2003). Countries may use ICM to address the depletion of coastal and ocean resources, deal with pollution that endangers public health, distribute the economic benefits of using the coast and ocean, and develop and manage coastal and marine areas that are not yet being exploited. At least 107 of the world's 134 coastal developing nations are involved in some type of ICM effort at the national or subnational level (Jens 2003). In general, the most successful ICM efforts share several characteristics:

1. Multiple stakeholders, including representatives from all levels of government, NGOs, indigenous groups, communities, and the private sector.
2. A strong scientific foundation to inform the management process.
3. A formalized mandate and funding mechanism.

4. Formal decision-making that incorporates social, environmental, and economic data.
5. Public participation starting at the initial stages of policy formulation and program development.
6. Community-based management initiatives to develop community experience, build support, and provide information about regional or national programs.
7. Capacity building of local experts through training, education, and applied research.
8. Strong outreach services that provide information and education to all levels of management.
9. Regular collection of reliable data to measure the success of management initiatives (Biliana and Robert 1998).

References

Washington Post, August 31, 2004

Biliana C, Robert K (1998) Integrated coastal and ocean management: concepts and practices. Island Press, Washington DC

Hinrichsen D (1998) Coastal waters of the world: trends, threats, and strategies. Island Press, Washington DC

Jakarta Post, October 11, 2004

Jens S (2003) Baseline 2000: background report www.uhi.umb.edu/b2k/baseline2000.pdf.

John T (2002) Coastal cities: living on the edge. Environ Health Perspect 110(11):674–681

Linder Staffan B (1986) The Pacific century: economic and political consequences of Asia-Pacific dynamism. Stanford University Press, Stanford, CA

Lutz W, Sanderson W, Scherbov S (1997) Doubling of world population unlikely. Nature 387:803–804

The Nation (2000) 271(4), 16, Thailand, ISSN: 0027–8378

United Nations Population Division (2001) World population prospects 1950–2050 (The 2000 Revision). United Nations, New York

United States National Oceanographic and Atmospheric Administration (NOAA) (2003) What is integrated coastal management? www.icm.noaa.gov/story/icm_def.html

Vietnam News Agency, December 26, 2003

WRI (2001) World resources 2000–2001—people and ecosystems: the fraying web of life. World Resources Institute, Washington DC, pp 69–79

World Bank (2001) World development indicators 2001. World Bank, Washington DC

Yeung Y, Hu X (1992) China's coastal cities: catalysts for modernization. University of Hawaii Press, Honolulu

2.3.2 Development in River Basins

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Accelerated Industrialization

The first characteristic of the recent rapid economic growth in East Asia is that it involved a dramatic transformation of the industrial structure that could be called "accelerated industrialization" (industrialization that took several generations in the developed nations was achieved in just one generation). For example, Taiwan began as an agricultural society, but the proportion of the total population engaged in its industrial sector grew rapidly from 29% in 1965 to 48% in 2000. On the other hand, its agricultural sector decreased from 27% in 1965 to 5% in 2000. Even in countries such as Thailand and Indonesia, which are still basically agricultural societies, their respective industrial sectors have risen quickly from 23% and 13% in 1965 to 41% and 42% in 2000, respectively. Meanwhile their agricultural sectors fell from 43% and 50% in 1965 to 10% and 11% in 2000, respectively.

Explosive Urban Growth

The second characteristic of rapid economic growth in East Asia is the explosive urban growth. This was magnified by the impoverishment of rural areas suffering under the burden of huge populations. For example, in Japan, over a period of two decades from 1950 to 1970, the urbanization ratio jumped from 50% to 71%. From then the increase slowed somewhat (Table 2.3.2.1, United Nations 1995). But urbanization in South Korea has proceeded even faster than in Japan, increasing from 21% in 1950 to 41% in 1970, and then after another two decades to 90% in 2000. Thailand and Indonesia are on the whole still at relatively low levels of urbanization. But even in these countries the rates of urbanization are truly explosive. There are major concentrations of population in urban centers such as Bangkok and Jakarta (Table 2.3.2.1).

Accelerated industrialization is another major factor triggering Asia's rapid urbanization.

Table 2.3.2.1. Urbanization ratios in seven East Asia economies. (From United Nations 1995.)

	Japan	South Korea	Taiwan	Thailand	Malaysia	Indonesia	China
1950	50.3	21.4	–	10.5	20.4	12.4	11.0
1970	71.2	40.7	–	13.3	33.5	17.1	17.5
1990	77.2	73.8	(75.9)	18.7	49.8	30.6	26.2
1994	77.5	80.0	(76.6)	19.7	52.9	34.4	29.4
2010 (predicted)	80.6	91.0	–	27.4	64.4	49.7	43.0

Notes: Owing to differing conceptions of cities depending on country, urbanization ratio (i.e., urban population/total population) here is based on urban population estimates (prepared by the UN Population Bureau with the cooperation of the UN Statistics Bureau) in urban agglomerations instead of urban areas proper. Thus there are no figures for Taiwan, whose parenthetical values are taken from *Statistics Yearbook of the Republic of China*.

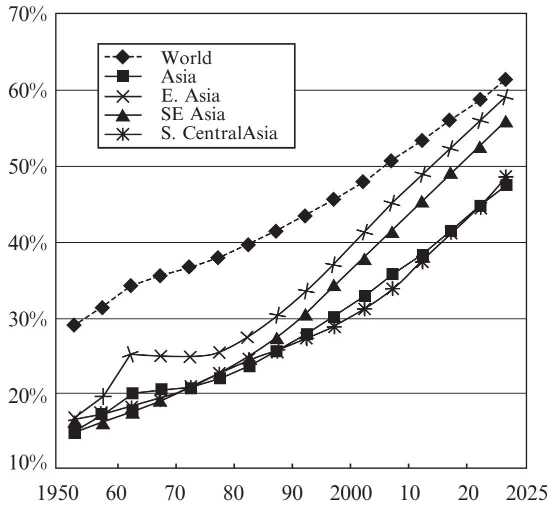

FIG. 2.3.2.1. Urbanization from 1950 to 2025. (From United Nations 1995.)

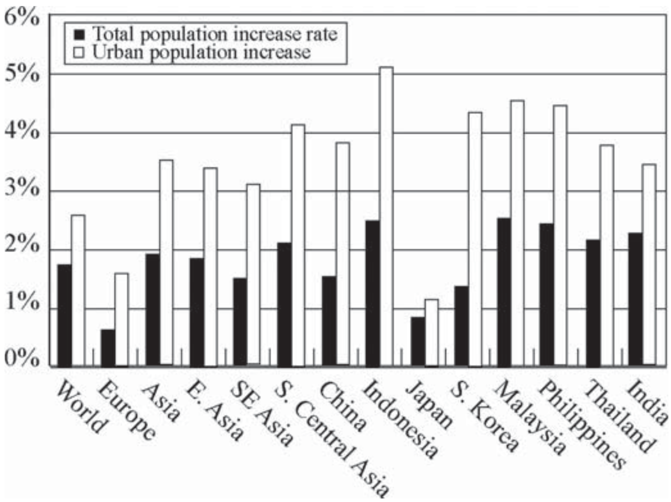

FIG. 2.3.2.2. Average annual rates of increase in total and urban populations from 1970 to 1994. (From United Nations 1995.)

Asian countries with urbanization levels of 60% or more are, presently, Japan and the Newly Industrializing Economies (NIEs) of Hong Kong, South Korea, Singapore, Taiwan-China, Indonesia, Malaysia and Thailand. These have all experienced rapid economic growth and industrialization. There is a clear connection between economic level and urbanization whereby, generally speaking, countries that are highly developed economically also have

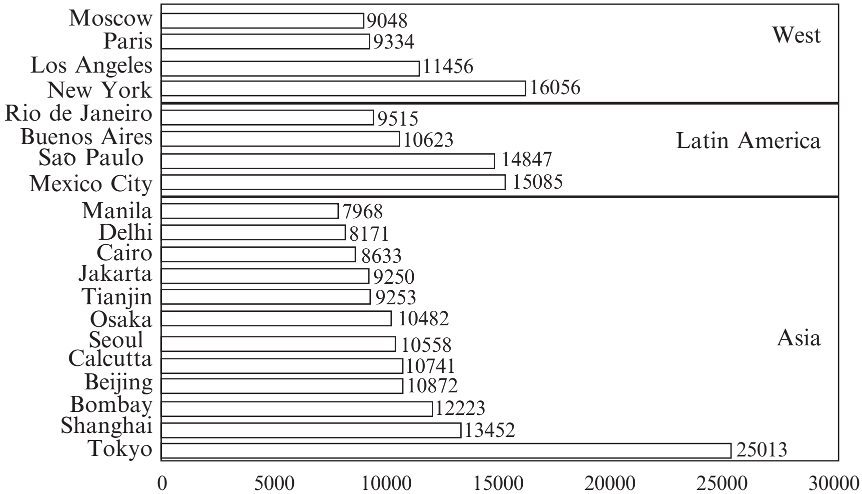

FIG. 2.3.2.3. The 20 largest urban agglomerations in 1990 (thousands). (From United Nations 1995.)

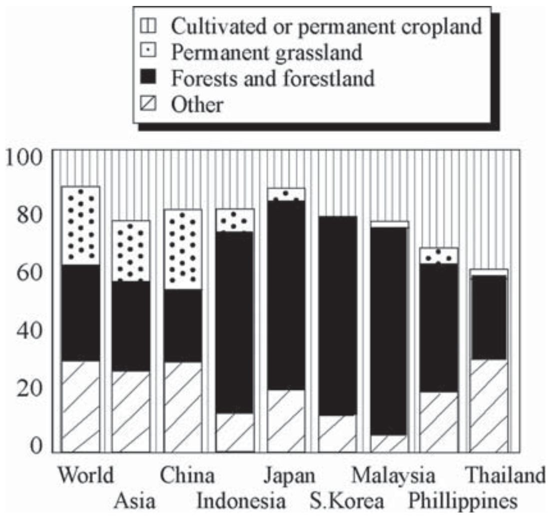

FIG. 2.3.2.4. Types of land use. (From FAO 1995.)

high urban population percentages. Malaysia and the Philippines are promoting economic growth and urbanization in an attempt to emulate Japan and South Korea. The urban population levels in the populous Asian countries of China, India and Indonesia in 1994 were relatively low at 29%, 27%, and 34%, respectively, but from now on, they will probably surge in conjunction with economic growth (Figs. 2.3.2.1 and 2.3.2.2, United Nations 1995).

Asia's pace of urbanization is far faster than that in developed Western countries. For example, Great Britain, France, and the USA required 70–80 years, 100 years, and 60 years, respectively, to raise their urbanization percentages from 20% to 50%. A further increase from 50% to 70% took 35, 28, and 40 years, respectively. In Japan, however, the increase from 20% to 50% took 31 years, and from 50% to 70% only 15 years, or about half the time. Urbanization occurred even faster in South Korea, which required 30 years to go from 20% to 50%, and a mere decade from 50% to 70% (Fig. 2.3.2.2, United Nations 1995).

In Asia the formation of megacities is also very pronounced. Cities defined by the UN as "mega-cities", i.e., those with populations of at least 10 million, are growing in number, especially in Asia. In 1950 the only megacities were New York and London. These had populations of only 10.2 million and 8.7 million, respectively. But as of 1990, 12 of the world's 20 biggest cities were in Asia, and the largest of them – Tokyo – had a population of 25 million (Fig. 2.3.2.3, United Nation 1995). Predictions say that in 2015 the world will have 33 megacities, 22 of which will be in Asia.

Mass Consumption Society

Japan joined the mass consumption society (where people buy, use and abandon too many goods) at the end of the 1950s and was close behind the US a decade later. Other economies made their entries at a later date: Hong Kong at the beginning of the 1960s, Taiwan at the end of the 1960s, South Korea in the early 1970s, and China's major coastal cities at the beginning of the 1980s. This means that many Asians have become fully fledged members of the energy-intensive, mass-consumption, mass-refuse society. This will place great stress on the coastal area, for example, by reclaiming land as a dumping site for wastes.

Deforestation

In East Asia, the ratio of forest in land use is rather high (Fig. 2.3.2.4, FAO 1995). Therefore, deforestation is becoming a big problem both for

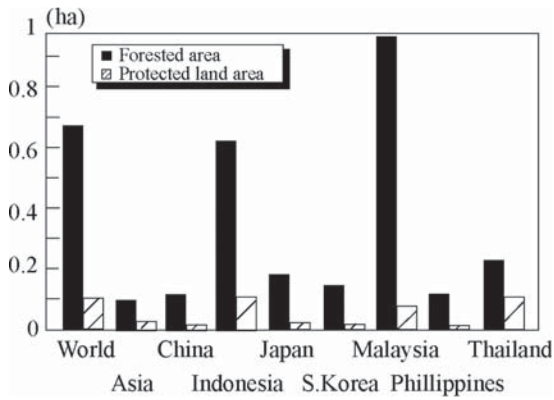

Fig. 2.3.2.5. Per-capita forested and protected land. (From FAO 1990.)

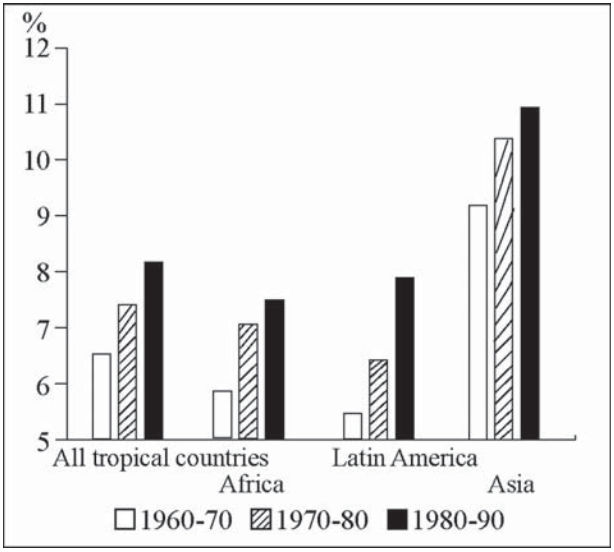

Fig. 2.3.2.6. Rate of tropical forest loss between 1960 and 1990. (From World Resources Institute 1996.)

changes in sand transport and also for the coast. Deforestation is believed to be caused by nontraditional rough agriculture, by people who make their way into the forests along logging roads, and by conversion of forestland, especially for the development of farmland and pastureland. Compared with Indonesia and Malaysia, which have high proportions of forested land, the high proportions of tilled land in China, the Philippines, and Thailand make for low proportions of forestland (Fig. 2.3.2.4). Since the 1970s protected areas, including national parks, have increased quickly in terms of number and size. In Asia the number and total area of protected regions are large, especially in China and Indonesia. However, even if protected marine areas are included, the per-capita size of protected areas is still far below the forested land (Fig. 2.3.2.5, FAO 1990). In Asia, there are both aforestation projects carried out by Asian governments and through aid provided by other governments, although at present they cannot keep up with deforestation.

During the decade from 1980 to 1990, Asia lost its rainforests at a rate of 11%. This is much higher than the rate of about seven percent in Africa and Latin America (Fig. 2.3.2.6, World Resources Institute 1996). Although the Philippines and Thailand were once the main exporters of tropical timber, they are now wood importers because of their depleted forests.

Dam Construction

Many countries try to meet the growing demand for water by building dams or pumping more ground water. Currently under construction on China's Changjiang River is the huge Three Gorges Dam. This will be 185 m high, have a reservoir of 1,084 km^2, and impound 39.3 billion tons of water. On the upper reaches of the Mekong River, 14 dams are under construction or have been completed. The first of these, the Manwan Dam (132 m high, 23.9 km^2 reservoir, 920 million tons impounded), was completed in 1996. Most development on the upper reaches of the Mekong is for hydropower.

Dam development causes a number of problems, the first of which is the relocation of people living in areas that will be inundated. The Three Gorges Dam, for example, will displace over 1.1 million people. Such relocation, in turn, causes problems of increased stress on the displaced people and on the communities that take them in, as well as the burden of compensation. Dam construction also strains public finances.

Building dams brings about considerable change in a river's aquatic environment, and sometimes triggers changes in their biota. There are concerns that construction of the Three Gorges Dam will lead to the extinction of the Chinese river dolphin, for example.

Stagnant water bodies generated by dams let freshwater diatoms take up Dissolved Silicate (DSi) fuelled by loaded nitrogen (N) and phosphorus (P). The diatoms then sink to the sediment. Consequently, non-diatom algal species (non-siliceous and potentially harmful) increase in place of diatoms (siliceous and mostly benign, forming the basis of a healthy marine ecosystem) in the coastal seas downstream because diatoms need DSi in addition to carbon (C), N and P, nominally in the ratio of C:N:P:Si = 106:16:1:[16–50]. Evidence of this process has been illustrated in typical cases such as the system of the Danube – Iron Gate Dam – Black Sea (Humborg et al. 1998).

References

FAO (1990) Forest resources assessment global synthesis, 1990. World Conservation Union (IUCN), United Nations List of National Parks and Protected Areas

FAO (1995) FAO yearbook production, vol 49

Humborg C, Ittekot V, Cociasu A, Bodungen B (1998) Effect of Danube River dam on Black Sea biogeochemistry and ecosystem structure. Nature 27:385–388

United Nations (1995) World urbanization prospects: the 1994 revision.

World Resources Institute (1996) World resources 1996–1997

2.3.3 Coastal Development

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Coastal zones are unique. Special features such as daily tides, storm waves, tidal flats, mangrove forests, coral reefs, and vast sandy beaches exist only on the coast. On the other hand, the coastal zones are used for human settlement, agriculture, trade, industry, and amenity and as shore bases for maritime activities such as shipping, fishing, aquaculture, and sea mining. In the same coastal zones, destructive natural disasters take place, killing tens of thousands of peoples and destroying upland properties, as demonstrated by the tsunami disaster due to the big Sumatra earthquake of 2004.

Sustainable development and utilization of coastal zones, such as development of industrial areas and living activities, stabilization of fishery resources, development of seabed oil, natural gas and mineral resources, and utilization of ocean energy, are essential to the sustainable development of human society. Economic activities of many of the Asian countries heavily depend on development in the coastal zones. This section considers trends in coastal development in two of the most influential countries among the Asian nations, Japan and China. This is followed by consideration of coastal development at the sector level, with special emphasis on environmental issues related to development of the Asian coastal zone.

In Japan, the majority of the population and economic activities are concentrated in coastal zones. As shown in Fig. 2.3.3.1, the area of coastal municipalities occupies only about 32% of the total area of 370,000 km^2. They home for about 46% of the total population of approximately 120 million. They produce about 47% of the industrial output. Amazingly, 77% of the total expenditure for retail business or market goods is spent in coastal municipalities (Kojima 2000). Marine transportation and fisheries infrastructure are highly developed in Japan, with 1,094 commercial and industrial ports and 2,950 fishing ports. These numbers are quite large as compared with those of the US and the UK. Environmental Agency of Japan (1992) conducted a study of the ratio of three types of coastal features, namely natural beaches, artificial beaches and semi-natural beaches. In the entire country, the natural beaches cover about 57% of the total length of the coastline, about 35,000 km,

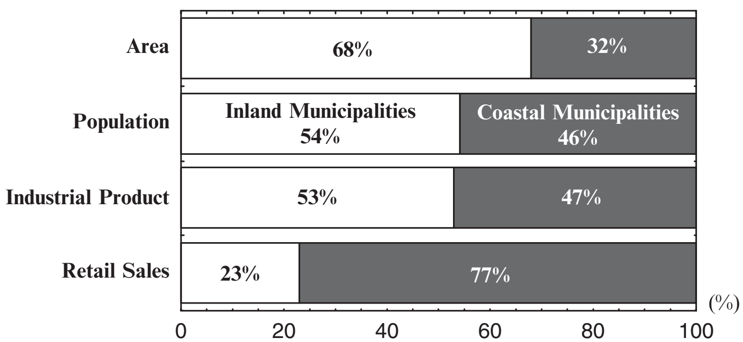

Fig. 2.3.3.1. Basic statistics of Japanese Coastal Zone. (From Kojima 2000.)

with 29% for the artificial beaches and 14% for the semi-natural beaches. Land reclamation and artificial islands, amounting to 1,357 km^2, have contributed to an increase in the percentage of the artificial beaches. They have been constructed to obtain land for industrial facilities, power plant facilities, farming ground, and other development. Land reclamation usually takes place in the shallow seas, such as a tidal flat. The loss of tidal flat is approximately 288 km^2 since 1945. The remaining area of tidal flat amounts to a little more than 540 km^2.

China, even with its vast area, has also been conducting similar coastal-oriented development: coastal municipalities, the area of which accounts for only 14% of the total land area of 9.6 million km^2, have about 40% of the total population of approximately 1.32 billion. But they produce 60% of the industrial output. As shown in Table 2.3.3.1, the total output of marine-related industries is about 1,284.1 billion Yuan, equivalent to $US157.4 billion in 2004. It increased by 177% from 2001. The most notable increase among marine industries is for marine construction. This sector had a 850% growth from 1.78 billon to 15.15 billion Yuan. All of the marine industries except marine salt industry have experienced economic growth.

Development of Human Settlement

In line with global trends, more than half of Asia's population – 1.7 billion people – presently reside in the coastal zone (Middleton 1999). Given the relentless and cumulative process of global environmental change driven by, among other factors, demographic changes, urbanization and industrial

Table 2.3.3.1. Economic value of Marine sectors in China in 2001 and 2004 (10^8Yuan[a]). (From: China's Ocean Yearbook 2002 & 2005, the State of Oceanic Administration, China.)

Marine sectors/industry	Total output 2001	Total output 2004	Percent increase 2001–2004
Total	7233.8	12841.0	177.5
Marine fishery	2256.6	3795.0	168.2
Marine oil and gas	320.7	595.0	185.5
Marine sand mining	3.2	5.1	162.1
Marine salt industry	91.0	69.3	76.2
Marine chemical industry	76.3	319.7	419.1
Marine pharmacy	20.9	64.0	306.7
Marine electronic power	421.3	844.9	200.5
Ship and boat building	292.7	740.0	252.8
Marine construction	17.8	151.5	850.8
Marine transportation	788.9	2434.0	308.5
Coastal tourism	2502.9	3369.0	134.6
Marine information service	13.1	–	–
Other marine-related industries[b]	428.5	453.4	105.8

[a] $1.00 = 8.16 Yuan

[b] including marine equipment, public service, seawater-use industry, etc.

development, trade and transport demands, and lifestyle changes, the coastal zones of Asia are under increasing anthropogenic pressures (Turner et al. 1996). This trend is clearly indicated by the increased number of megacities (here defined as those with 10 million inhabitants or more), as shown in Table 2.3.3.2. In 1950 New York was the only one megacity in the world. Two countries, Tokyo and Shanghai, in Asia became a megacity in 1975. The number of megacities rose from five in 1975 to 17 in 2001, among those cities nine urban agglomerations being located in the coastal zone of the Asian area. With 26.5 million inhabitants, Tokyo was the most populous urban agglomeration in the world in 2001, followed by São Paulo (18.3), Mexico City (18.3), New York (16.8), and Mumbai (16.5). Among the Asian coastal megacities are Calcutta (13.3), Dhaka (13.2), Shanghai (12.8), Jakarta (11.4), Karachi (10.4), and Metro Manila (10.1) (Table 2.3.3.2). It is projected that the number of coastal megacities in Asia would grow at least 10 of the world's 21 by the year 2015, added by Tianjin, China. Tokyo will remain the largest urban agglomeration with 27.2 million inhabitants, followed by Dhaka, Mumbai (Bombay), all

Table 2.3.3.2. Population of cities with 10 million inhabitants or more, 1950, 1975, 2001, and 2015 (millions). (From United Nations Population Division, World Urbanization Prospects: The 2001 Revision.)

Year of 1950			Year of 2001			Year of 2015		
	City	Population		City	Population		City	Population
1	New York	12.3	1	Tokyo	26.5	1	Tokyo	27.2
			2	Sao Paulo	18.3	2	Dhaka	22.8
			3	Mexico City	18.3	3	Mumbai (Bombay)	22.6
	Year of 1975		4	New York	16.8	4	Sao Paulo	21.2
	City	Population						
1	Tokyo	19.8	5	Mumbai (Bombay)	5	5	Delhi	20.9
2	New York	15.9	6	Los Angeles	6	6	Mexico City	20.4
3	Shanghai	11.4	7	Calcutta	7	7	New York	17.9
4	Mexico City	10.7	8	Dhaka	8	8	Jakarta	17.3
5	São Paulo	10.3	9	Delhi	9	9	Calcutta	16.7
			10	Shanghai	10	10	Karachi	16.2
			11	Buenos Aires	11	11	Lagos	16.0
			12	Jakarta	12	12	Los Angeles	14.5
			13	Osaka	13	13	Shanghai	13.6
			14	Beijing	14	14	Buenos Aires	13.2
			15	Rio de Janeiro	15	15	Metro Manila	12.6
			16	Karachi	16	16	Beijing	11.7
			17	Metro Manila	10.1	17	Rio de Janeiro	11.5
						18	Cairo	11.5
						19	Istanbul	11.4
						20	Osaka	11.0
						21	Tianjin	10.3

Note: Shaded indicates megacities located in the Asian coastal zones of which are the Asian coastal cities. All are expected to have more than 20 million inhabitants.

The consequences of this population growth, accompanied by a rapid expansion in urban areas, pose a significant threat to environmental and socioeconomic systems located in the Asian coastal zones. All coastal areas are facing an increasing range of stresses and shocks, the scales of which now pose a threat to human and environmental coastal systems.

Port/Harbor Development

Most of the world's megacities, like Tokyo, New York, and Shanghai, are situated in coastal zones. This is because of the benefits of harbor development that gives primary access to maritime transportation. The shipping world today is dominated by the container trade. Roughly 70% of general cargo is already containerized. It is expected that this figure will continue to grow to more than 90% by 2010. In the year 2000, the container trade recorded a massive 200 million TEUs (Twenty-feet Equivalent Units). The traffic is estimated to grow at an average rate of 5% per annum over the next 10 years. It might even double by 2010 (Armadillo Marine Consultants, 2005). To a large extent this growth has been, and will continue to be, spurred by the growth of many Asian countries, most notable among them being China, Singapore, Korea, and Malaysia. Table 2.3.3.3 shows the ranking of container throughput of various ports in 1980 and 2002. In 1980 the port of Hong Kong ranked

TABLE 2.3.3.3. Ranking of container throughput of ports in the world in 1980 and 2002. (From *Containerisation International Yearbook 1981*, 2003.)

Year 1980		Country,	Through-	Year 2002		Country,	Throughput
Rank	Port	Region	put (TEU)	Rank	Port	Region	(TEU)
1	New York	USA	1,947,000	1	Hong kong	China	18,100,000
2	Rotterdam	Netherlands	1,901,000	2	Singapore	Singapore	17,040,000
3	Hong Kong	China	1,456,000	3	Pusan	South Korea	9,453,356
4	Kobe	Japan	1,456,000	4	Shanghai	China	8,610,000
5	Kaohsiung	Taiwan	979,000	5	Kaohsiung	Taiwan	8,493,000
6	Singapore	Singapore	917,000	6	Shenzhen	China	7,613,754
7	San Juan		852,000	7	Rotterdam	Netherlands	6,515,449
8	Long Beach	USA	825,000	8	Los Angeles	USA	6,105,863
9	Hamburug	Germany	783,000	9	Hamburug	Germany	5,373,999
10	Oakland	USA	782,000	10	Antwerp	Belgium	4,777,387
				11	Port Kelung	Malaysia	4,533,212
12	Yokohama	Japan	722,000	12	Long Beach	USA	4,526,365
				13	Dubai	UAE	4,194,264
15	Pusan	South Korea	634,000	14	New York	USA	3,050,036
				15	Tokyo	Japan	2,899,452
18	Tokyo	Japan	632000				
				19	Yokohama	Japan	2,317,489
				22	Kobe	Japan	2,265,991

TABLE 2.3.3.4. The number of container terminals with the 15 m depth in current and future operation.

Country	South Korea	Taiwan	China	Singapore	Japan	
No. of container terminals as of 2000	8	3	4	11	10	(Tokyo3, Yokohama1, Kobe4, Nagoya2)
No. of container terminals in the future (year)	16 (2003)	3	10 (2004)	31 (2009)	19	(2003) (Tokyo7, Yokohama3, Kobe6, Nagoya2, Osaka1)

third in terms of container throughput after New York and Rotterdam. It was followed by Kobe, Kaohsiung, and Singapore. All of the top six in 2002 were Asian ports Hong Kong being in first place and Singapore in second place.

The broad expansion of APEC economics accelerated the trade growth. Aggregate APEC exports and imports grew at 20.1% and 20.6% in 2004, respectively (APEC 2005). Container carriers are looking at bigger and bigger vessels to improve their economies of scale. In order to accommodate these large ships some of the Asian ports are implementing massive expansion plans, as shown in Table 2.3.3.4. Singapore port is now operating 11 container terminals with a water depth of 15 m. It is planning to increase to 31 terminals by 2009. Japan and South Korea almost doubled the number of such container berths. With ever increasing in trade, further development of ports and harbors among the major Asian countries is inevitable.

Oil and Natural Gas Development

Oil is perhaps the most important and attractive resource in the South China Sea. The hydrocarbon resources encouraged the littoral states to occupy islands in order to claim rights in future negotiations. Regional, as well as much of the international interest, centers primarily on these potential hydrocarbon resources (Zhiguo and Mingjie 2003). Oil deposits have been found in most of the littoral countries of the South China Sea. As indicated in Table 2.3.3.5, the South China Sea region has proven oil reserves estimated at about 7.5 billion barrels, and oil production in the region is currently over 1.3 million barrels per day. Malaysian production accounts for about one half of the region's total. Total South China Sea production has increased gradually over the past few years, primarily due to additional production by China, Malaysia, and Vietnam. Natural gas might be the most abundant hydrocarbon resource in the South China Sea. Most of the hydrocarbon fields explored in the South China Sea regions of Brunei, Indonesia, Malaysia, Thailand, Vietnam, and the Philippines contain natural gas, not oil. Estimates by the US Geological Survey, and others, indicate that some 60–70% of the region's hydrocarbon resources are gas. Significantly, natural gas usage in the region is projected to grow by 5% per year over the next two decades. This is faster than any other

TABLE 2.3.3.5. Petroleum and gas reserve and production in the South China Sea. (From United States Energy Information Administration, Country Analysis Briefs, August 1998.)

	Proven oil reserves (billion barrels)	Proven gas reserves (trillion cu. ft.)	Oil production (barrels/day)	Gas production (billion cu. ft.)
Brunei	1.4	14.1	145,000	340
Cambodia	0.0	0.0	0	0
China	1(est.)	3.5	290,000	141
Indonesia	0.2	29.7	46,000	0
Malaysia	3.9	79.8	645,000	1300
Philippines	0.2	2.7	<1,000	0
Singapore	0.0	0.0	0	0
Thailand	0.3	7.0	59,000	482
Vietnam	0.6	6.0	180,000	30
Total	**7.5(est.)**	**145.5**	**1,367,000**	**2323**

fuel, reaching as much as 20 trillion cu. ft./year. With increased consumption of oil and gas, hydrocarbon exploration activities in the region will inevitably increase and additional infrastructure will be built.

Development of Coastal Tourism

The World Tourism Organization (WTO) has reported that tourism, now the world third largest sector of income generation after oil and automobile industries, will continue to grow in the coming decade. Asia and Pacific will be outperforming many other regions of the world in tourism growth and development. A major underlying factor, contributing to the high tourism potential of the region is its coastal tourism assets. If the projections of WTO come true, it is quite certain that the coastal areas of the countries in the ESCAP region will have to shoulder a higher pressure from fast growing coastal tourism, at least, in the coming decade or even longer (ESCAP 1996).

Table 2.3.3.6 presents gross earnings from tourism. Thailand had the greatest earnings in 1993. The lowest amount was recorded in Bangladesh where gross earnings from tourism had been declining over the years. However, the amount of earnings does not reflect the relative importance of the tourism sector in an economy. The contribution of tourism to GDP and its importance as compared to other sources of foreign exchange must be considered as well. In 1993, tourism accounted for 30% of total GDP in the Maldives. The situation in the other countries is different, with the contribution of tourism in many countries being less than 5% of GDP. Tourism accounted for less than one percent of GDP in Bangladesh, India, and Pakistan. As Table 2.3.3.6 shows, however, tourism is the biggest single source of foreign exchange for Maldives and is a major source for other countries of the region. Philippines (20.2%) and Thailand (15.7%) have a significant share from tourism in their total export earnings. Almost all developing countries face trade deficits, and tourism earnings appear to be one of the best means for correcting current account imbalances.

TABLE 2.3.3.6. Foreign exchange earnings from tourism in selected countries, 1993 (in million $US). (From Country reports, and Economist Intelligence Unit country reports.)

	Gross earnings from international tourism	Merchandise exports	Tourism earnings as percent of GDP	Tourism earnings as percent of export earnings
Bangladesh	8	2,138	0.0	0.4
India	1,401	22,500	0.6	6.2
Indonesia	3,600	36,600	2.5	9.8
Malaysia	1,910	46,000	3.0	4.2
Maldives	120	35	30.0	
Pakistan	115	6,760	0.2	1.7
Philippines	2,300	11,375	4.2	20.2
Republic of Korea	3,502	82,200	1.1	4.3
Sri Lanka	210	2,786	2.0	7.5
Thailand	5,719	36,400	4.6	15.7

In coastal and marine areas, tourism impacts the coastal and marine environment in terms of land utilization for hotel and residential purposes, impact on coastal infrastructure (roads, energy production, etc.), production of wastes (sewage, garbage, etc.), water uses, whale/wildlife watching, and inshore water uses for water sports, diving and cruise ships. Sustainable management of coastal tourism is essential to maintaining the productivity of the tourism sector (APEC 2002).

Development of Coastal Aquaculture

Asia dominates world aquaculture, producing four fifths of all farmed fish, shrimp, and shellfish (FAO 1997). Farming of fish, shrimp, shellfish, and seaweed has become a vital source of food supply in Asia in recent decades. Fishery products are staples for the Asian population and are embedded in its culture. Fish, an important source of food protein, is critical to food security in many countries of Asia, particularly among poor communities in coastal areas. The annual fish catch and aquaculture production in Asia reached a peak at about 20.7 and 19.1 Mt, respectively, in the year 1998 (IPCC 2001).

Coastal aquaculture has been conducted in Thailand for more than 30 years. Shrimp is the most important cultured resource because of increases in national consumption and demand for frozen shrimp for export. Shrimp farming has rapidly increased from 24,000 t in 1987 to 162,000 t in 1991. Aquaculture operations, however, have brought about significant adverse effects on mangrove ecosystems. In 1989 the total mangrove area in Thailand was only about 180,560 ha. During 1979–1986, about 64% of the mangrove area has been exploited for aquaculture (Clark 1995). Thailand lost more than 15% of its mangrove forests to shrimp ponds from 1987 to 1993 (World Bank 1996). Destruction of mangroves has left these coastal areas exposed to erosion and flooding, altered natural drainage patterns, and increased salt intrusion.

TABLE 2.3.3.7. Loss and causes of mangrove destruction in the South China Sea. (From Spalding M, Blasco F, and Field C, World Mangrove Atlas 1997.)

				Causes of mangrove destruction			
Country	Area before (ha)	Area now (ha)	Area loss (%)	Shrimp culture	Wood -chip and pulp	Urban development/human settlements	Domestic use
Cambodia	170,000	85,100	50	•			•
China	42,001	14,749	65	•		•	
Indonesia	4,254,312	733,000	83	•	•	•	
Malaysia	505,000	446,000	12	•	•	•	
Philippines	400,000	160,000	60	•		•	•
Thailand	550,000	247,000	55	•			
Vietnam	400,000	252,500	37	•			•
Total	6,321,313	1,938,349	69				
Global total		18,107,700					

Mangroves in the seven countries of the South China Sea region constitute 10% of the current global area of slightly over 18 million ha (Table 2.3.3.7). The total amount of area lost over different time spans (70 years for the Philippines) is estimated to be 4.3 million ha, or 24% of the current global mangrove area. The causes for mangrove destruction include urban development and human settlements, woodchip and pulp production, conversion to pond culture, and harvest of products for domestic use. The precise impact of these economic activities in each country is difficult to quantify. Nonetheless, shrimp culture across the region in recent years seems to be the most pervasive economic imperative for mangrove conversion.

References

Armadillo Marine Consultants (2005) Containerisation, http://amchouston.home.att.net

APEC Economic Committee (2005) 2005 APEC Economic Outlook, 314p

APEC Marine Resource Conservation Working Group (2002) Report of the APEC integrated oceans management forum 2. Canberra, Australia

Clark JR (1995) Coastal zone management handbook. CRC Press, 694p

Environmental Agency of Japan (1992) A basic study on natural environmental preservation. Report of marine area study, 339pp

ESCAP (1996) The economic impact of tourism in the Asian region. United Nations, 167p

FAO (1997) The state of world fisheries and aquaculture, yearbook vol 84. Food and Agriculture Organization of the United Nations, Rome, Italy, 57p

IPCC (2001) In: McCarthy JJ et al. (eds) Climate change 2001: impacts, adaptation, and vulnerability. Contribution of working group II to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press, 1032p

Kojima H (2000) Vulnerability and adaptation to sea-level rise in Japan. Proceedings of APN/SURVAS/ LOICZ joint conference on coastal impacts of climate change and adaptation in the Asia-Pacific region, pp 81–88

Middleton N (1999) The global casino: an introduction to environmental issues, 2nd edn. Arnold, London, 370p
Turner RK, Subak S, Adger WN (1996) Pressures, trends and impacts in coastal zones: interactions between socio-economic and natural systems. Environ Manag 20:159–173
Spalding M, Blasco F, Field C (1997) World mangrove atlas. ISME, Okinawa, 178p
World Bank (1996) Chao Phraya flood management review, final report. The Royal Thai Government, Thailand
Zhiguo Gao, Mingjie Li (2003) Evironmental issues facing the South China Sea. International conference on geo-agenda for the future: securing the oceans. Institute of Ocean Policy, Ship and Ocean Foundation

2.3.4 Pollutants

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The pollutants discharged into Asia-Pacific coasts by human activities can be categorized into five groups, namely domestic wastes, agricultural wastes, industrial wastes, petroleum hydrocarbons and solid wastes.

Domestic Wastewater

Rapid population growth has brought about resource and environmental quality degradation. Water pollution is the most serious environmental problem for many countries in the East Asian seas region.

Sewage is the major source of organic pollution in various populous coastal areas in the region. While varying degrees of treatment are employed in some localities, disposal of untreated sewage directly or indirectly is the general practice. In Thailand, for instance, pollutants discharged from the Chao Phraya River are the major contributors to coastal water pollution in the Upper Gulf of Thailand. The estimated net Biological Oxygen Demand (BOD) reaching the Gulf of Thailand via this river alone is 114.7 t/day. The estimate for all the rivers emptying into the Gulf is 305.2 t/day (Thailand 1984).

BOD levels for selected East Asian seas countries are shown in Table 2.3.4.1. Their distribution around the region is shown in Fig. 2.3.4.1. It has been estimated that 6 million tons of BOD are generated by the coastal population in seven of the countries of the South China Sea, namely Cambodia, China, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. Only about 11% of the BOD generated is removed by sewage treatment. There is clearly a need to raise the volume removed by sewage treatment, especially for coastal waters that receive pollutants from large urban cities.

Eutrophication in various coastal waters receiving high organic inputs from sewage is common in the region. Substantial information on the biological effects of organic enrichment is available from a series of studies in

TABLE 2.3.4.1. Population and Estimated BOD Generation and Removal in Selected East Asian Seas Countries. (From UNEP (2000) reprinted with the permission of UNEP)

Country	Population ('000 persons)*	Population growth rate (%)	BOD generated (103 t/year)	BOD removed by sewage treatment (103 t/year)
Cambodia	1,985	2.7	36.2	n.a.
China	59,694	1.6	1,089.4	<109
Indonesia	105,217	2.9	1,920.2	364
Malaysia	10,336	3.3	188.6	53
Philippines	23,633	2.1	431.3	149
Thailand	37,142	1.4	677.8	89
Vietnam	75,124	1.6	1,371.0	n.a.
Total	**313,131**	**1.4**	**5,714.5**	**655**

* Only populations of subdivisions interacting with the South China Sea are included.

Hong Kong. For example, Fig. 2.3.4.2 illustrates an 8-fold increase in the number of red tides per year in Hong Kong harbor in the period 1976–1986 (Lam and Ho 1989). This increase shows a striking correlation with the 6-fold increase in human population in Hong Kong and the concurrent 2.5-fold increase in nutrient loading, mainly contributed by untreated domestic and industrial waste.

Agricultural Waste

Pollutants contained in agricultural waste consist primarily of fertilizers, pesticides, and animal waste. Land clearance for agricultural activities can lead to large quantities of silt entering stream channels, contribute to sediments in rivers discharged into the marine environment and make up the second most important group of pollutants in the marine environment (Koe and Aziz 1995).

Data on pesticide use and its presence in the marine environment are scarce. Organochlorines such as DDTs, PCBs, CHLs, HCHs, HCB have been detected in green mussels in the tropical waters of Asia, as shown in Fig. 2.3.4.3. Although the use of organochlorine pesticides such as DDT for agricultural purposes has been banned in many countries in the region, they still remain in the aquatic organisms and environments. Considerable residues of *p, pp* DDT in the DDTs found in green mussels from some locations may indicate the presence of significant current sources of DDT in this region (Tanabe et al. 2000). However, based on the results shown in studies by Menasveta and Cheevaparanapiwat (1981) and Cheevaporn et al. (2005) it appears that DDT concentrations have declined in Thailand's coastal waters since restrictions on the use of DDT were introduced in 1983.

Of the seven South China Sea countries, China uses the greatest amount of fertilizers at about 1,000 ka/ha/year (Table 2.3.4.2). China reports more than 89,000 t of pesticides used in its South China Sea areas in 1995 When leached to aquatic environments, fertilizers contribute to nutrient loading in addition

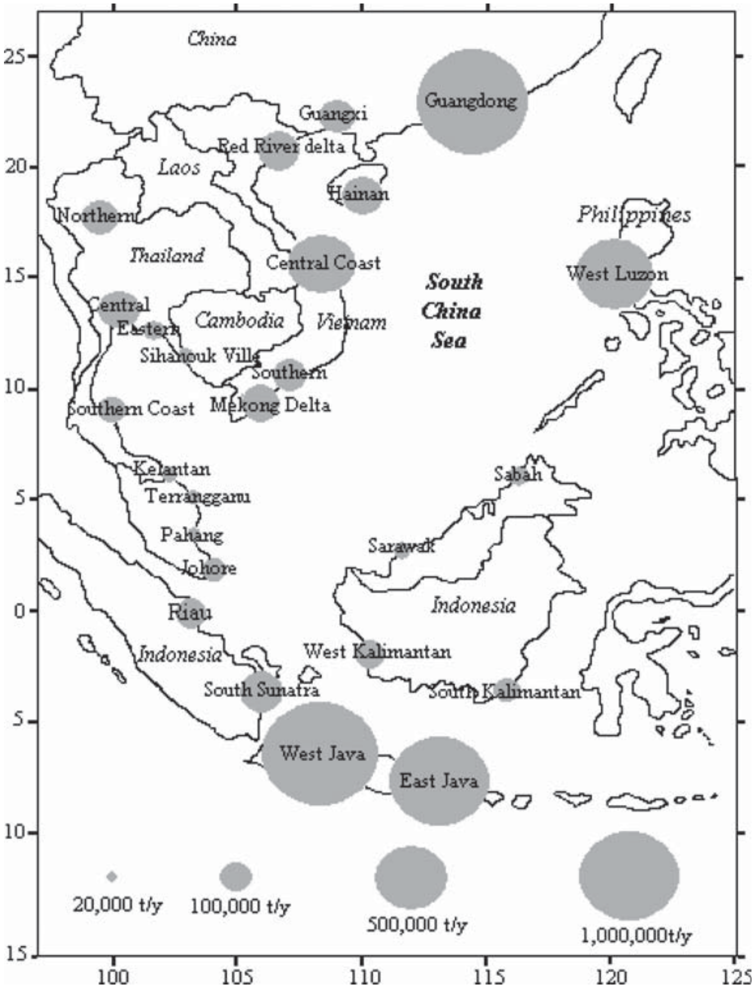

FIG. 2.3.4.1. Biochemical Oxygen Demand (BOD) loading from domestic sources in East Asian seas. (From UNEP 2000, reprinted with the permission of UNEP.)

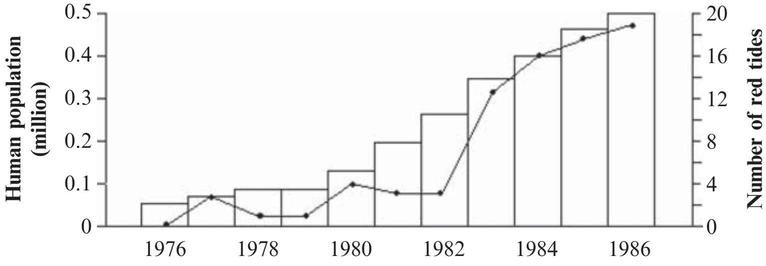

FIG. 2.3.4.2. Correlation between the number of red-tide outbreaks per year in Tolo Harbor (continuous line) and the increase of human population in Hong Kong (bar diagram), in the period 1976–1986. (From Lam and Ho 1989, reprinted with the permission of Elsevier.)

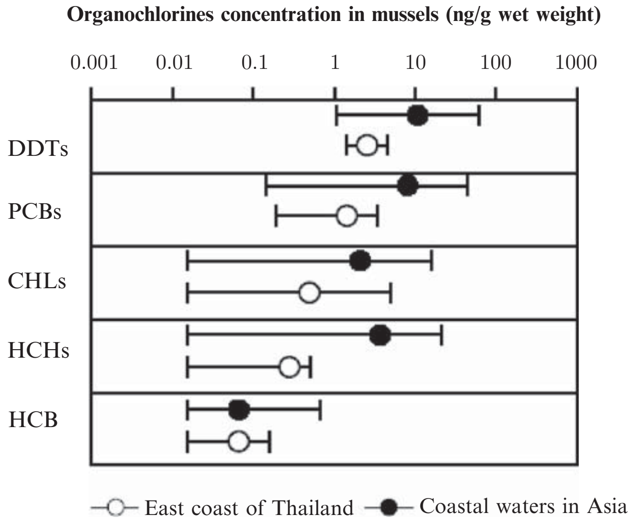

FIG. 2.3.4.3. Range and mean concentrations of persistent toxic contaminants in green mussel from the east coast of Thailand during the period 2002–2003 (from Cheevaporn 2005) compared with those from tropical coastal waters in Asia during the period 1994–1995. (From Tanabe et al. 2000, reprinted with the permission of the Pharmaceutical Society of Japan.)

TABLE 2.3.4.2. Use of fertilisers and pesticides in South China Sea countries. (From UNEP (2000) reprinted with the permission of UNEP.)

Country	Paddy field area (103 ha)	Fertilisers use (t/year)	Pesticide use (t/year)
Cambodia	1,800	>40,000	n.a.
China	3,400	3,640,000	>89,000
Indonesia	5,000	>5,600,000	29,000
Malaysia	n.a.	n.a.	n.a.
Philippines	1,200	181,000	n.a.
Thailand	8,600	n.a.	38,000
Vietnam	1,500	110,000	n.a.

to that generated by domestic sources. The total loading of nitrogen in the South China Sea area is shown in Fig. 2.3.4.4.

Industrial Waste

Data provided in Table 2.3.4.3 show that industry released a minimum of about 95,873 t of BOD into aquatic systems interacting with the South China Sea. Ninety percent of the reported values come from the Philippines, Indonesia, and China, of which half the total is attributable to river systems.

Considering the incomplete database, Vietnam reports an annual load of heavy metals of at least 13,000 t/year, 520 times more than those reported by China (25.4 t/year). Vietnam indicates that in the Northern Economic Zone, the amounts of Pb, Zn, and Cu are 7–10 times the allowable limits.

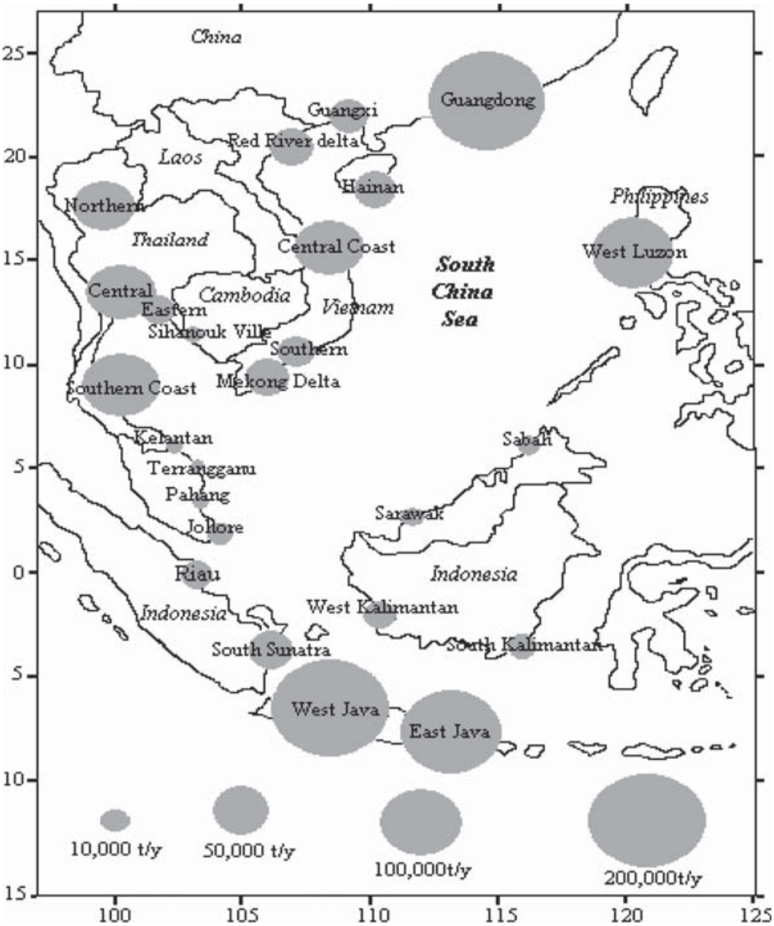

FIG. 2.3.4.4. Total nitrogen loading in East Asian Seas countries. From UNEP 2000, reprinted with the permission of UNEP.)

TABLE 2.3.4.3. Estimated industrial waste discharge from coastal and non-coastal installations. (From UNEP (2000) reprinted with the permission of UNEP.)

Country	BOD (t/year)	Heavy metals (t/year)
Cambodia	n.a.	n.a.
China	10,300	25.4
Indonesia	26,000	n.a.
Malaysia	430	n.a.
Philippines	>49,000	n.a.
Thailand	5,643	n.a.
Vietnam	>4500	>13,000

In the Gulf of Thailand there is little evidence of significant metal contamination of seawater, as the levels found are comparable to estuaries elsewhere in the world (Hungspreugs 1982). Investigation of selected metals in commercially popular bivalves was undertaken in the Gulf of Thailand. The metal levels appear quite low by comparison to the same species from elsewhere in the world (Hungspreugs and Yuangthong 1983).

Total mercury concentrations in biota in the Gulf of Thailand are shown in Table 2.3.4.4. In the coastal area almost all mercury concentrations in fish were less than 0.2 μg/g wet weight. These concentrations can be regarded as a natural amount of mercury in fish in general. Nevertheless fish in the offshore area, in the vicinity of natural gas platforms, exhibited higher mercury concentrations. Between 5% and10% of fish have mercury concentrations higher than 0.5 μg/g (ARRI 1998).

Widespread occurrence of tar balls was also noted on the beaches of the Pari Island Group, Jakarta Bay. Toro and Djamali (1982) reported seasonal variations ranging from 0.28–2101.4 g/m^2.

TABLE 2.3.4.4. Total mercury in biota of the Gulf of Thailand.

Study period	Location	Type of biota	Total mercury (μg/g wet weight)	Reference
1974	Bang Pra Coast	3rd trophic level fish	0.003–0.010	Menasveta (1976)
		4th trophic level fish	0.002–0.057	
1976	Chao Phraya Estuary	Fish and shellfish	0.009–0.205	Menasveta (1978)
1977–1980	Inner Gulf	Fish and shellfish	0.002–0.206	Sivarak et al. (1981)
1978–1979	River estuaries	Bivalves	0.013–0.120	Menasveta and Cheevaparanapiwat (1982)
1976–1977	Inner Gulf	3rd trophic level fish	0.002–0.130	Cheevaparanapiwat and Menasveta (1979)
		4th trophic level fish	0.010–0.650	
1979–1981	Inner Gulf	Fish and shellfish	0.012–0.051	Sidhichaikasem and Chernbamrung (1983)
1980	Estuarine areas			
	Mae Klong	Mullets	0.04±0.03	Menasveta and Cheevaparanapiwat (1982)
	Ta Chin	Mullets	0.07±0.04	
	Chao Phraya	Mullets	0.15±0.06	
	Bang Prakong	Mullets	0.08±0.03	
1980	Estuarine areas			
	Mae Klong	Green mussels	0.07±0.04	Menasveta and Cheevaparanapiwat (1982)
	Ta Chin	Green mussels	0.09±0.03	
	Chao Phraya	Green mussels	0.21±0.06	
	Bang Prakon	Green mussels	0.09±0.04	
	Hua Hin	Green mussels	0.04±0.03	
1982–1983	Inner Gulf	Bivalves	0.001–0.041	Sivarak et al. (1984)
1982–1986	Inner Gulf	Bivalves	0.001–0.153	Boonyachotmongkol et al. (1987)
1990	Sichang Island Mab	Fish	0.012–0.032	Menasveta (1990)
	Tapud	Fish	0.013–0.049	
	off-shore (Erawan)	Fish	0.055–0.324	
1997	Outer Gulf of Thailand	Demersal Fish	0.003–0.93	ARRI (1998)

The concentration of heavy metals in some localized coastal waters of Indonesia has been reported to be very high. Among these are the coastal waters of Jakarta Bay, Surrabaya and the Straits of Malacca. Studies by Razak et al. (1984) revealed significant heavy metal pollution in Jakarta Bay. Copper, mercury, lead, and cadmium levels were found to be higher than the standard set by the Indonesia government. High levels of mercury, copper, manganese, zinc, iron, cadmium, nickel, cobalt, and chromium were found in sediments in Jakarta Bay, Indonesia (Martin et al. 1983).

The levels of copper and zinc in sediment in Victoria Harbor, Hong Kong were between 2.5 and 5 times higher than those in other areas of Hong Kong. This can be attributed to urban and industrial discharges in Victoria Harbor. Contamination of sediment by copper, zinc, and lead was less marked in Deep Bay (Phillips and Yim 1981).

For peninsular Malaysia, metal concentrations in sediments from the South China Sea were found to be in the normal range for cadmium, copper, zinc, nickel, and lead. These metal levels indicate that this area is unpolluted (Noor Ahzar et al. 1986).

Aside from pesticides and heavy metals, hazardous and toxic materials produced from industrial manufacturing or processing are considered a major group of pollutants. Indicative estimates of the production rates of hazardous waste for a number of South China Sea countries are shown in Table 2.3.4.5.

The foregoing results highlight the need to monitor the production and disposal of hazardous waste and to strategically control these wastes at source through the use of clean technologies.

Petroleum Hydrocarbons

Indonesia is an oil-producing nation and a major route for transporting petroleum products. As a result, hydrocarbon pollution in its waters, especially Jakarta Bay, has been critical. Samples taken around the harbor were recorded as having concentrations of 60–100 μg/l, whereas samples collected away from the harbor registered a concentration in the range of 0.5–4.0 μg/l (Martin et al. 1983). Hydrocarbon concentration in sediments from Jakarta Bay was found ranging from 9.0 to 331 μg/g. Highest concentration were found in samples outside Sunda Kelapa and in Tanjung Priok harbors.

Table 2.3.4.5. Estimated production of toxic substances in selected East Asian countries. (From UNEP (2000) Reprinted with the permission of UNEP.)

Country	Estimated production of hazardous waste (106 t/year)
China (1987)	50
Indonesia (1986)	5
Japan (1988)	0.82
Malaysia (1987)	0.4
Philippines (1987)	0.08–0.15
Thailand (1986)	0.88

Widespread occurrence of tarballs was also noted on the beaches of the Pari Island Group, Jakarta Bay. Toro and Djamali (1982) reported seasonal variations ranging from 0.28–2101.4 g/m^2.

A report on hydrocarbon contamination in the South China Sea off the Terengganu coast of Malaysia showed very high overall mean dissolved hydrocarbon levels in the range of 960–990 µg/l. These high values were probably the result of offshore oil and gas exploration and exploitation in the area. Oil concentration in the sediments of offshore Terrangganu were found to be in the range of 6.43–1332 µg/g, while the surface sediment off the Kuantan coast showed an average of 42.92 µg/g. The higher value areas indicate significant contamination (Law and Mahmood 1987).

Information on the level of hydrocarbons in ASEAN waters is summarized in Table 2.3.4.5. In general the level of hydrocarbons in the water column of the Straits of Malacca is higher than in other areas. In some parts of the straits (e.g., the Riau Archipelago), dispersed or dissolved petroleum hydrocarbon (DDPH) concentration is greater than 1,000 µg/l, sometimes reaching as much as 7,200 µg/l. In addition, results from studies on the distribution of oil in Port Dickson clearly indicate a trend toward increasing oil pollution in both water and sediments. The oil content of Port Dickson waters was about 180 µg/l in 1993 compared to less than 20 µg/l in 1986. On the other hand, oil in sediments increased from about 20 mg/kg dry weight to around 60 mg/kg dry weight from 1986 to 1990 (Cheevaporn 1995) (Table 2.3.4.6).

Numerous loading ports, production fields, and refineries line the coasts bordering the Straits of Malacca and Singapore. Twelve of the coastal refineries have a total output of over 1.4 million barrels of refined oil per stream day. From 1983–1992 oil spills from oil industry operations in Malaysia alone were estimated to be about 20,641 barrels or an equivalent of 3,000 t (Rizali 1993). The number of marine accidents resulting in oil and chemical spillage is shown in Fig. 2.3.4.5. These incidents further threaten the marine and coastal resources of the East Asian seas.

Solid Waste

In many of the region's urban areas solid waste is commonly disposed of either by sanitary landfill or by incineration. However, direct dumping of garbage in many rural as well as urban areas is also widespread. While coastal landfills

Table 2.3.4.6. Hydrocarbon levels in Southeast Asian waters.(From Cheevaporn 1995.)

Location	Date	Range of hydrocarbon concentration (µg/l)
East Coast of Malaysia	April–May 1979	0.130
Jakarta Bay	–	0.5–46
Andaman Sea (Thai waters)	1985	0.04–1.21
Straits of Malacca (east of Sumatra)	1976–1978	0.1–7,200
Straits of Malacca (Penang)	1979	10–120

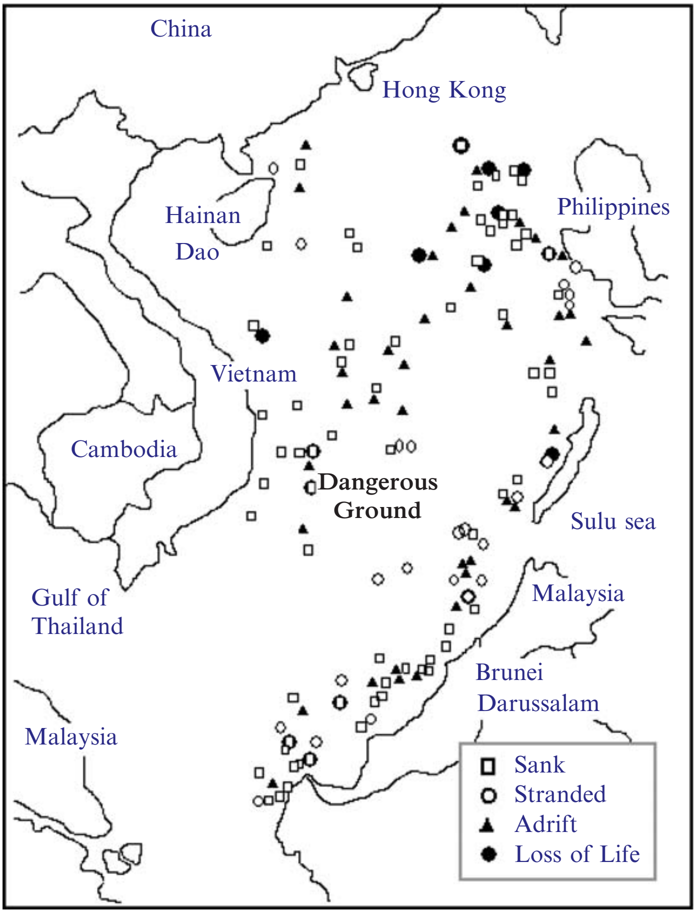

FIG. 2.3.4.5. Marine accidents resulting in oil and chemical spillage in the South China Sea, 1974–1994. (From Olson 1996, reprinted with the permission of the University of Chicago Press.)

release sediment and organic materials into neighboring waters, direct dumping of domestic refuse poses a greater threat. The increased use of plastic materials in recent years has substantially increased the load of nondegradable litter in the sea. This, more than any other refuse material, presents a potential detrimental impact. A considerable amount of the garbage from urban beaches can be observed in many East Asian countries such as Thailand, Indonesia, Philippines, Cambodia and Vietnam. However, information on this issue is scarce.

When solid waste reaches aquatic systems it reduces the aesthetic value of beach and underwater scenery for coastal tourism. Table 2.3.4.7 compares estimates of reported solid waste generated by domestic activities in selected South China Sea countries. The largest proportion of solid waste from domestic

TABLE 2.3.4.7. Solid waste from domestic sources in selected South China Sea countries. (From UNEP (2000) reprinted with the permission of UNEP.)

Country	Solid waste production (103 t/year)
Cambodia	435
China	13,073
Indonesia	23,042
Malaysia	2,264
Philippines	5,176
Thailand	6,134
Vietnam	16,452
Total	**66,576**

sources comprises, in order of amount, organic material, paper, plastic, metal, glass, and other forms of waste.

References

United Nations Environment Programme (UNEP) (2000) Overview on land-based sources and activities affecting the marine environment in the East Asian seas. UNEP Reg Seas Rep and Stud 173

Thailand, Department of Health (1984) Survey of water quality in the estuary. In: Proceedings of the third seminar on water quality and the quality of living resources in Thai waters. Bangkok, 26–28 March 1984. Bangkok, National Research Council, pp 62–78

Koe Lawrence CC, Aziz MA (1995) Regional programme of action on land-based activities affecting coastal and marine areas in the East Asian seas. RCU/EAS technical report series no. 5, United Nation Development Programme (UNDP), Bangkok, 117pp

Cheevaporn V, Duangkaew K, Trangkrock-Olan N (2005) Environmental occurrence of organochlorines in the east coast of Thailand. J Health Sci 51(1):80–88

Tanabe S, Prudente MS, Kan-atireklap S, Subramanian A (2000) Mussel watch: marine pollution monitoring of butyltins and organochlorines in coastal waters of Thailand, Phillipines, and India. Ocean Coast Manag 43:819–839

Menasveta P, Cheevaparanapiwat V (1981) Heavy metals, organochlorine pesticides and PCBs in green mussels, mullets and sediments of rivers in Thailand. Mar Pollut Bull 12:19–25

Lam CWY, Ho KC (1989) Red tides in Tolo Harbour, Hong Kong. In: Okaichi T, Anderson DM, Nemoto T (eds) Red tides: biology, environmental science and toxicology. Elsevier Science, New York pp 49–52

Hungspreugs M (1982) Baseline levels of cadmium, chromium, copper, lead, zinc in seawater from the Gulf of Thailand. J Sci Soc Thailand 8:193–204

Hungspreugs M, Yuangthong C (1983) The present levels of heavy metals in some mollusc of the Upper Gulf of Thailand. Water Air Soil Pollut 22:402–415

Aquatic Resources Research Institute (ARRI) (1998) Mercury monitoring in the Gulf of Thailand, 1997. Final report submitted to Mineral Resource Department, Bangkok, Thailand, 77 pp

Razak H, Hutagalung H, Surtipanti S (1984) Pengamatan Kebutuhan Kimiawi (KOK) oksigin biologi (KOB) dan logam berat di perairan Selat Malaka. In: Moosa MK, Praseno DP, Kastoro W (eds.) Evaluasi kondisi perairan Selat Malaka 1978–1980. Jarkarta, LON-LIPI, pp 67–73

Phillips DJH, Yim WWS (1981) A comparative evaluation of oysters, mussels, and sediments as indicators of trace metals in Hong Kong waters. Mar Ecol Progr Ser 6:285–293
Martin SL, Marchand M, Le Gueblec AM, Caprais JP (1983) Determination de la Pollution chimique des baies de Jakarta, Banten, Cilacap (Indonesia), hidrocarbures, organochlores, methane. Paris, CNEXO-COB-ELGEM, Doc El/Chimie/YLM-MM/233/83:57p
Noor Azhar MS, Mohamed AR, Arima S, Higashikawa S (1986) Trace metal in sediments and benthic organisms from the south-western protion of the South China Sea. Fac Fish Mar Sci, University Pert. Malaysia, Occasional Publishing 4:77–84
Toro V, Djamali A (1982) Fluctuation of tarball in P. Pari, Kepulauan Seribu. Jakarta, LON-LIPI, 9p
Law AT, Mahmood ZB (1987) Distribution of petroleum hydrocarbons in the south-western portion of the South China Sea. Fac Fish Mar Sci, University Pert. Malaysia, Occasional Publishing 4:53–60
CheevapornV (1995) Oil pollution in the Straits of Malacca. Tropical Coasts 2(1):11–13
Olson H (1996) Marine traffic in the South China Sea. In: Borgese EM, Ginsburg N,
Morgan JR (eds) Ocean year book, vol 12. The University of Chicago Press, Chicago, 632p
Razali Mohd. Taib (1993) Offshore exploration for hydrocarbon and its impacts on the marine environment. Paper presented at the conference of an appraisal of issues facing the Malaysian marine environment. Malaysian Institute of Marine Affairs, Kuala Lumper, December 14 1993
Boonyachotmongkol T, Boriboon P, Rojpanthip L (1987) Total mercury in bivalves of the coastal areas of the upper Gulf Thailand. In: Proceedings the 5th seminar on research in water quality and quality of living resources in Thai waters 7–9 July 1987 National Research Council Thailand, pp 245–260
Cheevaparanapiwat V, Menasveta P (1979) Total and organic mercury in marine fish of the upper Gulf of Thailand. Bull Environ Contam Toxicol 23:291–299
Menasveta P (1976) Total mercury in the food chain of Bang Pra coastal area, Chon Buri. J Sci Soc Thailand 2:117–126
Menasveta P (1978) Distribution of heavy metals in the Chao Phraya River Estuary. In: Lohani BN, Thanh NC (eds) Proceeding the international conference on water pollution control in developing countries. Asian Institute of Technology, Bangkok, Thailand, pp 129–145
Menasveta P, Cheevaparanapiwat V (1982) Heavy metals in bivalves collected from various river estuaries of Thailand. Report No. RR-52–82, Institute of Environmental Research, Chulalongkorn University, 16 p. (Unpublished manuscript)
Menasveta P (1990) Total mercury in marine fishes collected from Sichang Island, Mab Tapud, and the Off-shore area of the Gulf of Thailand. A report to the Petroleum Authority of Thailand. (Unpublished manuscript)
Sidhichaikasem S, Chernbamrung S (1983) Contamination of heavy metals in the estuarine environment of the Inner Gulf of Thailand. A report of Marine Fisheries Laboratory, Department of Fisheries, Bangkok 17p (Unpublished manuscript)
Sivarak S, Boriboon P, Jangsawang J, Iswas A (1981) Mercury in marine fauna. In Proceedings the symposium on survey and research of pollution in Thai waters, National Research Council of Thailand
Sivarak S, Boriboon P, Rojpanthip L (1984) Total mercury in bivalves of the east coast of the inner Gulf of Thailand. In Proceedings the 3rd seminar on research in water quality and quality of living resources in Thai Waters 26–28 March 1984, National Research Council of Thailand, pp 285–289

3
Environment Problems in the Coastal Zone

Chairs: Hideo Sekiguchi and Sanit Aksornkoae

3.1 Coastal Characteristics and Changes in Coastal Features

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Understanding coastal dynamics and natural history is important in developing a better understanding of natural systems and human impacts in coastal zones. This chapter outlines the characteristics of sedimentary environments in coastal zones which must be understood in order to manage and preserve coastal environments.

3.1.1 Coastal Classification, Shoreline Migration, and Controlling Factors

The world's coastal environments and topography are classified into two types on the basis of the changes which occurred during the Holocene when they were particularly influenced by millennial-scale sea-level changes. Transgressive coastal environments, where shorelines migrate landward, are characterized by barriers, estuaries, and drowned valleys (Boyd et al., 1992). Regressive coastal environments, where shorelines migrated seaward, consist of deltas, strand plains, and chenier plains (Fig. 3.1.1).

Thus regressive shorelines at river mouths are called deltas, while transgressive shorelines at river mouths are called estuaries. The latter consist of drowned, incised valleys. In regressive environments, coastal lagoons separated from the open ocean by barriers are well developed alongshore, whereas estuaries cross the general coastline. A strand plain is a coastal system that develops along a wave-dominated coast; it is characterized by beach ridges, a

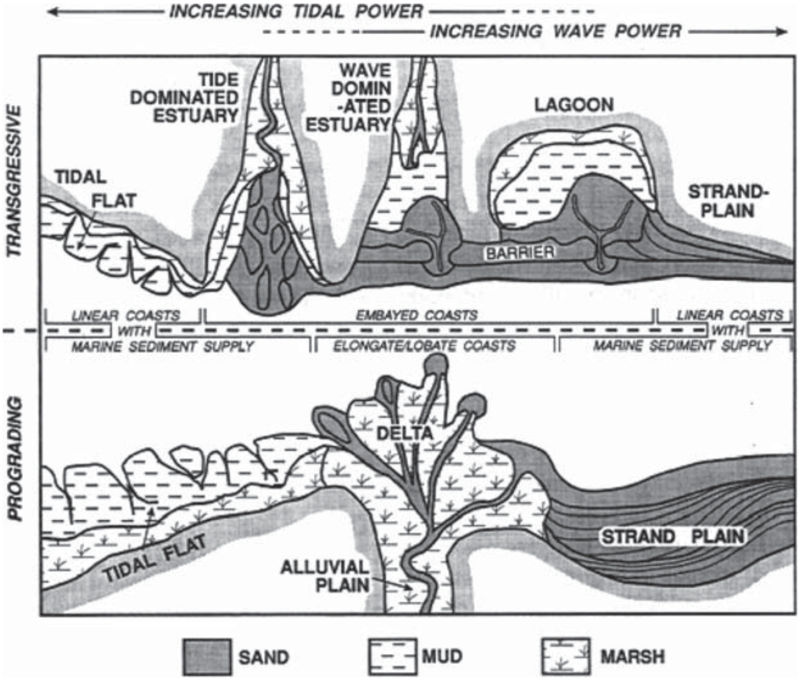

Fig. 3.1.1. Coastal depositional systems. (After Boyd et al., 1992.)

foreshore, and a shoreface. A chenier plain is composed of muddy tidal flats with isolated sand or shelly ridges that form episodically.

The global distribution of these coastal systems is controlled mostly by relative sea-level changes, particularly eustatic sea-level changes and glacio- and hydro-isostasy. After the last glacial maximum (LGM), about 20,000 years ago, eustatic sea level (global sea-level changes) rose until 4,000 years ago, and since then the sea level has been comparatively stable. However, a relative (observed) sea-level change is locally determined by the combination of these eustatic sea-level changes, isostatic effects of glaciers (glacio-isostasy) and meltwater (hydro-isostasy), and local factors (e.g., tectonics, human-caused subsidence etc.). Glacio-isostasy and hydro-isostasy have strongly impacted Holocene sea-level changes on a global scale. In glacio-isostasy, areas surrounding regions glaciated during the LGM that bulged because of glacial loading, have since subsided; therefore, in such areas, the relative sea level has risen on a millennial timescale. Thus the mid to southern parts of North America, mid to southern Europe, and the Mediterranean region have experienced a rising sea level through the Holocene as a result of glacio-isostasy. The relative sea level has risen in these regions at a rate of ca.1 m/ky for the last 7,000 years; therefore, transgressive systems are found in these areas. On the other hand, most of Asia, Oceania, central to southern Africa, and South America were far from glaciers during the LGM. Hence, although direct influence from glaciers is less significant, the isostatic effects of melt-water loads (the increased loading of seawater on the mantle) have also led to Holocene sea-level changes in these regions. As a result of movement of the mantle from beneath the ocean floor to under continental areas, land areas have uplifted on a millennial timescale, resulting in a relative sea-level fall of 2–3 m during the last 6,000–7,000 years. Therefore, regressive coastal systems are well developed in these areas. Most lagoons and estuaries that formed in these regions during the early Holocene have been filled or abandoned during the subsequent sea-level fall.

Sediment supply is also a key factor controlling shoreline migration. Although the general distribution of coastal systems is controlled by relative sea-level changes, the amount of sediment supply also influences shoreline migration. Even when the relative sea level is rising, the shoreline may migrate seaward if the sediment supply is high. The Mississippi and Nile deltas, both located where sea level rose through the Holocene, are good examples of regressive coastal systems developed during a sea-level rise. Conversely, along Australian coasts, estuaries are well developed even though the relative sea level has fallen over the last 6,000 years. The estuaries and lagoons that formed during the early Holocene have persisted, remaining unfilled because of the very low sediment supply from that dry and ancient continent (Saito 2001, 2005b).

Figure 3.1.2 summarizes the relationship between sediment supply and relative sea-level change with regard to shoreline migration. Barriers and estuaries are typical coastal features when the shoreline is migrating landward. A rise in sea level causes marine inundation of the incised valleys that formed during the sea-level lowstand, resulting in the formation of drowned valleys and estuaries. The sand composing the barriers is supplied mostly from coastal erosion at headlands and by recycling marine sand, because river mouths are in retreat during transgressive periods. As a result the distribution of riverine sand is generally limited to within the estuarine head. The sea-level rise leads to an increase in wave energy along coasts because of the increase

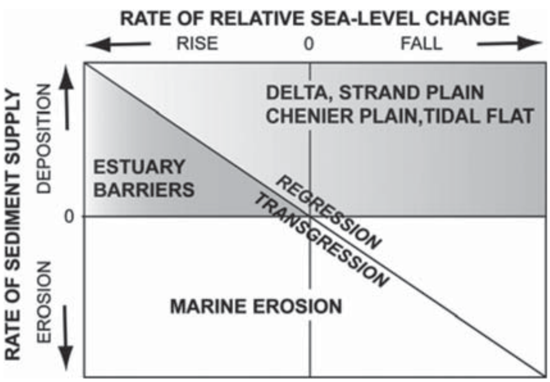

Fig. 3.1.2. Factors controlling shoreline migration. (Modified after Curray,1964.)

in water depth, resulting in increases in both coastal erosion and the sediment supply to barriers.

Shoreline migration is controlled mostly by sea-level changes and sediment supply. However, even if sea level is stable or falling, a shoreline with little sediment supply is likely to migrate landward. On a wave- or storm-dominated coast, the nearshore zone is typically erosional because of wave action. Transgression may thus occur along such coasts even during periods of falling sea level. Sea cliffs developed along some coasts during the Holocene illustrate this phenomenon.

In addition to sea-level changes and sediment supply, waves and tide are important controlling factors in coastal environments. This is because they move sediment particles, resulting in deposition or erosion. The main difference between waves and tide in terms of general sediment movement normal to the shoreline is the direction of sediment movement. During storms, except for washover sediments deposited on the land, most sediments are moved seaward by offshore bottom currents. These, in combination with gravitational sediment movement in the nearshore zone (shoreface or delta front slope), result in an erosional environment. Energetic conditions affecting the bottom sediments increase landward. The foreshore (intertidal zone) experiences the highest wave energy (wave swash and backwash). The wave influence decreases offshore, resulting in offshore fining of the sediments.

On the other hand, tidal currents cause asymmetric sediment movements and tend to move sediments landward. Flood tidal currents result in more landward movement of sediment than do ebb tidal currents, a phenomenon known as tidal pumping. The amount of energy available for sediment movement depends on the tidal current, particularly in terms of water depth. Energetic conditions increase offshore, resulting in onshore fining of the sediments. Therefore, on a tide-dominated coast, sediment is accreted onto coasts, and finer sediments are found landward and coarser sediments offshore.

3.1.2 Wave- or Storm-Dominated Coast

On a wave- or storm-dominated coast, the coastal zone from onshore to offshore consists of dunes, backshore, foreshore, upper shoreface, lower shoreface and shelf. In general, the shoreface zones have the steepest gradient on the shelf, forming a step between the onshore plain and the shelfal platform.

Coastal Sediments and Their Succession

On accumulating or progradational beaches, the succession of coastal sediments consists, in ascending order, of lower shoreface, upper shoreface, foreshore, backshore, and dunes (Saito 1989, 2005a, Fig. 3.1.3). This is the typical succession on a wave- or storm-dominated sandy coast. The shoreface, located in the nearshore zone, has a concave topography created by wave action. The upper shoreface, also called the inshore, is characterized

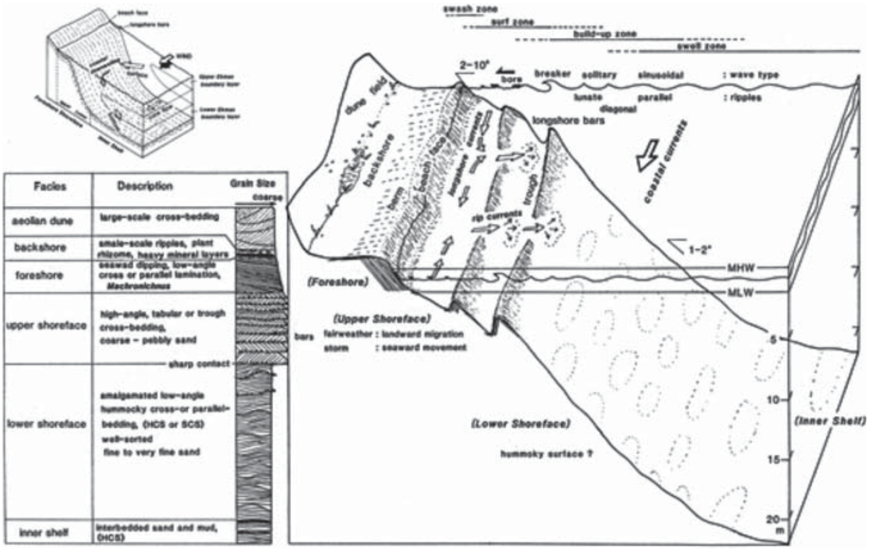

FIG. 3.1.3. Coastal features on a wave- and storm-dominated coast. (Modified after Saito, 1989.)

by bar and trough topography as a result of being constantly influenced by waves and wave-induced currents. Rip currents and the landward or seaward migration of bars result in the tabular and trough cross-stratification that characterize upper shoreface sediments. Two- and three-dimensional wave ripple structures are also commonly found. These sedimentary facies reflect mostly fair-weather wave conditions. The upper shoreface sediments overlie the lower shoreface sediments, which are characterized by swaley cross-stratification (SCS) or hummocky cross-stratification (HCS). HCS displays low-angle (less than 15°) erosional lower set boundaries with subparallel and undulatory laminae that systematically thicken laterally, and scattered lamina dip directions (Harms et al., 1975). SCS is amalgamated HCS with abundant swaley erosional features. These sedimentary structures are thought to be formed by the oscillatory currents of storm waves interacting with offshore-directed currents.

During storms beaches are eroded and longshore bars migrate seaward. Strong (long-period) oscillatory currents caused by storm waves agitate sea-bottom sediments at the shoreface. Some of the sediments are transported offshore by bottom currents caused by coastal set up and gravity currents. Oscillatory currents related to calming storm waves produce HCS/SCS in the shoreface to inner shelf region overlain by wave ripple lamination. HCS and SCS are found only in sediments composed of coarse silt to fine sand. Similar wave conditions form large dunes in coarse-grained sediments. As lower shoreface sediments are deposited mainly during storms, there is a sharp boundary between upper and lower shoreface sediments. This is formed by bar migration, The lower shoreface topography depends on the inner-shelf topography. Because typical shoreface topography can form only on a gently sloping to flat basal surface, no clear shoreface topography can form in the steep shelf regions of active plate margins. Thus, sometimes only the upper shoreface is referred to as the shoreface. In middle latitudes, typical storms are summer typhoons and winter storms. However, tropical regions closer to the equator do not experience such storms. Therefore, wave conditions and sediment distribution in tropical regions are different from those of middle latitudes. Development of bars and troughs is weak, and they are located at much shallower depth than storm-dominated coasts in middle latitudes.

The coastal succession and sedimentary facies reflect the current velocities under fair-weather and storm conditions as well as seaward-decreasing energy conditions. Under fair-weather conditions the bedforms (sedimentary structures) found from the foreshore to the upper and lower shoreface are upper plane beds (parallel lamination), 3D and 2D subaqueous dunes (trough and tabular cross-bedding, respectively), and 3D and 2D ripples (ripple lamination). On the other hand, under storm conditions, beaches are eroded and the lower shoreface resembles an upper flow regime characterized by long-period oscillatory waves, resulting in the formation of HCS and SCS. Ripples are formed in shelf regions. The preservation potential of storm deposits is higher than that of sediments deposited during fair weather, particularly in the lower shoreface and offshore areas. However, in tropical regions, sediments deposited under fair-weather conditions are relatively well preserved because storms are infrequent.

Key Boundaries and the Mud Line

There are three important boundaries on storm- or wave-dominated coasts: one between the upper and lower shoreface, one between the lower shoreface and the inner shelf, and one at approximately 50–60 m water depth on the shelf.

The upper shoreface is characterized by longshore currents and alongshore sediment movement. On the upper shoreface, longshore bars migrate frequently. They often move landward during fair weather, carried by breakers. The positions of the outermost longshore bars are relatively stable. These bars are thought to be formed during storm waves. Sediments in the upper shoreface are relatively coarse grained, forming dunes and 2D and 3D ripples. Thus active morphological change and sediment movement are typical on the upper shoreface. However, they are not typical on the lower shoreface under fair-weather conditions. Small ripples are often found, but alongshore sediment movement is not active in the lower shoreface. Most sediments are storm generated (HCS/SCS). These differences between the upper and lower shoreface result in a clear erosional boundary and time gap. The water depth of this boundary ranges from 4 to 8 m, depending on wave conditions.

Under fair-weather conditions sediment movement and its budget form a closed system in the upper shoreface. The closure depth is located at the boundary between the upper and lower shoreface. However, during storms, when some foreshore and upper shoreface sediments are transported offshore, the closure depth is deepened. Therefore, the sediment budget of the upper shoreface in a shore-normal section is fixed during fair weather, and negative during storms because of sediment loss due to offshore transport. If the sediment supply to the upper shoreface is not enough to compensate for the sediment loss by alongshore sediment movement, coastal erosion will occur along such a coast. As alongshore sediment transport for sands and gravels occurs only in the upper shoreface zone, it is important that coastal structures such as groins and jetties do not cross the whole of the upper shoreface zone and cut off alongshore sediment movement. If the depth and length of such structures are such that the upper shoreface is blocked, sediments will not be transported downcurrent beyond the structures, resulting in coastal erosion in downcurrent areas. Most human-caused coastal erosion is the result of cessation of alongshore sediment transport.

The second important boundary is between the lower shoreface and the shelf. Wave ripples are often found in a lower shoreface. These are composed of fine to very fine sand. Muddy sediments are rare in the lower shoreface. The mud line is usually defined as the most landward boundary of muddy areas. If it is between the shoreface and shelf it is called the nearshore mud line. This depth is very important because it is regarded as the fair-weather wave base for sediment movement. This boundary is at about 15 m water depth on a storm-dominated coast in middle latitudes (coasts facing the Pacific Ocean or the Japan Sea) and at less than 10 m water depth on a wave-dominated coast at low tropical latitudes.

The last boundary is the storm wave base. There are two kinds of storm wave base. One is for sediment movement by storm waves, and the other is for bottom erosion. The erosional wave base is deeper than that for simple sediment movement. The erosional wave base is regarded as the maximum depth of bottom sediment movement of 0.5-mm sand grains caused by storm waves. It is thought to be at 50–60 m water depth in areas facing the open ocean. The storm wave base also coincides with the boundary between neritic sand and offshore mud when the inner shelf is steep and shoreface topography is not clear. This mud line is known as an offshore mud line.

All of the above characteristics apply to sandy coasts. However, on coasts that receive abundant mud, sediment distributions are different. In general, sediments from foreshore to shoreface are finer than on sandy coasts. A common characteristic of both sandy and muddy coasts is that the coarsest sediments are found around the boundary between the upper and lower shoreface.

Sediment Sources

Understanding sediment sources is an important prerequisite to the development of countermeasures against coastal erosion. There are three major sediment sources for coastal sediments: rivers, sediment supplied by coastal erosion from coastal cliffs or headlands, and recycled marine sediment. Most sands and gravels supplied by rivers are deposited in the river-mouth area, except for hyperpycnal flows. Sands deposited in the upper shoreface or delta front platform are removed by waves and transported alongshore by longshore currents, forming bars and foreshore deposits, or offshore by storm waves and offshore-directed bottom currents. Sands supplied from sea cliffs and headlands are also transported alongshore. These point-source sands are transported alongshore and accreted onto the foreshore (beaches), resulting in shoreline migration seaward. However, intense storms pick up these sediments and transport them offshore. Thus, these coastal sediments are regarded as a line source of offshore sediments. Sediment recycling is very important on both wave-dominated and low-energy coasts. Barriers in the northeastern Gulf of Mexico and in the Wadden Sea of the North Sea are composed of recycled sands. Some barriers are maintained during transgression by the recycling of both overwash sediments and sediments of retreating barriers. However, at present, some beaches on barriers in the Wadden Sea are maintained by beach nourishment. Mud sediment sources are also from rivers and coastal erosion. Most mud is transported in suspension via various pathways to the offshore.

Coastal erosion occurs as a result of an imbalance between sediment supply and removal. The construction of jetties, groins, and harbors interrupts alongshore sediment transport, resulting in a decrease in the sediment supply. Seasonal wind changes (e.g., in a monsoon climate) cause the direction and strength of alongshore sediment transport to change. A decrease in the sediment discharge of rivers due to dam construction, irrigation, or sand mining in channels and river banks is also a cause of coastal erosion. An increase in water depth in nearshore zones induces an increase in wave energy, resulting in increased sediment transport offshore. A relative sea-level rise due to a eustatic sea-level rise or ground subsidence also accelerates coastal erosion. The specific causes of coastal erosion must thus be understood before countermeasures can be developed.

3.1.3 Tide-dominated Coast

Tide-dominated coasts differ from storm- or wave-dominated coasts in terms of sediment transport and coastal morphology. Very wide, flat morphology that is well developed in the intertidal to subtidal zones is called a tidal flat. Bars and trough topography are also found in these zones. Two directional currents, the flood current and the ebb current, give the sediment transport a characteristic pattern. The capacity for sediment transport of flood and ebb currents is controlled by current velocity and duration. In general, sediment transport by flood currents exceeds that of ebb currents, resulting in a prevailing landward sediment transport. This phenomenon is called the tidal pump. Moreover, current velocity increases with water depth, resulting in more energetic conditions offshore. Therefore, sediment deposits on a tide-dominated coast show a landward fining (seaward coarsening) distribution (Fig. 3.1.4). Typically, sandy sediments in subtidal zones change to muddier

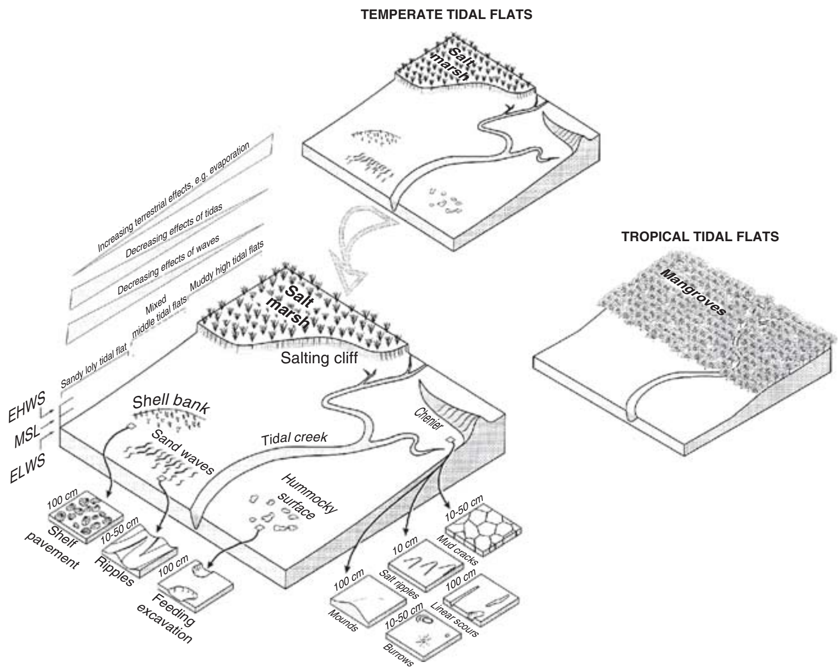

FIG. 3.1.4. Coastal features of a tide-dominated coast. (After Semeniuk, 2005.)

sediments in the intertidal zone and in the vegetated supratidal zone. From the upper part of the intertidal zone to the supratidal zone salt marshes are well developed, particularly in coastal lagoons and estuaries. In tropical to subtropical regions, mangroves are found between the mean tide level and the high tide level. Vegetation effectively traps fine-grained sediments transported from offshore by the tidal pump. Fine-grained sediments supplied by rivers are transported alongshore and are trapped in tidal estuaries and tidal flats by tidal processes.

3.1.4 Impact of Sea-level Rise

Sea-level rise has affected coastal morphology and systems on a millennial timescale, but a short-term sea-level rise also affects coastal environments. The future sea-level rise due to global warming is expected to be 11–88 cm by the year 2100 (IPCC 2001). On a wave- and storm-dominated coast, the shoreface topography is thought to represent an equilibrium profile controlled by waves and sediments (sea level 1 in Fig. 3.1.5). When sea level rises, a new equilibrium profile is formed. As the sediment supply is generally not enough to fill all the accommodation space to maintain the shoreline position, the shoreline retreats and a new profile forms at the new shoreline position (sea

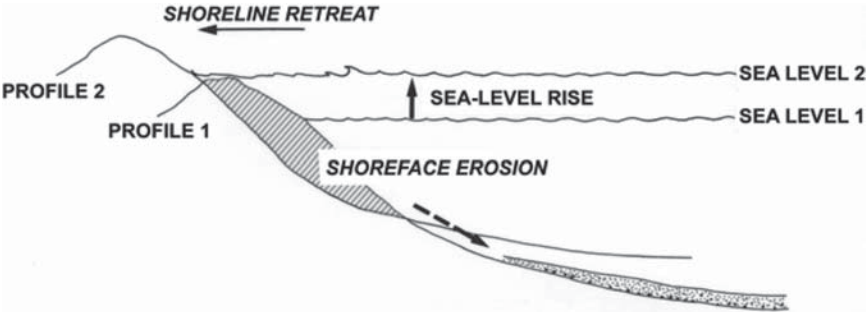

FIG. 3.1.5. Shoreface erosion due to a sea-level rise. (After Bruun 1962; Saito 1989.)

level 2 in Fig. 3.1.5). Some of the shoreface sediments are eroded in the process of forming the new equilibrium profile. This phenomenon is called shoreface erosion according to the Bruun principle or rule. It is important to note that erosion occurs not only at the shoreline but also in the shoreface region, at water depths of less than about 15 m. The sea-level rise leads to an increase of wave power caused by the increase in water depth. Coastal erosion of cliffs and strand plains will also be accelerated by a sea-level rise.

Mimura and Kawaguchi (1996) estimated that sand beach erosion will occur at all Japanese beaches when sea level rises. Their results show a 60% loss of beaches with a 30-cm sea-level rise, an 80% loss with a 65-cm rise, and a 90% loss with a 100-cm rise. Although a sea-level rise would also increase the sediment supply to beaches as a result of cliff erosion, that was not considered in this estimate. Because most cliffs in the Japanese islands that used to supply sediments to beaches are now protected from wave action by concrete blocks, this additional supply is no longer overly large.

On the other hand, the impact of a sea-level rise on a tide-dominated coast is not modeled according to the Bruun rule. The increase in water depth causes more energetic conditions in such coastal zones. This changes the distribution of sand and mud and causes some shoreline erosion by increased wave action.

The northern coast of the Gulf of Thailand is a good example of the impact of a relative sea-level rise on a muddy coast. Subsidence due to groundwater pumping has occurred not only in Bangkok but also in the coastal zone south of the city. The mouth of the Chao Phraya River is located south of these areas. At the river mouth, and in the neighboring coastal zones, more than 60 cm of subsidence occurred during the 1960s to 1980s, resulting in severe coastal erosion (Vongvisessomjai 1992; Vongvisessomjai et al., 1996). The shoreline retreat was 700 m in total up to the early 1990s. The main causes of this erosion and retreat are submergence and an increase of wave energy as a result of the nearshore zone being deepened by subsidence. As the nearshore zone has a very gentle slope of 1/1000, the more than 60 cm of subsidence (deepening) directly caused an increase in wave energy. Moreover, destruction of mangroves in conjunction with shrimp pond farming has enhanced shoreline retreat. Once frontal mangroves were destroyed, the shoreline retreated past the shrimp ponds to the next mangrove forest. Recently, coastal erosion continues to propagate along the coast, in addition to the river mouth, in response to widespread subsidence, with approximately 20 cm of subsidence occurring between 1992–2000. The reduced sediment supply from the Chao Phraya River caused by dam construction has also affected the coastal zone and its ecosystems (Winterwerp et al., 2005).

The total eroded area at the Chao Phraya river mouth and in its vicinity was 1.8 km^2 during the initial phase of subsidence (1969–1973); therefore, a relative sea-level rise of only 10 cm induced substantial erosion on this muddy coast. The future sea-level rise predicted by the IPCC (2001) will inevitably influence this and other vulnerable muddy coasts. As the 700-m shoreline retreat experienced in this area is smaller than the shoreline retreat estimated for a 60-cm sea-level rise given the coastal topography, mangroves will play an important role in the adaptation and preservation of the shoreline.

3.1.5 Asian Coasts

Asian coasts are characterized by large river deltas: for example, the Indus, Narmada, Godavari, Ganges-Brahmaputra, Ayeyarwady (Irrawaddy), Chao Phraya, Mekong, Song Hong (Red River), Zhujiang (Pearl River), Changjiang (Yangtze River), and Huanghe (Yellow River) deltas. Nine of the world's 16 largest rivers (in terms of sediment discharge) are located in Asia – 10 if the Fly River in Papua New Guinea is included. Rivers in Asia and Oceania contribute about 70% of the world's sediment flux from the land to the ocean: large rivers in Asia contribute about 40%, and small rivers in mountainous Oceania contribute 30% of the world's flux. This huge sediment supply causes the formation of large river deltas with a high progradation rate. During the last 2,000 years, the shoreline has migrated seaward about 80 km at the mouth of the Huanghe, 100–150 km at the mouth of the Changjiang, 20–30 km at the mouth of the Song Hong, 30–40 km at the mouth of the Mekong River, and 10–25 km at the mouth of the Chao Phraya River (Table 3.1.1). Moreover, recently Asian deltas have suffered and undergone rapid change as a result of human activities, particularly the construction of dams.

TABLE 3.1.1. Shoreline migration of major Asian deltas during the last 2,000 years. (Data from Saito et al., 2001; Hori et al., 2002; Ta et al., 2002; Tanabe et al., 2003a, b.)

	Shoreline migration during the last 2,000 years	Average rate (m/year)
Huanghe (Yellow River)	About 80 km	About 40 m
Changjiang (Yangtze River)	100–150 km	50–75 m
Song Hong (Red River)	20–30 km	10–15 m
Mekong River	30–40 km	15–20 m
Chao Phraya River	10–25 km	5–13 m

After the construction of the Hoa Binh Dam on the middle reaches of the Song Hong, completed in 1989, sediment delivery was decreased by more than 30% compared with its former level. Sediment supply to the mouth of the main distributary of the Song Hong changed from about 26 million tons/year in 1949 to 11 million tons/year in 2000, resulting in coastal erosion. The Mekong River also has several dams in its drainage basin. After the Manwan Dam, in the upper reaches in China, began operating in 1993, it caused a reduction of the sediment load in Laos of approximately 35 million tons/year (MRC 2003). More than 10 dams are planned or under construction in the drainage basin. The Chao Phraya River in Thailand has also been influenced by dam construction, resulting in decreased of discharge of sediment. The sediment load at Nakhon Sawan, about 300 km upstream of the river's mouth, showed a clear reduction after the Bhumipol and the Sirikit Dams were completed in 1965 and 1972, respectively. The sediment load of more than 30 million tons/year before 1965 was reduced to less than 5 million tons/year by the 1990s (Winterwerp et al., 2005). The Huanghe, which was once the second largest river in the world in terms of sediment discharge, delivers less than 10% of its former discharge because of dam construction and irrigation, resulting in serious coastal erosion. The Changjiang has also experienced a sediment-load reduction of more than 40%.

Since a delta is defined as a convex coastal topographic feature formed by seaward shoreline migration, a stable shoreline is not a natural deltaic feature. In order to evaluate changes to deltas caused by human activities, it is important to understand that deltaic progradation is a natural state. Recently, Asian deltas have suffered as a result of human activities and have undergone rapid change. Moreover, the impacts of future global warming, notably sea-level rise, on deltaic coasts are of concern. Coastal erosion is a key issue. At a minimum, the evaluation of deltaic coasts and human impacts on the shoreline requires knowledge of the natural state of deltas and the natural changes that

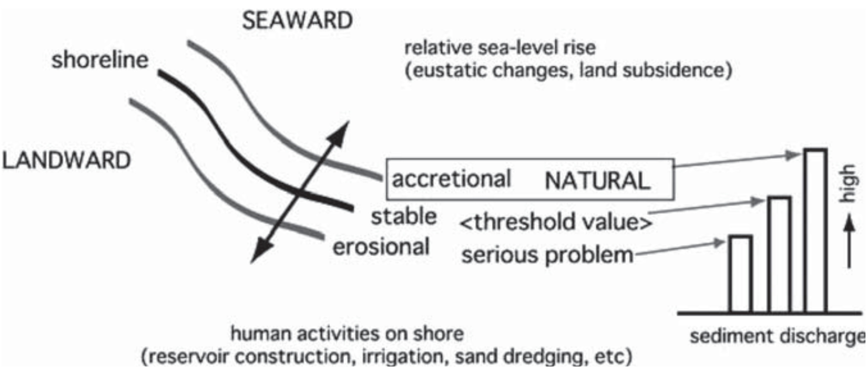

FIG. 3.1.6. Shoreline migration/retreat in relation to sediment discharge from rivers. (After Saito 2005b.)

they undergo. To prevent the erosion of present shorelines, appropriate quantities of sediments are needed, above a threshold value. If the sediment supplied from rivers decreases below this value, which is different for each river and delta, deltaic coasts experience serious coastal erosion problems (Fig. 3.1.6). We must know these basic values to increase our understanding of delta environments and to develop future measures against erosion.

References

Boyd R, Dalrymple D, Zaitlin BA (1992) Classification of clastic coastal depositional environments. Sediment Geol 80:139–150

Bruun P (1962) Sea level rise as a cause of shore erosion. Proc Am Soc Civ Eng J Waterways Harbors Div 88:117–130

Curray, JR (1964) Transgressions and regressions. In: Miller RL (ed) Papers in marine geology, Shepard Commemorative volume. Macmillan, pp 175–203

Harms JC, Southard JB, Spearing DR, Walker RG (1975) Depositional environments as interpreted from primary sedimentary structures and stratification sequences. Lecture notes for short course no. 2, SEPM, 161p

Hori K, Saito Y, Zhao Q, Wang P (2002) Evolution of the coastal depositional systems of the Changjiang (Yangtze) River in response to Late Pleistocene–Holocene sea-level changes. J Sediment Res 72:884–897

IPCC (2001) In: Houghton JT, Ding Y, Griggs DJ, Noguer M, van der Linden P, Dai X, Maskell K, Johnson CI (eds.) Climate change 2001: the scientific basis. Contribution of working group I to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press, 881p

Mimura N, Kawaguchi E (1996) Responses of coastal topography to sea-level rise. Proceedings of the 25th ICCE, 1349–1360

MRC (2003) State of the basin report: 2003. Mekong River Commission, 300p

Saito Y (1989) Classification of shelf sediments and their sedimentary facies in the wave-dominated shelf: a review. J Geogr 98:350–365 (in Japanese with English abstract)

Saito Y (2001) Deltas in Southeast and East Asia: their evolution and current problems. In: Mimura N, Yokoki H (eds) Global change and Asia Pacific Coast proceedings of APN/SURVAS/LOICZ joint conference on coastal impacts of climate change and adaptation in the Asia–Pacific region. APN and Ibaraki University, pp 185–191

Saito Y (2005a) Beach stratigraphy. In: Schwartz ML (ed) Encyclopedia of coastal science. Springer, pp 179–181

Saito Y (2005b) Deltaic coast dynamics. In: Crossland CJ, Kremer HH, Lindeboom, J.I. Marshall Crossland HJ, Le Tissier MD (eds) Coastal fluxes in the Anthropocene. IGBP Book series, Springer, pp 48–49

Saito Y, Yang Z, Hori K (2001) The Huanghe (Yellow River) and Changjiang (Yangtze River) deltas: a review on their characteristics, evolution and sediment discharge during the Holocene. Geomorphology 41:219–231

Semeniuk V (2005) Tidal flats. In: Schwartz ML (ed) Encyclopedia of coastal science. Springer, pp 965–975

Ta TKO, Nguyen VL, Tateishi M, Kobayashi I, Tanabe S, Saito Y (2002) Holocene delta evolution and sediment discharge of the Mekong River, southern Vietnam. Quat Sci Rev 21:1807–1819

Tanabe S, Saito Y, Sato Y, Suzuki Y, Sinsakul S, Tiyapairach N, Chaimanee N (2003a) Stratigraphy and Holocene evolution of the mud-dominated Chao Phraya delta, Thailand. Quat Sci Rev 22:789–807

Tanabe S, Hori K, Saito Y, Haruyama S, Vu VP, Kitamura A (2003b) Song Hong (Red River) delta evolution related to millennium-scale Holocene sea-level changes. Quat Sci Rev 22:2345–2361

Vongvisessomjai S (1992) Coastal erosion in the Gulf of Thailand. Res Dev J Eng Inst Thailand 3(1):38–58

Vongvisessomjai S, Polsi R, Manotham C, Srisaengthong D, Charulukkana S (1996) Coastal erosion in the Gulf of Thailand. In: Milliman JD, Haq BU (eds) Sea-level rise and coastal subsidence. Kluwer Academic, Dordrecht, pp 131–150

Winterwerp JC, Borst WG, de Vries MB, (2005) Pilot study on the erosion and rehabilitation of a mangrove mud coast. J Coastal Res 21:223–230

3.2 Water and Sediment Pollution

3.2.1 Eutrophication and its Causes/Consequences: The Case of the Seto Inland Sea

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Introduction

The Seto Inland Sea suffered from the most serious water pollution and negative effects of eutrophication about 30–40 years ago when the sea was called “the dying sea”. It has gradually recovered thanks to the strenuous efforts of a variety of groups and bodies, along with strong political and legal support. However, the Seto Inland Sea still has many eutrophication-related problems to be solved (Okaichi et al., 1997). The lessons learned from the Seto Inland Sea are a valuable example of a successful case of eutrophication control. The basic mechanism of the eutrophication system found there is also applicable to other areas.

In the face of urgent necessity due to rapid increases in water pollution, the Law on Temporary Measures for the Environmental Conservation of the Seto Inland Sea was enacted in 1973. This law was made permanent in 1978. It has played a very important role in the environmental conservation of the area ever since. Total pollution load control, in terms of COD load, is one of the major pollution control mechanisms of the law. COD discharged in the coastal zone of the Seto Inland Sea was, for example, 1,700 t/day in 1972. It was amazingly reduced to 718 t/day by 1996 (International EMECS Center 2003).

In order to prevent the negative effects of eutrophication in coastal areas, the national government established environmental standards for nitrogen and phosphorus. Further countermeasures against eutrophication in terms of total phosphorus load control have also been applied to the Seto Inland Sea since 1980. As a result of these countermeasures, a reduction in total phosphorus load was achieved much faster than that of total nitrogen load, based on measurements starting from 1995. This is partly because of the differing sources for nitrogen and phosphorus.

New environmental policies contributing to the recovery of a sound environment were initiated in the Seto Inland Sea in the late 1990s. Based on what the environment was like in the past, and what it should be like in the future, the cooperation of a variety of groups, including local and national governments, local citizens, nongovernmental organisations (NGOs), Knops (explain), scientists, and fishermen, was sought. They have been requested to play a leading role in promoting various projects. Recently, new environmental management systems, aimed at the restoration of the damaged environment using environmentally friendly technologies, are being developed in this area.

As a result of more than 30 years of the “Biosphere Experiment”, in which control of eutrophication has been actively addressed, it is true to say that the case of the Seto Inland Sea is one of the best cases by which to study the process of eutrophication and effective countermeasures against eutrophication as a social experiment.

Outline of the Seto Inland Sea

This summary is based primarily on International EMECS Center (1997). The Seto Inland Sea is the largest enclosed coastal sea in Japan. It is surrounded by three main islands, namely Honshu, Kyushu, and Shikoku. The sea covers an area of 23,000 km^2. The area has a temperate climate with an average annual precipitation of 1,000–1,600 mm. The Sea has a coastline of approximately 6,900 km and is very shallow sea with an average depth of only 38 m. It is dotted with approximately 1,000 small islands and is connected with the outer ocean via the Kii Strait between Honshu and Shikoku, the Bungo Strait between Shikoku and Kyushu, and the Kanmon Strait between Honshu and Kyushu.

Since the coastal area of the Seto Inland Sea provides a suitable site for many kinds of human activities, in particular for chemical and heavy industries, the area is highly populated. The coastal regions of the Seto Inland Sea, including its watershed area, are home to 30 million people or 24% of the entire population of Japan (130 million). The population density in this area is significantly high. At 47,000 km^2, the area represents a mere 12% of the entire land area of Japan (380,000 km^2). This high population density, along with many industrial activities, has had a strong impact on the coastal environment in numerous ways.

The Sea is also a major fishing ground, with a yearly fish catch of approximately 270,000 t and a yearly harvest of 320,000 t of aquaculture in recent years. It should also be noted that reclamation for the construction of industrial zones has significantly reduced the fishing area in the shallow waters, including tidal flats and seaweed beds along the coast.

As mentioned above, the Seto Inland Sea has only three openings connecting it to the outer ocean. However, since water exchange through the Kanmon Strait is very restricted, the major portion of water exchange between the Inland Sea and the outer ocean is made through both the Kii and Bungo Straits. The Seto Inland Sea has many narrow straits also inside the sea that connect many open areas of the sea with each other. Since the term "Seto" means strait in Japanese, the name of the Seto Inland Sea originally indicates an enclosed inland sea with many straits. This highly complicated structure of the sea provides both high environmental and biological diversity and also high biological productivity. This is due to a significantly long residence time of inflowing nutrients and also to strong water mixing in the area of each strait (Hashimoto et al., 1997).

Major Problems on Environmental Conditions and Living Resources

During the period of the nation's rapid economic growth in the mid-1960s to mid-1970s, the increase in industrial activity and the expansion of landfills along the waterfront caused a rapid increase in water pollution, a reduction in the shallow water area and the destruction of the marine environment and habitat in the Seto Inland Sea.

Red tides occurred very frequently all over the area in the mid-1970s. Around 300 occurrences of red tide were recorded in 1976. These caused mass mortality of fish, in particular cage-cultured fish. In 1972, for example, 14 million cultured yellowtails were killed by red tides, resulting in economic losses of 7.1 billion yen. In recent years, as a result of various environmental conservation measures, the number of red tides has been reduced to around 100/year (Okaichi 2003).

Deterioration of sediment quality and oxygen depletion in the bottom water, particularly in areas with stagnant water or weak tidal movement, are also critical problems for living resources by which benthic habitat and benthic ecosystems have been seriously damaged.

Widespread dredging of sea sand dredging (i.e., sea sand mining) from the sea bottom to be used for construction and/or reclamation, seriously changed both the bottom topography and sediment quality. In some extreme cases, not only have depth, bottom topography and sediment quality been entirely changed, but the biomass and composition of benthic organisms have also been significantly affected.

In the shallow water areas, seaweed beds are important habitat, spawning and nursery grounds for many marine organisms. Tidal flats are the most important habitat for bivalves and they also play an important role in the decomposition of organic matter – in other words, the purification of organic pollutants. Both seaweed beds and tidal flats have long been significantly decreased in the Seto Inland Sea. During the period 1978–1991, 1,500 ha of seaweed beds and 800 ha of tidal flats were lost from the Seto Inland Sea (Figs. 3.2.1 and 3.2.2), mainly due to reclamation, dredging, and other human activities. Since shallow areas area also valuable recreational spaces, it is very important to restore these lost environments.

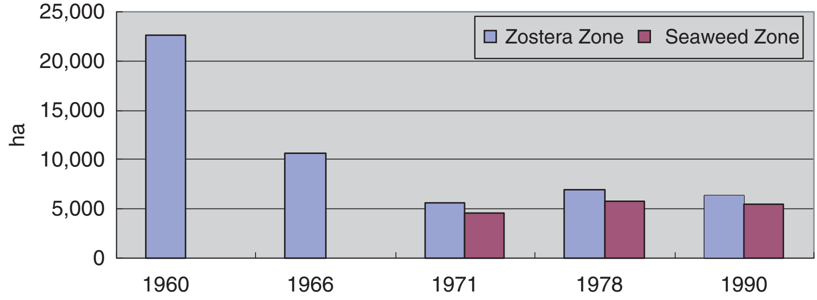

FIG. 3.2.1. Changes of areas of *Zosteria* and seaweed zones in the Seto Inland Sea. (After Okaichi and Yanagi 1997.)

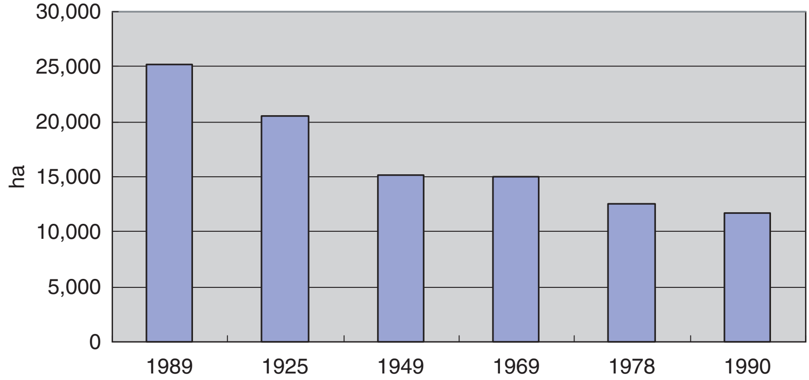

FIG. 3.2.2. Changes of areas tidal flats in the Seto Inland Sea. (After Okaichi and Yanagi 1997.)

A significant portion of the natural coastline has been converted to man-made coastlines of upright concrete walls (Fig. 3.2.3) Those do not provide a suitable habitat for many organisms and other living resources. The fact that a significant portion of the shallow water area has been lost indicates that there has also been a loss of the buffer action against the pollutant load due to the uptake of nutrients or organic matter by living filters such as seaweeds and bivalves. Hence, in the case of artificial coastlines without shallow areas, terrestrial pollution load has a more direct impact on the coastal seawater. This is because of the lack of a bio-filter action, thereby enhancing the occurrence of algal blooms. The disappearance of shallow water areas, in particular of shallow slopes, has a strong effect on tidal water movement. Horizontal tidal excursion has been minimized by upright concrete walls, which then enhance water stratification causing a stronger algal bloom in the upper layer and oxygen-depleted water in the deeper layer, especially during the summer season.

The total fish catch increased until the mid-1980s during the increase in eutrophication. This was mainly due to an increase in the catch for the

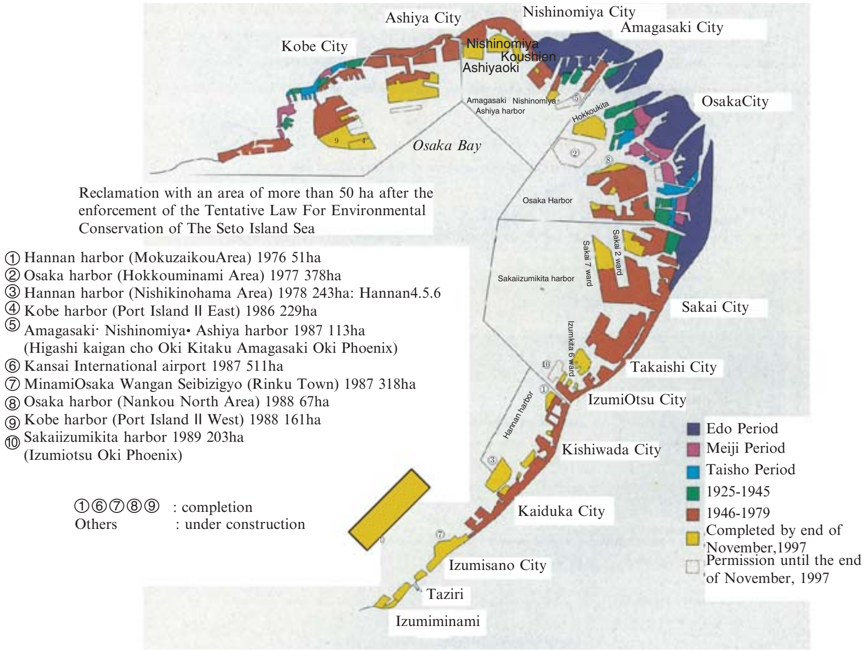

FIG. 3.2.3. Shoreline migration/treatment of Osaka Bay. (After Okaichi and Yanagi 1997.)

sardine-anchovy group. However, the total fish catch constantly decreased thereafter, with a remarkable decrease in benthic organisms such as bivalves and sea cucumber in shallow areas. Without stock replenishment, the catch of many benthic fish species has also gradually decreased. These substantial changes in fish catch statistics indicate a decrease in the stock level of living resources, in particular of benthic animals. This is partly due to oxygen depletion in bottom water, partly to a change in sediment quality and also to a decrease in spawning and nursery grounds in the shallow water areas (Nagai et al., 1997).

Environmental health is a new concept for the holistic evaluation of environmental conditions and functions. In the same way that people try to have regular check-ups as a precaution or to diagnose an illness at an early stage, routine health examinations should also be applied to the marine environment and ecosystems. Hence, examinations of the health of coastal seas are essential not only for evaluation of the present status but also for planning remediation and restoration of the environment. Although examination of the health of the coastal marine environment is widely accepted as a concept analogous to human health check-ups, a definition of marine environmental health and a practical methodology for carrying out such examination has not yet been adequately developed. A new scheme for health examinations as a new ecosystem-based approach to environmental monitoring and management was recently proposed, in which two major functions of the marine ecosystem are included. These two functions are ecosystem stability and smoothness of material cycling in the particular ecosystem under consideration. These functions will be very important both in sustainable fisheries and also in other types of utilization of the coastal environment in future. Based on the established "Master Plan and Guidelines", a preliminary health examination was conducted in 88 officially recognized enclosed coastal seas in Japan, among which a health examination of the Seto Inland Sea was also performed. The results of this preliminary examination pointed out the deterioration of the habitat with regard to the extent of the stability of the ecosystem. The study also highlighted the affect of material cycling on the primary production and decomposition processes.

Cause and Effect Consequences Relating to Eutrophication

In order to clarify the cause and effect consequences of eutrophication, this section describes the relationship between pollutant load and water quality in the Seto Inland Sea as well as for two other specific areas – Tokyo Bay and Ise Bay.

1. Area-wide total pollutant control system

An area-wide total pollutant control system has been implemented for every 5 years since 1979 in order to prevent water pollution in the Seto Inland Sea, Tokyo Bay and Ise Bay (Fig. 3.2.4). Under the system, target reductions and years for chemical oxygen demand (COD), nitrogen, and phosphorus were established for each sea area. Recently, the 6th total pollutant load control program has been implemented with a target year of 2009. Substantive means to reach the targetted reductions include: (1) development of household sewage treatment facilities; (2) application of total amount control standards with regard to industrial wastewater (50 m^3 or more per day on average); and (3) provision of guidance for small-scale and non-controlled industries and, farmers, stock raisers.

Fig. 3.2.4. Location of Tokyo Bay (right), Ise Bay (center), and Seto Inland Sea (left) in Japan. Arrow indicates Osaka City.

2. Relationship between COD load and COD concentration
COD loads in 1979, the year that the area-wide total pollutant load control system started, were 1,012 t/day in the Seto Inland Sea, 477 t/day in Tokyo Bay, and 307 t/day in Ise Bay. Implementation of pollutant load control measures is expected to decrease these loads to 630 t/day, 228 t/day, and 203 t/day, respectively, by 2004. This is the year targeted by the basic policy on the 5th total pollutant load control program. The ratios of reduction in the period between 1979 and 2004 come to 38%, 52%, and 34%, respectively, for the Seto Inland Sea, Tokyo Bay, and Ise Bay, respectively. In accordance with the decrease in pollutant load, a generally proportional decrease in COD concentration was observed during the period, although the levels of load and concentration differ according to the area (Fig. 3.2.5). It is of note that the level for Osaka Bay in the Seto Inland Sea is very high compared with other areas of the Seto Inland Sea.

3. Relationship between load and concentration of nitrogen and phosphorus
In the prefectures concerned, the pollutant loads of nitrogen and phosphorus had been estimated before these two substances were added to the specified items under the area-wide total pollutant load control system. Nitrogen loads estimated for 1979 amounted to 666 t/day in the Seto Inland Sea, 364 t/day in Tokyo Bay, and 188 t/day in Ise Bay. Those for phosphorus were 62.91 t/day, 41.2 t/day, and 24.4 t/day, respectively. When the pollutant loads of nitrogen and phosphorus in 1979 are compared to the reduction targets for 2004, expected decreases in nitrogen and phosphorus loads are estimated to be 15% and 39% in the Seto Inland Sea, 32% and 53% in Tokyo Bay, and 27% and 43% in Ise Bay, respectively.

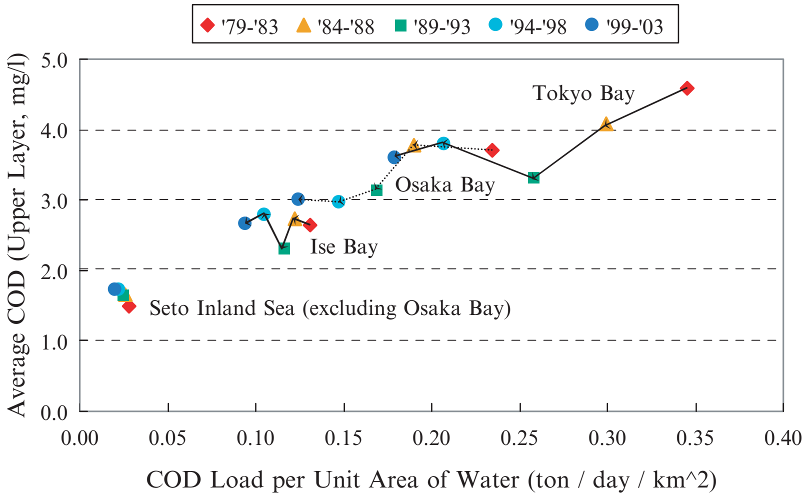

FIG. 3.2.5. Relationship between COD load and average COD concentration of sea water. (After Ministry of Environment of Japan 2005.)

Consistent with the decrease in nitrogen and phosphorus load, relatively proportional decreases of nitrogen and phosphorus concentration were observed during the period (Figs. 3.2.6 and 3.2.7 respectively). However, the relationships for nitrogen and phosphorus differ slightly. It is also of note that the level for Osaka Bay in the Seto Inland Sea is very high compared with other areas of the Seto Inland Sea.

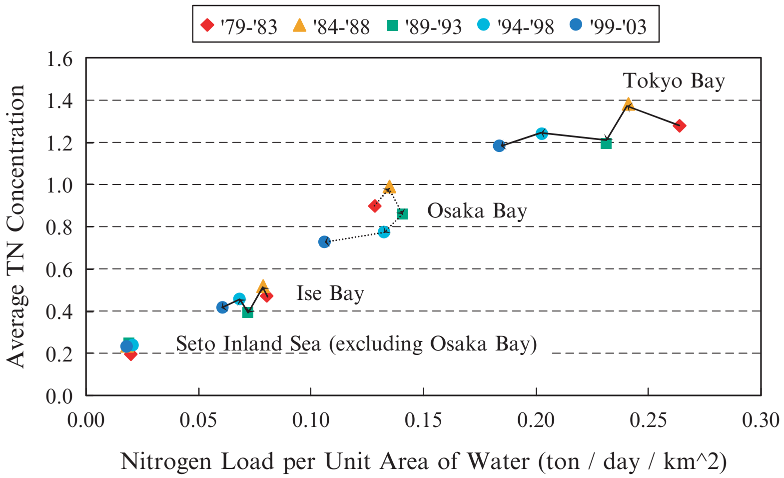

FIG. 3.2.6. Relationship between TN load and average TN concentration of sea water. (After Ministry of Environment of Japan 2005.)

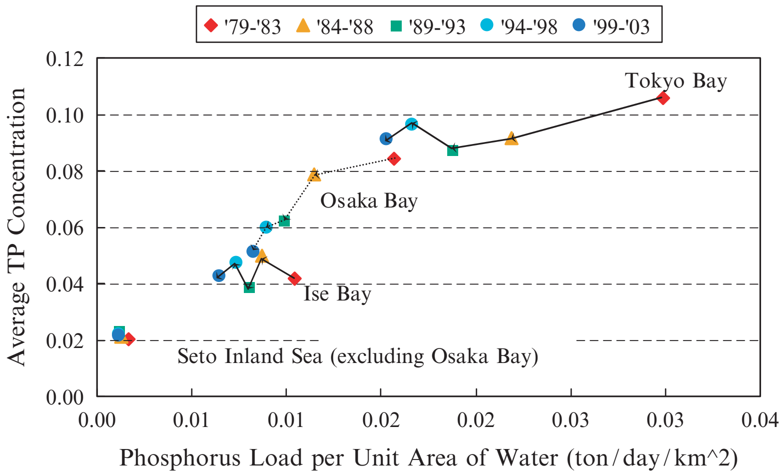

FIG. 3.2.7. Relationship between TP load and average TP concentration of sea water. (After Ministry of Environment of Japan 2005.)

Control of Eutrophication and Countermeasures Taken

1. The Enactment of "the Seto Inland Sea Law"
Historically, the Seto Inland Sea has long been blessed with beautiful nature and valuable living resources. However, the rapid growth in population and industrial development of the area seriously affected water quality in the late 1960s. In 1971, the 11 prefectures and 3 municipalities in the coastal regions of the Seto Inland Sea established the Governors and Mayors' Conference on the Environmental Management of the Seto Inland Sea. As a result of subsequent calls for the national government to establish a special law, the Interim Law for Conservation of the Environment of the Seto Inland Sea was enacted in 1973. In order to reduce the damage to fisheries due to red tides this law was revised in 1978 to include new policies aimed at preventing eutrophication. The amendment also made it a permanent law, and the law was renamed the Law Concerning Special Measures for Conservation of the Environment of the Seto Inland Sea. This legal system played a valuable role in eutrophication control and also worked as an effective countermeasure against environmental deterioration. Comprehensive conservation measures have been promoted under this legal system.

To promote long-term policies relating to environmental management of the Seto Inland Sea in a comprehensive and systematic manner, the national government enacted the Basic Plan for the Environmental Management of the Seto Inland Sea, and the individual prefectures established their own prefectural plans for environmental management of the Seto Inland Sea. In 2000, the Basic Plan established in 1978 was completely revised. The revised plan enhanced conservation policies and added new policies in order to restore lost environments and promote wide-ranging cooperation and participation among the national government, local public organizations, private citizens, companies, and other entities.

2. The effect of countermeasures
(a) Improvement of water quality
Total Pollutant Load Control in terms of COD
To improve water quality in the Seto Inland Sea a system of area-wide total pollutant load control has been established to restrict the quantity of organic pollutants flowing into rivers and the sea in coastal zones. Under this system chemical oxygen demand (COD) is used as an indicator for the establishment of reduction targets for the total quantity of organic pollutants discharged from factories, sewage treatment plants and domestic households. Effluent restrictions and guidance were also implemented.

As a result, the total quantity of COD produced in the coastal zones of the Seto Inland Sea, which was 1,700 t/day in 1972, was reduced to 672 t by 1998 (Fig. 3.2.8).

Prevention of damage by eutrophication
Prevention of outbreaks of red tides due to eutrophication was identified as an urgent necessity. Measures to reduce levels of nutrients were put in place.

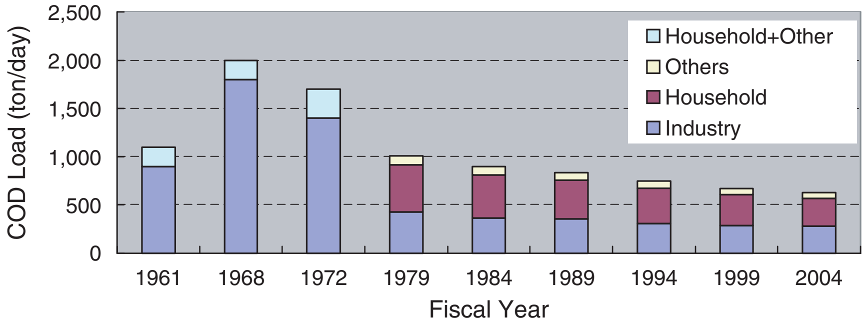

FIG. 3.2.8. Trends in the change of COD load classified into pollutant types in the the Seto Inland Sea. (After Ministry of Environment of Japan 2005.)

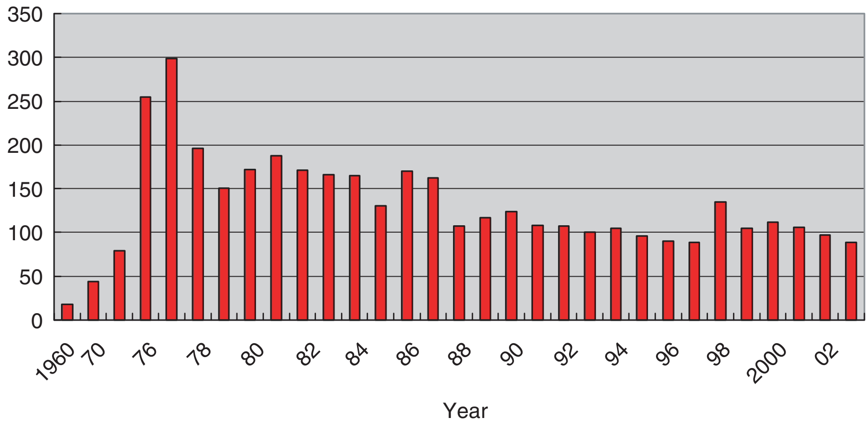

FIG. 3.2.9. Changes in the number of occurrences of red tide in the Seto Inland Sea. (After Ministry of Environment of Japan 2005.)

Under the system, guidance was given to reduce levels of phosphorus and its compounds from 1979. Based on this policy, prefectural governments instructed factories and other business entities with regard to such matters as the rectification of the use of raw materials and facilities management, and the incorporation of advanced treatment facilities. In order to further decrease eutrophication, the total pollutant control system was revised in 2001 to include restrictions on nitrogen and phosphorus, reflecting their impacts on COD.

Effects on the water environment

Strict legislation-based regulation of factory wastewater was implemented. Sewer systems were also constructed in the basin. As a result, the number of red tide occurrences has decreased (Fig. 3.2.9) and water quality in the river basin has been improved (Okaichi 1997).

However, the ratio of achievement ratio related to the environmental quality standard for COD indicates that water quality in the Seto Inland Sea has

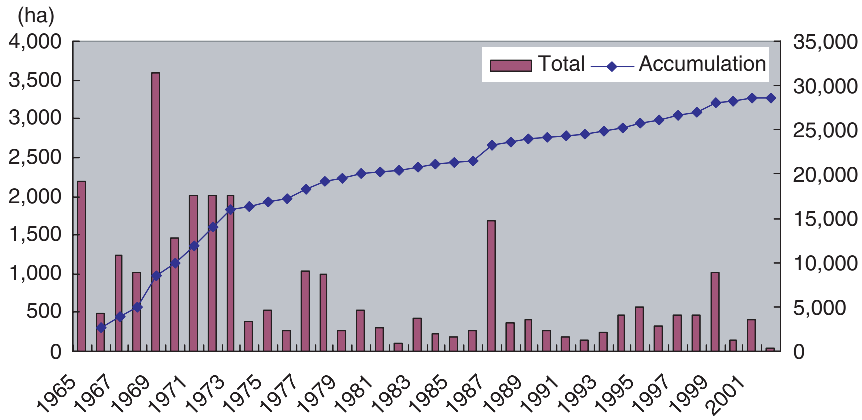

FIG. 3.2.10. Trends in areas for which reclamation has been authorized. (After Ministry of Environment of Japan 2005.)

not been totally improved overall by the total pollutant load control system. There has been no marked improvement in recent years. The reasons may be that the internal production of COD from inorganic nitrogen and phosphorus accounts for 40% of total COD and that organic compounds dissolved by deterioration on the bottom of the sea causes anoxia and decomposition resistant COD staying in the sea even after the introduction of wastewater treatment systems.

3. Environmental conservation on land reclamation
In the Seto Inland Sea numerous reclamation projects have been undertaken in a number of locations. A total man-made land area of about 450 km^2 has been created between the end of 19th century and 2001 (Fig. 3.2.10). As a result, one half of the coastline of the Seto Inland Sea is artificial, mostly in the form of vertical seawalls.

4. Natural environmental preserves
The Seto Inland Sea includes some of the most magnificent scenery in Japan. In 1934 this vast region was declared one of the first national parks in Japan. In addition to 834 wildlife protection areas, 27 locations have been designated as protected water surface areas suitable for aquatic animals to lay eggs and as habitats for young fish and so on. Moreover, 91 natural seashore conservation areas have been established so the sandy beaches, and other areas on the shores of the Seto Inland Sea will be preserved in their natural state and can be used for swimming and similar activities now and in the future.

New Environmental Conservation of the Seto Inland Sea

1. New Environmental Policy
New environmental policies contributing to the recovery of a sound environment were officially introduced to the Seto Inland Sea in 2000. Based on past environmental conditions the main target of the policy was changed from

water-quality control to environmental remediation and restoration of habitat. Led by the new policy for the Seto Inland Sea, a new law on the restoration of natural environments was enacted in 2002. This applied not only to the Seto Inland Sea but all over Japan. Collaboration of various groups, such as local and national government, local residents, NGOs, not-for-profit organizations (NPOs), scientists, and fishermen is expected to play an important role in promoting individual restoration projects.

2. Possible improvement in habitat conditions and living resources

Four possible causes of the decrease in fish stocks in the Seto Inland Sea have been proposed, namely changes in the natural environment due to a regime shift (large-scale climatic and oceanographic changes), overfishing, destruction of spawning, and nursery grounds or habitats, and long term changes in the ecosystem due to the effect of human activities. Decreases in sand eel stocks are more directly affected by habitat destruction due to large-scale sea-sand dredging for concrete construction industries.

Among the four possible causes identified above, countermeasures against regime shift and long-term ecosystem change are very difficult or almost impossible to be achieved in a relatively short period of time. Realistic countermeasures can only be taken against overfishing and against destruction of spawning and nursery ground or habitat. Here lies the importance of habitat restoration – in particular of tidal flats and seaweed beds and of living resource management in shallow areas.

In the shallow coastal waters seaweed beds are important habitat and reproduction grounds for many marine organisms. Tidal flats are the most important production area of bivalves. They also play an important role in the decomposition of organic matter. Both of these important habitats have undergone long-term decreases in the Seto Inland Sea area. Between 1978 and 1991, 1,500 ha of seaweed beds and 800 ha of tidal flats were lost from the Seto Inland Sea, mainly due to reclamation, dredging or other human activities. As a result, a significant portion of natural coastline has been converted to man-made coastline, consisting of upright concrete structures. These have not provided a good habitat for many organisms living along the seashore and have not provided the valuable functions of a natural coastline such as purification of organic pollution and denitrification.

3. Some cases of environmental restoration in the Seto Inland Sea

Among the many enclosed coastal seas of Japan, the Seto Inland Sea is one of the main sites of environmental remediation and restoration. Remediation and restoration carried out by different organizations in the Seto Inland Sea ranges over a variety of methods, depending on their objectives. Some examples include simple restoration of tidal flats or seaweed beds, or a combination of tidal flats and seaweed beds, artificial rocky shores, artificial lagoons, artificial submerged slopes, reuse of dredged sediment, and bird sanctuaries. Typical examples of such activities are introduced below.

In the port of Amagasaki, in Hyogo Prefecture, a unique environmental restoration project was undertaken. The best combinations of individual remediation technologies were investigated. The main objectives of the investigation were to find out the best way of combining technologies for the most effective material recycling. Many groups and bodies firstly participated in the project to develop their own remediation technology, but finally they successfully found way to integrate individual technology to produce the best performance on the material recycling.

At the estuary of the Fushino River in Yamaguchi prefecture very comprehensive habitat restoration is being conducted, including the environmental remediation of the Fushino River watershed. Reforestation of the upstream area is included. A local currency, called Fushino, was also introduced to the area in order to promote the project supported by the wide variety of stakeholders.

In Etashima Bay, Hiroshima Prefecture, has a highly enclosed topography and is an important culture ground for oysters. Oxygen depletion in the bottom water in summer and a deterioration in sediment quality, have been serious problems. The local government of Hiroshima Prefecture initiated the restoration of Etashima Bay using a multi-sectoral approach in which five prefectural research institutes participated in the development of efficient tidal flats and sea grass beds in order to activate local fisheries and oyster culture.

Along the coast of Kansai International Airport, which is located on an artificial island in Osaka Bay, a gentle slope of natural rocks and stones rather than a vertical concrete wall was used for the airport construction. The environmentally friendly gentle slope provided an appropriate site for seaweed beds and a suitable habitat for many kinds of organisms. As a result, the artificial structure is now working as a new seaweed bed and habitat. This is a good example of environmentally friendly, creative regeneration of the environment as the original site on which the airport was constructed was an area of muddy sea bottom. Although the effect of the artificial island should be correctly evaluated, the effect of a more natural gentle slope itself should also be evaluated since the newly created seaweed bed plays a mitigating role in the widely lost seaweed bed in Osaka Bay.

As to restoration of the effects of large-scale sea-sand dredging, environmental change is being monitored and the basic design for a restoration plan has been discussed but practical restoration activities have not yet been achieved.

4. Future directions

As has already been stated, the results of the preliminary examination of the environmental health of the Seto Inland Sea made clear the deterioration in habitat conditions. Hence, restoration of such habitats in shallow water, including tidal flats and seaweed beds, is one of the most pressing actions that needs to be taken in the Seto Inland Sea. Therefore, one of the major directions in future should be creative restoration, and possibly creative regeneration of a new Seto Inland Sea.

A new creation, "Sato Umi", was proposed by the Research Institute for the Seto Inland Sea. "Sato Umi" means, in Japanese, a coastal sea under the harmonization of sustainable, wise use with conservation of an appropriate natural environment and habitat. Compared with a deteriorated coastal environment, "Sato Umi" is able to provide a higher biological diversity as habitat, and higher biological production as fishing grounds. These characteristics of "Sato Umi" are also suitable for demonstrating the multi-functional roles of fisheries.

Development of a new holistic approach for sustainable biological production and control of eutrophic levels is a prerequisite to establishing functionally efficient "Sato Umi" in each local coastal area. Promotion of integrated environmental management towards environmental remediation and restoration of a wide variety of habitats are recommended to be undertaken in the near future. This should involve the international exchange of information, ideas and methodologies.

With respect to the future direction of habitat conservation and resource management, top priority should be given to the original objective. In the case of seaweed bed restoration this includes the high performance restoration of seaweed beds. However, other viewpoints are also important. Future methods of habitat restoration and resource management should be examined from the viewpoint of low environmental impact, high recycling of material used, low-cost with high-cost performance, energy saving technology, and applicability of adaptive management. Continuous monitoring after restoration activities is also very important in evaluating the effectiveness of the restoration methods that have been used.

Important and yet practical future directions are itemized below:

Active creation of a new environment in the Seto Inland Sea

- Preferable habitat environments and recreational spaces to recover seaweed beds, tidal flats and other shallow water areas
- The strict control of reclamation and excavation
- Promoting fisheries from the view point of the multifunctional role of fisheries

Regeneration of forests, rivers and sea, with effective participation and partnerships among the various stakeholders

- Preferable water and material cycle, recognizing the interactions between forests, river basins and coastal seas

Establishment of mitigation systems

- Minimizing waste dumping in the area
- The wise and efficient use of vacant land along the coast
- Securing new environments in historically disappearing areas

Comprehensive management

- Wide-ranging cooperation among the national government, local governments, local citizens, companies and other entities
- A unified authority to be organized with all rights on management of the Seto Inland Sea

In conclusion, the development of a new holistic approach for sustainable biological production and control of eutrophic levels, or a kind of new creative restoration, is a priority. Promotion of integrated environmental management, including watershed management, should be adopted from the viewpoint of interrelated water and material cycling in the river basin, forest and coastal seas. The concept of "Sato Umi", originating from the traditional ideas of the local people for wise and sustainable use of coastal areas, can support the new creative restoration of the environment and habitat in the Seto Inland Sea.

References

Hashimoto H, Hashimoto T, Matsuda O et al. (1997) Biological productivity of lower trophic levels of the Seto Inland Sea. In: Okaichi T, Yanagi T (eds) Sustainable development in the Seto Inland Sea Japan from the view point of fisheries. Terra Scientific Publishing Company, Tokyo, pp 61–94

Nagai T, Ogawa Y (1997) Fisheries production. In: Okaichi T, Yanagi T (eds) Sustainable development in the Seto Inland Sea Japan from the view point of fisheries. Terra Scientific Publishing Company, Tokyo, pp 61–94

Okaichi T (1997) Red tides in the Seto Inland Sea. In: Okaichi T, Yanagi T (eds) Sustainable development in the Seto Inland Sea Japan from the view point of fisheries. Terra Scientific Publishing Company, Tokyo, pp 251–304

Okaichi T (2003) Red-tide phenomena. In: Okaichi T (eds) Red tides. Terra Scientific Publishing Company, Kluwer Academic, pp 7–60

Okaichi T, Yanagi T (1997) Seto Inland Sea-historical background. In: Okaichi T, Yanagi T (eds) Sustainable development in the Seto Inland Sea Japan from the view point of fisheries. Terra Scientific Publishing Company, Tokyo, pp 9–14

The International EMECS Center (1997) Environmental conservation the Seto Inland Sea, pp 1–20

The International EMECS Center (2003) Seto Inland Sea. In: International EMECS Center (eds) Environmental guidebook on the enclosed coastal seas of the world, pp 65–72

3.2.2 Eutrophication and its Cause/Consequences: The Case of the Philippines

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In the Philippines, the inseparable relationship between land use and water quality has become a major issue in the coastal zone. One of the alarming concerns related to the country's coastal waters is increased nutrient loading associated with domestic, agriculture, and aquaculture activities. These have been linked to problems such as eutrophication, contaminants, and harmful algal blooms.

Eutrophication from sewage, agriculture, and aquaculture inputs can result in algal blooms, which at times lead to fish kills and paralytic shellfish poisoning. In the Philippines there have been reports on the outbreaks of toxic and harmful algal blooms associated with deteriorating water quality. From 1983 to 1994 there were 16 areas country-wide that were affected by red tide and shellfish poisoning (Deocadiz 1997). The major fish kill that occurred in Bolinao, Pangasinan in February 2002, was principally attributed to the increased mariculture activity in the area. It also coincided with a bloom of a dinoflagellate identified as *Prorocentrum minimum*, an organism associated with eutrophied waters (Azanza et al., 2005). The decomposition of the high organic load contributed by the die-off of the bloom, and a large amount of unconsumed fish feed material, were considered significant factors as these used up oxygen in the water column and subsequently led to the fish kill.

Water Quality

San Diego-McGlone et al. (2004) made an initial assessment of the water-quality status of 12 bays in the Philippines. The assessment included 11 priority fishing areas identified by the Fisheries Sector Programme (FSP) of the Bureau of Fisheries and Aquatic Resources (BFAR) namely: Manila Bay, Calauag Bay, San Miguel Bay, Ragay Gulf, Lagonoy Gulf, Sorsogon Bay, Carigara Bay, San Pedro Bay, Ormoc Bay, Sogod Bay, and Panguil Bay. Data on Lingayen Gulf, the Pacific seaboard of the Philippines and the South China Sea (SCS) were also included in the assessment (Fig. 3.2.11). The status of each of the bays was evaluated with respect to water quality parameters such as nutrients (NO3, NO2, NH3 and PO4), dissolved oxygen (DO), chlorophyll-a (Chl-a), pH, total suspended solids (TSS), fecal coliform, heavy metals and pesticides. Criteria values used included those set by the Department of Environment and Natural Resources (DENR) [Department Administrative Order (DAO) No. 34 (Series of 1990)], the proposed marine environmental quality criteria of the Association of Southeast Asian Nations (ASEAN) (McPherson et al., 1999), and the Malaysian water quality standard (PEMSEA and MBEMP TWG-RRA 2004).

In most of the bays coastal pollution due to increased nutrient and pesticide concentrations is usually brought about by intensification of agri-aquaculture activities. The obvious increase in human population in the coastal areas also causes a consequent increase in domestic sewage. Other issues identified were siltation and contamination brought about by heavy metals from industries and mining related activities.

The mean and range of nutrient levels were determined for the 12 bays, the Pacific seaboard, and the SCS. These were plotted relative to the criteria value or allowable limit set for each nutrient. Some interesting observations emerged (Fig. 3.2.12a). For NO_2 the range of mean values (0.06–0.68 μM) for all of the bays did not exceed the criteria (3.95 μM) except for some high values in Lingayen Gulf and in Manila Bay. Data used for Lingayen Gulf include

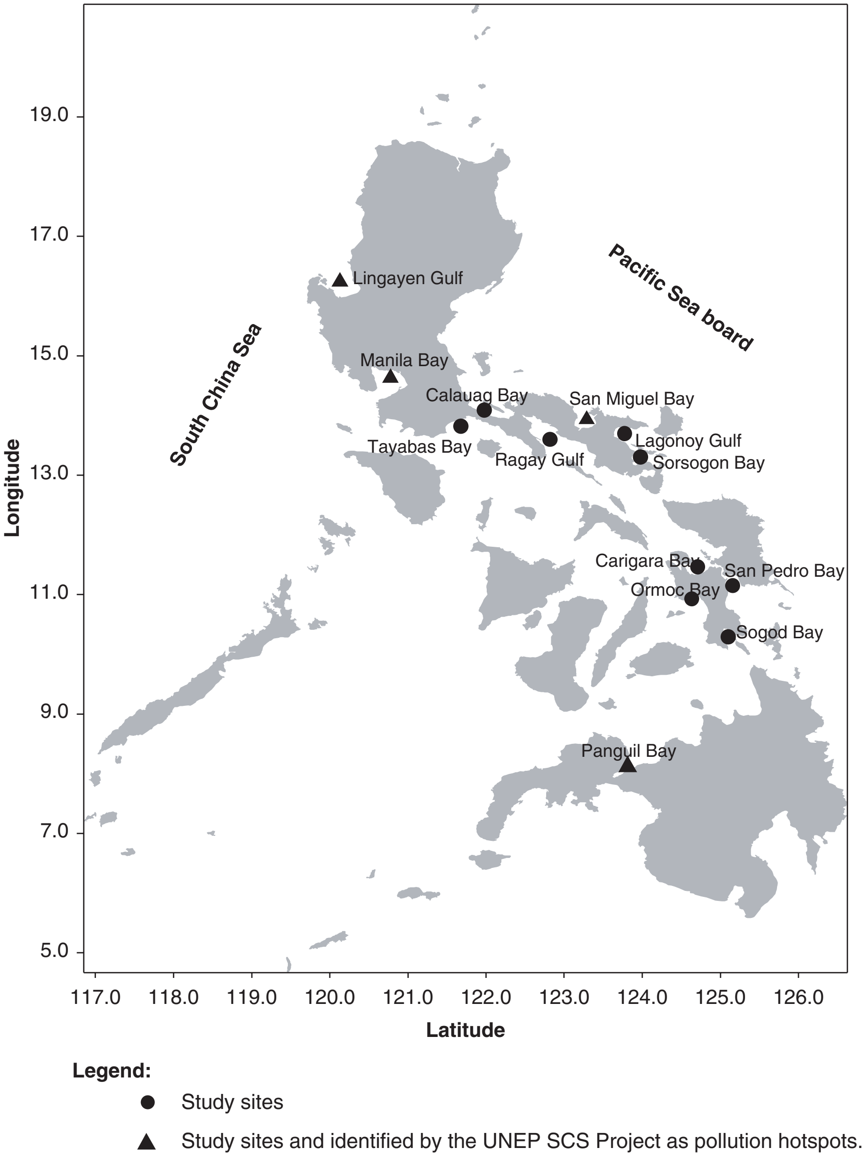

FIG. 3.2.11. UNEP SCS Project in the Philippines. Solid circles and triangles indicate study sites and study sites identified by the UNEP SCS Project as pollution hotspots.

those of the Bolinao and Dagupan areas. These are affected by mariculture (Bolinao), aquaculture activities and the contribution of several river systems (Dagupan). The mean value computed for Ragay Gulf (5.9 µM) exceeded the allowable limit set for NO_3 (4.29 µM). The average NO_3 concentrations in Lingayen Gulf, Manila Bay, Lagonoy Gulf, Sorsogon Bay, Carigara Bay,

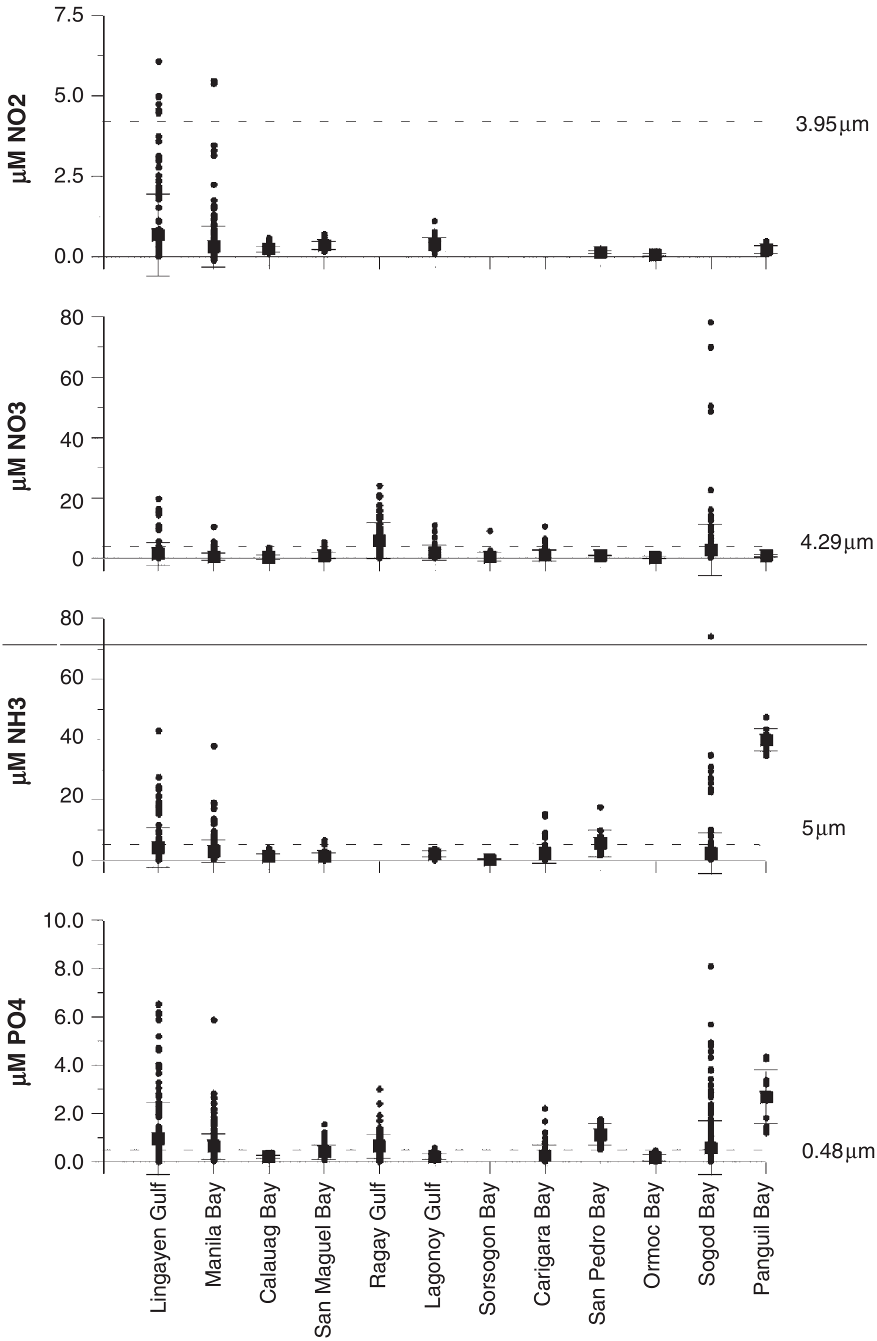

FIG. 3.2.12. (Continued)

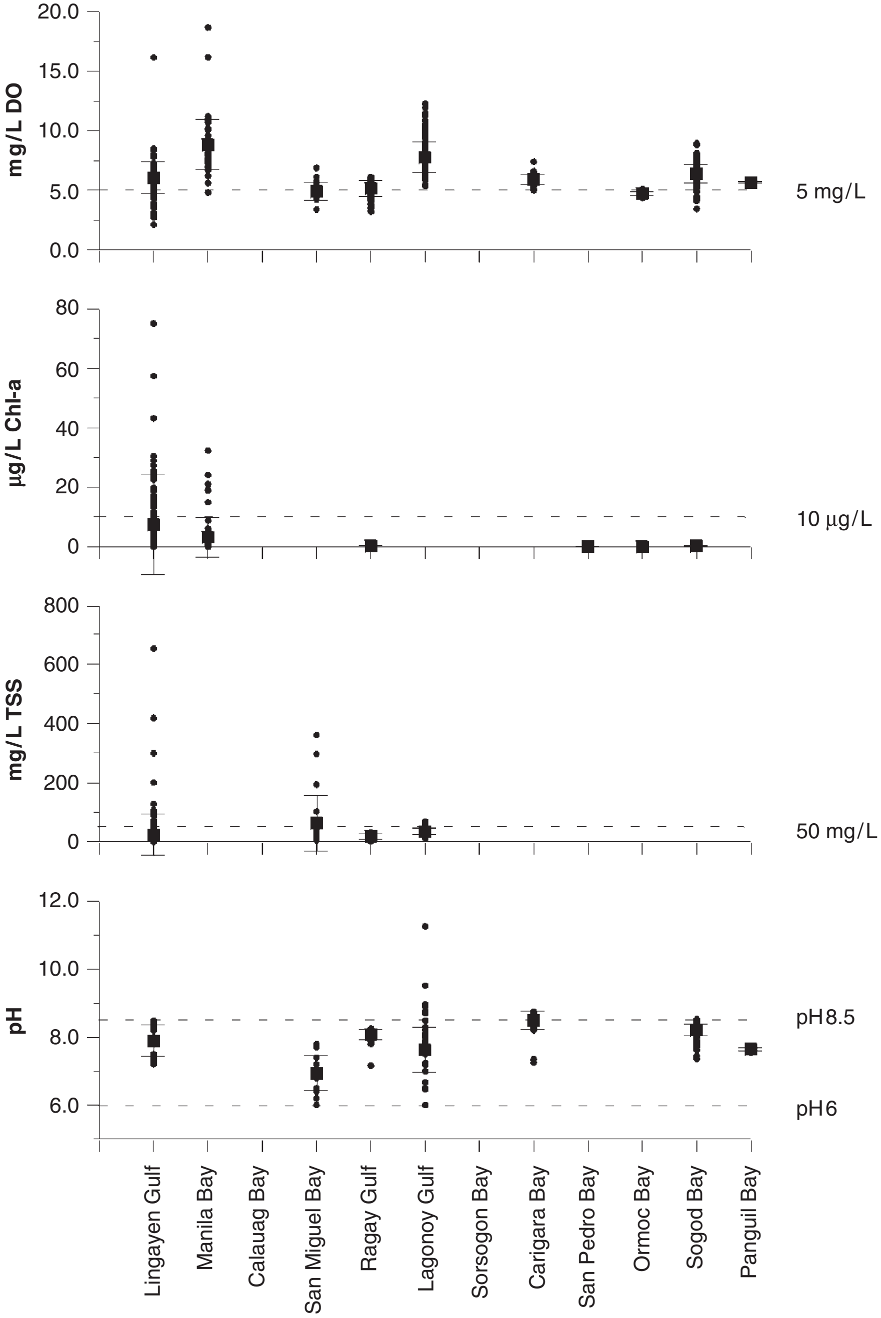

FIG. 3.2.12. The mean and range of nutrient levels at study sites identified by the UNEP SCS Project as pollution hotspots in the Philippines.

and Sogod Bay were below the criteria. However, some measured NO_3 values exceeded the criteria. For NH_3 the mean value of Panguil Bay (39.81 μM) was very high compared to the other bays, and seven times higher than the criteria value of 5 μM. San Pedro Bay (5.56 μM) also exceeded the criteria for NH_3 as did some values in Lingayen Gulf, Manila Bay, Carigara Bay, and Sogod Bay. Phosphate values were found to be high in six bays, namely Lingayen Gulf, Manila Bay, Ragay Gulf, San Pedro Bay, Sogod Bay, and Panguil Bay.

Fig. 3.2.12b shows the mean and range of values of the other water-quality parameters DO, Chl-a, TSS, and pH. These are plotted relative to the criteria value for each of these parameters. Based on the criteria, DO values should not be below 5mg/L. Mean DO concentrations in San Miguel Bay (4.9 mg/L) and Ormoc Bay (4.72 mg/L) were below the criteria. The mean values of Chl-a and pH for all the sites were within the allowable limit. The mean value for TSS in San Miguel Bay exceeded the criteria (50 mg/L). This may be attributed to river discharges in the bay.

Based on the initial assessment undertaken by San Diego-McGlone et al. (2004), the mean concentration of the different water quality parameters were, in general, still within the allowable limit (criteria value) set for each parameter (Fig. 3.2.12). However the data used in the assessment have wide concentration ranges; thus standard deviations from the mean were large. Hence, a simulation tool (Monte Carlo, Crystal Ball, Descioneering, Inc.) was used to assess and predict the probable status of a bay using the data obtained from the different sources. The purpose of the analysis was to forecast the likelihood that the ambient concentration will exceed the criteria value. The annual mean concentrations that passed the criteria, and their standard deviations, and the risk quotient (RQ = ambient concentration divided by the environmental criteria) were used in the simulation. Monte Carlo simulation determines the probability (with >10% certainty) of exceeding an RQ of 1 or the mean concentration exceeding the criteria value.

Given the current water-quality status, and assuming continuous increase in population and anthropogenic activities, the simulation results suggest that there is high probability that the criteria will be exceeded. In the case of NO_3, there is 24% certainty for Lingayen Gulf, 15% for Lagonoy Gulf, 42% for San Pedro Bay, and 20% for Sogod Bay. For NH_3, the certainty of exceeding the criteria is 42% and 12% for Ragay Gulf and Sogod Bay, respectively. According to the assessment undertaken by San Diego-McGlone et al. (2004), PO_4 is the parameter of concern. Based on the Monte Carlo simulation, two out of the seven bays with low PO_4 showed a probability of surpassing the PO_4 criteria, namely Carigara Bay (17%) and San Miguel Bay (26%). In the case of DO, Lingayen Gulf (25%), Ragay Gulf (46%), and Sogod Bay (22%) showed certainty of reaching values below 5 mg/L.

DO values in Manila Bay were acceptable relative to the criteria value. DO distribution in this bay is affected by seasonal variations, with vertical stratification of the water column observed during the rainy season. From 1985 to the present, the bottom waters of the bay show continued deterioration in water quality, especially within thevicinity of Pasig River and Port Area, Manila (Acorda 1985; PRRP 1998; Jacinto 2000). The combined data of the Marine Science Institute-University of the Philippines (Jacinto 2000) and the Pasig River Rehabilitation Project (PRRP 1998) from different stations and several sampling periods showed a decreasing trend in the DO profiles (Fig. 3.2.13). The lowest values (<5.0 mg/L), from the surface to the bottom were recorded in 2000. The decrease in DO concentrations was consistently observed near the bottom of the water column.

Sediment Quality

Excess sediment damages the aquatic environments by smothering the organisms that live on the bottom. In the water column, high-sediment content decreases water transparency, resulting in decreased phytoplankton productivity due to attenuation of the incoming light. Also, sediments are capable of transporting adsorbed nutrients, pesticides, heavy metals, and other toxins. The potential sources of excess sediments include siltation due to intensified agriculture activities and development, erosion due to the conversion of coastal areas into industrial or residential areas, and dredging. Although siltation and its associated problems are emerging concerns in various coastal areas in the Philippines, very few studies and monitoring efforts have included sediments because of costs and logistical difficulties. Among the 12 bays, sediment quality monitoring was undertaken in Manila Bay, Lingayen Gulf, Lagonoy Gulf, San Miguel Bay, and Ragay Gulf.

In Manila Bay, estimates of sedimentation rates provided by different groups have consistently identified areas were rates are high. These areas are likely sinks of sediments and possibly of pollutants in the bay. The sediment in Manila Bay is predominantly grayish clayey-muddy substrate, which is soft, fine in texture, and with 5–19% organic matter content (PRRP 1998). Based on trace metal values, there is localized metal enrichment in the bay. Elevated levels of Pb and Zn in the sediments were consistently observed within the vicinity of Metro Manila. Based on the concentration of Cd, Hg, Zn, Pb, and Cr in the sediments from the mouths of major river systems in the bay (e.g., Malabon-Navotas, Paranaque, Pasig and Bulacan), the rivers are point sources of these metals (PEMSEA and MBEMP TWG-RRA 2004). Benthic fluxes of the nutrients NH_3 and PO_4 vary with the season and are higher near the rivers of Pasig, Bulacan, and Pampanga (San Diego-McGlone et al., 2004). Based on the Refined Risk Assessment (RRA) undertaken in 2004, there is intermediate risk for total polyaromatic hydrocarbon (TPAH) in Manila Bay (PEMSEA and MBEMP TWG-RRA 2004). Moreover, the RRA showed localized contamination in the eastern part of the bay, which is more commercialized and urbanized (PEMSEA and MBEMP TWGRRA 2004).

Since 1993, when Lingayen Gulf was officially declared as an "Environmentally Critical Area" under Presidential Proclamation No. 156, efforts were undertaken to look into the economic viability and the environmental

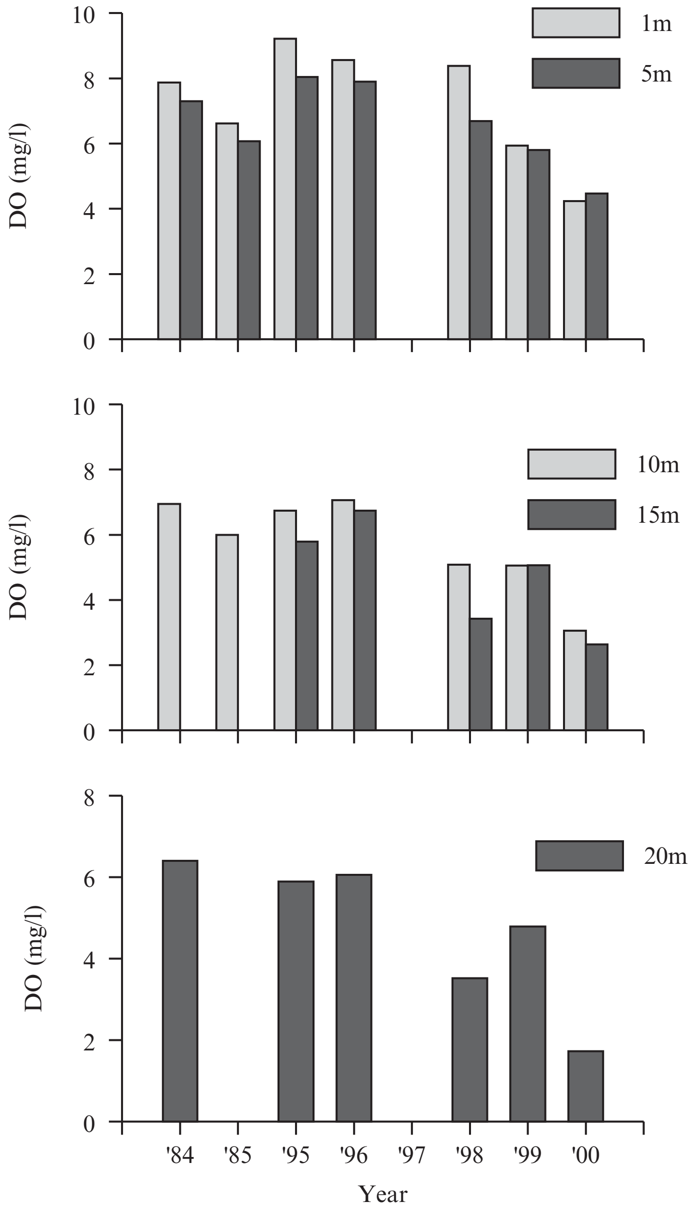

FIG. 3.2.13. Trends in the DO profiles of combined data at different stations in the Philippines. (After PRRP 1998; Jacinto 2000.)

sustainability of this coastal area (CZERM 2002). The identified issues and problems that may cause sediment pollution in the Gulf include siltation due to intensive agricultural activities and deposits from denuded watersheds; erosion of the eastern coast of the Gulf due to strong current and intensive seashore mining. Mine tailings from upland mining have also affected the sediment quality, although there has been limited focus on studying this factor due to the more critical problems of fish kill and phytoplankton blooms.

In the absence of an allowable limit or criteria for sediments in the Philippines, sediment contamination in the bays were assessed by comparing the metal concentration with the low limit of Hong Kong – ISQV Contamination Classification (HK-ISQV) (EVS 1996). Relative to the criteria, Cd concentration in the sediments of Lagonoy and Ragay Gulf were higher than the allowable limit of 1.5 mg/kg. Mercury (Hg) in the sediments of Lagonoy Gulf was significantly higher than the limit of 0.28 mg/kg. The presence of elevated levels of Cd and Hg in these bodies of water may be due to effluent from industries draining into the rivers surrounding the bay.

Summary

Sediment quality in the Philippines has not been extensively examined. However, the available information in selected bays in the country consistently show localized contamination of sediments and continued deterioration in sediment quality.

The UNEP SCS project identified pollution hotspots in the Philippines. They include Lingayen Gulf, Manila Bay, San Miguel Bay, and Panguil Bay (UNEP 2000). This was based on an assessment of areas considered to be regional growth centers and where there have been incidences of red tide (e.g., in Manila Bay). Moreover, these bays are of primary importance to the South China Sea. Based on results of the assessment undertaken by San Diego-McGlone et al. (2004), this study and of the Monte Carlo simulation, these bays have exceeded the criteria for nutrients (NO_3, NH_3, PO_4) and DO. In Lagonoy Gulf, San Pedro Bay, Sogod Bay, Ragay Gulf, and Carigara Bay, simulation analyses indicate that there is more than a 10% probability that the ambient concentrations of NO_3, NH_3, and PO_4 will be exceeded.

References

Acorda L (1985) Manila Bay study. Quezon City, Philippines

Azanza RV, Fukuyo Y, Yap LG, Takayama H (2005) *Prorocentrum minimum* bloom and its possible link to a massive fish kill in Bolinao, Pangasinan, Northern Philippines. Harmful Algae 4:519–524

Coastal Zone Environment and Resource Management Project (CZERM) (2002) http://www.amsat.com.au/czermp/level_1/countries/czphdfww.html (Date accessed: 24 Feb 2005)

Deocadiz ES (1997) Land-based sources of pollution in the Philippines. Environmental Management Bureau, Department of Environment and Natural Resources

DAO 34 Department of Environment and Natural Resources Administrative Order No. 34 Series of (1990) Philippine EISPC Guidebook DENR, December 1995

Department of Environment of Malaysia as cited in Manila Bay Initial Risk Assessment (2001) GEF/UNDP/IMO regional programme on partnerships in environmental management for the seas of the East Asia

EVS Environment Consultants (1996) Classification of dredged material for marine disposal. Report to Civil Engineering Department, Government of Hong Kong, prepared by EVS Environment Consultants, North Vancouver, BC
Jacinto GS (2000) Hypoxia and dissolved inorganic nutrients in Manila Bay (unpublished).
McPherson CA, Chapman PM, Vigers GA, Ong KS (1999) ASEAN marine water quality criteria: contextual framework, principles, methodology and criteria for 18 parameters. ASEAN Marine Environmental Quality Criteria–Working Group (AMEQC-WG), ASEAN-Canada Cooperative Programme on Marine Science – Phase II (CPMS-II). EVS Environment Consultants, North Vancouver and Department of Fisheries, Malaysia, 568pp
Pasig River Rehabilitation Program (PRRP) (1998) Annual report 1998. Pasig River rehabilitation program, Department of Environment and Natural Resources, Quezon City, Philippines and Danish International Development Assistance (Danida), Denmark
PEMSEA and MBEMP TWG-RRA (2004). Manila Bay: refined risk assessment. PEMSEA technical report no.9. Global Environment Facility/United Nation Development Programme/International Maritime Organization Regional Programme on Building Partnerships in Environmental Management for the Seas of East Asia (PEMSEA), and Manila Bay Environmental Project (MBEMP), Technical Working Group for Refined Risk Assessment (TWG-RRA) Quezon City, Philippines, 169p
San Diego-McGlone ML, Jacinto G, Velasquez I, Padayao D (2004) Status of water quality in Philippine coastal and marine waters, pp 96–108. In DA-BFAR (Department of Agriculture-Bureau of Fisheries and Aquatic Resources). In turbulent seas: the status of Philippine marine fisheries. Coastal Resource Management Project, Cebu City, Philippines, 378p
UNEP (2000) United Nations Environment Programme East Asian Seas Regional Coordinating Unit. National report of the Philippines on the formulation of a transboundary diagnostic analysis and preliminary framework of a strategic action programme for the South China Sea

3.2.3 Marine Pollution of Hazardous Chemicals in Asian Waters

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Introduction

The earth's environment has worsened as the human population has increased and industrial activity develops without significant consideration of environmental conservation. Economical and technological development has enhanced the production of chemicals since the Indu strial Revolution in the mid-18th century. Thoughtless use of chemicals and incompetent management have led to local and/or global contamination by toxic chemicals, and imposed a serious threat to a wide range of ecosystems. In Asian waters, the people have for several decades faced severe marine pollution from such sources and activities as hazardous chemicals, oil spills, garbage incineration, and sewage treatment. This section focuses on marine pollution from hazardous chemicals such as organochlorine compounds, organotin compounds and heavy metals.

Hazardous Chemicals

1. Organochlorine compounds
In 2001 agreement was reached on the Stockholm Convention on persistent organic pollutants (POPs). It is a global treaty designed to protect human health and the environment from persistent organic pollutants. POPs remain in the environment for long periods of time, become widely distributed globally, accumulate in the fatty tissue of living organisms, and are toxic to humans and wildlife. In implementing the Convention, governments will take measures to eliminate or reduce the release of POPs into the environment.

Organochlorine compounds (OCs) have been recognized as endocrine disrupting chemicals. Bioaccumulation, metabolization and transfer of these chemicals has given rise to concern about long-term and global environmental contamination, and serious biological impacts on marine animals (Holden 1978; O'Shea et al., 1980; Tanabe et al., 1983; Reijnders 1988; Tanabe and Tatsukawa 1991). For monitoring marine environmental conditions, marine mammals are considered to be one of the most important biological indicators because they have a long life and occupy the highest ecological niche. Since the latter half of 1960s a mass die-off of marine mammals has often occurred in the closed areas of the northern hemisphere. In particular, mass die-offs of grey and ringed seals in the Baltic Sea, California sealions, belugas in the St. Lawrence River, Baikal seals, and Caspian seals are known to be linked to biological impacts of organochlorine compounds (Helle et al., 1976; Helle 1980; Bergman and Olsson 1986; DeLong et al., 1973; Reijnders 1980, 1986; Béland et al., 1987; Martineau et al., 1987; Grachev et al., 1989; Osterhaus et al., 1989; Forsyth et al., 1998; Kennedy et al., 2000; Miyazaki 2001). Biological impacts such as uterine occlusion, skull-bone lesions, and pathological and immunological disorders have been observed in grey and ringed seals in the Baltic Sea. Distemper was considered to be the primary cause of a mass die-off of Baikal seals in 1987–1988 and 1998, and Caspian seals in 1997 and 2000. Influenza A virus was also detected in Baikal seals, Caspian seals, and ringed seals in the Arctic Ocean. (Ohishi et al., 2002–2004).

The levels of DDTs and PCBs in dolphin blubber were considerably higher than those of other OCs (e.g., CHLs, HCHs, HCB) since these compounds are highly persistent, relative lipophilic and less biodegradable. They are therefore retained in an animal's body for a long time (Tanabe and Tatsukawa 1991). The maximum level of DDTs, ranging from 80–96 μg/g wet weight, was found in northern right whale dolphins from temperate waters. However, a similar concentration of DDTs has also been observed in animals from tropical waters. Higher concentration of DDTs has also been reported in surface seawater samples from open oceans (Iwata et al., 1993). Probably the relatively higher levels of DDT found in tropical odontoceti species appear to reflect DDTs originating in tropical countries where they are still used for protection against malaria. The highest level of PCBs (76–130 μg/g wet wt) was recorded in Risso's dolphins from the Pacific coast of Japan, followed by melon-headed whales (51–55 μg/ wet wt) and Fraser's dolphin (38–76 μg/g). Odontoceti species from temperate and cold waters showed higher PCBs concentration than those from tropical waters. These elevated levels of PCB seemingly imply the ongoing use by and dispersion from mid-latitude countries in the northern hemisphere.

A comparison of concentration of DDTs, PCBs, and HCHs in marine mammals and surface seawater was made in the Bering Sea, the western Pacific Ocean, and the Southern Ocean (Fig. 3.2.14). All odontoceti species taken from the northern hemisphere showed much higher values of DDT, PCB, and HCH than did those from the southern hemisphere (Tanabe et al., 1983). In particular, the concentrations found in odontoceti species were much higher in the mid-latitude waters of the Northern Hemisphere. In surface seawater, a higher concentration of DDTs, PCBs, and HCHs was also found in the northern hemisphere than the southern hemisphere. In the northern hemisphere the mid-latitude areas were much more polluted by OCs than other areas, reflecting the extensive use of OCs in countries of the mid-latitude areas of the northern hemisphere. Thus, in Asian waters, it is very important to monitor pollution by organochlorine compounds, based on a well-organized, international research system.

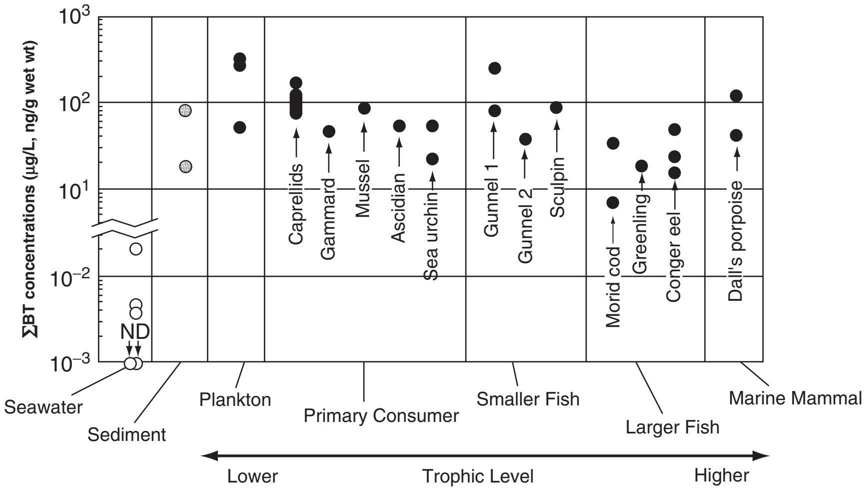

FIG. 3.2.14. Concentration of DDTs, PCBs, and HCHs in marine organisms (including marine mammals) and sea surface in the Bering Sea, the western Pacific Ocean, and the Southern Ocean. (After Tanabe et al., 1983.)

2. Organotin compounds

Since the 1960s, butyltin compounds (BTs) have been used worldwide for various purposes. These include tributyltin (TBT) as an antiflouling agent in paints used by boats and aquaculture nets, and monobutyltin (MBT), and dibutyltin (DBT) as stabilizers for chlorinated polymers or as catalysts for silicones and polyurethane foams (Evans and Karpel 1985). Widespread use of these compounds has caused severe environmental contamination and severe biological impacts. On 5 October 2001 the International Marinetime Organization (IMO) adopted the "International Convention on the Control of Harmful Anti-fouling Systems on Ships." This agreement prohibited the use of harmful organotins in anti-ouling paints used on ships by 1 January 2008. It also established a mechanism to prevent the potential future use of other harmful substances in antifouling systems.

The effect of BTs on animals in the lower tropical levels in the marine ecosystem has been studied in terms of physiological abnormalities such as growth reduction in marine microalgae (Maguire et al., 1984), shell thickening and spat failure in oysters (Alzieu et al., 1986; Alzieu 1991), imposex in gastropods (Gibbs and Bryan 1996), and whelks (Gibbs and Bryan 1986; Gibbs et al., 1987), decreases in survival rate and growth rate, prolongation of maturation, abnormality of external formation, failure of reproduction by TBT exposure in the post-hatching stage of *Caprella danileviskii*, and a decrease in the ratio of males by exposure to TBT in the embryonic stage of *C. danileviskii* (Ohji et al., 2002–2004). In view of these investigations, control measures on the use of BTs have been adopted in several countries. However, such action has not appreciably reduced the consumption of organotins on a global scale (Kannan et al., 1995). Environmental monitoring and toxicological studies dealing with water (Fent et al., 1991; Maguire and Tkacz 1985), sediment (Quevauviller et al., 1994; Kan-atireklap et al., 1997; Maguire and Tkacz 1985), mussels (Kan-atireklap et al., 1997), and fish (Kannan et al., 1995; Fent 1992) imply that these compounds continue to pose a major ecotoxicological threat in the aquatic environment.

Tanabe et al. (1998) determined the levels of butyltin concentrations in the livers of marine mammals. They showed higher levels in animals inhabiting coastal waters than those inhabiting pelagic waters. A higher concentration of BTs was found in animals from the waters of developed countries compared with those from developing ones, suggesting that waters in the developed countries have more serious BT contamination than those in developing ones (Fig. 3.2.15). Kannan et al. (1995) analyzed concentrations of butyltin residues in the muscle tissue of fish collected from local markets and sea food shops in India, Bangladesh, Thailand, Indonesia, Vietnam, Taiwan, Australia, Papua New Guinea, and the Solomon Islands. They reported that intensive ship scrapping activities, sewage disposal and antifouling paints are considered the major sources of butyltins in these countries. The intake of butyltins by humans via consumption of fish in these countries was estimated at less than 25% of the tolerable daily intake of 250 ng/kg body weight/day.

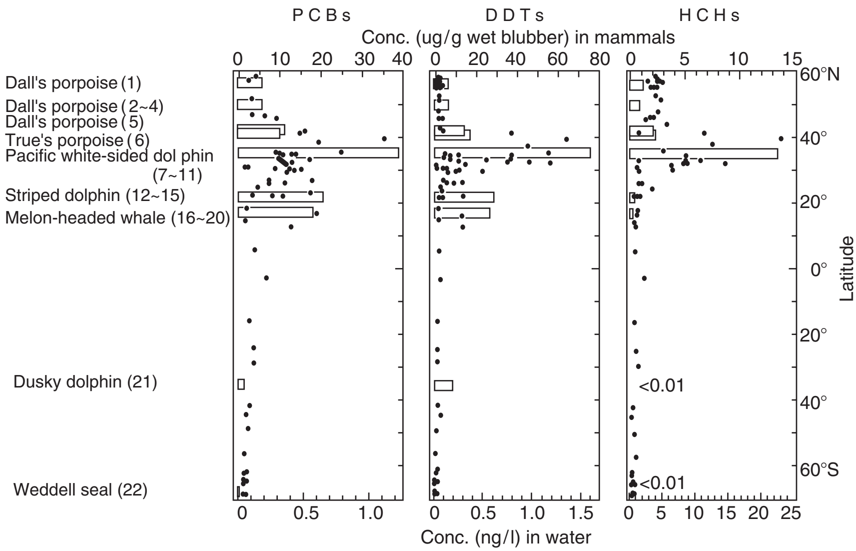

FIG. 3.2.15. Global comparison of the concentration of PCBs, DDTs, and HCHs in marine mammals (bar) and in surface waters (solid circles). (After Tanabe et al., 1998.)

Butyltin concentrations in fish from Asia and Oceania were lower than those reported for Japan, Canada, and the USA.

Nakata et al. (2002) studied biological effects using mitogen-induced responses in marine mammal and human lymphocytes by *in vitro* exposure to butyltins. Peripheral blood mono-nuclear cells isolated from Dall's porpoises (*Phocoenoides dalli*), bottlenose dolphins (*Tursiops truncatus*), a California sealion (*Zalophus californianus*), a larga seal (*Phoca largha*), and humans (*Homo sapiens*) were exposed to varying concentrations of BTs. Concanavalin A-stimulated mitogenesis was found to be significantly suppressed ($P < 0.01$) when the cells were exposed to 300 nM (89 ng/ml) of TBT and 330 nM of DBT (77 ng/ml), while MBT showed little cytotoxicity at treatment levels of up to 3,600 nM (620 ng/ml) in the above marine mammals as well as in humans. This suggests that BTs could pose a serious threat to immune functions, and both TBT and DBT are much more toxic than MBT.

To monitor organotin compounds in the ecosystem of Otsuchi Bay, Japan, Takahashi et al. (1999) reported clear evidence that BTs were accumulated in most of the organisms, in concentrations up to 50,000 times greater than in seawater (Fig. 3.2.16). However, there were no significant differences in the BT residue levels between the trophic levels. This means that there is no substantial biomagnification of these compounds through the food chain. This indicates that there is a big difference in the movement of organotin compounds in the ecosystem compared with organochlorine compounds. In particular, *C. danilevskii* is a highly sensitive animal to organotin compounds and is thus a most useful bio-indicator for ecotoxicological studies. A a three-generation

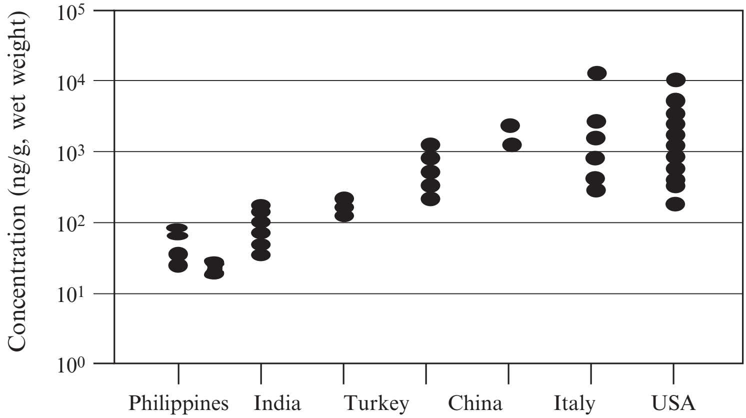

Fig. 3.2.16. Concentration of BTs of marine organisms of Otsuchi Bay along the Pacific coast of northern Japan. (After Takahashi et al., 1999.)

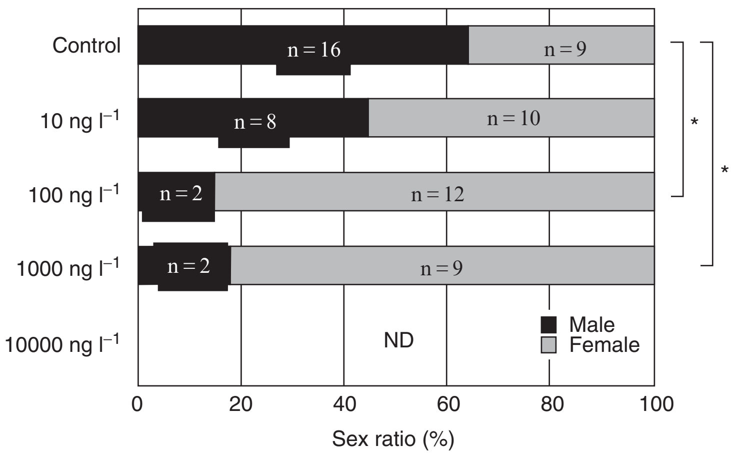

Fig. 3.2.17. Embryonic exposure to TBT for *Caprella* amphipods. (After Ohji et al., 2002–2004.)

experimental study can be done in a small glass beaker over a short period of time from June to September. Ohji et al. (2002–2004) implemented an experimental study of the biological effects at five levels of TBT (0, 10, 100, 1,000, and 10,000 ng/l) in the Caprelid amphipod *C. danilevskii*. They obtained the following interesting scientific evidence.(a) Embryonic exposure to TBT indicated that the female ratio of 36% in the control group dramatically changed to 55.6% at 10 ng/l to more than 80% at 100 ng/l and 1,000 ng/l. All specimens died at 10,000 ng/l (Fig. 3.2.17). However, in contrast, no significant difference was observed in the sex ratio in response to TBT exposure after hatching.

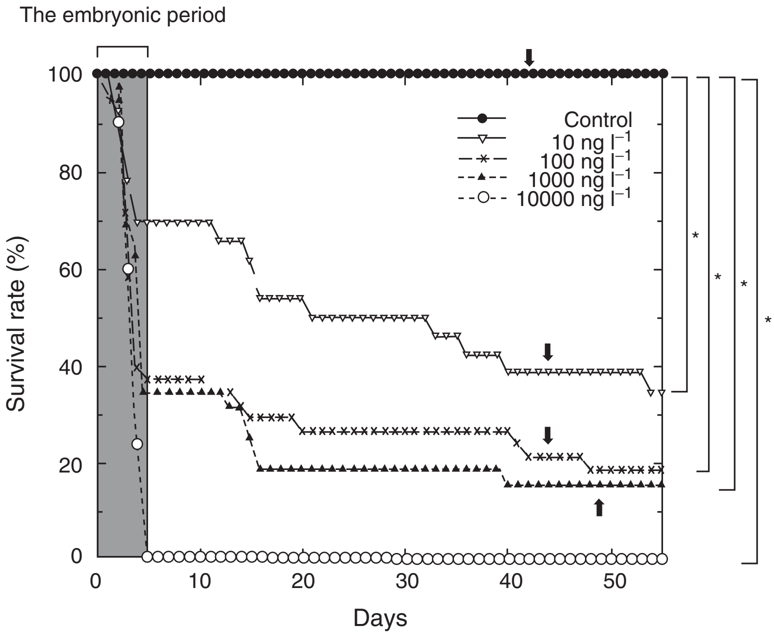

FIG. 3.2.18. Changes of survival rates of *Caprella* amphipods exposured to different concentration of TBT. (After Ohji et al., 2002–2004.)

(b) Survival rate decreased drastically as the TBT concentration of exposure increased from 10 ng/l to 1,000 ng/l in both the embryonic and the post-hatching stages (Fig. 3.2.18).

(c) In both embryonic and post-hatching stages reproductive inhibitions such as brood loss and oogenensis inhibition occurred at even 10–100 ng/l exposure, a concentration which is often observed in more polluted coastal waters.

This evidence suggests nanogram concentrations of TBT similar to those encountered in coastal waters can directly affect the sex ratio, and reproductive and survival rates in caprellid animals, and that this phenomenon occurs at environmentally realistic concentrations in the coastal ecosystem. In particular, as *C. danilevskii* is the main food species of small fish, the above evidence confirms that use of organotin compounds might cause an extraordinary disturbance in the coastal marine ecosystem.

3. Heavy metals

With regard to marine pollution from heavy metals, it is well known that Japanese people faced two severe environmental problems. These are known as "Minamata disease," caused by mercury pollution, and "Itai-itai disease," caused by cadmium pollution. The problems occurred in the highly industrially active period of the 1950s to 1970s. In the case of the "Minamata disease" there was a 22-year-controversy in Japan, culminating in a judicial decision in 2004. However, even after the decision human health problems still remain among the local people. Recently the problem of mercury pollution from gold mining was also raised in the city of Manado, Indonesia and along the Amazon River, Brazil. Local people consuming fish and marine organisms as food are expected to face severe health problems (Kehring et al., 1997; Harada et al., 2001; Limbong et al., 2003 and 2004).

According to Limbong et al. (2004), the Ratatok area of North Sulawesi, Indonesia, has had a long history of gold mining following the activity of a Dutch company, Nederland Mybouw Maschapai during the period from 1887 to 1922. Artisanal or small groups of local people started to seek their fortune in gold mining, using techniques learned from the Dutch company. These consisted of excavating gold vein tunnels and using mercury amalgamation. In the Ratatotok artisanal gold mining area the concentration of mercury in the surface soil decreases from 5 mg/kg in dry weight at a distance of 5 m from the gold mining unit to 2 mg/kg at 30 m. This suggests the concentration gradually decreases with increasing distance of the sampling location from the gold mining unit. About 40 artisanal gold mining units are worked, mainly by informal, illegal and small, less-organized groups. The total number of local people living in coastal villages in this area is about 5,678, of whom about 8% are fishermen. Total fish production in the area is about 150,000 kg/year. Thus, mercury pollution by gold mining has become a severe environmental issue. Corresponding to gold bullion production of about 235 kg/year, total mercury emissions of 1,000 kg/year are spread through the amalgam-burning process. In the ecosystem, methylmercury is accumulated by biota and magnified through the food chain. Most of the mercury in fish tissue is methylmercury. Fish are probably the most common indirect route of exposure to humans. In humans, methylmercury can cause damage to the neurological, excretory and reproductive systems. Methylmercury is the form of mercury of greatest toxicological concern. Limbong et al. (2004) recommended that the gold-processing practices themselves should be improved, or changed to clean technologies, in order to guarantee minimal risk of poisoning the miners as well as the community, and that the Provincial Government of North Sulawesi should play a strong leadership role against the problem of mercury pollution.

Future Directions

The present study has described the current environmental issues related to hazardous chemicals in Asian waters. People should face up to severe environmental problems and put great effort into environmental conservation at both local and global scales, bringing together the best of human wisdom. As the most meaningful direction for the future, it is proposed that a more useful and constructive way of resolving pollution issues should be pursued, as follows:

1. Stop the actual sources of pollution on a local and/or global scale under the strong leadership of local government and national government, as well as international organizations such as UNEP, UNESCO, and UNU.
2. Establish a social watching system to stop pollution, with cooperation between the general public and NGOs; these will actively work towards solutions to environmental issues.
3. Establish a well-organized system of research on environmental issues, which involves a system for a network of leading scientists on the study of pollution, a database for effective information for pollution surveys, and a system for banking specimens of important species.
4. Establish an active education system for resolving current environmental issues and implementing an effective strategy for future environmental conservation.

References

Alzieu C (1991) Environmental problems caused by TBT in France: assessment, regulation, prospects. Mar Environ Res 32:7–18

Alzieu C, Saujuan J, Deltriel JP, Borel M (1986) Tin contamination in Arcachon Bay effects of oyster shell anomalies. Mar Pollut Bull 17:494–498

Béland P, Michaud R, Martineau D (1987). Recensements de la population de belugas du Saint-Laurent en 1985. par embarcations. Rapp Techn Can Sci Halieut Aquat No. 1545.

Bergman A, Olsson M (1986) Pathology of Baltic ringed seal and grey seal females with special reference to adrenocortical hyperplasia: is environmental pollution the cause of a widely distributed disease syndrome? Finn Game Res 44:47–62

DeLong RL, Gilmartin WG, Simpson JG (1973) Premature births in California sealion: association with high organochlorine pollutant residue levels. Science 181:1168–1170

Evans CJ, Karpel SJ (1985) Organotin compounds in modern technology. J Organomet Chem Libr 16:178–217

Fent K, Muller MD (1991)Occurrence of organotins in municipal waste water and sewage sludge and behavior in a treatment plant. Environ Sci Technol 25:489–493

Fent K, (1992) Embryotoxic effects of tributyltin on the Minnow *Phoxinus phoxinus*. Environ Pollut 76:187–194

Forsyth MA, Kennedy S, Wilson S, Eybatov T, Barrett T (1998) Canine distemper virus in a Caspian seal (*Phoca caspica*). Vet Rec 143:662–664

Gibbs PE, Bryan GW (1986) Reproductive failure in populations of the dog whelk *Nucella lapillus*, caused by imposex induced by tributyltin from antifouling paints. J Mar Biol Assoc UK 66:767–777

Gibbs PE, Bryan GW (1996) TBT-induced imposex in neogastropod snails: masculinization to mass extinction. In: de Mora SJ (ed) Tributyltin: case study of an environmental contamination. Cambridge University Press, Cambridge, pp 212–276

Gibbs PE, Bryan GW, Pascoe PL, Burt GW (1987) The use of the dog whelk, *Nucella lapillus*, as an indicator of tributyltin (TBT) contamination. J Mar Biol Assoc UK 67:507–523

Grachev MA, Kumarev VP, Mamaev V, Zorin L, Baranova V, Denikina NN, Belikov SI, Petrov VA, Kolesnik S, Kolesnik RS, Dorofeev M, Beim AM, Kudelin VN, Nagieva FG, Sidorov VN (1989) Distemper virus in Baikal seals. Nature 338:209

Harada M, Nakanishi J, Yasoda E, Pinheiro MDN, Oikawa T, Guimaraes GD, Cardoso BD, Kizaki T, Ohno H (2001) Mercury pollution in the Tapajos River basin, Amazon, Mercury level of head hair and health effects. Environ Intl 27(4):285–290

Helle E, Olsson M, Jensen S (1976) PCB levels correlated with pathological changes in seal uteri. Ambio 5:261–263

Helle E (1980) Lowered reproductive capacity in female ringed seals (*Phoca hispida*) in the Bothnian Bay, northern Baltic Sea, with special reference to uterine occlusions. Ann Zool Fenn 17:147–158

Holden AV (1978) Pollutants and seals – a review. Mamm Rev 8:53–66

Iwata H, Tanabe S, Tatsukawa R (1993) Distribution of persistent organochlorines in the oceanic air and surface seawater and the role of ocean on their global transport and fate. Environ Sci Technol 27:1080–1098

Kan-atireklap S, Tanabe S, Tabucanon S, Hungspreugs M (1997) Contamination by butyltin compounds and organochlorine residues in green mussel (Perna viridis, L.) from Thailand coastal waters. Environ Pollut 97:79–89

Kannan K, Tanabe S, Iwata H, Tatsukawa R (1995) Butyltin in muscle and liver of fish collected from certain Asian and Oceanian countries. Environ Pollut 90:279–290

Kennedy S, Kuiken T, Jepson PD, Deaville R, Forsyth M, Barrett TVD, Bildt MWG, Osterhaus ADME, Eybatov T, Duck C, Kydyrmanov A, Mitrofanov I, Wilson S (2000) Mass die-off of Caspian seals caused by canine distemper virus. Emerging Infect Dis 6:1–5

Kehring HA, Malm O, Akagi H (1997) Methylmercury in hair samples from different riverine groups, Amazon, Brazil. Water Air Soil Poll 97(1–2):17–29

Limbong D, Kumampung J, Rimper J, Arai T, Miyazaki N (2003) Emissions and environmental implications of mercury from artisanal gold mining in north Sulawesi, Indonesia. Sci Total Environ 302:227–236

Limbong D, Kumampung J, Ayhuan D, Arai T, Miyazaki N (2004) Coastal Mar Sci 29(1):69–74

Maguire RL, Wong PTS, Rhamey JS (1984) Accumulation and metabolism of tri-n-butyltin cation by a green alga, Ankistrodesmus falcatus. Can J Fish Aquat Sci 41:537–540

Maguire RL, Tkacz RJ (1985) Degradation of the tri-n-butyltin species in water and sediment from Toronto harbor. J Agric Food Chem 33:947–953

Martineau D, Béland P, Desjardins C, Lagacé, A (1987) Levels of organochlorine chemicals in tissues of beluga whale Delphinapterus leucas from the St. Lawrence estuary, Québec, Canada. Arch Environ Contam Toxicol 16:137–147

Miyazaki N (2001) A review of studies on the ringed, Caspian and Baikal seals (*Pusa hispida, P. caspica and P. sibirica*). Otuchi Mar Sci 26:1–6

Nakata H, Sakakibara A, Kanoh M, Kudo S,Watanabe H, Nagai N, Miyazaki N, Asano Y, Tanabe S (2002) Evaluation of mitogen-induced responses in marine mammal and human lymphocytes by in-vitro exposure of butyltins and non-ortho coplanar PCBs. Environ Pollut 120:245–253

Ohji M, Arai T, Miyazaki N (2002) Effects of tributyltin exposure in the embryonic stage on sex ratio and survival rate in the caprellid amphipod *Caprella danilevskii*. Mar Ecol Prog Ser 235:171–176

Ohji M, Arai T, Miyazaki N (2003) Chronic effects of tributyltin on the caprellid amphipod Caprella danilevskii. Mar Pollut Bull 46:1263–1272

Ohji M, Arai T, Miyazaki N (2004) Biological effects of low concentrations of tributyltin on the caprellid amphipod *Caprella danilevskii*. Coastal Mar Sci 29(1):13–27

Ohishi K, Ninomiya A, Kida H, Park C-H, Maruyama T, Arai T, Katsumata E, Tobayama T, Bolthnov AN, Khuraskin LS, Miyazaki N (2002) Serological evidence of transmission of human influenza A and B biruses to Caspian seals (*Phoca caspica*). Microbiol Immunol 46:639–644

Ohishi K, Ninomiya A, Kida H, Maruyama T, Arai T, Miyazaki N (2003) Influenza virus infection in seal (Phocidae): seroepidemiological survey of influenza virus in Caspian seals (*Phoca caspica*). Otsuchi Mar Sci 28:39–44

Ohishi K, Kishida N, Ninomiya A, Kida H, Takada Y, Miyazaki N, Boltuna AN, Maruyama T (2004) Antibodies to human-related H3 influenza A virus in Baikal seals (Phoca sibirica) and ringed seals (*Phoca hispida*) in Russia. Microbiol Immunol 48(11):905–909

O'Shea TJ, Brownell RL Jr, Clark DL, Walker WA, Gay ML, Lamont TG (1980) Organochlorine pollutants in small cetaceans from the Pacific and South Atlantic Oceans, November 1968–June 1976. Pestic Monit J 14:35–46

Osterhaus ADME, Groen J, Visser IKG, VD, Bildt MWG, Bergman A, Klingeborn B (1989) Distemper virus in Baikal seals. Nature 338:209–210

Quevauviller P, Donald OF, Etcheber H (1994) Butyltin distribution in a sediment core from Arcachon harbour (France). Environ Pollut 84:89–92

Reijnders PJH (1980) Organochlorine and heavy metal residues in harbour seals from the Wadden Sea and their possible effects on reproduction. Neth J Sea Res 14:30–65

Reijnders PJH (1986) Reproductive failure in common seals feeding on fish from polluted coastal waters. Nature 324:456–457

Reijnders PJH (1988) Ecotoxicological perspectives in marine mammalogy: research principles and goals for a conservation policy. Mar Mamm Sci 4:91–102

Takahashi S, Tanabe S, Takeuchi I, Miyazaki N (1999) Distribution ans specific bioaccumulation of butyltin compounds in a marine ecosystem. Arch Environ Contam Toxicol 37:50–61

Tanabe S, Mori T, Tatsukawa R, Miyazaki N (1983) Global pollution of marine mammals by PCBs, DDTs and HCHs (BHCs). Chemosphere 12(9/10):1269–1275

Tanabe S, Tatsukawa R (1991) Persistent organochlorines in marine mammals. In: Jones KC (ed) Organic contaminants in the environment: environmental pathways and effects. Elsevier, Amsterdam, pp 275–289

Tanabe S, Prudente M, Mizuno T, Hasegawa J, Iwata H, Miyazaki N (1998) Butyltin contamination in marine mammals from North Pacific and Asian coastal waters. Environ Sci Technol 32(2):193–198

3.3 Ecological Changes

The Asian and Pacific coasts are characterized by the variety and richness of ecosystems such as mangroves, coral reefs, and sea grasses. These ecosystems are precious assets of the region's coastal zones, which provide a variety of goods and services to the people and other natural organisms. They have been experiencing large changes in the face of huge pressures from human activities and global environmental changes. This trend has led to the complete loss and degradation of the ecosystem. In this section, we will review the past trends and present situation of these ecosystems in the region.

3.3.1 Mangroves

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Introduction

Mangrove forests of varying size are distributed in various countries in Asia, from the Arabian Peninsula in the west to Japan in the east. Large areas of mangrove forests can be found in India, Bangladesh, Myanmar, Thailand, Vietnam, Malaysia, the Philippines, and Indonesia. It has been suggested that Indonesia has the largest area of mangrove forest in the region. This is due to its long coastline and diverse coastal habitats. The Sundarbans, located in the Gangetic delta in India and Bangladesh, is the largest continuous area of mangrove forest in the world. Approximately 40% of all mangrove forests in the world are in Asia (Aksornkaoe 1993).

Mangroves are mainly found in tropical latitudes growing in intertidal zones along coasts and estuaries in areas sheltered from strong tidal action and wind/sea storms. The occurrence and distribution of mangrove species are governed by various parameters such as temperature, wind/tidal range and frequency, availability of freshwater, soil type, terrain and salinity. On a local scale, factors such as salinity, temperature, the frequency and duration of tides, topography, sedimentation, and freshwater influx and light regime interact to produce environmental settings for the growth, zonation, and sustainability of different mangrove species.

Mangroves play a very important role, particularly in the lives and economies of people living in the coastal regions of different countries in Asia. They provide timber, fuelwood, poles, thatching material, honey, wax and industrial raw materials for cellulose-based industries. Mangroves are major sources of employment and income generation. Many coastal communities are principally dependent on mangrove. Mangrove waters are also very rich in fishery resources and act as a nursery and spawning grounds for a large number of species of fish, crustaceans, molluscs, and reptiles. In addition, mangrove forests are also very rich in biodiversity in both flora and fauna.

Mangrove Biodiversity

Mangrove forests are very diverse at the ecosystem level. Mangroves can grow in a wide range of geographical, climatic, hydrological and edaphic (soil) conditions. They cover the intertidal area and thus interact with aquatic, inshore, upstream, and terrestrial ecosystems. Mangrove forests support a diverse flora and fauna of marine, freshwater, and also terrestrial species.

Flora

A list prepared by Santisuk (1983) shows 53 genera and 74 species belonging to 35 families of trees and shrubs in the mangrove forests. Tomlinson (1986) recorded 54 species of true mangroves (34 major and 20 minor) worldwide. Around 40 species belonging to 14 families were recorded in mangroves in the Philippines, with a high diversity of about 26 species found in the island province of Bohol (Mapalo 1992). In India, mangrove comprises 35 species, of which 33 (16 genera and 13 families) occur along the east coast (Kathiresan 1998). Hong (1991) recorded 74 mangrove species in Vietnam, including 32 species of true mangrove and 42 species of associated species.

Most of the dominant and important species are in the family Rhizophoraceae, genera *Rhizophora*, *Bruguiera*, and *Ceriops* and the family Avicenniaceae, with many species of *Avicennia*.

The species diversity and distribution of mangroves is variable on different spatial scales: global, regional, estuarine and intertidal (Duke et al., 1998). Duke (1993) divided the distribution of mangroves into two global hemispheres – the Atlantic East Pacific and the Indo-West Pacific. These areas have similar areal extents of mangrove forests, but the Indo-West Pacific region is about five times more diverse. The Indo-Malesia region has the most species (Duke et al., 1998). Ricklefs and Latham (1993) provided an explanation for the high diversity in this region. Southeast Asia was the centre of the origin of mangrove speciation; the presence of an adjacent diverse terrestrial flora, and a constant wet humid climate may also have been contributory factors. The continuous presence of these factors since the end of the Cretaceous may have enabled diversity to continue to increase when conditions were not ideal elsewhere, or prevented species extinctions. In the latter sense, the Southeast Asian mangroves today represent an important refugium of mangrove biodiversity.

Mangrove pneumatophores and aerial roots are colonized by a film of diatoms and unicellular algae, as well as a turf of small red algae. Most characteristic is a mixed community of *Bostrychia*, *Caloglossa*, *Murrayella*, and *Catanella*, which in various permutations of species, is found virtually throughout the tropics (Hogarth 1999). Photosynthetic algae also grow on the mud surface; most are unicellular diatoms, but blue-green cyanobacteria are also present. Unattached red algae (Rhodophyta) *Gracilaria* and *Hormosira* can also be found in permanent patches.

Fungi are another much-ignored group of organisms. These are probably fundamental to many aspects of decomposition and energy flow in mangrove forests. Fungi occur on the vegetation, in the soil and in the water of mangrove swamps. They are also strongly associated with the rhizosphere, or root-association of *Rhizophora* and other trees. The diversity of mangrove fungi is shown by a study in mangrove plantation and natural mangrove forest. It recorded 49 species of 19 genera, with common genera of fungi belonging to *Trichoderma*, *Aspergillus*, *Penicillium*, and *Fusaruim* (Kongamol 2001).

Fauna

Mangroves support a high diversity of wildlife - both micro-and macroscopic, terrestrial and aquatic (marine and freshwater), temporary and residential. Mangrove fauna have been poorly studied in comparison to mangrove flora, with the exception of the most prominent groups, namely the large intertidal crustaceans and molluscs (e.g., Berry 1975; Jones 1984; Macintosh 1988).

Examples of residential organisms include vertebrates: kingfishers, mudskippers, snakes and mangrove monitor lizard; terrestrial invertebrates: spiders, ants, termites, moths, and mosquitoes; aquatic invertebrates: molluscs, crustaceans and polychaetes, and bacteria and meiofauna (Aksornkoae 1993).

The richness of fish species is generally high in the creeks, pools, and inlets of mangrove forests. Estimates of diversity depend heavily on catching methods and intensity so the figures reported may not be directly comparable. However, the following data indicate the diversity of mangrove-associated fish species.

In Selangor, Malaysia, 119 species have been recorded. In Thai mangrove there are approximately 72 fish species (Monkolprasit et al., 1987), 30 species (Naiyanetr 1985), 26 species of mollusc (Isarankura 1976), and 15 species of shrimp (Chaitiamvong 1983). Anon (1987) reported that in the Pichavaram mangrove ecosystem in India there are 30 species of prawns, 30 species of crabs, 30 species of molluscs, and 200 species of fish.

A number of mangrove faunal species have been recognized as endangered, such as the milky stork (*Mycteria cinerea*), lesser adjuntant stork (*Leptoptilos javanicus*), sunderbans tiger, manatee, estuarine crocodile (*Crocodylus porosus*), and proboscis monkey (*Nasalis larvatus*).

Meiofauna

The meiofauna of mangrove soils (meiofauna are defined as organisms ranging from 63–1,000 μm in size) are an important component in the mangrove benthic communities. Foraminiferans, nematodes, and copepods are widely distributed and abundant in mangroves. Other minor groups of meiofauna are turbellarians, polychaetes, oligochates, nemerteans, tanaidaceans, acarids, ostracods, kinorhynchs, bivalves, and sipunculids.

The major roles of these meiofaunal organisms in the mangrove forests are in decomposing organic matter and in regenerating nutrients. Most meiofauna are detritivores, such as copepods, tanaidaceans and sipunculids. Nematodes are widely distributed in the mangrove forests. They feed on detritus, microalgae and other meifauna. The meiofauna are also a potential source of food for other animals, such as some polychaetes, holothurians, sipunculids, crabs, other small crustaceans and fishes. Diversity and abundance of mangrove meiofauna varies with the type of forest and soil depth. The soil meiofauna also build up in density as the mangrove becomes more established (Sasekumar, 1984). Mangrove vegetation helps to consolidate the sediment and generate litter as a substratum and food source for meiofauna in the system.

Fig. 3.3.1. Conversion of mangrove forests to shrimp ponds and resettlement areas in Southeast Asian countries. (Photograph courtesy of Professor Dr. Sanit Aksornkoae.)

Loss of Mangroves and its Effect

The total area of mangrove lost in Asian countries over different time spans has been estimated by FAO (2003) and Kashio (2004). They estimate that the area of mangroves has been reduced by approximately 26% during the 20 years from 1980 to 2000 (Table 3.3.1). However, it should be noted that in the literature estimates of mangrove areas in each country vary greatly, reflecting differences in definition and mode of assessment.

As in other tropical countries in the world, mangrove forests in Asia are under threat of severe degradation. Various causes of mangrove destruction in this region include conversion to pond aquaculture (particularly of shrimp – Fig. 3.3.1), clear felling of timber for charcoal, firewood, woodchip and pulp production, land clearance for development of urban areas, ports and harbors, agriculture, salt pans, industry and power plants, roads and transmission lines, excessive siltation and human settlements. Shrimp culture would appear to be the most serious cause for mangrove conversion, particularly in the Southeast Asian countries such as Indonesia, Vietnam, Philippines, Malaysia, and Thailand (Bhandari et al., 2004).

Clearance of mangrove forests has a serious, direct impact on the ecosystem as a whole and also causes socioeconomic problems, including the degraded environmental condition of adjoining ecosystems in the coastal areas, particularly sea grass beds and coral reefs. Research in Southeast Asia has revealed that the destruction of mangroves directly impacts on fish and prawn

TABLE 3.3.1. Loss of mangrove forest in Asian countries. (From Forest Resources Assessment 2000 (for mangrove forests), FAO 2003; Kashio 2004.)

Region	Most reliable, recent mangrove area estimate		Mangrove area 1980	Mangrove area 1990	Annual change 1980–1990		Mangrove area 2000	Annual change 1990–2000	
	000 ha	Ref Yr	000 ha	000 ha	0 ha	%	000 ha	000 ha	%
WEST ASIA									
Bahrain	100	1992	100	100	n.s.	0.0	100	n.s.	n.s.
Islam. Rep. of Iran	20,700	1994	25,000	21,000	−400	−1.7	20,000	−100	−0.5
Kuwait	2	2000	n.a.	n.a.	n.a.	n.a.	2	n.a.	n.a.
Oman	2,000	1992	2,000	2,000	n.s.	n.s.	2,000	n.s.	n.s.
Qatar	500	1992	500	500	n.s.	n.s.	500	n.s.	n.s.
Saudi Arabia	20,400	1985	20,400	20,400	n.s.	n.s.	20,400	n.s.	n.s.
United Arab Emirates	4,000	1999	3,300	3,600	30	0.9	4,000	40	1.1
Yemen	927	1993	1,100	980	−12	−1.1	800	−18	−2.0
Subtotal	48,629	–	52,400	48,580	−382		47,802	−78	
SOUTH ASIA									
Bangladesh	622,482	1996	596,300	609,500	1,320	0.2	622,600	1,310	0.2
India	487,100	1997	506,000	492,600	−1,340	−0.3	479,000	−1,360	−0.3
Maldives	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Pakistan	207,000	1990	345,000	207,000	−13,800	−5.0	176,000	−3,100	−1.6
Sri Lanka	8,688	1992	9,400	8,800	−60	−0.7	7,600	−120	−1.5
Subtotal	1,325,270		1,456,700	1,317,900	−13,880		1,285,200	−3,270	
SOUTH-EAST ASIA									
Brunei Darussalam	17,100	1992	18,300	17,300	−100	−0.6	16,300	−100	−0.6
Cambodia	72,835	1997	83,000	74,600	−840	−1.1	63,700	−1,090	−1.6
East Timor	3,035	2000	4,100	3,600	−50	−1.3	3,035	−57	−1.7
Indonesia	3,493,110	1988	4,254,000	3,530,700	−72,330	−1.8	2,930,000	−60,070	−1.8
Malaysia	587,269	1995	669,000	620,500	−4,850	−0.7	572,100	−4,840	−0.8
Myanmar	452,492	1996	531,000	480,000	−5,100	−1.0	432,300	−4,770	−1.0
Philippines	127,610	1990	206,500	123,400	−8,310	−5.0	109,700	−1,370	−1.2
Singapore	500	1990	2,700	500	−220	−15.5	500	n.s.	n.s.
Thailand	244,085	2000	285,500	262,000	−2,350	−0.9	244,000	−1,800	−0.7
Vietnam	252,500	1983	227,000	165,000	−6,200	−3.1	104,000	−6,100	−4.5
Subtotal	5,250,536	-	6,281,100	5,277,600	−100,350		4,475,635	−80,197	
EAST ASIA									
China	36,882	1994	65,900	44,800	−2,100	−3.8	23,700	−2,110	−6.2
Japan	400	1980	400	400	n.s.	n.s.	400	n.s.	n.s.
Subtotal	37,282	3974	66,300	45,200	−2,100	−3.8	24,100	−2,110	−6.2
Grand total Asia	6,661,717	1991	7,856,500	6,689,280	−116,722	−1.6	5,832,737	−85,655	−1.4

Note: 1 n.a. = not available, n.s. = not significant.

abundance and lowers productivity (Janekitkarn et al., 1999). Mangrove clearance also alters soils in many ways, including accelerating coastal soil erosion, increasing sedimentation transportation and reducing biodiversity of soil fauna. Other serious impacts caused by the destruction of mangroves are a reduction in biodiversity of both flora and fauna due to elimination of their habitats for shelter, spawning grounds, food and nurseries in the system, increasing levels of toxic chemicals causing an adverse effect on the quality of the surrounding water and depleting organic matter through leaching. All impacts caused by the clearance of mangroves will finally result in the loss of productivity of inshore and near shore fishery and have a serious adverse impact on coastal communities. In such communities large numbers of people are highly dependent on mangrove for food, income generation, protection from sea storms and other benefits.

Sustainable Management/Wise Use of Mangroves

The mangrove forests in Asia have been managed for several decades, particularly in Southeast Asian countries, beginning with commercial exploitation for timber and charcoal products.

However, one major weakness of mangrove management in these countries is that, almost exclusively, management aims at the management of specific economically important species of plants. In fact, mangrove forest is not just a collection of trees. It is an ecosystem, which has a rich diversity of ecological resources. Mangrove ecosystems differ completely from other ecosystems. Mangroves have special, highly complex characteristics. They are transitional ecosystems between land and sea and between fresh water and sea water. The sustainable management of these ecosystems, therefore, has to be treated as a special case.

The achievement of sustainable management of mangroves must be emphasized with regard to the following important issues:

1. Integrated mangrove resource management among wood, nonwood, aquatic resources, and coastal protection should be implemented; it should also meet local, national, and regional needs.
2. Mangrove resource sustainability should be given high priority; their management must be closely considered in terms of ecological carrying capacity.
3. Mangrove rehabilitation should be carried out in degraded mangrove forests, such as abandoned shrimp ponds (Fig. 3.3.2), and also new mudflats; they should be managed on a long-term, sustainable basis.
4. Interaction among local communities, scientists, managers, and policy makers should be strengthened, particularly by exchanging of ideas on the management and conservation of mangrove ecosystems.
5. Local, national and regional databases should be developed and strengthened in order to support mangrove ecosystem research and sustainable management planning.
6. Mangrove forests should be protected by fully supporting local communities and by strict law enforcement and regulations to prevent illegal activities.

Fig. 3.3.2. Mangrove rehabilitation in abandoned shrimp ponds in Southern Thailand. (Photograph courtesy of Professor Dr. Sanit Aksornkoae.)

7. Education and public awareness on the conservation and sustainable management of mangrove ecosystems should be promoted by producing educational materials, video, CD-ROM, and other mass-media tools.
8. Finally, it is necessary to note that an immediate need is the incorporation of sustainable management interventions for other components of mangrove forests to ensure that the sustainability, which has been achieved at mangrove tree resource level, can also be achieved at an ecosystem level, following the "Ecosystem Management Approach".

References

Aksornkoae S, (1993) Ecology and management of mangroves. IUCN, Bangkok, Thailand.
Anonymous (1987) Mangroves of India. Status report. New Delhi: Government of India, Ministry of Environment and Forests, 150pp
Berry AJ (1975) The natural history of West Malaysian mangrove faunas. Malayan Nat J 25:135–192
Bhandari BB, Kashio M, Nakamura R (2004) Mangroves in Southeast Asia: Status, issues and challenges. Tokyo Ramsar Center, Japan/IGES
Chaitiamvong S (1983) Shrimps in mangrove and adjacent areas. The UNDP/UNESCO regional training course on introduction to mangrove ecosystems. NRCT, Bangkok, 20p
Duke NC (1993) Mangrove floristics and biogeography. In: Robertson AI, Alongi DM (eds) Tropical mangrove ecosystems. American Geophysical Union, Washington DC pp 63–100
Duke NC, Ball MC, Ellison JC (1998) Factors influencing biodiversity and distributional gradients in mangroves. Global Ecol Biogeogr Lett 7:27–47

FAO (2003) FAO's database on mangrove area estimates. Forest resources assessment working paper no. 62. Forest Resources Division FAO, Rome
Hogarth PJ (1999) The decline in Indus Delta mangroves: cause, consequences and cures. Proceedings of international conference on mangroves, Kuwait, 1998. Kuwait Institute for Scientific Research, Kuwait
Hong PN (1991) Ecology of mangrove vegetation in Vietnam. PhD thesis, Hanoi University Vietnam
Isarankura K (1976) Status report on faunistic aspects of mangrove forest in Thailand. Paper presented at the first national seminar on mangrove ecosystems held from 10–15 January 1976 at Phuket Marine Biological Center, Thailand
Jones DA (1984) Crabs of the mangal ecosystem. In: Por FD, Dor I (eds) Hydrobiology of the mangal. Dr. W. Jink Publishers, The Hague, pp 89–109
Janekitkarn S, Premchareon S, Vitheesawat P (1999) Estuarine fishes of the Tha-Chin River, Samut Sakorn, Thailand. Paris Soc Fr Ichtyol 57–64
Kashio M (2004) Mangrove resources and management in Southeast Asia. In: Bhandari BB, Kashio M, Nakamura R (eds) Mangrove in Southeast Asia: status, issues and challenges. Ramsar Center Japan/IGES, Tokyo, 266p
Kathiresan K (1998) India-A pioneer in mangrove research too. ENVIS Species Publication, Annamalai University, India, 66pp
Kongamol S (2001) Decomposition rates and associated degradation fungi on mangrove leaf litters of *Rhizophora apiculata* and *Avicennia alba* at Thachin Estuary, Samut Sakhon Province. PhD thesis, Kasetsart University, Bangkok, Thailand, 171p
Mapalo AM (1992) Mangrove species distribution in Bohol, Phillippines. Ecosyst Res Dig 3(2):55–62
Macintosh DJ (1988) The ecology and physiology of decapods of mangrove swamps. Symp Zool Soc Lond 59:315–341
Monkolprasit S, Vimolohakarn, Sonkririkul T (1987) Fishes of Thailand. Faculty of fisheries. Kasetsart University, Bangkok, Thailand (in Thai)
Naiyanetr P (1985) Life history of selected species of crabs in mangroves. The UNDP/UNESCO regional training course on life history of selected species of Flora and fauna in mangrove ecosystem held from 8–12 April 1979. Prince Songkhla University, Hatyai, Thailand (in Thai)
Ricklefs RE, Latham RE (1993) Global patterns of biodiversity in mangrove flora. In: Ricklefs RE, Schulter D (eds) Species diversity in ecological communities. University of Chicago Press, Chicago, pp 215–229
Santisuk T (1983) Taxonomy of the terrestrial trees and shrubs in the mangrove formations in Thailand. The UNDP/UNESCO regional training course on introduction to mangrove ecosystems, March 2–30. NRCT, Bangkok, Thailand
Sasekumar S (1984) Mangrove secondary productivity. Proc. Workshop Mangr. Prod. Univ. Sains Malaysia
Tomlinson PB (ed) (1986) The botany of mangrove change of tidal flat areas in the Seto Inland Sea

3.3.2 Present Status of Coral Reefs in Asia-Pacific Coastal Zone

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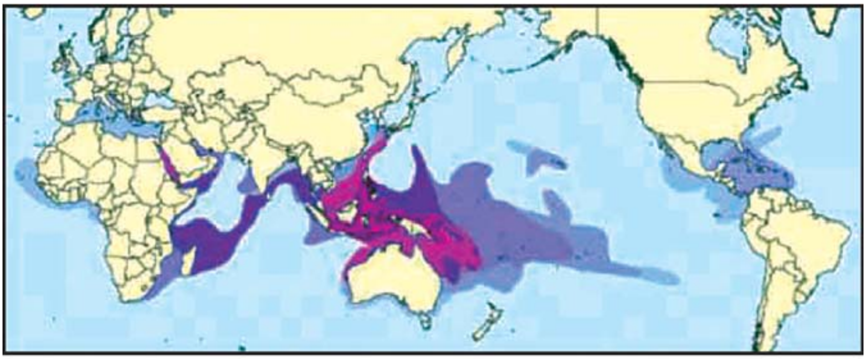

Number of species: Less than 50; 50-100; 101-200; 201-300; 301-500; Over500

FIG. 3.3.3. Distribution and diversity of coral reef species worldwide. (From Veron JEN and Mary Stafford-Smith Corals of the World, Cape Ferguson, AIMS 2000.)

Introduction

The Asia-Pacific marine environment comprises three major sea regions, namely the South Asian, the East Asian, and the Pacific Islands regions. The South Asian seas region includes Bangladesh, India, the Maldives, Pakistan and Sri Lanka, and Myanmar. The East Asian Seas region covers eight ASEAN countries, namely Brunei Darussalam, Cambodia, Indonesia, Malaysia, the Philippines, Singapore, Thailand and Vietnam, as well as other bordering countries, i.e., the People's Republic of China, Taiwan, Korea, and Japan. The Pacific Island sea region, which has many coral reefs and lagoons, seagrass beds, and mangroves, is partially surrounded by the Asian, Indian, and Australian land masses.

The Indo-West Pacific marine biogeographic province has long been recognized as the global center of marine tropical biodiversity. Fifty of a global total of 70 coral genera occur in this marine basin. Compared to the Atlantic, the tropical Indo-West Pacific is very diverse (Fig. 3.3.3). Only some 35 coral species are found in the Atlantic compared with over 450 coral species recorded for the Philippines alone. Coral reefs in Southeast Asia are the most biologically diverse, both in terms of extent and species diversity. An estimated 34% of the earth's coral reefs are located in the seas of Southeast Asia (Burke et al., 2002), which occupies only 2.5% of the global sea surface. The region includes more than half the coral reefs of the world.

Distribution, Status, and Change of Coral Reefs in Asia-Pacific Coastal Zone

Distribution of coral reefs in Asia-Pacific is shown in Figs. 3.3.4 and 3.3.5. The status of coral reefs in this region can be summarized as follows:

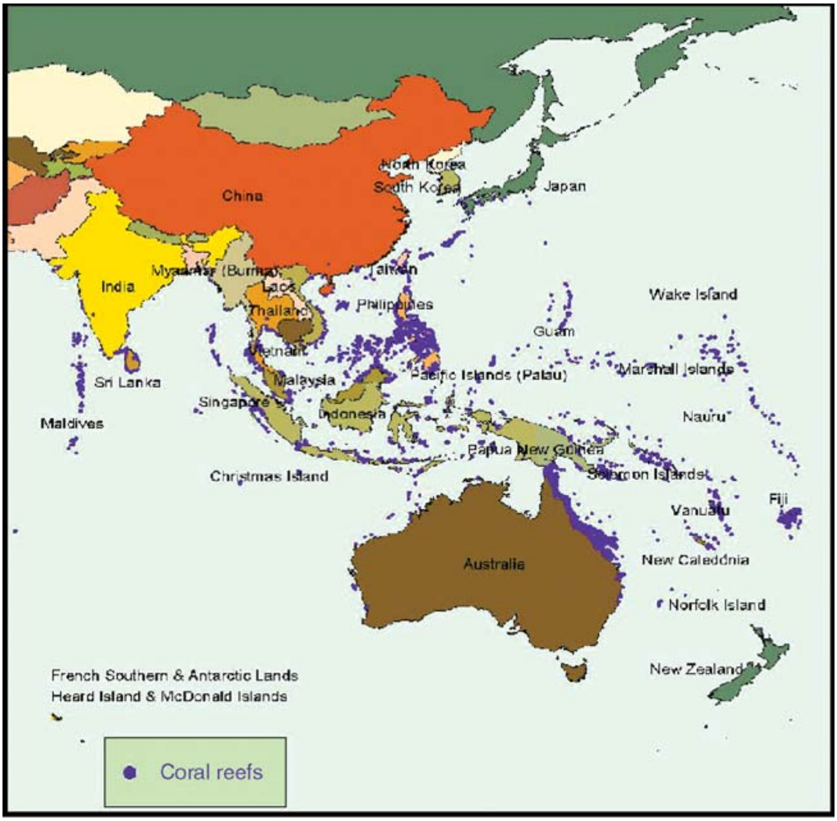

FIG. 3.3.4. Map of coral reefs distribution in Asia-Pacific. (www.reefbase.org.)

South Asia

Coral bleaching has caused major damage to reefs around the oceanic islands of Lakshadweep, Maldives, and Chagos, and the mainland reefs of India (Gulf of Mannar and Gulf of Kutch) and Sri Lanka. Recovery of corals is generally poor because natural and human disturbances are impeding successful new coral recruitment. However, some areas of the Maldives are recovering well. The high islands of Andaman and Nicobar remain healthy having escaped bleaching damage. Capacity for monitoring coral reefs continues to improve with donor assistance; however, the monitoring data are largely ignored by resource managers, such that most MPAs in South Asia continue to be degraded. Several new protected areas have been declared (Maldives and Andaman-Nicobars) but will not succeed unless management and enforcement are improved and local communities are included in the process.

Southeast Asia

The Reefs at Risk analysis in 2002 reported that 88% of these reefs are at medium to very high threat from human impacts. By far the most serious

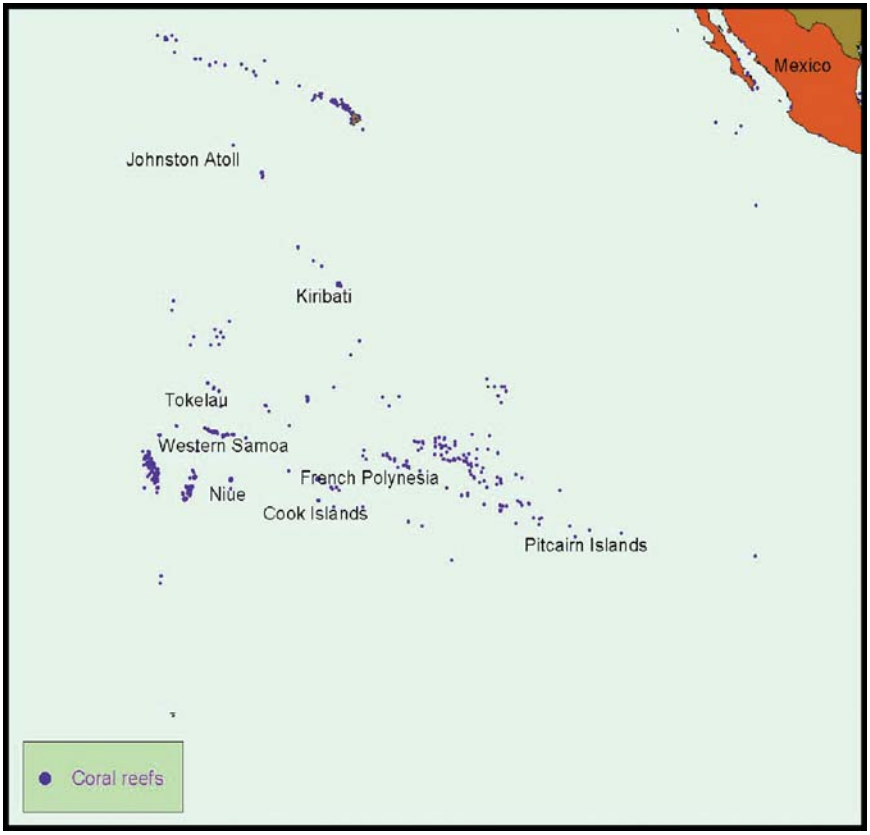

FIG. 3.3.5. Map of coral reefs distribution in Asia-Pacific (continued). (www.reefbase.org.)

threats are destructive and over-fishing, followed by coastal development, increased sedimentation and pollution.

Monitoring capacity is relatively strong but is insufficient for a region that has the largest area of coral reefs in the world with the highest biodiversity. (Figs. 3.3.6–3.3.8) Management capacity continues to be weak in most countries, with the drive for development taking priority over environmental conservation. There are, however, some excellent examples of effective management and successes in reef protection through community control.

East Asia

Most of the reefs in Japan and Taiwan that were damaged in 1998 (Fig. 3.3.9) are recovering. This may also apply to reefs in China. However, there was further bleaching in Japan in 2001, with some reefs experiencing about 50% mortality. There appears to be a crown-of-thorns starfish (COTS) outbreak in southern Japan, but sediment runoff from coastal development and damaging and overfishing continue as the major threats. The Japanese government has established an international coral reef centre to facilitate coral reef monitoring for the GCRMN, and conservation in the region.

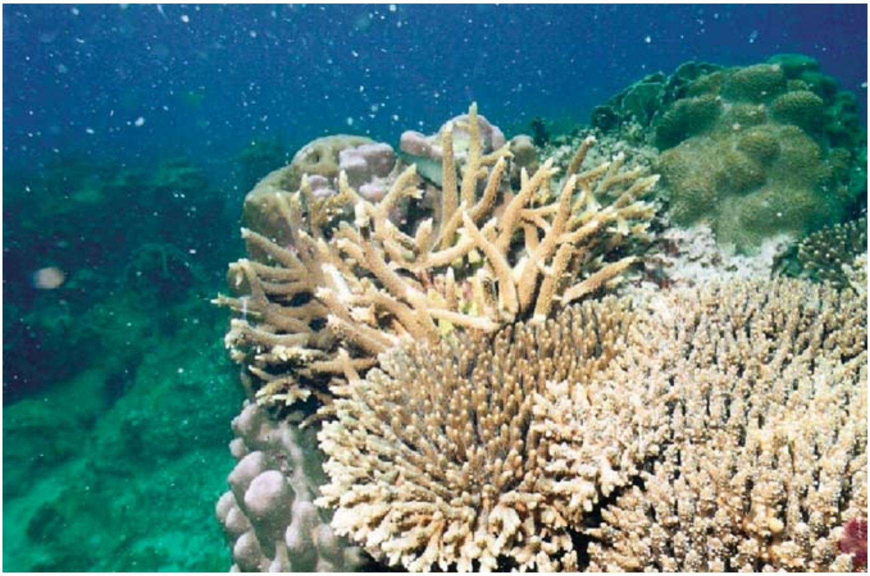

Fig. 3.3.6. A coral community at Mu Koh Chang – a newly developed area for ecotourism in the eastern part of the Gulf of Thailand.

Fig. 3.3.7. An assemblage of branching *Porites* sp. at Anambus Island, Indonesia.

Fig. 3.3.8. A coral community in Palawan, the Philippines.

Fig. 3.3.9. A large area of shallow reef at Ishigaki Island, Japan.

Australia and Papua New Guinea

There was major coral bleaching in early 2002 on the Great Barrier Reef (GBR) of Australia with almost 60% of all reefs affected. Some inshore reefs suffered up to 90% coral death, and there was up to 95% mortality on the remote Flinders and Holmes Reefs in the Coral Sea. Otherwise the GBR and other reefs off Western Australia remain in a predominantly good condition due to low human pressures and effective management. However, a major concern is an outbreak of the COTS and coral disease in the central GBR. Management is supported by substantial research and monitoring.

In contrast, there is little monitoring of the coral reefs of Papua New Guinea (PNG).However, most are considered to be in relatively good condition. There are warning signs of increasing human pressures from fishing, deforestation and coral bleaching. Capacity within government is weak, but there has been a marked increase in involvement by large NGOs. These are strengthening community-based management.

Southwest Pacific

Coral bleaching has emerged as the major threat to the coral reefs of countries in this region. The reefs also continue to be degraded as human pressures increase. Most of these reefs escaped bleaching in 1998, but there was serious coral bleaching and mortality in 2000 and 2002, especially in Fiji, and to a lesser extent in Tuvalu and Vanuatu. There has been an expansion of coral reef monitoring and capacity under the Global Coral Reef Monitoring Network (GCRMN) and Reef Check frameworks. Similarly, many local and international NGOs have assisted communities to establish their own MPAs to monitor and conserve their coral reef resources, particularly in Samoa and Fiji. Ethnic tensions in the Solomon Islands have reversed much progress with communities in that country.

Southeast Pacific

The coral reefs of the countries and states of Polynesia have changed little since 2000 and predominantly remain in good condition. However, there are few monitoring data from the region, except for French Polynesia and, to a lesser extent, Wallis and Futuna. Tourism is important to the region, despite relatively remoteness from the market. Black pearl culture is important in the Cook Islands and French Polynesia. Coral reef conservation is generally poorly developed, with poor enforcement and a lack of political will, although all countries have considerable legislation. Encouragement of the traditional management systems of the recent past would assist in raising public awareness and implementing conservation.

Micronesia and American Samoa

The coral reefs in this region are comparatively healthy, although the reefs in Palau suffered extensive damage from coral bleaching in 1998. Human pressures are also increasing. Most of the countries and territories in this region are now included in many of the coral reef initiatives of the USA, such as improved mapping, monitoring and training, and improved coral reef conservation. Reefs in American Samoa are recovering from COTS invasions, as well as tropic cyclones and coral bleaching, but fish populations are not recovering well. The export of "live rock" and scuba fishing were recently banned. There has been major progress in coral reef monitoring in the countries of Micronesia and several new MPAs have been established. These are beginning to show positive recovery of corals and fishes. The recently opened Palau International Coral Reef Center is coordinating coral-reef monitoring in the region for the GCRMN.

Northeast (American) Pacific

There has been considerable monitoring and mapping of the reefs of the Hawaiian Archipelago and the Northwestern Hawaiian Islands. This followed a major injection of funds and expertise. The Northwestern Islands are close to pristine and are protected in a newly created reserve which includes large "no-take" zones. In contrast, reefs on the main Hawaiian Islands continue to suffer from over-fishing, sediment and tourism pressures. Fish populations are greater in reserves than in nearby, heavily fished areas, but efforts to create new no-take reserves are resisted. They are an urgent priority.

A prognosis of coral reef condition in Southeast Asia, based on percent live coral cover within each country, and the region as a whole, was made for four time periods – current 2004 condition; condition in 1994, when ICRI was formed followed by the formation of the GCRMN in 1995; estimated condition in 1904; and estimated optimistic and pessimistic conditions in 2014 (Table 3.3.1).

Among the countries considered in the study the greatest decline in reef condition between 1994 and 2004 was recorded for the Philippines, Vietnam, Malaysia, and Singapore. Thailand showed a mixed pattern, with improvements in some reefs and deterioration in many others within the Gulf of Thailand, while the Andaman Sea reefs showed relatively little change in their condition. Indonesia was the only country that showed improvement in reef conditions for all categories.

Threats to Coral Reefs in Asia-Pacific Coastal zone

There is a substantial loss of coastal habitats in the region. Certain activities affect, indirectly, commercial demersal fisheries that rely on the mangroves and coral reefs as nursery areas. Coastal construction, particularly for tourist facilities and inland mining, as well as poor land-use practices, have resulted in increased sediment loads in coastal waters in countries such as Fiji, Malaysia, Indonesia, and Thailand. The increased sediment has adverse impacts on sensitive coral reef systems. However, in Thailand there has been a significant improvement in the condition of the reefs as a result of the efforts of non-governmental organizations (NGOs) and local people.

TABLE 3.3.1. Prognosis of coral reef benthos condition in SEA C 1904, 1994, 2004, and 2014, based on percent live coral cover. O: Optimistic estimates if management measures are improved, implemented, and enforced P: Pessimistic estimates if management measures fail to have effect (Adapted from Wilkinson 2004.)

	Reefs with >75% coral cover				Reefs with between 50–75% coral cover				Reefs with between 25–50% coral cover				Reefs with <25% coral cover			
	1904 (100 Years Ago[a])	1994[c]	2004[d]	2014[b]	1904 (100 Years Ago[a])	1994[c]	2004[d]	2014[b]	1904 (100 Years Ago[a])	1994[c]	2004[d]	2014[b]	1904 (100 Years Ago[a])	1994[c]	2004[d]	2014[b]
Brunei (185 hard coral spp.)	*>40*	20	*~10*	*O: > 10* *P: < 10*	*<20*	30	*~20*	*O: > 20* *P: < 10*	*<30*	40	*~60*	*O: < 60* *P: > 60*	*<10*	10	*~10*	*O: < 10* *P: > 20*
Cambodia (111 hard coral spp)	*>30*	*~10*	0	*O: > 10* *P: ⇔*	*>30*	*~30*	29	*O: > 40* *P: < 20*	*<30*	*~30*	57	*O: < 40* *P: > 60*	*<10*	*~10*	14	*O: < 10* *P: > 20*
Indonesia (590 hard coral spp.)	*>60*	6	7	*O: > 10* *P: 0*	*>20*	22	27	*O: > 40* *P: < 20*	*<10*	30	38	*O: < 30* *P: > 40*	*<10*	42	29	*O: < 20* *P: > 40*
Malaysia (>350 hard coral spp)	*>60*	8	0	*O: > 10* *P: ⇔*	*>20*	30	22	*O: > 40* *P: < 10*	*<10*	40	72	*O: < 45* *P: > 80*	*<10*	22	6	*O: < 5* *P: > 10*
Myanmar (65 hard coral spp.)	*>60*	*~40*	33	*O: > 40* *P: < 20*	*>20*	*~30*	42	*O: > 40* *P: < 30*	*<10*	*~20*	17	*O: < 10* *P: > 30*	*<10*	*~10*	8	*O: < 10* *P: > 20*
Philippines (464 hard coral spp)	*>60*	2	0.2	*O: > 5* *P: 0*	*>20*	22	6	*O: > 20* *P: 0*	*<10*	52	53	*O: < 45* *P: < 50*	*<10*	24	41	*O: < 30* *P: > 50*
Singapore (197 hard coral spp.)	*>60*	8	0	*O: > 5* *P: ⇔*	*>20*	25	8	*O: > 20* *P: 0*	*<10*	17	17	*O: < 25* *P: > 20*	*<10*	50	76	*O: < 50* *P: > 80*

(continued)

TABLE 3.3.1. (continued)

	Reefs with >75% coral cover				Reefs with between 50–75% coral cover				Reefs with between 25–50% coral cover				Reefs with <25% coral cover			
	1904 (100 Years Ago[a])	1994[c]	2004[d]	2014[b]	1904 (100 Years Ago[a])	1994[c]	2004[d]	2014[b]	1904 (100 Years Ago[a])	1994[c]	2004[d]	2014[b]	1904 (100 Years Ago[a])	1994[c]	2004[d]	2014[b]
Thailand (>250 hard coral spp.)	*>60*	0	13	*O: > 20* *P: < 10*	*>20*	46	17	*O: > 30* *P: < 10*	*<10*	46	34	*O: < 20* *P: > 40*	*<10*	8	36	*O: < 30* *P: > 40*
Vietnam (300–350 hard coral spp)	*>50*	1	0	*O: > 5* *P: ⇔*	*>20*	26	12	*O: > 20* *P: < 5*	*<20*	41	40	*O: < 35* *P: > 50*	*<10*	32	48	*O: < 40* *P: > 60*
SEA (>600 hard coral spp.)	*>60*	3	9	*O: > 20* *P: < 5*	*>20*	30	21	*O: > 35* *P: < 15*	*<10*	40	30	*O: < 15* *P: > 40*	*<10*	27	40	*O: < 30* *P: > 50*

[a] Values for 1904 are rough estimation based on opinions of country experts, and with reference to historical and existing data
[b] Values for 2014 are rough optimistic and pessimistic estimations based on opinions of country experts, and with reference successful or failed current and future implementation of management measures
[c] 1994 is just an indicative year; values indicated were obtained from available survey data that ranged from 1992–1994, depending on country, and is indicated below
[d] 2004 is just an indicative year; values indicated were obtained from available survey data that ranged from 1999–2004, depending on country, and is indicated below
***>, <, ~ab*; ab** Values that are in highlighted italicized bold indicate estimations that are not based on existing quantitative data; values in plain bold are from summarized survey data

Data sources for 1994 and 2004 indicative years
Brunei: 1994 values derived from Rajasuriya et al., 1992, 2004 values are expert estimates
Cambodia: 1994 values are expert estimates; 2003/4 data from DoF
Indonesia: 1994 and 2003 data based from COREMAP
Malaysia: 1993/4 data for Peninsula Malaysia from LCR Dataset (>10 sites) and 1997 East Malaysia data from; 2002/3 data from UMS
Myanmar: 1994 values are expert estimates; 2003/4 data from Reef Check Europe (12 sites)
Philippines: 1993/4 data from Gomez et al., 1994; 2003/4 data from UPMSI
Singapore: 1993 data from ASEAN-Australia LCR dataset (6 sites); 2003/4 data from NUS (6 sites)
Thailand: 1993 data from ASEAN-Australia LCR dataset (13 sites); 1999 data from Department of Fisheries (13 sites)
Vietnam: 1994–1997 (15 areas) and 2003 2/3 (9 areas) data from Tuan VV, IO

Tourism, tourism encroachment and recreational activities can themselves be a threat to coral reef biodiversity and environments. The construction activities that accompany most tourism developments, such as hotels, beach clubs and marinas, have a variety of direct and indirect impacts on coral reefs, through infilling, dredging and the resuspension of contaminated silts. Furthermore, pressure from large numbers of visitors can lead to continuing impacts, such as physical damage to reefs from trampling, boat abrasion and the removal of coral for "souvenirs". In addition, the discharge of untreated or partially treated sewage, operational leaks, discharges of hydrocarbons and waste dumping also put pressure on coral ecosystems.

Coastal erosion, resulting from increased land subsidence from groundwater extraction, sediment starvation as a consequence of inland dam and irrigation barrage construction, and off-shore mining of sand are notable problems in some localities in the region. The high volume of maritime traffic, and increasing numbers of international tourist arrivals, pose additional threats to the marine and coastal environments of the region. Although the consequences of marine environmental pollution are becoming increasingly evident, the level of pollution in most coastal waters is still manageable. The countries of the Asia-Pacific region have joined various international and regional agreements to resolve the problem. The situation in the coastal zone has improved in a few localities in the region.

TABLE 3.3.2. Expert projections on possible changes in the 5 R@R threat indicators in SEA 10 years from now (2014) compared to the 2002 analysis. (From Wilkinson 2004.)

Coastal development	Brunei	Cambodia	Indonesia	Malaysia	Myanmar[a]	Philippines	Singapore[b]	Thailand	Vietnam
	⬄	⇧	⬄	⇧	Unable to determine	⇧	⬄	⬄	⬄
Marine-based pollution	⬄	⇧	⬄	⬄	Unable to determine	⇧	⬄	⬄	⬄
Sedimentation	⬄	⇧	⬄	⬄	Unable to determine	⬄	⬄	⬄	⬄
Overfishing	⬄	Unable to determine	Unable to determine	⬄	Unable to determine	⬄	⬄	⬄	⬄
Destructive fishing	⬄	Unable to determine	Unable to determine	⬄	Unable to determine	⬄	⬄	⬄	⬄

[a] R@R calculation for overfishing threat in Myanmar not reflective of actual condition; ranking reflected here are based on expert opinion

[b] Threat estimates for Singapore using R@R calculations not reflective of actual conditions; ranking reflected here are based in local expert opinion

⬄ No significant change expected

⇧ Increase in threat likely, given current status of reefs, their management and projected coastal development over the next 10 years

Moreover, there are other threats to coral reefs such as coral reef bleaching, over-fishing, destructive fishing, use of poison, bomb fishing and the aquarium trade.

The snap-shot of expert estimates for the 2004 R@R threat indices for Southeast Asia (reference) reflects slight (1–5% increase from 2002) to moderate (5–15% increase) increases in all five key indices, mostly in coastal development, marine-based pollution and sedimentation (Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam), with slightly fewer increases in over-fishing and destructive fishing (Cambodia, Indonesia, Philippines, Vietnam). As with the 2002 assessment, the leading threats in 2004 are still attributed to over-fishing and destructive fishing, with coastal development beginning to show increased impacts. The proportion of the projected five threat indices for each country in 2004 is illustrated in Table 3.3.2.

References

Bryant D, Burke L, McManus J, Spalding M (1998) Reefs at risk: a map-based Indicator of potential threats to the World's coral reefs. World Resources Institute, Washington DC, 56pp

Bunce L, Townsley P, Pomeroy R, Pollnac R (2000) Socioeconomic manual for coral reef management. Australian Institute of Marine Science and GCRMN, Townsville, Australia, 183pp

Burke L, Selig E, Spalding M (2002) Reefs at risk in Southeast Asia. World Resources Institute, Washington DC, 72pp

Cesar HSJ (ed) (2000) Collected essays on the economics of coral reefs.CORDIO, Kalmar University, Sweden, 244pp

IMA (2003) The East Asia-Pacific Coral Reef Conservation Initiative 2002–2003 World Wide Web electronic publication (www.marine.org.)

IUCN (2002) The IUCN red list of threatened species. World Wide Web electronic publication (www.redlist.org/search/search-expert.php)

Talbot F, Wilkinson C (2001) Coral reefs, mangroves and seagrasses: a sourcebook for managers. Global Coral Reef Monitoring Network and Australian Institute of Marine Science, Townsville, Australia, 193pp

UNEP (2004) Asia Pacific environment outlook. World Wide Web electronic publication. (www.rrcap.unep.org.)

UNEP (2004) Coral reefs in the South China Sea. UNEP/GEF/SCS technical publication no. 2. World Wide Web electronic publication (www.marine.org)

Veron JEN (2000) Corals of the world. Vol. 3. M. Stafford Smith (Ed.) Australian Institute of Marine Science, Townsville, Australia, 490pp

Wilkinson C (1998) Status of coral reefs of the world: 1998. Global coral reef monitoring network and Australian Institute of Marine Science, Townsville, Australia, 184pp

Wilkinson C (2000) Status of coral reefs of the World: 2000. Global coral reef monitoring network and Australian Institute of Marine Science, Townsville, Australia, 363pp

Wilkinson C (2002) Status of coral reefs of the world: 2002. Global coral reef monitoring network and Australian Institute of Marine Science, Townsville, Australia, 378pp

Wilkinson C (2004) Status of coral reefs of the world: 2004. Vol. 1–2. Global coral reef monitoring network and Australian Institute of Marine Science, Townsville, Australia, 935pp

World Fish Center (2004) Reef Basi's Online Geographic Information System. World Wide Web electronic publication (www.reefbases.org)

3.3.3 Ecological Changes in Sea-Grass Ecosystems in Southeast Asia

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Sea-grass Habitat Profile of Southeast Asia

Sea grass beds are a discrete community dominated by flowering plants with roots and rhizomes (underground stems), thriving in slightly reducing sediments and normally exhibiting maximum biomass under conditions of complete submergence (Fortes 1995). They grow best in estuaries and lagoons where they are often associated, physically and ecologically, with mangrove forests and coral reefs, often forming the ecotone between these two divergent ecosystems. Sea-grass bed, as an ecotone, is an area of tension between these two habitats. It mediates the structural and dynamic components of the neighboring ecosystems via control of material, water, and energy flows between them. More importantly, sea-grass meadows support a rich diversity of species from adjacent systems and provide primary refugia for both economically and ecologically important organisms. As such, sea-grasses are sensitive to fluctuations because species coming from their neighboring systems encounter "marginal conditions" and are at the extremes of their tolerance levels to environmental alterations. This sensitivity makes sea-grasses useful indicators of changes not easily observable in either coral reefs or mangrove forests.

The centres of sea grass diversity have a clear focus in the seas of East Asia, reaching up to southern Japan, and a second focus of diversity in the Red Sea and East Africa. Fortes (1990, 1995) have reviewed the sea-grass resources of Southeast Asia, discussing their status and potential as a resource, as well as their environmental roles and prospects for management. So far 16 species of sea grasses have been identified in Philippine waters (Fortes 1989) while 14 species have been reported from Indonesia (Kuriandewa, personal communication, 2004). Currently Australia has the highest number of sea grass species, with a total of 30 (Kuo and Larkum 1989). In other parts of the region, where conditions are favorable, sea-grass beds can also be extensive, though often less dense (ESCAP/ADB 1995). The boundaries of sea-grass bed distribution in East Asia are uncertain as there have been few detailed studies and only shallow beds can be seen in satellite and aerial images.

The uses of sea-grass systems are well known. They support a rich diversity of species from adjacent systems and provide primary refugia for both economically and ecologically important organisms. Most of the major commercial fisheries in the region occur immediately adjacent to sea-grass beds. Globally, sea-grass systems occupy an area of about 600,000 km^2, contributing 12% of the total carbon storage in the ocean (Duarte and Cebrian 1996). The contribution of sea-grass beds of the East Asian seas to these figures is not known.

Sea-grass Resource Status in Southeast Asia

For decades the main interests of marine scientists of Southeast Asia focused almost solely on the corals, seaweeds, animals or fish that either live in coastal habitats or are associated with them (Fortes 1989). On the other hand, the traditional orientation of the region's marine science has been to view the ocean as a deep water mass, neglecting the shallow coastal fringes where sea grasses abound. Investigators with an interest in sea-grass research are few. Priorities for research and developmental activities are usually directed towards other resources with immediate economic impacts. Ironically in Southeast Asia, where the second highest sea-grass diversity in the world is found, the sea-grass ecosystem has been a focus of scientific inquiry only in the last 15 years and, as an object of natural resource management, only in the last 8 years.

Particularly in terms of sea-grass resources, a large percentage of Southeast Asia's coastline remains unstudied. Despite the high biodiversity and abundance of sea grasses in the region, there is still poor understanding of the habitat. Hence, it appears only marginally useful when, in fact, the ecosystem plays significant economic and ecological roles. It is the high diversity and abundance of sea grasses, however, which makes them highly vulnerable, especially to human perturbation. Since the early 1990s, the current rate at which we are gaining information on sea grasses is lower than the rate the resources are being lost and degraded.

Table 3.3.3 briefly describes the current status of sea grasses in Southeast Asian countries. The Philippines, Indonesia, Malaysia, Thailand, and Vietnam have relatively large resources of sea grasses. The other countries may have sizeable beds but these are presently unknown. The areas of sea grasses reported are estimates from selected study sites, not reflecting the area for the country. The total area reported for Indonesia is as yet unconfirmed.

Sea Grass Decline in Southeast Asia: The Issues

In Southeast Asia sea grasses are under threat due to the loss of mangroves which act as a "filter" for sediment from land, coastal development, urban expansion and bucket dredging for tin (Lean et al., 1990). Other threats include, substrate disturbance, industrial and agricultural runoff, industrial wastes and sewage discharges. At the Seagrass Workshop held in Bangkok in December 1993, seagrass scientists of the ASEAN-Australia Living Coastal Resources (LCR) project indicated that sea-grass habitats in the region are rapidly being destroyed. In Indonesia about 30–40% of the sea-grass beds have been lost in the last 50 years, with as much as 60% being destroyed around Java. In Singapore the patchy sea-grass habitats have suffered severe damage largely through burial under landfill operations. In Thailand losses of the beds amount to about 20–30%. Very little information on sea-grass loss is available from Malaysia. In the Philippines sea-grass loss amounts to about 30–50%.

In Southest Asia sea-grass beds are also under increasing threat of coastal pollution (Fortes and McManus 1994). Estuaries in most parts of urbanized

TABLE 3.3.3. Current status of sea-grass habitats in Southeast Asia.

Country	Area km^2	Location of beds	Causes of loss
Cambodia	Unknown	Mostly in Kampot and Sihanoukville	Disturbance by local people and tourists
China	Unknown	Futien Nature Reserve and Oinzhou Bay (plants might have been confused with seaweeds and freshwater weeds)	Pollution from agricultural and domestic wastes
Indonesia	30,000*	Western and eastern sections	80% lost in Banten Bay due to industrial activities; disturbance by fishing boats
Malaysia	Unknown	Sabah, Sarawak; muddy sediments of the west and sandy sediments of the east coasts	Trawling, dredging for port access, land reclamation
Philippines	978	From 96 sites, mostly in northwestern, western, and southern sections, with outlying islands having sizeable beds	Eutrophication, siltation, pollution, dredging, unsustainable fishing methods
Singapore	Unknown	Used to have sizeable beds around the islands, now only at the southern coral islands	Land reclamation and dredging for port construction, boat traffic and oil pollution from ships and industry
Thailand	Unknown	Gulf of Thailand to the east, Andaman Sea to the west	Trawlers, pollution and sediment from ponds, tourism industries
Vietnam	Unknown	All along its coasts, but mostly from the middle to the southern sections	Sedimentation, pollution from domestic and agricultural sources

*From partially verified satellite data

coastal capital cities, in particular, are among the worst off. They suffer the added pressures of coastal development, loss of habitat and over-fishing. In most other places in the world, despite national and international agreements on priorities and frameworks for wetland conservation, many sea-grass beds, and the species that depend upon them, continue to be threatened, degraded, or lost through human action, both direct and indirect.

The major long-term threat to sea-grass ecosystems in Southeast Asia is derived from coastal eutrophication (Fortes 2001). A particular problem in embayments with reduced tidal flushing, nutrient loading or eutrophication results from wastewaters which reach the coasts from industrial, commercial and domestic facilities. In addition, inadequate septic systems, boat discharge of human and fish wastes, and storm drain run-off carrying organic waste and fertilizers add substantially to the load. Eutrophication-mediated enhancement of growth in many plant forms results in reduction of light. Ultimately,

Table 3.3.4. Coastal environmental problems in Southeast Asia. Ranked in order of priority and classified into urgency categories i.e., immediate, short-term or within the next 5 years, and long-term or within the next 10 years or more. (Modified from UNEP 1990.)

Problem	Immediate	Short-term	Long-term
Habitat destruction[a]	1	1	1
Sewage pollution[a]	2	2	3
Industrial pollution[a]	3	3	2
Fisheries overexploitation[a]	4	4	6
Siltation/sedimentation[a]	5	5	4
Oil pollution[b]	6	6	8
Hazardous waste[c]	7	7	7
Agricultural pollution[b]	8	8	5
Red tides[c]	9	9	11
Coastal erosion[b]	10	10	10
Natural hazards[c]	11	12	12
Sea-level rise[c]	12	11	9

Problems marked with superscript a, b, and c are those which are known to impact heavily on sea-grass beds:
[a] Indicating severe impact
[b] Moderate impact
[c] Slight or no impact

the cause of nutrient loading along the region's coasts is people - increased population density increases the problem.

The coastal environmental problems perceived as exerting the most severe impact on the coastal and marine environment in Southeast Asia in the last decade are given in Table 3.3.4.

Causal chain analysis (Fortes 2001) revealed that these problems arise not only from overpopulation but also as a result of the use of inappropriate technology, people's consummate attention to the material and political, and insensitivity to the cultural aspects of human life. It is the product of these 4 primary forces that is really responsible for the crises in our coastal and marine environment. With the growing complexity of the interrelationship between society and the oceans as a resource, marine science has emerged to have a very defined role. This role is likely to be even greater in the future. Interestingly, after a decade, the priority coastal environmental problems in the region remain basically the same and the perception is carried over into the year 2020.

Table 3.3.5 shows sea-grass habitats affected or associated with land-based activities and environmental problems in selected coastal areas in Southeast Asia. SPP – number of species; A – extent of the major beds that may be affected; B – status and uses of the beds; C – quantification of the loads of sediments, nutrients, organic materials and toxic chemicals affecting the beds; D – identification ofther related environmental problems; E – whether or not there is a cure for the problems in place, x – not studied/implemented plans exist; xx – moderately studied plans exist; xxx – well-studied plans exist.

TABLE 3.3.5. Sea-grass habitats as these are affected or associated with land-based activities and environmental problems in selected coastal areas in Southeast Asia. (Modified after EAS/RCU 1995.)

Country	SPP	A	B	C	D	E
Cambodia	6	x	x	xx	xx	x
Indonesia	13	x	xx	xx	xxx	xxx
Malaysia	12	x	x	x	xx	xx
Philippines	16	xx	xx	xx	xx	xxx
Singapore	7	x	x	x	xx	xxx
Thailand	12	x	x	x	x	xx
Vietnam	15	x	x	xx	xx	xx

Impediments to Addressing the Issues

The major obstacles to solving the environmental problems and issues with regards to the sea grasses of Southeast Asia are as follows:

1. Lack of trained sea grass researchers – scientists from only two countries produce half of the scientific papers on sea grasses in primary literature.
2. Limited scope of work – most of the studies are focused on only 10% of the sea grass flora and from only two biogeographic areas of the world.
3. The works are largely descriptive – published works are largely qualitative and not synthetic; hence, they have low predictive value compared to what is required for resource management.
4. There are gaps in basic knowledge – no information exists on the extent, status, and uses of sea-grass beds that are affected by sedimentation, pollution, and unsustainable fishing practices.
5. Lack of appreciation of sea grasses – the importance of sea grasses and of managing these resources is generally academic and peripheral.
6. Limited and uncoordinated research - coordination in the region's sea grass research is extremely limited and fragmented.
7. Misguided management efforts – these have remained focused mainly on identifying the problems and planning remedial or curative, not preventive measures; such efforts do not solve the problems that the marine and coastal environments face.
8. Lack of enforcement of legislation – simple rules and regulations protecting the coastal environment and resources are not implemented, or are often violated where such legislation exists. Marine policy in many member countries remains unenforced, for various reasons.
9. Lack of effective linkages – this is especially between marine science institutions (scientific production) and the productive sector (application).
10. Failure to consider the social and cultural dimensions – the sociocultural aspects of the problems sea grasses are facing have either not yet been studied or not perceived to be an integral part of the process.

The above barriers are directly or indirectly related to the improper or non-use of scientific knowledge that has been generated, coupled with the small importance (hence, support) governments in the region give to sea grasses. Addressing these barriers effectively would substantially reverse the trend in sea-grass ecosystem degradation in the region.

The sad state of research on sea grasses is a reflection of the dismal state of marine science worldwide. In Southeast Asia the latter has been confronted. This includes the greatest barrier to its development and diffusion, namely the lack of effective linkages between science institutions (scientific production) and the productive sector (application). With it comes the other obstacles which, in the next decade, would still be a shortage of funds for research, low salaries for staff, lack of access to needed technologies, weak technical support infrastructure, poor public appreciation of coastal resources and environment, and the relatively small number of researchers trained in promoting an integrated management approach. Unless there is a substantial change in the legislative agenda on marine science within the majority of developing Southeast Asian countries, the lack of national commitments to support and encourage the development of the science will remain a major deterrent.

References

Duarte CM, Cebrian J (1996) The fate of marine autotrophic production. Limnol Oceanogr 41:1758–1766

Economic and Social Commission for Asia and the Pacific (ESCAP) and Asian Development Bank (ADB) (1995) 1995: State of the Environment in Asia and the Pacific. United Nations, New York, 638p

Fortes MD (1989) Seagrasses: a resource unknown in the ASEAN region. ICLARM Education Series 5. International Center for Living Aquatic Resources Management, Manila, Philippines, 46pp.

Fortes, MD (1990) Seagrass resources in East Asia: research status, environmental issues and management perspectives. In: ASEAMS/UNEP Proceedings of the first ASEAMS symposium on Southeast Asian marine and environmental protection. UNEP regional seas reports and studies no. 116. UNEP, pp 135–144

Fortes MD (1995) Seagrasses of East Asia: environmental and management perspectives. RCU/EAS technical report series no. 6, United Nations Environment Programme, Bangkok, Thailand, 75pp

Fortes MD (2001) The effects of siltation on tropical coastal ecosystems Chap. 7, pp 93–112. In: Wolanski E (ed) Oceanographic processes of coral reefs. CRC Press, Boca Raton, 356p

Fortes MD, McManus LT (1994) Issues and challenges in coastal zone development in Southeast Asia. Paper presented at the regional workshop on planning and management of coastal resources, Tuaran, Sabah (Malaysia), 8–9 November 1994

Kuo J, Larkum AWD (1989) Seagrass taxonomy, structure and development pp 6–73. In: Larkum AWD, McComb A.J, Shepherd SA (eds.). Biology of seagrasses. Elsevier, Amsterdam, 841p

3.4 Fisheries-Based Industries in the Asia-Pacific Region: Toward the Conservation and Sustainable Use of Marine Resources

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3.4.1 Fish as a "Global Commodity"

Fish is an Important Source of Human Nutrition

People in the Asia-Pacific region have always relied on fish and fishery products as their main source of animal protein intake more than in any other region. The average consumption of fish per capita outside PR China is 14 kg, while China alone shows a consumption of 25.6 kg per capita. The Japanese still consume 38.7 kg per capita. There is a large gap as regards the amount of consumption per capita per year between countries in the region, but a number of nations show the highest per capita consumption of fish in the world (APFIC 2004a).

Local Product is Transformed into a Regional Commodity

Fish is regarded as a typical local commodity that has been marketed within a narrow locality. However, during the colonial period, some traditional commodities like dried, salted, fermented, and boiled fish were transported to neighboring countries, where plantation and mining industries employed a huge number of immigrant workers. They could afford to consume these imported fisheries products at cheaper prices, together with the rice that was also imported. The combination of rice and fish became the basic pattern of food intake throughout the Asia-Pacific region. Such an interregional trade in fisheries products and main crops gave a great impetus to improve fisheries technology and enhance productivity. In Southeast Asia, Chinese immigrants brought and extended relatively labor-intensive technologies like the purse seine and the large-scale set net. These urban-based fishing industries increasingly provided a great number of job opportunities and means of income generation. A number of entrepreneurial fisher folk were engaged in large-scale commercial production, although the great majority of them persisted with a self-sufficient economy.

As a Global Commodity

After World War II a strong inducement to modernize fishing technologies came from consumer markets in developed nations, especially in Europe and Japan. Crustacean and mollusk production increased rapidly.

These became major export commodities instead of the traditional fisheries products. Trawl fisheries expanded throughout the region in the 1960s and 1970s, and targeted these highly valuable species. The mid-1980s was the decisive turning point whereby fisheries products were dealt with as a global commodity. With the liberalization of the food trade, fisheries industries in the Asia-Pacific region have since evolved into a new phase of development.

Three big consumer markets have increasingly imported a wide variety of fisheries commodities, namely the EU, North America and Japan. Hence, fisheries commodities moved from the South to these markets in the North. The importers' consumption behavior influenced the production and distribution of fisheries in the developing world. The huge Japanese market, which accounts for 25% of world fish imports, plays a decisive role in fisheries trade and fisheries development in the Asia-Pacific region.

Growth in New Seafood Businesses

New seafood business grows continuously to achieve lucrative overseas markets. Shrimp culture is a typical example. Aquaculture today represents one of the most lucrative food industries, with a noticeable ripple effect on the economics of related business. A recent case is the technical innovation of ready-to-eat and ready-to-cook commodities. Following the rapid change of food intake habits among consumers, Japanese-based investors opened up processing factories abroad that produce labor intensive, but sophisticated high value-added commodities. Japan and many developed nations rely upon an ever-increasing supply of frozen, processed, and cooked fish products from countries such as China, India, Indonesia, Thailand, and Vietnam, to name a few.

New Trends in the Fisheries Trade

The Asia-Pacific region has grown as a huge center of the seafood-processing industry, having caused drastic changes in the inflow and outflow of fisheries commodities. Seafood processing that has to procure the bulk of standardized and graded raw materials strongly drives aquaculture development. Cultured shrimp and fish are cost-effective raw materials. Shrimp aquaculture provides the base of this industry. It is well known that aquaculture is primarily a developing-world industry. Asia accounts for 87% of global aquaculture production by weight (IFPIC and WFC 2004). Aquaculture and seafood processing have developed side by side in the Asia-Pacific region.

The flow of fisheries trade from South to South and from North to South has increased. The seafood processing industry is likely to reduce its dependence on wild fish as raw materials. Naturally, too, it is likely to procure imported materials to achieve further business efficiency and sustainability. Large exporters, whose seafood industry has suffered from the shortage of domestic raw materials, suddenly incline at the import of standardized raw materials. Thailand, China, and Vietnam are good examples. Within the Asia-Pacific region, new flows of fisheries trade have emerged.

Under the WTO regime the liberalization and globalization of fisheries trade has pushed forward a challenging business model of export-oriented seafood production. A seafood company is dedicated to importing raw materials such as salmon, trout, cod, prawn and shrimp, squid and any other species that are available for processing. It produces high value-added products by adopting labor-intensive technology, and exports them to Japan, Korea, the USA, and EU. Fast-food and chain restaurants, take-out shops and big supermarkets are major customers of these products, purchasing the commodities through many different distribution channels.

The Appearance of East Asian Markets

As the Chinese economy shows a sharp rise in per capita income, the total per capita consumption of food fish represents an annual growth rate of 10.4% (1985–1997). Consumption per capita increased almost 5-fold from 1997 to 2003. It increased almost 10-fold from 1981 to 1997. While importing raw materials for export-oriented seafood business, China purchases a wide variety of fish and ingredients from the Southeast Asian and Pacific islands. In East Asia, Japan, and Korea have just begun to export high value species to Chinese markets. The trade relation between China and these countries changes interactively (Fig. 3.4.1), as if Japan, Korea, and China constitute the sole sphere of consumption markets. Many Asian and Pacific nations are deeply connected with such enlargement of consumer markets,

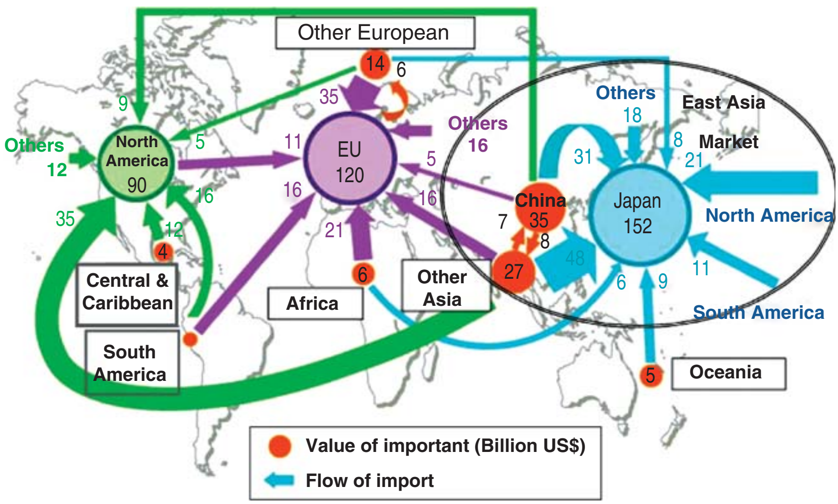


FIG. 3.4.1. Trade flow of fisheries products (1999–2001).

whereby they obtain the chance of exporting any possible valuable product. Together with high value-added products, fresh and live fish and traditional processed commodities, aquarium fish are also being increasingly traded.

3.4.2 Development of Marine Capture Fisheries and Aquaculture Production Trends

Development Process of Marine Capture Fisheries

Starting with Full-scale Development

Marine capture fisheries in the Asia-Pacific region started full-scale development in the 1960s. According to the FAO's statistical data, the region produced 44.7 million tonnes in 2002, accounting for 48.0% of the world total production. Five countries are ranked in the top-ten, namely, PR China, Indonesia, Japan, India, and Thailand.

Figure 3.4.2 shows the long-term trends of fisheries production in Asia (excluding PR China). The period from the 1950s to the present may be divided into three development stages: rapid growth, extent of growth, and fluctuations. The first stage (the 1950s to the 1970s) represents a full-scale development with structural changes in production and utilization. Through the modernization of fishing technology and the use of engines in boats, traditional and self-sufficient fisheries evolved into the productive and market-oriented ones. Lucrative marketing of crustaceans and mollusks greatly attracted new investors from both inside and outside fisheries. The total catch effort kept increasing until the 1970s.

The most striking changes in marine capture fisheries were landed species and their utilization. Especially in Southeast Asia, where trawl and trawl-modified technologies were widely expanded, demersal species accounted for

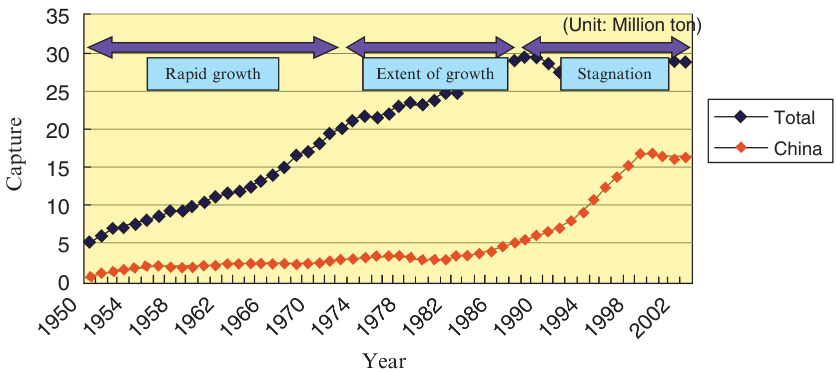


Fig. 3.4.2. Capture production in China and Asia excluding China between 1950 and 2002. (From FAO Yearbooks of Fishery Statistics, APFIC Status and aquaculture in Asia and the Pacific.)

the greatest majority of catch in volume, while crustaceans represented the larger portion in terms of value. As regards utilization, "trash fish" became one of the most important species, being defined as low-value fish in economic terms. In Thailand this economic category represented more than half the total catch. It was utilized as non-eligible fish, being processed into fish meal and oil. Yet another change was the destinations of export. Most countries much preferred to export high-value species, like crustaceans and mollusks to the developed world, particularly Japan, rather than sticking to traditional neighboring trade.

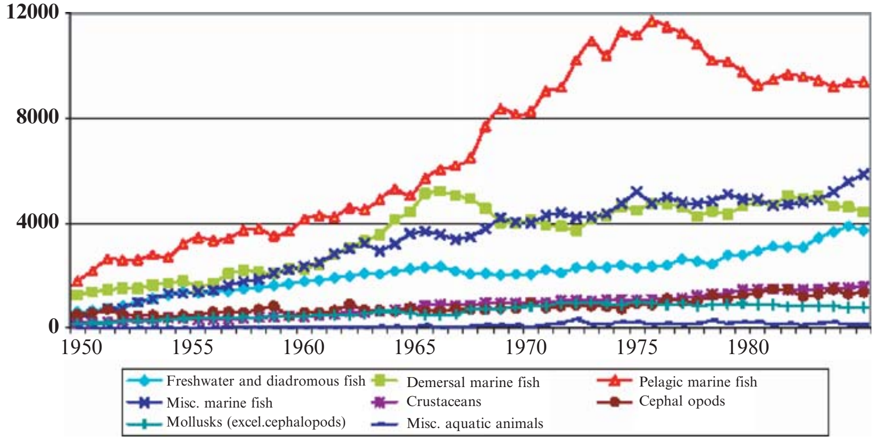
Dual Structure and the "Tragedy of Commons"

In the second stage, namely "extent of growth", technological innovation rapidly advanced even in the small-scale fisheries sector. Coastal small-scale fishers were involved in commercial production on a very small scale. At this stage strong competition occurred, not only between commercial and small-scale fishers, but also within the small-scale fisheries sector. Under the de facto open-access regime the principle of "first-come-first-served" became the watchword. The decrease and depletion of coastal marine resources became a social constraint. The "Tragedy of Commons" characterized the second stage of development. Moreover, the dual structure of fisheries production was firmly established: a small number of fisheries establishments (commercial fisheries sector) shared the greater majority of the catch, while a tremendous number of fisher folk (small-scale fisheries sector) had a much smaller portion. There appeared a large difference with regard to productivity between the two sectors. Because of the scarcity of marine resources and the lack of job opportunities outside fisheries, the poor remained marginalized in the coastal community and tended to increase their catch efforts without compromise, leading to a "vicious circle of poverty" that accelerated over-fishing and overcapitalization of coastal fisheries, which, in turn, led to the collapse of coastal marine resources.

Falling into Stagnation

In the 1990s, fisheries production in the Asia-Pacific region fell into stagnation. Production in Asia reached a peak of 24.7 million tons in 1989.

Figure 3.4.3 shows that the main species were pelagic marine fish from 1950 to 2002. This fishery increased moderately from about 2 million tons in 1950 to 5.5 million tons in 1973, and then grew rapidly and reached a peak of nearly 11.7 million tons in 1988. Subsequently, there was a downward trend and by 2002 it fell to (9.4 million tons). The catch of demersal species increased gradually from about 1.5 million tons in 1950 to 5.2 million tons in 1974, and decreased to nearly 4 million tons in 1983 before it fluctuated in 2002. In Southeast Asia a rapid increase in the marine catch after the 1960s was attributed to the rapid development of trawl fisheries. Demersal fish, even today, account for the majority of fish landed. Other species like freshwater/diadromous fish, crustaceans and cephalopods grew stably.



* Excluding aquatic plants Unit:1,000 tonnes

Source: FAO Yearbooks of Fishery Status and aquaculture in Asia and the Pacific

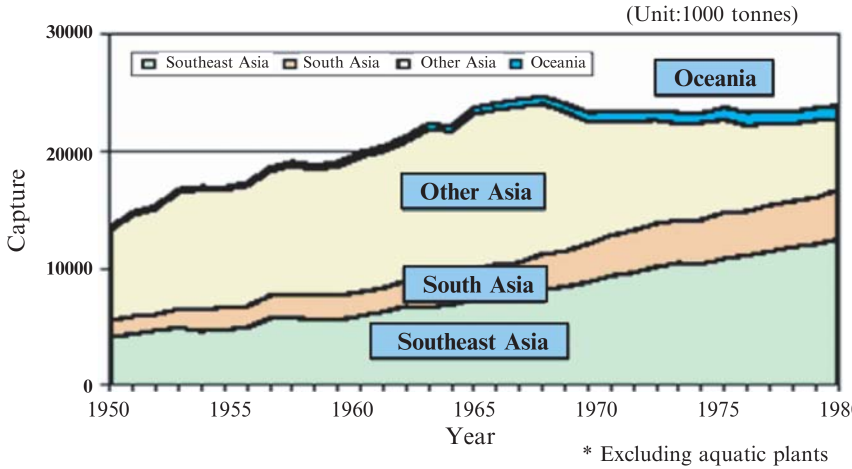
FIG. 3.4.3. Trends in capture production by species group outside China. (From FAO Yearbooks of Fishery Status and aquaculture in Asia and the Pacific.)

Replacement of Position by other Asian Countries

Fisheries production in Southeast Asian nations increased dramatically during these two decades (Fig. 3.4.4). Japan and Korea peaked in terms of fisheries development and carrying capacity in the 1970s. Their dominance has since declined. Nowadays, they are large importers of fisheries commodities, ranking in the top 10 among world importers. They had to undertake structural adjustment programs, including a reduction in the number of fishing boats and the creation of alternative job opportunities outside fisheries. Fishing technology and accumulated capital in these countries have been transferred to Southeast Asia. This includes the tuna fisheries. Under the influence of the WTO and FTA, Japan and Korea may never recover their former positions in Asian fisheries.

Aquaculture Development and its Impact

While marine capture fisheries are on a downward trend, aquaculture has been expanded throughout the Asia-Pacific region. It has dramatically increased its share of the total marine production, which nowadays accounts for more than 30%. The development of shrimp culture is the foundation of the aquaculture industry today. It is well known that aquaculture is primarily a developing-world industry. Asia accounts for 87% of global aquaculture production by weight (IFPIC and WFC 2004). Freshwater, rather than marine, culture used to flourish, which is linked to agricultural production such as rice cultivation, livestock and poultry farming. Since the 1980s, technological innovation has advanced rapidly in marine and brackish water aquaculture. Many species of marine fish are produced and exported to neighboring countries. Standardization of aquaculture technology is the foundation for the rapid increase



Source: FAO Yearbooks of Fishery Statistics, APFIC Status and quaculture in Asia and the Pacific

Fig. 3.4.4. Trends of capture production in marine waters by subregion outside China. (From FAO Yearbooks of Fishery Statistics, APFIC Status and quaculture in Asia and the Pacific.)

in production through the Asia-Pacific region. Regardless of whether they are large or small scale, aquaculture-related companies that are involved in feeding, hatcheries, disease control, equipment, processing, and marketing, vigorously attempt to integrate any farmer into their business chains and networks. Supported by the growth of aquaculture-related industry, farmers can specialize in production by adopting highly productive technology that has grown in cost-effectiveness. Division of labor has been firmly established in this industry. Naturally, a number of Asian-based companies have grown to become mature as multinationals, conglomerate enterprises covering a wide variety of the food business. However, too rapid development in aquaculture production has had a negative impact in various ways, which has caused environmental problems including mangrove destruction, water pollution, and the escape of genetically modified species that potentially have a negative effect on wild species. Such consequences of aquaculture development may not be calculated into the formulation of market prices. This is considered to be negative “externality”, which has increased tremendously.

3.4.3 Issues of Responsible Production in Marine Fisheries and Aquaculture

Emphasizing the Participatory Approach and Community-based Coastal Resource Management (CBRM)

The de facto open-access regime of utilizing marine resources is regarded as a great obstacle, as this tends to cause the “Tragedy of Commons” everywhere in the Asia-Pacific region. In spite of the enactment of fisheries laws and regulations, local fisher folk still face illegal and unreported fishing operations that damage the coastal resources and the environment. It is not only commercial fishing vessels, but also the small-scale fisher folk themselves, who often adopt destructive fishing gear with which to satisfy their quality of life on a daily basis. In coastal communities, because of the scarcity of alternative livelihoods, the fisher folk tend to overfish and overinvest in cost-effective and productive, but destructive and nonselective technologies.

In developing countries, a vigorous attempt has recently been made to explore the participatory approach and decentralized management. Taking the place of the top-down approach, citizens' and stakeholders' participation in the decision making of fisheries management is greatly emphasized, while enhancing awareness of the sustainable use of marine resources. In the 1980s and 1990s community-based resource management (CBRM) was widely accepted in the region, and a number of pilot projects were designed and implemented. Through the experiences and lessons gained in the projects, many nations started to enact new fisheries laws and regulations that would institutionalize decentralized and locally based coastal resource management.

Law Enforcement Through Establishing a Practical Framework of Locally Based Coastal Resource Management

Because of poor law enforcement, illegal, unreported and unregulated (IUU) fishing has extended throughout the Asia-Pacific region, together with commercialization in fisheries production. Nationwide registration and licensing are composed of multiple administrative arrangements. It is unlikely that one sole entity can manage and control the different types of fisheries. Multiple administrative organizations undertake registration and grant permission for fishing according to the types of fisheries and the kind of resource management.

Especially in coastal fisheries, a locally based management body, with authority granted, should enhance the capability of monitoring, control, and surveillance. There should be an appropriate mechanism in the decentralization that forces such a body to ensure resource users' compliance in the coastal fisheries. However, as small-scale fisher folk have very few options for their livelihood other than fisheries, flexibility, and tolerance are substantial elements in drawing up a practical local registration and licensing system. A part of coastal resources might be continuously under an open-access regime, so that local people can access a common-pool of resources for their livelihood and diet.

At this moment, the CBRM approach is at a watershed. Establishing local and nation-wide networks of CBRM, like bay-based management bodies, should be given a higher priority. While emphasizing citizens' participation in the decision making process of resource management, and taking into account local realities, a CBRM approach evolves into comanagement (CM) that will share responsibility between stakeholders and government, and between local and central bodies. More practical and sophisticated approaches should be developed, rather than stressing one sole approach. This is the latest challenge for coastal resource management programs in the Asia-Pacific region.

Integrated Approaches to "Responsible Fisheries"

The FAO has proposed the establishment of responsible fisheries at regional level. In conjunction with this initiative, many nations are establishing "codes of conduct for responsible production" in marine fisheries and aquaculture. The Southeast Asian nations form the codes for fishing operations, management, aquaculture, and postharvest. They have come to realize that establishing ethics among resource users is a prerequisite for the implementation of responsible fisheries, besides preparing for the institutional arrangements of MCS. Enhancing resource user's awareness is a decisive tool to secure the sustainable use of resources.

In most developing countries over-fishing is a problem of poor law enforcement – also the problems related to open-access fishing regimes, stagnation, declining or booming economies, lack of any alternative income sources and poverty (White et al., 1998). Poverty alleviation and the sustainable use of coastal resource management are indispensable elements in the improvement of life in overpopulated coastal areas. Fisher folk and their family members must increase alternative sources of income inside and outside fisheries in order to reduce their heavy dependence on coastal resources. Without such an approach to their livelihood, they can hardly accept the ethics and spirit of the code for responsible fisheries.

International Cooperation and Transborder Management

There is a pressing need to organize a regional fisheries body (RFB) that is in charge of managing common fishing grounds among related nations and has a mandate for species groups that migrate across state boundaries (APFIC 2004b). In the Asia-Pacific region a number of RFBs have appeared. They have different objectives, but all have a coordinating function among nations, share fish stocks and exchange information between members. In particular, collaborative efforts to control IUU fisheries are required for the sustainable use of common-pool resources.

Trans-boarder management is not such a new topic in the Asia-Pacific region. Fisheries conflicts between neighboring countries often occur. However, central governments have not solved these conflicts. Traditionally, fishing operations were carried out beyond the boarders everywhere. Even nowadays, fisher folk catch common-pool resources around or across the borders. Decentralized and local management bodies might take charge of coordinating IUU fishing operations, in collaboration with those local bodies in neighboring countries. A regional fisheries body and agreement are anticipated to support such locally based, transborder management, particularly in the East China Sea and South China Sea.

Food Security and Multifunctions of Fisheries in the APFIC Region

Food security cannot be achieved simply by increasing food production. Accessibility is one of the most essential elements of food security, while quality and variety should be acceptable within a given culture (Hotta 2003). Sustainability of marine resources must be secured for future generations. This is also related to the multifunctional nature of fisheries and coastal communities. However, under an expanding market economy, excessive demand for fisheries products leads to a rapid exploitation of valuable marine resources. With global free trade, the Asian and Pacific nations are under pressure to open domestic markets and import fisheries products freely. Some of the nations have great difficulty in protecting their domestic fishing industry that contributes to the growth of the national and local economy. As a result, multiple roles of fisheries and coastal communities are weakened, which will ruin various externalities with noncommodity outputs of fisheries (such as conservation of the environment, biological diversity, landscape, culture, and society) that cannot be calculated in monetary value.

How to sustain the multifunctional nature of fisheries and coastal communities are regarded as non-trading concerns (NTC) in the WTO. Many developing countries stress that developed countries should remove all barriers for free trade. On the other hand, large importers like Japan and Korea insist on holding import barriers, to support domestic fisheries. This is a very controversial issue, which may affect the conservation of the coastal environment and the revitalization of fisheries-based society.

Conclusion

Fisheries and aquaculture in the Asia-Pacific region have grown to be highly commercialized and productive. A strong inducement to develop capital-intensive fisheries comes from foreign demand for high-value species. Not only large-scale but also small-scale coastal fisheries are put into operation in cost-intensive and labor-intensive ways. Their fishing operations are also resource-exploitative in nature. Fisheries and aquaculture attract enormous amounts of capital inflow, providing employment opportunities and income sources to local society. Under the de facto open-access regime, little control over excessive investment in the means of production has been achieved so far. In most developing countries, fisheries and aquaculture have a fundamental role in sustaining the livelihood of the rural poor in the Asia-Pacific region. For their survival and food security, the fisheries sector brings flexible and diverse forms of income generation (FAO and NACA 2004).

However, the rural poor cannot keep pace with the recent development of commercial production by adopting highly productive technologies. Because of the lack of alternative livelihoods, they are likely to increase their catch efforts without any consideration of the maximum economic yield, or even beyond the maximum sustainable yield. Such short-sightedness aggravates the coastal environment and habitat problems. Depletion of renewable resources occurs everywhere in the Asia-Pacific region. Meanwhile, conflicts between the fisheries sector and other industrial purposes are increasing. The livelihood of fisher folk is threatened by other industries. This also quickens enlargement and expands the vicious circle of rural poverty.

It is time for the Asia-Pacific nations to direct their attention toward realizing "responsible fisheries" and "environmentally-friendly aquaculture" in order to achieve the sustainable use of renewable marine resources and improve the multi-functional nature of coastal communities.

References

APFIC (2004a) Status and potential of fisheries and aquaculture in the Asia and the Pacific. RAP publication, pp 1–53

APFIC (2004b) Regional fishery bodies and arrangements in Asia and the Pacific. FAO, pp 1–37

International Food Policy Research Institute (IFPRI) and WoldFish Center (WFC), 2004. Fish to 2020, World Fish Center, pp 1–152

FAO and Network of Aquaculture Centers in Asia-Pacific (NACA), 2002. Focusing small-scale aquaculture and aquatic resource management on poverty alleviation, FAO and NACA, pp 1–25

Hotta M (2004) The sustainable contribution of fisheries to food security in the Asia and Pacific region. Regional synthesis, FAO (http://www.fao.org/docrep/003/x6956e/x6956e02.htm, 1–17)

White AT et al. (1998) Coastal management in Asia: are donor-assisted programs sustainable and beneficial?, CRMP document no.43-CRM, 1–12

3.5 Tourism

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3.5.1 Introduction

Tourism, as defined by the World Tourism Organisation, ranges from an incipient to a highly established industry in the Asia-Pacific region. In this section, tourism will be considered only in the coastal countries of the Asia-Pacific region. Except for the last few years, these countries have witnessed a healthy growth in the industry in the past two decades (Table 3.5.1).

Since the 1960s growth in tourism has been attributed to several factors: an increase in intraregional travel; high rates of economic growth; reduced travel costs; and increased leisure time (Mak and White 1992). Many destinations had negative growth following the terrorist attacks of 11 September 2001 in New York and Washington, the Bali bombing of 12 October 2002, and the Severe Acute Respiratory Syndrome (SARS) in early 2003. Generally, the region has recovered, but not uniformly. The recent Indian Ocean tsunami has also impacted negatively on the tourist industry of Thailand and Sri Lanka.

TABLE 3.5.1. Coastal Asia-Pacific tourist arrivals, 1980, 1990, 2000, and 2002.

	Tourist arrivals (thousands)			
Countries	1980	1990	2000	2002
EAST ASIA				
China	5,703.0	27,462.0	83,444.0	97,908.0
Hong Kong	2,801.0	6,581.0	13,059.0	16,566.0
Japan	1,317.0	3,236.0	4,757.0	5,239.0
Macao	641.0	5,942.0	9,162.0	11,531.0
Rep of Korea	976.0	2,959.0	5,322.0	5,347.0
Taiwan*	NA	NA	2,624.0	2,978.0
SOUTHEAST ASIA				
Brunei	270.0	377.0	1,307.0	NA
Cambodia	NA	NA	466.0	786.0
Indonesia	561.0	2,173.0	5,064.0	5,033.0
Malaysia	2,105.0	7,446.0	10,222.0	NA
Myanmar	38.0	21.0	208.0	NA
PN Guinea	40.0	41.0	58.0	NA
Philippines	947.0	894.0	1,842.0	1,849.0
Singapore	2,562.0	5,320.0	7,691.0	7,567.0
Thailand	1,859.0	5,299.0	9,509.0	10,799.0
Vietnam	NA	250.0	1,383.0	NA
SOUTH ASIA				
Bangladesh	57.0	115.0	199.0	207.0
India	1,204.0	1,707.0	2,641.0	NA
Pakistan	299.0	424.0	557.0	498.0
Sri Lanka	322.0	298.0	400.0	393.0
OCEANIA				
American Samoa	20.0	26.0	NA	NA
Australia	950.0	2,215.0	4,931.0	4,841.0
Cook Islands	22.0	34.0	73.0	73.0
Fiji	185.0	279.0	294.0	NA
Fr Polynesia	89.0	132.0	252.0	189.0
Guam	301.0	780.0	1,287.0	NA
Kiribati	2.0	3.0	4.0	NA
Marshall Is	NA	5.0	15.6	14.0
Micronesia	6.0	8.0	33.0	14.0
New Zealand	445.0	976.0	1,649.0	1,956.0
Niue	1.0	1.0	1.6	2.1
N Mariana Is	119.0	426.0	517.0	NA
Palau	NA	33.0	58.0	NA
Samoa	45.0	48.0	88.0	NA
Solomon Islands	6.0	9.0	NA	NA
Tonga	13.0	21.0	35.0	NA
Tuvalu	1.0	1.0	1.0	NA
Vanuatu	22.0	35.0	50.0	NA

*WTO 2004.
NA = not available.
Sources: UNESCAP Statistics Division 2004; WTO 2004

TABLE 3.5.2. First and second generating countries for tourists in selected Asia-Pacific countries, 2002.(Computed from data in World Tourism Organisation 2004.)

Country	% total arrivals	1st country	2nd country
EAST ASIA			
China	36.6	Japan (21.8)	Korea (15.8)
Japan	40.1	Korea (24.3)	Taiwan (16.8)
Korea	53.5	Japan (43.4)	China (10.1)
SOUTHEAST ASIA			
Indonesia	39.1	Singapore (25.6)	Japan (13.5)
Malaysia	65.6	Singapore (56.8)	Thailand (8.8)
Singapore	28.5	Indonesia (18.3)	Japan (10.2)
Thailand	23.7	Malaysia (12.3)	Japan (11.4)
SOUTH ASIA			
India	34.5	Bangladesh (18.3)	UK (16.2)
OCEANIA			
Australia	31.1	New Zealand (16.3)	Japan (14.8)

The intraregional flows, especially in Northeast Asia, are an important factor to be considered for the future development of tourism in the region (Table 3.5.2). China is expected to be a major player by virtue of its population size, vast tourism resources, and positive government policies on development (Zhang and Lew 2003).

3.5.2 Development and Patterns

The traditional attraction of water in the Asia-Pacific region dates back before modern coastal tourism. Visiting spas was a traditional recreational activity in Japan and Korea. In East Asia, Lushan in China and Nagasaki in Japan were the first to be used as coastal retreats by foreign travellers. Southeast Asia's first coastal resort is Hua Hin in southern Thailand (Franz 1985).

Modern coastal tourism in Southeast Asia developed after the War World II at Kuta, Batu Ferringhi, and Pattaya. With the setting up of many Asian airlines in the 1950s, and boosted by the founding of the Pacific Asia Travel Association (PATA) in 1951, tourism in the region developed rapidly. Except for the socialist countries, for many countries in the Asia-Pacific region tourism came of age in the 1980s (Muqbil 1991).

Coastal tourism in the Asia-Pacific region has some distinctive features. East Asia and southern Australia and New Zealand have a distinctive tourist peak in summer, in contrast to the rest of Asia-Pacific which has virtually an all-year tourist season. Some significant patterns, features and factors of modern coastal tourism development will be highlighted for countries in different subregions.

Industrialization in Japan has blighted much of the country's coastline. The best beaches are on the islands of Okinawa, and the Izu and Ogasawara islands south of Tokyo. Okinawa enjoys a subtropical climate and coastal resorts were established during the 1970s. Several factors favored the development of coastal recreation and tourism in Japan. During the oil crisis in early 1970s economic restructuring was undertaken, with the policy of regional development based on leisure and construction industries. The Tourism and Recreation Promotion Act of 1987, also known as the Resort Act, was a boost to coastal tourism development (Rimmer 1992). Working hours were reduced in 1988. This encouraged the development of holiday and leisure resorts, which saw an exponential growth in the 1990s (Harada 1994). In 1993 Japan built the only indoor-controlled beach environment in the Asia-Pacific region at Miyazaki.

In Korea rapid economic growth from the 1980s spurred tourism development and outbound travel was eased in 1989 (Kim and Kim 1996). Coastal resorts are insufficient on the mainland and those on Cheju Island are suitable for international tourists. The government has comprehensive plans to develop tourism belts in the east, west, and south coasts and favoured a three-party (central government, local government, and private sector) investment approach for tourism development (Jung 1999).

With its "open door policy" dating from 1978, China is a late entry in tourism development in Asia-Pacific. It faces many problems, many of which are similar to those of other developing countries in the region (Hall 1994). The government has selected five pilot zones (the Bohai Bay Rim, the Yangtze River Estuary and the Hangzhou Bay Area, the southeastern offshore area of the Fujian Province, the Pearl River Estuary, and the Beibuwan Bay Area) for developing the oceanic economy with coastal tourism as part of the development. Half of the state-designated tourism resorts are at coastal sites: Beihai (Guangxi), Sanya (Hainan), Putian (Fujian), Dalian (Liaoning), Qingdao (Shandong), and Heng Sha Island (Shanghai) (Xiao 2003). Hainan is the most popular coastal resort with international tourists. Taiwan lacks beaches for the development of seaside resorts except in the south at the Kenting National Park.

India's international coastal resorts are at Goa and Kerala. Under the current 10th Five Year Plan (2002–2007) a number of sites on the west coast of India are being developed as beach resorts by the private sector. Because of easier access by air, these sites will primarily be on the beaches of Goa, Kerala and North Karnataka. The Nicobar and Andaman islands are international diving sites. During the Tenth Plan, Kochi in Kerala and the Andaman and Nicobar Island will be developed as international cruise destinations because of their proximity to international cruise routes and their exotic appeal. In Sri Lanka, Hikkaduwa is the most popular coastal resort stretch, located 100 km south of Colombo.

Pattaya in Thailand is probably the best-known coastal resort in Southeast Asia. It is near Bangkok. It grew rapidly as a result of R&R (rest and recreation) activities during the Vietnam conflict. In recent years Thai coastal tourism is spreading from Phuket to the Andaman Triangle, focusing on Krabi and Phang Nga. In the Gulf of Thailand, Ko Samui and Hua Hin are the major coastal resorts. Indonesia has a wide range of coastal resorts, with international resorts concentrated in Bali, Lombok, North Sulawesi, and other islands in Nusa Tenggara. In the Philippines the better-known coastal resorts are in the provinces of Panay (e.g., Boracay), Cebu (e.g., Mactan Island), Palawan, and Bohol (e.g., Panglao Island). West Malaysia is noted for Penang and Pulau Langkawi on its west coast and a number of smaller resorts off the east coast. Vietnam is actively developing its tourism infrastructure, including coastal resorts in Nha Trang and Phan Thiet. Myanmar is beginning to develop its international coastal resorts.

The Pacific islands have the advantage of a distinctive "south Pacific" or "Polynesian" image, with good beaches as a basis for coastal tourism development. It is also the principal geographic focus of the surf tourism industry. Surf and diving tourism are increasingly important, although air access is a critical constraint (Buckley 2002). The smaller Pacific island nations have had much less success in tourism than Australia and New Zealand. Fiji, Guam, Saipan, Cook Islands, New Caledonia, and French Polynesia are the major tourist destinations in the Pacific islands.

In Australia the major coastal resorts are on the Gold Coast of Queensland. The Great Barrier Reef is the largest single attraction, with tourism starting in the 1930s. There was considerable increase in the 1970s and 1980s (Craik 1991). Marine tourism is concentrated in two small areas, at Cairns and Whitsundays (Harriott 2002).

New Zealand's coasts are more important as part of scenic landscapes rather than for coastal tourism. The wider based coastal infrastructure supports marine tourism and also cruises to the Antarctic. The coasts are used primarily in summer and autumn, when water visibility is better.

Apart from other factors, Horner and Swarbrooke (2004) have indicated that some of the best beaches in the Asia-Pacific region have contributed to the region's tourism development. Recently PATA identified several dominant forces that will affect Asia-Pacific travel and tourism over the next few years. These include the expanding East Asian and Indian markets, more airline seats, changing demographics and improving disposable income (News@PATA 17.11.2004). Another feature to note is that coastal tourism is being widened by marine tourism and several niche coastal and marine-based activities, e.g., adventure and extreme sports, especially in Oceania. These are being emulated in other countries of the Asia-Pacific region.

3.5.3 Environmental Impacts

The development of coastal tourism in the Asia-Pacific region has been unplanned to a large extent. This has resulted in negative impacts on both the natural and human environments. Pleumarom (1996) labeled this environmental degradation as the *costa disasta* effect, reminiscent of the experience of many Mediterranean coastal resorts. The worst environmental damage occurs in the most sensitive areas such as coastal areas, small islands and coral reefs. These are the same the most attractive places, and are therefore intensively developed for tourism.

A preliminary study of the environmental impacts of coastal tourism in Asia-Pacific was carried out by ESCAP (1992). The deteriorating environmental conditions resulting from coastal tourism development were further highlighted in the 1995 UNEP Workshop on coastal tourism held in Cha-am (*Inter Press Service* 13.2.1995). The impacts on the coastal environment are usually classified as biophysical (e.g., congestion within resorts, pollution, litter, the removal of vegetation cover, soil erosion) and ecological (e.g., damage to fragile ecosystems such as coral reefs) (ESCAP 1995). In recent years, the ecological aspects are being emphasized in coastal tourism, as this is threatening the region's marine biodiversity. In particular, the construction of hotels, beach clubs and marinas has degraded marine and coastal environments, particularly coral reefs through infilling, dredging and the resuspension of contaminated silt (UNEP 2001).

Pattaya is a typical example of the adverse consequences of unplanned coastal tourism development. Within two decades it grew from a coastal village, and a weekend retreat for Bangkok residents, to eventually become a coastal resort city (Smith 1992a). The unplanned growth resulted in water pollution and by 1989 it was not possible to swim in the sea (Charoenca 1993). The decline in environmental standards reached its lowest point towards the mid-1990s. This has been attributed to the lack of clear policy guidelines on the part of the government, ignorance of the value of the environment on the part of local people for contributing to the degradation of the environment and government officials' failure to enforce the law strictly.

Even in developed countries such as Australia, coastal tourism has caused many environmental problems, including pollution, algal blooms, destruction of coastal dunes and coastal erosion (Hall 1991). However, relative to many other countries in the Asia-Pacific region, Australia's legislation and controls on development are more environment friendly, including legislation covering the likely impacts on the Great Barrier Reef Marine Park (Harriott 2002).

One of the biggest problems has been the promotion of golf and the consequentlial impacts on coastal resorts, especially in Southeast Asian countries. Golf courses use a large amount of water, introduce non-native species, and the fertilizers and pesticides used on the greens not only threaten the coastal environment but also pose some health concerns. An average golf course in Thailand uses nearly 6,500 m^3 of water per day, enough water for 60,000 rural villagers (Traisawasdichai 1995). China is seen as the next country for golf course development, but if she exercises "environmental authoritarianism" the negative impacts could be lessened (Hildebrandt 2003).

In many instances tourism development has also accelerated coastal erosion. One common example is the removal of coral for construction purposes, thus removing the protection function of reefs, e.g., Candidasa in Bali. Sand is also mined for construction or for beach nourishment elsewhere, leading to coastal erosion and disappearance of small sandy islands. Inappropriate coastal protection structures, the most common being seawalls or groins, are constructed by developers without adequate understanding of beach processes (Wong 1998). Seawalls constructed too close to the beach encourage erosion. The construction of groins leads to erosion on one side of the structure, e.g., the one-km extension of the airport in Bali affected 300 m of beach with erosion badly affecting the Pertamina cottages. These had to be subsequently protected by a series of minor groins and beach nourishment.

Inadequate understanding of the natural environment in coastal tourism development has also caused a number of problems (Wong 1990, 1998). For example, the unnecessary removal of rocks can lead to coastal erosion. At the same time, the rock coast can be adapted for resorts using various coastal structures as well as beach nourishment and selective removal of rocks, as in Mactan Island, in Cebu, Philippines (Wong 1999). Changing river mouths, particularly within monsoon Asia, are difficult to be incorporated into the landscape of coastal resorts. The river mouth normally opens during most of the year, but is closed by a sand bar during the onshore monsoon period, resulting in the retention of water that becomes putrid with time. Except for the Maldives and the countries in Oceania, few countries in the Asia-Pacific region have taken into consideration the potential impacts of a future sea-level rise on their coastal resorts (Wong 2005). As a result of the recent Indian Ocean tsunami, Thailand and other countries are considering coastal hazards more seriously in their tourism development plans.

3.5.4 Towards Sustainable Development

Integrated resort development, first implemented in Hawaii, was touted as the answer to unplanned or sporadic development in Southeast Asia. Nusa Dua was the first integrated resort in Southeast Asia and this was meant to be the model for Indonesia. However, sporadic or ad-hoc development could still occur outside Nusa Dua (Smith 1992b). The 23,000-ha Bintan Beach International Resort (BBIR), a joint development between Singapore and Indonesia, is currently the largest integrated resort in the region. Each hotel environmental management and monitoring plans must fall within the guidelines of regional environmental impact assessment for the integrated resort. Available data show that the overall quality of coastal water has been maintained within the guidelines since the coast was opened to resort development (Wong 2003)

Rehabilitation would be a logical step for coastal resorts with an already degraded environment. Pattaya started its rehabilitation programme in 1997. The wastewater treatment capacity of approximately 13,000 m^3/day was inadequate to handle a daily wastewater output of 20,000 m^3/day. The new system introduced in November 2000 processes up to 120,000 m^3/day, well above the current levels produced by the city. The coastal water quality along Pattaya beach has been monitored since 1993. It has improved significantly. By 2002 the water in Pattaya Bay was clean and safe for swimming (TAT no date).

The scale and type of operation are being realized as important factors in the success of coastal tourism development. Integrated tourism development has not been completely successful, even in developed countries. For example, in the Queensland coast of Australia the Integrated Resort Development Act provided a mechanism which did not fast-track development but instead set up a cumbersome assessment process (Craik 1991). The integrated resort also entails large investment and a longer-term return period for investors. BBIR has now planned smaller lots for development (*Business Times*, 12.2.2005). Within Southeast Asia small-scale and community-based sustainable coastal ecotourism has been implemented (Wong 2001).

For the Asia-Pacific region, sustainable management of coastal tourism would be within an appropriate coastal management programme that takes into consideration a wider range of coastal issues and the various coastal stakeholders.

For coastal tourism to be within a coastal policy framework, it is necessary to consider the problems that relate resource use conflicts and resource depletion to pollution or resource degradation (Noronha 2004). Coastal resources management plans and environmental impact assessments should be the top priority, and implemented before development takes place. For example, environmental impacts of tourism in the Pacific islands have much wider consequences and thus require broader interdisciplinary and inter-sectoral coverage within the mandate of the South Pacific Applied Geoscience Commission (SOPAC) and the South Pacific Regional Environment Programme (SPREP), while the South Pacific Tourism Organisation (SPTO) aims to promote sustainable coastal tourism activities.

The participation of three prime stakeholders – the local community, the tourist industry and the government – is necessary to attain sustainable development. The private sector is perhaps the most problematic. Often, it is difficult to convince private developers of the importance of preserving long-term environmental values. Both environment impact assessment and regional planning can assist in setting guidelines. Local groups could also be encouraged to take community-level responsibility for the conservation of the coastal resources and also to act as pressure groups on commercial tourism activities to conform to long-term, sustainable development goals (ESCAP 1995).

Coastal tourism development in Asia-Pacific will also respond differently as ecolabeling makes headway in the region, an indication that the industry is moving in the direction of more sustainable practices. In 1994 the World Travel and Tourism Council (WTTC) initiated the "Green Globe," an Agenda 21-based industry improvement programme. Green Globle aims to be the primary global standard of environmental commitment by the global travel and tourism industry. Currently, Green Globe Asia-Pacific, based in Canberra, provides the environmental certification program for PATA. This would affect hotels, golf courses, marinas, and protected areas in the coastal areas of the Asia-Pacific region. PATA's own Green Leaf programme merged with Green Globe in 2000. The Green Globe programme is active in Australia,New Zealand, China and Indonesia (Green Globe website). Countries with a higher percentage of tourists interested in natural attractions are seeing the advantages of environmental certification programmes. Since 1987, a certification scheme for beaches and marinas has been applied in Europe under the Blue Flag (an ecolabeling programe for beaches in Europe). UNEP supported a feasibility workshop on the

Blue Flag for Malaysia, Thailand and the Philippines in August 1999 but nothing has yet been implemented in these countries.

3.5.5 Conclusion

Coastal tourism in the Asia-Pacific region will continue to remain popular and will expand with increasing demand, especially from East Asia. At the same time, there will be increasing specialization in niche activities that will benefit islands and countries with more than just beaches. Coastal resorts are also increasingly aware of the importance of preserving the coastal environment and practice a more sustainable development. Within the coastal management framework, there is scope for more small-scale projects and community-based coastal tourism. Ecolabeling is likely to become more prevalent, especially with pressure exerted from the tourism industry of the developed countries inside and outside this region. An important point is the political will of individual countries to enforce laws and regulations to ensure sustainable coastal tourism development in the Asia-Pacific region.

References

Buckley R (2002) Surf tourism and sustainable development in Indo-Pacific Islands. 1. The industry and the islands. J Sustainable Tourism 10:405–424

Business Times, Singapore, 12.2.2005. Bintan Resorts hopes to bring back the buzz

Charoenca N (1993) Tropical coastal pollution: a case study of Pattaya. In: Hay JE, Chou LM (eds), Contributions to training in coastal zone management in the Asia-Pacific region and report of the first NETTLAP resources development workshop for education and training at Tertiary level in coastal zone management. UNEP/ROAP network for environmental training at Tertiary level in Asia and the Pacific. Publication no. 7, Bangkok, pp 123–142

Craik J (1991) Resorting to tourism. Allen and Unwin, North Sydney

ESCAP (1992) A preliminary study on environmental management of tourism development in the ESCAP region. UN, New York

ESCAP (1995) Guidelines on environmentally sound development of coastal tourism. UN, New York

Franz JC (1985) Part one: the seaside resorts of Southeast Asia. Tourism Recreation Res 10:15–23

Green Globe website. http://www.greenglobe21.com.

Hall CM (1991) Introduction to tourism in Australia: impacts, planning and development. Longman Cheshire, Melbourne

Hall CM (1994) Tourism in the Pacific Rim: development, impacts, and markets. Longshire Cheshire, Melbourne

Harada M (1994) Towards a renaissance of leisure in Japan. Leis Studies 13:277–287

Harriott VJ (2002) Marine tourism impacts and their management on the Great Barrier Reef. CRC Reef Research Centre technical report No 46, CRC Reef Research Centre, Townsville

Hildebrandt T (2003) What if all China golfed? Prospects for an environmentally-friendly and conflict-free golf industry in China. China Environ Ser 6:125–131

Horner S, Swarbrooke J (2004) International cases in tourism management. Elsevier Butterworth-Heinemann, Oxford

Inter Press Service, 13.2.1995. Asia-Pacific/environment: tackles problems of coastal tourism

Jung P (1999) Development potential and future direction of marine tourism in Korea. Ocean Policy Res 14:1–15

Kim SG, Kim EYJ (1996) Overview of coastal and marine tourism in Korea. J Tourism Studies 7:46–53

Mak J, White K (1992) Comparative tourism development in Asia and the Pacific. J Travel Res 31:14–23

Muqbil I (1991) Overview of tourism development in the Asian region. In: Tourism development in the Asian region – ESCAP. Tourism Rev 7:15–141

News@PATA 17.11.2004. Seven dominant forces in travel today.

Noronha L (2004) Coastal management policy: observations from an Indian case. Ocean Coastal Manag 47:63–77

Pleumarom A (1996) Environmental and socioeconomic implications of tourism in South-East Asia. In: State of the environment in Malaysia. Consumers' Association of Penang, Penang, pp 314–323

Rimmer PJ (1992) Japan resort archipelago – creating regions of fun, pleasure, relaxation and recreation. Environ Planning A, 24:1599–1625

Smith RA (1992a) Coastal urbanization: tourism development in the Asia-Pacific. Built Environ 18:27–40

Smith RA (1992b) Review of integrated beach resort development in Southeast Asia. Land Use Policy 9:209–217

TAT (Tourism Authority of Thailand), no date. E-magazine. The rehabilitation and renaissance of Pattaya: a vital role model for sustainable tourism. (http://www.tatnews.org/emagazine/1957.asp).

Traisawasdichai M (1995) Chasing the little white ball. New Internationalist, January 1995, 263:16–17

UNEP (2001) Asia-Pacific Environment Outlook 2. UNEP RRCAP

UNESCAP Statistics Division (2004) Asia-Pacific in figures. Database updated on 11 March 2004

Wong PP (1990) The geomorphological basis of beach resort sites – some Malaysian examples. Ocean Shoreline Manag 13:127–147

Wong PP (1998) Coastal tourism development in Southeast Asia: relevance and lessons for coastal zone management. Ocean and Coastal Manag 38:89–109

Wong PP (1999) Adaptive use of a rock coast for tourism, Mactan Island, Philippines. Tourism Geogr 1:226–243

Wong PP (2001) Trends in coastal ecotourism in Southeast Asia. UNEP Industry Environ 24(3–4):20–24

Wong PP (2003) Tourism development and the coastal environment on Bintan island. In: Gössling S (ed) Tourism development in tropical islands: political ecology perspectives. Edward Elgar, Cheltenham, pp 263–282

Wong PP (2005) Tourism, criteria for coastal sites. In: Schwartz M (ed) Encyclopedia of coastal science. Kluwer, New York, pp 1249–1253

World Tourism Organisation (2004) Yearbook of tourism statistics data 1998–2002. 2004 edn. Madrid

Xiao H (2003) Leisure in China. In: Lew AA, Yu L, Ap J, Zhang G (eds) Tourism in China. Haworth Hospitality Press, New York, pp 263–275

Zhang G, Lew AA (2003) Introduction: China's tourism boom. In: Lew AA Yu L, Ap J, Zhang G (eds) Tourism in China. Haworth Hospitality Press, New York, pp 3–12

3.6 Oil Spills: Impacts and Responses

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3.6.1 The First "Shoreline Shock" in the World

Looking back on the history of oil spills, many countries started to develop their own response systems after they experienced large-scale accidents with serious environmental consequences. The world's first such case was the sinking of the Liberian supertanker, the *Torry Canyon,* at Lands End, off the coast of southwest England in March 1967 (Fig. 3.6.1). As a result of the accident approximately 93,000 kl of crude oil on the ship spewed out, and contaminated a total distance of about 300 km along the southwestern coastline of England and the northwestern coastline of France.

Fig. 3.6.1. Image of Torrey Canyon in 1967. (From http://www.lboro.ac.uk/departments/hu/ergsinhu/aboutergs/lasttrip.html)

It is well recognized that the accident triggered a reexamination of the direct application of the "polluters pay principle". After the first attempt by a Dutch company to salvage the vessel failed, the tanker owner, Bermuda Tanker, abandoned its ownership. Nothing was done to the wrecked ship for about 10 days. Finally the UK government decided to bomb the ship using a Royal Navy fighter jet, as they realized the polluter showed no "good will" to clean up the wreckage and respond to the spill. Although the accident brought about enormous environmental damage, it also promoted the establishment of the Marine Pollution Control Unit (MPCU) in the UK, as well as the Fund Convention in 1971 and the International Convention for the Prevention of Pollution from Ships in 1973.

Oil Spills Around the Northwest Pacific Region

In general, people are likely to think that oil spills, such as the one caused by the huge wreckage of the *Torrey Canyon,* occur only rarely. But if small-scale spills are included, they are, in fact, quite frequent. Spills of over 2 kl occur 400 times or more a year in Japanese waters alone. Table 3.6.1 lists the large-scale accidents that occurred in Japan, South Korea, China, and Taiwan between 1992 and 2001.

TABLE 3.6.1. List of oil spills occurring around the Northwest Pacific region. (From Sawano 2003.)

Date (YMD)	Country	Location	Vessel	Amount	Type of oil
1992.5.1	Japan	Kushiro, Hokkaido	Shell Oil base	246 kl	Unknown
1993.9.27	South Korea	Jeonnam Yeocheonsi, east coast of Myo Island	*Gumdong No.5*	1,228 kl	Heavy B–C
1994.10.17	China	Qinhuangdao, Hebei	*Fwa Hai No.5*	Unknown	Unknown
1995.7.23	South Korea	Jeonnam Yeocheonsi Sori Island	*Sea Prince*	5,035 kl	Crude/bunker
1995.9.20	South Korea	Busan South Hoyongie Island	*No. 1 Yuilu*	Unknown	Unknown
1995.11.17	South Korea	Jeonnamyeosu Honam Oil Refinery berth	*Honam Sapphire*	1,402 kl	Crude
1996.9.19	South Korea	Nine miles from Jeonnam Yoso Island	*Ocean Joedo*	207 kl	Heavy B–C
1997.1.2	Japan	Near Oki Island, Shimane Pref.	*Nakhodka*	8,660kl*	Heavy C
2001.1.17	Taiwan	Kenting National Park	*Amorgos*	1,150 kl	Bunker
2001.3.30	China	Mouth of Yangtze River	*Deiyong*	700 kl	Styrene

* This volume is based on Sao (1998), official value announced by Japan Coast Gourd was 6,240 kl.

Both Korea and Japan experienced “shoreline shocks” relatively recently. After the accidents they started to revise their spill response and disaster management systems. Before these shocks the two countries employed quite similar systems and legal provisions for oil spill accidents. But in the past few years the systems used by each country have become highly differentiated. Problems that are derived from the different approaches used by each country, and the possibility of a uniform approach to tackling oil contingencies, will be discussed in the following sections.

Sea Prince: A Case in Korea

Accident. On June 28, 1995 the oil tanker *Sea Prince* loaded 260,000 t of crude oil at Nastanu Port in Saudi Arabia. About 3 weeks later she arrived at the off-coast loading bridge of Kwan-Yang Port, South Korea, and started unloading her cargo. During this operation the tanker received an emergency message on 22 July warning her of a typhoon named “Fay.” She immediately tried to escape to the safe zone in the bay.

While trying to escape the typhoon, she first collided with a reef near Sori Island due to the extreme weather conditions (Fig. 3.6.2). After the collision a fire started in the engine room. This stopped her main engine. Weather conditions at that time were classified as “Class A (Maximum) Typhoon Warning” under the Korean system, with wind speeds of 40 m/s and a wave height of about 8–10 m. The center of the typhoon registered an atmospheric pressure of 940 hPa and the storm area occupied an area 890 km in diameter. The tanker lost control and finally grounded on submerged rocks 27 miles away from

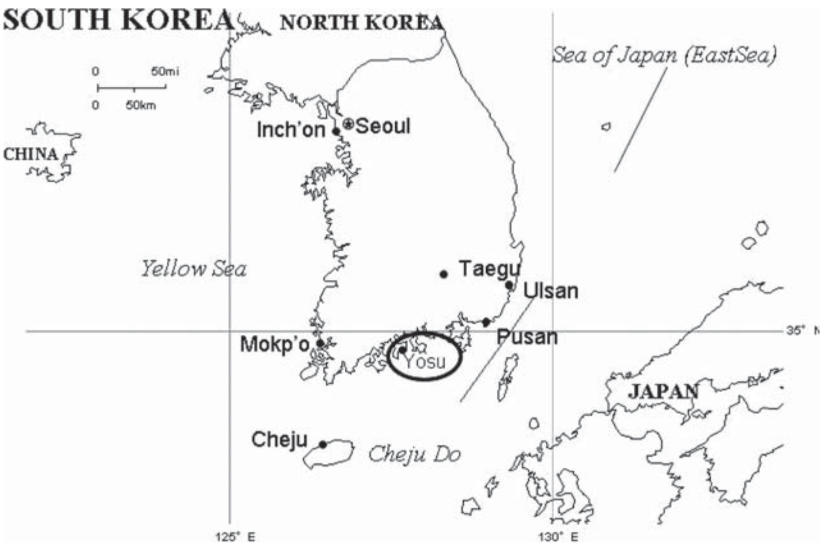

FIG. 3.6.2. Location of *Sea Prince* in 1995.

FIG. 3.6.3. The *Sea Prince* on fire near Yosu, Sori Island. (From Korean Ministry of Maritime Affairs and Fishery 2002.)

Gwang-Yang near Sori Island Port on July 23. The incident resulted in an oil spill of 5,035 t of crude, including fuel oil.

Area of the Oil Spill. Oil spilt from the ship spread a little more than 200 km along the coasts of Geo-Je, Busan, Ulsan, and Po-Hang from 25 km off the coast of Sori Island. The oil slick was even found in the sea 32 km away from the west coast of Tsushima Island, Japan. Discharged oil polluted 73 km of shoreline along many islands along the south coast of Korea, including the coastlines of Jeon-Nam Province (47 km) and those of Busan and Gyung-Nam Province (26 km). The most seriously affected area was along Sori Island. A large number of tar balls were beached on Busan and Ulsan (Lee 2001).

Success in Fighting the Fire. Fire first broke out in the engine room of the ship, as it lay on submerged rock. It was impossible to put out the fire, and it spread to the cargo tank. This could have resulted in the hull of the tanker

Fig. 3.6.4. Example of oil-covered shoreline. (From Korean Ministry of Maritime Affairs and Fishery 2002.)

Fig. 3.6.5. Oil-contaminated aquaculture facility in Yasu. (From Korean Ministry of Maritime Affairs and Fishery 2002.)

exploding. A salvage and patrol ship of the Busan Maritime Police Station, a 3,000 t (G/T) class vessel, arrived at the site of the accident at 16:00 on July 24, and fought the fire magnificently for about 4 h. Thanks to their success, it was possible not only to prevent the fire from engulfing the cargo tanks but to also successfully reload most of the tanker cargo to a barge, thus preventing a spill of as much as 88,000 t of oil.

In the evening of the same day an oil recovery vessel of the Korean National Maritime Police Agency (KNMPA) deployed an 864 m boom around the tanker to prevent oil from mobilizing. But by that time a considerable quantity of oil had already discharged into the open sea. High waves hindered recovery work until July 25, 1995.

Oil Recovery Work. Although large-scale oil recovery work started on July 25, the response to the spill was filled with difficulties because, as mentioned above, the oil had already spread to the open ocean. KNMPA had to call out ships, oil-combating equipment and materials from relevant governmental organizations, as well as private companies, from all over Korea. As many as 500 ships each day, including fishing boats, were mobilized for the task.

According to Lee (1997), 1,390 kl of discharged oil was recovered by large sized "trawl skimmers" and "screw skimmers". However, the main cleanup operation had to depend on sorbent and dispersant application. In fact, most ships mobilized by KNMPA had no equipment for recovering oil from the sea.

Along with KNMPA's cleanup operation, aerial dispersant spray onto the open sea was carried out by a professional oil spillage company, EARL of Singapore. However, the dispersant application method became a hot issue in the media, and later with policy makers (Lee 2005). Marine cleanup operations were carried out for a period of 19 days from July 25 to August 11, 1995 (Korean Ministry of Maritime and Fishery 2002).

Shoreline Cleanup. Discharged oil was stranded on the shorelines of 38 coastal villages of Jeon-Nam Province and 13 coastal villages of Busan and Gyung-Nam Province (Lee 2001). Firstly, screw skimmers and portable high-pressure pumps were used to recover thick, belt-like stranded oil on the shoreline of Sori Island. After that, oily wastes were recovered by trucks, and the oily shorelines were swept by ships. Moreover, weathered oil and oily wastes were recovered manually with ladles and shovels, mainly by policemen and local residents. People even wiped off oil adhering to the surface of rocks and stones, using rags and sorbent. Stranded oil penetrated into the subsurface of the beach so excavators for construction were used to recover oily sand gravel. This was washed by sorbent and dispersant. This mechanical removal was carried out mainly around Sori Island as the island was heavily contaminated. Other areas deluged by oil were cleaned largely by hand. Many people and a great deal of time were thus required for the cleanup. To make matters worse, the accident occurred in the summer season, so the high temperature made the stranded oil lose viscosity. Low viscosity oil was hard to recover, so cleanup operations along the shoreline had to be carried out for 5 months from July 25 to December 31, 1995 (Lee 2001).

Nakhodka: A Case in Japan

On January 2, 1997, the Russian tanker *Nakhodka* was navigating towards Petropavlovsk-Kamchatski in the Sea of Japan, carrying 19,221 kl of heavy

C oil. Approximately 100 km off Oki Island she broke into two sections in heavy seas with an 8-m effective wave height, and spilled approximately 8,660 kl of oil. There are two estimations for the amount spilt: one is based on the Ishikawa Prefectural Government and other authorities – 6,240 kl (e.g., Ishikawa Prefectural Government 1998), while the other is Sao's estimation of 8,660 kl (Sao 1998). The latter estimation should be more plausible because a "formal value" was obtained only from the capacity of her oil tanks and neglected loading manual violations as well as leakage while the tanker was drifting toward Mikuni Town.

The tanker could not resist the force of the bending moment raised by the wave action in the gale; she broke into two sections. The major section of the ship sank to the sea floor at 2,500 m, with about 10,000 kl of oil remaining in her tanks. The remaining bow section of the ship turned upside down and drifted for 5 days in the current, until waves and wind finally grounded it on the coast of Mikuni Town, Fukui Prefecture on January 7, 1997.

Cause of the Accident. The cause of the accident was investigated through an underwater survey of *Nakhodka* using an ROV (Remotely Operated Vehicle) as well as a comprehensive check of the grounded bow section. The survey concluded that the *Nakhodka* had been very poorly maintained and that her strength had decreased to two thirds of its original construction. Furthermore, the oil was not loaded properly and did not follow the loading manual of the tanker. The arrangement of cargo was so inadequate that the resulting longitudinal bending moment was twice the value of the normal cargo oil arrangement specified in the ship's operation manual (Sao 1998). Besides

FIG. 3.6.6. Location of the *Nakhodka* accident. (From Sawano 1998.)

this, the severe winter weather finally triggered this accident. In this area, "typhoon-like weather" is common from December to mid-February.

Recovery Work with Five Casualties. The *Sea Prince* was a case of combating "high temperatures" in summer, while the *Nakhodka* was a case of "low temperatures and snow" in winter. More than 270,000 volunteers (unit = person-days, this figure is quoted from http://www.city.inazawa.aichi.jp/koho_back/2001_08_01/2001_08_01npo.html but there are some other estimations) were said to have joined the recovery works at various places along the oil-stranded beaches. Discharged oil affected more than 1,300 km of shoreline, including nine prefectures and 88 cities and towns.

The affected length of the shoreline is one of the most conspicuous characteristics of this type of accident. The worst tanker accident, the *Amoco Cadiz*, occurred in France in 1978, in which NOAA HAZAMT (1992) reported 257,429 kl of crude (about 30 times as much as in the case of the *Nakhodka*) was discharged and 320 km of shoreline was contaminated. An even worse accident occurred in the US waters with the *Exxon Valdez* in 1989, in which 41,256 kl was spilt and 1,600 km of shoreline was contaminated (http://www.facts.com/cd/v00034.htm). Yet, the *Nakhodka* polluted a far wider area when the specific discharged volume is compared.

Stranded oil was heavily emulsified (actual kinematic viscosity was over 100,000 cSt) and thus jet pumps for drainage were used along some parts of the shoreline in Ishikawa Prefecture. Emulsified oil is extremely hard to treat, and most recovery work had to depend on manual removal in snowstorms. Recovery work on shorelines was carried out until the end of April. During these activities as many as five local volunteers died of fatigue.

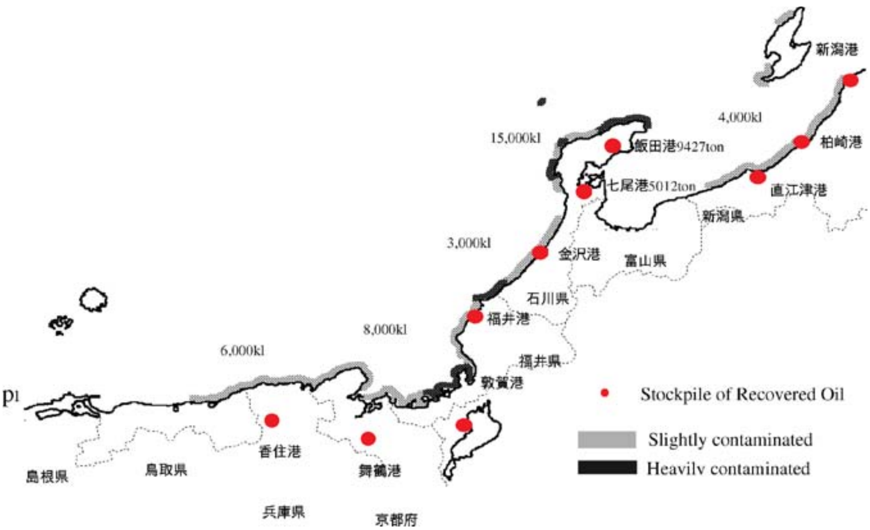

FIG. 3.6.7. Contaminated shoreline. (From Sao 1998.)

At that time, Japan did not have either national or regional contingency programs for such large-scale oil pollution. Countermeasures were taken only to meet immediate needs, with little formal planning. Volunteer efforts were not always effective because there were too many of them in the Mikuni area where the bow section was grounded while some other shorelines were left uncleaned.

So many inappropriate cleanup activities were also carried out here and there. Use of chemical solvents has to be a good example. Exxon's chemical solvent, *ISOPAR H*, was actually used not only for washing the cleanup crews' property such as clothes and gloves, but also for wiping the oil off the rocks. An important fact is that Mikuni Town officials explained that *ISOPAR H*

FIG. 3.6.8. Volunteers and local people form a "Human Chain" to recover oil at Mikuni Town. (Courtesy of the Marine Disaster Prevention Center of Japan.)

平成9年（1997年）1月22日 （水曜日） 社会2 （24）

悲報に生徒らぼう然

「疲れ残っていたのでは」

重油回収中 死亡の松原さん

松原さんも中にいたとみられる現場の油除去作業。この約30分後、松原さんは倒れた＝21日午前10時35分、珠洲市長橋海岸

強風の中、土のう運搬

珠洲の重油回収

ボランティア登録の教諭急死

荒天の作業で疲労か

松原茂樹さん

FIG. 3.6.9. Local newspaper article reports the death of Shigeki Matsubara, a school teacher from Wajima City, who participated in the oil-recovery work along the Nagahashi Coast of Suzu City.

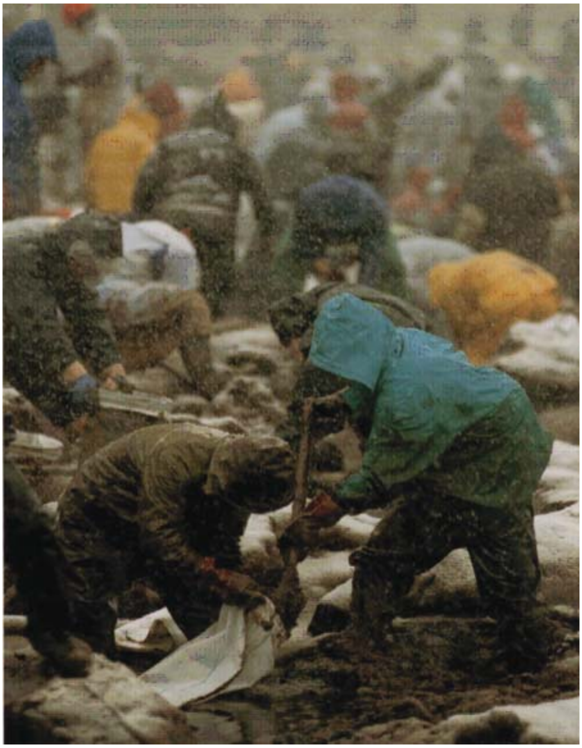

Fig. 3.6.10. Recovery work was a fight against snow and stormy weather. (Photo taken at Nagahashi Coast, Ishikawa Prefecture, courtesy of Hokuriku Chunichi Shinbun Co. Ltd.)

was an "earth-friendly detergent" and they recommended volunteers use it for recovery work. Volunteers believed this "official information", so some workers washed their hands and even their faces with it because public officials had said that *ISOPAR H* was "Senzai", which means detergent or soap in Japanese (Sawano 1998).

Chinese characters on the container mean "detergent" or "soap" in Japanese. Oil-recovery works were maintained for about 3 months. Finally about 50,000 t of oil and oiled wastes were recovered. Most of the recovered materials were incinerated in industrial waste facilities. It took more than 2 years for final disposal.

Most local authorities made "declaration of safety" at the end of April 1997. This declaration involved "political judgment" for prevention of harmful rumors and other effects. Most of the oiled areas were located in good fishery and tourist resorts. This short-term activity caused insufficient cleanup and some part of the shoreline was left uncleaned. Consequently, heavy contamination can be seen in some places of Noto Peninsular even 7 years after the accident.

FIG. 3.6.11. Even a small child joins in the recovery work. (Photo taken at Kotobiki-Hama, Kyoto Prefecture, courtesy of Hokuriku Chunichi Shinbun Co. Ltd.)

After the "Shoreline Shocks"

The Korean Situation. Through the response to the *Sea Prince* disaster a fundamental defect in the incident command system was revealed. Before the accident the responsibility for response to an oil spill had been distributed among the Marine Transport Bureau, prefectural and local governments and KNMPA. In this situation many ships were engaged in oil recovery, but their performance with regard to collection was very poor. Reflecting on the accident, the Korean government started working on changing the Marine Pollution Prevention Law from November 1998. According to Mok (1990) their main revisions are quite similar to those of the US and Canada and can be summarized as follows:

- Centralize response authorities and their responsibilities in the hands of one on-the-scene coordinator.
- Adoption of a "tier" approach; each spill to be classified into three levels with regard to the anticipated volume of spill, such as large (tier-3), medium (tier-2) and small (tier-1).

Fig. 3.6.12. A local volunteer tries to "cut" emulsified oil with a knife. High viscosity made recovery work extremely difficult. (Courtesy of Hokuriku Chunichi Shinbun Co. Ltd.)

Fig. 3.6.13. Containers of the chemical solvent *ISOPAR H*. (From Sawano 1998.)

FIG. 3.6.14. Heavy oil contamination can be seen at a few centimeters below the surface of the gravel beach. (This photo was taken on October 3, 2004 at Shakuzaki inlet in Suzu City where 150 km remote from the tanker grounded site. These heavy oil residues and contaminations can be observed here and there around Noto Peninsular even today.)

- Professional working groups for combating oil spills, called "scientific support coordinators" (SSCs), to be organized to support the on-the-scene coordinator for effective spill response.
- Levying defrayment for marine environment remediation; the defrayment is aimed at the restoration and remediation of fisheries.
- Setting up the Korean Marine Pollution Response Corp (KMPRC), a cooperative association funded by energy companies.

Before 1995, both the authorities and people in general had little interest in oil spills or marine environment pollution. The response capacities of national agencies was so poor that they kept only ten 140-t-class oil collection vessels, 34 oil skimmers and little more than 7 km of oil boom (Lee 2001). As for oil spill-combating materials, such as dispersant and sorbent, their quantity was also very limited for an initial response. Since the *Sea Prince* accident the central government has set 10,000 t of response capacity as the numerical target of the National Marine Police Agency, and they have started to improve their capabilities. Their final goal is to deploy 23 collection vessels, 84 skimmers, six "500-G/T-class" barges, and 220 response personnel by the end of 2004.

To improve the private sector response capability, KMPRC was established in November 1997. As of 2001, KMPRC was composed of four departments and 10 sections with 398 staff involving five oil purification, seven oil storage and 84 oil transport companies. The government has set 5,000 t of response capacity as the numerical target for KMPRC by the end of 2004. Other than KMPRC, 23 companies have been registered as oil spill response contractors and they had 36 oil collections vessels, 191 skimmers and 180 km of oil booms as of February 2001. The government also has set 5,000 tons of response capacity as their numerical target.

As of February 2005 more than 70% of the numerical targets had been achieved (Mr. Lee Bon-gil, Director General of the Marine Pollution Bureau of KNMPA, 2004)

A scheme for international cooperation for marine environmental protection, the North-West Pacific Action Programme (NOWPAP) is one of the regional action plans advocated by the United Nations Environmental Progamme. The programme consists of four member countries: Korea, China, Russia, and Japan. An environmental monitoring programme called "NOWPAP/4" has been focusing on oil spills. The Korean government established the "Marine Environmental Emergency Preparedness and Response Regional Activity Centre (MER/RAC)" in Taejon in March 2000 (http://merrac.nowpap.org/).

The Japanese Situation. The initial response to the *Nakhodka* disaster was delayed because the accident occurred outside Japanese waters. Another, but more important reason was that government authorities could not identify "who should bear the cost". In view of this some provisions have been added to the Marine Pollution and Disaster Prevention Law. The following two points are the main revisions concerning response to oil spills (Sawano et al., 2005):

- The Director of the Japan Coast Guard (JCG) was enabled to "order" the relevant organizations to respond to a spill in the case of an accident outside Japanese waters. (Chapter 41 section 2, added in 1998)
- The Director of the JCG or other response directors (assumed to be local governors) can make advance payments for response to spills such as oil recovery and shoreline cleanup, and then ask the polluters to reimburse them. (Chapter 41 section 3, added in 1998)

References

Ishikawa Prefecture Government (1998) Formal archives for the Russian Tanker Nakhodk oil spill (in Japanese)

Korean Ministry of Maritime Affairs and Fisheries (2002) White papers on marine pollution of the *Sea Prince* oil spill accident. (Korean official report of the accident)

Lee C (1997) Present status of Korean marine oil pollution and systems for oil spill prevention and preparedness. (In Japanese) Reports of international symposium on the preservation of the environment of the Japan Sea, Dec. 12, 1997. Kanazawa. Faculty of Economics, Kanazawa University pp 36–46

Lee B (2001) Changes in oil spill response system after the Sea Prince accident. (In Japanese) Reports of international symposium of changes on OSR system in major countries/recent movements in the compensation scheme. March 1–2, 2001. Tokyo. Petroleum Association of Japan. This material can be obtained from the following URL: http://www.pcs.gr.jp/doc/jsymposium/2001/2001_lee_bong_gil_j.pdf

Mok J (1999) Preparedness for oil spill and establishment of national contingency plan on a rational legal basis. (In Korean) This material can be obtained from http://www.riss4u.net.
NOAA HAZMAT, 1992. Oil spill case histories 1967–1991
Sao K (1998) Cutting down oil spill response system. (In Japanese) Heavy oil pollution: For tommorow, Can "Nakhodka" change Japan? Ocean Engineering Research, pp 372–431
Sawano N (1998) What has happened after the Nakhodka's oil spill, Recent advances in marine science and technology, *98*. PACON International, Pp 245–252.
Sawano N (2003) Marine pollution of Japan Sea. (In Japanese) White paper on the Asian environment 2003/04. Toyo-Keizai-Junpou-sha, pp 158–173
Sawano N (2004) Sakhalin's oil: outline of the world biggest energy development projects. Proceedings of the fifth APEC round table meeting on the involvement of the business/private sector in the sustainability of the marine environment, Asian-Pasific Economic Cooperation Marine Resource Conservation Working Group, II 1–1 to 1–16.
Sawano N, Yazaki N, Goto S, Sao K, Sao K, Yeahee Y (2005) Oil spill contingency plans: difference between Korea and Japan, recent advances in marine science and technology, 2005. PACON International (in press)

4
Policy for Conservation and Sustainable Development of the Coastal Zone

Chair: Nobuo Mimura, Asami Shikida, and Masahiro Yamao

4.1 Trends and General Concepts in Integrated Coastal Management (ICM)

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4.1.1 International Trends in ICM

Since the 1970s all countries have faced serious marine and coastal pollution, and have been forced to resolve these problems. For instance, Japan has long suffered from frequent occurrences of "Red Tide" in semi-enclosed bays and inland seas. This is symbolic of widespread marine pollution. On the other hand, the USA was challenged by diminishing and degradation of coastal wetlands, and the decline of fishery resources. In parallel with these local problems, global environmental issues have emerged since the late 1980s, including global warming, ozone layer depletion and marine pollution.

In face of such an increase in both local and global environmental problems, Integrated Coastal Management (ICM) has received increasing attention globally as a policy tool that leads to a comprehensive framework to address multiple management issues in coastal areas. Major international organizations such as World Bank (1993), The World Conservation Union (IUCN 1993), United Nations Environmental Programme (UNEP 1995), and OECD (1995) have published ICM guidelines. These initiatives were triggered by Agenda 21, the action plan for the protection and conservation of the global environment adopted at the Earth Summit (UNCED) held in 1992. Its Chapter 17, which has a long title "Protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas, and coastal areas and the protection, rational use and development of their living resources", is devoted to the protection of marine and coastal environments. These guidelines and action plans contain some common concepts and methods, as summarized in Table 4.1.1 (Kojima et al., 1999).

N. Mimura (ed.), *Asia-Pacific Coasts and Their Management: States of Environment.*

Table 4.1.1. Common elements of integrated coastal management in international guidelines.

Item	Description
Purpose	To harmonize use/development and environmental protection in the coastal zones, then to achieve sustainable coastal development
Philosophy	To follow the principles confirmed in the UNCED, such as Intergeneration Equity Principle, Precautionary Principle, and Polluter-Pay Principle ICM is an integrated and multisectoral policy based on assets of scientific knowledge and information
Functions	To harmonize and strengthen the sectoral management To conserve and protect biological diversity and productivity of the coastal zone, and to maintain its authentic and cultural values To promote rational economic development and sustainable use of coastal/marine resources, and to help stakeholders to resolve constraints between them
Spatial integration	ICM planning covers all areas associated with it, both land and ocean Seaward boundary extends to the edge between coastal sea and ocean, covering all the areas of territorial seas and exclusive economic zones (EEZ). Each Government has responsibility to manage these areas according to UN Convention on the Law of the Sea and UNCED Action Plan
Horizontal and vertical integration	Major purpose of ICM is to remove obstacles such as competition among sectors and segmentalized management schemes in the coastal zones ICM's basic role is to coordinate, effectively and efficiently, conflicting planning and activities among sectors and among different administrative organizations Such coordinating mechanisms should be designed based on the traditional background and characteristics of each country
Science and technology	Future prediction of the coastal environment is uncertain to some extent, because the coastal zones consist of complex systems and processes. Therefore, ICM planning should use the latest scientific knowledge, both natural and social. Implementation of ICM should be also based on appropriate techniques such as monitoring, risk assessment, vulnerability assessment, resource analysis, and cost–benefit analysis

The common understanding behind such concepts is that coastal zones are a unique resource system which needs special management. Their characteristics are highlighted by high-biological productivity, high environmental variability caused by dynamic physical forces such as waves and currents, and active interaction between land and ocean. Based on this spatial nature of the coastal zones, concepts emphasized for management are:

- To give priority to biological resources rather than nonbiological ones; also nonexclusive and renewable uses should be given higher priorities than exclusive and nonrenewable uses.
- Because of the public nature of marine resources, public management is needed for marine and coastal resources. Constraints between multiple stakeholders should be resolved on a public and equitable basis.

- Fair solution should be achieved for the competition around benefits among different users. In all processes of ICM, participation of the local communities and stakeholders should be promoted.
- International cooperation is needed to resolve trans-boundary issues.

These concepts reflect the multiple nature of the coastal zone; i.e., precious and vulnerable environment and at the same time a rich resource system. They recognize that the coastal zone is not merely passive environment which is subject to varying external forces, but is a space which provides human society with a variety of benefits, such as space for development and economic resources. However, in order to continue such benefits into the future, wise use of coastal zones is essential, recognizing their fragile nature. ICM is thus necessary as a management framework.

In 2002 the World Summit on Sustainable Development (WSSD) was held in Johannesburg, South Africa, to follow up on developments since the 1992 Earth Summit. This conference reviewed the implementation of Agenda 21, and future directions and action plans were contained in the Declaration on Sustainable Development and Plan of Implementation. The Plan of Implementation requests coastal countries to ratify the United Nations Convention on the Law of the Sea and to implement Chapter 17 of Agenda 21 to promote sustainable development in the coastal zones. These movements show that during the past decades the necessity for ICM has been widely recognized in the world, and its goals and concepts have been expanded.

4.1.2 Characteristics of Coastal Management in the Asia and Pacific Region

Consistent with the preceding global developments, Asian countries have also moved toward introducing and establishing ICM frameworks. In China, to respond to increasing pressures of population and economic development on the coastal environment and resources, the Government has developed a framework for ICM. Chinese Ocean Agenda 21 was released in 1996, and the National Sea Area Use Management Law was enacted in 2001. This is the basis of today's coastal zone management in China. At the same time, most of coastal provinces and municipalities took the initiative to develop local regulations for sea area uses. In this way, China has incorporated the issues of wise use and the protection of coastal resources and environment into national and local coastal and marine policy (PEMSEA 2003a).

Korea also has developed the framework for ICM and coastal resource use. These efforts were accelerated by establishment of the Ministry of Maritime Affairs and Fisheries in 1996. This governmental agency took an initiative to establish an integrated coastal and ocean governance system, which was strengthened by legislative, such as the enactment and amendment of the Coastal Management Act, the Marine Pollution Prevention Act, and the Wetland Conservation Act in 1999 (PEMSEA 2003b).

Japan's major actions toward ICM were the amendments to the Coast Act in 1999, the enactment of the Fishery Basic Law, and amendments to other marine and coastal related laws. In spite of such progress, Japan is still seeking a way to develop a comprehensive framework for ICM.

As an initiative for collective international efforts in the East Asia region, Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) was established in 1994 with the support of the Global Environment Facility (GEF), the United Nations Development Programme (UNDP), and the International Maritime Organization (IMO). Currently twelve countries are PEMSEA members. Its activities cover a wide area of protecting life support systems and enabling the sustainable use and management of coastal and marine resources through intergovernmental and multisectoral partnerships. These activities mean that the concept of ICM has been widely accepted by governments and regional organizations. In some countries and areas it has already reached the implementation stage.

At the same time, today's trend of coastal management is a recent development in the region compared with long-established traditional practices. Moreover, approaches to coastal management in the Asia-Pacific region are quite diverse. In most countries, at a local level, there still exists a range of traditional customs and sometimes sea tenure systems that govern access to coastal resources. These practices underlie, and in many cases, coexist with recent forms of coastal management derived from western models of centralized environmental management (APN 2005).

These traditional approaches have shown remarkable resilience over time. They are flexible and responsive to local circumstances. The goal of these approaches is to sustain resources, such as fisheries, by modifying rates and patterns of harvest depending on local resource availability. This approach is entirely consistent with modern concepts of sustainability, but it is seldom recognized and protected. In contrast, many countries in the region have adopted western models of coastal management, which have tended to be formalized and prescriptive, highly centralized, and hierarchical. There are fundamental difficulties applying this western model of coastal management in the region, where emphasis has been on conflict resolution between competing users of coastal resources, with few constraints on urbanization and other development.

In Southeast Asia there are many pressing problems related to the coastal environment and to development, including decrease and degradation of mangrove forests and wetlands, water pollution from land- and marine-based sources, destruction of coral reefs due to illegal fishing and uncontrolled tourism uses. Coral reefs are also victims of bleaching caused by increased sea surface temperatures, which are in turn a result of global environmental changes like El Nino and warming. On the other hand, as the coastal ecosystem is a resource base for the local economy and well-being of the local population, countries of this region tend to rely more and more on community-based management of coastal zones. In many places good practices have been created in terms of community-based management which involves local government, local enterprises, self-employed individuals, and other inhabitants. Coastal assets are important both for economic base and as environmental heritage, and local organizations and inhabitants use coastal zones as users and environmental managers. As a result, community-based management will become more important and predominant in order to overcome the constraints of environmental protection and development in the Asia and Pacific region.

As mentioned above, different types of coastal zone management with different concepts and background are on-going in the region. The management varies with target coastal systems and countries as well. This chapter will present an overview of the present situation, and lessons learnt focusing on the coastal systems and some countries.

References

Asia Pacific Network for Global Change Research (2005) Global change coastal zone management synthesis report, 37p

Kojima H, Gomyo M, Mimura N (1999) Development of coastal zone management, its directions and countries status. J Japanese Assoc Coastal Zone Studies 11:1–20

PEMSEA (2003a) The development of national coastal and marine policies in the People's Republic of China: a case study, 63p

PEMSEA (2003b) Case study on the integrated coastal policy of the Republic of Korea, 57p

4.2 Management of Coastal Systems

The previous section has highlighted the need for an integrated approach to coastal management. The following sections describe the importance of key coastal systems in the Asia-Pacific region, and the issues related to their effective management as part of the integrated approach to coastal management.

4.2.1 Wetlands

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Functions of Wetlands

To need to adopt integrated coastal management approaches for wetland areas is generally well known. This is because there is considerable literature on the nature and properties of wetland ecosystems. However, how to undertake such integrated management is far less understood, due to the multiplicity and diversity of processes and objectives that must be considered. The great importance of the subject has been summarized by describing wetlands as "the kidneys of the landscape" or "biological supermarkets" (Mitsch and Gosselink 2000).

The former highlights the important regulative activities of the water regimes, as the downstream receivers of water and waste from natural and human sources, stabilizing water supply and ameliorating floods and drought. Such activities of wetlands result from their positioning at the interface of land and sea. At the same time, wetlands are biological filters, changing the quality of percolated water by adsorbing or releasing nutrients, decreasing suspended matter, and retaining many pollutants (Haslam et al., 1998). The activities are affected not only by the physical nature of the vegetation structure but are also dependent on the microbial synthesis in its surface and in water, conducted by plankton, metaphyton (plankton of interstitial water), and periphyton (attached algae and microorganisms).

The description of "biological supermarket" refers to the extensive food chain and rich diversity of wetlands, with their unique habitats for a variety of flora and fauna. Nevertheless, wetland vegetation is often considered to be a uniform field of a single plant species because of its dominancy. It can be referred to as a "biotope", defined as the subdivision of a habitat, characterized by a high degree of uniformity in its environment (Burchfield 1986). Therefore, habitats of the main components of the biotope ecosystem, which sometimes include dragonflies, must also be investigated in support of management. Rice paddy can also be categorized as a biotope, based on several arguments (Kuwabara 2002).

The definition of wetlands in the *Oxford English Dictionary* is a simple sentence that defines wetlands to include marshes, bogs, swamps, and any still water less than 6m deep (Burchfield 1986). But these isolated water bodies are not consistent with the uniformity of wetlands. Therefore several kinds of the definition, including hydrological, geomorphological, and biological elements, were proposed by Mitsch and Gosswelink (2000). The definitions covered most aspects except legal definitions related to conservation. Definitions are distinguished by regional properties, nature of the water bodies, seasonal changes and others, making it necessary to apply them on a case by case basis. Thus, choosing definitions becomes an important part of the management practices.

Classification of Wetlands and Their Characteristics

Here the types of wetlands are examined from the perspective of uniformity in the aquatic plant vegetation. The global-scale domains of plant communities and geomorphologic patterns are fundamental to this approach. Water bodies found in wetlands are classified according to form. They are normally such as (i) mire: muddy soil sufficient to stop a car; (ii) bog: muddy but hosts mosses and low grasses; (iii) fen: a wet- and lowland of moderately big – size; (iv) marsh: grassy with sedge (*Carex*), cattail (*Typha*), and rush (*Juncus*), among others; (v) swamp: accompanying bush or trees; and (vi) any still water less than 6m deep (Burchfield 1986; Kuwabara et al., 2003). Arctic tundra in the coast of the Eurasian Arctic is sometimes called the"tundra bog-belt" due to the presence of numerous bogs and mires of various sizes. This is due to less precipitation (1/5 of that in tropical forest areas) and evaporation (Chernov 1985).

Sometimes marsh is the focus of wetland investigations. This is because large-sized salt marshes are frequently a target of ecological studies. As they are located mostly in the ocean coast the waters are filled with seawater or brackish water variously diluted, as in some estuarine areas. Plants of salt marshes are normally emergent macrophytes making up a uniform vegetation. For example, reeds (*Phragmites australis*) have a worldwide distribution and are often surrounded by land and a few dominant species of submerged macrophytes. When establishing objectives for the management of freshwater marshes Weller (1978) proposed firstly to preserve marshes in a natural and aesthetically pleasing state, as habitat for wildlife. The second objective was to maintain the high productivity of the characteristic flora and fauna. This indicates the necessity of strict and high level efforts for conservation and restoration. Many available results of marshland exploitation suggest that it is easy and speedy to destroy such ecosystems. The fragility of wetland ecosystems is likely due to the high diversity of the biota. It is well known that preservation of swamp areas has been undertaken by natural trusts, to return them to their natural state, as a haven not only for wetland flora but also for birds and animals. Some recent marsh management initiatives have started with proposals for new definitions that provide standards for the restoration, enhancement, creation and mitigation of marshes (Haddad and Joyce Jr. 1997).

The coastal geomorphologist, Zenkovich (1967), mentioned only tidal flats and marshes as wet forms of world coastal development. Mangrove swamp was noted as the main contributor to sediment deposition (Zenkovich 1967). Mangrove community (mangal), and intermingled zones of mangal and salt marsh, are found in the low-latitude regions of the both hemispheres. Mangal reaches its optimum development in the tropics, rather than the subtropics. This is because mangal flourishes where air temperatures in the coldest month do not fall below 20°C, and where the range is around 10°C (Chapman 1977). According to a summary prepared by the Tropical Agriculture Research Center, Japan (1986), Asian tropical wetlands are classified as mangal (being salty), freshwater wetland forest, and peat-land forest, according to the zonation of the vegetation from ocean coast to inland areas. Thus the classes range between water and forest. In such cases the main management objectives are related to forest resources, with attention being given to various ways to reduce use and exploitation of mangroves (Hogarth 1999; Lacerda 2002; Saenger 2002). Similarly, management of mangals covers two opposing objectives, namely: (i) development of mangrove-wood industry and silvifisheries; and (ii) conservation of mangrove forest for such uses as a bird sanctuary for feeding and resting.

Wetland areas often accompany an isolated, bigger-sized water body, referred to as a "lagoon". These are in fact a type of coastal lake, often with diluted seawater. In the coast of Eastern Hokkaido, Japan, there are twenty-two lagoons (Fig. 4.2.1). They are categorized by form, such as: (i) elongated lagoon, with the long axis parallel to the coastline and and elongated barrier; (ii) perpendicular lagoon, with the long-axis perpendicular to the coast

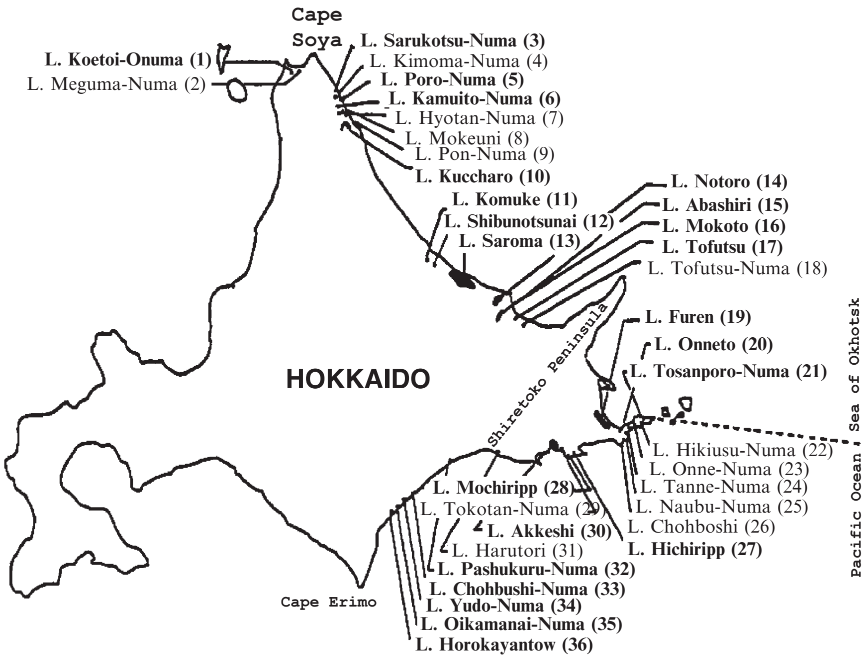

FIG. 4.2.1. Location of the coastal lakes including lagoons in Hokkaido Island, Japan (bold face indicates lagoon).

line; (iii) semi-perpendicular lagoon; (iv) rounded lagoon, often filled with seawater; and (v) uncategorizable forms of lagoon lakes (Kuwabara 1996). As the development of a lagoon barrier is very rapid in geological terms, the cycle of sedimentation and erosion needs monitoring, along with changes in the vegetation and associated biota in the surrounding salt marshes (Packham and Willis 1997). One of the biggest barriers globally has a length of 75 km. This is the Songkhla lagoon system in Thailand. In this system the partition of wetland is very restricted (Kuwabara 1996). Geomorphological analysis of each lagoon reveals a dependency with associated swamps or estuaries. The analysis uses morphometric parameters of general lakes (Kuwabara 2003).

Management of Wetland Environments

In wetland management the density of human habitants is always considered as it reflects the potential for human impacts. Analysis of the population density must incorporate population size as this influences the kinds of human activities. Thus successful framing of wetland management systems may necessitate a distinction between processes related to natural impacts and human impacts.

Basic planning of wetland investigations for management purposes may need to be, framed in terms of general considerations similar to those proposed by Morris (1985) in an estuarine survey. Based on that study, an appropriate approach is: (i) development of objectives following the legal and/or scientific definition, (ii) planning of sampling and analysis using in situ observation, GIS and satellite images, (iii) decision of location and frequency of sampling, and (iv) scale of survey and research. Even though these approaches are still too abstract, concerned parties will easily handle the practical details when undertaking the research.

References

Burchfield RW (ed) (1986) Wetland. A supplement to the Oxford English Dictionary, vol. IV. Se-Z, Oxford, Clarendon Press, Oxford, 1409+45pp

Chapman VJ (1977) Introduction. In: Chapman VJ (ed) Wet coastal ecosystems. Ecosystems of the world 1, Chap. 1, 1–29. Elsevier Scientific , Amsterdam, 428pp

Chernov YuI (1985) The living tundra (translated by Love D) Studies in polar research. Cambridge University Press, Cambridge, 213pp

Haddad KD, Joyce EA Jr. (1997) Management. In: Coultas CL, Hsieh Yuch-Ping (eds) Ecology and management of tidal marshes, a model from the Gulf of Mexico 12, 309–329. St. Lucie Press, Delray Beach, FL, 355pp

Haslam SM, Klotzli F, Sukopp H, Szczepanski A (1998) The management of wetlands. In: Westlake DF, Kvet J, Szczepanski A (late) (eds) The production ecology of wetlands 8, 405–464, Cambridge University Press, Cambridge, 568pp

Hogarth PJ (1999) The biology of mangroves. Oxford University Press, Oxford, 228pp

Kuwabara R (1996) Barriers of lagoon lakes in Japan, South Sakhalin, and Kurile Islands. Abstract. The 11th International. Symposium Okhotsk Sea and Sea Ice, Mombetsu, 270–275

Kuwabara R (2002) The term paddy biotope defined as a quasi-natural ecosystem. Proceedings of the Asian Wetland Symposium, 2001, Penang, Malaysia

Kuwabara R (2003) Characteristics in geomorphological parameters of the coastal lakes facing to the Sea of Okhotsk. Proceedings of the International Workshop on Wise Use of Lagoon Wetlands, Kushiro, Japan, 114–121

Kuwabara R, Satrawaha R, Magtoon W, Maxwell GS, Hirai Y, Asakuma K Wongwattana C, Suzuki A (2003) Researches on the wetland areas and the river waters in Nemuro and Kushiro districts, eastern Hokkaido, Japan. In: Kuwabara R (ed) Annual report 2002 and proceedings of the third workshop of the sub-project studies on natural environment and culture in Asia (The Hydrosphere). Academic frontier research project, Tokyo University of Information Sciences, integrated study of environment, culture, and information in Asia, Part 1, annual report 2002 (The Activities) 3–16

Lacerda LD (ed) (2002) Mangrove ecosystems: function and management. Springer, Berlin, 292pp

Morris AW (1985) Estuarine chemistry and general survey strategy. In: Head PC (ed) Practical estuarine chemistry, 1, 1–60. Cambridge University Press, Cambridge, 337pp

Mitsch WJ, Gosselink JG (2000) Wetlands, third edn. Wiley, 920pp

Packham JR, Willis (1977) Ecology of dunes, salt marsh and shingle. Chapman & Hall, London, 334pp

Saenger P (2002) Mangrove ecology, silviculture and conservation. Kluwer Academic, Dordrecht, 360pp

Tropical Agriculture Research Center, Ministry of Agriculture, Forestry and Fisheries of Japan (1986) Lower wetlands of Southeast Asia. The tropical agriculture technology series, no. 20, 301pp (in Japanese)

Weller MW (1978) Management of freshwater marshes for wildlife. In: Good RE, Whigham DF, Simpson RL, Jackson CG Jr. (eds) Freshwater wetlands, ecological processes and management potential, 267–284. Academic Press, New York, 378pp

Zenkovich VP (1967) In: Steers JA (ed) Processes of coastal development. Oliver & Boyd, Edinburgh, 738pp

4.2.2 Mangrove Forests

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Mangrove Habitat Dynamics in Natural Processes

Mangroves are precious ecosystems of the coastal environment in the tropical and subtropical regions. They provide important resources for local people. They grow in the upper and middle areas of tidal zones and are sensitive to the rate of sedimentation from terrestrial zones, to the rate of accumulation of mangrove peat, and to tide level (Fig. 4.2.2). The distribution of mangrove habitat has dynamically changed in relation to the sea-level change (Fig. 4.2.2).

The age of the present-day mangrove habitats is less than 2,000 years. This is related to the change of global sea level. It rose gradually during the last 10,000–2,000 years and became stabilized afterwards. If the speed of a rise in the sea level is up to about 1 mm/year, mangrove peat accumulation and mud sedimentation are suitable terrain for forest and thus help it expand. In fact, the area of natural mangrove forest in Japan, Australia and the Pacific Islands has been sustained, or even expanded (ISME 2004). However, there has been concern that a rapid rise in the sea level caused by the global warming could reduce the area of mangrove forest. If the sea level rises as rapidily as 5 mm/year (Fujimoto et al., 1999) there would not be sufficient time for mud sedimentation in many places.

Mangrove Forest Degradation in Southeast Asia

The mangrove forests of Southeast Asia have been widely devastated and the area has decreased rapidly in recent years due to various human pressures. During the past decades, mangrove forests in Asia have suffered from most severe destruction to occur anywhere in the world. As the international demand for products such as shrimps, charcoal and wood chips for pulp has increased, mangrove forests in the area have been massively deforested,

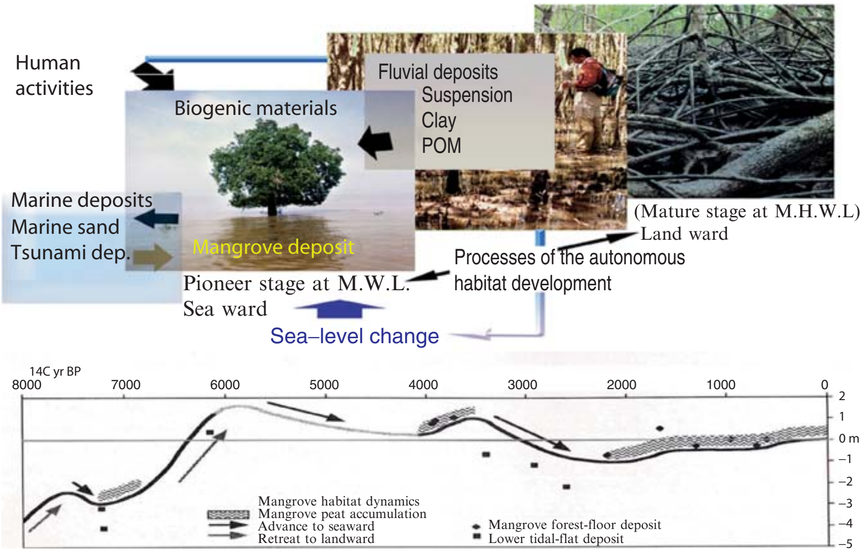

FIG. 4.2.2. Geo-ecological basic frame of the mangrove forest development. Above: Mangrove ecosystem development by the interaction of land, ocean, and vegetation (Miyagi 2002). Below: Holocene sea-level changes and mangrove habitat dynamics in the southwestern Thailand. (From Fujimoto et al., 1999.)

and the coastal environment has been widely damaged (Fig. 4.2.3 and 4.2.4). As a result, various problems have occurred, such as sulphuric acid affected soil caused by construction of fish ponds, salt damage to adjacent paddy fields, huge coastal erosion, and exhaustion of marine resources. There is still a huge demand for shrimps produced for cheaper prices. To fulfil this demand, there has been widespread construction of shrimp farming ponds, often by clearing mangrove forests. However, generally a shrimp farming pond can function for no longer than for 10 years. This is because endemic organisms can emerge and infect the shrimps in the pond within a rather short period of time. An old shrimp farming pond is usually discarded, or turned into a fish faming pond. In order to keep shrimp farming construction of shrimp ponds must continue as the demand for shrimp in the world market is quite strong. Countries such as Japan, USA, China, and EU are the big markets for those shrimps. In recent years, the main area in the Southeast Asia where shrimps are produced is the southern part of Thailand and Vietnam and a part of India.

Traditional Interaction of Mangrove Ecosystems and Local People

During the last 100 years mangrove forests in the Asia and the Pacific area were maintained as semi-natural forests. People living in the area used them for fuel. From ancient times mangrove forests had been recognized as a

FIG. 4.2.3. Charcoal production in the mangrove forest in southern Thailand.

FIG. 4.2.4. Large and intensive shrimp farming in southern Thailand. Sugar palms and the paddy fields died out by salt affection.

natural resource that can be utilized in various ways, such as forestry, fisheries and also environmental protection. People in the area used the ecosystem effectively. They coexisted with the ecosystem and interacted mutually, without destroying the ecosystem.

The devastating destruction of forests in many countries in Asia in recent years has taken place since a commercial use for mangrove was found. The land has been used and developed in a very exclusive way, resulting in a new environment in the coastal area. However, faced by the negative effects of this devastation, many countries showed increasing interest in the restoration of mangrove forests.

New Wave of Mangrove Ecosystem Rehabilitation

In 1990 an international organization was established, with the objective of understanding the mangrove ecosystem and restoration of forest environments. Around the time this organization started, many countries in Southeast Asia began to prohibit deforestation of mangrove areas and encourage afforestation (Fig. 4.2.5). This was also the time when the international community started to pay attention to global environmental problems. Many countries have recognized restoration of mangrove ecosystems and forests as a major global task, and worked on it very hard. In addition to governments, various private enterprises, associations such as NGOs, and international organizations such as UNESCO's Man and the Biosphere Programme (BAM), International Tropical Timber Organization (ITTO), World Bank (WB), Food and Agriculture Organization (FAO), and Japan International Cooperation Agency (JICA) have started to work on the restoration. Two examples are presented here.

UNESCO/MAB maintains Biosphere Reserves in various places in the world. The purpose is to protect the natural environment and to let people live and interact mutually with the nature in the area. These areas include Yaku Island in Japan, Ranong province in Thailand and the Can Gio area, a suburb of Ho Chi Minh city in Vietnam.

In Ranong a very rich mangrove forest that is very close to primordial is preserved. Mangrove trees more than 30 m high exist only in this area of Thailand. The Thai Government has appointed the Mangrove Ecosystem Research Center to play a key role in restoration of mangrove forests in the whole country. In Thailand destruction of forests for various reasons, such

Fig. 4.2.5. Mangrove plantation at the Red River delta, Vietnam.

FIG. 4.2.6. Mangrove forest and the tsunami disaster by Sumatra earthquake 26th December 2004. Mangrove forest stopped the transported materials by tsunami at Phi Island southern Thailand (wave height 7–8 m).

as charcoal production, construction of shrimp farming ponds and illegal deforestation, has not occurred recently. Today, there is a major emphasis on restoration and afforestation of mangrove in Thailand.

Can Gio in Vietnam was affected by chemical bombs during the Vietnam war. The forests in the area were destroyed almost completely. However, constant afforestation by the inhabitants, and a strong afforestation policy led by the government, has restored the forests. The forests have been designated as a Biosphere Reserve. This is a rare case since usually an artificial forest is not designated as a Biosphere Reserve. However, in Vietnam there has been severe deterioration of the coastal environment caused by the expansion of shrimp farming ponds. The area where restoration of the natural environment has been attempted is limited to areas such as Can Gio and the Red River Delta (Phan Nguyen Hong, 2004).

Through the 1970s Southeast Asia experienced huge devastation of mangrove forests and the coastal environment. Today attempts to restore the environment are undermined by some continuing devastation of mangrove forests.

Tsunami and Mangrove Plantations

On December 26th, 2004, an earthquake in Sumatra caused serious damage to various coastal areas of the Indian Ocean. After the disaster studies on the Andaman Sea coasts in the southern part of Thailand investigated the relationship between presence of mangrove forests and damage caused by the tsunami waves. Inland movement of the rubble carried by the tsunami waves was reduced by the forest made up of *Rhizophora apiculata* (Fig. 4.2.6).

If the height of a tsunami wave is 3–4 m it causes little harms to the mangrove forest In the areas where the tsunami waves reached 7–8 m in height, shallow-rooted plants such as *Avicennia* species, *Aegiceras* species, and *Bruguiera parviflora* were ripped from the bottom by the waves. On the other hand, forests made up of *Rhizophora apiculata* were destroyed at their margins. It is unlikely that *Rhizophora apiculata* can stand a tsunami wave with a height of more than 15 m. However, it appears that a forest consisting mainly of *Rhizophora* is a certain deterrent to damage caused by tsunami waves. Therefore, conservation and management of mangrove forests are also important as a countermeasure against coastal hazards such as tsunamis, storm surges and high waves.

References

Aksornkoae S, Maxwell GS, Havanond S, Panichsuko S (1992) Plants on mangroves. Chalongrat, Thailand, 120ps

Fujimoto K, Miyagi T, Murofushi T, Mochida Y, Umitsu M, Adachi H, Pramojanee P (1999) Mangrove habitat dynamics and Holocene sea-level changes in the southwestern coast of Thailand. Tropics, 8–3:239–255

ISME (2004) Comparative study of the mangrove forest distribution for the monitoring of coastal ecosystems and the rapid sea-level rise in Okinawa prefecture, Japan. 153ps

Miyagi T (2002) Mangrove ecosystem development – a comparative study between the natural habitat and plantation one. The third meeting of the project on ASPACO, 30–37

Phan Nguyen Hong (ed) (2004) Mangrove ecosystem in the Red river coastal zone. Biodiversity, ecology, socio-economics, management and education. Agricultural Publishing House, Hanoi, Vietnam, 509 ps

4.2.3 Coral Reefs

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Distribution of Coral Reefs

Coral reefs are geological structures that occur along tropical and sub-tropical coasts and are made of living marine organisms, including scleractinian corals and calcareous algae. The biodiversity of coral reefs is high, equaling that of rainforests. Scleractinian corals do not survive in water with temperatures below 18°C, low salinity and insufficient light. Coral reefs are restricted to shallow waters between 30°N and 30°S (Table 4.2.1, Fig. 4.2.7). The total area of coral reefs is estimated to be 285,000 km^2 (Table 4.2.1).

The Value of Coral Reefs

Coral reefs provide nearly 500 million people with food, coastal protection and a livelihood. It is likely that 30 million poor people are heavily dependent on the resources from coral reefs (Wilkinson 2004).

Today, coral reefs provide major protein sources to people, especially in the Pacific Islands. The consumption of fish is over 100 kg per capita in some countries, such as the Maldives, Kiribati, and Tuvalu. Both subsistence and commercial fishing, including live fish export, are based on reef resources. The fishing methods vary from gleaning, undertaken mostly by women and children on the reef flat, net fishing, including cast net, gill net and fixed net, fish trap, spear, to hook and line fishing, including trolling on the outer reef slope. Blast fishing and poison are still used in some areas. During the last decades the importance of aquaculture has been increasing. This includes food products such as shrimp (typically in mangrove areas), clams, algae, as well as high-value products such as pearl oysters and corals for aquaria.

TABLE 4.2.1. Size of coral reefs in each region and the level of threat to the reef ecosystems. (Data from Spalding et al., 2001.)

Region	Coral reef area (km^2)	Destroyed reefs (%)	Reefs at critical stage (%)	Reefs at threatened stage (%)	Reefs at low or no threat level (%)
Red Sea	17,640	4	2	10	84
The Gulfs	3,800	65	15	15	5
East Africa	6,800	12	23	25	40
South Western Indian Ocean	5,270	22	36	31	11
South Asia	19,210	45	10	25	20
South East Asia	91,700	38	28	29	5
Australia and Papua New Guinea	62,800	2	3	15	80
South West Pacific	27,060	3	18	40	40
Polynesia	6,733	2	2	3	93
Micronesia	12,700	8	3	5	85
Hawaii Islands	1,180	1	2	5	93
US Caribbean	3,040	16	56	13	15
North Caribbean	9,800	5	9	30	56
Central America	4,630	10	24	19	47
East Antilles	1,920	12	67	17	4
South Tropical America	5,120	15	36	13	36
Total	**284,803**	**20**	**24**	**26**	**30**

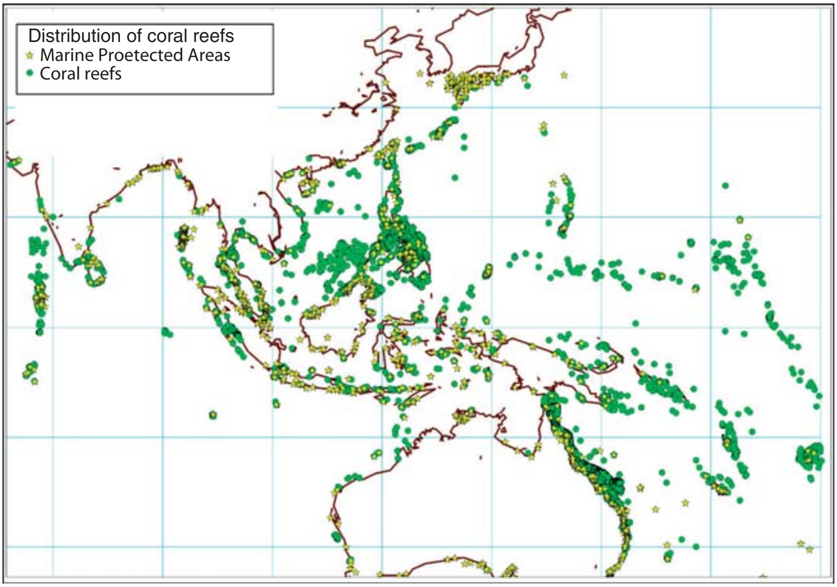

FIG. 4.2.7. Map showing distribution of coral reefs and marine protected areas in Southeast Asia. (Data from ReefBase World Fish Center, Malaysia.)

Because of the high biodiversity of the coral reefs and the scarcity of earlier studies of the genetic resources, there is an immeasurable potential of bioproducts for new pharmaceuticals. In a large number of small island countries, tourism is the only driving force for economic development. SCUBA diving is a relatively new activity, but now is one of the most important industries in those countries. Marine-based tourism consists of a wide range of activities, including snorkeling, glass-bottomed boats and fishing. Other services the people can enjoy from coral reefs include opportunities for education and construction and building materials. Coral reefs are the major provider of sand for the beaches that are an important attraction for tourists. Sandy beaches also help to purify waters rich in organic matter derived from this land.

Threats and Current Status

- As they are very finely balanced and sensitive ecosystems, coral reefs are probably one of the most endangered ecosystems in the world. A large proportion of coral reefs worldwide are categorized as threatened (Fig. 4.2.8). The threats include:Physical destruction or loss of habitats, including landfill and reclamation, as well as damage caused by ship grounding, anchoring, reef walking and military activities, including nuclear-weapons testing
- Unsustainable fishing practices, including blast fishing and fishing with poisons. Various types of overfishing (economic-, growth-, recruitment-, ecosystem-, Malthusian-, and target species-overfishing) (Spalding 2001)

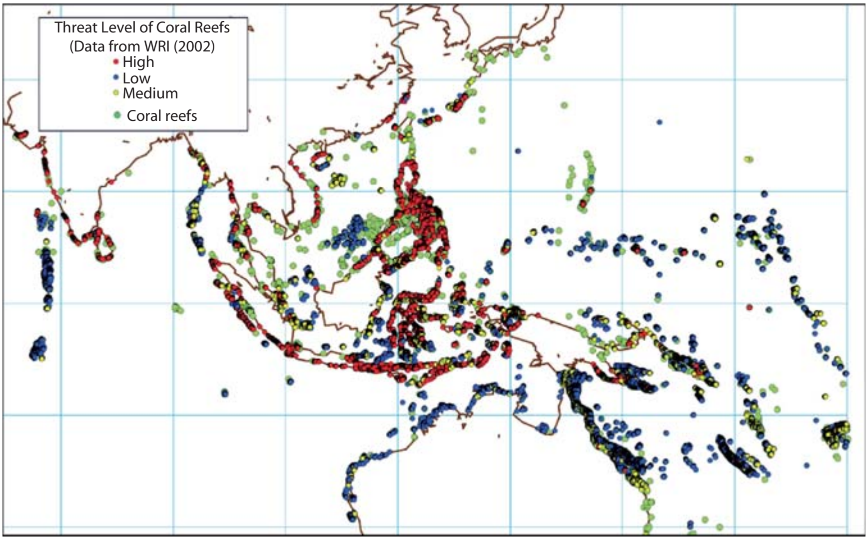

FIG. 4.2.8. Map showing coral reefs with different levels of threat in Southeast Asia. (Data from Reef Base, World Fish Centre, Malaysia.)

- Nutrient enrichment due to sewage and fertilizers; these cause algae blooms that, in turn, overgrow and kill corals and prevent settlement of coral larvae. Algal blooms also reduce light penetration into seawater where coral grow
- Sedimentation due to coastal development, deforestation, inappropriate agriculture, dredging, and reclamation. Sediment and resuspension prevent growth of corals by reducing light penetration through the water column, smother corals and impede settlement of coral larvae
- Outbreaks of the crown-of-thorns starfish, which may be related to eutrophication of reef waters
- Coral diseases
- Coral bleaching due to various types of stresses – corals expel their symbiotic algae (zooxanthellae) or the zooxanthellae lose their chlorophyll, causing loss of color and their white skeletons can be seen. Types of stresses include extremely high and low water temperature and unusual salinity. In 1998, due to El Niño Southern Oscillation (ENSO), maximum seawater temperature rose higher than average by 1–2°C. Global climate change is believed to increase the frequency of bleaching events. Small island countries may be especially affected by coral mortality and sea-level rise.

The Responses

Agenda 21 recognizes the importance and vulnerability of coral reefs. It was approved during UNCED in 1992. It states the need for enhancement of interregional and international collaboration for the sustainable development of small island countries. The need for this action was endorsed during the Global Conference on the Sustainable Development of Small Island Developing States held in Barbados in 1994, in the Millennium Declaration approved in the Millennium Summit held in 2000, as well as at the 2002 World Summit on Sustainable Development held in Johannesburg. There have been various management measures for the sustainable use of the resources.

Traditional Management

People on the tropical and subtropical coasts have developed measures to control the use of coral reefs. Those include customary marine tenure systems, including temporary or permanent closure of fishing grounds for certain species (taboos). In many cases the introduction of Western lifestyles, and government interventions as well as the cash economy, have eroded cultural and traditional values, including traditional management systems of coral reefs. However, in areas where these practices remain, there are efforts to recognize and incorporate customary marine tenure into formal management systems. If this occurs, the number of locally managed marine areas will increase.

International Designations

In addition to the increase in small-scale village-based MPAs, there are protected areas recognized internationally. These include the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention), the Convention Concerning the Protection of World Cultural and Natural Heritage (World Heritage Convention), and the UNESCO Man and the Biosphere (MAB) Programme. Listing protected areas in these frameworks is an effective way to motivate the government's appropriate management for conservation and sustainable use.

Legal Framework and MPAs

Modern legal systems are also being applied for conservation and sustainable use of coral reef fisheries resources. These measures, in theory, include licensing, gear restriction, species protection, catch restrictions (number, size), seasonal restrictions and area restrictions. All these measures require enforcement. Fisheries in coral reefs involve: (a) a large number of target species; (b) a variety of fishing methods, gear and fisher groups; and (c) innumerable remote landing sites. These conditions make enforcement difficult and expensive. Many countries with coral reefs cannot afford such expensive enforcement. Therefore, there is increasing understanding of the usefulness of marine protected areas (MPAs) or no-take zones (NTZs) as these are comparatively easy to manage. The MPAs/NTZs resemble traditional management measures, such as closed areas and seasons for fishing. Especially in the Pacific island countries, they are comparatively well accepted by people.

Another growing understanding is that participation of stakeholders in the process of establishing such MPAs/NTZs, especially those at village level, is critical for their success (LMMA 2003). In order to improve management it is now well understood that when management of resources in more remote areas is directed by central government (centralized management) it is not efficient. Neither is management where everything is planned and operated by communities (community-based management). Nowadays, co-management is seen the most successful system. This is where rural communities are given authority to govern their resources, and central government and the community share responsibility (King and Fa'asili 1999; Huber and McGregor 2002).

A study which compared the effectiveness of MPAs among five Pacific Island Countries suggested that public participation, along with the existence of customary marine tenure and active involvement of NGOs, are critical for success (Nakaya 2004, Table 4.2.2). In order to enhance public participation at village level from an early stage, the application of participatory learning and action (PLA) approaches is increasing.

Limitations of MPAs and Needs of ICZM

Experience with MPAs/NTZs has proved their effectiveness. However, their limitations have been shown as well. These include powerlessness against threats caused by remote activities. Examples include: (a) eutrophication due to sewage and fertilizer; (b) sedimentation due to construction and poor agricultural practices and deforestation; and (c) poaching by outsiders. To solve such problems, MPAs, especially those of small scale, should be managed within a larger geographical scale. To maximize the effectiveness of each MPA, connectivity between MPAs and land areas, as well as among MPAs, should be considered. There is a tendency to establish protected areas, including terrestrial areas such as beaches, mangrove areas, grassland and forests, and to network a web of smaller MPAs.

Table 4.2.2. Comparison of factors that potentially affect the level of success of MPAs among Pacific Island countries. (From Nakaya 2004.)

Country	Legislation	Public Participation	Customary marine tenure	NGO activities	MPAs size	GNP (US$)	No. of MPAs	MPA success
Tonga	National law	Poor	None	Poor	Large	1,300	7	Not effective
Fiji	Fisheries law	Good	Yes	Active	Small	2,300	>100	Many successful FLMMA* sites
Samoa	Bylaws	Good	Yes	Active	Small	1,500	>70	Successful Comanagement
Vanuatu	Customary tabu	Good	Yes	Active	Small	1,100	>50	Successful Comanagement
Tuvalu	National law	Good	None	Active	Large	1,200	1	Successful large Funafuti MPA

*FLMMA is Fiji Locally Managed Marine Area.

Moreover, simply establishing MPAs is an ineffective solution of potential conflicts among different user groups, such as subsistence fishing, commercial fishing, leisure fishing, diving and boating, since these can occur simultaneously. It is also necessary to include programs of awareness enhancement and formal and public education. All these conditions strongly support the application of integrated coastal management (ICM) to coral reef management.

References

Huber M, McGregor K (2002) Issues for community-based sustainable resources management and conservation: considerations for the strategic action programme for the international waters of the Pacific small island developing states, vol. 1: A synopsis of information relating to marine protected areas, South Pacific Regional Environment Programme

King M, Fa'asili U (1999) A network of small, community-owned village fish reserves in Samoa. Parks 8(2):11–16

Locally Managed Marine Area Network (LMMA) (2003) Learning framework for the locally managed marine area network, LMMA Network, Suva, Fiji

Nakaya S (2004) Public participation in the nature conservation: Cases of marine protected areas in the tropics, Institute for International Cooperation, Japan International Cooperation Agency (in Japanese)

Spalding MD, Ravilious C, Green EP (2001) World atlas of coral reefs. University of California Press, Berkeley

Wilkinson C (ed) (2004) Status of coral reefs of the World: 2004, AIMS

4.2.4 Fisheries and Aquaculture in the Asia-Pacific Region

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Conflicts Between Traditional and Industrial Sectors

In the traditional coastal society of the Asia-Pacific region, fisheries and aquaculture were the major sectors occupying coastal zones, not only for people's livelihood activities but also for their daily life. Unlike the developed nations, where industrial and service sectors have rapidly expanded their businesses into coastal zones, fisheries and aquaculture still occupy a larger part of the coastal zones in the Asia-Pacific region. Along with economic development, however, these traditional sectors have increasingly faced severe conflicts with other growing economic sectors. People who are engaged in capture fisheries and aquaculture on a small scale are less competitive in economic terms. They are usually in a vulnerable position vis-à-vis the industrial and service sectors. They are often excluded from the decision-making processes of coastal zone planning and management. In particular, growing marine tourism tends to have negative impacts on the sustainability of the fisheries sector, since both parties utilize the local common resources and environments. Coordination and adjustment among all stakeholders are becoming a very challenging task.

Destructive Utilization of Coastal Resources in Fisheries Sector

A strong inducement to expand the production of market-oriented fisheries brings a sharp increase in the catch effort in coastal fisheries. Production exceeds a point of Maximum Sustainable Yield (MSY), with overexploitation of valuable resources. This leads to the decrease and/or depletion of coastal aquatic resources. In the fertile fishing grounds of coastal zones, trawl, purse seine, and the types of small-scale fishing gear that would destroy the sustainability of coastal resources should be controlled. In some Asian countries, destructive fishing gear and methods, such as dynamite and cyanide fishing, still occur. Tremendous numbers of small-scale fishing gear, such as set nets, gill nets and traps, dominate the entire fishing grounds of semi-enclosed bays and coastal zones in tropical waters (Fig. 4.2.9). Without a clear-cut legal framework for coastal fisheries management, and under a de facto open access regime, the small-scale fishers living in overpopulated communities would increase their catch effort as much as possible, in order to catch scarce resources. It is very hard to manage the limited fishing grounds where a large number of fishers have already constructed various types of set nets and occupied particular zones on a first-come-first-served basis. As Fig. 4.2.10 shows for a lake in Thailand, there is little space even for the passage of boats. The introduction of limited entry into fisheries, which is expected to control and reduce catch effort, would be useful in sustaining valuable target resources. However, people in fishing communities would then suffer from a shortage of

Fig. 4.2.9. Excessive number of set nets and traps in Songla Lake, Thailand.

FIG. 4.2.10. Congested fish cages in Songlha Lake, Thailand.

livelihood; in reality they rarely cease the investment and operation of set nets and trap fisheries. In traditional coastal societies, community organizations and people's groups monopolize considerable parts of coastal zones and allocate parcels of fishing grounds to fishers on an informal basis. Of course, they should pay rent or tax for such fishing operations. These are examples of community-based, self-management approaches led by influential leaders.

Aquaculture Development and its Impact on Coastal Zone Management

In the Asia-Pacific region, aquaculture and its related industries have largely contributed to the rapid growth of the fisheries sector. Aquaculture production accounts for more than 30% of total production in this region. Large-scale and capital-intensive aquaculture brings a higher level of output in a cost-intensive manner. However, capital-intensive and cost-effective aquaculture often damages the environment and coastal resources. Negative economic externalities are large. Small-scale conventional fishing, as well as nature-based aquaculture, have negative effects on coastal environments. The demand for wild-caught feed stock increases with high stocking densities. Feed is small minced fish, and results in pollution of the water. Such nature-dependent aquaculture forces the exploitation of marine fish stocks. Target juvenile fish are caught mainly by effective traps with fine mesh nets. Pressure on wild-caught fish is ever increasing. This aquaculture system also encourages the expansion of destructive fishing devices for catching small fish, which are used as feed. Trawl and gill nets are commonly put into operation in coastal fishing grounds of major aquaculture areas.

In some countries of the Asia-Pacific region, the small-scale fishers who wish to invest in cage culture extend their territory, often illegally or without any official permission. The first-come-first-served principle is followed; pioneers and influential people are likely to monopolize a wider area of sea for fish and shell fish culture. The unlimited expansion of cage culture naturally damages the coastal environment and resources, also causing severe conflicts between fishers, and between the fishery and non-fishery sectors. As Fig. 4.2.10 shows, congested cages and poles may increasingly damage coastal resources and prevent the appropriate allocation of particular zones for aquaculture.

Aquaculture development should include water management, effluent control, disease control, and minimization of land use. Responsible aquaculture is essential not only for the sustainable growth of this sector, but also for the preservation of the coastal environment. Otherwise the "tragedy of the commons" will be widespread within the aquaculture zones.

Increase in Conflicts and Resolution Measures

Because of the various types of resource users in the fisheries sector, there is increasing incidence of conflicts related to resource utilization. Subsistence fisheries are in a vulnerable position vis-à-vis commercial fisheries. In many developing countries small-scale and capital-intensive fisheries are often put into operation in the same fishing grounds, as a result of ineffective law enforcement. They compete each other. Small-scale capture fisheries are excluded from their fertile fishing grounds as a result of the rapid expansion of marine fishing and shell culture. Land-based shrimp farms seriously impact mangrove forest resources and have degraded the coastal environment. Sport fishing, diving and marine tourism eliminates small-scale fishers from beaches, dive spots and landing sites. However, these businesses do provide alternative income sources for coastal communities.

A zoning plan should be set up in a certain demarcated coastal area, based on consultations with all stakeholders, including those inside and outside fisheries. Capture fisheries and aquaculture businesses have so far utilized the largest part of coastal zones. The overdependence of fishers on coastal aquatic resources has to be lightened in the process of setting up a zoning plan, leading to the creation of alternative job opportunities and income sources. In order to address conflicts between the fisheries and non-fisheries sectors, an appropriate integrated coastal management plan should be designed by local management institutions, and involve consultation and the participation of all stakeholders in the decision-making process of planning. In Okinawa, Japan, as well as other parts of the Asia-Pacific region, the expansion of marine tourism used to cause conflicts between fishers and tourism businesses. Local governments normally make a concerted effort to intercede, and also to encourage all the sectors concerned to prepare an institutional framework for coastal management. Currently, a fishing ground management plan serves as an integrated coastal management plan. Supported by local government, a fishers' organization has taken the effort to prepare an integrated coastal management plan.

Zoning for Sustainable Use of Coastal Fisheries Resources

However, preparing a sustainable zoning plan by way of consensus among all stakeholders is hard work. This is due to the lack of institutional coordination and adjustment among stakeholders in a coastal society.

In the Asia-Pacific region, traditional community-based resource management (CBRM) has undertaken various kinds of management measures in the immediate fishing grounds. Fishers used to adopt sustainable practices with which to continuously catch target species. However, growing economic incentives coming from domestic and foreign markets tend to break traditional rules and bury the ethics developed by people for the sustained use of fisheries resources. Under a de facto open access regime for coastal fisheries, traditional territorial boundaries might disappear. Local communities lose the power and authority to control illegal fishing operations and eliminate destructive fishing devices. This increases conflicts in coastal zones. By taking the place of local communities and self-management arrangements, local governments and intermediary organizations are expected to take part of the responsibility for coastal management, in partnership with fishers and other stakeholders. Through a formal procedure for decision-making, an appropriate allocation of the coastal area can be achieved. Without a legal framework of licensing and registration, such a zoning plan is difficult to make effective.

Figure 4.2.11 shows Japanese practice on the demarcation of fishing grounds for oyster, fish and seaweed culture. Under Japanese fisheries laws, both the fishery cooperative association (FCA) and individual fishers can

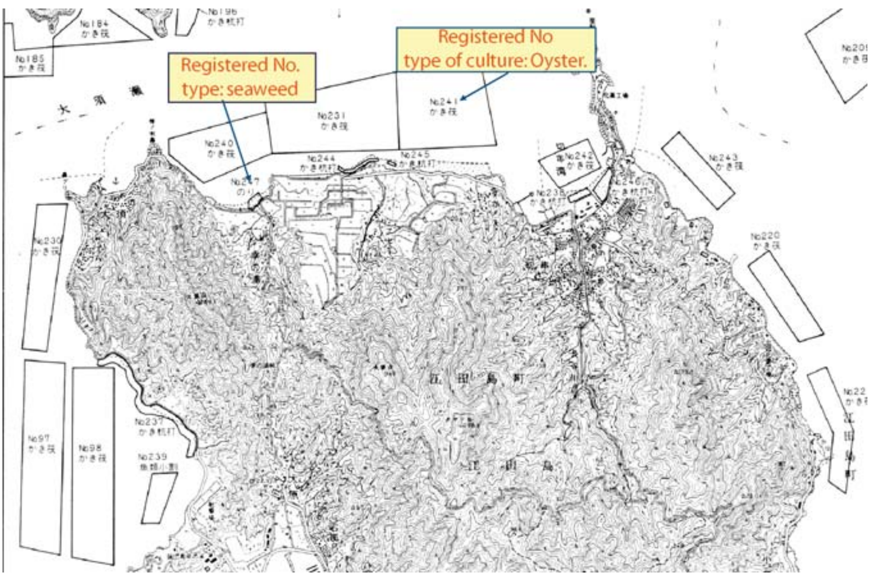

Fig. 4.2.11. Demarcated rights for oyster and seaweed culture on Seto Inland Sea, Japan.

apply for demarcated rights for aquaculture. In reality, the provincial government gives a FCA a higher priority to a demarcated rights application than is given to individuals. This is because the FCA has a mechanism for allocating the granted demarcated rights amongst its members on an equal basis. It has long been thought that common fishing grounds should not be occupied by any particular group of fish farmers. Only in cases where the FCA does not apply for grants are individual fishers given demarcated rights within common fishing grounds.

Challenges in Establishing a Framework of CBFM

Japan has a long history in community-based fisheries management (CBFM), including territorial use rights in fisheries for common fishing grounds. The CBFM has at least three functions and aspects: i) ecological aspect of coastal fisheries resources for conservation; ii) economic aspect that fishers maximize their profit by catching particular target species and selling them to the market; and iii) the social and cultural background of the CBFM secures equality and equity among local fishers and people in a fishing community. Its mechanism includes an adjustment function to avoid conflicts, and to enhance social unity through achieving consensus on local rules and their enforcement.

Not many Asian developing countries have had the historical practices of CBFM, with zoning management in demarcated coastal areas. However, some countries have made considerable efforts to establish a new framework of zoning and demarcation under a decentralization scheme. As Fig. 4.2.12

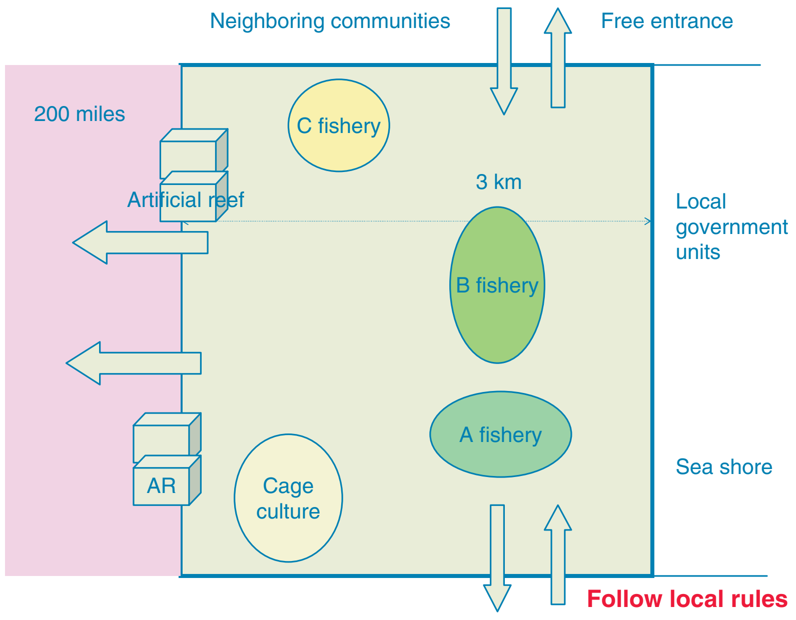

FIG. 4.2.12. New challenge of zoning in demarcated areas in Thailand.

illustrates, local fishers, stakeholders, and local government units draw up a zoning plan within the demarcated coastal fishing grounds. They also propose to establish a management body whose functions are to generate the procedures for decision-making, build an effective organization, finding problems and solutions, making plans for management, announcing local rules, and enforcing them. It takes some time to achieve these purposes. It is obvious that a single fishing community can hardly manage such a demarcated coastal zone, since it cannot manage migratory species in appropriate ways. It is usual for several communities and local government units to create a partnership among themselves in order to manage the common pool of resources of a far wider area.

Integrated Approach with Improving Quality of Life in Fishing Communities

Since fishers and fish farmers wish to obtain better livelihoods from fisheries, they endeavour to sustain an economic maximum yield for the targeted resources. However, their short-term views often hinder the sustainability of the resources. Excessive self-motivation, based on economic interest, leads to a rapid increase in catch effort, which necessarily causes conflicts among fishers, and between fisheries and non-fisheries sectors. To lessen the excess pressure on scarce coastal resources, and overuse of coastal environments, a better quality of life should be secured by adopting alternative livelihood measures outside fisheries. These are less a problem if there is poor law enforcement. A more holistic and integrated approach should be prepared, with the aim to utilize coastal zones in sustainable ways. On one side, if there is a clear jurisdictional mandate and stronger institutions for coastal management, such sustainable measures can be carried out. Increased participation of people in management bodies is a decisive factor to achieve effective coastal management. On the other side, improvement of alternative livelihoods helps to reduce fishing pressures. Fishers and family members have to obtain alternative income sources inside and outside the fishing communities. Both approaches are interlinked at the local level.

4.2.5 Management of Semi-enclosed Sea: Case of the Seto Inland Sea, Japan

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Geographical Characteristics

The Seto Inland Sea is a semi-enclosed sea located in the western part of Japan, with an east–west length of ca. 450 km, north–south width of

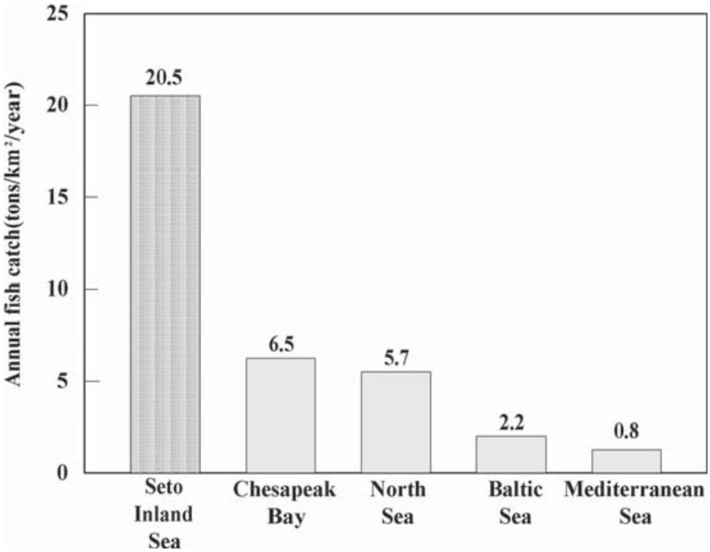

FIG. 4.2.13. Comparison of annual fish catch per unit area among various enclosed or semi-enclosed seas. (From Takeoka 1997.)

15–55 km, an area of 23,203 km^2 and an average depth of 38 m. The area is traditionally famous for its beautiful landscape, including ca. 1,000 islands, and hence was designated as Japan's first national park in 1934. It is also a productive fisheries ground; the annual catch per unit area of 20.5 t km^{-2}/year, is one of the world's highest values (Fig. 4.2.13). However, due to relatively narrow mouths, the Kii and Bungo Channels both opening to the Pacific Ocean and the Kanmon Strait to the Sea of Japan, the displacement of the water within the Sea is slow; the average water residence time in the Seto Inland Sea is ca. 15 months. At present, 34 million people, about a quarter of total population of Japan, live on the adjacent coastal land. Therefore, the anthropogenic impact to the environment is significant and also to the Seto Inland Sea ecosystem.

Environmental Deterioration After World War II

After World War II, Japan was eager to industrialize. Many heavy industrial factories were constructed along the coast of the Seto Inland Sea, most intensively in the 1960s and 1970s. This area had great attraction for industrialization, such as good traffic conditions, less natural disasters, a mild climate and ease of land reclamation because of its shallowness. At the same time, there occurred a remarkable increase in the human population and associated urbanization. Consequently, pollution by industrial as well as household wastes increased. For example, COD (chemical oxygen demand) load to the sea was 925 t/day in 1962. It increased to 1,900 t/day in 1989. Such an increase in eutrophication-enhanced phytoplankton growth, to give rise to frequent occurrences of red tides (Fig. 4.2.14). The number of the red tides reached a maximum in the mid 1970s, when the Seto Inland Sea was even referred to as a "dead sea" because of severe environmental deterioration such as benthic deoxygenation, oil spilling, and mass killing of finfish, and of shell fish, PCB/heavy metal contamination and deformed fish.

Promulgation of Laws and Other Countermeasures

In the light of this situation, calls for action by the local communities, such as the Governors and Mayors' Conference on the Environmental Protection of the Seto Inland Sea, resulted in the enactment in 1973 of the Law Concerning Provisional Measures for Conservation of the Environment of the Seto Inland Sea. This was made permanent as the Law Concerning Special Measures for Conservation of the Environment of the Seto Inland Sea (referred to in brief as "Seto Inland Sea Law") in 1978. Among the special measures specified by this law, the following two were most important: (i) Restriction on the total load of pollutants such as COD, P and N; and (ii) Special care with regard to reclamation. By the former measure, the current COD load decreased to less than half the peak value. The reduction of P and N loads is continuing. In response to this water quality regulation, the number of red tides decreased by half (Fig. 4.2.9). The latter measure was also effective. The rate of reclamation slowed down after the enactment. But on average, 4.4

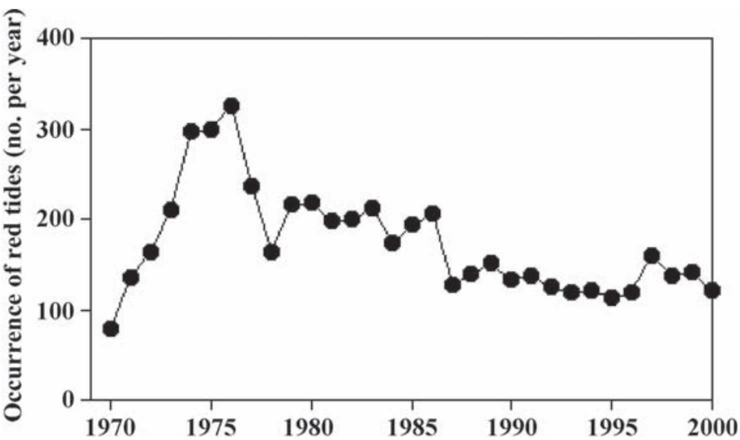

Fig. 4.2.14. Temporal variations in the annual occurrence of red tides in the Seto Inland Sea. (From the Setonaikai Fisheries Coordinate Office, Fisheries Agency.)

hectares of land is still being reclaimed annually for various purposes, including waste disposal (Fig. 4.2.15). The area of the Seto Inland Sea is defined by the Seto Inland Sea Law (Fig. 4.2.16).

Efforts must be focused on effectively reducing the total loads of pollutants in enclosed water bodies in populated and industrialized regions, in order to improve the water quality. The Water Pollution Control Law was amended in 1978 to implement the "Areawide Total Pollutant Load Control System" for such large enclosed water bodies. This was to ensure that Environmental Quality Standards for Water Pollution were met.

The Areawide Total Pollutant Load Control targets regions where the current effluent standards, including stringent effluent standards, are insufficient for meeting and maintaining the Environmental Quality Standards. Targeted regions are Tokyo Bay, Ise Bay, and the Seto Inland Sea. Additionally, specific regions contributing to water pollution are designated within each designated water body (designated water bodies). Every five years the Minister of the Environment sets COD pollutant load reduction targets for each designated water body, along with a target year by which they are to be met. Regulations in accordance with the total pollutant load control standards are the core of load-reducing measures based on the Areawide Total Pollutant Load Reduction Plan. The total pollutant load control standards are applied to specified commercial facilities with an effluent volume of 50 m^3/day, or more. The standards indicate the permissible limit for the discharge of pollutant loads per commercial facility.

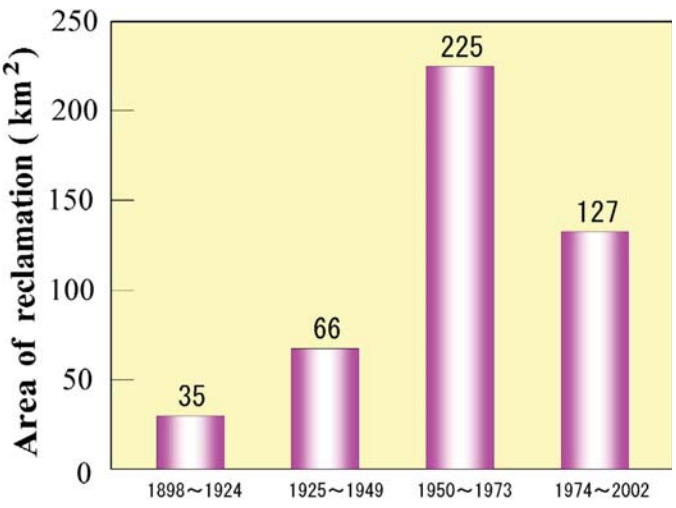

Fig. 4.2.15. Temporal variation in the area of reclamation in the Seto Inland Sea during respective periods. (From the Ministry of Environment.)

FIG. 4.2.16. Water body and watershed area defined by the law concerning special measures for conservation of the environment of the Seto Inland Sea.

COD is the major indicator of organic contamination. Although the Areawide Total Pollutant Load Control has been implemented and targeting COD since 1979, organic contamination is also caused by eutrophication. This is triggered by the influx of nitrogen and phosphorus. Thus while the levels of COD in designated water bodies have remained virtually unchanged, red tides have again become an issue.

For this reason, in December 2001 the fifth Areawide Total Pollutant Load Control (with the target year set at fiscal 2004) established the Basic Policy for Areawide Total Pollutant Load Control, adding nitrogen and phosphorus to the previous regulations for COD. In July 2002 concerned prefectural governments created an Areawide Total Pollutant Load Reduction Plan in order to meet the reduction targets set out in this policy. The prefectures are currently taking comprehensive action to meet these targets, including the implementation of measures for household wastewater and industrial effluent, in addition to other measures.

With the cooperation of national government, local public organizations, private companies, local residents, and other entities, the Association for the Environmental Conservation of the Seto Inland Sea was established in 1976. For research purposes, the Research Institute for the Seto Inland Sea was set up in 1992 by researchers and university professors who were committed to the environmental preservation of the Seto Inland Sea. To promote international collaboration toward the Environmental Management of Enclosed Coastal Seas (EMECS), five conferences have been held in various parts of the world at 3-year intervals since 1990. The EMECS office was established in Kobe in 1994. These groups are collaborating and working together on various aspects of the environmental management of the Seto Inland Sea.

The Research Institute for the Seto Inland Sea is endeavoring to establish the ideal way for the environmental preservation and other protection of the Seto Inland Sea, and is aiming to encourage the spread of the research and knowledge to contribute to the maintenance of the overall environment of the Seto Inland Sea and its proper use. The Institute is preparing the necessary proposals, and facilitating cooperation in the investigation, the research, and the educational activities concerning the Seto Inland Sea. As for the research conference, it is organized by an interdisciplinary group including researchers in government, companies, and academia and by people with interest in the natural sciences and social sciences. An activity such as the Seto Inland Sea research forum or a workshop is held every year. In addition, a member of the research institute has introduced the results at the International Conference of Enclosed Coastal Sea (EMECS conference). Interdisciplinary research studies of the Seto Inland Sea receive high acclaim as a worldwide research model for an enclosed coastal sea.

The Governors' and Mayors' Conference on the Environmental Protection of the Seto Inland Sea reports on the various investigations that the Environment Agency advances jointly after " the Law Concerning Special Measures for Conservation of the Environment of the Seto Inland Sea " was established in 1978. It also resolves various declarations, etc., involved in establishing the necessary organizations and in spreading understanding. It has also enhanced information exchange concerning various problems. To advance the approach of environmental preservation smoothly, many organizations have thus been established. Moreover, the Conference endeavors to enlighten the environmental preservation consideration in groups and residents in the coast region. For these organizations "The Seto Inland Sea Special Declaration" is adopted, and the slogan to advance the environmental preservation of the Seto Inland Sea is promoted.

Since the law was passed 30 years ago, The Governors' and Mayors' Conference on the Environmental Protection of the Seto Inland Sea has encouraged examination of a new subject. While performing information exchange about the environment of the Seto Inland Sea, the Conference is also encouraging cooperation between prefectures and cities, in order to promote environmental preservation of the Seto Inland Sea. As a result, examination of the following four items was agreed in 1998.

(a) Plan of environment creation measures: The technology and the promotion methods for restoring the lost environment are examined.
(b) Prohibition of sea gravel collection: Collection of gravels on the sea floor is prohibited and alternative materials for construction use should be investigated.

(c) Simplification of permission application procedure: The procedural methods that relate to the Seto Inland Sea special measures are simplified.
(d) Prefecture plan concerning the environmental preservation of the Seto Inland Sea: This addresses the maintenance of water-quality control and the natural environment; the target is set at each administrative divisional level, and the measure to achieve the target is planned, and executed. As a result, the prohibition of the collection of the sea gravel will start from 2006.

The prefecture plan concerning the maintenance of the environment of the Seto Inland Sea was reviewed by the Basic Plan for the Conservation of the Environment of the Seto Inland Sea that the Ministry of Environment changed in 2002. The measure to achieve the target was planned and made public, setting up the target concerning the maintenance of a water quality conservation and a natural landscape in consideration of the characteristics of the region.

The document "Demand concerning the preservation and restoration of the environment of the Seto Inland Sea" was published in 2005. It highlighted the need to protect the biodiversity of the Seto Inland Sea, considering it at as a rich sea and treating the recovery of fishery resources. A law to restore the beautiful nature of the Sea was also demanded. Thus, the Governors' and Mayors' Conference on the Environmental Protection of the Seto Inland Sea is intended to act as a form for negotiations on policy adjustments that examine how to restore the loss of nature, while also cooperating on the solution of large issues in the future.

Slow Recovery of the Environment

Although implementation of the measures based on the Seto Inland Sea Law has achieved some success, particularly in reducing the loads of pollutants, many problems still remain unsolved. One of these problems is the decline in fish catch. The total annual catch increased gradually after World War II, until the mid-1970s, when the eutrophication was most significant. During the period between the early 1970s and mid-1980s, the catch was highest (mean: ca. 4×10^5 t), followed by a significant decrease to ca. 2.5×10^5 t (Fig. 4.2.17). A variety of factors are thought to explain the decline in fish catch. But the loss of tidal flats and grass beds by land filling is assumed to be most responsible. These areas are critical for the reproduction of commercially important fish species. Fish catch can be an integrated indicator with which to assess the healthiness of the environment and sea ecosystem. In this sense, the environment of the Seto Inland Sea is far from recovery, in spite of the previously described attempts related to pollution prevention and water quality improvement. New approaches, such as preserving biodiversity, promoting the circulation of water and other substances, remediation of the tidal flats and grass beds, and integration of natural, geographical, socioeconomic, and other conditions, are needed for the future recovery of the environment and ecosystem of the Seto Inland Sea.

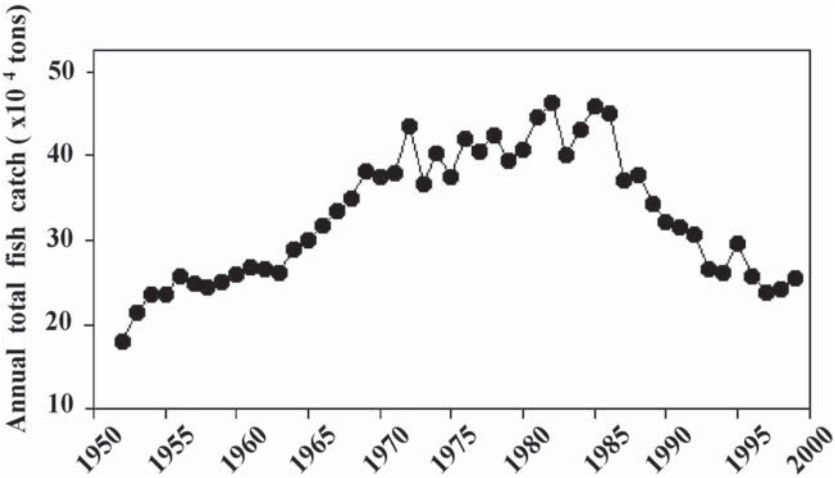

FIG. 4.2.17. Historical trend of annual fish catch.

References

Takeoka H (1997) Comparison of the Seto Inland Sea with other enclosed seas from around the world. In: Okaichi T, Yanagi T (eds) Sustainable development in the Seto Inland Sea, Japan. Terra Science, Tokyo, pp 223–247

International EMECS Center (2005) Water quality conservation for enclosed water bodies in Japan, International Center for the Environmental management of enclosed coastal seas (EMECS)

4.2.6 Coastal Management in Developing Countries: New Development in Coastal Management

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Compromising Between Ecological and Economic Aspects

In the Asia-Pacific region there is great difference in regard to the level of development in coastal management. Government policy and people's attitude toward conservation and utilization of coastal resources differ from country to country. As in developed countries, many of the developing countries in the region tend to proceed on the common process.

As Costanaza (1999) describes, six core principles necessary to achieve sustainable governance of the ocean and coastal areas. They are: (1) the responsibility principle; (2) the scale-matching principle; (3) the precautionary principle; (4) the adaptive management principle; (5) the full cost allocation principle; and (6) the participation principle. Developing countries rarely adopt and implement at one and the same time these six core principles in coastal management. Even though recognition of the necessity to adopt these principles is increasing, the countries tend to compromise, more or less, between the ecological and economic aspects.

Sustainable development is emphasized in various aspects like economics, society, ecology and the environment. It has becomes the dominant paradigm for coastal management, but the Asia-Pacific countries still suffer from the lack of a precise definition of sustainability. There is also disagreement between countries over the prioritized issues of sustainable development. Economic sustainability tends to be given a higher priority, rather than environmental and resource sustainability.

Towards an Integrated and Participatory Approach

Coastal management can only effectively be evaluated and managed in the total context of the social and cultural environment (Ehler 1995). It is very difficult to concede a unified objective or to best manage the coastal zone (Makhatar and Aziz 2003). The perceptions or approaches of management tend to focus on sectoral matters. However, it is gradually, and now generally accepted that the integrated approach aims for a multi-disciplinary and sustainable management of coastal resources. Policy for coastal management increases the focus on comprehensive environmental and resource management.

Recent years have been seen a rapid development in the participatory approach. In the 1980s public interest in the participatory approach increased, since there was a pressing need for integration and coordination between sectors in coastal management. However, bureaucratic and administrative boundaries at central level blocked development of integrated coastal management at the local level. A number of pilot projects were started, with such purposes as accumulating experience and lessons on the integrated approach and creating a practical model for locally-based management. Through the implementation of pilot projects, the advantage of people's participation in the decision making of coastal management has been widely acknowledged. Fitting in with local reality, and satisfying the people's demands, are essential factors to success in coastal management.

Policy and Administrative Institutions

Policy for coastal management always fluctuates between a short-term and a long-term view. Both views are often in conflict in the Asia-Pacific. Resource users and stakeholders are likely to exploit coastal resources from a short-term viewpoint, while government pays less attention to the quality of their daily lives. It is obvious that ensuring the quality of human life of both current and future generations is the overall goal of coastal management. Pursuing this goal has led to the development of the concept and framework of environmental economic policy, considering how environmental quality and the output of economic goods are related in the short and long run (Field 1994). However, too much expectation from environmental economic analysis may result in a pessimistic appraisal, when local people and resource users regard "sustainability thinking" as dream-like.

Therefore, policies for coastal management often fluctuate between optimistic and pessimistic appraisal of the people's behavior. Government attitudes towards coastal management are unsteady. As a result, both parties have reciprocal distrust. Balancing and compromising are indispensable in any further development of coastal management.

How to build a more effective administrative organization is also still a key issue, along with a rapid increase in the number of participatory projects. Experience and lessons gained through implementing the projects provide a profound insight into the direction of policy for coastal management. Thus there is now substantial evidence and guidance regarding the most appropriate approach. However, central governments still find it difficult to build a well-structured organization that can secure people's participation and respond to local concerns.

Balancing Between Livelihood Improvement and Environmental Issues

In some tropical countries of the Asia-Pacific region people consider that overfishing, the loss of marine diversity, coastal zone degradation and coral reef destruction are the major problems and are among the top priorities. They are encouraged to take action for the establishment of sustainable coastal management by both government and non-governmental agencies. However, resource users and local society make excuses to avoid controlling illegal and destructive exploitation of resources. This is because there are no alternative income and job opportunities. They are aware of the deteriorated coastal environment and depleted coastal resources. But without adequate alternative livelihood schemes they hesitate to join conservation programs. In overpopulated coastal areas a large part of the poor people might be alienated from the means of livelihood if conservation programs are implemented. The success of the pilot projects suggests that alleviating poverty is an effective tool for establishing the sustainable use of coastal resources. Therefore, a balance between livelihood opportunities and conservation should be proposed as much as possible (see Fig. 4.2.18).

Moreover, resource users and local society consider that environmental conservation and resource management should be viewed in the complex interaction of livelihood, culture and society. This may be called the Asian-value. Focusing on the sole aspect of conservation may lead to the collapse of fishing communities and local institutions that function in multiple roles.

Decentralization, People's Participation, and Local Government

Decentralization of Coastal Management

In many of the Asia-Pacific countries a top–down approach has failed to manage local issues and take action against irresponsible and illegal activities. Law enforcement is a problem in this approach, because of the lack of personnel

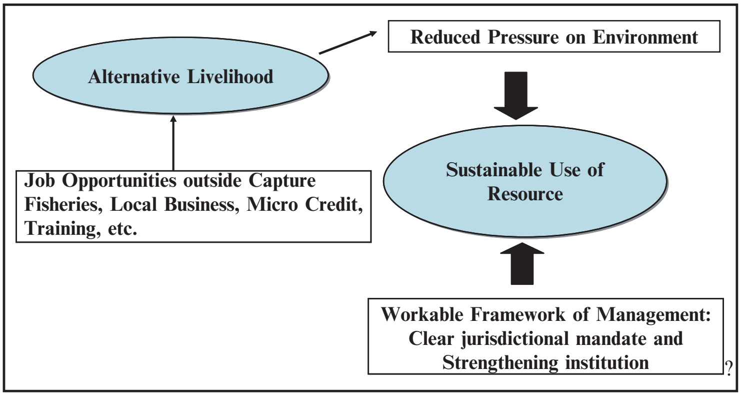

FIG. 4.2.18. Strategy of coastal resource management.

and inadequate budget allocations. This may result in de facto open access to coastal resources. Decentralization is a strategic approach and has several advantages. The transaction cost of coastal management is much lower than the top-down approach, although the decision-making cost is more expensive. The transfer of technology and knowledge is useful at the local level. Resource users' and local knowledge can be adopted in the decentralization of coastal management.

A decentralized system empowers local government and people to arrange self-regulated activities, while establishing locally based and people's organizations that take a part of government's responsibility. Community-based resource management (CBRM) and co-management (CM) are typical cases. CM is to share responsibility between government and users. This improves coordination and communication between central and local. It needs well-structured institutions that consist of management units at local level, intermediary coordinating bodies and a clearly defined legislative framework.

It takes much time to pass through sequential stages towards the overall objectives of CM. The task and responsibility delegated by the central government will gradually cover a wider scope of coastal management. Figure 4.2.19 shows a model for decentralization in resource utilization and conservation.

Public Participation in Coastal Management

Greater public participation in decision-making and implementation of coastal management is an essential factor to make locally-based coastal management succeed. Many countries attempt to establish participatory organizations that will function as a local management unit. It is anticipated to have at least six roles: representatives, consensus, suggestion, implementation, enforcement and adjustment. Clearly a single management

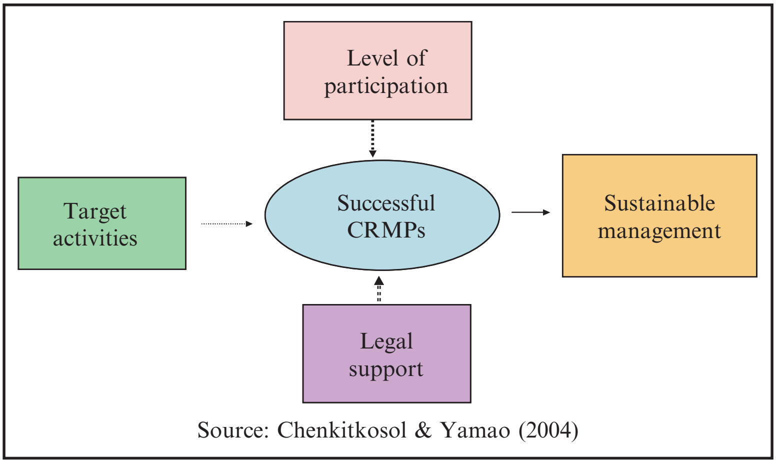

FIG. 4.2.19. Strategy of coastal resource management.

unit can rarely achieve these substantial roles. There should be networks of management units, or intermediary organizations that will provide support. As the ideal of comanagement indicates, good coordination between primary and intermediary levels will assist a management unit to have the above-mentioned roles in coastal management. There is much argument about what type of management unit is appropriate – resource users' (professional) or residential groups, traditional communities, local government units (LGU), and so on.

An increasing number of participatory projects in coastal resource management (CRM) have succeeded due to adopting comprehensive approaches. As Fig. 4.2.20 shows, substantial external and internal factors determine the success or failure of CRM's target activities. One is the level of public participation; another is the extent of legislative support from government. Reducing conflicts among stakeholders is not an easy task, even for a locally-based management unit. In CRM projects need a clear-cut legal framework defining the authority delegated.

A management unit is then empowered to develop its own procedures, including local rules, zoning, and marine protected areas (MPA). Without monitoring, control and surveillance (MCS) conducted by government, few management units would achieve their management objectives by encouraging public participation. It is widely recognized that exercising strict control over illegal activities, such as employing unselective fishing gear and blatantly exploiting mangrove areas, is an indispensable factor for promoting participatory and self-regulatory management activities. In other words, much attention should be given to understanding how to build a more sophisticated comanagement mechanism.

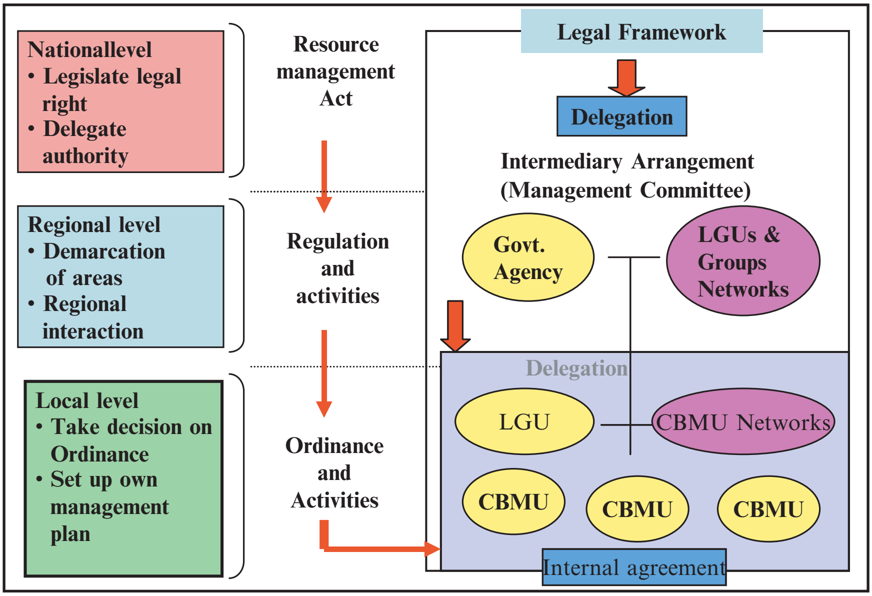

FIG. 4.2.20. Mechanism of decentralization (coastal resource management).

Roles of Local Governments in Coastal Management

As shown by the recent experiences in some countries in Southeast Asia, including the Philippines, Indonesia and Thailand, local governments should be empowered to share a large portion of government's responsibility for coastal management. In Southeast Asia the local administrations will move quickly towards a process of polarization. Although still uncertain, this movement may contribute to decentralization and less officialdom. Some roles and functions that intermediary government agencies hold will be delegated to primary levels; some functions undertaken by traditional communities will be absorbed into a local government unit. Local government plays a very important role in community development, especially by having various sorts of administrative works in which coastal management and environmental conservation are included. The local government unit can enact ordinances through coordination among stakeholders, take charge of registration and licensing, watch and control unreported and illegal activities, and promote human resource development for locally based coastal management.

In coastal resource management, traditional community rules and a local consensus are partly transformed into the formal proclamations and regulations by a local government unit. These are put into legal effect inside and outside the community. This will overcome a weakness of traditional community-based management, and stimulate a trend of public participation in decision making and implementation of resource management and environmental conservation.

In the Asia-Pacific region, developing countries are searching for a variety of models of co-management, with a focus on the increasing role of the local government unit in coastal management while emphasizing the importance of public participation.

Important Issues for Coastal Management in the Asia-Pacific

Capacity Building

Capacity building is essential for integrated coastal management. In particular, community-based capacity building serves to enhance a moral sense of duty (Flether 2003). Decentralization and public participation are strongly supported in many countries. But poor awareness among people and weak incentives for stakeholders are great obstacles. A lack of human resources and financial capacity at community level mitigates against sustainable coastal development. Brief reports from selected countries described hereafter will give an insightful view of how to enhance capacity building at local and national levels.

Regionalization of the "Code of Conduct for Sustainable Coastal Management"

In the Asia-Pacific region, environmental degradation and resource overexploitation in the coastal zone affect neighboring countries directly. In semi-enclosed areas of East Asia and Southeast Asia, resource users and stakeholders are beyond states' borders. Trans-boundary management between the states needs regional guidelines and principles that they should follow. Harmonization and standardization of policies for conservation of the coastal environment and for sustainable use of common-pool resources should be implemented. Technology transfer from developed countries may be a prerequisite to developing countries accepting the regional version of the code of conduct. Coastal management is an urgent field for stimulating international cooperation.

References

Chenkitkosol W, Yamao M (2004) Recent trends and challenges of coastal resource management projects in Thailand. IIFET proceedings of the twelfth biennial conference of international institute of fisheries economics and trades, 1–9

Costanaza R (1999) Ecological economics and sustainable governance of the oceans. Ecolog Econ 31(2):171–187

Field BC (1994). Environmental economics. McGraw-Hill, London, pp 1–481

Fletcher S (2003) Stakeholder representation and the democratic basis of coastal partnerships in the UK. Mar Policy 27:229–240

Makhatar MB, Aziz SABAG (2003) Integrated coastal zone management using the ecosystem approach, some perspective in Malaysia. Ocean Coastal Manag 46:407–419

4.2.7 Coastal Management in Urban Areas

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The Urban Coastal Zone, and its Definition

The coastal zone is a dynamic space where the terrestrial environment influences coastal shallow water, and vice versa. Thus, the coastal zone cannot be divided into land and sea. The coastal zone encompasses the coastal ecosystem itself. Many coastal organisms living in the space do not distinguish its boundary. The zone can be thought of as an ecotone (transitional zone) where different ecosystems encounter each other and a gradual transition of ecosystems occurs. However, land and sea have been treated separately for a long time. The seeming difference in both land and sea is apparent. Most urban areas and the surrounding shallow waters have been highly developed. Thus the management of the urban coastal zone clearly differs from that for undeveloped or less populated areas.

In this section we will consider the Japanese coastline as an example of the urban coastline. The coastal zone in Japan is especially important, as about a half of the Japanese population lives there. It is also the focus of many economic and industrial activities. In the urban areas where industries and population concentrate, it is apparent that we have to consider the value of the coastal zone for society itself.

The first appearance of the word coastal zone in Japanese society occurred in the third National Comprehensive Development Plan established in 1977. However, the word has not been commonly used. The definition of coastal zone in Japan was tentatively released by the Japanese Association of Coastal Studies as “coastal water can extend to the 12 nautical mile boundary of the territorial waters and the terrestrial zone encompasses the administrative area of the municipalities that have a coastline, subject to consideration of the river system to the space.” This definition refers to overseas examples such as the Coastal Zone Management Act (1972) of the USA, which states that the “Coastal zone consists of littoral water within the territorial waters and land that the utilization of it has direct influence on that littoral water”. In fact, specification of the coastal zone is desirable from the administrative point of view. However, lack of an integrated management act for the coastal zone in Japan prevents sharing a clear definition. It is necessary to have a clear definition in order to develop the appropriate administrative arrangements.

Characteristics of Coastal Use and its Classification in Urban Areas

As often discussed, many different uses and users exist in urban coastal zones. Such a complicated utilization scheme is called multipurpose utilization or multiple utilizations. It is defined as "polyphyletic utilization" from the standpoint that the many kinds of utilization, although not mutually exclusive and independent, form the urban coastal zone utilization.

The coastal zone utilization is currently classified by form (e.g., OECD 1993). Although this approach may be effective for solving individual problems among individual users, it is seen as ineffective in an integrated approach to coastal zone management, since this must control conflicting interests. The classification of use was made from three standpoints; industrial versus non-industrial utilization; use by local residents versus non-local residents; and a small number of specific users versus large number of unidentified users. These standpoints represent a coastal utilization in terms of purpose, subject, and form.

The first standpoint, industrial utilization versus nonindustrial utilization, addresses the purpose of utilization. Industrial utilization represents profit seeking activities, while nonindustrial utilization has nonprofit purposes, such as marine leisure and recreation. Features of the nonindustrial utilization include difficulty in quantifying and monitoring utilization. The second standpoint, local resident users versus nonlocal resident users, categorizes the subject responsible for the utilization of the coast line. It is generally accepted that local residents should be the primary decision-makers. Indeed, the participation of residents is a key element in achieving sustainable use of the environment. The third standpoint, large number of anonymous users versus small number of specific users, represents the utility form, Fig. 4.2.21.

Uses of Urban Coastal Zone and its Management

The three categories of coastal utilization are not mutually exclusive. Coastal recreation is often carried out by a large number of anonymous, nonindustrial users coming from outside the local area. For example, in the summertime in Japan, it is observed that 70% of the sea bathers visiting the local beach came from outside of the area (i.e., are nonlocal residents). By contrast, in the case of utilization by coastal fisheries, most employees are local residents belonging to the fishery cooperative. It is industrial utilization by a small number of specific users living in the area.

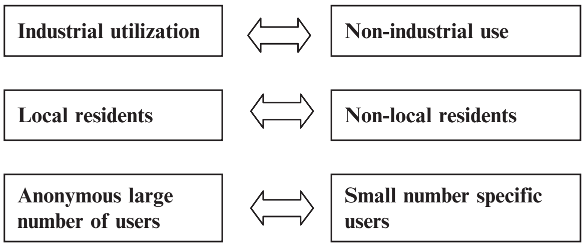

FIG. 4.2.21. Classification of the coastal utilization by nature and conflicting relationships between two user groups.

The environmental protection of the coastal zone cannot be disregarded, even if the balance between the various user groups is kept steady. The utilization of the coastal zone is heavily dependent on the coastal environment. A solution devised by individual concerned parties typically lacks consideration for the environment and resources. It is frequently accompanied by the depletion of resources, and results in increased externalities. Therefore, it is strongly recommended that consideration be given to the environmental protection and resource management standpoint, in addition to the utilization standpoint. This relation is shown in Fig. 4.2.22. In this case, nonindustrial and industrial utilization and environmental protection form a triangle. Maintaining a balance between these three factors is critical.

Urban coastal zone management should endeavor to maintain the appropriate balance in these three triangles. To this end, it is necessary to consider the large number of anonymous versus small number of specific users, and local versus nonlocal residents, while taking account of the environmental sustainability as well. A management factor should be added to the triangular model. The management factor is located at the top of the tetrahedron in the newly developed model shown in Fig. 4.2.23. The intent of this diagram is that a

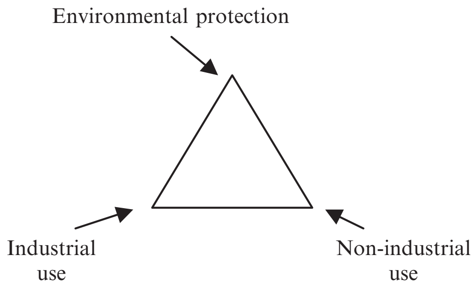

Fig. 4.2.22. Triangular model describing the relationship between user groups and the environmental protection (an example of industrial and nonindustrial use).

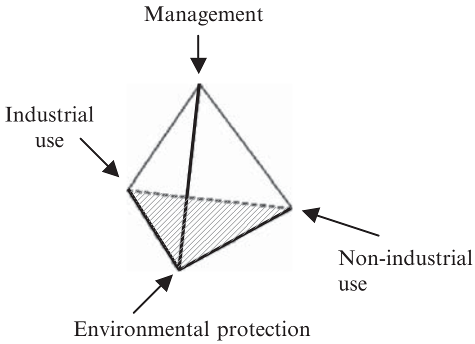

Fig. 4.2.23. Tetrahedron structural model of the coastal zone management (an example of industrial and nonindustrial use).

symbiosis among users and the environment is to be achieved when the shape of this tetrahedron is well balanced.

Issues for Future Urban Coastal Zone Management

As discussed, most urban coastal zones have been highly developed and utilized by both locals and visitors. The economic value of urban coastal zones has been rising because they have been redeveloped for the last 20 years, following the restructuring policy of large cities such as the Tokyo metropolitan area. However, coastal zone management in urban areas uses a sectoral approach. This results in an ineffective and inefficient management exercise because many problems in the coastal zones are trans-boundary. They require a synthetic and integrated approach.

Today urban areas, including the developed coastal areas, need to achieve sustainable development in the whole city planning and management. In sustainable development, one of the main issues is to achieve a balance between coastal development and environmental conservation. Landscape conservation is a typical issue; economic efficiency-oriented development is not always supported because a large number of urban residents and visitors have an aesthetic preference.

Participation of residents and nonresidents in urban coastal zone management is another important issue. Decision making around coastal zone management should be made based on the public participation principle. Thus, institutional and administrative processes need to be designed appropriately. Furthermore, decision making should be open not only to residents but also nonresidential visitors and interest groups. Their activities also have significant influences on the coastal zone. There would be better understanding of the coastal zone and its management in the future if the participation process is extended more widely from decision making to planning and the design processes.

Reference

OECD (1993) Coastal zone management-integrated policies, OECD, 126p

4.3 Policies and Practices in the Asia and Pacific Countries

We have seen that coastal zones in Asia and the Pacific region continue to experience unprecedented environmental changes that are driven both by pressures of local human activities and global environmental changes. Further growth in the population and economies of the region, along with progressive global warming and climate change, will increasingly affect the region's coastal environment. Coastal zones provide a common foundation for economic, academic, cultural and aesthetic resources for local communities throughout the region. Therefore, relevant management of the coastal zones is of great importance for the region's sustainable development. Many countries in the region have attempted to develop their own coastal management framework and practices. They are both national and community levels. Because the coastal resources are a base for the local economy, and the well- being of the local population, countries in this region tend to increasingly rely on community-based management of coastal zones. In this section, we will see the past and current coastal management (CM) practices in some countries in the region.

4.3.1 Effective Coastal Zone Management Practices in the Philippines

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Introduction

The Philippines is situated in the convergence areas of two major oceans found in the Indo-west Pacific Region, and bounds the eastern flank of the large marine ecosystem, the South China Sea (Aliño and Gomez 1995). Its position provides it a strategic and significant role in biodiversity conservation, fisheries management and environmental management (e.g., having particularly sensitive sealane areas [PSSAs] PEMSEA 2003). Its natural endowments are placed in dire straits due to the historical fetters it has experienced and its on-going social and economic constraints. Population growth is seen as one of the highest in Asia, and the number of fisher populations has led to highly overexploited fisheries (DA-BFAR 2004). Coastal degradation, as seen in the decline of its mangrove and coral reef areas, is one of the gravest conditions in the region (Burke et al., 2002). Degradation of coastal areas may have led to losses of at least $ 9B per year, based on replacement costs. It is projected that tremendous pressures on food and social security will result in the future (Bernascek 1996). Pollution and other trans-boundary concerns are starting to become recognized as emerging problems [Jacinto et al., 2000; McGlone et al., 2004], thus exacerbating the poverty, population and environment quandary. Despite the seemingly formidable challenges, the Philippines has proven to be a great reservoir of strength and perseverance in the realm of coastal and ocean management. These attributes are seen in the many laudable efforts and experiences in relation to community-based coastal management and coastal governance, marine sanctuary stewardship and initiatives towards archipelagic integration. The following synopsis provides an overview of some of the predominant effective practices that have been noted in the Philippines. This brief review aims to:

1. Describe some effective practices, and the causes that these purport to address as they relate to prevalent issues and problems.
2. Characterize their objectives and the management and their development trajectories.
3. Identify the future steps, cognizant of the gaps, constraints, and opportunities to pursue improved management effectiveness.

Approaches: Pressures, States, and Responses

Consistent with the general approach of the chapters in this book, we present the pressures that are relevant to the environmental states of the coastal ecosystems of the Philippine archipelago. The matrix in Table 4.3.1 provides the encompassing framework of this review, akin to the trans-boundary diagnostic analyses presented in UNEP-Philippines 2000. Using the pressure–state–response model we derive the general categories for good practices of the on-going interventions in the Philippines.

Results and Discussion

Community-based Coastal Resources Management and Local Governance

Adoption by the Republic of the Philippines of the regalian doctrine during the Spanish period, its continuance with American colonial rule and up until the present Philippine 1987 Constitution, the coastal resources are owned by the State. But considerable developments have occurred in relation to the management of resources, especially in the late 1970s up until entry into the new millennium. Reports consider these under what might be a convergence of political assertion of many environmental efforts as a response to many interrelated development issues. The environmental awakening, as brought about by the political militance under a dictatorial regime, found common cause in many environmental movements that have been awakened in the Philippines. This has been manifested in some of the early community-based marine reserve programs that have been developed in the early 1980s on Apo Island, after learning from the shortcomings of the Sumilon Island experience (Alcala and Russ 1990; Alcala 2001; Alcala et al., 2004). The desire for greater local governance and community participation has been facilitated with the enactment of the 1987 Constitution, and formally expounded in the local government code of 1991. This also afforded local government units (LGUs) jurisdiction of municipal waters to 15 km from shore. At about this time the emergence of the National Integrated Protected Areas System (NIPAS) Act also paved the way for a more holistic perspective for protected areas, including both land and sea. After this period (mid-1990s), around 250 Marine Protected Areas (MPAs) have been identified, with less than 15% being considered effective (Kelleher et al., 1995). After concerted efforts by local communities and civil society groups, the local fisheries code was enacted.

TABLE 4.3.1. Summary matrix of relationship of the pressures, state, and responses and how these relate to some good practices in Philippine CRM.

Pressures	State	Responses	Good practice
Illegal and destructive fishing and overcapacity of the fishing sector	Overexploited municipal and commercial fisheries in at least 70% of coastal areas	Fisheries code was enacted in 1998 and FRM are manifested in many local marine sanctuaries	400 marine sanctuaries are declared, many of these with village level involvement of Peoples Organizations [POs]; e.g., PAMANA
Degradation of coastal ecosystems and mangroves	Less than 40% of mangroves are left and only around 20% of reefs are in good condition	Access for community mangrove stewardship through Community-based Mangrove Stewardship Agreement (CBMSA)	At least 20 CBMSA have been established in the country with many areas converging with fisheries and ecotourism initiatives
Unabated pollution and poor land use	Many coastal areas are starting to experience siltation and pollution	Integrate archipelagic development with coastal management convergent with efforts on Programmatic Environmental Impact Assessment Programs	Vertical and horizontal convergence efforts that paves the way for scaling up of good governance and ecosystem-based management efforts and development of corporate social responsibility
Population pressure and poverty of coastal communities	Food deficits in relation to fisheries intake would be experienced by 2010	Emergent reproductive health and environment programs	Save our Children and PATH foundation efforts in CRM

This paved the way for local governments to establish marine sanctuaries through local ordinances. It encouraged that at least 15% of municipal waters should be allocated for marine fisheries reserves, sanctuaries, and refugias. These developments encouraged the proliferation of over 400 marine sanctuaries around the country (Pajaro et al., 1999). Despite their usually small size (i.e., mostly less than 20 ha) and limited management effectiveness (i.e., less than 20% effective), these have provided the stimulus for many coastal communities and local governments to establish their municipal marine sanctuaries (Arceo et al., 2004). These were very important empowering experiences for both local communities and LGUs, especially to have hand-son shared experience in the management of an area that is within their operational capability and financial resources. Despite concerns in some areas where sustenance fishers resisted the MPA establishment due to the potential loss of their fishing area, many of the areas have become learning areas to regulate fishing activities and start clarifying area-based access arrangements (e.g., especially the regulation of entry within the 10–15 km from shore municipal area). The development of more explicit tenurial instruments, vesting on communities the management of their coastal resources, is best exemplified in the community-based mangrove stewardship agreements. Presently, these instruments have allowed local communities to benefit from the local management of their areas (e.g., Olango Island). Some have even been afforded international recognition for such efforts.

Some coral reef marine sanctuaries and reserves have been noteworthy. Aside from the learning experience, actual improvement in the fish stocks and fisheries yield has been demonstrated, especially for Apo Island. In addition, the development of user fees (e.g., visitor fees) has provided supplemental income to the locals, as demonstrated in the Gilutongan marine sanctuary, where the village earns at least $20,000 a year (Ross et al., 2004) and also on Apo Island. Other areas have utilized marine sanctuaries as reproductive reserves to reseed depleted stocks, to help regulate areas for grow-out (Arceo et al., 2002; Juinio-Meñez 2004). In addition, this has been an important entry point for many local governments to appreciate the need for a more integrated planning and management regime. To date, an increasing number of local governments have developed coastal zoning management plans, with various participatory mechanisms incorporated into the process (Aliño et al., 2002).

Scaling up Local Governance to Provincial, Bay-wide, and Large Marine Ecosystem Management

The initial steps where local governments have undertaken coastal resource management (CRM) initiatives have paved the way for potential complementation of efforts to foster inter-municipality cooperation. This can be seen in many areas where provincial support provided the sustaining mechanisms for project driven efforts at the municipal level. This effort is most developed in the case of the Province of Palawan where a republic act was enacted to establish the

Palawan Council for Sustainable Development (PCSD). The PCSD provided the political and financial leverage mechanisms for municipalities to work together. Previously these were not in place. On the other hand, other areas have started to develop their own coordinating mechanisms, such as seen in various bay management councils (e.g., LIPASECU and Illana Bay Regional Alliance 9 [IBRA 9]), area clusters around the Danahon Banks [CeLeBoSoLe] and the Bohol Marine Triangle and other provincial bodies (e.g., in Negros and Batangas). The larger political influence and areal coverage may facilitate a greater potential for complementation as well as capital buildup to deal with the transactional costs of a larger area and longer-term management. Simultaneously, the development at the local level bottom-up process has seen a convergence in national government initiatives (e.g., the Integrated Fisheries and Aquatic Management Councils [IFARMC] and Sulu-Sulawesi Commission (DeVantier et al., 2004). This top-down and bottom-up integration also facilitates both vertical and horizontal complementation. It remains to be seen whether these efforts will result in synergies, but the fact that these various initiatives are being pursued provides hope that people will work together. Aside from the strict no-take areas and integrated coastal management, there are moves to improve the governance processes and thrusts to incorporate other development areas. The other emergent areas are those that address reproductive health and supplemental livelihood, linked to coastal resource management interventions such as seaweed culture and MPAs.

Next Steps Towards Sustainability: Network of MPAs and Philippine Archipelagic Development

Though the good practices noted here could be distinct and separate efforts, the development towards greater complementation and synergy may be considered a good networking effort. To date various networks have evolved, such as the Community-Based Coastal Resources Management Network [CBCRM Net], the network of MPA people's organizations as embodied in Pambansang Alyansa ng Maliliit na Mangingisda at Komunidad na Nangangalaga sa Sanktwaryo at Karagatan sa Pilipinas ([PAMANA] National Alliance of Small-Scale Fisherfolk Stewarding Sanctuaries and Seas of the Philippines [Filipino acronym when read as a word PAMANA means "heritage"]) have now been in existence for over 4 years. Site-based area management networks, as mentioned earlier, are starting to develop capabilities in managing joint network funds. The development of these funds is the greater challenge that needs to be addressed in order to sustain financing for these areas. Some incipient developments can be seen in the Batangas Provincial Environment and Resources Office. Together with private corporation locators, a foundation was established to help in the monitoring and coastal management of the bay, thus fostering corporate social responsibility and partnerships with the public.

Now local governments are starting to allocate budgets for CRM, despite considerable budget constraints. Many coastal development plans have been enacted through their local ordinances. These legitimization efforts are part of mainstreaming good coastal governance. But implementation of these plans needs to be practiced more effectively so that capabilities are developed at the LGUs and with the active participation of the civil society groups and other stakeholders in the community. Participatory coastal resources assessment and adaptive management processes are starting to take root in the marine sanctuaries. Synergy to work with local governments has to be further developed, together with performance-based incentive systems. In many cases there remain considerable unmet expectations in the delivery of basic CRM services (e.g., fishery registration and coastal regulation of the foreshore areas). Cognizance of these problems has been taken head-on by many Non-Governmental Organizations (NGOs), especially through the efforts of public interest law groups like Tanggol Kalikasan (Environmental Defense) and Environmental Legal Assistance Center (ELAC). With all these efforts, hope springs eternal. The Philippine's people power revolution has not only been manifested in the streets but also in a sea change of attitudes and its coastal people, albeit slowly, but perhaps surely.

References

Alcala AC (2001) Marine reserves in the Philippines: historical development, effects and influence on marine conservation policy. Bookmark, Makati City, Philippines, 115p

Alcala AC, Russ GR, Maypa AP (2004) Evidence for fishery enhancement effects of marine reserves in Central Philippines, pp 215–218. In: DA-BFAR (Department of Agriculture-Bureau of Fisheries and Aquatic Resources). In turbulent seas: the status of Philippine marine fisheries. Coastal Resource Management Project, Cebu City, Philippines, 378p

Alcala AC, Russ G (1990) A direct test of the effects of protective management on abundances and yield of tropical marine resources. J Cons CIEM 46:40–47

Aliño PM, Gomez ED (1995) Philippine coral reef conservation: its significance to the South China Sea. Proceedings of the regional conference East-West center association Okinawa, Japan, November 5–6, 1993, pp. 222–229

Aliño PM, Arceo HO, Palomar NE, Uychiaoco AT (2002) Challenges and opportunities for marine protected area (MPA) management in the Philippines. Proceedings of the 9th international coral reef symposium 2:635–640

Arceo HO, Aguinaldo MMS, Aliño PM (2002) An orientation on marine protected areas: Coastal resources management tools. In Enhancing community participation in fishery resources management. Marine Science Institute, University of the Philippines, the Royal Netherlands Embassy and International Development Research Center, Canada, 45p

Bernascek G (1996) The role of fisheries in food security in the Philippines: a perspective study for the fisheries sector to the year 2010. Paper presented during the second national fisheries policy planning conference, Puerto Azul, Cavite, Philippines

Burke L, Selig E, Spalding M (2002) Reefs at risk in Southeast Asia. World Resources Institute, Washington, 72p

DA-BFAR (Department of Agriculture-Bureau of Fisheries and Aquatic Resources) (2004) In turbulent seas: the status of Philippine marine fisheries. Coastal Resource Management Project, Cebu City, Philippines, 378p

DeVantier L, Alcala A, Wilkinson C (2004) The Sulu-Sulawesi Sea: environmental and socioeconomic status, future prognosis and ameliorative policy options. Ambio 33(1):88–97

Jacinto GS, Aliño PM, Talaue-McManus L, Gomez ED (2000) The Philippines. In: Sheppard CRC (ed) Seas at the millenium: an environmental evaluation, vol II. Regional chapters: The Indian Ocean to the Pacific. pp 405–423

Juinio-Meñez MA (2004) Invertebrate stock enhancement, pp 241–245. In: DA-BFAR (Department of Agriculture-Bureau of Fisheries and Aquatic Resources). In turbulent seas: the status of Philippine marine fisheries. Coastal Resource Management Project, Cebu City, Philippines, 378p

Kelleher G, Bleakley C, Wells S (1995) A Global representative system of marine protected areas, vol 3. Great Barrier Reef marine park authority, The World Bank and the World Conservation Union, Washington DC, 147pp

McGlone MLSD, Jacinto G, Velasquez I, Padayao D (2004) Status of water quality in Philippine coastal and marine waters. In: DA-BFAR (Department of Agriculture-Bureau of Fisheries and Aquatic Resources). In turbulent seas: the status of Philippine marine fisheries. Coastal Resource Management Project, Cebu City, Philippines, 378p

Pajaro M, Olano F, San Juan B (1999) Documentation and review of marine protected areas in the Philippines: a preliminary report. Haribon Foundation for the Conservation of Nature, Quezon City, Philippines

PEMSEA (Partnerships in Environmental Management for the Seas of East Asia) (2003) Sustainable development strategy for the seas of East Asia: regional implementation of the world summit on sustainable development requirements for the coasts and oceans. PEMSEA, Quezon City, Philippines

4.3.2 Current Coastal Resources and Management Outlook for Malaysia

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Introduction

With 4,675 km of coastline and 549,500 km^2 of sea area (including the EEZ), the Malaysian marine environment is endowed with a variety of rich marine ecosystems. These include mangroves, mudflats, sea grasses, coral reefs, lagoons, and estuaries The coastal zone and its resources are central to the quality of life for the Malaysian people, supporting food production, agriculture, industry use, shipping, recreation, and tourism. However, the coastal zone is under pressure from a range of activities which threaten its health and in turn compromise its ability to support the numerous activities that depend on its health. Marine water quality off the mainland coast and developed islands is generally polluted. In 2002 almost 75% of the 1,063 samples of coastal water monitored by the Department of Environment exceeded the interim standard for total suspended solids, 51% for oil and grease and 43% for *E. coli* (DoE 2003). This has particularly affected poorer coastal communities, especially small-scale fishers, who are totally dependent on aquatic resources as their means of livelihood.

Characteristics of the Malaysian Coastal Zone

Shoreline

The shoreline character of the Malaysian coastal zone is highly variable. In the West Coast of Peninsular Malaysia the coastline is characterized by large stretches of mudflats, usually fringed by mangroves. These extend as far as 1.5 km out to sea, interspersed by short stretches of sandy or rocky beach. The East Coast of Peninsular Malaysia, on the other hand, is largely sandy beaches, with mud beaches found only in the estuaries. In Sarawak, muddy beaches dominate the southern coastline up to the Lassa delta, after which the shoreline is largely sand and rocky beach. A similar situation prevails in Sabah, with West Sabah largely of muddy beach while East Sabah is almost entirely dominated by sand beaches, with notable tracts of mangrove around Tawau. Human intervention in these shoreline processes of the Malaysian coastal zone, by the construction of hard structures and maintenance dredging for deep access or navigation channels, have in many places permanently changed the general alignment of the coastline and caused serious erosion problems. Coastal erosion affects many locations to various degrees, in almost every state in Malaysia. A 1999 study indicated that 29% of coastline was undergoing severe erosion, of which 226km was in critical condition. This figure has since increased to 240 km.

Coastal Ecosystems

Coastal Forests

Mangroves cover a total area of 6,410 km^2, covering 52% of Malaysia's coastline. Peninsular Malaysia has about 1,400 km^2, Sabah 3,654 km^2 and Sarawak, 1,356 km^2. Mangrove forests in Peninsular Malaysia have decreased by approximately 35%, especially in the west coast of Peninsular Malaysia. This is due to domestic, industrial and agricultural development. Other coastal forest types include beach forests, heath forests, Nipah forests and freshwater swamp forests. Knowledge of their ecological value is limited, though they are clearly a major part of the coastal habitats support system.

Mudflats

Mudflats are the dominant feature of the coastline on the west coast of Peninsular Malaysia, Sabah, and Sarawak. They are usually associated with mangrove forests, especially if the mangrove areas are in the phase of active accretion. The mudflats of the west coast of Peninsular Malaysia are very productive, producing 72,000 t of marketable cockles and 11,000 t of cockle seeds annually. However, they are not protected (except in conjunction with mangroves), and remain prime targets for reclamation and dumping of waste materials.

Coral Reefs

Corals are found along the coast of Kuala Terengganu to Chukai and around the offshore islands in the South China Sea, the Straits of Malacca, and the Sulu Sea. About 64% of the coral reefs surveyed since mid-1980s are in fair condition, with an average of 25–50% live coral cover. Though major hard reefs are protected through the Marine Park system, smaller reefs are not protected and have suffered from collection and pollution.

Sea Grasses

Sea grass beds are found along the coastal waters of the west and east coasts and the southern part of the Peninsular Malaysia, west and southeastern coasts of Sabah and near reef atolls of the South China Sea. There is no organized monitoring mechanism for sea grass health. However, preliminary studies indicate that trawling, sedimentation, and dredging have destroyed many of the sea grass beds.

Marine Mammals

A total of nine species of dolphins, two species of whales and one sirenid (the dugong (*Dugong dugon*)) have been reported in Malaysian waters. Four of the seven species of marine turtles in the world are also found in Malaysian waters. In addition, the estuarine turtle is represented by one species, the painted terrapin. All five species are listed in the IUCN (International Union for the Conservation of Nature, now the World Conservation Union) Red Data Book as Endangered or listed in Schedule 1 of CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora). Turtle populations have declined, due to loss of nesting sites following coastal development, the collection of eggs for consumption and accidental capture and drowning by fishing nets. Drift/gill nets have also been known to have accidentally caught dugongs.

Major Pressures

Fisheries

Annual fish production, per capita fish consumption, and fisheries sector employment have increased over the past decade. However, sustainability is a key issue. Many Malaysian fishing grounds are fully or overexploited. The level of uncertainty in scientific assessments of the status of fisheries remains relatively high, due to the sporadic nature of stock assessment studies and the unrecorded levels of fishing effort by illegal fishing and poaching by foreign fishermen.

Aquaculture

Coastal aquaculture has expanded rapidly in recent years, growing by 150% in volume and 1200% in value over the 1991–2002 period. The increase has come mainly from shrimp, which has been the fastest growing sector of the aquaculture industry over the past several decades. Though the industry has a bright future, the tendency for farms to be located in state mangrove forests has met with considerable criticism. Though farms are better located behind the mangroves, such lands are not readily allocated to the industry.

Land Reclamation

Reclamation of land from the sea has resulted in sedimentation of beaches, and alteration of natural ecosystems. About 700,000 ha of these wetlands have been converted to agriculture, and more are likely to be drained given growing population pressures. The present system of planning, employing structure and local plans, does not take the marine environment into account. The result is a considerable degree of conflict or overlap with activity and development within the coastal zone.

Mining

Offshore mining is largely focused on sand mining, to meet the growing demand for fill material for land reclamation and beach nourishment. Sand mining has the potential to destroy and pollute the seabed. It can also lead to sedimentation, smothering of benthic habitats such as corals and sea grasses, release toxic substances, nutrients, and heavy metal ions into the water column and to deleterious shifts in littoral patterns, causing the shoreline to erode excessively.

Solid Waste Disposal and Sewerage

With the increase of urban population and rapid economic development, waste disposal is becoming a serious environmental issue, requiring immediate attention. Currently sewage forms a major pollutant in the aquatic environment of Malaysia, especially in the rivers and coastal waters. Malaysia produces more than 5 million tons of sewage each year.

Recreation and Tourism

Increased tourism related traffic in ecosystems that are supportive of inland marine fisheries (coral reefs and mangrove belts) tend to have a negative impact on catch sustainability, in terms of both species and volume. The environment and fishing habitats are adversely affected by indiscriminate removal of young fish, rocks, and coral formations, to be sold as souvenirs to tourists.

Current Initiatives in the Coastal Zone Management

Integrated Coastal Zone Management

Much of the coastal zone in Malaysia is under state jurisdiction. It is the responsibility of the various state governments to development *Integrated*

Coastal Zone Management (ICZM) plans. At present, 3 states (Sabah, Sarawak, and Penang) have already developed their own ICZM plans.

Turtle Sanctuaries

Efforts have been made to conserve and protect marine turtles, through the establishment of sanctuaries and hatcheries. At present there are 15 turtle hatcheries in Peninsular Malaysia, of which 10 are located in Terengganu. In Sabah, the Turtle Islands Park (constituting 8 islands) was established by the State, to conserve and protect marine turtles.

Marine Parks

Marine parks or reserves have been established under Federal and State legislation to protect habitats such as coral reefs. At present there are 11 marine parks in the country covering a total of 588,490ha as well as 5 smaller fisheries protected areas. A further two (both in Sabah), covering a further 325,000 ha, have been identified as potential park areas and are expected to be fully protected by end of 2005.

Establishment of Fishing Zones

Management zones have been established to prevent overfishing, ensure equitable allocation of the fishery resources among different sizes of fishing vessels and types of fishing gear, and to reduce the conflict between traditional and commercial fishers. Four fishing zones have been established through a licensing scheme whereby the country's maritime waters were delineated and designated for specific fishing gear, class/size of fishing vessel, and ownership. The fishing zones established are: Zone A, 5 nautical miles or less from the coast, reserved solely for small-scale fishermen operating traditional fishing gear and owner-operated vessels; Zone B, beyond 5 nautical miles from the coast, for fishing vessels of less than 40 GRT using commercial fishing gear, such as trawl net and purse seine net; Zone C1, beyond 12 nautical miles from the coast, for commercial fishing vessels of 40 GRT; and Management Zone C2, beyond 30 nautical miles from the coast for commercial fishing vessels of 70 GRT and above.

Forest Reserves

Substantial tracts of mangrove forest are protected within reserves, where felling and clearing are strictly controlled. The largest mangrove reserve, the Matang mangrove forest, is considered one of the best managed in the world.

Future Directions in ICZM

Planning for the Coastal Zone

Management planning for most states in Malaysia is nonexistent. However, to address this, the Federal government is currently developing a National

Integrated Coastal Zone Management (NICZM) Policy framework on which the individual states can base their planning framework. The NICZM policy is also expected to influence the development of a National Physical Planning Framework. This is expected to set the pace for all urban planning regimes throughout the country.

Aquaculture Industry Zones

Aquaculture Industry Zones are expected to be established throughout the country, to enable the sustainable growth and development of coastal aquaculture. These zones are expected to be equipped with the necessary infrastructure to treat effluent discharge to acceptable standards.

Concluding Remarks

Malaysia is endowed with rich aquatic resources. However, these ecosystems are currently threatened by the rapid economic development that has taken place since the early 1970s. Adverse environmental changes, such as habitat destruction, pollution, decline in marine resources, and loss of biodiversity have seriously impacted on ecosystems. These include coral reefs, sea grass beds, beaches, mangroves, estuaries, and other coastal environments. To address these problems, and ensure that the coastal zone continues to sustain the country's much needed living marine resources, the Malaysian Government has initiated a comprehensive plan for the integrated coastal zone management for the country. The plan is expected to be fully implemented during the 9th Malaysian Plan period from 2006–2010.

Reference

DoE (Department of Fisheries Malaysia) (2003) Environmental quality report 2002. Department of Environmental Malaysia. Ministry of Science, Technology and the Environment Malaysia. Kuala Lumpur, 62pp

4.3.3 Current Status of Integrated Coastal Zone Management in Indonesia

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Indonesia's coastal area is a productive system in supporting economic activity of coastal communities, therefore the sustainability of the environment of coastal and marine ecosystem is paramount to the interest of the largest archipelagic country in the world. Degradation of coastal environment of Indonesia has been alarming which include the destruction of coral, sea-grass and mangrove ecosystems, decreasing coastal biodiversity and polluted coastal area.

These phenomena are found in several areas of the country's 81,000 km length and more than 17,000 islands. The consequences are impoverishment of coastal communities especially small scale fishermen and fish farmers, lowering quality of life of coastal inhabitants and deterioration of coastal environment especially on most populated island of Northern Java Island, but other islands are considered in good condition (Kusumastanto, 2005).

In the development of coastal and marine management, several government institutions, universities, international donor have put an effort in developing policy and implementation of Integrated Coastal Management (ICM) towards sustainable coastal and marine development. These efforts include conceptualizing and implementing integrated coastal management projects (see Table 4.3.2). After more than 20 years of endeavors, it is recognized that implementation of ICM in the government policy (local and central) and through ICM projects have limited impact because of lack support of strong national and local government policies, complex institutional arrangement, and limited adoption of stakeholders. Strategic actions have to be done to achieve the sustainable development coastal and marine development while improving quality of life of Indonesian people. Based on those conditions several lesson learned can be drawn include:

1. Improve quality of the formulation of policies and strategies option, ICM program must to employ best strategy in formulating management and policy given the condition of resources, political setting, cultural, and socioeconomic. In this situation ICM should facilitates optimization of the economic, social benefit and environmental sustainability from the use of coastal and marine resources. Especially when development dealing with multiple use resources and sector economy, the renewable resource must be considered as an indicator of sustainable coastal and marine management and development which maintains integrity of constant flow resources. The quality of environment and sustainability of renewable natural resources is important in sustaining food supply and food security for the human population while supporting other economic activities without adverse effect to quality of the life.
2. Developing best ICM planning using participation management process, ICM planning will be effective as participation, proactive planning, and quality management mechanism, since ICM planning is a dynamic and subject to periodic improvement. Therefore, ICM planning should involve increase *awareness* the value of coastal resources within social, economic and environmental context; *cooperation* of stakeholders to achieve common objectives; *coordination* of policies, strategies, institutional, and administrative arrangement; *integration* of implementation and monitoring policies in order to meet the stated objectives (Chua and Scura, 1992). In the era of decentralization in Indonesia, the coordination of planning between national and local is very important so that programs and projects can be integrated to tackle a certain issues completely. Review and evaluation of alternative management plan should be done that include an extended benefit-cost analysis and sensitivity analysis, then therefore, the best alternatives selected for consideration of adoption.

Table 4.3.2. List of ICM programs and projects in Indonesia, 1987–2005.

Donor	Program/project
Asian Development Bank (ADB)	• Marine Resource Evaluation Project (MREP)
	• Marine Sciences and Education Project (MSEP)
	• Coastal Environmental Management Project (CEMP)
	• Coral Reef Rehabilitation and Management Project (COREMAP)
	• BAPEDAL Regional Network Development Project
	• Sulawesi Mangrove Management and Rehabilitation Project
	• Segara Anakan Project
	• Marine and Coastal Resource Management Project
United Nation Environmental Program/UNEP	• Regional Seas Program-Coordinating Body on the Seas of East Asia (COBSEA)
	• Conference of Parties II on the Convention Biological Diversity (Jakarta – November 1995).
UN/FAO	• Cendrawasih Bay Coastal Area Development Project
UNDP	• Marine Pollution, Monitoring, and Training Program
	• Riau Zone Land Use Management Project
	• Reforestation in critical watersheds
	• Watershed Rehabilitation in Nusa Tenggara Timur Project
	• Research and Application to Mangrove Ecosystems
	• GEF/UNDP/IMO Regional Program for the Prevention and Management of Marine Pollution in the East Asian Seas
World Bank	• Environmental Management Technical Assistance Project
	• BAPEDAL Development Project
	• Coral Reef Rehabilitation and Management Project
USAID	• ASEAN-US Cooperative Coastal Resources Management Project (co-funded by ASEAN)
	• Natural Resources Management Project (NRMP) (Bunaken National Marine Park)
	• Coastal Resources Management Project
USA	• Columbia University – Indonesia Project on Marine Tracers
CIDA	• Environmental Management Development in Indonesia Project (EMDI)
	• Collaborative Environmental Project in Indonesia (CEPI)
	• ASEAN – Canada Cooperative Program on Marine Science
	• ASEAN – Canada Marine Pollution Criteria
Norway Agency for Development (NORAD)	• Integrated Marine and Coastal Biodivesity Management Project
	• Sea Watch
USAID	• ASEAN-Australia Living Coastal Resources Program

(continued)

Table 4.3.2. (continued)

Donor	Program/project
	• ASEAN-Australia Regional Ocean Dynamics
	• ASEAN-Australia Coastal Resources Management Project
	• ASEAN-Australia Economic Cooperation Program
JICA	• Coastal Resources Inventory Project
	• Urban Drainage and Waste Water Disposal
Japan-Overseas Economic Cooperation Fund	• Environmental Study Center Development (PSLs)
Japan	• ASEAn-Japan Management of Multi-species and Multi-gear Fisheries Project
	• Japan-Indonesia JAMSTEC Project in Indonesia Through Flows
Republic of South Korea	• ASEAN-ROK Industrial Use of Marine Biological Resources
Multi-national, Multi-agency	• International Coral Reef Initiative (ICRI)
WWF	• Strategi on Coral Reef Ecosystem Consrvation and Management (with MLH and EMDI)
Asian Wetland Bureau	• Bintuni Bay & Pulau Dolok Reserves, Wasur National Park (Irian Jaya)
The Nature Conservancy	• Komodo National Park (Marine Component)

3. Best practice in implementation of ICM program which consider an integration of important and essential issues of special importance for implementation of relevant actors; national and local participation in implementation; and mechanism for monitoring, evaluation and updating of the plan (IWICM, 1996). The good practices of the implementation of ICM should:

   – Adopt a systematic approach in implementing ICM programs and projects which include apply ICM framework for sectoral management, use a combination of management actions, adopt precautionary approaches, and strictly follow the ICM procedure.
   – Involve the public in the ICM process, the involvement of stakeholders at all phases and levels of ICM program development and implementation will enhance the cohesion of community in the implementation of ICM.
   – Integrate environmental, economic, and social information from the beginning and due to the complex and dynamic nature of the coastal systems, it is important to have good scientific information.
   – Establish mechanism for integration and coordination, the development of institutional mechanism will bring the harmonization of policies and legislation between national, provincial and local government.
   – Establish sustainable financing mechanisms in order to ensure implementation and also the continuity of ICM program.
   – Develop ICM capacity at all levels, in the case of Indonesia, a major constraint is the lack of technical and management capacities, especially at local level. Therefore ICM program need to employ strategies aimed at strengthening human resources and institutional capacities.

4. Monitoring and evaluation, a feedback mechanism is necessary to monitor, validate and reassess the efficacy of the plan during and after implementation. Many of ICM programs and projects do not consider monitoring and evaluation as important, this condition explain unsustainability of ICM programs in Indonesia. Monitoring of environmental, social, and economic impacts throughout the life of the ICM program because of the complex and dynamic nature of coastal and marine systems, is not always feasible to accurately predict the economic effectiveness and environmental performance of ICM programs and projects. This situation is especially true for Indonesia's coastal and marine systems where scientific knowledge is limited. Monitoring and evaluation, in addition to importance to provide means of assessing the effectiveness of ICM programs and projects in meeting the establish goals and objectives, it is also provides a powerful tool for assessing the performance of ICM programs and projects and gives an early warning system of adverse effects, therefore, a corrective action can be done to modify the design and management in order to avoid irreversible impacts.

In the end of December, 2004, as a tsunami hit Aceh, North Sumatra and Nias, Indonesia became aware of the importance ICM approach in prevention and mitigation of such a coastal disaster, especially in planning, providing guideline, and practical implementation for the local people and the government. With the development of enhanced skills and experiences, every country could develop their specific approach to address new coastal and marine management problems and also expand the ICM programs by integrating the river basin and ocean (Integrated River Basin Coastal and Ocean Management–IRCOM) as one large ecosystem to be considered in integration of national sustainable development agenda (Kusumastanto 2005).

References

Thia-Eng, Scura LF (eds) (1992) Integrative framework and methods for coastal area management. ICLARM, Manila

Sida, UNDP (1996) Enhancing the success of integrated coastal management. GEF/UNDP/IMO, Manila

Kusumastanto T (2005) Iniatiative and implementation of integrated coastal management in Indonesia. Center for coastal and marine resources studies. Institute for Tropical Coastal and Ocean, Bogor Agricultural University, Bogor

4.3.4 Best Practices in Thailand: Example of Erosion and Sedimentation in Songkla Lake Basin

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Background

Songkla Lake Basin is situated on the eastern side of the Southern Thai Peninsula (latitudes N 6° 27/ and 8° 12/ and longitudes E 99° 44/ and 100°

41/). The basin stretches 150 km from Nakhon Sri Thammarat Province to the State of Kedah in Malaysia, and varies in width from 50 to 65 km in the east–west direction (Fig. 4.3.1). The lake basin covers an area of approximately 8,463 km^2, of which 1,043 km^2, or 12%, comprises water bodies in the form of three interconnected lakes: Thale Noi, Thale Luang, and Thale Sap Songkla. The lake basin consists of three main topographic units: the mountains forming the western boundary, a band of foothills, and terraces along the east side of the mountain range, and lowlands to the east and west of the lake. More than 100 streams of all sizes drain the basin from the western mountain range into the lakes, but there is one narrow outlet to the sea.

The economy of the basin is predominantly agriculture in nature. The most common soils in the Songkla Lake Basin are Ultisols, Alfisols, and Entisols. The principal crop is rubber, which is grown mostly on sloping land with good drainage. The cultivation of fruit trees is mainly restricted to the deep and well-drained soils on the foothills and terraces to the west of the basin. The most important crop of the lowlands is rice. Recently an increasing coastal area has been devoted to shrimp farming. Mean annual precipitation across the basin averages 2,000 mm, with over 60% of the rain falling between October and January. About 2% of Thailand's population resides in the basin. The lake system is a resilient and productive ecosystem, containing rich fishing grounds, productive brackish culture systems, and natural attractions for tourism.

Land Use Changes

As in other parts of Thailand, forest resources in the Songkla Lake Basin have been drastically destroyed to a considerable extent. Between 1982 and 1996, the forest area in the basin declined by 51,881 ha, equivalent to a decrease of 35% (Table 4.3.3). This represents an annual loss of 3,705 ha. In Thailand, during the same period, deforestation was taking place at the rate of 179,379 ha per annum, which was equivalent to a decrease of 16% (Charuppat 1996). Thus, the pace of forest destruction in the basin was faster than that in Thailand as a whole. Deforestation in Thailand has been attributed to an increasing demand for agricultural land to meet the needs of the growing population, and to illegal timber harvesting. Of the remaining forest areas, most are now reserved as national parks and/or wildlife sanctuaries, but this does not prevent their steady attrition. The removal of vegetation and/or a change in the density of vegetation cover inevitably results in a disturbance in the basin's hydrological functions, thereby creating erosion hazards.

Consequences of Land Use Changes

By using the Universal Soil Loss Equation (USLE) it was estimated that the total soil loss was 5,340,195 t/year in 1996 (Tanavud et al., 1999), representing an average soil loss of 7.2 t/ha//year (Table 4.3.4). This, it is worth pointing out, is nearly twice the amount of soil loss in 1982. The observed differences in soil losses between the two dates indicate the critical role which vegetation

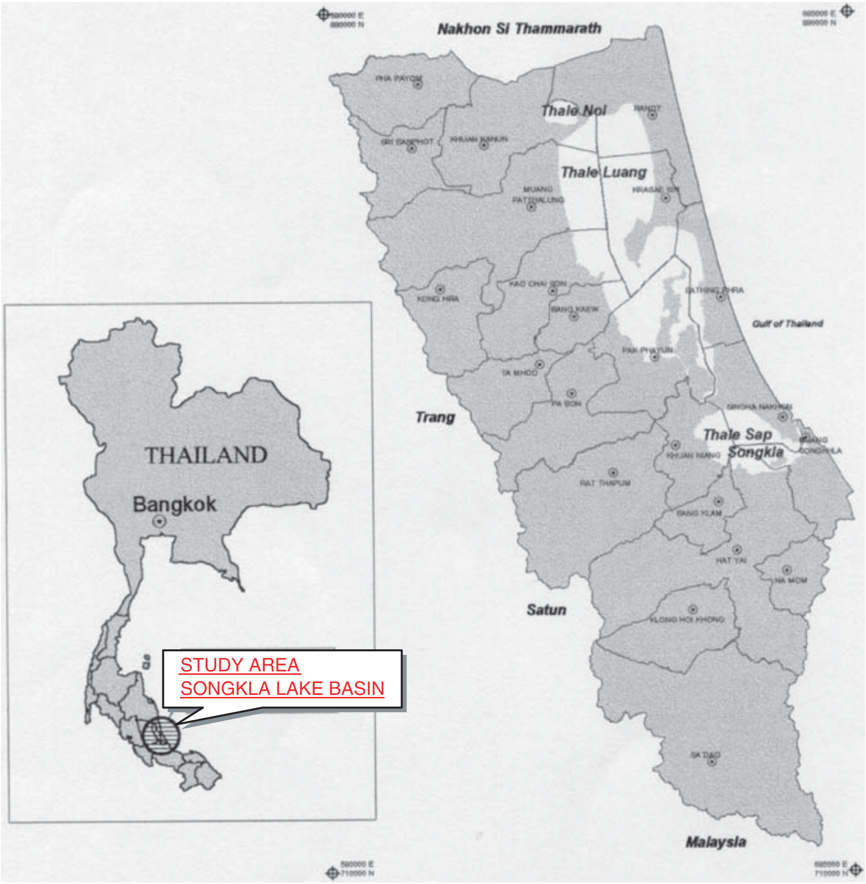

FIG. 4.3.1. Location map of Songkla Lake Basin.

TABLE 4.3.3. Land use changes between 1982 and 1996.

Land use types	Area* (ha) 1982	1996
1. Forest	146,568	94,687
2. Rubber	292,610	356,314
3. Rice	208,599	209,183
4. Orchards	21,412	12,359
5. Perennial crops	1,169	2,118
6. Aquaculture	3,491	6,148
7. Open land	–	16,890
8. Urban and built up land	30,990	8,100
9. Miscellaneous land	35,796	34,551
10. Water body	1,334	1,591
Total	**741,967**	**741,967**

*Does not include lake surface.

TABLE 4.3.4. Soil losses from different erosion classes for 1982 and 1996.

Erosion classes	Rating (t/ha)	Soil loss (t/year)		Area* (ha)				Average (t/ha/year)	
				1982		1996			
		1982	1996	ha	%	ha	%	1982	1996
Very slight	<6.25	612,581	629,865	681,066	92.0	661,339	89.3	0.9	1.0
Slight	6.25–31.25	382,684	470,370	25,343	3.4	30,828	4.2	15.1	15.3
Moderate	31.25–125	1,865,888	2,585,854	29,927	4.0	39,687	5.4	62.3	65.2
Severe	125–625	770,820	1,616,998	4,291	0.6	8,479	1.1	179.6	190.7
Very severe	>625	4,509	37,108	6	0.0	43	0.0	751.5	863.0
Total		**3,636,482**	**5,340,195**	**740,633**	**100**	**740,376**	**100**		

*Does not include water body and lake surface.

cover, in one form or another, plays in preventing soil erosion. It should be noted that in 1996 8,439 and 43 ha of the total land area of the basin were in the severe and very severe erosion classes, respectively (Table 4.3.4). Most of the severely and very severely eroded lands were found on the mountain terrain to the west and south of the basin.

Further, it was estimated that the total amount of sediment eroded from the basin catchment in 1996 was 5,340,195 t. In general, the amount of sediment leaving a drainage basin is less than that removed from the eroding portions of the upland watershed. This is because of deposition of material at the base of the slopes, on the flood plains and in the channel itself. A countrywide study of 105 agricultural production areas in the United States by Wade and Heady (1978) revealed that between 0.1% and 38% of the total amount of eroded sediment from the catchment reached the basin outlets.

If the maximum figure of 38% was applied to the present study, the sediment reaching the basin outlets would be 2,029,274 t annually; an average of 273 t/km^2/year of the catchment. Assuming a sediment density of 1.5 g/cm^3, the sedimentation rate of approximately 1.2 mm/year would have occurred in the lake in 1996, provided the sediment was evenly deposit over the lake. As a substantial, albeit unknown, proportion of the lake sediment passed through a narrow outlet on the south of the lake to the sea, the value of 1.2 mm/year may be an overestimate of the sedimentation rate. It is noteworthy that NESDB and NEB (1985) estimated the lake sediment rate to be 0.5 mm/year in 1985.

The occurrence of erosion and sedimentation in the basin had serious environmental and economic implications. Sedimentation decreased the storage capacity of the lakes and choked irrigation canals and tributaries. In addition, sediment deposited in the lakes not only impaired its nursery and feeding functions for many commercially important aquatic species, but also degraded the water quality of the lake, affecting irrigation, livestock raising, fish farming, and rural domestic water supplies. Furthermore, nutrients, particularly nitrogen and phosphorus, carried by the sediment have led to eutrophication of the lake. These issues have inevitably had an adverse effect on the socioeconomic advancement of the basin's population.

Mitigation Options

To mitigate soil erosion hazards, and their adverse consequences, a watershed classification system has been practiced in the Songkla Lake Basin, as well as in other parts of the country (Tangtham 1997). The criteria for the classification are based primarily on the physical characteristics of landscape units, namely slope, elevation, landform, soil, and geology. According to this system, the watershed area is classified and mapped into five numerical classes. In each class, the potential uses of land are established for the prevention of land degradation and the achievement of sustainable land use across the basin. The watershed class and major land uses recommended for each class are shown in Table 4.3.5 and Fig. 4.3.2.

For successful mitigation of soil erosion and sediment transport in the Songkla Lake Basin, the watershed classification system must be strictly applied and effectively enforced. In this respect, the remaining natural forests in areas designated as watershed class 1 must be protected and enriched. The deforested portions should be reforested. Incentive packages should be offered to encourage farmers to abandon cultivation in areas designated as watershed classes 1 and 2. Agroforestry practices, which have both production and conservation benefits, should be utilized by farmers cultivating in watershed class 2. Appropriate conservation measures to minimize soil losses, such as contour cultivation, bench terraces, hillside ditches and

Table 4.3.5. Watershed classification and recommended land use in each class.

Watershed classes	Areas (ha)	Characteristics and major land use recommended
Class 1	63,956	Protected forest and headwater source areas at higher elevations and steep slopes. This area is dedicated to the protection of biological diversity and no human interference with the environment is permitted in this zone.
Class 2	44,355	Protected and/or commercial forests at higher elevations with steep slopes. Landforms less erosive than watershed class 1. This area may be used for grazing or certain crops with effective soil and water conservation measures.
Class 3	47,322	Uplands with steep slopes and less erosive landforms. These areas may be used for growing certain crops, grazing, and mining with appropriate soil and water conservation measures.
Class 4	94,224	Gently sloping lands suitable for row crops, fruit trees, and grazing with moderate need for soil and water conservation measures.
Class 5	495,276	Gently rolling to flat areas used for paddy fields or other agricultural uses with few restrictions.

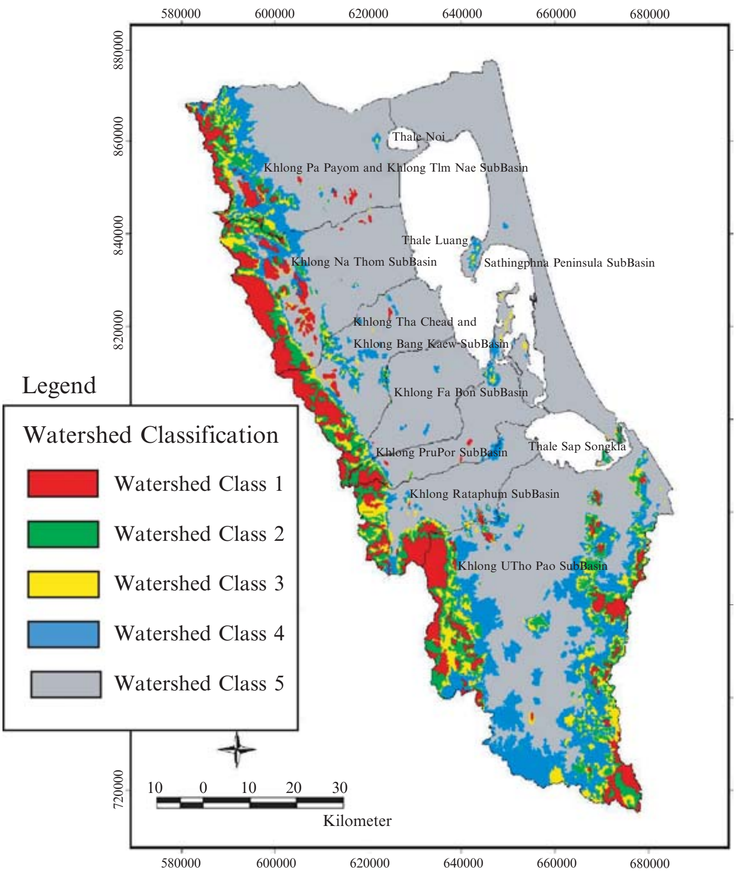

FIG. 4.3.2. Watershed classification in Songkla Lake Basin.

vetiver grass barriers, should be integrated into the cultivation practices in watershed classes 3 and 4. Agricultural development opportunities in areas assigned as watershed class 5 should be enhanced to offer alternatives to further encroachment of areas assigned as watershed class 1. Successful application of the watershed classification system in the Songkla Lake Basin is the most critical element for longer-term sustainability of environmental quality and agricultural production for the Songkla Lake Basin and its people.

References

Charuppat T (1996) Application of remote sensing in monitoring of tropical forest, pp. 10–18. In: Thamminchа S, Puangchit L, Silapa-Thong C (eds)Tropical forestry in the 21st century, vol. 9. FORTROP'96 international conference. NRCT, Bangkok

NESDB and NEB (1985) Songkla Lake Basin planning study. Final Report, vol. 2. Main report. John Taylor &Sons, 349pp

Tanavud C, Yongchalermchai C, Kimura M, Komamura M, Bennui, A, (1999) Land use changes and its environmental consequences in Songkla Lake Basin
Tangtham N (1997) Erosion and sedimentation studies and management in Thailand, pp 325–344. In: Proceedings of international symposium on hydrology and water resources for research and development in Southeast Asia and the Pacific. Nong Khai, Thailand
Wade JC, Heady EO (1978) Measurement of sediment control impacts on agriculture. Water Resour Res 14:1–8

4.3.5 Policy Direction of Integrated Coastal Zone Management in Korea

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Introduction

Korea has 11,542 km of coast line, 51 harbors, 815 fishing ports, and 84 industrial complexes on the coast. Nearly 30% of the total national population live in the coastal areas. Attention has been given to the coastal zone since the mid-1980s. Broad investigations into the actual condition were accomplished over the period from 1987 to 1989 and the Ocean Development Act was enacted in 1989. Furthermore, the plan for ocean development was established in 1990. However, the research and the plans were wholly aimed at developing marine areas, not for the conservation and management of coastal zones.

It can be said that coastal zone management in Korea was started fundamentally after the UN Conference on Environment and Development held at Rio in 1992. Since then the Ministry of Marine Affairs and Fisheries (MOMAF) was inaugurated in 1996. The Coastal Management Act, the Wetland Conservation Act were enacted, and the Ocean Pollution Prevention Act and the Public Waters Management Act were revised in 1999. Based on these initiatives, coastal zones in Korea could be conserved and managed, especially with an announcement of the plan for integrated coastal management as a priority.

Progress

According to the Coastal Management Act enacted in 1999, the plan for coastal management is divided into two sub-plans: (i) the plan for integrated coastal management; and (ii) the plan for regional coastal management. The first is a higher-level plan made by the government and the other is a lower-level plan established by local government. The plan for integrated coastal management was established and notified in August 2000. Its objective was to realize an integration of coastal utilization, cooperation between local and central governments, and finally to achieve sustainable development of the coastal zone by integrating marine and land areas. Under this plan, the nation is divided into 10 areas (Table 4.3.6) and provided a basic goal of coastal utilization and policy direction of integrated coastal management. In addition, it is prescribed that the plan can be changed every 5 years, after an investigation into the condition of coastal areas.

The areas of the plan for regional coastal management in Korea comprise 78 cities and counties in which the central government assigned one, 3 areas are scheduled, and local governments are making plans for the others, as shown in Table 4.3.7.

However, the first ten-year coastal improvement plan was established in 2000, in order to conserve national land from natural disasters and to improve coastal areas. Actually 99 areas were improved during 2000–2003, with a fund of 130 billion wons. However, it was inevitable to modify the plan for coastal improvement as conditions changed significantly. According to the modified plan for coastal improvement, it was scheduled that 981 billion wons would used to support 680 management initiatives, including 630 cases for coastal conservation and 30 for ocean improvement. It is especially worth noting that constructing coastal roads and constructing artificial lakes in white sands were excluded.

Another interesting thing in relation to the coastal zone management was to reclaim public waters in environment-friendly ways. Reclamation of public waters is enforced by the plan for public waters reclamation. This is developed every 10 years under the Public Waters Reclamation Act. The second plan for public waters reclamation was established and announced in July 2001. Unlike the first plan, the second plan required a preliminary analysis of environmental impacts when making plans for reclamations. Large reclamations

Table 4.3.6. Ten areas of the Plan for Integrated Coastal Management.

Coastal zone	Areas
West sea area	Middle of West Sea I, Middle of west Sea II, Southern West Sea I, Southern West Sea II
South sea area	Western South Sea, Middle of South Sea, Eastern South Sea, Jeju island
East sea area	Middle of East Sea, Southern East Sea

Table 4.3.7. Current situation of the Plan for Regional Coastal Management.

	Completion	Establishing	Scheduled
Central government	–	Gulf of Gwangyang	Mouth of Gum river, Gulf of Masam, Gulf of Garorim
Local government	Seosan city	Busan (10), Incheon (7), Kyounggi (1), Gwangwon (2), Chungnam (2), Cheonbuk (1), Cheonnam(6), Kyoungnam(7), Kyoungbuk (2), Jeju (4)	Others

were limited in number, and the use of an environmental-friendly method of construction was encouraged.

Construction of a database system for coastal zone management can also be noted as a successful initiative. It is aimed at managing coastal zones effectively, by collecting data on the utilization of coastal areas from central government, local governments, research institutions, and providing these to users. During the first step from 1999–2003, 400 maps were made and the database system for fish farms in 78 coastal cities and counties, islands, and reclamation of public waters was constructed. In addition, a web service for satellite images has been provided since February 2003.

Problems

Based on an evaluation of the policy of coastal zone management, the following can be noted as problems.

First, although the Coastal Management Act includes general factors for coastal management, it leaves much to be desired in the integration of management plans and construction of mediating functions. That is, it does not clearly prescribe relationships among the plans for integrated coastal management, the plan for regional coastal management, and the plan for coastal improvement. Furthermore, relationships with acts made by other ministries for national lands management are very obscure.

Second, standards for the creation of coastal areas are not clear. For example, a criterion for coastal land area is uniformly within 500 m. Moreover, although management areas of ocean by local governments are not clearly defined, local governments establish coastal management areas.

Third, methodologies for the evaluation of the effectiveness of the plan for integrated coastal management, and the plan for regional coastal management, are not yet developed. This might be the result of the policy being in effect for only a short period. However, evaluation methods must be properly developed in order to maximize their effectiveness.

Fourth, there are no clear criteria for prescribing permitted and illegal behaviors in each coastal area. Therefore, local governments have difficulty in devising plans and, as a result, this becomes an obstacle to developing coastal areas in an efficient manner.

Finally, management of marine pollution is divided between two ministries. That is, while the MOMAF is in charge of preventing pollutants originating from the oceans, the Ministry of the Environment controls pollutants originating from the land. Therefore, considering almost all pollutants in oceans originally come from the land, it might be not possible to solve the problem of ocean pollution without cooperation with the Ministry of Environment.

Policy Direction of Coastal Management

In order to achieve sustainable development of coastal zones, the coastal management policy must be strengthened in several ways.

First, the legal contents in the Coastal Management Act must be clearly established. That is, it is necessary to make the Coastal Management Act regulate all coastal areas and integrate with the plan for national lands.

Second, a clear criterion for coastal areas must be established and coastal boundaries among areas must be created in a consistent manner. However, because this problem is very sensitive for local governments, it must be determined after discussions with experts and local people.

Third, in order to evaluate the effectiveness of coastal management policy, detailed indicators must be developed. Moreover, it is necessary to establish a coordinating committee in the MOMAF for deliberating permitted and illegal behaviors.

Fourth, central government should support local governments that conserve and manage coastal areas effectively. In addition to this, the plan for regional coastal management should be integrated with the database system for coastal management, to allow integrated management of wetlands, water quality, and marine ecosystems.

Fifth, the MOMAF should cooperate with the Ministry of the Environment in order to prevent marine pollution. For example, both ministries may construct facilities for controlling pollutants through preliminary consultations and may expand activities for decreasing ocean pollution as a result of sea-bottom dredging.

4.3.6 Integrated Coastal Zone Management of Small Islands in the Pacific: Example of Fiji

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Introduction

The Pacific region is home to 8 million people, 22 island countries, and 30,000 islands (WWF SPP, 2004). Coastal zones in the small islands of the Pacific are very important, socially, politically, and economically. Increased coastal development due to social and economic needs have exerted pressures on the fragile island ecosystems. Uncontrolled expansion and reclamation of coastal areas to cater for increased population and urbanization have led to environmental degradation of the rich coastal biodiversity and ecosystems. Even though numerous regional and national programes have targeted coastal resource management, the situation in regard to integrated coastal management in many Pacific Island Countries is not encouraging (SPREP 2004). The aim of this section is twofold, first to identify important regional and national issues that are a priority concern for implementation of ICZM concepts and policies; and second to identify appropriate ICZM concepts and policies for the Pacific Islands.

Nature of the Coastal Zone in the Pacific

In order to gauge the social, economic and environmental impacts of coastal zone development, the following regional and national issues conducive for implementing appropriate ICZM concepts and policies for small island countries in the Pacific are highlighted.

Resource Tenure and Use

Indigenous people communally own most of the lands. This pattern of land tenureship is found across most of the indigenous communities in the Pacific. In Fiji, for example, the indigenous community owns 83% of the land, while the rest is state and freehold land (Table 4.3.8). As such, any form of development initiated by government and the private sector in the future would impinge on resources largely owned by indigenous people.

In Fiji the sea is also part of the marine tenure system. It falls under the Native Land Customary Fisheries Commission (NLC). The colonial government put into place a legislative framework to safeguard the rights of the indigenous Fijian people to fish, and to have access to their traditional fishing grounds for cultural purposes besides fishing. The ownership of the coastal and foreshore resources rests with the state, but Fijian clans and tribes are allowed to use the fishing ground (I-qoliqoli). This is dual ownership, where the state owns resources beneath the sea and the Fijian clans own the right to fish for subsistence living. There are two political boundaries, one is the Inshore Demarcated Area (IDA) (13 miles = 21 km), which begins from the high water mark from onshore to the fringes of the barrier reefs. The second is the Offshore Demarcated Area (ODA), which begins from the offshore fringes of the barrier reefs to the economic exclusive zone (EEZ), which is 200 miles (322 km) offshore. In these demarcated zones, illegal and overfishing by local and foreign boats is increasing. Since commercial fishing is on the rise, both from the Industrial sector and also from within the Fijian communities, increased pressures are being exerted on marine resources. For example, Table 4.3.9 shows the estimated annual fisheries production by volume and value for Fiji in the late 1990s.

Tuna is the key target species in the pelagic commercial fishery. The annual total allowable catch (TAC) for tuna in Fiji's waters is currently set

TABLE 4.3.8. Land tenure system in Fiji. (From Fiji Islands National Assessment Report to BPoA+10 2003.)

Tenure type	Area (ha)	Percentage of total land area
Native land	1,646,814	90.00
Freehold	147,448	8.06
State land	31,195	1.70
Rotuman Communal Land	4,452	0.24
Total	**1,829,909**	**100.00**

TABLE 4.3.9. From Gillet and Lightfoot 2001.

Fishing method	Volume (metric tons)	Value (in US $'000)
Subsistence Fishing	21,600	24,675
Coastal Commercial Fishing	9,320	15,232
Offshore fishing	5,500	25,640
Offshore foreign fishing	917	555
Total	**37,337**	**66,102**

at 15,000 t, according to the Department of Fisheries. This target has not been achieved.

The number of licenses issued currently stands at 90 per year, i.e., around 30 more than the sustainable limit proposed by the Secretariat of the Pacific Community (SPC). This has raised concerns within the industry regarding excessive fleet sizes and the threat of overfishing. Despite the fact that the number of licenses issued already exceeds the SPC-recommended level, Government stands by its estimated total allowable catch (TAC) of 15,000 t, of which it reports only 11,000 t are being harvested annually. It therefore would like to further increase the number of fishing licenses granted, to the legally allowed maximum number of 110 (Fisheries Department 2003).

WWF Fiji has spearheaded programes to mitigate problems of overfishing on nearshore resources, including damage to coral reefs. The method is to integrate traditional systems with more modern ownership practices such as conservation of valuable fisheries resources. This includes establishment of networks of marine protected areas (MPAs) to protect breeding stocks from overharvesting These are undertaken by the adjacent communities and affected resource users, in order to manage their foreshore resources well.

Smallness

Geographically both atolls and high and rugged volcanic islands have limited land that is suitable for population expansion and increased urbanization. As such, a high concentration of the population and civil infrastructures, such as roads, bridges, buildings, towns and cities, are located in low-lying coastal areas in volcanic islands. As for atolls, the lack of land hinders development as such. In Fiji, for example, 90% of public infrastructure is located in coastal areas.

Rich Biodiversity

Despite their small landmass compared to continents, Pacific islands generally have a very high concentration of terrestrial and marine biodiversity. The coastal habitats are home to some of the most unique varieties of coastal and marine species in the world. Approximately 90 of the 120 species of marine mammals live or pass through the Pacific Ocean. It also contains the world's richest fishing grounds, including globally important stocks of tuna.

For example, the terrestrial flora and fauna of Fiji demonstrate a high degree of endemism (unique occurrence of species within a limited geographic area) – over half of Fiji's 1,594 known plant species are endemic, with some groups being completely or almost entirely endemic (e.g., all 24 native species of palms in Fiji are found nowhere else). More than 40 percent of the native forest cover of the islands is still intact. Some islands, such as Taveuni, still have contiguous forest cover stretching from the mountain peaks to the coast. Forested areas provide habitat for a wide array of unique birds, mammals, reptiles, amphibians, insects and other invertebrates. In the marine environment, areas such as the Vatu-I-Ra Channel that separates Viti Levu and Vanua Levu islands, harbor some of the most unusual assemblages of coral reefs in the world, comprising barrier, fringing, and lagoon reefs. These reefs support varied biodiversity, including large groupers and Napoleon wrasses, other coral reef fishes and invertebrates, sharks, and cetaceans. The area is also of ecological importance and of great research interest because it is believed to show resilience toward large-scale climatic events, including coral bleaching. This has devastated reefs in other areas (WWF 2002). The biodiversity resources of Fiji are summarized in Table 4.3.10.

The marine biodiversity of inshore areas of selected Pacific Islands, in terms of inshore fish, hard coral, and marine algae, is shown in Table 4.3.11.

The largest concentrations of mangroves are found in deltaic formations of large river mouths, especially in the Ba, Rewa and Nadi Rivers on Viti Levu and the Labasa River on Vanua Levu. Climatic conditions are important for mangroves. In dry leeward areas (western shores), hypersaline mudflats characteristically occur in the mangrove areas, while these are virtually absent from the wetter, windward mangrove areas (eastern shores). It has been estimated that of an original 41,000 ha of mangrove forest, 38,543 ha remain. The other 2,457 ha (6%) have been reclaimed for other uses (Watling, 1985). All but about 2,000 ha of the remaining mangrove are on the two large islands of Viti Levu and Vanua Levu, with the Rewa, Ba and Labasa deltas alone supporting a combined total of 10,683 ha, or 28% of the national resource (Woodroffe 1987).

In 1952 over 50,000 m^3 of mangrove wood were harvested and processed by the Forestry Department. However, with the increased availability of fuel oil, the demand for mangroves dropped to less than 5,000 m^3/ year after 1967, and is now negligible. A limited amount of mangrove is used for poles and charcoal (DOE 2002). By far the greatest loss of mangroves in Fiji has been caused by reclamation for agriculture, e.g., in the Labasa River delta. However, about 300 ha of mangroves have been converted for aquaculture of penaeid prawns, and in recent years the principal threat has been reclamation of mangroves for urban and industrial development.

There is also some overexploitation of mangroves to satisfy the demands for fuelwood, but this is localized. It has been estimated that more than 60% of Fiji's commercially important food fishes utilize the mangrove resource at some stage of their life history. In 1983, the value of Fiji's mangrove forests to the fisheries industry was estimated at over Fiji $20 million (DOE).

Table 4.3.10. Native, endemic, extinct, threatened and introduced species in the Fiji Islands. (From Fiji Biodiversity Strategy and Action Plan FBSAP 1999.)

Group	Estimated total no. of living native species	Estimated no. (%) endemic (unique) to Fiji	Number of extinct species	Number (%) of threatened species	Number of intro-duced species
TERRESTRIAL					
Birds	56	27 (48%)	7	13 (23%)	11
Mammals	6	1 (17%)	1	2 (33%)	5
Amphibians	2	2 (100%)	1	2 (100%)	1
Reptiles	26	10 (38%)	1	8 (31%)	0
Invertebrates	N/A	N/A	N/A	N/A	N/A
Macrolepidoptera-butterflies, moths	400	17 (4%)	2	N/A	N/A
Cicadas	15	14 (93%)	N/A	N/A	0
Phasmids stick insects	19	12 (63%)	N/A	10 (52%)	0
Odonata dragonflies, Damselflies	33	22 (67%)	N/A	N/A	?
Plants – flora	1594	893 (56%)	1	281 (18%)	936
Ferns	303	90 (30%)	N/A	58 (19%)	7
Palms	24	24 (100%)	N/A	12 (50%)	6
Psychotria spp. Rubiaceae	76	72 (95%)	N/A	21 (28%)	0
AQUATIC					
Freshwater bivalves, Gastropods and Crustacea	61	7 (11%)	N/A	1 (2%)	3
Fresh and brackish water fish	91	Few if any	N/A	N/A	10
Fish (freshwater and marine combined)	1930	1 (<1%)	N/A	N/A	10
Marine Invertebrates					
Echinoderms	240	0 (0%)	N/A	N/A	N/A
Crustaceans	262	1? (<1%)	N/A	N/A	N/A
Gastropods - Cones	99	0 (0%)	29	N/A	N/A
Gastropods – Cowries	71	0 (0%)	4	N/A	N/A
Insects	2	2 (100%)	N/A	N/A	N/A
Bivalves	382	0 (0%)	96	N/A	N/A

Fiji is believed to harbor at least one thousand different reefs. These include the seven major types, namely fringing, platform, patch, barrier, oceanic ribbon, atolls, near atolls and drowned reefs (UNEP/ICUN 1998; Zann 1992). Fiji has about 3% (equivalent to 10.020 km^2) of the world's coral reefs, placing it in the top 10 of the 80 countries and geological locations with reefs

Table 4.3.11. Inshore marine biodiversity in the Pacific Islands. (From South Pacific Forum Secretariat 2001. Biodiversity Planning Support Programme.)

Area/Country	Inshore Fish		Hard Coral			
Species Ref	Species	Ref	Species	Ref		Marine Algae
Papua New Guinea	2146	1	350	2		
Micronesia	1681	1			550	3
Fiji	1400	4	160	4	310	3
Samoa	890	5	50	5	287	5
Cook Islands	492	6	58	7		

(UNEP-WCMC 2001). Fiji reefs are recognized as being of high ecological significance from a biodiversity standpoint (Zann 1992; Zann et al., 1997). Studies have researched 198 species of scelractinians corals, 15 zoanthids, 123 species of gastropods from 12 families and 1900 species of fish from 162 families (Fiji Government 1999). Many more species are yet to be researched and the number of new species is likely to increase, especially given that the Great Astrolabe Reef is the third largest reef formation in the world.

However, biodiversity in Fiji is threatened due to a number of important factors, including: (i) cyclones and destructive waves, which cause physical damage to coral reefs; (ii) overfishing; (iii) pollution and deteriorating water quality; (iv) forest denudation; and (v) introduction of a wide range of exotic and invasive species of plants and animals that out-compete and displace native species. The factors are compounded by an increase in atmospheric temperature and by sea-level rise, due to global warming.

Cultural Links Naturally many Pacific Islanders are coastal dwellers, and their attachment to the sea is culturally strong. Most of their social and cultural way of life is derived from their age-old interactions with the sea, such as reflected in their traditional dances, myths, gods, and lyrics in traditional songs. Moreover most of their protein supplements come from surrounding inshore waters, in particular with fish being their staple diet. As a result, inshore fishing pressure is particularly high in peri-urban coastal areas. These are also under pressure from mangrove reclamation projects, housing development, and pollution. For example, the island of Viti Levu, where 77% of the people of Fiji live, has only 15% of the country's reefs. But these provide the major proportion of the artisanal fish catch. The concentration of population in Pacific urban centres can also be seen, for example, in Kiribati, where 45% of the population lives on the small atoll of Tarawa, and in Tuvalu, where 40% of the population is concentrated in Funafuti (MSP USP 2003) Increased Economic Activity. As more small island countries are engaged in the regional and global economy, greater dependence on overseas economies is anticipated. National and private institutions that facilitate economic development follow a top-down approach, whereby decisions are made at the top and passed down through the management hierarchy (DOE 1999).

One area of development which is becoming a very fast growth sector in the Pacific is tourism. From 1999 to 2003 the increase in tourist arrivals has been phenomenal, especially for a country like Fiji. Fiji saw the percentage increase change from 5.9 in 1997 to 13.0 in 2004 (Bureau of Statistics 2004). Table 4.3.12 shows the increased tourist arrivals into the Pacific between 1999 and 2003 for each island country with the exception of Kiribati, Solomons, and New Caledonia. The general trend has been the increase for the islands listed in the table.

Tourism has also become the biggest foreign income earner in most of the Pacific countries and in particular for the Cook Islands, Vanuatu, and Fiji. Table 4.3.13 indicates the GDP and employment percentage in the tourism sector.

As a result, development of tourist hotels along coastal fringes is increasing. Even though the economic benefit has been high, the effect of large-scale 3- to 4-star hotels, along with smaller and medium-sized tourism business, has been devastating to the coastal marine ecosystem. A study for the Ministry of Tourism, conducted by the Asian Development Bank(ADB) and called the strategic environment assessment (SEA) of the tourism development plan (TDP), indicated that there are particular areas within Fiji where tourist development is causing serious environmental degradation and where the situation is extremely precarious. Many environmental pressures, for example, on coral reefs, are close to levels at which irreversible damage could occur. Further

Table 4.3.12. South and Central Pacific visitor arrivals: 1999–2000. (From South Pacific Tourism Organization [SPTO].)

Country	1999	2000	2001	2002	2003
Fiji	409,995	294,070	348,014	397,859	430,800
French Polynesia	210,800	233,326	227,658	189,003	212,767
Kiribati	6,107	4,377	4,831	4,288	3,676
New Caledonia	83,016	109,587	100,515	103,933	101,983
Niue	1,778	2,010	2,069	1,632	2,758
PNG	67,368	58,429	54,280	53,482	56,185
Samoa	85,124	87,688	88,263	88,960	92,313
Solomon Islands	17,395	10,134	3,418	4,508	4,000
Tonga	30,883	34,694	32,386	36,585	40,110
Tuvalu	770	1,504	976	1,236	1,496
Vanuatu	50,746	57,591	53,300	49,463	50,400

NB: Figures for the Solomon Islands 2003 is from January–August only.

Table 4.3.13. Economic importance of tourism in countries within the region. (From SPTO 2004.)

Country	Tourism GDP %	Tourism % Employment
Cook Islands	47.0	–
Fiji	12.8	9.5
Kiribati	14.5	1.7
Niue	13.0	–
Papua New Guinea	6.3	3.2
Samoa	9.5	10.0
Solomon Islands	2.9	1.6
Tonga	14.7	3.2
Tuvalu	3.0	–
Vanuatu	16.6	12.0

pressures could tip the balance, resulting in long-term environmental damage (ADB 2003). One reason why this has occurred is that many of the coastal infrastructural developments in Fiji have not been monitored well, due to the lack of environmental policies that govern coastal developments. While a lot of tourist developers and operators are following good practice, Fiji lacks the frameworks to ensure such practices are adopted across the industry. Much of the policy, legislation and regulation needed to ensure good practice already exists on paper. However, much of the necessary legislation has not been enacted, or has not been implemented or enforced (ADB 2003). Even the new Environment Management Legislation, which was passed in Parliament in February 2004, does not include ICM.

Environmental Impacts Increasing environmental pressures that are affecting coastal zones management include the effect of global warming on sea level, weather systems, climate variability and change, land and sea earthquakes that induces tsunamis and the increasing frequency of tropical cyclones.

ICZM Policies for Small Island Countries

There are two aspects of ICZM in the Pacific. One is traditional and the other is modern or western policy. The traditional ICZM is based on the customary rights of the indigenous people to gather, utilize and fish coastal and marine areas, as explained in section 2, above. This is based on traditional community-based controls and on check systems on resource use, such as demarcation of marine protected areas to respect the death of a high chief for a defined period of up to 2 years. Another example is intricate weather pattern information held by elders. This was passed down from their forefathers through oral tradition. It includes such information as to which traditional crops are best used for coastal re-vegetation, when they should be planted, and the best land area to be cropped. One of the oral traditions is the Lunar Calendar, specifying the specific dates and months of monthly and yearly harvests of resources. As such, marine conservation methods, including *tabu* (no fishing) sites for stock replenishment (Koshy 2001), are to be defined to allow breeding seasons for turtles, fish and other sea creatures. Others include preservation of coastal vegetation and their medicinal and herbal values, and demarcation of setback zones as windshields against coastal erosion and sea storms (Vanualailai 2001).

Other examples include the use of fishing practices such as the "moka". Stones are placed around deep water holes in shallow tidal flats to trap big fish and allow smaller fish to escape the trap. In Fiji the religious significance of having traditional totem regarding marine flora and fauna, whereby excess fishing of different fish totems and fauna totems are a taboo, brings forth the principles of sustainable development. Traditional demarcation of coastal fringes as setback areas due to the herbal importance of coastal vegetation also plays a major role as windshields and natural coastal protection systems. In today's society the immense pressures from the sociocultural and economic factors, such as increased population, urbanization and developments of tourism related infrastructure and activities, have restricted the flexibility of traditional management systems to cope with such developments. In fact, traditional management systems have difficulty coping with modernization. Therefore, western policy regarding ICZM should be streamlined and integrated into the traditional management systems.

The traditional system is also based on a communally-based intricate system of interrelationships, where people traditionally inherited from birth their place in society. This is based on a hierarchical set-up of governance, beginning from the top and downward through the hierarchical pyramid. The Paramount chiefs for the clans come first, then the tribal chiefs, then their spokespeople. The next in line are the priests, then come the warriors, the fishermen and the carpenters, and last are the common people. The communication channels are passed down from the top. However, power distribution is not wholly and totally concentrated at the top. The powers are shared among the different levels of the pyramid. For example, when it comes to coastal development or fishing, the tribe, clan or household that are traditional fishermen have total say and authority over the use of coastal and marine resources. As for chiefly initiation ceremonies, the warriors have a special place to bring order to the masses. In this way the rest of the people are included in the pyramid. Therefore, only people who are traditionally fishermen are allowed to fish, whereas the rest are restricted to their own sphere of influence. As time evolved, the strict traditional system has been modified to suit the new developments. One in particular is the use of communal participation of gender for subsistence fishing. Nowadays women take over the task of traditional fishermen, and men are more involved with the terrestrial subsistence farming. Non-governmental organizations, like the World Wildlife Fund (WWF), have been heavily involved with community-based organizations in Fiji, especially to integrate both the traditional and modern types of coastal management of resources. This programe is called Marine Protected Areas (MPAs). In Fiji alone there are about six programes. These are very successful, whereby they integrate modern planning with traditional planning and management, especially in the areas of restocking fish and marine resource management in depleted areas.

The concept of ICZM in the Pacific Islands of Tuvalu, Samoa, Fiji, Tonga, Cook Islands, Vanuatu, Kiribati, and Solomons regarding traditional knowledge in customary practices has been widely practiced for thousands of years. However in today's world of commerce and global trade, compounded by increasing environmental impacts from the effect of global climate variability and change, traditional knowledge is insufficient to mitigate and adapt to the rapid social, economic and environmental changes in coastal areas. Therefore, appropriate ICZM concepts and policies, such as those mentioned above, are alternative adaptation tools for small islands in the Pacific.

The modern management of coastal development in the Pacific by governments has been mainly trying to encourage the industrial sector to grow. Most of the developments have disregarded the environmental importance for many years. Fiji, since its independence in 1970 and until 2003, did not put into place environmental legislation to safeguard its marine and terrestrial resources against economic developments. A makeshift environmental management regime, which lacks a major component of environmental planning such as the ICZM, was enacted in 2004. For example, most of the modern type of systems lack coastal setback strategies. Developments have always resulted in exclusion of the local people in the initial developmental plans. Consultations are only done at the higher levels of management and do not filter down to the local people. After the developments local people are left to fend for themselves. For example, in local villages where entire coastal areas are bulldozed, mangroves are cut down and heavy earthworks are carried out, high siltation damages pristine coastal areas, especially coral reefs. In Fiji about 70% or more of the coral reefs of the Coral Coast, the main tourist destination in Fiji, have undergone coral bleaching and coral death due to siltation and dumping of sewerage in these areas.

In addition, there is a lack of ICZM plans in other key stakeholders in governments beside the Department of Environment. This includes agencies responsible for fisheries, tourism, agriculture, public works and the industrial sectors. There is no coordinated body to monitor coastal developments. The strength of modern ICZM plans is that they foster the integration of traditional management plans as part of the overall management plan. For example, the MPAs in Fiji are good indicators of modern plans to tackle existing problems. They encourage greater involvement of communal groups in villages in order to manage mangrove and coral reefs as protected areas. A village in Kadavu Island, called Ono, implemented its MPA program in 1998. It has noticed that fish stocks have been returned to their original state. Now the other 14 village communities living along the coast are benefiting from the fish stock. Moreover, greater care with development of coastal areas is a higher priority in these coastal communities. Now the 14 village communities are applying for similar MPA programes to be conducted in their villages.

Based on the above analysis, there is a strong traditional tenure and a fragmented governance system coupled with poor legal and institutional frameworks for coastal management. In general the management responses from Pacific Island Countries have been hampered by an overall lack of appropriate legislation for ICZM and in many cases, insufficient capacity to implement sectoral management strategies (SPREP 1995). The UN Food and Agriculture Organization (FAO) also reported that "responsibility for management of human interaction with the coastal environment is still predominantly sectorally based". It suggested that there is not only a lack of cooperation between the agencies traditionally responsible for management of activities in the coastal areas, such as Fisheries, Environment, Board of Works and Planning Departments, but there is often active competition for both financial resources and management roles, complicated further by overlapping and sometimes conflicting legislation (FAO 1995).

Therefore, a three-track ICZM approach to coastal management is suggested in order to maintain and sustain a healthy coastal environment. The first is to establish locally-based management activities to address the issue of capacity building and to achieve sustained progress in maintaining healthy coastal areas. This will require full participation by local communities and landowners to maintain healthy coastal areas. Therefore, policies for developing and maintaining public involvement and education programes to promote public awareness and public involvement are to be put into place. This would include requirements to disseminate information on different mass media channels, such as in written, audio and visual forms.

The second is to establish frameworks and a policy environment at the top level of management, to forge links between local communities and the national government (SPREP 2004). This will address the issue of fragmented governance, replacing it with a systematic framework for proper facilitation and implementation of coastal programes. For example in Fiji the classical development model is mostly based on a "top - down approach", whereby different government and private bodies have their own development agendas to implement, Due to Fiji's intricate land tenure system many problems have arisen from this development approach, in particular within and among the grassroots level, middle management and the top management (decision-making body) of government and private sectors involved. This is where a clash of ideals, fabrication, overlapping, and inconsistency in a lot of developmental processes occurs, largely due to the lack of consultation, communication, integration and monitoring between the specific bodies involved. Therefore the first step is establishment of an ICZM national steering committee (NSC), to provide effective and cocoordinated decision making on coastal resource planning, development and management. It should also ensure that activities within the coastal zones are undertaken in such a manner so as to not affect the carrying capacity of coastal resources. Second, there is a need to appointment senior NSC members from stakeholders in governments and statuary bodies to function as an interdisplinary CZM committee. This committee would be responsible for appointment of new NSC members from the business communities, non-governmental organizations (NGOs), statuary bodies, academic institutions and the private sector. Third, the chair of ICZM NSC is to be appointed on the advice and recommendation of the NSC.

In view of the above, the third track is to develop a top-down and bottom up approach. The aim would be to provide a mechanism for a more integrated approach by all parties involved, whether government, nongovernment, private, or rural community. The aim would be to facilitate any form of developmental process, and its implementation. The model integrates vertical and horizontal consultation. For example, it has been seen that in Fiji's case the traditional system cannot cope with coastal management. It needs

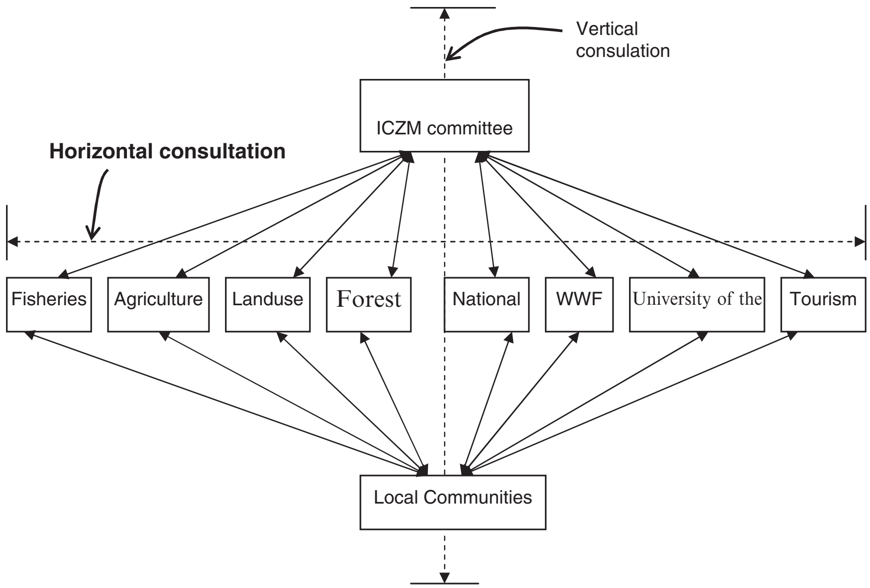

FIG. 4.3.3. An integrated top-down and bottom-up approach of ICZM.

to promote integration at multidisciplinary, multi-sectoral and multi-levels (wide involvement of community) in order to avoid the above and related problems associated with the *top-down approach* within the top, middle and lower management. Moreover, and more importantly, the integration needs to include the indigenous people who own the land. This will ensure that the people concerned are properly advised and consulted regarding the developments taking place, including the effects on their natural resources. Therefore, policies to actively involve them in the decision-making process and management in community-based coastal resource management are to be established. There is a need for policy that provides an bridge between government and communities, allowing them to be involved in a systematic analysis of coastal management issues and as well as planning for implementation of responsible action. Figure 4.3.3 describes an ICZM top-down and bottom-up approach.

References

DOE 1999. Integrated Coastal Zone Management. US Country Studies Programme. Department of Environment, 18 Richards Road, Suva

FAO 1995. Integrating Fisheries into Coastal Management in Pacific Small Island developing states. *Report on the workshop on the implementation of the 1995 code of conduct*, pp.1–13

Koshy .K 2001 Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) see *Tiempo*, Issue 40/41, September 2001.

SPREP 2005. Integrated Coastal Management in the Pacific. Pacific Regional Environment Programme January 2005 Report.

Vanualailai 2001. Technology Assessment of Coastal Protection System. Ibaraki University. A Masters thesis dissertation

USP 2000, Modelling a gender sensitive approach to fisheries research: Canada - South Pacific Ocean Development Program Marine Studies Programme, *Pacific Voices*

5
Regional Conditions

Chairs: Yoshiki Saito and Porfirio M. Alino

5.1 East Asia

In this chapter, we will see the geographic and societal situation of the coast and its management on a sub-regional basis. The subregion introduced first is East Asia, for which we will see China, Korea, Taiwan, and Japan. Coastal zones of East Asia are characterized by diversity of coastal morphology and strong oceanic and climatic activities. They have long suffered from natural hazards such as typhoons, storm surges, high waves, and tsunamis, resulting in huge damage to the human society. At the same time, concentration of large populations, economic activities, and development in the coastal zones are another feature in this region. Recent enormous economic development in the countries has accelerated the pressure to the region's coastal environment together with global environmental changes such as sea-level rise and climate change. Therefore, the region has a strong need to develop a management framework for the coastal zones and its implementation. In this section, we will see the preset status of such efforts in this subregion.

5.1.1 The Coast of China

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Basic Characteristics of the China Coast

China's coastline is approximately 32,000 km long, 18,400 km of which encompasses the mainland from the Yalujiang river mouth at the China–Korea border to the China–Vietnam border. The remaining 13,600 km or so of coastline belongs to China's offshore islands, of which there are more than 6,000. The Chinese coast can be classified into four categories, based on their mode of formation and characteristics (Table 5.1.1).

N. Mimura (ed.), *Asia-Pacific Coasts and Their Management: States of Environment.*

TABLE 5.1.1. Classification of the China Coast. (From Wang 1996.)

The coast of China	Bedrock-embayed coast	Marine erosional-embayed coast
		Marine erosional-deposition coast
		Marine depositional coast
		Tidal inlet-embayed coast
	Plain coast	Alluvial plain coast
		Marine depositional plains coast
	Estuary coast	Delta coast
		Estuary coast
	Biological coast	Mangrove coast
		Coral reef coast

Bedrock-embayed Coast

The bedrock-embayed coast is characterized by irregular headlands and concave bays, and forms where mountains meet the sea. The subaqueous slope of the coast is steep and exposed to high-wave energy. The dominant surface sediment types for this coast are coarse-sand and gravel. Evolution of the coastal morphology mainly depends on wave action, the gradient of the subaqueous slope, lithology of the bedrock and sediment source (Wang et al., 1986; Wang and Aubrey 1987). These coasts are mostly developed in the areas south of the Hangzhou Bay, i.e., in Zhejiang, Fujian and Guangdong provinces, and are also found in the Shandong peninsula and Liaodong peninsula in the north (Fig. 5.1.1).

Plain Coast

The plain coast of China is more than 2,000 km long, with a very gentle slope (generally it is 1/4000) and composed mainly of fine sand. These coastlines are quite unstable, due to rapid erosion and accumulation. Tidal marshes that can be up to tens of kilometers wide are usually located between the shallow shelf seas and plains. Most plain coast is located in the west of Bohai Bay, the outer margin of the Songliao plain and the coastal area of the Huabei plain in the north. Another area is in the south of the Hangzhou Bay (Fig. 5.1.1). The progradation and retreat of the plain coast mainly depends on the balance of sediment supply and the coastal erosion induced by the coastal dynamics (Wang 1980; Wang and Zhu 1994).

Estuary Coast

The estuary coasts are most developed where the large rivers join the sea. The river–sea interaction results in a wide plain coast, including the delta coast and the coastal bays, due to the accumulation of the river-derived sediment. The Huanghe (Yellow River) mouth coast, the Yangtze estuary coast and the Hangzhou Bay are examples of this type (Fig. 5.1.1).

Biological Coast

The biological coast is mostly located in the inshore areas of south China and the South China Sea. It can be classified into two types: coral reef coast and mangrove coast. The coral reef coast is a particular kind of biological

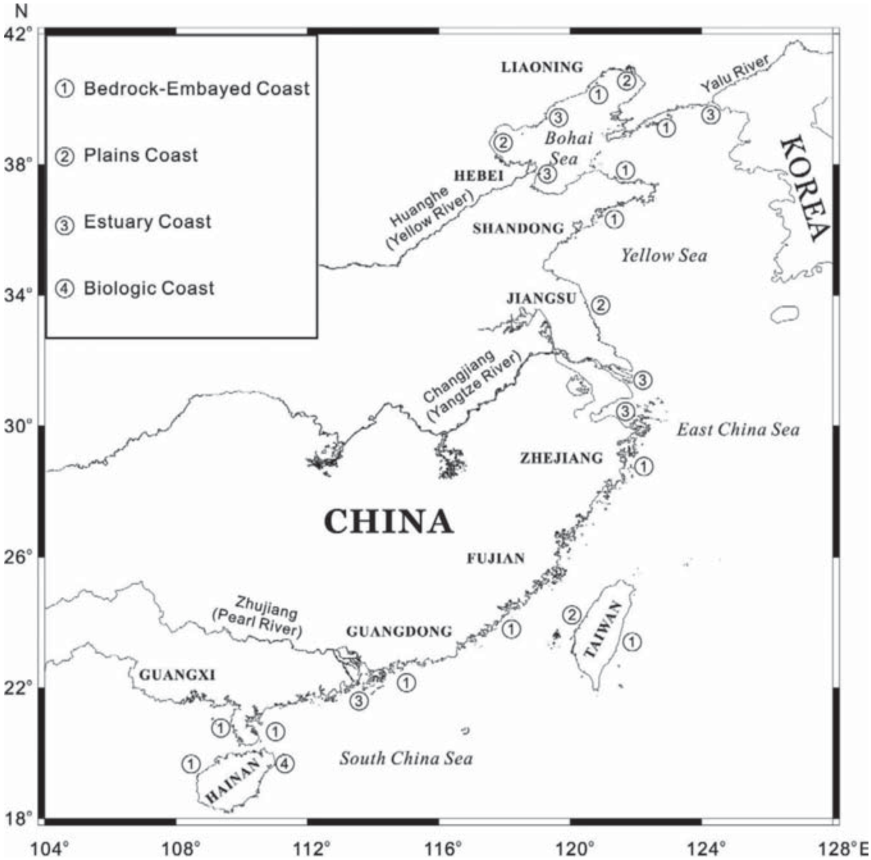

FIG. 5.1.1. The coast of China and its classification. (After Wang, 1996.)

one, and is usually found along the coast of the tropical seas of China, i.e., Taiwan, Hainan Island and some islets around them (Fig. 5.1.1). The coast of the Nansha archipelago is composed of coral reef, except for the Xisha islands, which are composed of tuff (Wang and Zhu 1994). The floor of the coral reef coast includes Tertiary folded ridges with a coral reef layer 1,000 m deep due to tectonic subsidence of the floor (Wang PX 1985).

The mangrove coast is also a biological coast in tropical and subtropical areas. Mangroves mainly grow in areas south of latitude 27° N in China, and are scattered in the estuaries and the lagoons.

As for the entire coast of China, the Hangzhou Bay should be regarded as a borderline. To the, north the ascending bedrock-embayed coast and the descending plain coast intergrade due to tectonic differences. T the south the bedrock-embayed coast is dominant. Tectonics control the course of the Chinese coast. N–NE and N–NW faults intersect with each other, forming a large and deep x-shaped fault structure that is very influential on the shape of the China coast. Some islands, such as the Zhoushan islands, are composed of bedrock extending north-northeastwards in general, while the principle axis extends west–northwestwards.

Transition of the Quaternary Paleo-coastline

The early Pleistocene strata of marine facies of the east of China coast are found only in a few areas in the west shore of the Bohai Sea (Wang 1964). The maximum transgression boundary of the early Pleistocene in the coasts of Jiangsu, Zhejiang and Fujian provinces is located outside the present coastline. The Leizhou Peninsula in south China was submerged during the maximum transgression, with a boundary reaching the present coastal areas of Guangdong and Guangxi provinces. The early Pleistocene lowest coastline is to the west of 125° N (Chen and Min 1985).

Based on comparisons of paleo-geomagnetism from a borehole in Haixing, Heibei province, Wang PX (1985) suggested that the Quaternary transgression layer in the east of China formed about 300 ka BP, during the Sangamon interglacial period. Wang also presented evidence of the largest transgression in this period. The middle Pleistocene paleo-coastline of the Bohai Sea was traced from a line through Nanbao, Baodi, Yongqing, Baxian, Yanshan and Wudi counties. From the South Yellow Sea to the East China Sea the transgression boundary reached Yancheng, Shanghai and Hangzhou during this period. In south China, the transgression only influenced some sunken basins, such as the Wenhuang plain in Zhejiang, Pingyang, Hanjiang deltas, and the Pearl delta (Huang and Li 1982; Li 1989; Li 1987).

In the late Pleistocene, there were two significant transgressions in the east coast of China, i.e., the Riss-Yurm Interglacial transgression of 100–70 ka BP and the sub-Yurm Interglacial transgression of 40–24 ka BP. Between the two transgressions there was a period in which the sea level fell.

The paleo-coastline during the transgression period of 70–100 ka BP is now distributed in Tianjin, Wen'an, Cangzhou, Wudi, Guangrao (Qin 1985). During the regression period of 40 ka BP the paleo-coastline retreated to the –80 m to –100 m isobaths. The Bohai Sea was land, and the continental shelf of the Yellow Sea was almost bare. By 32 ka BP there was a transgression in the east coast of China and in the west coast of the Bohai Sea, which was submerged. In the lower reaches of the Yangtze, the corresponding paleo-coastline was in Yixing, Liyang counties (Wang PX 1985), and in Hua County and Sanshui out of the north of Guangdong Province (Li 1989).

In the Last Glacial Maximum (LGM) the sea level fell to 130–150 m below the present level in the East China Sea, and 100–120m lower than that in the South China Sea. The fall in sea level paused several times; this resulted in shell ridges being buried on the continental shelf of the East China Sea. According to the buried depth and ^{14}C dating, it was assumed that the paleo-coastline was at −110 m isobath at 23 ka BP, −136 m isobath at 20 ka BP and −155 m isobath at 15 ka BP, the lowest coastline during the fall in sea level.

After the glacial period, the sea level started rising at 15 ka BP. In the beginning, the sea level rose rapidly and the seawater reached the −110 m isobath at 12 ka BP. As the sea level rise paused, shell ridges were formed, at the age of 12,400

± 500 years by ^{14}C dating. When the seawater reached −60 m isobath, at 11 ka BP, a paleo-coastal sand bar was formed, with an age of 11,340±550 years by ^{14}C dating. The maximum transgression after the LGM in the coast of the Yellow Sea, the Bohai Sea and most of the East China Sea happened at 7–6 ka BP. The coastline pushed 100–200 m inland.

A small regression of the Chinese coast occurred after the Holocene maximum transgression and the coastline prograded to its present location. Transitional pauses of the regression resulted in the formation of several shell ridges in the west coast of the Bohai Sea (Wang 1964) and the North Jiangsu Plain (Yu 1982; Gu 1983). These are regarded as indicators of the coastline at different stages.

The Erosion of the China Coast

Coastal erosion is a common issue for the Chinese coast. Over the last 30 years the coastlines of China have been eroded extensively. This has become an important problem for protection of the coast.

The main factor influencing coastal erosion is dam construction that facilitates flood controls, agricultural irrigation and navigation. Dam construction is resulting in a decrease of most of the river-laden sediment and consequently sharp decreases in the sediment input to the sea, which cannot compensate for the eroded sediment by sea dynamics. The Huanghe (Yellow River) used to be second among the world's largest rivers in terms of sediment load, with 1.1×10^9t of sediment transported annually to the coastal sea. In recent years the large number of dams being built in the middle and the lower reaches has fragmented the river, and reduced sediment load to the sea sharply to 1/5 of that before. This has consequently caused significant coastal erosion of the Huanghe delta. The coastline has been eroded at a rate of 1.0 km/yr on average in recent years (Fig. 5.1.2). The well-known Three Gorges Dam will directly decrease the sediment discharge to the Yangtze delta and cause more extensive coastal erosion than before (Yang ZS et al., 2005; Yang SL et al., 2003). The coast of the Yangtze delta is also being eroded, threatening Shanghai, the most developed and prosperous metropolitan area of China.

In addition, excavation of sand, exploitation of the coral reef and unreasonable coastal engineering measures are other important factors responsible for coastal erosion. For example, on the eastern shore of Liaodong Bay, half of the more than 80 km coastline retreated at a rate of 5 m/year due to the excavation of sand. The coastal erosion induced by the excavation of sand is also serious in the Xiangshan County (Zhejiang Province) and the western area of Penglai (Shandong Province). In the Bangtang Bay of Hainan Province some villages that were far away from the coastline are now facing the danger of submergence by seawater. The overexploitation of the coral reef has led to destruction of coastal buildings in recent years. In the meantime, a large amount of the sediment eroded from the coast has been transported to the main channel of Qinglan port and deposited there, resulting in siltation of the navigation channel. Unreasonable construction along the coast has accelerated coastal erosion as well. For example, the low tidal line in the Lanshan port of Shijiusuo County

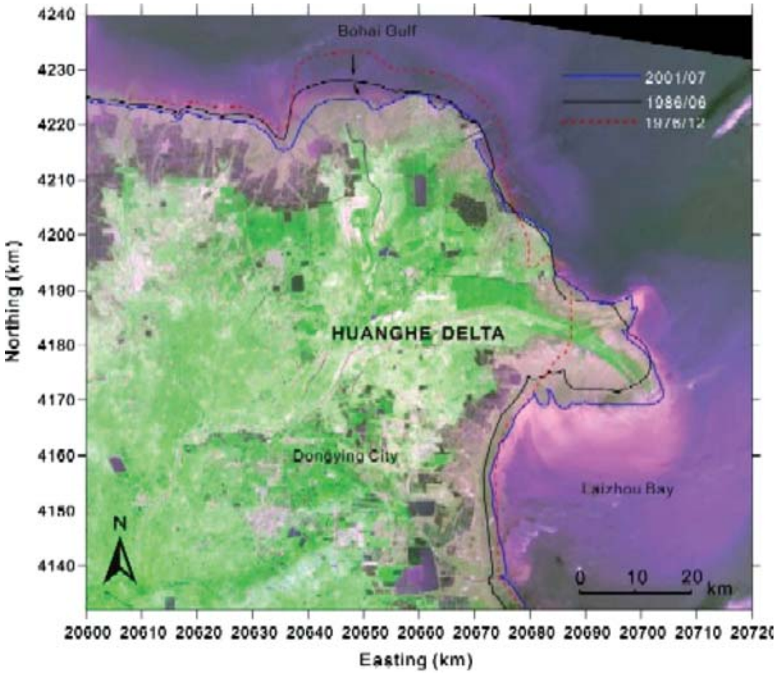

FIG. 5.1.2. Coastline retreat of the Huanghe Delta. In the northern part of the Huanghe delta, the coastline retreated continuously from 1976 due to cutoff of fluvial sediment supply. The coastline in the southeastern part prograded seaward after 1976 as the end river channel shifted to the present course. (By courtesy of G Li.)

(Shandong Province) retreated landward by 100 m 4 years after its completion in 1970, while the beach above the high tide line has been eroded by coastal waves, and a considerable amount of bedrock beach has been exposed.

The storm surge and the sea-level rise are natural factors that cause coastal erosion, as well as waves, tides, coastal currents and river flows. On September 15, 1989, typhoon No. 23 induced a super storm surge in the area of Songmen-Sanmen Bay, Zhejiang. This resulted in the complete destruction of more than one half of the coastal dykes in this area. On August 31, 1992, a super storm surge induced by typhoon Sinlaku destroyed the coast from Fujian to Hebei (Fig. 5.1.3). The entire sandy coast in Shandong was damaged, with extreme erosion and land loss of 133.3 ha.

Reasonable regulations on the river dams and coastal engineering are necessary to protect the China coast, as well as effective countermeasures for natural hazards such as storm surges and strong waves.

Summary

The coast of China, connecting the largest Euro-Asian continent with the largest Pacific Ocean, is a typical area of intensive land–sea interaction.

Fig. 5.1.3. The super storm surge induced by typhoon Sinlaku attacked the coast in Zhejiang province, China, in September 1992, destroying harbors and causing loss of life.

Approximately 45% of China's population and 60% of its GDP are concentrated in this coastal area, which makes the Chinese coast essential for the social and economic development of the country. Due to tectonic differences, the coast of China illustrates diverse features. The relics of sandy bars and shell ridges buried under the continental shelf of the China seas provide effective indicators for identifying the transition of the quaternary paleo-coastlines during periods of transgression and regression. A large proportion of the present coast of China is now facing serious erosion due to the combination of human activities and natural hazards. Extensive damming of the rivers, exploitation of the sands and unreasonable coastal construction have reduced the sediment supply to the coastal area and damaged the coastal environment. Natural hazards such as storm surges and strong coastal waves also change the coast and result in tremendous losses. Therefore, regulations on hydraulic engineering and coastal engineering, as well as effective countermeasures for the natural hazards, are necessary to protect the coast of China.

References

Chen HH, Min LR (1985) Paleo-geography map of China in the early Pleistocene and its instructions. In: Collective of paleo-geography map of China. Map Press, China, Beijing

Gu JY, (1983) Shell bars in the plain coast of central area of North Jiangsu. Acta Sedimentol Sinica 1(2):47–59

Huang ZG, Li PR, (1982) Formation and evolution of the Pearl (Zhujiang) Delta. Science Public Press, Shanghai, China

Li PR, (1987) The Hanjiang River Delta. Science Press, Beijing, China

Li PR, (1989) Quaternary geology in the area of Guangzhou. South China University of Technology Press, Guangzhou, China

Qin YS, (1985) Marine geology of the Bohai Sea. Science Press, Beijing, China

Wang PX, (1985) A preliminary study on the Quaternary transgression layer in the east of China. Acta Geol Sinica 55(1):1–11

Wang Y, (1964) Shell bars and the paleo-coastline in the west Bohai Gulf. J Nanjing Univ 8(3):424–440
Wang Y, (1980) The coast of China. Geosci Canada 7(3):109–113
Wang Y, Ren ME, Zhu DK (1986) Sediment supply to the continental shelf by the major rivers of China. J Geol Soc, Lond 143(6):935–944
Wang Y, Aubrey G (1987) The characteristics of the China coastline. Continental Shelf Res 7(4):329–349
Wang Y, Zhu DK (1994) Tidal flat in China. Oceanography of China Seas, vol 2. Kluwer Academic Press, pp 445–456
Wang Y, (1996) Marine geography of China. Science Press, Beijing, China
Yang ZS, Wang HJ, Saito Y, Milliman JD, Xu KH, Qiao SQ, Shi GY (2005) Dam impacts on the Changjiang (Yangtze River) sediment discharge to the sea: the past 55 years and after the Three Gorges Dam. Water Resour Res (in press)
Yang S, Belkin I, Belkin A, Zhao J, Zhu, Ding P (2003) Delta response to decline in sediment supply from the Yangtze River: evidence of the recent four decades and expectations for the next half-century. Estuarine, Coastal Shelf Sci 56:1–11
Yu ZY (1982) New understanding on the formation age of the paleo-sandy bars in the plain coast of central area of North Jiangsu. Acta Oceanol Sinica 4(4):11–14

5.1.2 The Coasts of the Korean Peninsula

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The Korean seas are divided into three by their geomorphological and physical characteristics: West Sea (or Yellow Sea), South Sea and East Sea (or Sea of Japan) (Fig. 5.1.4). The coastal environments of the Korean Peninsula can be generally typified and classified by the physiography and tide/wave influence of the surrounding seas (Fig. 5.1.5).

Yellow Sea (West Sea) and its Korean Coast

The Yellow Sea (often called West Sea by Koreans) is a shallow, postglacially submerged epicontinental sea with an area of about 500,000 km^2. It is arbitrarily bordered to the northern East China Sea by a line connecting Jeju Island and the southern part of the Changjiang (Yangtze) River mouth (Fig. 5.1.4). The Yellow Sea is characterized by a flat, broad, and featureless seafloor with average water depth of about 55 m (maximum less than about 100 m). The western part of the seafloor is bordered by the deltas of both the Huanghe and Changjiang rivers. The isobaths are approximately parallel to the coastline. The eastern Yellow Sea is fringed by numerous islands and a long stretch of tidal flat along the coast. Tidal sand ridges are ubiquitous in the eastern Yellow Sea, in water less than about 70 m deep, and trending slightly oblique to the coastline. The seafloor deepens progressively toward the axis that lies in roughly the eastern two thirds of the sea. The seafloor of the shelf

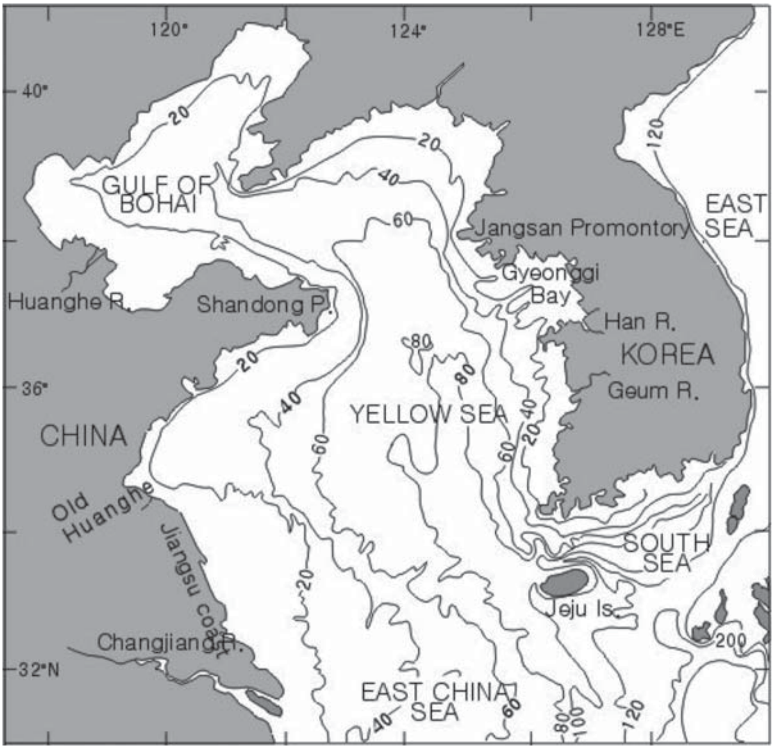

FIG. 5.1.4. Korean Peninsula and its surrounding seas.

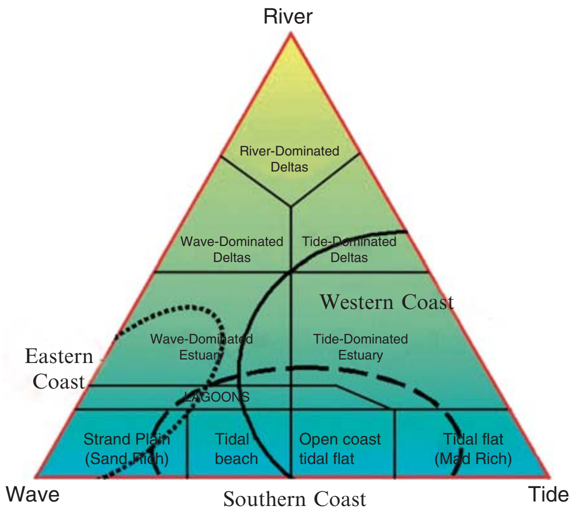

FIG. 5.1.5. Classification of clastic coastal environments. (Modified from Yang et al., 2005). Coasts of Korean seas can be roughly typified in the diagram.

deepens progressively southeastward to form the northern extension of the Okinawa Trough. The seafloor around Jeju Island exceeds a depth of 100 m.

These western coasts of the Korean Peninsula, a ria-type coast bordering the Yellow Sea to the east, have extremely high tidal ranges (up to 10 m at spring tide), resulting in extensive development of tidal flats (Table 5.1.2). Most of the tidal flats extend seaward for several kilometers, without any prominent geomorphological elements such as offshore sand bars or barrier islands (Frey et al., 1989; Alexander et al., 1991; Chun et al., 1992). Various types of intertidal flats, such as embayed, estuarine, semi-enclosed and open-coast tidal flats, drape almost all areas of the western coast. The extensive tidal flats are recognized worldwide as rivaling those of the North Sea. The tidal flats of the North Sea are approximately 9,000 km^2 while those of South Korea are 2,550 km^2. However, this would be more than 6,000 km^2 if the tidal flat of North Korea is included. Also, the tidal range of the coast is much higher than that of the North Sea.

The western tidal flats are mostly 4–10 km wide and face directly onto the Yellow Sea. They mostly correspond to the open-coast type, except for typical embayed muddy or estuarine tidal flats. They are generally bordered on the landward side by rocky coastal cliffs, or by artificial dykes that have been constructed to reclaim tidal marshes in a former embayment. These dykes inhibit the introduction of terrigenous sediment from landward sources. Tides are semi-diurnal (diurnal inequality of about 1 m), with a mean spring range of 4.3–9.1 m. The maximum tidal-current velocity is mostly 0.9–3.8 kt during spring tides and 0.7–4.3 kt during neap tides, except for some tidal channels with especially strong flows. Actual speeds depend strongly on the wind magnitude and direction.

The wind in this coastal area shows a pronounced seasonality associated with the monsoon. During the winter winds blow mainly onshore from the NW to NNE, with a mean speed of ca. 5–6 m/s. In summer, by contrast, winds blow mainly from the south, in an obliquely offshore direction, with a mean speed of 2–3 m/s. Storms, defined as >13.9 m/s in wind speed, also display a pronounced seasonality, occurring less than 2–3 days/month during the summer, but more than 10 days/month during the winter, when waves with a height of 1.5–2.0 m are common. Typhoons (>17 m/s in wind speed) occur mainly during the summer season. There is an average of one to three typhoons each

Table 5.1.2. Physiography and social use of marine and coastal areas of South Korea.

Total land area	99,461 km^2	Tide of coast	West: 4.3–9.1 m South: 1.8–3.9 m East: 0.2–0.9 m
Coastal area	31,641 km^2	Wetland area	2,550 km^2 (2.4% of land area)
Territorial sea	71,000 km^2	Ocean-related industry	US $2.6 billion (7% of national GDP)
Coastline	12,051 km	Fisheries production	2.5 million M/T(2003)
No. of Islands	3,170	Shipping and transport	800 million M/T 10 million TEU

year. Although some typhoons can produce waves up to 5 m high, the summer season is generally characterized by weak coastal waves with significant height of 0.5–1.0 m, resulting in the deposition of tide-dominated mud-rich sediment. However, in winter, the onshore-directed winds generate significant wave heights of 1.5–2.0 m on the flat, resulting in dominant deposition of wave-dominated sand-rich sediment. Some intertidal swash bars and/or cheniers are developed on the upper intertidal flats, which are 100–300 m wide and 0.5–1.5 m high. These migrate landward at various rates. These bars are formed and migrated mostly by storms and typhoons.

The winter storms and summer typhoons have caused severe erosion on the western coastal area. The long history of small-scale reclamation on the upper tidal flats and salt marshes over the past 1,500 years, as well as recent large-scale reclamation, mean there is no longer any natural coastal shape along these coasts, except for rocky coasts. For the last two decades the rapidly increased need for construction materials has expedited the destruction of subtidal sand ridges and the erosion of some coastal zones. These long-term changes in these western coastal areas highlight the need to keep in watching and monitoring the changes in these coastal environments.

South Sea and its Coast

The area south of the peninsula between Jeju Island and Tsushima Island has been named the South Sea by Koreans, whereas the East China Sea is arbitrarily demarcated from the Yellow Sea by the Yangtze-Jeju line. The South Sea, bounding the southern coast of the Korean Peninsula, is also shallow and flat, but characterized mostly by numerous postglacial rocky embayments and nearshore islands, forming a ria-type coast like that along the western coast. Sedimentation is controlled largely by moderate tidal currents and a mesotidal regime (1.8–3.9 m in spring tide), depositing fine-grained sediments (Table 5.1.2. These sediments are either riverborne or transported from offshore. Only a few large rivers drain into the southern coast, such as the Somjin and Nakdong. These rivers deliver a substantial volume of clastic sediments, forming estuarine environments. The Nakdong River, the biggest river along the southern coast, discharges approximately 63 million tons of water and delivers about 10 million tons of sediment into the sea annually. The major portion of the discharge (about 71%) occurs during the summer floods.

Muddy tidal flats, about 2–3 km wide, are developed in the embayed coasts and sheltered coasts by islands, whereas narrow wave-dominated coasts (beaches) are developed on the rocky coast facing directly to the open sea. During the winter, winds blow mainly onshore from the N to NNW with a mean speed of ca. 3–4 m/s. In summer, by contrast, winds blow mainly from the south or southeast, in an obliquely offshore direction, with a mean speed of 2–3 m/s. Storms are infrequent even during the winter. Typhoons attack the southern coast directly, mainly during the summer to fall season, with an average of one to three times each year.

The East Sea and its Korean Coast

The East Sea (Sea of Japan) is a semi-enclosed marginal sea or back-arc basin surrounded by the east Asian continent and the islands of Japan. The average water depth is about 1,350m, with a maximum depth of about 3,700m in the northeastern part. The sea is connected to the Pacific Ocean through shallow straits. There are three deep basins (the Japan, Yamato and Ulleung basins), separated by submarine topographic highs such as the Korea Plateau, Oki Bank and the Yamato Ridge. These rise to within about 500m of the sea surface. The western part of the East Sea (Sea of Japan) is characterized by a narrow shelf with a straight coastline.

The eastern coasts show a relatively steep slope and a microtidal setting (0.2–0.9m in spring tide), resulting in developing simple wave-dominated coastal environments that are represented by narrow sandy or rocky beaches and lagoons (Fig. 5.1.5). Many very small rivers drain into the eastern coast, but their discharges of water and sediment are not substantial as compared to wave energy. Their drainage areas are mostly mountainous, so that the pressures related to human use are generally low in relation to other coasts. However, the sediment transport is so fast as to be very vulnerable to environmental damage, even under small changes in the coastal environment.

Holocene Relative Sea-level Change

A recent sea-level curve for the Korean coast has been constructed based on an integration of radiocarbon dates obtained from plant remains, peat and shells of intertidal flats and other coastal areas (Fig. 5.1.6B, Kim et al., 1999; Chough et al., 2004). This reconstructed Holocene sea level generally shows a relatively rapid rise up to about 7ka, followed by a gradual rise without discernable fluctuation. The sea level reached −5m around 7ka and approached its present level at about 3ka. Based on shallow-marine, intertidal and submerged terrestrial data from the East China Sea, Yellow Sea and Sunda shelf, Liu et al. (2004) suggested a step-wise Holocene sea-level curve for the western Pacific coast, showing a series of rapid flooding events (as fast as 80mm/year), separated by long-term slow rises (2–10mm/year) (Fig. 5.1.7).

Coastal Management

For the last four decades intense socioeconomic activities in the coastal area of Korea have degraded and destroyed many coastal and marine ecosystems. Recognition of the importance of these ecosystems has encouraged the Korean government to enact laws and to formulate policies to protect the various types of coastal environments.

Up to December 2003, a total of 428 sites (9,274km^2 in area) along the coasts of South Korea were designated as coastal and marine protected areas (MPA). They are managed under nine Acts (Table 5.1.3). The rapid increase in the number of MPAs since the mid-1990s was due to efforts by the public, in addition to those of government. Both recognized the ecological/aesthetic

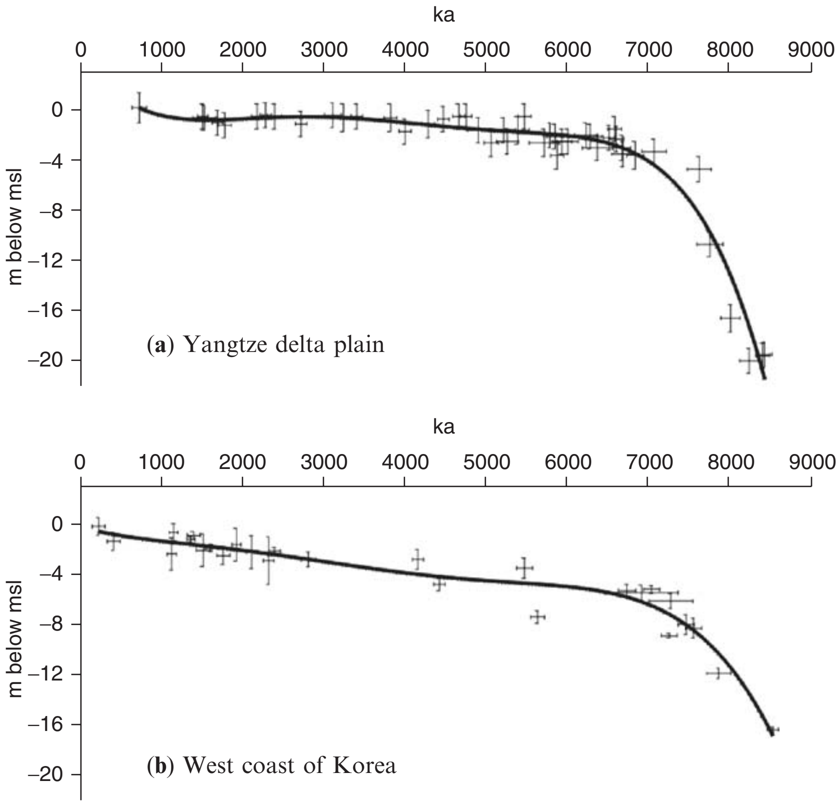

FIG. 5.1.6. Holocene relative sea-level curves based on radiocarbon dates and estimated paelo-mean sea level in the Yangtze delta plain (A) (after Zong 2004) and the western coast of Korea (B).

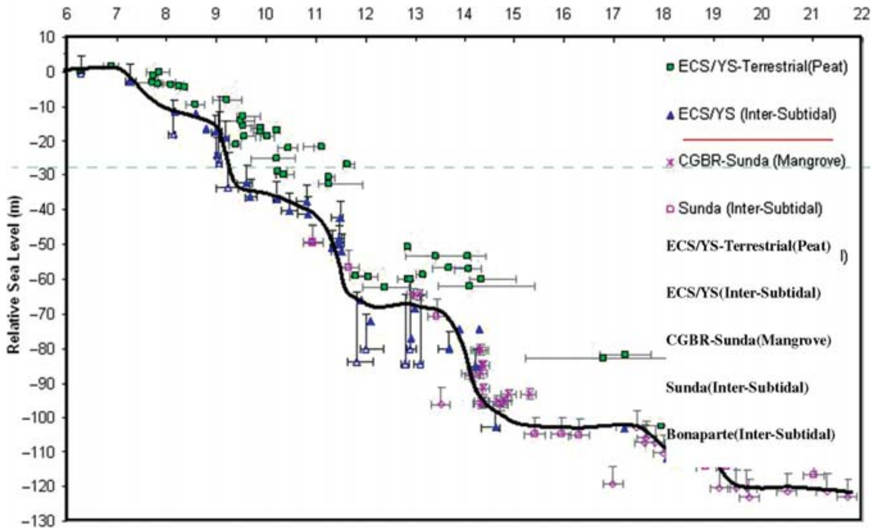

FIG. 5.1.7. A seal-level curve showing the western Pacific post-glacial sea-level history suggested by Liu et al. (2004).

TABLE 5.1.3. Coastal and marine protected area (MPA) in South Korea.

Name	Number	Area(km^2)	Acts
Ecosystem reserves	5	104.6	Natural Environment Conservation Act (1997)
Wetland protected	7	175.0	Wetland Preservation Act (1999)
Bird habitats	86	149.6	Wildlife Protection Act (2003)
Uninhabited island	155	10.2	Special Act on the Ecosystem Preservation of Islands including Dokdo Island (1997)
National parks	4	3,348.4	Natural Park Act (1980, 2001)
Marine resources	4	2,192.8	Marine Pollution Prevention Act (1977, 2001)
Fisheries protected	10	2,556.0	Comprehensive National Territorial Development Planning Law (2002)
Natural heritage	152	737.7	Cultural Heritage Protection Act (1982)
Total	428	9,274	9

value and economic contribution of coastal and marine ecosystems. Researchers, NGOs, and government officers have all been trying continuously to find a better way to protect and manage such valuable coastal zones. On the coastal management side, the most outstanding issue is still a lack of a comprehensive and integrated management system for coastal and marine protected areas. These should be managed in a holistic way through the cooperation and coordination of all stakeholders involved.

References

Alexander CR, Nittrouer CA, DeMaster DJ, Park YA, Park SC (1991) Macrotidal mudflats of the southwestern Korean coast: a model for interpretation of intertidal deposits. J Sed Petrol 61:805–824

Chough, SK, Lee HJ, Chun SS, Shinn YJ (2004) Depositional processes of late Quaternary sediments in the Yellow Sea: a review. Geosci J 8:211–264

Chun SS, Lee HJ, Shin DH, Yoo HR, Han SJ (1992) Sedimentological implications of vertical and lateral facies changes in the modern, non-barred macrotidal flats of the west coast of Korea. 3rd international research symposium Tidal Clastics 92, Willhelmshaven, Germany. Cour. Forsch.-Inst. Senckenberg, 151:16–18

Frey RW, Howard JD, Han SJ, Park BK (1989) Sediments and sedimentary sequences on a modern macrotidal flat, Inchon, Korea. J Sediment Petrol 59:28–44

Kim YH, Lee HJ, Chun SS, Han SJ, Chough SK (1999) Holocene transgressive stratigraphy of macrotidal flat, Yellow Sea. J Sediment Res 69:328–337

Liu JP, Milliman JD, Gao S, Cheng P (2004) Holocene development of the Yellow River's subaqueous delta, North Yellow Sea. Mar Geol 209:45–67

Yang BC, Dalrymple RW, Chun SS (2005) Sedimentation on a wave-dominated, open-coast tidal flat, southwestern Korea: summer tidal flat – winter shoreface. Sedimentology 52:235–252

Zong Y (2004) Mid-Holocene sea-level highstand along the southeast coast of China. Quater Intl 117:55–67

5.1.3 Taiwan

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Geographical Setting

Taiwan, an island with an area of 36,000 km^2, is located at the southeast corner of mainland Asia and at the very western margin of the Pacific Ocean. It is situated between the latitudes of 20 degrees 53 min and 25 degrees 18 min north, and hence, crosses the Tropic of Cancer. The average annual temperature is above 22°C, and the average annual rainfall is more than 2,500 mm.

Corresponding to the varied topography are numerous climatic zones, including tropical, subtropical, warm temperate, and cold temperate zones. Atop the higher mountains the climate is comparable to that of the tundra. Coniferous and broadleaf forests, grassland, savanna, and alpine vegetation occur within these different zones. In all, 55% of the land is covered with forest rich in floral and faunal resources. Aquatic plants grow in localized areas.

Geology and Geomorphology

Taiwan is also unique with respect to her global tectonic setting. In the course of the geological evolution, the island probably did not emerge until late in the Paleozoic. However, denudation, uplifting and river cutting of the land mass made the Taiwan of today vastly different from that shortly after its first appearance. Taiwan is at the midway of the western Pacific ring of fire, which is a series of volcanic island arcs along the Pacific plate margin. As it is located at the boundary between the Pacific and Eurasia, Taiwan is marked by frequent earthquakes. One low angle thrust fault may create an uplift of up to 10 m.

Approximately 30% of the land area is lowland, with the remainder occupied by hills and mountains. These parallel the long north–south axis of the island. More than two hundred of the mountain peaks are over 3,000 m above sea level.

Taiwan also has many typhoons and heavy rainfall. Accompanied by a high average annual temperature and steep slopes, the island experiences a very high erosion rate and is represented by active denudation and heavy mass movement.

The major subdivisions of the island landform are the Coastal Mountain Range, the Hua-tung Longitudinal Valley, the Central Mountain Range, the Pin-tung Plain and the West Coast Plain (Fig. 5.1.8). Along the various parts of the coast many interesting landscapes have been incorporated in national parks and national scenic areas (Wang et al., 1994).

Coastal Areas and Their Subdivision

Geographically the coast of Taiwan can be divided to four zones, namely the northern rocky coast with abundant promontories and bays, the western sandy

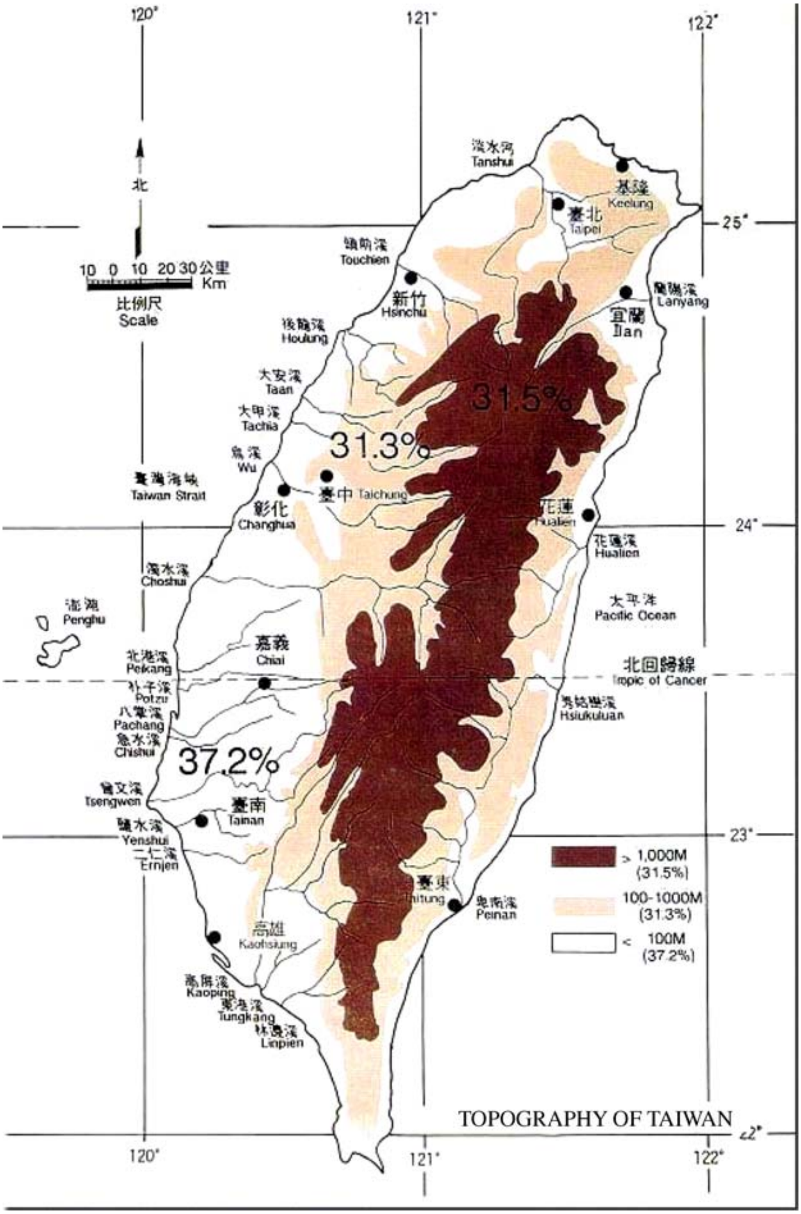

FIG. 5.1.8. Topography of Taiwan. (Frim Water Resource Agency http://eng.wra.gov.tw/ct.asp)

and muddy coast with flat beaches and adjacent lowland, the southern reef-coast and the eastern rocky coast with uplifted marine terraces (Wang 2004a, b).

Coastal areas are highly dynamic. The west coast of Taiwan is marked by a sandy and muddy coast and depositional features such as alluvial plains.

These originated from the deposition of transported sediments carried along by rivers from the mountainous areas, and reworked along the coast. The coast appears to be advancing. The west coast lies adjacent to the Taiwan Strait (between the Asian continent and Taiwan island-proper). Since the tide moves back and forth daily from both north and south of the strait, the central part of the west coast has a higher tidal range. The range decreases toward the north and south. Coastal landforms in the central part of the west coast are marked by very broad sand or muddy tidal flats. To the south there are more barrier islands, coastal sand dunes and lagoons.

West of the island is the Taiwan Strait, a shallow sea which is less than 100 meters deep in most of the areas between Taiwan and the China mainland.

To the east of Taiwan is the Pacific Ocean – actually, the Philippine Sea, a marginal sea of the Pacific Ocean. This reaches a depth of 4,000 m in a distance of 40 km.

The coast of eastern Taiwan is mostly rocky, as mountains approach the coast in most of the eastern areas. Only at the river mouths are there low and flat areas. The Ilan plain is exceptional; it is a subsiding area filled with alluvial deposits. North of Hualien the Central Range stretches to the sea. South of Hualien lie the eastern Coastal Ranges. To the far south of the east coast the Central Range again lies adjacent to the sea. Facing the Pacific, strong wave erosion often occurs, particularly when typhoons and the winter monsoon attack the east coast. Coastal retreat and slope failures are both very common.

The northern coast of Taiwan has many promontories and bays. This is because the regional strike of the strata is more or less perpendicular to the coast. In general, geomorphological landscapes in the northern coast are very scenic and of high value for scientific studies.

The south coast of Taiwan is represented by reef coast. There are both uplifted reef limestone tableland and undersea living corals. Kengting National Park is located on the south coast. It manages to protect more of the coastal environment. The tropical climate, its flora and fauna, and particularly its undersea coral world, are valuable tourist attractions. Fortunately the north coast and the east coast are largely covered in national scenic areas managed by the Tourism Bureau. This protects the coast to a certain degree.

On the land the backbone ridges are situated on the eastern side of the island. Most long rivers discharge to the western lowland and discharge into the western Taiwan Strait. As a result the west coast is represented by lowland, broad beaches, mud flats, lagoons and offshore bars.

In between Taiwan and mainland Asia there is a group of small basaltic islands called the Penghu islands (or Pescadores). Columnar basalts are widely distributed. The scenic quality of the basalt columns is excellent. Some islets have been designated as strict nature reserves. Most of the Penghu Islands are zoned in a National Scenic Area. A few islets have been recommended for designation as geoparks.

Environmental Issues

After relief from the Marshall Law (1992), the everlasting development of the coastal zone for various purposes has changed the face of the natural coast. There are too many harbors; industrial complexes are increasing and they are always very large. Coastal highways, landfill sites, recreational parks, and residential development are common. Even if there is no development there is a need for shore protection engineering works, such as dikes and other structures, in order to protect the coast. Reclamation of coastal wetland was popular for many years in Taiwan. This also destroyed many natural coasts.

All these developments have certain social and economical forces behind them. The increase in population and rise in GNP are two straightforward reasons for such controlled growth. The result is a fragmented coastal zone where nature has been lost, primary productivity has decreased and the clean sea is polluted.

Such problems and environmental issues are very well known and are being discussed at many conferences. A great deal of research has been commissioned by government agencies and completed. Many government projects have been executed, but with very limited success. In general, the environmental quality of the coastal zone is still declining. Warnings from academic groups and even citizen groups have not helped at all. Researchers and planners know of "Integrated Coastal Zone Management", but for the administration and the decision-making authorities such an approach is not practical and possible at all. For government agencies that are used to working separately as independent and isolated units, integration is just too far away. There are no embedded structures or functions that allow government agencies to integrate. Many academic research reports remain on the shelf only. A separation between planning and decision-making is clearly shown.

Management Actions

During the past 50 years Taiwan's population has increased dramatically, accompanied by a rapidly developing economy and expanding urban centers. Under such conditions the pressure for exploiting coastal resources has become urgent. However, owing to the lack of a profound understanding of coastal ecosystems, and the effects of the misuse of coastal resources, the natural environment of the coastal regions has been seriously threatened, to the point that many precious ecosystems and landscape resources have directly or indirectly suffered. Due to the great expectation of growth, the expansion of economic development to these regions is high on the government agenda. To ensure sustainability, the utmost importance and urgency at this time is to establish laws to systematically manage the coastal resources, including the preservation of those that are valuable and rare.

The government also has recognized that, with the rapidly developing economy, unending increases in the population, expanding urban centers and an increasingly advanced industry, the demand for land has become greater than ever before. Accompanying the changes in economic structure and social needs, obtaining land for development has become very urgent. Many sectors and local governments have, and still will, develop even marginal land for industrial and residential use, without considering land degradation and environmental problems.

The coastal lands, which were of low agricultural value in the past, have turned out to be the focus of keen land use competition. The multiple and mixed uses of Taiwan's coastal areas have created the following problems:

1. Many types of land use have gradually come into conflict, and compete with one another
2. There is confusion in the specific scope of development and ownership rights along the coastal zone
3. There is a lack of specialized bodies to take responsibility and manage laws
4. There is lack of clarity in the concrete and direct economic value of the landscape and ecological resources.

In 1982 the government passed the "Taiwan Coastal Region Natural Landscape and Ecological Resources Protection Program" and directed the Ministry of the Interior to "rapidly survey and draw up a plan for the coastal regions."

The Ministry of the Interior drew up a "Taiwan Coastal Environmental Protection Plan" and submitted it to the Executive Yuan. In the plan seven coastal nature reserves were designated. This became effective on February 23, 1984. In subsequent years five additional coastal reserves were added. This program was reviewed periodically and carried out. It was not a completely successful program, but it did open up a new way of coastal land management that slowed down uncontrolled development. The program was reviewed once more in 2004. Hopefully, it will become part of the new National Land Use Plan under the proposed National Land Planning Act.

The responsibility for, and supervision of, the Coastal Environmental Protection Program comes under the jurisdiction of the Ministry of Interior. In accordance with the stipulations of the program it was put into effect by local governments and other related organizations. These also examine and evaluate the effects of operation. The policies of the Coastal Environmental Protection Program are to be based on current laws that are provided by supervisory agencies or government bodies and which are in accordance with the directives of the Executive Yuan. In this way the reserves are managed in accordance with the Regional Planning Act and the zoning regulations, with ecological protection zone receiving the strictest level of protection in the plan.

The Coastal Environmental Protection Program is executed by order of the Executive Yuan. Although its power lies directly in established law, there have been no increases in manpower or in financial resources for the program. Also as a result of a lack of specialists, and the nonexistence of a governing body, the operation of this program is far from effective. Furthermore, because local governments are engaged in pursuing economic development that overemphasizes local construction, they have failed to coordinate this with the policies of protection and preservation. Therefore the protection of the natural environment in the coastal area in many respects is still in need of reinforcement.

The most important tasks that the Ministry of the Interior should take upon itself to carry out are: (i) to immediately draw the attention of the public; (ii) to strengthen the concept of environmental protection in the minds of the citizenry; and (iii) to organize local conservationists to assist and guide the work of preservation.

Some of the important government actions and government-sponsored planning activities after 1982 are as follow:

1997 Ministry of the Interior: Draft of the Coastal Zone Act

2002 Ministry of the Interior: Taiwan's Coastal Zone Natural Environmental Protection Program (Review of 1982 program)

2003–2004 Executive Yuan Taiwan Sustainable Development Action Plan IC: Enhancing Coastal Zone and Marine Conservation and Management

2003 Water Resource Agency: Program on Enhancing Coastal Environment and Landscape

2003 Water Resource Agency: Dikes and Sea walls Environmental reconstruction program.

2004 Marine Corps, Executive Yuan: Guidelines for National Marine Policy (http://www.cga.gov.tw/index.asp)

2005 Ministry of the Interior: Taking marine, coastal and offshore island areas into the jurisdiction of a regional planning System

The actions for 2003–2005 will be supervised by the Water and Land Resources Working Group of the National Council for Sustainable Development. The Executive Yuan set up the National Council for Sustainable Development in order to enhance the protection of the environment and ecology, guarantee social fairness and justice, promote economic development and establish a green silicon island, so as to promote citizens' living standards and pursue national sustainable development. The chairman of the Council is the Premier of Taiwan. For more details of NCSD please see http://ivy2.epa.gov.tw/ncdn).

In 1972, the government of Taiwan promulgated the National Park Law as the legislative basis for managing Taiwan's National Parks. The first national park, the Kengting National Park, was established in 1982. It is located on the southern tip of the island. The park has a terrestrial zone and an aquatic zone and lies within tropical latitudes. The park is characterized by a varied terrain, including isolated peaks, shell sand beaches, reefs, rocky coast and a limestone tableland. Flora and fauna in this area are a valuable asset to the country.

Recommendations

The above programs indicate not only the government efforts over the past few years, but also the difficulties that the government has faced. A willingness to improve management effectiveness cannot be achieved by simply commissioning more research or even by supporting more action plans.

A fundamental change in the bureaucratic system is necessary. Changes include capacity building in legal systems, strengthened institutions, and training programs for government officers who take care of daily administrative work. An environmental education program for stakeholders and citizens is also necessary for a significant period of time.

References

Wang S, Sheu LY, Tang HY (1994) Conservation of geomorphological landscapes in Taiwan. In: O'Halloran D, Green C, Harley M, Knill J (eds) Geological and landscape conservation. Geological Society, London, pp113–115

Wang S (2004a) Outstanding geomorphological landscapes of Taiwan – Northern Taiwan. Yuan-tsu Publishers (in Chinese)

Wang S (2004b) Outstanding geomorphological landscapes of Taiwan – Southern Taiwan. Yuan-tsu Publishers, (in Chinese)

Web sites:

National Council for Sustainable Development, Executive Yuan (http://ivy2.epa.gov.tw/ncdn).

Water Resource Agency (http://eng.wra.gov.tw/ct.asp)

Ministry of the Interior (www.moi.gov.tw)

Ministry of the Interior, Construction and Planning Administration, City and Countryside Planning Bureau (www.tcd.gov.tw/a.htm)

National Center for Ocean Research (http://www.ncor.ntu.edu.tw)

5.1.4 The Coast of Japan

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Japan is an archipelago located in the East Asian continent. It is surrounded by the Pacific Ocean and the East China Sea (Fig. 5.1.9). The territorial water of Japan is about 430,000 km^2, which is larger than the mainland area of nearly 380,000 km^2. The size of the exclusive economic zone, which contains territorial water, is 4,470,000 km^2. This is the sixth largest in the world, after Canada.

Japan is composed of four main islands – Honshu, Shikoku, Kyushu, and Hokkaido – and 6,800 other smaller islands, some of which are uninhabited (Bureau of Statistics, Ministry of Internal Affairs and Communications). This is a distinguishing feature between the four main islands and the numerous small islands dispersed within the Japanese archipelago.

According to statistics produced by the Ministry of Land, Infrastructure and Transport, the total extent of the Japanese coastline was 34,812 km in 2003. It is increasing every year, due to land reclamation. In comparison with the 377,907km^2 of land area, the length of the coastline is about 91 km per 1,000 km^2. This high value is due to the irregularity of the coastline, which is far greater than other countries such as America with 2 km and England with 51 km.

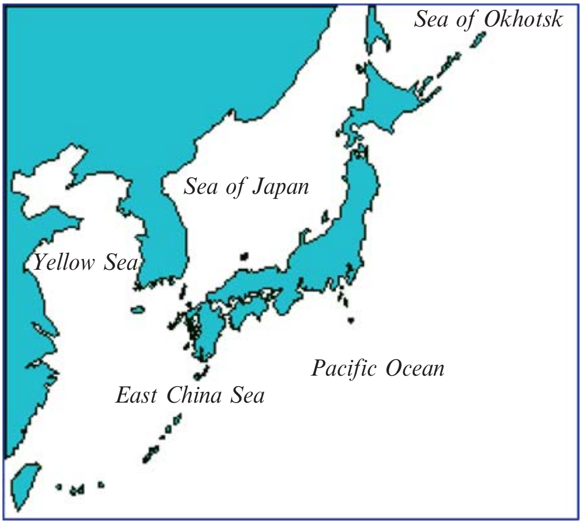

FIG. 5.1.9. The seas surrounding Japan.

The coastline itself comprises sandy coasts and rocky shores that are mixed together. From a regional aspect, the Pacific Ocean side of the central Tohoku district consists mainly of deeply indented coastlines, while the Sea of Japan side is rich in sandy coasts. The semi-closed Seto Inland Sea (approximately 23,000km^2) is located in the southern part of the main islands. There are many inlets and bays in the same area.

About 12% of the coastline comprises sandy coast, while the coastline that is covered by structures for shoreline protection amounts to 28%. There is a great deal of artificial seashore, with artificial structures such as coastal roads around the seashore and airport facilities. In all, the ratio of natural coast to the entire coastline of Japan is only 53% (Shikida and Koarai 1997).

The reason why the ratio of natural coast to the entire coastline is unusually low can be explained by the historical coastal utilization of Japan. Before the Edo period (approximately 1603–1867), Japanese coastal dwellers used the coast chiefly for coastal fisheries and salt production. These users had a relatively low impact and were small in scale. Therefore, the pressure from such utilization of the coast was not that intensive and there was no drastic change in the coastal zone at that time. However, after the Meiji era (1869–1912), industrial development in the coastal zone started. Intensive port and coastal area development commenced under the Japanese government's influence, It encouraged economic development under the policy of a wealthy nation and strong army. It can be said that the prosperity of Japan today was achieved under this national doctrine. As a result, land reclamation and landfills were carried out mostly in shallow coastal waters for the creation of usable land. In fact, the size of reclaimed land reached 145,000 ha after the Second World War alone (Wakabayashi 2000). This tendency lasted during Japan's era of economic development and slowly decreased due to the limitation in coastal shallow waters and the economic benefit of the reclamation and landfill.

About half of the Japanese population lives in coastal municipalities that have coastline within their area. This was accelerated by major population movements from inland areas to livable coastal lands, particularly in large cities such as Tokyo and Osaka. Large amounts of reclaimed land have been newly created for household and residential use. At the same time, the maturation of Japanese society has dramatically changed the life style from one that is relatively low key and work-orientated to one with a preference for leisure time. This trend has caused changes in land use of the coastal zone.

The coastal environment has now been dramatically altered. Most of the shallow waters are affected by large-scale reclamation and landfills. This has caused the loss of important tideland and littoral zones. According to the Environmental Agency of Japan, 30,000 ha of a total 85,000 ha of wet land in Japan (as of 1945) were lost in the 13-year period from 1978 to 1991. In addition, 6,400 ha of seaweed beds were destroyed by coastal developments. This record of destruction can be shown by the change in the ratio of natural coast. Figure 5.1.10 shows major changes in the ratio of natural to entire shoreline, with a continued decrease from 78% in 1960 to 55% in 1995. A drastic decline is observed in the 1960s. It is apparent that artificial modification in Japan has further progressed since the period of high economic growth in the 1960s (Shikida and Koarai 1997).

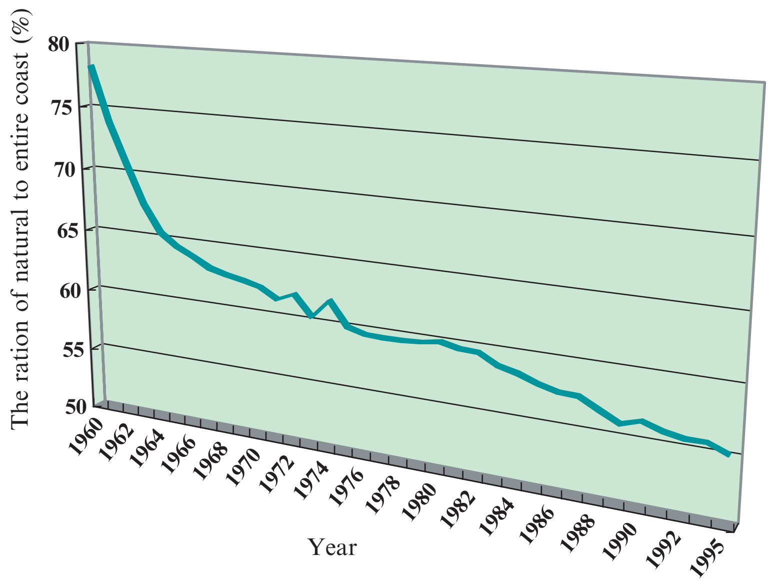

FIG. 5.1.10. The nation-wide ration of natural to entire coasts in Japan (From National coastal statistics.)

This alteration apparently correlates with the accumulation of landfills and reclaimed lands. However, at the same time, large-scale installation of artificial structures for shoreline protection and seashore preservation greatly affected the rate of modification. At the same time, construction of large ports for Japan's improved trade induced the modification of natural coastlines. As of 1997 there were 1,094 ports for marine transportation in Japan (Ministry of Transportation 1997). These constructions, accompanied by the installation of related facilities, caused large-scale losses of coastal estuaries. In addition, construction of small, local fishing ports have resulted in incremental and piecemeal losses of important coastal wetlands. Approximately 2,500 fishing ports have been constructed and reconstructed since 1945 (National Fishing Port Association 1997).

On the other hand, the preservation of the natural environment in the coastal zones is one of the most important issues in Japan, not only because of its significance for coastal dependent development and industries such as fishing, but also its recreational and tourism value. In fact, a large number of people take pleasure in staying in the coastal zone for tourism purposes, spending some of their leisure time there, enjoying swimming and recreational fishing. A national survey conducted in 1995 suggested that approximately 50% of people going to coastal areas use the coastal zone for recreational purposes (Prime Minister's Office 1995). For example, more than 30 million people go to beaches for bathing, particularly in the summer season (National Leisure Center 1995). Another 30 million recreational fishermen enjoy saltwater fishing throughout the year (Ministry of Agriculture, Forestry and Fisheries 1995). Furthermore, over 300,000 pleasure boats are currently operating in navigable coastal waters around Japan, and the number is increasing every year (National Leisure Center 1995).

The current issues concerning the Japanese coastal zone can be summarized by the following four points. Firstly, as mentioned above, the environmental degradation of Japan's coastal zone is serious. Also as mentioned previously, environmental degradation is a factor. Furthermore, damage from coastal and marine litter adds further pressure to the coastal environment and its aesthetic value (Japan Environmental Action Network 1999). The degree of environmental change is likely to approach an unacceptable level for use by future generations.

Secondly, coastal utilization, particularly nonindustrial use, has been growing, due to the recent increase in leisure time. Simultaneously, the type of coastal users has diversified due to developments in technology and changes in individual values. This has resulted in increased conflicts over coastal use between new and old users.

Thirdly, even though 72% of the coastline is managed by a single authority, the National Land and Transportation Ministry, the rest of the coastal zone is still under divisional management. Synthesized or integrated management cannot be achieved today, and collaborative and comanagement has not been introduced at the national level. Consequently, finding solutions to the problems of coastal issues, such as environmental disruption and user conflict, is unlikely to be easy. This also discourages the achievement of sustainable development without environmental destruction in the coastal zone. On the other hand, there has been a recent transformation in the wave of revisions in major coastal acts in Japan. These acts have been revised in an environmentally-conscious way that has even led to establishing a network covering a wide variety of coastal zone issues. The revisions are expected to stimulate achievements in coastal zone management at the local level and it is likely that such efforts will build a robust coastal zone management framework in the foreseeable future.

Fourthly, although much effort has been put into finding solutions to conflicts resulting from coastal uses, it has not been enough to balance and manage industrial and nonindustrial use. Our major concern is how we can keep sustainable use of the coastal environment, for both current and future generations. It is essential that the coastal community build a new balance between industrial use, nonindustrial use and environmental protection.

In conclusion, the coastal zone in Japan has been drastically altered during the last 100 years by rapid and dramatic economic development. We now understand that the environmental status of the coastal zone is not at a sufficient level for use by future generations. However, demands for use of the coast by the new users, mostly nonindustrial users, are growing. Thus, we now have to balance increasing coastal utilization and environmental sustainability, yet at the same time under a sectoral and inefficient coastal zone management system. In spite of these obstacles, the future coastal zone of Japan can be created due to the coastal zone management efforts being made at the local level. These have started by reconciling the sectoral approach and integrating the management system.

References

Japan Environmental Action Network (1999) Clean up campaign 98 report, Japan Environmental Action Network, 185p

Ministry of Agriculture, Forestry and Fisheries (1995) Report no 2 of the 9th fisheries census, surveyed at November 1 of 1993

Ministry of Transportation (1997) Port handbook 1997

National Fishing Port Association (1997) Fishing port and fishing village handbook 1997

National Leisure Center (1995) Leisure white paper

Prime Minister's Office (1995) Needs for coasts in Japan, Monthly Public-Opinion-Poll 27(5):2–37

Shikida A, Koarai M (1997) Statistical analysis of artificial modification of natural coastline in Japan ince 1960. J Japanese Assoc Coastal Zone Studies 9:17–25

Wakabayashi K (2000) The environmental history of Tokyo Bay. Tokyo, Yuhikaku, 408p

5.2 Southeast Asian: The State of Marine Ecosystems

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The Southeast Asian region is situated between latitudes 30° N and 11° S. It includes the Philippines, Indonesia, Malaysia, Thailand, Vietnam, Myanmar, Taiwan, Brunei Darussalam, Singapore, and Cambodia. Its coastlines have a total length of 175,258 kilometers. Recent estimates revealed a total population of more than 510 million, 69% of whom live within 50 km of the coast and rely heavily on marine resources (Table 5.2.1). The heavy dependence of the coastal population on marine resources, coupled with development along the coastal areas, has resulted in the overexploitation and degradation of important marine ecosystems, such as coral reefs, sea-grass beds, mangrove forests and wetlands.

5.2.1 Mangroves

Mangroves are highly productive and play a significant role in the health of some fisheries (UNEP 2004a). Mangrove forests support a high diversity of fauna, including juvenile fish and macro-crustaceans, some of which are commercially important. Being in the transition between terrestrial and coastal areas, mangroves are important in protecting coastal communities by stabilizing sediment and preventing erosion. Mangrove habitats are also critical staging posts for migratory species, including many shore birds that move seasonally from the northern to the southern hemispheres. The two main centers of mangrove diversity in the world are the Indo-Pacific and the eastern seaboard of Africa. The Indo-Pacific has about five times the species diversity recorded in the Western Indian Ocean.

Southeast Asia has more than 61,000 km^2 of mangroves, comprising 35% of the world's total mangrove area (Burke et al., 2002; UNEP 2004a). There are 41 genera of true mangrove species found in the Indo-West Pacific, and 51 species occur in the Southeast Asian region. The most extensive and diverse

TABLE 5.2.1. Demographic and coastal profile of Southeast Asia.

Country	Population (2000) (thousands)	Coastline
Brunei Darussalam	328	269
Cambodia	11,168	435
Indonesia	212,107	95,181
Malaysia	22,244	9,323
Myanmar	45,611	14,708
Philippines	75,967	36,289
Singapore	3,567	268
Thailand	61,399	2,614
Vietnam	79,832	11,409

TABLE 5.2.2. Mangrove, sea grass and coral reef diversity in Southeast Asia. (From UNEP 2004a–c)

Country	Coral reef area (km^2)	No. of reef-associated fish genera	Mangrove area (km^2)	No. of mangrove species	No. of sea-grass species
Brunei Darussalam	210	38	170	29	4
Cambodia	<150	56	850	5	1
Indonesia	51,020	268	42,550	45	13
Malaysia	3,600	144	6,420	36	12
Myanmar	1,870	86	3,790	24	3
Philippines	25,060	307	1,610	30	19
Singapore	<100	77	6	31	11
Thailand	2,130	77	2,640	35	15
Taiwan	700	–	340	23	5
Vietnam	1,270	83	2,530	29	9

stand of mangroves can be found in Indonesia (Table 5.2.2). Animal diversity is also high. The numbers in Table 5.2.2 are underestimates since the fauna in most locations are not yet fully described. In addition, there is no available information as to the monetary value of the goods and services provided by mangroves. This is due to a lack of agreement concerning the techniques by which a value should be determined, as well as a lack of comparability between values across spatial boundaries.

It is estimated that over half of the region's original mangrove area was lost during the last century. In fact, one species of mangrove, *Bruguiera hainesii,* and a mangrove-associated flora, *Brownlowia tersa*, are listed in the IUCN plant red data book as being endangered. Mangroves are being destroyed by many of the same activities that threaten coral reefs and sea-grass beds. Specifically, clear-cutting for timber, fuel wood, conversion to aquaculture farms, land clearance for urban and port development and human settlements can destroy mangrove habitats. In the 1990s Malaysia and Myanmar lost almost 75% of their original mangrove cover. Thailand lost 84%, while the Philippines and Vietnam lost 37% and 36%, respectively. A recent report showed that Indonesia's 80,000-hectare of shrimp farming is the largest in the world and is constructed on land reclaimed from mangrove. In the Philippines about 279,000 ha of mangroves were lost from 1951 to 1988. These were developed into culture ponds. Furthermore, 95% of brackish water ponds in the same period were derived from mangroves. In Guangxi, China, up to 75% of mangroves were removed due to coastal reclamation. Chamberlain (2001) reports that in twelve Asian countries more than 60% of shrimp farms are converted mangrove areas.

5.2.2 Sea Grasses

Sea-grass beds, like coral reefs and mangrove forests, form a highly productive ecosystem that supports an equally diverse flora and fauna. Some species of juvenile and small adult fish, reptiles, mammals, epibenthic invertebrates, and benthic seaweeds inhabit sea-grass beds (UNEP 2004b).

East Asia has the second highest sea-grass diversity in the world (Fortes 1995). A total of 23 species of sea grass are found in the Southeast Asian region, the majority of which occur in the Philippines (Table 5.2.2). However, being the least studied among the ecosystems of the coastal environment in the region, there are no adequate maps and actual data to enable estimation of the total sea grass area and allow calculation of lost sea-grass cover in the entire region. Little attention has been focused on sea grasses since most people do not consider sea grasses as important as coral reefs and mangroves. Much of the information available is on a per country basis. For example, in the Philippines a total of 978 km^2 of sea-grass beds have been measured for 96 sites. These estimates are, however, from selected study sites and do not reflect the total area for the country. In addition, in the last 50 years between 30% and 50% of Philippine sea-grass beds have been lost due to industrial development, ports and recreation. In Indonesia about 30–40% of sea-grass beds have been lost, with as much as 60% being destroyed around Java. Patchy sea-grass habitats in Singapore have suffered much damage, largely due to burial under landfill operations. Losses amounting to about 20–30% of total sea grass area have been reported for Thailand. In general, sea grasses in the region are being threatened largely from the loss of mangroves, coastal development, mining and natural perturbations (Fortes 1989, 1991).

Sea-grass habitats are physically and functionally linked to mangroves and coral reefs, although the most important relationships lie in the substantial support to fisheries by providing spawning and nursery grounds to commercially important offshore fish species. Moreover, some endangered species of reptiles and mammals are known to occur in sea-grass beds in the region. Six species of marine turtles are reported from the region. The green sea turtle (*Chelonia mydas*), the olive ridley (*Lepidochelys olivacea*), the loggerhead (*Caretta caretta*) and the flatback (*Chelonia depressa*) are among these species. Also, the sea cow, or dugong (*Dugong dugon*), has been reported in many areas of the region. Large and common epibenthic invertebrates in sea-grass beds include shrimps, sea cucumbers, sea urchins, crabs, scallops, mussels, and snails. Some of these commercially important species have been unsustainably harvested. In the Philippines and Indonesia farms of the red seaweed *Eucheuma* are established mostly in association with sea grasses.

5.2.3 Coral Reefs

Coral reefs, which are essentially distributed in warm tropical waters, are highly productive and extremely complex systems. The primary productivity of coral reefs is in the order of 1,500–3,500 g/cm. The large number of reef-associated species, many of which are commercially important, makes coral reefs economically valuable resources, particularly in the Southeast Asian Region.

Southeast Asia has the largest coral reef area of 100,000 km^2, which comprise 34% of the world's coral reefs (Table 5.2.2). The region has been known as the global center of coral reefs, not only for its extent but also in terms of species diversity. There are more than 600 species of scleractinian corals found in the region, the majority of which occur in the Indo-Malayan Triangle bounded by the Philippines, the southern islands of Indonesia and Papua New Guinea. Aside from corals, more than 1,650 species of fish have been recorded in eastern Indonesia alone. The majority of these are associated with reefs. The estimated annual contribution of sustainable coral reef fisheries alone to the region's economy is US $2.4 billion, providing food security and employment to local communities. Coral reefs are also important to tourism, pharmaceutical research and shoreline protection.

However, Southeast Asia is faced with an unprecedented decline in coral reef area. The report of the Global Coral Reef Monitoring Network in 2004 showed that indirect pressure of global climate change and direct human pressures bring about the continuous decline of coral reefs worldwide (Tun et al., 2004). Other studies showed that sea-surface temperatures are reaching the thermal limits of coral tolerance (Hoegh-Guldberg 1999). Consequently, changes in water temperatures during natural climatic events, such as the El Nino Southern Oscillation, have caused massive coral bleaching. The 1997–1998 El Nino event resulted in mortality of around 18% of reefs in Southeast Asia. Surveys also revealed evidence of subsequent coral recovery in Indonesia, Cambodia, Thailand, Vietnam, and the Philippines, although patterns of recovery are site specific. In most areas the rate of recovery may be affected by other factors, particularly the prevailing levels of human disturbance.

The increased demand on marine resources, as well as the need for economic development in most areas of the region, has resulted in the overexploitation and degradation of coral reefs, especially within major population and regional growth centers. Overfishing, destructive fishing activities, coastal development, sedimentation and pollution from land-based sources now threaten about 88% of the region's coral reefs (Burke et al., 2002). Around 50% of these reefs registered a "high" or "very high" level of threat, while only 12% are at low risk. In Cambodia, the Philippines, Vietnam, Singapore, as well as the Spratly Islands in the South China Sea, more than 90% of reefs are threatened, while more than 85% of reefs in Malaysia and Indonesia are at risk.

Overfishing threatens the largest portion (64%) of the region's coral reefs, followed by destructive fishing practices (56%) (Burke et al. 2002). Efforts to reduce fishing pressure in some areas have failed, due to the absence of alternative sources of income for fishers. There is also a growing concern over the loss of certain fish species (target species overfishing) due to the live reef food fish and aquarium trade. These activities use destructive fishing methods such as poison and blast fishing. If not reduced, these may be detrimental to the fisheries resource base and may lead to irreparable damage to coral reefs. In the Philippines, overfishing and destructive fishing (blasting and poisoning) remain the primary cause of coral reef decline.

Coastal development in Southeast Asia has been driven by rapid population growth, industrialization and growing tourism industry. Construction of a new coastal infrastructure, which, among others, involves land reclamation and dredging harbors and channels, has sometimes caused removal of reef substrate and increased sedimentation, resulting in outright obliteration of coral reefs. For instance, around 60% of coral reefs in Singapore were lost due to land reclamation. To date an estimated 25% of reefs in the region are at risk from coastal development.

Land-use changes and development in the coastal zone have increased sedimentation and pollution of the region's coastal areas. Sediment loads due to unregulated logging, for instance, may be 10 times higher than present. Moreover, the lack of adequate sewage treatment systems has sometimes caused increased nutrient loads. These can lead to eutrophication and toxic algal blooms. In Indonesia a 30–60% decline in coral diversity has resulted from pollution and sedimentation.

5.2.4 Management of Coastal Resources in South East Asia

Critical to the goal of sustainable development is the aim of protecting and effectively managing marine resources. The increasing consciousness among the different governments around the region gave birth to numerous policies, programs, and guidelines. For example, the ASEAN Strategic Plan of Action on the Environment (ASPAE) was formulated in response to the recommendations of Agenda 21. Since the early 1980s, policies and legal responses relating to protected areas have also been developed by ASEAN. These include: Bangkok Declaration on ASEAN Environment 1984; Manila Declaration 1987; Jakarta Resolution on Sustainable Development 1987; Singapore Resolution on Environment and Development 1992; Bandar Seri Begawan Resolution on Environment and Development 1994; ASEAN Criteria for Marine Heritage Areas 2002; ASEAN Agreement on Transboundary Haze Pollution 2002; Hanoi Plan of Action (1999–2004); and the most recent Putrajaya Declaration of Regional Cooperation for the Sustainable Strategy of the Seas of East Asia 2004.

The realization of the need to address the accelerating threats to the coastal and marine resources of the region is evident in the proliferation of marine protected areas (MPA) in the South East Asian region. These MPAs have been established in many areas, to serve as a tool to conserve important marine resources. At present there are over 300 MPAs around the region, and many more are still being proposed. The majority of these MPAs contain coral reefs but represent only 8% of the region's total coral reef area (Table 5.2.3). Other habitats, like sea-grass beds, tidal mud flats and marshes, are even less represented. Among the nine ASEAN member countries, the Philippines has the highest number of MPAs, while countries like Brunei, Cambodia, Singapore, Myanmar and Vietnam have major gaps in terms of MPA establishment on a national level. In terms of management, around 90% of MPAs in East Asia

TABLE 5.2.3. Estimated number of established and proposed marine protected areas I in the Southeast Asian region. (From Cheung et al., 2002.)

Country	Declared MPAs	Proposed MPAs
Brunei Darussalam	6	>2
Indonesia	29	>14
Malaysia	>40	>3
Philippines	>180	>100
Singapore	2	4
Thailand	23	0
Vietnam	22	7
Cambodia	4	1
Myanmar	4	1

fail to achieve management objectives (Kelleher et al., 1995). A recent review of MPAs in South East Asia showed that the majority of the declared MPAs in the region have no or very little management, 28% are under moderate management and only 10–20% are effectively managed. In terms of coral reef protection, there are only a few instances of success. For example, improved reef health was reported for managed reefs in the Philippines, Thailand and Vietnam. The very low management success has been attributed to insufficient monitoring capacity of some countries, including Myanmar and Brunei Darussalam. A complete regional assessment cannot be made unless information gaps are filled. Many monitoring programs have been initiated, yet some of these programs were only given short-term support. The information obtained was not sufficient to support good management decisions. Moreover, there is oftentimes non-uniformity in reporting the data and, in some instances, analyses of these data are not done in a timely manner so as to be useful to management. Other common problems include inadequate legislation, poor implementation of laws, limited financial support and institutional conflicts. Based on the identified pressures on the marine environment, state of the habitats and MPA management needs, proposals have been made for a priority action agenda for the region and each country, as well as for a regional strategic MPA framework.

Current regional initiatives are viewed as possible venues for sustaining MPA implementation and further cooperation among the countries in the region. More recently, emphasis was given to the importance of establishing a network of MPAs in response to the call at the 2002 World Summit on Sustainable Development and the 2003 World Parks Congress. Although such a network might be costly (Balmford et al., 2004), it was suggested that the return on such investment would be substantial. The transboundary nature of some important resources, as well as major threats like pollution, justify the move towards the setting up a regional MPA network. Priority areas for such a scheme are the South China Sea and the Sulu-Sulawesi Sea.

The South China Sea (SCS) lies within the global center of marine biodiversity, where it forms a large marine ecosystem that is bordered by nine coastal states. In recent decades high rates of population and economic growth, as well as rapid coastal development, occurred in this region. This led to the over-exploitation and degradation of coastal resources. As the countries bordering the South China Sea do not exist in isolation, and are unable to contain the impact of their activities within their national boundaries (Talaue-McManus 2000), there is a great need to form coordinated efforts to protect and manage the deteriorating environment and dwindling resources in the South China Sea. One of the first significant initiatives to assess the status of coastal environment and resources in the SCS was the transboundary diagnostic analysis of the SCS and associated catchment areas. This analysis identified the water-related problems and concerns, their socio-economic root causes and the sectoral implications of the required actions (Talaue-McManus 2000). The main goal of this effort was to provide the basis for a strategic action program that may be coordinated at the national and regional levels. This was followed by the implementation of the project "Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand". The major goals of the project are: (i) to foster regional collaboration and partnership in addressing environmental problems of the SCS; and (ii) to build the capacity of participating governments to incorporate environmental concerns into national level development planning. Seven countries participate in this project, namely: Cambodia, Vietnam, Indonesia, Malaysia, Philippines, China, and Thailand. Four subcomponents of the project focus on the key marine and coastal habitats of mangroves, sea grass, coral reefs and wetlands, while another two components deal with fisheries overexploitation and land-based pollution.

The Sulu-Sulawesi Sea, bordered by Malaysia, Indonesia and the Philippines, is one of the global priority areas for immediate conservation initiatives owing to the enormous pressure from coastal development, overexploitation, destructive fishing, and pollution (DeVantier et al., 2004). It has suffered great loss of mangroves, sea grass, and coral reef habitats, but also a significant reduction in fisheries resources (Rossiter 2002). The resulting changes in ecosystem productivity, and deterioration in ecosystem services, led to conflict among resource users (Sharma 2000 as cited in DeVantier et al., 2004). It was also suggested that a fully integrated network of protected areas can play a key role in minimizing future habitat loss and restoring harvested stocks in this area. However, forging cooperation at the local, national and international levels has slowed down the progress of such initiatives. Aside from the numerous transboundary concerns, one important issue is the trilateral nature of the Sulu-Sulawesi Sea, being bounded by three different national jurisdictions. These countries have enough legislation to deal with most of the issues, but trilateral coordination in implementing the laws is essential. In order to achieve this, several policy options have been put forward. Also, the WWF and its partners have developed an approach which created the Sulu-Sulawesi Marine Eco-region (SSME). It is hoped that this will provide a model for policy development and implementation. In 2001 a Biodiversity Vision was formulated. This focuses on biodiversity conservation, maintenance of productivity to sustain human needs and stakeholder participation in management across cultural and political boundaries (Tun et al., 2004). This was followed in 2003 by the development of the SSME conservation plan, which seeks to involve government, non-government organizations and other stakeholders in regional conservation activities.

In summary, the sustainable development of the marine ecosystems in South East Asia require the following integrated efforts at local, national and international levels:

- Fill gaps in priority information and research (e.g., ecosystem-based management) through the establishment of knowledge-based communities.
- Facilitate the feedback-response cycle to effectively deal with the pressures of the marine ecosystem through an adaptive management approach.;
- Harmonize complementation of various frameworks for action and strategies to be mainstreamed through various regional and local bodies and networks.
- Utilize the existing initiatives to develop a common fund to support priority representative transboundary synergy and convergence areas, e.g., target a set of priority integrated demonstration sites in a network of marine protected areas in various large marine ecosystems (e.g., the SSME and the South China Sea).
- Institutionalize various hierarchical levels of effective coastal and ocean governance procedures at the local, national and international levels.

References

Balmford A, Gravestock P, Hockey N, McClean CJ, Roberts C (2004) The worldwide costs of marine protected areas. Proc Natl Acad Sci USA, Vol. 101(26): 9694–9697

Burke L, Selig E, Spalding M (2002) Reefs at risk in Southeast Asia. World Resources Institute, Washington. 72 pp.

Chamberlain G (2001) Sustainable shrimp farming: issues and non-issues. Paper presented at Shrimp 2001: Fourth World Conference on the Shrimp Industry and Trade and Buyer-Seller Meeting, September 27–29, 2001, Chennai, India

Cheung, C.P.S., Alino, P.M., Uychiaoco, A.J. and Arceo, H.O. (2002). Marine protected areas in Southeast Asia. ASEAN Regional Centre for Biodiversity Conservation, Department of Environment and Natural Resources, Los Banos, Philippines. 142 pp., 10 maps. UP-MSI, ABC, ARCBC, DENR, ASEAN

DeVantier L, Alcala A, Wilkinson C (2004) The Sulu-Sulawesi Sea: Environmental and socioeconomic status, future prognosis and ameliorative policy options. Ambio 33(1): 88–97

Fortes MD (1989) Seagrasses: A resource unknown in the ASEAN region. ICLARM Education Series 5, International Center for Living Aquatic Resources Management, Manila, Philippines, 46 pp.

Fortes MD (1991) Seagrass-mangrove ecosystems management: A key to marine coastal conservation in the ASEAN region. Marine Pollution Bulletin 23:113–16

Fortes MD (1995) Seagrasses of East Asia: Environmental and management perspectives. RCU/EAS Technical Report Series No. 6. UNEP

Hoegh-Guldberg, O (1999) Climate change, coral bleaching and the future of the world's coral reefs. Mar. Freshwater Res. 50, 839–866.

Kelleher G, Bleakley C, Wells S (1995) A global representative system of marine protected areas. Great Barrier Reef Marine Park Authority, The World Bank and The World Conservation Union, Washington, D.C., USA, Volume 3, 147 pp.

Rossiter WW (2002) Fisheries conservation crisis in Indonesia. Massive destruction of marine mammals, sea turtles and fish reported from trap nets in pelagic migratory channel. http//Darwin.bio.uci.edu

Talaue-McManus L (2000) Transboundary diagnostic analysis for the South China Sea. EAS/RCU Technical Report Series No. 14. UNEP, Bangkok, Thailand

Tun K, Chou LM, Cabanban A, Tuan VS, Philreefs, Yeemin T, Suharsono, Sour K, Lane D (2004) Status of coral reefs, coral reef monitoring and management in Southeast Asia. In Wilkinson C (ed.) Status of Coral Reefs of the World: 2004 Vol. 1, pp. 235–275.

UNEP (2004a) Mangroves in the South China Sea. UNEP/GEF/SCS Technical Publication No. 1, 14 pp.

UNEP (2004b) Coral reefs in the South China Sea. UNEP/GEF/SCS Technical Publication No. 2, 11 pp.

UNEP (2004c) Seagrass in the South China Sea. UNEP/GEF/SCS Technical Publication No. 3, 12 pp.

5.3 South Asia

Coastal zones are quite important for countries in South Asia. In the following section, we will see the conditions and problems for Bangladesh, Pakistan, India, and Sri Lanka. For these countries, the coastal zones are precious resource bases to support the lives of a huge population, coastal industries, and sea transportation. The coastal zones in the region also face severe natural disasters such as tropical cyclones, storm surges, coastal erosion, and tsunamis. At the same time, anthropogenic activities in the river basin have had enormous impacts on sediment supply to the coast, salinity intrusion to rivers, and coastal ecosystems such as mangroves. Sea-level rise and climate change will interact with these local human-induced problems resulting in further complicated impacts on the coastal environment. Therefore, the management of the delta should become a part of an integrated coastal zone management approach in a holistic manner. The introduction to the current status of the coast in the region will lead to the necessity of comprehensive management, which is closely related to sustainable development of the countries.

5.3.1 Coastal Hazards and their Management in Bangladesh

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Introduction

Bangladesh, with an area of about 144,000 km^2 and with 130 million people (BBS 2001), lies on the Tropic of Cancer. It has a tropical monsoon type of climate. A major part of the coastal plains, with an area about 36,000 km^2, is an active delta of the Ganges-Brahmaputra river systems. More than 85% of land is covered with Quaternary deposits. The rest is underlain by Tertiary sediments. The coastal plains, with 710 km of coastline, are characterized by three distinct morphometric and hydrodynamic characteristics (Fig. 5.3.1). A micro- to meso-tidal (low-energy) environment, which prevails in the Deltaic Coastal Plain, has created vast horizontal tidal mudflats, with a very gently sloping subaqueous delta extending towards the sea as far as about 85km from the coastline. On the other hand, a meso- to macro-tidal (high-energy) condition in the Estuarine Coastal Plain has developed estuarine plains composed of silts, sands, and their mixture, along with a subaqueous delta even longer than the Deltaic Plain. The Intra-Deltaic Coastal Plain (Chittagong-Cox's Bazar Coastal Plain) is characterized by a mainly meso-tidal (mixed-energy) environment, with a narrow coastal plain that is muddy in the north and sandy in the south.

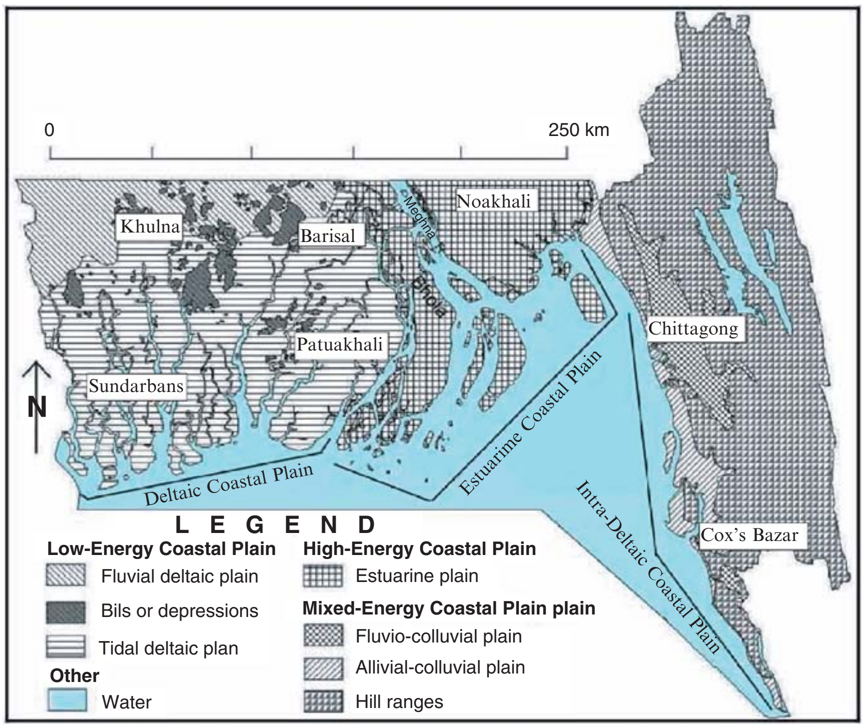

FIG. 5.3.1. The coastal segments of Bangladesh.

The subaqueous part is also very narrow in this area of the coast, in comparison to other parts. It is limited to about 25 km from the coastline. A number of natural hazards, of diversified nature and magnitude, have occurred along and across the coastal plains since prehistoric times.

Erosion has dominated deposition along major coastal parts in recent years when the length of coastline is considered, although overall coastal progradation, especially in the estuaries, is still much higher than the total coastal retreat. Tropical cyclones are also a very common phenomenon in the Bangladesh coast. Water logging and coastal salinity in the coastal area also have become major threats in the last few decades. Conditions are deteriorating gradually. Arsenic contamination in groundwater has recently developed as a major threat to human health. Mangroves in the Sundarban forest are also under stress, as a result of several natural and man-made causes.

Environmental Degradation

Environmental degradation along some parts of the coast has also been occurring due to increased industrial activities, ship-breaking, and spillage of oil from the ships. Different types of environmental hazards are occurring in the coastal plains of Bangladesh and are described briefly in the following paragraphs.

Cyclones

The coastal regions along the northern Bay of Bengal have the highest potential for massive loss of life from storm surges associated with a tropical cyclone. Over the last two centuries massive coastal changes due to accretion and erosion have led to an enormous impact on the life style of more than 20 million people (Khalil 1992). Bangladesh has been hit by 60 severe cyclones from 1797 to 1991, of which 32 were accompanied by storm surge (Table 5.3.1). The frequency of wave heights of 12 m and 7 m are once per 20 years and 5 years, respectively. Waves of 3m in height may occur under unfavorable conditions in the coastal region (FEC and BWD 1989).

The phenomena of recurvature of tropical cyclones in the Bay of Bengal, a shallow continental shelf, high tidal range, a triangular shape at the head of the Bay, an almost sea-level topography, and a high density of population are prime factors in the large impact of cyclones and storm surges along the Bangladesh coast (Murty and El-Sabah 1992).

The intensity of cyclones on different coasts and their paths are shown in Fig. 5.3.2.

For a long time, construction of small dykes or embankments has been undertaken to protect life and properties from cyclones, but in most cases these measures proved useless. Planned settlements, public awareness, effective early warning systems and construction of adequate cyclone shelters may minimize the magnitude of loss due to cyclones and associated storm surges. The use of geomorphological maps in GIS-based surge modeling may provide new opportunities in the cyclone and storm surge management analysis in Bangladesh (Khan, 1995).

TABLE 5.3.1. Few major cyclones and storm surges in Bangladesh. (Compiled from Murty et al., 1986; Khalil 1992; and Murty and El-Sabh 1992.)

Date	Coastal Area affected	Nature, wind speed, surge height, tide height	Lives lost
May 1822	Barisal	Cyclonic storm	40,000
October 27–November 1, 1876	Patuakhali to Chittagong	Storm surge of 12 m height	400,000
October 1897	Chittagong and Kutubdia Is.	Hurricane with surge	175,000
April 1911	Teknaf	Cyclonic storm	120,000
May 1917	Sundarban	Cyclonic storm	70,000
September 1919	Barisal	Cyclonic storm	40,000
May 26, 1941	Eastern Meghna estuary	Cyclonic storm	7,000
October 21–24, 1958	Noakhali and Meghna estuary	Cyclonic storm	12,000
October 10–11, 1960	Meghna estuary	Cyclonic storm, 129 km/h, 6.6 m, 1.5 m	> 6,000
May 27–30, 1961	Chittagong-Noakhali	Cyclonic storm, 95–145 km/h	10,466
October 26–30, 1962	Feni-Chittagong	Cyclonic storm, 200 km/h, 5.8 m, 0.0 m	50,000
May 28–29, 1963	Noakhali-Cox's Bazar	Cyclonic storm, 201 km/h, 5 m, 0.3 m	11,520
May 10–12, 1965	Barisal-Chittagong	Cyclonic storm, 161 km/h, 4.0 m, 1.2 m.	19,270
November 12–13, 1970	Khulna-Chittagong	Cyclonic storm, 222 km/h, 5.5m, 2.1m.	300,000
November 28–30, 1971	Sundarban	Cyclonic storm, 110 km/h, 1.0 m, 0.0 m.	11,000
May 24–25, 1985	Noakhali-Cox's Bazar	Cyclonic storm, 154 km/h, 3.2 m, 1.8 m.	11,069
November 29, 1988,	Sundarban	Cyclonic storm, 160 km/h, 3.5m, 1.5m.	5,708
April 29, 1991	Patuakhali-Cox's Bazar	Cyclonic storm, 235 km/h, 4.5 m, 1.7 m	145,000

Coastal Erosion and Deposition

A major part of the Bangladesh coast is threatened by land erosion, due to sea level rise in recent years (Khan et al., 2001). On the other hand, the estuarine part of Meghna estuary (active river mouth and present delta lobe) is prograding at a considerable rate, overriding the balance of erosion with sedimentation. The land accretion in the Meghna Estuary during 1990–2001 has been estimated as 523 km^2, which is about 49 km^2/year (Fig. 5.3.3).

The rate of subsidence in the middle-western part of the delta has been found to be 1.5–2.5 mm/year. This increases to about 4.5–5.5 mm/year near the present delta lobe at the mouth of the Meghna estuary (Khan et al., 2001). For some time the rate of sedimentation kept the plain stable to prograding in nature. However, the construction of embankments along the tidal channels and rivers which started in 1960, has destroyed this balance. Very little or no sediment can deposit on the tidal flats nowadays. The coastal plains are

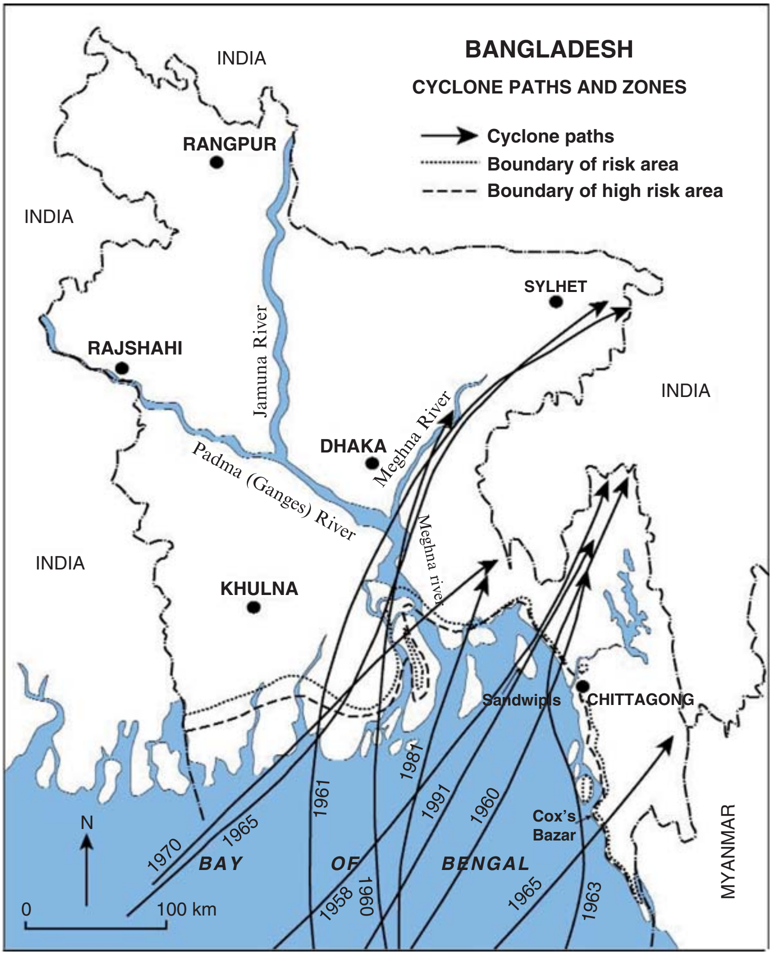

FIG. 5.3.2. High-risk cyclone hazard areas of Bangladesh and cyclone paths, 1958–1991. (From FAP 7, 1992, and Multipurpose Cyclone Shelter Project 1993.)

presently experiencing an adverse effect due to the mean annual rate of 3mm subsidence, and a 1.0–1.5mm sea-level rise, with little to no sedimentation. This may be further aggravated in future.

Enormous socioeconomic problems have emerged in recent years. The northern and northwestern part of the offshore islands of Hatia and Sandwip, as well as the northeastern part of the coastal peninsula (Bhola) of the Meghna estuary, have been eroding rapidly due to frequent shifting of river courses, differential rates of sedimentation and neotectonic activities. Most parts of these coastal areas are not protected to withstand tidal surges. An exception is the Chittagong Metropolitan area, where most of the industries and overseas business centers of the country are located.

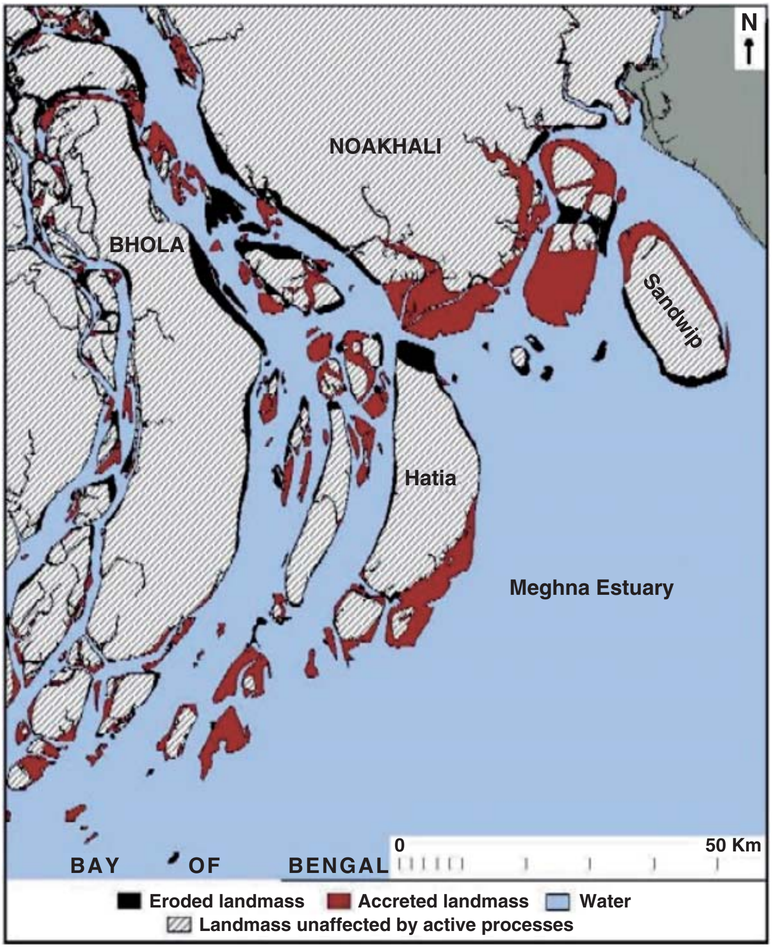

FIG. 5.3.3. Coastline accretion near Megna estuary.

Salinity

Saline water intrusion in groundwater and soil in the coastal areas of Bangladesh directly influences the overall ecosystem in the coastal areas. Farming in the coastal areas is usually done once a year during the dry winter season when water from the wells is mainly used for irrigation. Incremental increases in the population have forced the locals to cultivate a high-yielding variety of rice, which requires more water. Extraction of excessive ground water and nonavailability of fresh surface water as a result of a reduced flow of the Ganges river by commissioning the Farakka Barrage in 1976 located upstream in India, increased human interventions, siltation in different distributaries, and construction of polders and embankments helped to intrude further inland between 1973 and 1997 (Fig. 5.3.4). Salinity intrusion has not only reduced the yield of agri-based products, but has also had a severe impact on

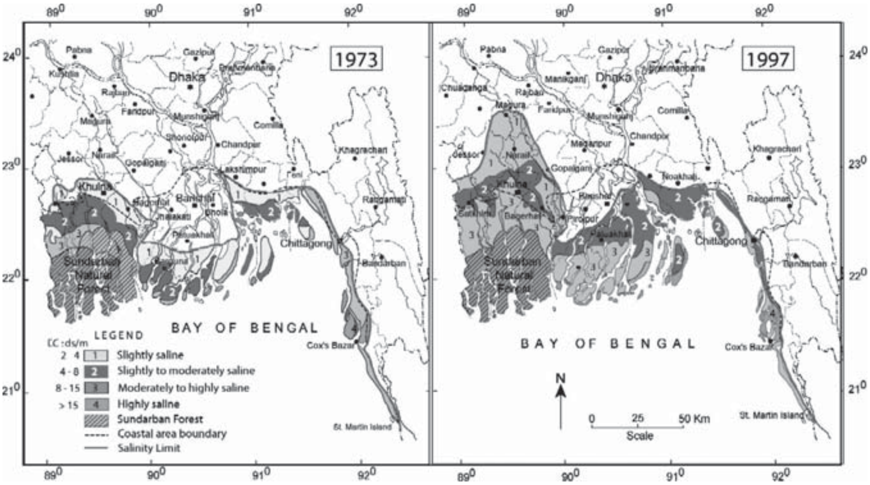

Fig. 5.3.4. Groundwater salinity in 1973 (left) and 1997 (right). (From Soil Resource Development Institute [SRDI].)

brick production. Bricks are the basic raw material for infrastructural development. Bricks made of saline soil are not at all suitable for construction. No preventive measures have so far been taken to reduce salinity problems in the groundwater.

Arsenic Contamination

In recent years arsenic pollution of groundwater has turned into a problem of unprecedented proportions in Bangladesh. It has been statistically determined that 25% of tube wells have arsenic contamination above the Bangladesh standard of 50 μg/L for drinking water, while 42% surpassed the WHO guideline value of 10 μg/L (BGS and DPHE, 2001). The estimated population exposed to this pollution is now more than 30 million, out of a total population of 130 million. It has been observed that shallow phreatic aquifers are responsible for the supply and mobilization of arsenic contaminated water, whereas the deeper wells are least affected. A natural geochemical process releases arsenic into groundwater from the Holocene alluvial sediments that make up almost 80% of the total landmass of Bangladesh. Geological processes of sediment transportation and deposition are responsible for the spatial variation in arsenic concentration in groundwater.

Geomorphologically, high arsenic-contaminated groundwater has been found in the lower Ganges and Meghna floodplain and deltaic regions of the country (Fig. 5.3.5). Preventive measures against arsenic contamination have been taken in recent years, by sinking deep tube wells. Also government, nongovernment organizations and some donor agencies are addressing this problem so that the sources of arsenic can be detected and the people in those localities can be provided safe drinking water.

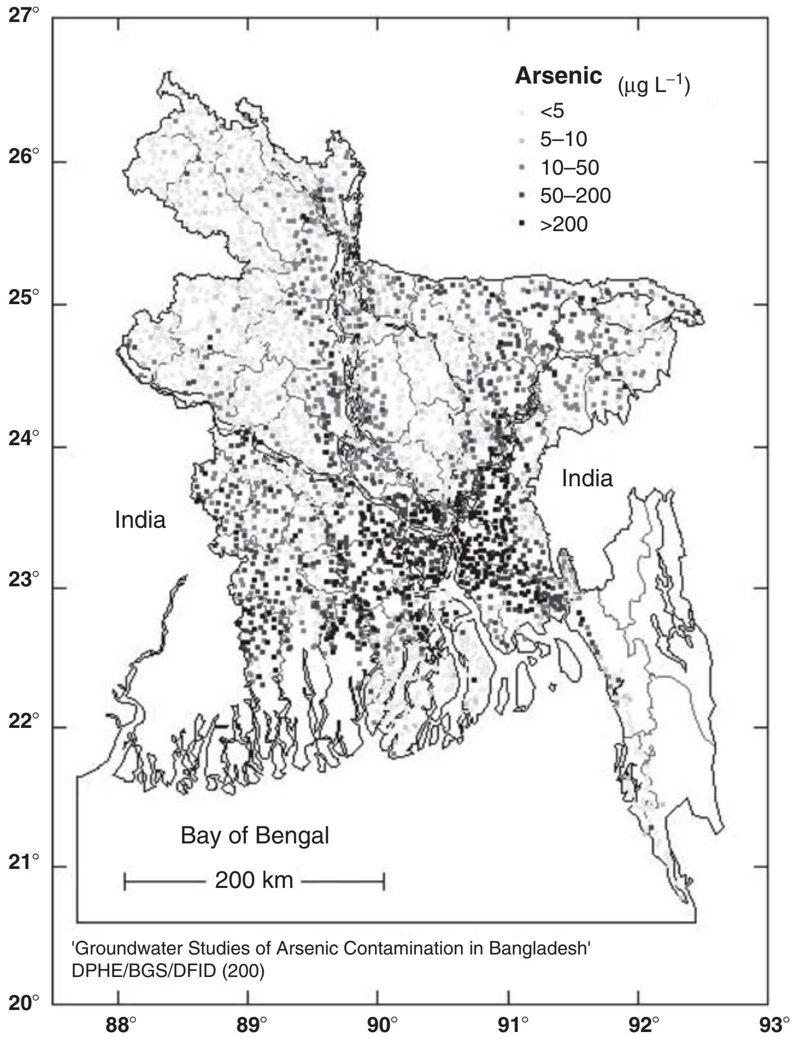

FIG. 5.3.5. Arsenic affected areas of Bangladesh.

Waterlogging

The Ganges-Brahmaputra-Meghna river system carries about 1.4 billion tons of sediment each year, through Bangladesh to the bay (Milliman and Syvitski 1992). About one third of the sediments deposit in the subaerial part of the delta. The Ganges-Brahmaputra delta, especially the lower deltaic plain, is subsiding rapidly. This was usually compensated by the deposition of transported sediments that maintain a balance between sedimentation and subsidence (Ali et al., 2001). However, the construction of polders disrupted this balance in the lower delta plain and resulted in rapid sedimentation in

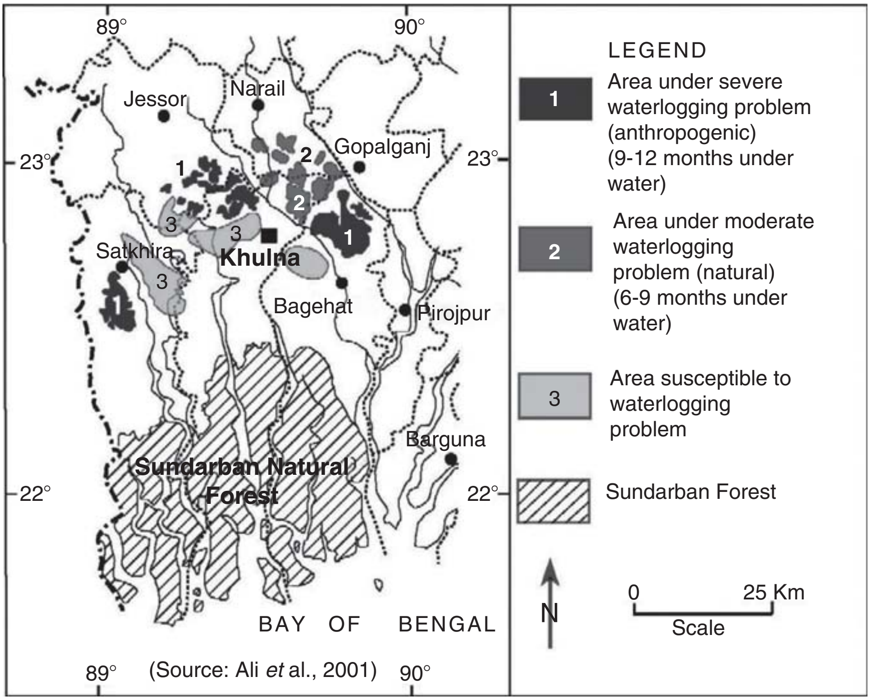

FIG. 5.3.6. Waterlogging in the southwestern part of Bangladesh.

the channel beds and little to no sediments on the tidal flats. Thus, the channel beds are elevating more gradually than the adjacent tidal flats, causing waterlogging problems in the tidal flats inside the polders. If this process continues, a major part of the land inside the polders will be converted into permanent brackish water lakes or marsh (Fig. 5.3.6) and normal cultivation will be severely hampered. Recently, the government took up the problem as a priority, and is trying to solve it through the re-excavation of silted channels and the redesign of polders.

Floods

River floods impact around 20–35% of Bangladesh almost every year. The area goes up to 60–70% in years of extreme flooding. Coastal areas usually do not experience river flooding, due to the presence of tidal activity, but flooding due to storm surges of different magnitudes is a major hazard for the country (MPO 1986; FEC 1989; Khalequzzaman 1994; Ahmed et al., 1997; Mirza and Dixit 1997; Ahmed 2000; Islam and Islam 2000). During the months of April–June and September–November storm surges due to tropical cyclones in the Bay of Bengal cause severe flooding and disasters along the coastal areas. About a 12,000 km^2 area of the coastal region is prone to cyclonic storm surge flood, of which 9,100 km^2 (6% of the total area) is inundated to a flood depth of 1 m. Tidal water due to storm surge rises up to 4.5–7.8 m and inundates about 15 km inland in the southeast region and 55 km inland in the southwest region (Chowdhury 1994a, b). A network of advance warning systems, increased public awareness and coordinated post-flood activities are necessary to minimize losses.

Earthquakes and Tsunamis

Bangladesh is surrounded by regions of high seismicity (Table 5.3.2). Although the epicenters of large earthquakes lie beyond the borders of the country, these equally affect the country due to its morphotectonic continuity. The seismicity of Bangladesh is deeply related to tectonic behavior in and around Bangladesh, namely the subduction of the Indian plate below the Eurasian plate in the north and the Burmese Plate in the east. Alam (1995) studied some suspected young faults in the eastern part of Bangladesh and found that most of these are still active.

Bangladesh narrowly escaped the recent devastating tsunami following the earthquake on December 26, 2004 in Sumatra. This had a magnitude of 8.9 on the Richter scale and claimed 275,950 lives (according to USGS). However, the risk of tsunamis along the Bangladesh coast cannot be ruled out. Measures against tsunamis have become a new task for the government, as they were not well known before. Several international organizations, such as the World Bank and JICA, are assisting Bangladesh to create a tsunami early warning system.

Table 5.3.2. Major earthquakes that have affected Bangladesh since the middle of the 19th century. (Modified after Khan AA and Chouhan RKS 1996.)

Date	Name	Epicenter	Magnitude
January 10, 1869	Cachar earthquake	Jainta Hill, Assam	7.5
July 14, 1885	Bengal earthquake	Manikganj, Bangladesh	7.0
July 12, 1897	Great Assam earthquake	Shillong Plateau, India	8.7
July 8, 1918	Srimangal earthquake	Srimangal, Bangladesh	7.6
July 3, 1930	Dhubri earthquake	Dhubri, Assam, India	7.1
January 15, 1934	Bihar-Nepal earthquake	Bihar, India	8.3
August 15, 1950	Assam earthquake	Assam, India	8.4

Reduction of Mangroves

The Sundarbans is a vast tract of mangrove forest situated on the southwest coast of Bangladesh and forming on the lower part of the Ganges Delta. The forest covers an area of approximately 577,000 ha within Bangladesh and is said to be named after "Sundari" (*Heritiera fomes*), a common large mangrove tree. In 1997 UNESCO designated Sundarbans as a world heritage site.

The area is one of the last reserves of the Royal Bengal tiger. The forest supports many industries by supplying raw materials, as well as supporting the local economy and professional groups by providing subsistence and employing neighboring people for their survival and livelihood (Amin 2003). The nature of exploitation is increasing day by day, affecting the delicate ecosystem in a negative way. Increased salinity also destroys the ecosystem of this mangrove forest. Massive changes in both the adjacent lands and upstream areas, with the construction of polders, embankments or barrages, are feared to generate fundamental changes in the hydrologic regime of the Sundarbans. This noticeable change in salinity and tidal siltation has resulted in a hostile anaerobic condition in which the "Sundari" tree finds healthy respiration difficult and which causes the "top dying" disease that has threatened the species' existence.

Due to the above socioeconomic and ecological conditions, the destruction of the forest will not only affect the ecology of the area but will have a far-reaching impact on the national economy, also causing immense damage to the marine resources of the Bay of Bengal. Also, the loss of mangrove trees in the Sundarbans will expose the entire southwestern region of the country to frequent cyclone and tidal surges. At present this is an area that acts as a vital barrier for southwestern coastal towns such as Khulna and Mongla Port. Protective measures are necessary for maintaining and regenerating high-quality mangrove forests within this site.

Marine Pollution

Disposal of waste into the sea has increased alarmingly in recent years. Industries such as tanneries, textile mills, oil refineries, TSP plants, DDT plants, chemical plants, steel mills, paper mills, soft drink factories, and pesticide manufacturing plants are situated on the banks of the Karnaphuli River and in the Chittagong coastal area. None of these industries has any pollutant treatment facilities. They are discharging their toxic wastes directly into the Karnaphuli River or the Bay. Also, in the Khulna district, industries such as match factories, fish processing plants, jute mills, steel mills, the Khulna shipyard and newspaper mills discharge liquid or solid wastes directly into the Bhairab-Rupsha river system, or to the Bay of Bengal. Moreover, municipal and domestic wastes are also adding pollutants through the various rivers that flow into the Bay. These pollutants may threaten the aquatic life and the ecosystem of the area.

Importation and delivery of crude oil, and its derivatives, is the most dominant source of pollution in the vicinity of the Chittagong port region. Moreover, thousands of river craft, steamboats and steamers are operating on waterways. These discharge waste oil, spillage and bilge water into the Bay. Large-scale ship breaking activities are also going on along the lower tidal flats of the Chittagong coast, where nearly 50 ships/oil tankers are dismantled and broken up each year. The sludge, other lubricants and engine oil of these ships constitute a considerable amount of oil spillage directly to the seawater. Mongla, the second sea port in the Khulna district, and its associated marine traffic, are also a frequent source of oil spills. There is a permanent risk of accidents with chemicals near the Sundarban forest coast. Pollution due to oil spillage and sewage discharge is increasing because of the lack of enforcement of environmental rules and regulations. This may cause depletion of fish resources, infectious diseases and a change in the aquatic ecosystem as a whole. Steps are required to conserve this coastal ecosystem from pollution before it gets out of control.

Conclusion and Recommendations

The coastal plains of Bangladesh are susceptible to various hazards, both natural and anthropogenic. Hazards due to cyclones, water logging, and a reduction in mangroves can be rated as the number one problem when considering their impact on life and property. Proper measures against these hazards can easily be taken beforehand. Other hazards, like coastal erosion and salinity intrusion, are slow processes and have no immediate effect on the coastal people. Earthquake and tsunami-related hazards, on the other hand, are sudden events. The people as well as the government at present are least prepared to cope with these events in Bangladesh.

The flat topography, unconsolidated nature of sediments and complex tectonics have an impact on the recurrence and intensity of natural hazards. In the past, many protective and training measures against these natural hazards have been taken in Bangladesh, but have not turned out to be effective. In most cases geological aspects have not been taken into consideration. Therefore, geological factors need to be addressed, along with other socioeconomic parameters in management planning against natural hazards. Use of remote sensing and Geographic Information Systems (GIS) would help in the integration, storage and analysis of geoscientific data for understanding the causes of these hazards. Regional and global cooperation is needed for the study and to take mitigating measures against natural hazards.

The following recommendations are made for the coastal areas:

1. Sluice gates on the mouth of tidal channels should be kept open during the monsoon period so that the depositional processes of sediments can continue through the flooding of the area. By this, the balance between subsidence of the area and deposition of sediments on the plain can be, more or less, restored.
2. Ponds, tanks, and artificial reservoirs can be extensively used for pisciculture, by raising their banks to avoid overflooding.
3. Detailed hydrological studies of the region should be undertaken to provide data for planned development of water supply facilities for irrigational and domestic uses.
4. Tidal flats, especially lower tidal flats, should be avoided for any engineering construction, such as construction of roads and highways, as well as buildings.
5. Embankments at a height of about 10 meters from the MSL may protect offshore islands, such as Hatia, Sandwip, from being inundated by tidal surges. Geo-textiles may be used for the construction of embankments, because of their low cost and high durability.

6. Cyclone-shelters in the area are inadequate in number and in most cases are not well maintained. As such, to fulfill long-term requirements and to avoid the problems mentioned above, mosques, schools and administrative buildings are to be built in sufficient numbers and a few meters above ground level on pillars (preferably 4 to 6 meters above ground level), and only within the supratidal flats of the island.

References

Ahmed QK (2000) Opening statement. In: Ahmed QK, Chowdhury AK, Azad Imam SH, Sarker M (eds) Perspectives on flood 1998. University Press Limited, Dhaka, pp 133–136

Ahmed E, Chowdhury JW, Hasan KM, Haque MA, Khan TA, Rahman SMM, Salehin M (1997) Floods in Bangladesh and their processes. Country report for Bangladesh. *Proceedings of the evolution of a scientific system of flood forecasting and warning in the Ganges, Brahmaputra and Meghna river* basins, Dhaka, 41–67

Alam AKM Khorshed (1995) Evaluation of neotectonic activities in the eastern part of Bangladesh. Abstracts of 2nd South Asian Geological Congress (GEOSAS II), Sri Lanka

Ali RME, Ahmed M (2001) Effects of poldering on the morphodynamic charaterization in the Khulna-Jessore area of Bangladesh – a case study. Proceedings of the international seminar on quaternary development and coastal hydrodynamics of the Ganges Delta in Bangladesh. Geological Survey of Bangladesh, June 2001, pp 13–25

Amin MN (2003) The Sundarbans of Bangladesh: its biodiversity, ethnobotany and conservation. Ecol Env Cons 9(4):519–531

Bangladesh Bureau of Statistics (BBS) (2001) Preliminary report population census 2001, Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of the Peoples Republic of Bangladesh

Chowdhury JU (1994a) Is the Gumbel distribution appropriate for AM discharge data in Bangladesh? J Instit Eng Bangladesh 22(2):23–31

Chowdhury JU (1994b) Determination of shelter height in a storm surge flood risk area of Bangladesh coast. Water Resours J ESCAP Ser. C/182:93–99

FAP 7 (Flood Action Plan 7) – Government of Bangladesh, Ministry of Irrigation, Water development and Flood Control (1992) Cyclone protection project II: feasibility and design studies (main report), Dhaka

French Engineering Contortion and Bangladesh Water Development Board (1989) Prefeasibility study for flood control in Bangladesh 4

Islam MB, Sultan-Ul-Islam (2000) Floods in Bangladesh: a geo-environmental assessment. In: Frank Toensmann and Manfred Koch (eds) River flood defence. 1:F95–F106

Khalequzzaman Md (1994) Recent floods in Bangladesh: possible causes and Solutions, Nat Hazards 9:65–80

Khalil GM (1992) Cyclones and storm surges in Bangladesh: some mitigative measures. Natural hazards, 6. Kluwer Academic, pp 11–24

Khan AA, Chouhan RKS (1996) The crustal dynamics and the tectonic trends in the Bengal basin, J Geodynamics 22(3/4):267–286

Khan SR (1995) Geomorphic characterization of cyclone hazards along the coast of Bangladesh. International Institute for Aerospace and Earth Sciences (ITC), The Netherlands (unpublished M.Sc. thesis)

Khan SR, Majlis ABK, Ali MA (2001) Impacts of sea level change on different coastal parts of Bangladesh. Bangladesh J Geol, Bangladesh Geol Soc 20:17–32

Master Plan Organisation (MPO) (1986) National water plan. Ministry of Irrigation, Dhaka, Water Development and Flood Control

Milliman JD, Syvitski JPM (1992) Geomorphic/tectonic control of sediment discharge to the ocean: the importance of small mountainous rivers. J Geol 100: 525–544

Mirza MMQ, Dixit A (1997) Climate change and water resources in the GBM basins. Water Nepal 5(1):71–100

Multi-purpose Cyclone Shelter Project (1993) Summary report. Bangladesh University of Engineering and Technology and Bangladesh Institute of Development Studies, Dhaka

Murty TS, El-Sabah MI (1992) Mitigating the effects of storm surges generated by tropical cyclones: a proposal. Nat Hazards 6:251–273

Murty TS, Flather RA, Henry RF (1986) The storm surge problem in the Bay of Bengal. Proc Oceanog 16:195–233

5.3.2 The State of the Environment of the Pakistan Coast

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Introduction

Pakistan has a coastline that stretches over 990 km along the Arabian Sea. It comprises two distinct units, the passive margin of Sindh, and the active margin of the Balochistan coast. The coastal and offshore geology of Pakistan tectonically exhibits both active and passive margin features. The Balochistan coast is active, whereas the Sindh coast and Indus deltaic area and offshore Indus basin is geologically passive. The Sindh and Balochistan coasts have differing climatic conditions, geographical location and socioeconomic factors. The Sindh coast can be further divided into two parts, namely the Indus deltaic coast and the Karachi coast. The coast in the vicinity of Karachi, which is approximately a 70 km stretch, is relatively well developed, as compared to the rest of the Pakistan coast.

The Sindh coastal region is located between the Indian border, along Sir Creek on the east to the Hub River coast on the west (320 km). The Indus River drains into the entire lower plain of Sindh. The Indus delta is the most prominent feature of the Sindh coast. The sediments are subjected to coastal dynamic processes, such as tides, winds, waves and currents, leading to accretion and erosion of the Indus deltaic coast. The coastal morphology is characterized by a network of tidal creeks and a number of small islands, with sparse mangrove vegetation, mud banks, swamps, and lagoons formed as a result of changes in river courses. The present delta covers an area of about 600,000 ha and is characterized by 16 major creeks and innumerable minor creeks, mud flats and fringing mangroves. The delta supports wetlands rich in nature and culture, and also nurtures the largest area of arid climate mangroves. This area is very arid with an average annual rainfall of about 200 mm. Some 27% of this land is under water in the form of creeks and water courses. These water courses intrude the island; they are calm and protected water, and are flushed daily by tides ranging up to 3 m.

The coast of Karachi is situated between Cape Monze, a high cliff projecting into the Arabian Sea, and the Korangi creek. The coastline of metropolitan Karachi is generally oriented NW–SE. On the western side it is bounded by the Hub River and on the east by the mangrove swamps and creeks of the Port Qasim area. The Layari and Malir river are seasonal streams that flow during the southwest monsoon. The rain water from Karachi and its adjoining area drains into the Arabian Sea. The prominent features of the Karachi coast are shallow lagoons, raised beaches, marine terraces and dune fields and four major inlets: Manora Channel (Karachi harbour), Korangi creek, Phitti creek, and Khuddi creek. A small crescent shaped sand bar exists at the mouth of the Korangi creek. The shore terraces and sea cliffs are due west of the Hawks Bay area. Cape Monze beach is an example of raised beaches along the coast of Karachi. The eastern coast has tidal creeks with mangrove and mud flats. In this region, the seabed is generally smooth. The bed slope has a low gradient, in the order of 1/500–1/1000.

The coast west of Manora breakwater to Bulleji consists of sand beaches – Manora, Sands Pit and Hawks Bay. Rocky protruding points separate these beaches from each other. From Bulleji to Cape Monze the coast consists of hard conglomerate and shale cliffs. Beyond Hawks Bay, towards the west and up to the Cape Monze, the unconsolidated sandy clays are exposed to coastal weathering and erosion. Small rivers supply sediment to the coast during the rainy periods. The rivers are the predominant sources of sediment to the sandy beaches. The Layari delta is well protected from the direct influence of the ocean surf by a belt of sand, but the mouth of the river is more or less blocked and there is very little supply of water.

Clifton beach is largely composed of dark, grey silty materials with minute flakes of mica. The fine micaceous sand drifts from the mouth of the river Indus by the strong littoral currents. The sand, after it accumulates on the beach by the waves, is blown inland in large quantities.. Further east of Clifton there is the agglomeration of Ghizri hills. The coastal areas of Karachi are densely populated. The beaches of Karachi also attract large numbers of people. These beaches are a source of recreation for the local habitants.

The Balochistan coast extends from the mouth of the Hub River in the east to the middle of Gwatar Bay in the west, and stretches over a distance of about 670 km. The Balochistan coast consists of Makran and Lasbella districts; they are also an arid coast, owing to the scanty rainfall and highly saline soil. The Balochistan coast has an almost entirely desert-like condition. The entire coastal area is arid with only 150-mm/year of rainfall. The coast is drained by small rivers – the Hingol, Basol, Shadi Khor, and Dasht. Despite having large catchment areas, these rivers flow only during rainy season. Flash floods are frequent, and even during periods of scanty rain there is erosion of top soil from the uncovered hillsides and muddy banks. The eroded material is deposited along the coast at the mouths of the rivers. The Balochistan coastal region has cliffs, occasionally with rocky headlands, and a number of sandy beaches with shifting sand dunes. The region of creeks and coastal lagoons is marshy, with scanty patches of mangroves.

The principal geomorphic features of the Balochistan/Makran coast are cliffs, headland, and mud volcanoes. Rocks exposed along the coast are the assemblages of sandstone, shale and mudstone. The mountains are composed of bare rocky limestone or conglomerate. With the exception of some upper highlands, there is little or no vegetation. The coastline faces considerable erosion. Owing to a shortage of promontories and sheltered areas, most of the littoral material is lost to the sea. Spectacular mud volcanoes, where gas-charged water escapes to the surface, are found in several locations along the Makran coast.

The Indus River, about 3,000 km long, is one of the largest and most important river systems in the world. It predominantly flows through Pakistan towards the western margin of the India-Pakistan subcontinent (Fig. 5.3.7). It is not only one of the oldest rivers existing today, but has also cradled one of the oldest and historically most important civilizations (Moenjo Dharo and Harrapa) on earth. It is now a life-line for the human consumption and agriculture of Pakistan. The Indus River drains one of the highest and most tectonically dynamic regions of the world (i.e., western Tibet, the Himalayas and Karakoram), and is fed by the rains of the southwest Asian monsoon. The flux from this river has produced a vast sediment body, the 'Indus Fan', in the Arabian Sea (totalling ~5×10^6 $km^{3)}$ (Naini and Kolla 1982), second only to the Bengal Fan in size. The Indus river basin stretches from the Himalayan Mountains in the north to the dry alluvial plains of Sindh in the south. The area of the Indus basin is 944,574 km^2 (Asianics Agro-Dev. International (Pvt) Ltd., 2000), making it the twelfth largest among the rivers of the world (Fig. 5.3.7). Its deltaic area is 3×10^4 km^2, ranking it seventh in the world. The Indus ranks 4th among the world's rivers in having a wave power at the delta shoreline of about 13 joules/s/unit crest width and 1st in having a wave power at a distance from the shoreline at which the water depth reaches 10 m, of about 950 joules/sec/unit crest width (Pakistan Water Gateway 2003). The Indus basin was one of the world's premier water laboratories in the late twentieth century. The water system of the Indus dates back six millennia to the Harappan period and continues through Hindu, Buddhist, medieval, Islamic, and colonial periods. However, the last six decades have seen the greatest developments and large scale management of the water system.

At the mouth of the Indus, east of Karachi, the modern Indus River Delta formed during the Holocene. Unlike deltas of many other rivers, the Indus Delta is composed of clay and infertile soils. Much of the modern delta plain is very arid, with swampy areas restricted to the immediate areas of tidal channels and the coastal tidal flood plains. Seasonal and annual river flows in the Indus River system are highly variable (Warsi 1991; Kijine et al., 1992; Ahmad 1993). The largest flow from the Indus occurs between June and late September, driven by the summer monsoon season and a peak in the flow from snow melt (from

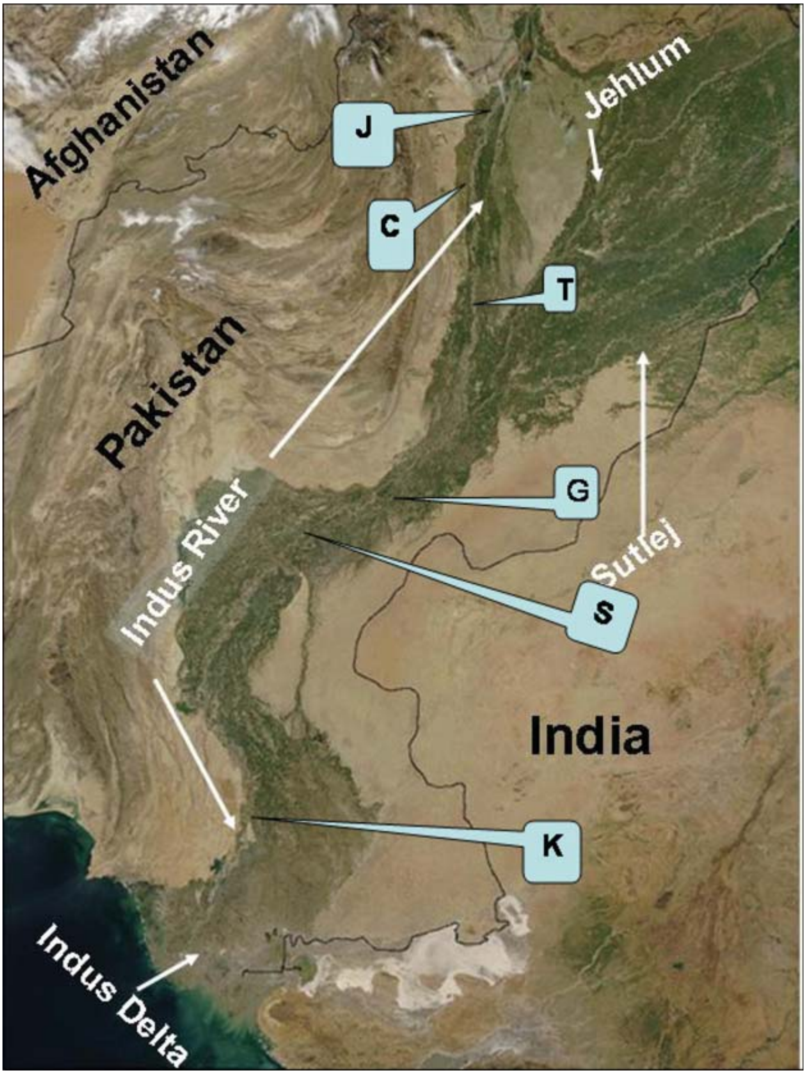

FIG. 5.3.7. Satellite image of Indus River and its delta. Major barrages over the Indus River are marked as K (Kotri), S (Sukkur), G (Guddu), T (Taunsa), C (Chashma), and J (Jinnah). (Satellite Image from NASA).

the mountains) that increases the discharge of water, along with the eroded sediments. These waters are used primarily for irrigation of agricultural crops. Dams have been constructed to provide flood control and hydroelectricity.

Damming of the Indus River

Pakistan depends on irrigation and water resources for 90% of its food and crop production (World Bank 1992). The irrigation system in Pakistan comprises three major storage reservoirs, 19 barrages or head works, and 43 main canals with a conveyance length of 57,000 km, and 89,000 water courses with a running length of more than 1.65×10^6 km (Table 5.3.3). It is estimated that up to 60% of the Indus water is used to feed Pakistan's irrigation networks, and that the Indus watershed irrigates up to 80% of Pakistan's farmland (Iftikhar 2002). Pakistan's vast irrigation system feeds more than 162,000 km^2 of land in Pakistan, a country with the highest irrigated and rain-fed land ratio in the world, 4:1. About 180,000 km^2 (6.6% of the global irrigated area) is presently being irrigated in Pakistan. The contribution of rainwater to crops in the Indus Basin Irrigation System is estimated at about 16.5 billion m^3/year (Ahmad 1993).

The development of infrastructure in the basin affected the sediment and water discharge downstream of Kotri Barrage (Fig. 5.3.8). Prior to the construction of major dams and barrages on the Indus River the recorded average sediment and water discharge down stream of Kotri Barrage was 193 million ton/year and 107 billion m^3/year, respectively (Table 5.3.4). As expected, the major decline in the sediment and water discharge occurred after the 1967 commissioning of Mangla dam and 1976 commissioning of the Terbela dam. From 1998 onwards the sediment and water discharge below Kotri Barrage declined at an alarming pace, mainly due to low rain fall. The overall impacts of man-made changes in the Indus River system are best observed downstream of Kotri Barrage where prior to the construction of the barrage there were no days without water discharge (Fig. 5.3.9). Zero flow days were observed during the post-Kotri period (1962–1967).The occurrence of zero flow days progressively increased following the commissioning of the Kotri and Guddu barrages and the Mangla Dam (Asianics Agro-Dev. International (Pvt.) Ltd., 2000). In the post-Kotri period (1961–1967) the maximum number of days with zero flows was 100. This increased to around 250 days in the post-Kotri and post-Mangla period (1967–1975). The present situation is much more alarming because of below average rain fall in the Indus River catchment area. Presently there are only two months (August–September) in a year when the Indus River flows downstream of Kotri Barrage.

Table 5.3.3. Major dams and barrages constructed on the Indus River system.

Structure	Year of construction with maximum discharge capacity
Tarbela Dam	Constructed in 1976
Mangla Dam	Constructed in 1967
Ghazi Barotha Hydro Power Project	Recently completed with a capacity of 500,000 cusec
Jinnah Barrage	Constructed in 1946 with a design discharge capacity of 950,000 cusec
Chashma Barrage	Chashma Barrage was constructed in 1971 with a design discharge capacity of 1.1 million cusec
Taunsa Barrage	Constructed in 1959 with a design discharge capacity of 750,000 cusec
Guddu Barrage	Constructed in 1962 with a design discharge capacity of 1.2 million cusec
Sukkur Barrage	Constructed in 1932 with a design discharge capacity of 1.5 million cusec
Kotri Barrage	Constructed in 1955 with a design discharge capacity of 875,000 cusec

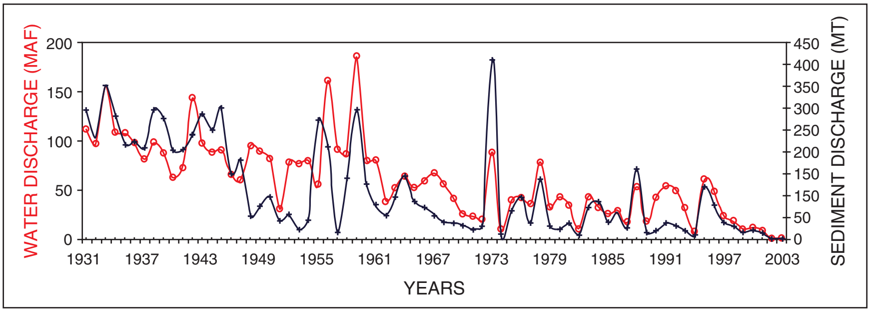

FIG. 5.3.8. Variation in the sediment and water discharge downstream of Kotri Barrage since 1930. (Modified from Milliman et al., 1984.)

TABLE 5.3.4. Changes in the sediment and water discharge downstream of Kotri Barrage with time.(From Irrigation Department of Pakistan.)

Peroid	Water discharge (billion m^3/year) Average	Sediment discharge million ton/year Average
1931–1954	107	193
1955–1962	126	149
1963–1967	72	85
1968–1976	47	82
1977–1997	45	51
1993–2003	10	13

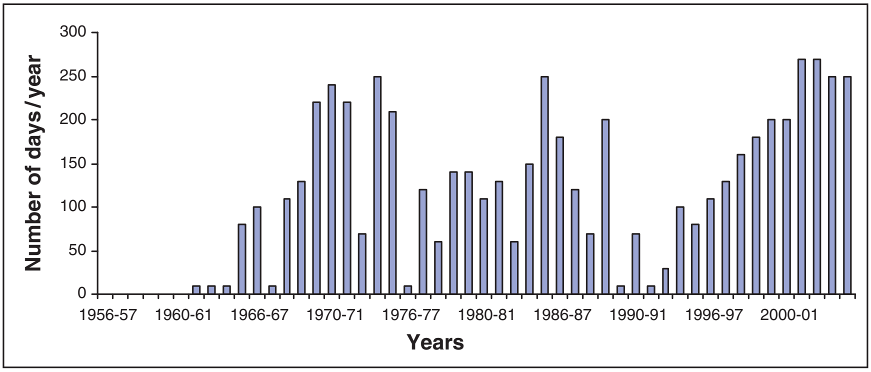

FIG. 5.3.9. Dramatic rise in the number of days with no river flow downstream of Kotri Barrage with the construction of dams and barrages on the Indus River. (Modified after Asianics Agro-Dev. International (Pvt.) Ltd., 2000.)

The amount of water in the Indus River has decreased dramatically from around 185,000 million m^3 per annum in 1892 to 12,300 million m^3 per annum in the 1990s (Iftikhar 2002). Little freshwater now reaches the lower Indus. As a result the floodplains and wetland ecosystems of the Delta have been severely degraded.

Indus Delta

There are 17 major creeks making up the original Indus delta, but due to reduced flows downstream of the Kotri barrage, only the Khobar Creek now receives water from the Indus (Fig. 5.3.7). Due to lack of environmental awareness any releases of water to the Indus Delta were considered as wasted. The Indus Delta itself was seen as a wasteland of mudflats, creeks and mangroves. The Indus Delta is subjected to the highest average wave energy of any major delta in the world (Wells and Coleman 1984). This is mainly due to the intense monsoonal winds, which produce high energy levels. The Indus River is currently contributing hardly any sediment to the delta, causing shrinkage as the active delta is now only 1,200 km^2 in area compared to the 6,200 km^2 before the construction of a series of dams and barrages on the Indus River (Asianics Agro-Dev. International (Pvt.) Ltd., 2000). Consequently, there has been an intrusion of seawater upstream of the delta, at places extending up to 75 km in the coastal areas of the Thatta, Hyderabad and Badin districts. The twin menace of an almost total absence of freshwater in the river downstream of Kotri, and heavy seawater intrusion from the delta, has destroyed large areas of prime agricultural land, including submersion of some villages in the coastal belt of these districts. In turn, this has caused desertification and displacement of several hundred thousand local residents who had been living there for many generations. An extreme level of wave energy, and little or no sediment contribution from the Indus River, is transforming the Indus Delta into a true wave-dominated delta. Development of sandy beaches and sand dunes along the former deltaic coastline is underway.

Agriculture Runoff, Water Logging, and Salinity

The topography of Sindh is more or less flat, so that the natural flow of the drainage is gradual, allowing a rapid increase in the groundwater table. The prevalent canal irrigation system has resulted in large scale water logging and salinity problems. Approximately 60% of the aquifer underlying the Indus Basin is of marginal to brackish quality. The problem of water logging and salinity became apparent in the late 1950s. In the lower Indus basin the area with a groundwater depth less than 3 m accounted for 57% of the total area.

To mitigate the menace of rising groundwater, and the associated problem of water logging and salinity, a network of drainage canals was constructed within the Indus Basin. This was designed to drain groundwater directly into the Arabian Sea. The drainage system has been less effective, due to low gradient/flat topography and has, in fact, resulted in the intrusion of seawater to about 80 km upstream (Panhwar 1999). Seawater intrusion is much worse during the southwest monsoon (Fig. 5.3.10).

Sea-level Rise

The historical recorded data on sea-level rise at Karachi, and the adjoining Indus Deltaic area, is based on data collected over the last 100 years. Sea level

FIG. 5.3.10. Seawater intrusion through the network of canals constructed for the discharge of saline groundwater to the sea.

has rised by 1.1 mm/year over this time. But this is expected to more than double during the next 50 to 100 years, resulting in a 20–50 cm rise in sea level (UNESCAP 1996). The adverse effect of sea-level rise on the Pakistan coast is expected to be pronounced in the Indus Delta. A sea-level rise of about 2 m is expected to submerge or sea encroach an area of about 7,500 km^2 in the Indus Delta. There are no direct measurements available on subsidence rates in the Indus Delta. However, experience in other deltas indicates that subsidence rates at the delta must have increased due to the lack of sediment flux. The Indus Delta could experience a relative sea-level rise of up to 8 to 10 mm/year, in light of the projected rate of the global component of sea-level rise of up to 6mm/year in the next century. If the present trends continue the Indus Delta will ultimately establish a transgressive beach dominated by aeolian dunes, due to a lack of sediment inputs and presence of high energy waves (Haq 1999).

Impact of Water Shortage on Mangroves

The Indus delta has about 1,600 km^2 of mangroves forests, of which about 500 km^2 can be classified as dense mangrove stands. The shortage of rainfall, the high evaporation rate and the decreasing flows of freshwater down the Indus as a result of dams and barrages means that salinity levels in the creeks often exceed that of seawater. Even though mangroves are generally able to survive in seawater without regular freshwater input, it is unlikely that they will able to survive. Apart from longer-term threats to the survival of Indus delta mangroves, there are pressures from over grazing and lopping for fuel wood, which result in stunted trees in some areas (Fig. 5.3.11). Because the lives of local people are closely linked to the natural resources of the Delta ecosystems, each environmental impact has a social impact. Local communities

Fig. 5.3.11. Destruction of mangrove forest in the deltaic area near Karachi.

are dependent on natural resources for their livelihood, including floodplain forests, mangrove forests and fishes.

The human population in and around mangrove forests on the Sindh coast is estimated to total 1.2 million people, nearly 900,000 of whom reside in the Indus Delta (Salman 2002). Of these, a predominantly rural population of more than 135,000 depends on mangrove resources for their livelihoods (Shah 1998). Reductions in freshwater inflows have had tangible impacts on mangrove ecology, and on the fish populations that rely on them for breeding and habitat. At least three quarters of the delta's rural population depend, directly or indirectly, on fishing as their main source of income. Most of Pakistan's commercial marine fishery operates in and around the mangrove creeks on the coast of Sindh Province. A large proportion of fish and crustaceans spend at least part of their life cycle in the mangroves, or depend on food webs originating there (Meynell and Qureshi 1993).

High Water Turbidity

Reduction in sediment and water discharge is causing coastal erosion in the Indus deltaic and coastal areas and is resulting in significantly high levels of seawater turbidity, rendering the water quality of coastal waters unsuitable for a number of marine organisms. The turbidities of the seawater influence the bottom limit of light penetration in the sea, thus controlling the primary productivity in the coastal and creek waters. The higher turbidities also influence the distribution of marine organisms, particularly fish and shrimp, in the coastal waters. The higher turbidities are not tolerated by filter feeding benthic organisms and hence they are usually absent in the areas which are affected by coastal erosion. The major impacts of turbidities on the marine environment is smothering of benthic fauna particularly filter feeding organisms, and a reduction of the photic zone by limiting light penetration, resulting in reduced primary productivity. The lower visibility in the seawater also influences the feeding, and migration of fish and shellfish. It is generally believed that the higher turbidities in the coastal waters due to southwest monsoon winds during the June–September period induces fish and shrimp stocks of coastal waters to migrate into deeper waters. The extent of this problem is increasing due to the increase in the sea encroachment in the area. The turbidity of the water in the Indus Delta varies spatially and seasonally. Turbidities are also influenced by the strong tidal flux, which reverses its direction during ebbing and flooding. Generally the turbidities are higher during ebb tides, particularly in the shallow creeks. The turbidities are also high within the delta area, and in the adjacent coastal waters, during river runoff after the rainy season of the southwest monsoon.

The turbidities in terms of transparency of seawater (Secchi disc disappearence depth) can also provide insight into the extent of the turbidities in the Indus Delta. During the January–February period the maximum water transparency in the major creeks of the Indus Delta are 2.5–4.5 m in the Gharo creek, 3.0–5.0 m in the Phitti Creek and 7.0 m in offshore water. During the May–August period the minimum values are 0.5–1.0 m of seawater transparency in the Gharo/Kadiro creek, <0.2m in the Phitti Creek and 0.2 m to > 2.0m in the offshore area adjacent to the creeks. The turbidities in the offshore waters adjacent to the delta are higher during the southwest monsoon period than during the rest of the year.

Conclusion

The anthropogenic impact of upstream water and sediment blockage has resulted in the shrinkage of the active delta, and stunted the growth of the mangrove forest. The beleaguered delta has been forced to face severe problems of coastal erosion due to unplanned coastal development in the area. The wellbeing of the Indus Delta demands a realistic assessment of the minimum quantity of freshwater and sediments required to prevent the total disappearance of the delta. There is need for a certain amount of water and sediment to be discharged into the delta on a year-round basis. It is also important that the management of the delta should become a part of an integrated coastal zone management approach, in a holistic manner that considers not only the coast but the whole ecosystem, from the source in the catchment area to the delta.

References

Ahmad N (1993) Water resources of Pakistan and their utilisation. Mirajuddin, PUB. 61-B/2, Gulberg III, i-5, 19, Lahore

Asianics Agro-Dev. International (Pvt) Ltd. (2000) Tarbela Dam and related aspects of the Indus River Basin, Pakistan. A WCD case study prepared as an input to the World Commission on Dams, Cape Town

Haq BU (1999) Past, present and future of the Indus Delta. pp 132–140. In: Azra Meadows, Meadows P (eds) The Indus River (biodiversity, resources, humankind). Oxford University Press, 441pp

Iftikhar U (2002) Valuing the economic costs of environmental degradation due to sea intrusion in the Indus Delta. In: IUCN, sea intrusion in the coastal and riverine tracts of the Indus Delta – a case study. IUCN – The World Conservation Union Pakistan Country Office, Karachi

Kijine JW, EJ Jr., Van der Velde, (1992) Irrigation management implications of Indus Basin climate change – case study. IIMI, Lahore

Meynell PJ, Qureshi MT (1993) Sustainable management of the mangrove ecosystem in the Indus Delta. In: Moser M, Van Vessen J (eds) Proceedings of the international symposium on wetland and water fowl conservation in south and west Asia, Karachi, pp 22–126

Milliman JD, Quraishee GS, Beg MAA (1984) Sediment discharge from the Indus River to the ocean: past, present and future, In: Haq BU, Milliman JD (eds) Marine geology and oceanography of Arabian Sea and coastal Pakistan. Van Nostrand Reinhold, New York, pp 65–70

Naini BR, Kolla V (1982) Acoustic character and thickness of sediments of the Indus Fan and the continental margin of western India. Mar Geol 47:181–195

Pakistan Water Gateway (2003) The gateway, hosted and managed by IUCN, addresses water as a resource in its many dimensions, serves to assess and disseminate shared experiences, publicize policies and guidelines and facilitate cooperation on water issues. http://www.waterinfo.net.pk.

Panhwar MH (1999) Seepage of water of the River Indus and occurrence of fresh ground water in Sindh, pp 180–197. In: Azra Meadows, Meadows P (eds) The Indus River (biodiversity, resources, humankind). Oxford University Press, 441pp

Salman A (2002) Draft proposal for economic valuation of mangrove ecosystem in Pakistan. Prepared for South Asia network for development and environmental economics, Kathmandu

Shah G (1998) Sociological report: Indus Delta mangrove ecosystem. DHV consultants and Sindh Forest Department Coastal Forest Division, Karachi

UNESCAP (1996) Coastal environmental management plan for Pakistan. New York

Warsi M (1991) Indus and other river basin of Pakistan. Stream flow records, case study report, WAPDA

Wells JT, Coleman M (1984) Deltaic morphology and sedimentology, with special reference to the Indus River Delta. In: Haq BU, Milliman JD (eds) Marine geology and oceanography of Arabian Sea and Coastal Pakistan. von Nostrand Reinhold Company, New York, pp 85–100

World Bank 1992. Reservoir maintenance facilities project (PCR), Agri Oper Div South Asia Region, Report 10725, 1992

5.3.3 An Overview of the Indian Coastal Environment

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Introduction

The Indian coastline extends for 7,500 km, with nine coastal states and four Union Territories contributing 75% of the coastline (Fig. 5.3.12). The rest is associated with about 500 oceanic islands, including Andaman and Nicobar in the Bay of Bengal and Lakshadweep in the Arabian Sea. The maritime states are Tamil Nadu, Andhra Pradesh, Orissa, West Bengal, and Andaman and Nicobar islands on the east and Kerala, Karnataka, Goa, Maharashtra, Gujarat, and Lakshdweep islands on the west.

The Indian subcontinent is a tropical zone, with recurring drought–flood phenomena. The coastal climate is generally uniform, except in Gujarat on the west coast, which experiences drought conditions. The SW and NE mon-

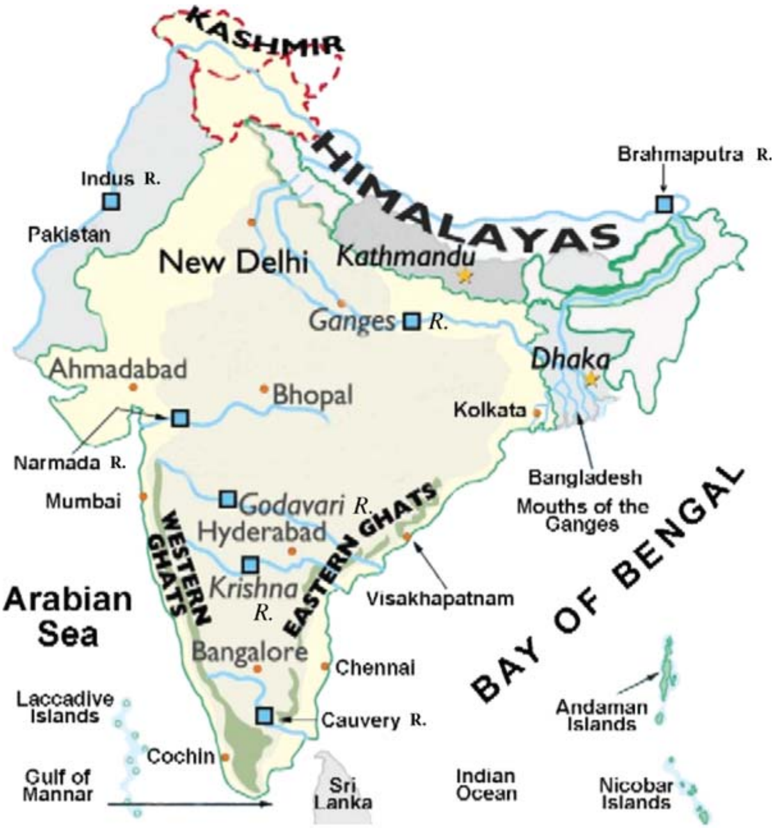

FIG. 5.3.12. Map of the Indian coast.

soon rainfall records its maximum of 3,600 mm along the Kerala coast, and decreases to a minimum of 400–600 mm near the Gujarat coast. Major precipitation is experienced from September to December along the east coast. The Gulf of Manner receives about 90 mm rainfall. Rainfall increases gradually towards the north of Porto Novo up to 1,500 mm and in the Sundarbans forest up to 1,908 mm. The Andaman and Nicobar Islands experience very high rainfall of up to 3,200 mm a year.

River basins of India are classified as major, medium and minor, based on their catchment areas, namely >20,000 km^2, 20,000–2,000 km^2; and <2,000 km^2, respectively. Ganga, Brahmaputra, Sabarmati, Mahi, Narmada, Tapti, Subarnarekha, Brahmani, Mahanadi, Godavari, Krishna, Pennar, and Cauveri basins fall into the major category, while forty four rivers belong to the second category and as many as 200 rivers constitute the third category. In addition, numerous desert rivers flow for some distance and are lost in the deserts (Bhattathiri 2001: Chandramohan et al., 2001). The rivers discharge about 12×10^{12} kg of sediment into the seas annually. This is roughly 10% of the global sediment flux (Subramanian 1993) (Table 5.3.4). The average run off from the major, medium and minor rivers of India is $1,406 \times 10^9$ m^3, 112×10^9 m^3, and 127×10^9 m^3, respectively (Rao 1979). Most of the rivers in India flow to the east coast in the Bay of Bengal. They carry a tremendous amount of silt during monsoons. This is the main reason why coral reefs are absent, and mangroves are well developed on the east coast. The major deltas, viz. Ganga, Mahanadi, Godavari, Krishna, and Cauvery, are confined to the east coast, whereas estuaries (Narmada, Tapti) occur on the west coast. There are 11 major and 130 minor seaports in India, and the coastal area can be regarded as mostly urban or semi-urban. Abiotic, namely cyclones, sea-level rise, flood, and biotic, namely overexploitation of groundwater, oil, and gas, pollution, deforestation, reclamation, factors are threats to the coastal population.

Coastal and Shelf Morphology

Some Indian shorelines are almost straight, some are fairly indented, some are markedly crenulate (Honavar and Janjira) and some are wavy (Cambay region) with major protrusions and embayments (Balasore region, Palk straits, Gulf of Mannar, Cambay). The deltas of Ganga, Mahanadi, Godavari, Krishna, and Cauvery exhibit an emergent shoreline, while the Maharashtra, Gujarat, Andaman, and Nicobar shores are submergent – rocky indented. The Laccadive Archipelago is a neutral shore, while the Kathiawar-Andaman and Nicobars have compound shores.

The Bay of Bengal and Arabian Sea together occupy only 3% of the world oceanic area, but receive 9% of the global river run off. The Bay of Bengal is an area of positive water balance that receives an annual precipitation of 11,000 km^3 and a run off of about 2,600 km^3. The Arabian Sea is an area of negative water balance, with run off varying between 7 and 10 km^3. These two seas together receive three times more river run off per unit area than the rest of the world oceans (Sen Gupta and Qasim 2001).

TABLE 5.3.4. Annual sediment load by Indian rivers at terminal points. (From Chandramohan et al., 2001.)

River	Sediment load ($\times 10^9$ kg)
Brahmaputra	597.000
Indus	450.000
Ganga	329.000
Narmada	44.358
Godavari	38.839
Brahmani	13.277
Mahanadi	13.204
Tapti	10.522
Baitarni	5.954
Subarnarekha	5.911
Mahi	5.879
Vamsadhara	1.836
Netravathy	1.223
Chellar	0.613
Cauvery	0.471
Bharatpuzha	0.444
Bhadar	0.354
Banas	0.322
Krishna	0.320
Pennar	0.257
Purna	0.238
Periyar	0.199
Muvattupuzha	0.157
Gundlakamma	0.064
Kallada	0.058
Vamanapuram	0.053
Shatrunji	0.041
Achenkovil	0.036
Sabarmati	0.018
Tambraparni	0.011

Coastal areas of the Indian Ocean are mostly tide-dominated, with the tidal amplitudes varying from 1 to around 2 m. The longshore currents of the east coast are towards NE during SW monsoon and SW during NE monsoon periods. On the west coast longshore currents move towards the north during pre- and post-monsoon periods, with a change towards the south during the monsoon period. The annual gross sediment transport along the coasts of south Orissa, north Tamilnadu, south Kerala, north Karnataka and south Gujarat is high (1.5×10^6 m^3 to 2.0×10^6 m^3). It is relatively low along the south Tamilnadu and Maharashtra coasts (0.5×10^6 m^3) and almost negligible between the coasts of Pondicherry and Pt. Calimere. The net annual transport at the southernmost tip of the Indian Peninsula is also negligible. The annual net transport along the east coast is northerly and along the west coast is southerly (Chandramohan et al., 2001).

The continental shelf has an aerial extent of about 3,100,000 km^2. Its width on the west varies widely (Saurashtra 70–110, Mumbai 260–300, Ratnagiri 100–128, Goa 60–185, Cochin 60 km) off the river mouths, becoming narrower South – eastwards and narrowest on the SW margin (Purnachandra Rao and Wagle 1997). The inner shelf is smooth with a gentle slope. An uneven topography occurs down to 55–60 m depth in the north and is narrow down to a depth of 25 m off Cochin. The middle shelf shows uneven topographical features. Submerged sand ridges are found on the outer continental shelf. The shelf break occurs at depths between 60 and 150 m. It is away from the coast in the northern part and close to the coast in the SW part of India.

The east coast is flat. The continental shelf is broad off the Ganges (210 km), gradually tapers towards the southwest and is at its minimum off Kakinada (6 km). Further south the shelf width increases to 43 km off Chennai and reaches a minimum of 2.5 km at Karaikal, south of Chennai. The shelf break occurs at depths between 50 and 300 m at a distance of about 10 to 70 km from the shore and shows diverse shapes owing to different origins (Purnachandra Rao and Kessarkar 2001). Prograding, constructed, regrading and indented types of shelf breaks have been reported, based on echo characters (Rajasekhara Reddy and Sreenivasa Rao 1997).

The Indian shore encompasses constructional features, viz. sea beach and beach ridges, offshore bars, spits, tombolos and barriers, lagoons, lakes, deltas, littoral concrete, coral reefs, and destructive/erosion features, namely cliffs, shoreline terraces. Beaches are more extensive on low coasts, like the east coast of India, but are relatively rare on the steeper or cliffed western shores of the country.

The east coast spits, like at Kakinada and Chilaka lagoon, are open in the NE and attached to the mainland on their SW or southern end. The west coast has numerous spits, particularly between Ratnagiri and Cape Comorin. The orientation of these spits indicates the direction of the long shore drift.

Coastal Geology

The geological formations comprising the Ganga Delta up to the western end of the Mahanadi River are Pleistocene to Recent alluvium. In the Mahanadi delta there are patches of older fossiliferous sedimentaries. In the coastal regions of northern Andhra Pradesh the geological formations are gneisses and granites, with frequent patches of charnockites and Khondalites. In the region of the Godavari and Krishna, between the crystalline and alluvium belt, there is a narrow belt of discontinuous rocks ranging from upper Gondwanas to Pleistocene. Between the Krishna delta and Cape Comorin there is a discontinuous belt of sedimentaries, ranging in age from the upper Gondwanas to Pleistocene. Near Cape Comorin the rock types are crystalline gneisses, granites and Tertiaries. North of Quilon a belt of alluvium adjoins the gneiss and granites of the Deccan massif, Warkale and Quilon beds. The coastal region of Goa is occupied by granites and gneisses (Ahmad 1972).

Living Resources

The Indian coastline has several geomorphic units that are niches of rich and diversified fauna and flora. The Arabian Sea and Bay of Bengal, along with two major island groups, have rich marine biodiversity. India has 2.015×10^6 km^2 Exclusive Economic Zone (EEZ). The estimated potential of living resource of India's EEZ is about 4 mt. of which 2.44 mt. is currently exploited, mostly from water depth of 50 m.

Marine Fishery

The fishing industry contributes 7% of the GDP to the national economy and the export of fishery products amounts to about 0.44 million ton, which fetched about 1,280 million dollars in 2000–2001 (Gopala Krishnan 2002). India ranked fifth in fish productivity in Asia in 1996 (Grainger and Gracia 1996), with half of its annual fish catch of 5.6 mt coming from marine fisheries (Anon 2001). This fishery has an estimated production potential of 2.8 mt. A major share of this, i.e., 21.307 mt, comes from the south west coast, followed by 1.217 mt from the northwest, 0.544 mt from the southeast coast and 0.321 mt from the northeast. The Andaman and Nicobar islands, and Lakshadweep, contribute 0.202 mt and oceanic/other deep sea resources 0.299 mt. Indian reefs, together with their shelves, lagoons and submerged banks, have a potential yield of 10% of the total marine fish catch (Anon 2000; 2001). Of the fishery resources available, 1.933 mt are demersal, 1.742 mt are neritic pelagic and 0.246 mt are oceanic pelagic. Depthwise, the 0–50 m depth zone can give 58.1% of the resources, followed by the 50–200 m depth zone registering 34.9% and the oceanic 6.3% (Anonymous 2001). The oceanic resources have not yet been tapped to their full potential. Tuna, sharks, and billfishes are plentiful.

The Indian fishery resources are being depleted by over fishing, excessive use of pesticides, industrial pollution and construction of coastal structures. The loss of inshore fish nursery habitat by coastal development, and pollution from land-based activities, cause significant changes to ecosystems. Cyclones cause adverse weather, creating hostile conditions for fishing. The SW monsoon also contributes to rough seas, decreasing the fishing activity. Similarly, there was a perceptible drop in sea catches after the tsunami of 26 December, 2005. Proper cyclone warnings, availability of safety equipment, rescue operations and post-cyclone rehabilitation are a few measures that may reduce loss of lives and resources available to the fisheries.

About 217 genera and 844 species of marine micro-algae, estimated to be more than 0.2 mt, have been reported from different maritime states of India, out of which only about 4,000 ton of seaweed resources are exploited annually by the agar and algin industries (Umamaheswara Rao 2005). Macro-algal resources can be used as food, feed supplements, health products and pharmaceuticals (Nagamalleswara Rao et al., 2003).

Non-living Resources

The important coastal resources include heavy mineral placer deposits, calcareous sands, lime mud, phosphorite, oil and gas, methane hydrates, and tourism.

Under favorable conditions commercially exploitable placer minerals viz., ilmenite, rutile, zircon, garnet, monazite, and sillimanite, are deposited in beach and dune sands of India.. The Indian resources of placer minerals are: 348 mt of ilmenite, 107 mt of garnet, 21 mt of zircon, 18 mt of rutile, 8 mt of monazite and 130 mt of sillimanite. Indian resources constitute about 35% of world resources of ilmenite, 10% of rutile, 14% of zircon and 71.4% of monazite. India accounts for about 10% of the world requirement for garnet (Ali et al., 2002).

The presence of oil and gas in deltaic deposits is established in Jaisalmer, Cambay, Cauvery, and Krishna-Godavari basins. The world's biggest discovery of natural gas occurred in the Krishna-Godavari basin, east coast of India. So far exploration has established nearly 200 mmt, out of an estimated 1060 mmt of resources (Rao 2002). Methane hydrates are considered to be a frontier gas resource in recent years. One estimate says that there could be 200 trillon cubic feet of gas entrapped in gas hydrates along the Indian continental shelf/slope. The methane in the Arabian sea and the Bay of Bengal of Indian continental shelf is estimated to be 14,572 trillion m^3, with a 5% probability in the water depth range of 600 to 3,500 m covering an area of about 80,000 km^2 (Subramanyam et al., 1998; Valsangkar 2001). India provides great potential for renewable energy sources in the form of Ocean Thermal Energy Conversion (OTEC), waves, tides etc. India has already established a wave energy plant of 150 kw capacity at Vizhinjam in Kerala (Qasim 1999).

Coastal Wetlands

Wetlands are very important in controlling floods, protecting the coastline, recharging groundwater and maintaining water quality. The Space Application Centre (SAC) of the Indian Space Research Organisation (ISRO) has studied several sites of coastal wetlands, covering a total area of 40,230 km^2, distributed in nine states and four Union Territories. State-wise, Gujarat has about 25,083 km^2 (62.3%), Tamil Nadu about 3,987 km^2, West Bengal about 3,604 km^2, Orissa about 1,854 km^2, Andhra Pradesh about1855 km^2 and Andaman and Nicobar about 1,078 km^2 of coastal wetlands (Garg et al., 1998). Among the various types, tidal mudflats (23,621 km^2) and mangroves (4,871 km^2) have the major share. Other categories are: estuaries (1,540 km^2), lagoons (1,564 km^2), sandy beach (4,210 km^2), marsh (1,698 km^2), other vegetated wetlands (1,391 km^2), coral reefs (841 km^2), creeks (192 $km)^2$, back water (171 km^2), rocky coast (177 km^2), salt pan (655 km^2), and aqua-culture ponds (769 km^2) (Garg et al., 1998). Ecosystems such as mangroves, coral reefs, estuaries and deltas are rich in biodiversity. These play a crucial role in fishery production, besides protecting the coastal zones from natural disasters. A variety of marine resources, like fish, prawn, lobster, crab, pearl oyster, shells, medicinal material and algae, are directly or indirectly dependent on the wetland ecosystem. However, studies by the Salim Ali Centre for Ornithology and Natural History (SACON) revealed that the wetlands in 14 states are polluted and 1,249 species of fish drawn from 115 water bodies contain pesticides or heavy metals. India has 19 wetlands of international importance listed under the Ramsar conservation of 1971. To address the question of pollution, experts have suggested the creation of a buffer zone around wetlands where organic farming would be actively encouraged, banning all other activities such as conversion into real estate, waste dumping, and sewage disposal.

Corals

Coral reefs are the most diverse and complex ecosystem on earth. They are crucial to the health of the entire marine ecosystem. Degradation of reefs represents a threat to marine life in general. They serve as a guard against the powerful tidal waves/tsunami and thus prevent both erosion on land and casualties. A number of species living around coral reefs have yielded a variety of drugs that have been found effective against a host of diseases. In India coral reefs were built up during the Tertiary and Quaternary periods. The most important sites include the Gulf of Kachchh, Malwan coast (Maharashtra), Lakshadweep Islands, Gulf of Mannar, Palk Bay, Andaman and Nicobar Islands (Table 5.3.5). The coral reefs of Indian Ocean

TABLE 5.3.5. Distribution and area estimates of coral reefs in India. (From Naik Shailesh (1997.)

	Coral Reef Area (km^2)			
Category	Gujarat	Tamil Nadu	Lakshadweep	Andaman & Nicobar
Reef flat	148.4	64.9	136.5	795.7
Sand over reef	11.8	12.0	7.3	73.3
Mud over reef	117.1	–	–	8.4
Coraline shelf	–	–	230.9	45.0
Coral heads	–	–	6.8	17.5
Live coral platform	–	–	43.3	–
Algae	53.8	0.4	0.4	–
Seaweeds	–	–	0.7	–
Sea grass	–	–	10.9	–
Reef vegetation	112.1	13.3	–	8.9
Vegetation over sand	17.0	3.6	0.4	10.5
Lagoon	–	0.1	322.8	–
Sandy substrate	–	–	(67.4)	–
Reef patch	–	–	(13.4)	–
Deep	–	–	(98.5)	–
Uncertain	–	–	(143.5)	–
Total	**460.2**	**94.3**	**816.1**	**959.3**

include fringing reefs (Gulf of Mannar and Palk Bay), Platform reefs (Gulf of Kachchh), Atoll reefs (Lakshadweep archipelago), fringing and barrier reefs (Andaman and Nicobar Islands) (Anonymous 2000). Coral reefs in the Indian Ocean occur from tropical regions in the south to subtropical and semiarid regions in the Gulf of Kachchh. The Gulf of Katchchh reefs are the most degraded among the Indian reefs. They are home to a large biomass of fish of great variety. This has led to large commercial exploitation of these resources.

Community management and ownership by local people have been recommended to safeguard the coral reefs from over fishing and degradation. Such an arrangement should prevent destruction due to developmental activities, including tourism, involving motor boat movements leading to oil slick and digging of large quantities of coral lime stone for the manufacture of cement, construction of roads, building and artworks (Gupta 2001).

Mangroves

Mangrove forests are essentially tidal and swampy. They are the most highly productive ecosystem next to the coral reefs, and provide energy to marine habitats through production and decomposition of plant detritus (Quasim and Wafer 1990). The rich diversity of migratory birds that frequently visit them every year is proof of their productivity. Mangroves provide nursery grounds for a number of commercially important fish, prawns and crabs. Some of these mangrove wetlands play an important role enhancing the fishery production of the adjacent neritic water, by exporting organic and inorganic nutrients.

India stands tenth in the 25 most plant-rich countries of the world (Nirupa Sen 2000). The total area of tidal forest in India is about 6,740 km^2, constituting about 7% of the world's area under mangroves (Anonymous 1987). About 380 km of the mainland's coast is covered by mangrove, and 260 km of Andaman and Nicobar are lined with mangroves (Singh 2000). Out of 487,100 ha of mangrove wetlands in India, nearly 56.7% (275,800 ha) is along the east coast and 23.5% (1,14,700 ha) along the west coast, and the remaining 19.8% (96,600 ha) is found in the Andaman and Nicobar Islands (Table 5.3.6) (Selvan 2003). This is because the terrain of the east coast has a gradual slope compared with the steep gradient along the west coast. Nearly 70% of the species found in the world are found in India.

The Ganga, the Mahanadi, the Godavari, the Krishna, and the Cauvery deltas, and the Andaman and Nicobar groups of islands, contain some of the best mangroves in the world. The largest stretch of mangroves is located in the Sundarbans in West Bengal. Eight states and union territories have mangrove forests. Mangroves are classified as tide dominated (Sundarbans and Mahanadi), river dominated (Godavari, Krishna, Pichavaram and Muthupet) and drowned bed rock type (Gujarat) (Selvan 2003). Mangroves have helped in the protection of coastal habitation from frequent cyclones and surges, as in the case of Sagar Island, from severe erosion (Paul and Bandyopadhya 1987), and from the 1999 super cyclone in

TABLE 5.3.6. Mangrove wetlands of India. (From Selvan 2003.)

State	Mangrove Wetland	Total area of the Wetland (ha)	Actual forest cover (ha)
East coast			
West Bengal	Sunderbans	4,26,000	2,12,500
Orissa	Mahanadi	67,000	21,500
Andhra Pradesh	Godavari	33,250	24,100
	Krishna	25,000	15,600
Tamil Nadu	Pichavaram	1,300	900
West coast			
Gujarat	Gulf of Kutch	58,200	85,400
	Gulf of Khambat	53,123	17,700
Other mangroves	–	–	11,600
Andaman and	Andaman islands	–	92,900
Nicobar islands	Nicobar islands	–	3,700
Total			**4,87,100**

some of the coastal regions of Orissa state. Mangrove forests along the east coast of India also play an important role in coastal protection. During the onslaught of the tsunami of 26 December, 2005, the mangrove forests of Pitchavaram in the Cauvery delta acted like a biowalk, resulting in minimum casualties (Ratnakar and Kar 2005).

Logging operations in the And aman Islands, aquaculture, reclamation of swamps, paddy cultivation on the east coast, and salt production on the west coast of India, are the main reasons for the degradation of mangroves. Reclamation of backwaters/lagoons, mudflats, mangroves for various uses is common, viz. for agricultural purposes in Kerala and Tamil Nadu, for aquaculture in Andhra Pradesh and Orissa, and for residential and industrial purposes in Maharashtra and Gujarat. To overcome these problems a series of conservation measures were initiated in the late 1980s. Mangrove species were planted in intertidal mudflats in Gujarat, West Bengal, Tamil Nadu, Karnataka, and Andhra Pradesh (Singh 2000).

Coastal Tourism

Among the maritime states of India, Maharashtra, Karnataka, Kerala, Goa, Tamil Nadu, Andhra Pradesh, Orissa, and West Bengal have developed excellent tourism facilities along the coast. Backwater tourism is equally important in states like Kerala. The coast of Goa has beautiful stretches of sandy shores and beaches. These attract large number of tourists from home and abroad. The Dakshina Kannada district of Karnataka has excellent recreational beaches. In Tamil Nadu tourist spots extend on the east from Pt Calimere to the Mudimalia wild life sanctuary in the west. The northern extreme is known for Pulicat Lake, while in the south lies Cape Comarin. The islands of Andaman and Nicobar are considered to be more attractive for eco-tourism.

Kerala is developing new beach resorts in the Bekal area and Maharashtra at Sindhu Durg is developing its tourism. Similar developments are also taking place in coastal areas of Tamil Nadu, Andhra Pradesh (Bheemunipatnam, Visakhapatnam, Perupalem) and Orissa. It is expected that there will be a 20% plus growth in tourism in all the developed coastal areas and beach resorts during the next five years.

Tourism is India's largest employment generator and foreign exchange earner, after jewellery and textiles. The coastal areas of India have been on a high tourism growth curve during the last few years, especially the last two, i.e., 2003–2004 and 2004–2005. Foreign tourist arrivals to places like Kerala and Goa have boomed to unprecedented levels, showing a growth of 25–30% every year. These coastal states are the most sought after by foreign tourists; in Goa, in particular, a large number of chartered flights land every week, bringing foreign tourists to the state.

The Coringa wild life sanctuary (East Godavari district of Andhra Pradesh) and the Krishna sanctuary (Nagayalanka of Andhra Pradesh) are both covered by mangrove forests and close to estuaries. Pulicate Lake on the Andhra Pradesh-Tamil Nadu border, Muthukadu, Kovalam, Mamallapuram, Pondicherry, Pichavaram, Kodikarai Island, Trichlendur and Kanyakumari are very important from an eco-tourism point of view.

Uncontrolled tourism activities, however, unduly impose one more dimension of human pressure on the earth's resources. The overexpanding tourism industry, along with urbanization in this coastal stretch, has contributed to an increase in the salinity of freshwater aquifers due to seawater intrusion, especially along the coast of Bardez taluk in north Goa and Udipi taluk in Karnataka.

Vulnerability

Besides physical exposure to sea-level rise, the socioeconomic development of the region is also important in increasing the vulnerability of the region to sea-level rise. From the physical point of view, Gujarat and West Bengal would be most affected since they stand to lose the maximum land area to a 1 m sea-level rise. In terms of population, West Bengal, Maharashtra, and Tamil Nadu would be worst affected because of their high population density. In terms of the fractional area, Goa would be most affected, as it would lose almost 4.34% of its total area.

Indian coasts are vulnerable to a rise in sea level, frequent occurrences of cyclones and storms, a high rate of coastal environmental alteration/degradation and nonsustainable development.

Any impact to the coastal ecosystem may affect the coastal population in almost every aspect of their lives. The problem of freshwater is already acute in coastal regions of Tamilnadu, Gujarat, West Bengal and Orissa. This is due to excessive extraction of groundwater, which has resulted in a lowering of groundwater and enhanced saltwater intrusion (Subramanian 2000; Mohanty 1990; Saxena et al., 2004). The arsenic pollution crisis in West Bengal, Orissa and Andhra Pradesh is a disaster due to over extraction from tube wells. The number of people potentially impacted by this problem is far greater than that for any of the individual problems facing humanity today (Saxena et al., 2004). Over extraction of groundwater, oil and gas can lead to subsidence of coastal land, causing submergence (Krishna Rao 1998).

Sea-level Rise

India is one of the 27 countries most vulnerable to the impacts of global warming and accelerated sea-level rise (UNEP 1989).

The mean sea level observations indicate a long-term rise of about 1.0 mm/year. However, recent observations show a rise of 2.5 mm/year along the Indian coast. These studies indicate that the oceanic region adjoining the Indian subcontinent may warm up at its surface by about 1.5–2.0°C by the middle of this century and by about 2.5–3.5°C by the end of the century, when sea levels may rise by about 15–38 cm and 46–59 cm, respectively (Lal and Aggarwal 2000). The latter figure is comparable with the projected global mean sea-level rise of 50 cm by the end of this century. This may have significant impact on the coastal zones of India. With such a rise, the cultivated land would be drastically reduced, not only due to inundation but also due to saltwater intrusion. The sea-level variations affect port cities. Many of the ancient ports have already been submerged. Sea-level rise reduces transport of river-borne sediments into the sea, decelerating delta progradation and wetland renewal.

Studies on the potential impact of a 1 m rise in sea level along the Indian coast provide an idea about the land which could be inundated, and the population that would be affected provided no protective measures are taken. It has been suggested that the total area of 5,763 km^2 along the coastal states of India, i.e., 0.41% of India's total land area, could be inundated and almost 7.1 million, i.e., 4.6%, of the coastal population could be directly affected (Table 5.3.7) (TERI 1996). The most vulnerable areas along the Indian coastline are the Kutch region of Gujarat, Mumbai, and South Kerala, deltas of the Ganges (West Bengal), Cauvery (Tamil Nadu), Krishna and Godavari (Andhra Pradesh), Mahanadi (Orissa) and also the islands of Lakshadweep.

Cyclones and Storms

The cyclones occurring in the Bay of Bengal and Arabian Sea form 6% of the global total. Cyclones and storms frequently affect the coastal states of India, causing much damage and loss of lives. The immediate damage caused by a cyclone is due to wind, rain and associated flooding, erosion and the storm surge. The frequency of the formation of cyclones is 5–6 times more in the Bay of Bengal than in the Arabian Sea (IMD 1979). More than 1,000 cyclonic disturbances occurred in the Bay of Bengal during the last century, among which over 500 were either depressions or deep depressions and over 400 were either cyclonic storms or even storms (Mascarenhas 2004) (Table 5.3.8). The east coast of India has been affected by a minimum of four high intensity cyclones every year for the last 100 years (Raghavan and Sen Sarma 2000). The Bay of Bengal is one of the six regions in the world where

TABLE 5.3.7. Potential effects of a one meter sea level rise on India's coastal area and population. (From TERI 1996.)

	Coastal area (million hectares)			Population (millions)		
State/Union territory	Total	Likely to be inundated	Percentage	Total	Likely to be affected	Percentage
Andhra Pradesh	27.504	0.055	0.19	66.36	0.617	0.93
Goa	0.370	0.016	4.34	1.17	0.085	7.25
Gujarat	19.602	0.181	0.92	41.17	0.441	1.07
Karnataka	19.179	0.029	0.15	44.81	0.25	0.56
Kerala	3.886	0.012	0.30	29.08	0.454	1.56
Maharashtra	30.771	0.041	0.13	78.75	1.376	1.75
Orissa	15.571	0.048	0.31	31.51	0.555	1.76
Tamil Nadu	13.006	0.067	0.52	55.64	1.621	2.91
West Bengal	8.875	0.122	1.38	67.98	1.6	2.35
Andama and Nicobar Islands	0.825	0.006	0.72	0	0	0
India	139.594	0.571	0.41	416.74	7.1	1.68

TABLE 5.3.8. Details of various types of wind system that formed in the Bay of Bengal and affected the east coast of India during the period 1891–2000.

Type of disturbance	Cyclonic disturbance	Depression/deep depression	Cyclonic storm	Severe cyclonic storm
Number	1087	635	279	173
Maximum (1891–1991)	158 (August)	131 (August)	51 (October)	38 (November)
Minimum (1891–1991)	4 (February)	1 (March)	0 (February)	1 (January)
Yearly average	10	6	3	1.5
Per cent of total	–	58	26	16
Wind speed (km/h)	31–118	31–61	61–88	88–118

severe tropical cyclones usually originate in the months of May, November and December. They are well known for their extreme destructive potential and impact on human activities. The 1999 tropical super cyclone that hit the coast of Orissa on 29 October, with wind speeds of 260 km/h, resulted in a death toll of over 10,000. This demonstrates the extreme significance of impacts related to climate variability and extreme conditions. Historically, all the tropical cyclones crossing the east coast had their landfall near the major deltas, such as the Ganges, Mahanadi, Godavari, Krishna, Penner, Palar, and Cauvery. Limited studies have been undertaken worldwide regarding the influence of coastal morphology on the cyclone track movement. Most of the severe cyclones crossing the Andhra coast had their landfall in Godavari, Krishna and Penner deltas. Very few severe cyclones have crossed the Ongole coast. The Visakhapatnam coast generally experiences storms and depressions of lesser magnitude and intensity.

Global warming will result in an increase in sea surface temperatures as a result of which changes in the frequency, intensity or tracks in cyclones hitting the coastal zones may take place. An increase in cyclone intensity of 10–20% is expected with a rise in sea surface temperature of 2–4°C.

Coastal Erosion

Erosion is caused by natural forces such as cyclones and is accentuated by human activities. Coastal erosion is a major environmental concern in many parts of India, where rates of shoreline erosion or beach retreat average several meters per year. Cyclones hit the deltaic coasts, frequently causing severe erosion at many places. The situation worsens due to the construction of dams in the river basin that impede sediment supply at the river mouths as a result of which the rates of subsidence and sea level may exceed rates of vertical accretion, leading to erosion of coastal lands (Hemamalini and Nageswara Rao 2004).

However, in some areas, such as Digha to Haldia (West Bengal), Uppada, Antervedi, Chinamainavanilanka, Gollapalem, Nizampatnam in Andhra Pradesh and some parts of Goa state, the problem is even more severe as the coastline is highly prone to erosion due to natural processes (the scouring effect of high waves, strong littoral transport, subsiding coastal plates), as well as human activity (coastal structures, mining sand in the rivers/on the beach (Qasim 1999).

At Uppada, 64 ha of land was lost along the beach prior to 1975 and 46 ha between 1976 and 1980. The erosion in this area is still continuing, and is attributed to the northward growth of the Kakinada sand spit. Due to the sand spit, the sediment transport across the Bay and further northwards along the main coast is cut off, since the major portion of the sediment supply is being utilized for the growth of the sand spit (Sastry et al., 1991). Further, the breakwaters constructed for the development of a minor port at Kakinada resulted in large-scale changes in the coastal morphology. As a result, the northern shorelines near Uppada have been subjected to severe erosion.

Beaches are unstable since waves, tides, currents, and winds constantly shift them. Littoral drift plays an important role in deciding areas of coastal erosion and accretion in shaping and orienting coastal land forms and finally in the evolution of the coast. There is a net littoral drift of about 1 mt/year from south to north, which is one of the largest along a world shoreline. To overcome shoaling problems, and to create navigable conditions, harbour breakwaters and other offshore installations have been created at various parts along this coast. As a result, sand is accumulated on the up-drift (south) side of the harbours, followed by erosion on the down-drift (northern) side (e.g., harbors at Chennai and Visakhapatnam).

Coastal Pollution

All developmental activities in the coastal zone use such natural resources as raw material, while the waste generated is disposed in different environments. The deleterious pollutants in the Indian ocean comprise heavy metals, oil, aquaculture residues, domestic and agricultural waste and untreated

TABLE 5.3.9. Type and quantum of pollutants entering annually into the coastal waters of India. (From Lal and Aggarwal 2000.)

Input/Pollutant	Quantum – Annual
Sediments	1600 million tons
Industrial effluents	50×10^6 m^3
Sewage – largely untreated	0.41×10^9 m^3
Garbage and other solids	34×10^6 t
Fertilizer – residue	5×10^6 t
Synthetic detergents –residue	1,30,000 t
Pesticides – residue	65,000 t
Petroleum hydrocarbons (Tar balls residue)	3,500 t
Mining rejects, dredged spoils and sand extractions	0.2. × 106 t

toxic industrial liquid waste (Lal and Aggarwal 2000; Sen Gupta and Qasim 2001) (Table 5.3.9). Heavy metals (Cd, Cu, Co, Pb, Hg, As) are beyond threshold limits in various coastal ecosystems and are thus of great concern (Selvaraj 1999). They are regarded as serious pollutants of the aquatic environment because of their conservation or nonbiodegradable nature and concentration in aquatic organisms. These elements are magnified in the food chain, causing deleterious effects (Mitra et al., 2000). It is well known that the intertidal ecosystem, where the residue may persist for a long time, may experience a great impact from such contamination (Ingole et al., 1995).

In natural disasters and calamities (cyclones, tsunamis, floods, etc.) aqua-toxicity may result from contamination of animal corpses and waste, and human waste, as well as ecological dysfunctions.

Among the heavy metals, copper may be derived from antifouling paints used in trawlers, coal tar and copper sulphate used in aquafarms. Arsenic may be introduced into the environment from the combustion of coal, phosphate minerals and mining of gold and lead. Large-scale arsenic poisoning in many areas is mainly due to contaminated drinking water from wells. Nearly 5.3 million people in West Bengal live in areas where arsenic concentration is above the permissible limit of 0.01 mg/l (Saxena, et al., 2004). It causes serious skin lesions. Mercury is derived from the discharge of power plants, and chlorine and cellulose industries. The Ennore Thermal Power Station may be the source of the mercury in the Pulicate Lake sediments, measured at 9.60 mg/g (Periakali and Padma 1998). Electrolytic production of chlorine has been considered the most likely source of high values of mercury in intertidal sediments of the southeast coast of India at Mahabalipuram near Chennai. These contain 560 mg/kg. Another serious problem which came to light in a manner similar to that of mercury was cadmium toxicity, sourced from cadmium sulphide, the pigment used in paints. The use of lead is wide spread. It is employed in plumbing, building materials, plastics, ceramics, paints and antiknocking agents in petrol, etc. It is present in air mainly due to the incineration of waste and automobile exhaust.

The Mumbai coast is vulnerable to contamination by petroleum hydrocarbons originating from domestic and industrial waste water discharge, port activities and marine operations including tanker and fishing trawlers, traffic, oil production and atmosphere fallout (Togi et al., 1981).

Oil pollution in the sea can also be caused by offshore oil exploration, tanker accidents, oil well blowouts (e.g., Pasarlapudi blowout on 8th January, 1995 in the Godavari basin, Andhra Pradesh), and accidental and intentional release of bilge and ballast water from the ships. Discharged oil in the sea can exist as oil slicks, dissolved/dispersed petroleum hydrocarbons, floating petroleum residues and tar on the beaches.

Of all the types of contamination, oil pollution in the Indian Ocean is far more intensive than either in the Atlantic or Pacific Oceans. This is because at the northern-end of the Arabian Sea, around the Persian Gulf, there is the highest concentration of oil producing countries. Since the Persian Gulf is a semi-enclosed sea, the outlet of oil-carrying tankers is mainly through the Arabian Sea.

The marine environment of Tarapur, located 100 km north of Bombay on the west coast, receives low level liquid waste from the Tarapur Atomic Power Station and fuel reprocessing plant (Baburajan et al., 1999). Fish are found floating on the sea when there is a disposal of waste from the IRE plant of Neendakara (Chavara), Manavalakurchi (Tamilnadu), and Orissa sand complex (OSC) at Chattarpur (Orissa).

Seawater intrusion is a common problem in coastal aquifers. A study of groundwater levels, and their chemical quality, along the Chennai and Krishna district coast (Saxena et al., 2004) showed that water levels are much below sea level – often as low as 3–6 m below msl. Establishment of big aquaculture farms along the coast caused groundwater salinization, due to large quantities of seawater being pumped into hinter land.

Coastal Radiation

The coastal population is affected by exposure to radiation from natural sources of radionuclides, such as ^{40}K, ^{87}Rb and the ^{238}U and ^{232}Th series, as well as human activities related to nuclear reactors, including release of radioactive effluents and nuclear tests. The magnitude of radiation varies from place to place due to differential proportions of heavy minerals like monazite, zircon, and rutile, which incorporate uranium and thorium within their crystal lattice.

Most important for such high radiation areas are Chavara (Kerala), Manavala Kurchi (Tamilnadu) (Paul et al., 1982), the Visakhapatnam-Bheeminipatnam region (0.15–1.50 m/Rh), and the delta regions (Krishna, Godavari) (0.01–0.12, 0.04–0.060 m/Rh) of Andhra Pradesh (Nagamalleswara Rao and Kshira Sagar 1992). The highest level of radiation, with an average value of 2.36 mSv/year, was recorded in the Erasama region (Mohanty et al., 2004) and Chattarpur (OSC), Ganjam district of Orissa. Ambient radiation levels ranging from 0.01 – 0.4 m/Rh have been reported from Mahabalipuram-Pundapatnam (Kalpakam beach) Tamilnadu (Iyengar 1989). Background radiation levels and distribution of radionuclides have been reported in the environment of coastal areas as well as Kaiga of Karnataka and Trombay of Maharashtra nuclear power plants.

Coal fired thermal power plants, such as Ennore (Tamilnadu), Simhadri (Visakhapatnam) located along the coastal tracts, also release radionuclides, since coal contains trace-level quantities of primordial radionuclides and these go in to the fly ash. The radionuclides form part of the atmospheric dust and are carried out several kilometers, reaching a maximum at about a kilometer (Ramachandran et al., 1990; Pushparaj et al., 1995).

Higher radiation levels are received by the fisher population inhabiting the beach, where monazite is disseminated, than by populations near nuclear power plants. The people residing on the coastal stretches are facing serious health problems, such as pains in the joints, oral cancer and blindness. A high incidence of Down syndrome (Mongolism), and other forms of mental retardation, chromosomal abnormalities in the population exposed to high levels of background radiation, the lowest values on the fertility index and the highest values of infant mortality and cytological damage in plant cells have been reported. The fishermen population inhabiting the beach areas is therefore likely to receive comparatively high natural radiation exposure due to external and internal sources.

Policy for the Conservation and Sustainable Development of Coastal Zone

Over 140 million people live in coastal districts of India (Naik 1997) as these areas are endowed with a wide range of natural resources and provide numerous benefits for human beings. Accelerated anthropogenic developmental activities associated with urbanization, industrialization and recreation have created intensive demographic pressure on the fragile coastal ecosystem, as seen in Kerala and Mumbai. Therefore, the Government of India has initiated measures to protect the coast from degradation. It has also allowed for the conservation and management of these rich areas of biodiversity, by declaring them ecologically sensitive areas, banning their exploitation and prohibiting development activities, and the disposal of wastes into them.

In this connection, the Ministry of Environment and Forest (MoEF) issued the Coastal Regulation Zone (CRZ) Notification in 1991 under the Environment Protection Act of 1986, to protect and conserve the coastal environment through regulated developmental activities within 500 m of the high-tide line by classifying the coastal area into four CRZ zones (Table 5.3.10). Marine productivity in India, as in much of the tropics, is concentrated in coral reefs, mangroves, estuaries, lagoons and sea grass beds, which also form the feeding and breeding ground for fish and other marine life (Phillips 1999). The government also initiated action to create a network of Marine Protected Areas (MPAs), under the Wildlife (protection) Act of 1972, to provide protection to critical and important marine ecosystems. Twenty-six protected areas, comprising national parks and wildlife sanctuaries, have been identified, covering mangroves, coral reefs, sea turtles, whale sharks etc., and including areas in the Andaman, Nicobar, and Lakshadweep islands, the Gulf of Mannar and the Gulf of Kuchchh.

Since the existing legal Acts were not adequate to protect and conserve the Coastal Regulation Zones, in July 2004 the MoEF established a committee

TABLE 5.3.10. CRZ system classification. (From Coastal Regulation Zone Notification 1991, MoEF of India)

Zone	Area
CRZ – I	Areas include ecologically sensitive areas, mangroves, coral reefs close to breeding ground of fish and other marine life, areas of outstanding natural beauty and Marine Protected Areas
CRZ – II	Areas that have already been developed up to or close to the shoreline
CRZ – III	Areas that are relatively undisturbed and those which do not belong to either category I or II
CRZ – IV	The Andaman and Nicobar Islands and the Lakshadweep Islands

to review the CRZ Notification of 1991. In its report of February 2005, the committee recommended dividing the coastal area into four Coastal Management Zones as follows:

Coastal Management Zone – 1 (CMZ-1) consisting of Ecologically Sensitive Areas (ESA), which include mangroves, coral reefs, sand dunes, inland tide/water bodies such as estuaries, lakes, lagoons, creeks and straits, mudflats, marine parks and sanctuaries, coastal forests and wildlife, coastal freshwater lakes, salt marshes, turtle nesting grounds, horseshoe crabs habitats, sea-grass beds, seaweed beds, and nesting grounds of migratory birds.

Coastal Management Zone – II (CRZ-II) consisting of areas identified as Areas of Particular Concern (APC), such as coastal municipalities/corporations, coastal panchayats with a population density of more than 400/km^2, ports and harbours, Declared Tourism Areas, mining sites, approved industrial estates, Special Economic Zone (SEZ), heritage areas, archaeological sites, defense areas/installations, atomic/thermal and other power plants.

Coastal Management Zone – III (CMZ-III) consisting of all open areas excluding those areas classified as CMZ-I, II, IV.

Coastal Management Zone – IV (CMZ – IV) consisting of the islands of Andaman and Nicobar and Lakshadweep (MoEF 2005).

The committee has also proposed establishing the National Board for Sustainable Coastal Zone Management. This would monitor implementation of the National Coastal Zone Management action plan, for timely execution and correction.

References

Ahmad E (1972) Coastal geomorphology in India. Orient Longman Limited, New Delhi

Ali MA, Krishnan S, Benerjee (2002) Beach and heavy mineral sand investigations and deposits in India – an over view. In: Exploration and research for atomic minerals, special issue on Beach and inland heavy mineral sand deposits of India. Exploration and Research for atomic minerals, 13. pp 1–21

Anonymous (1987) Mangrove in India. Status report. Government of India, Ministry of Environment & Forests, New Delhi, pp 1–150

Anonymous (2000) Report on the coral reef ecosystems of India. ENVIS Centre, C.F.S. in Marine Biology, Parangipetti, p52

Anonymous (2001) India 2001 – A reference annual compiled and edited by research, reference and training division, Ministry of Information and BroadCasting. Government of India, p873

Baburajan A, Rao DD, Chandramouli S, Iyer RS, Hegdu AG, Nagarajan PS (1999) Radio nuclides ratio of cerium and strontium in Tarapur marine environments, west coast of India. Indian J Mar Sci 28:pp 455–457

Bhattathiri PMA (2001) Features at some significant estuaries of India. In: Sen Gupta R, Desai E (eds) The Indian Ocean – a perspective. Oxford & IBH, New Delhi, V1, pp 271–297

Chandramohan P, Jena BK, Sanil Kumar V (2001) Littoral drift sources and sinks along the Indian coast. Curr Sci 81(3):292–297

Garg JK, Singh TS, Murthy TVR (1998) Coastal wetlands of India nation-wide wetland mapping project. Space Application Centre (ISRO), Ahmedabad, p237

Gopala Krishnan K (2002) Marine fish production in the upper east coast of India with special reference to coastal Andhra Pradesh. In: Naidu JVM (ed) Proceedings of the conference on eco-friendly development of coastal regions, pp 56–59

Grainger RJR, Gracia SM (1996) Chronicles of marine fishery landings (1950–1994)-Trend analysis and fisheries potential, FAO Fisheries Technical Paper, no. 359, Rome, FAO, p51

Gupta SK (2001) Coral crisis – the price we pay. Res J Chem Environ 5(1):3–6

Hemamalini B, Nageswara Rao K (2004) Coastal erosion and loss along the Godavari delta front – a fallout of dam construction (?) Curr Sci 87(9):1233–1236

IMD (1979) Tracks of storms and depressions in the Bay of Bengal and the Arabian Sea, 1877–1970, India Meteorological Department (IMD), New Delhi

Ingole SA, Kadam AN, Mayadeo MS, Dhadke PM (1995) Petroleum hydrocarbons in intertidal ecosystem along the Bombay coast. Indian, J Mar Sci 124:116–118

Iyengar MAR (1989) Natural radiation aspects of a low – monazite Environment In: Preprints symposium on Radiochemistry and radiation chemistry, Kalpakkam, 1T17–1–1T17–9

Krishna Rao G (1998) Geo-hazard with oil and gas production in Krishna-Godavari basin. Curr Sci 74(6):494

Lal M, Aggarwal D (2000) Climate change and its impacts in India, Asia-Pacific. J Environ Develop 10:32–40

Mascarenhas A (2004) Oceanographic validity of buffer zones for the east coast of India. A hydrometeorological prospective. Curr Sci V 86(3):399–406

Mitra A, Mitra S, Hazara S, Chaudhuri A (2000) Heavy metal concentration in Indian coastal fishes. Res J Chem Environ 4(4):35–39

MoEF, India (2005) Report on the committee to review the coastal regulation zone notification 1991, pp 1–115

Mohanty AK, Sen Gupta D, Das SK, Vijan V, Saha SK (2004) Natural radio activity in the newly discovered high background radiation areas on the east coast of Orissa, India. Radiation Measurements 38:153–165

Mohanty M (1990) Sea level rise: background, global concern and implications for Orissa coast, India. In: Victor Rajamanickam G (ed.) Sea level variation and its impact on coastal environment. Tamil University Press, Thanjavur, pp 197–233

Nagamalleswara Rao B, Kshira Sagar TVSR (1992) A study of Radiation Environment along parts of central East coast of India. Indian J Environ Protect 12(9):646–648

Nagamalleswara Rao B, Satyanarayana G, Kaladhar R, Muralikrishna R, Krishna TV, Vasudevau K (2003). Impact of zinc smelter effluent on the *Enteromorpha compressa* (L) *Griville*, Visakhapatnam, Andhra Pradesh. Environ Geochem 8(1&2):1–8

Naik Shailesh (1997) Information needs of integrated coastal zone management. Role of remote sensing and geomorphic information system. Proceedings of the workshop on integrated coastal zone management. Space Application Centre (ISRO), Ahmedabad: 6(25):166

Nirupa Sen (2000) Mapping the biognomi of India – The plants. Curr Sci 79(8):1046–1048

Periakali P, Padma S (1998) Mercury in pulicat lake sediments, East coast of India. J Indian Assoc Sedimentol 17(2):239–244

Phillips Andrian (1999) Guidelines for marine protected areas-best practice protected area guidelines series no.3 WCPA:IUCN, p117

Paul AC, Pillai PMB, Velayndhan J, Pillai KC (1982) In:Vora KG, Mishra VC, Pillai KC, Sadasivan S (eds) Natural environment. Willey Eastern, New Delhi, p50

Paul AK, Bandyopadhya MK (1987) Morphology of Sagar island a part of Ganga delta. J Geol Soc India 29:412–423

Purnachandra Rao V, Wagle BG (1997) Geomorphology and surfacial geology of the western continental – shelf and slope of India: a review. Curr Sci 72(4):330–350

Purnachandra Rao V, Kessarkar MP (2001) Geomorphology and geology of the Bay of Bengal and the Andaman sea. In: Sen Gupta R, Desai E (eds) The Indian Ocean – a perspective. Oxford & IBH, New Delhi, V2, pp 817–868

Pushparaj K, Ramachandran TV, Mahadevan TN, Bapat VN, Mishra VC (1995) Assessment of inhibition dose from radioactivity release from coal fired thermal power plants (TPT) and its impact related to chemical pollutants – Indian scenario. Bull Radiat Protect 18(1–2):286–290

Qasim SZ (1999) Coastal erosion and its protection. J Indian Ocean Stud 7(1):63–73

Qasim SZ, Wafer MVM (1990) Marine resources in the tropics. Resour Manage Optim 7:141–169

Raghavan S, Sen Sarma AK (2000) In: Storms RA, Pielke Sr, Pielke Jr., RA (eds) Tropical cyclone impacts in India and neighbourhood. Routledge Press, UK

Ramachandran TV, Lalit BY, Mishra KC (1990) Modifications of natural radioactivity content of soil samples around thermal power stations in India. J Environ Health, V 32(1):13–19

Rao GN (2002) Petroleum geology: Krishna-Godavari basin. J Geol Soc India 60 :705–706

Rao KL (1979) India's water wealth: its assessment, uses and projections. Orient Longman, New Delhi, p267

Ratnakar J, Kar RK (2005), Mangroves can check the wrath of tsunami. Curr Sci 88(5):675

Rajasekhara Reddy D, Sreenivasa Rao T (1997) Echo-characters of the continental margin, western Bay of Bengal, India. Mar Geol 140:201–217

Sastry JS, Vethamony P, Swamy GN (1991) Morphological changes at Godavari delta region due to waves, currents and associated physical process. In: Vaidyanathan R (ed) Quaternary deltas of India. Mem Geol Soc India 22:139–151

Saxena VK, Sanjeev Kumar, Singh VS (2004) Occurrence, behaviour and speciation of arsenic in groundwater. Curr Sci 8:281–284

Saxena VK, Mondal NC, Singh VS (2004) Identification of sea water ingress using strontium and boron in Krishna Delta, India. Curr Sci 86(4):586–590

Selvan V (2003) Environmental classification of mangroves wetlands of India. Curr Sci 84(6):757–765

Selvaraj K (1999) Total dissolvable copper and mercury concentrations in innershelf waters, Kalpakkam Bay of Bengal, Curr Sci 177(4):494–497
Sen Gupta R, Quasim SZ (2001) Health of the Indian Ocean. In: Sen Gupta R, Desai E (eds) The Indian Ocean – a perspective. Oxford & IBH , New Delhi, V2, pp 325–371
Singh HS (2000) Mangroves in Gujarat-Current status and conservation strategy. Gujarat Ecological Education and Research (GEER) Foundation, Gandhinagar p128
Subramanian B (1993) Sediment load of Indian rivers. Curr Sci 64:928–930
Subramaniam C, Reddy SI, Thakur NK, Gangadhara Rao T (1998) Gas-hydrate-a synoptic view. J Geol Soc India 52:497–511
Subramanian V (2000): In: Water quantity-quality perspective in South Asia. Kingston International, Surrey, UK, p49
TERI (1996) The economic impact of one meter sea level rise on Indian coastline-methods and case studies, Report submitted to the Ford Foundation
Togi RS, Noronha RJ, Fondekar SP (1981) Dissolved petroleum hydrocarbons in the Andaman Sea. Indian. J Mar Sci 10:241–242
Umamaheswara Rao M (2005) Marine macro algal diversity – resources and utilization in India. Proc AP Acad Sci 9(2):111–114
UNEP (1989) Criteria for assessing vulnerability to sea level rise: a global inventory to high risk area. Delft Hydraulics, Delft, The Netherlands, p51
Valsangkar AB (2001) Mineral resources In: Sen Gupta R, Desai E (eds) The Indian Ocean – a perspective. Oxford & IBH, New Delhi, pp 585–643

5.3.4 The Coastal Zone of Sri Lanka

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Introduction

The island of the Democratic Socialist Republic of Sri Lanka is located in the Indian Ocean (Fig. 5.3.13). There are also a few small islands scattered along its coast. From ancient times Sri Lanka was well known to travelers of many nationalities, because its coastline, with its numerous natural bays, anchorage and harbors, was able to provide adequate shelter for sailing ships. The coastal areas of Sri Lanka are shown on the first map of the island, drawn by Ptolemy in the AD 2nd century. The Portuguese, and then the Dutch, ruled the maritime areas of Sri Lanka after the beginning of 16th century. An accurate boundary of Sri Lanka with a clear coastline was mapped by surveyors under colonial rule by the British in the first half on the 19th century. Table 5.3.11 gives some geographical details of the country and its coastal areas.

Features and Resources

Natural Features

The climate of Sri Lanka is hot. Weather patterns are influenced by the southwest monsoon (May-early October) and northeast monsoon (November–February). Strong winds usually occur during the southest monsoon.

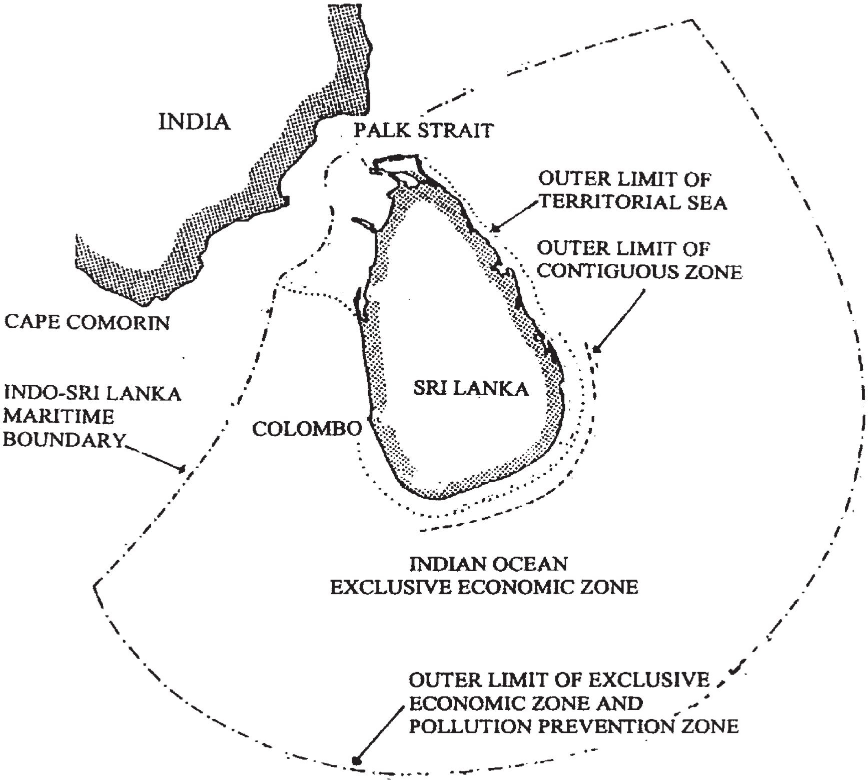

FIG. 5.3.13. Coastal and maritime jurisdiction of Sri Lanka.

The length of the coastline open to the sea, including bays, is 1,639 km, while the coastline of the other small islands belonging to Sri Lanka is about 281 km. Geomorphologically, two thirds of the coastline of Sri Lanka could be considered "straight coastline". Some lagoons are wide open to the sea, though others are not. There are a very few cliffs along the coast, and deltas occur on only three rivers. About 5% of the coastline is occupied by estuaries. Sandy beaches and spits, raised beaches, sand dune hills and barrier beaches are common in the NW and SE coastal areas of the island. Coastal marshes, mangrove swamps, tidal flats, and shallow beds of coastal and estuarine sea grass are also present.

Sri Lanka is separated from India by a shallow sea. During the Miocene period, the NW and SE corners of Sri Lanka were submerged and allowed sedimentary rocks such as sandstone and limestone to form above the Precambrian metamorphic rocks (Fig. 5.3.14). The uplift of these rocks during the Pliocene created new beaches and a shallow continental shelf. The southern tip of India and Sri Lanka stand upon the same continental shelf. Except for the in north, the shallow continental shelf, or the submerged plateau around

Table 5.3.11. General information on Sri Lanka's coastal region. Coast Conservation Deptartment (1991), Dayanande (1992), MaddumaBandara (1989), NARESA (1991)

Location	Latitude from 5° 55~ to 9° 51~ N. Longitude from 79° 41~ to 81°53~ E
Area	65,610 km^2; maximum length: 432 km from North to South; maximum width: 224 km from East to West
Coastline	Length 1,639 km. Total number of lagoons and estuaries: 45 (42,000 ha)
Climate	Rainfall from less than 1,000 mm to more than 2,000mm; 70%-90% humidity; 27–30°C. Two monsoons: NE and SW, wind speed 80–100 km/h
Coastal area	Continental shelf: 2.5–23 km, 30–90 m depth variation; 26,000 km^2 in area
Tidal range	Maximum 0.85 m, more than 50% of water level goes up 0.53 m. The water level exceeds the mean sea level more than 65% of the time, general current speed 3–15 cm/s
Economic zone	Over 230,000 km^2 of the ocean
Vegetation	6,000–10,000 ha covered by mangroves (23 species), and 23,819 ha covered by salt marshes and 12 species of sea grasses.
Coastal land	About 45% is urbanized and the rest is crop lands
Agriculture	17% of the country's agriculture production
Live corals	Coral reefs occur along the south-west, south and east coastal areas. At present, 171 species of stony coral have been recorded in the three major reef types
Sedimentation	From the erosion of country rock and discharged by rivers (total 103)
Fish	Annual production for food exceeds 200,000 metric ton/year. 139 species are ornamental fish for export
Dune sands	No accurate estimate of the rate of annual deposition.
Mineral resources	Mineral sands, shell and coral limestone, silica sand, peat, salt, and alluvial sand
Tourism	The average annual number of tourist arrivals is over 1 million. About 85% of tourist revenue comes from coastal areas. Over 75% of graded hotels are located along the coastal zone

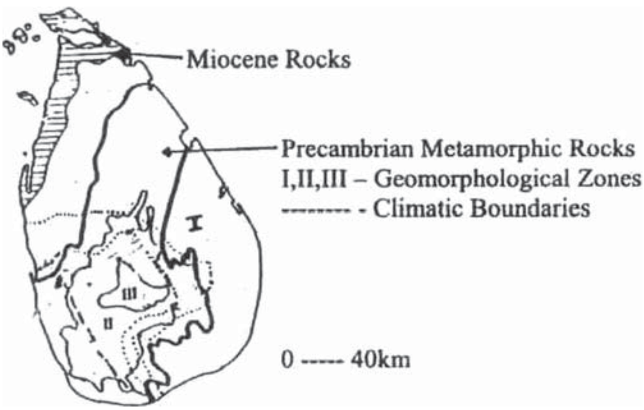

Fig. 5.3.14. Geographical location of Sri Lanka showing major climatic and geomorphological zones and geological boundaries.

Sri Lanka, reaches outward up to 20 km (Table 5.3.11). Trincomalee Bay is one of the finest natural harbours in the world.

Coastal Resources

The country's principal coastal resources are coastal habitats/ecosystems, coastal fisheries, mineral deposits, coastal land and water resources.

Coastal Ecosystems

A characteristic feature of the coastal zone is the presence of a number of ecologically and economically important ecosystems characterized by high rates of production, consumption, and exchange. These ecosystems serve as habitats for a wide diversity of plant and animal life. They also act as buffers against ocean waves that cause coastal erosion. These natural coastal habitats include coral reefs, estuaries and lagoons, mangroves, seagrass beds, tidal flats or salt marshes and barrier beaches, spits and dunes (Fig. 5.3.15).

There are five major lagoons on the island, but these are really basin estuaries. There are 103 rivers discharging water into the sea. About one third of these are riverine estuaries along the coastal line. The principal mangrove districts are Puttalam, Mannar, Jaffna, Trincomalee, and Batticaloa. Extensive seagrass beds occur in estuaries, lagoons and shallow seawaters along northeastern and northwestern coasts. Twelve species of seagrasses have been recorded. Salt marshes in sandy or muddy tidal flats occur in the arid areas in the north, northwest, northeast and southeast of Sri Lanka. Barrier beaches/spits and dunes mainly occur along the northwest, south and southeastern coasts.

The Coastal Fishery, Mineral Deposits, and Coastal Land

Some 80% of the country's total fish production comes from the coastal fishery industry (within 40km of the coast). The other 20% is from inland fishery and offshore fishery.

The important mineral resources of the coastal region in Sri Lanka are heavy mineral sands (ilmenite, rutile, monazite, garnet, and zircon), silica sands, sand from shallow seas, salt, Miocene limestone, coralline limestone, shell beds, brick and tile clays, laterite, iron ore, and peat (Cooray 1967).

About half the coastal lands fall into the category of croplands, while about 45% lie in urban areas. The soils are red earth, gravel deposits, regosols, solidized solonets, alluvial soils and bog and half bog soils. Sedimentary limestone and sandstone and different metamorphic rocks are the bedrock underlying in the coastal land area.

Water Resources

Several coastal lands in the Wet Zone are severely affected by flooding and water logging. The Dry Zone experiences heavy rain during the northwest monsoon, but virtually none at other times. The northwest and southeast coastal stretches receive less rain than elsewhere in the Dry Zone. Coastal surface waters include the estuaries of the country's 103 rivers. Some are

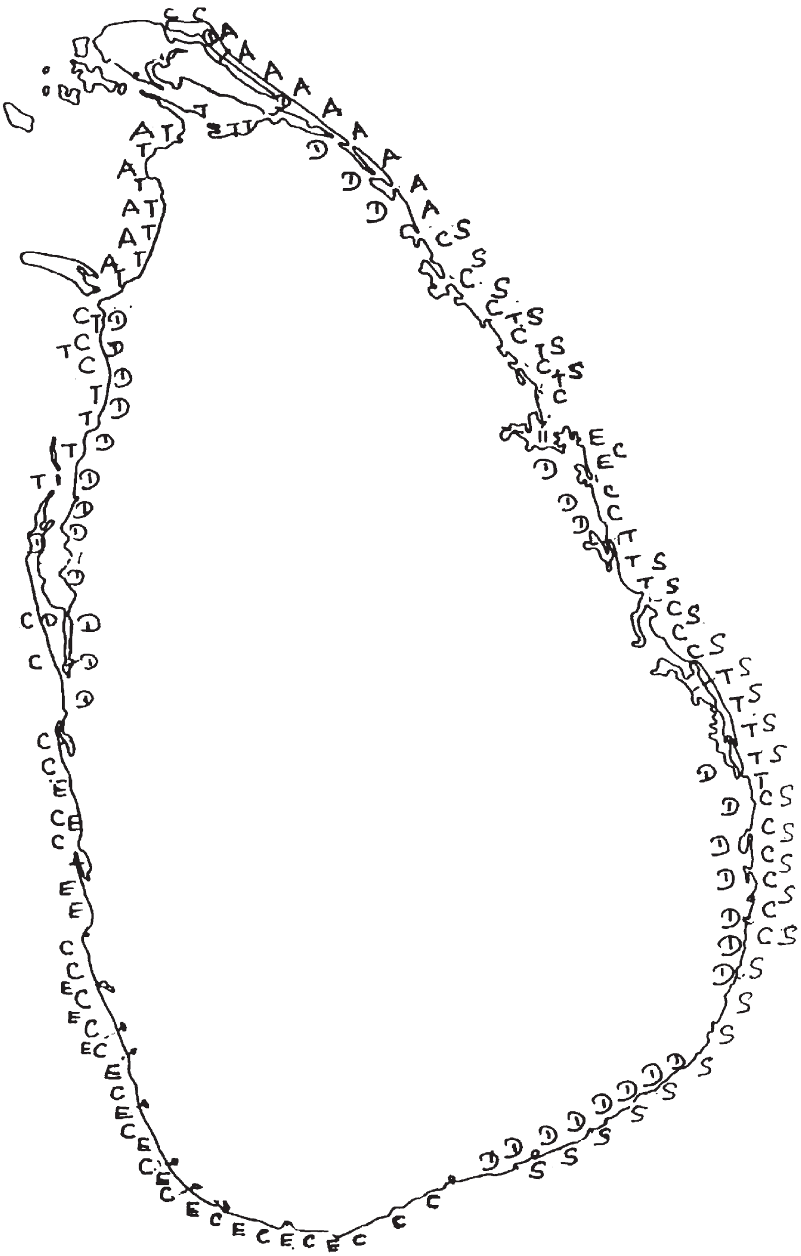

Fig. 5.3.15. State and features of the coastal zone: S: Stable zone; E: Erosion; A: Accretion; D: Dune coast; T: Tidal flats; C: Coral reefs.

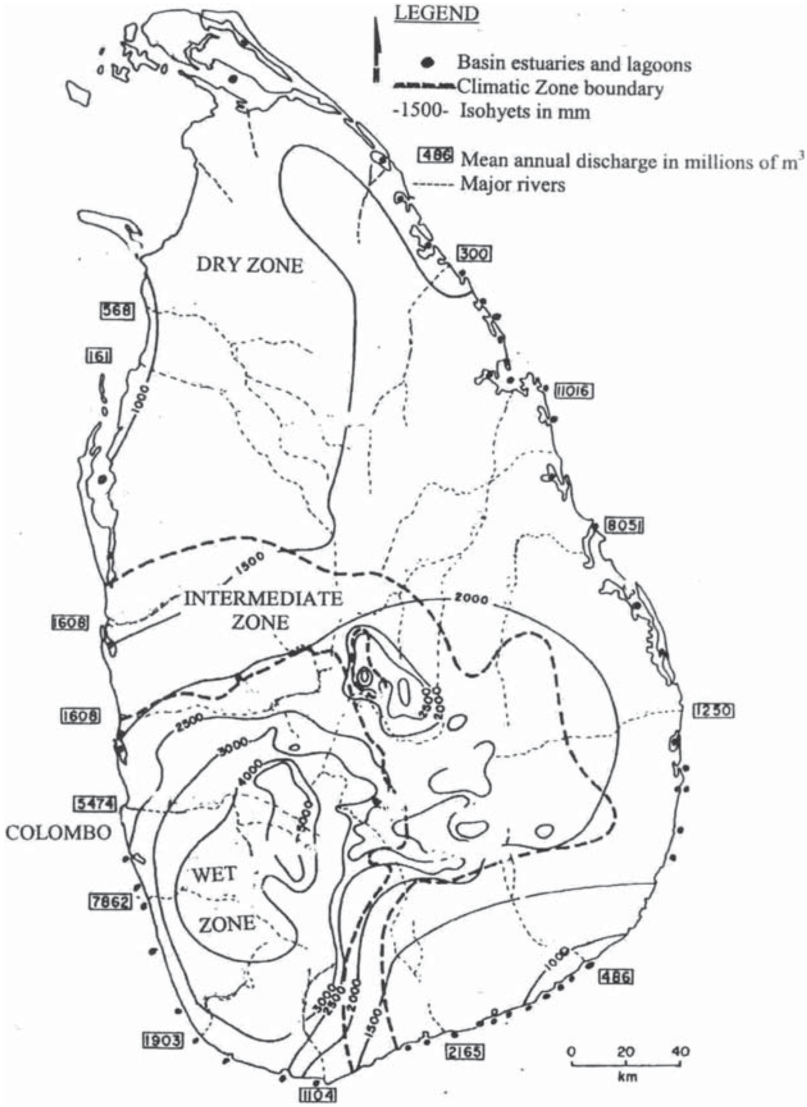

FIG. 5.4.16. Mean annual rainfall, annual discharge of major rivers, climatic zones, basin estuaries and lagoons of Sri Lanka. (From NARESA 1991.)

brackish waters. Groundwater is found at different depths, depending on the underlying geological formations. Fresh water lenses are often found in places close to the sea (Fig. 5.3.16).

Sedimentation

The main sources that nourish the beaches are the rivers. The major rivers that start from the central hills supply sediments to the coast. Sediments are supplied in a cyclic manner, with maximum supply coinciding with the heavy rains and the stronger wave climates that occur during the southwest monsoon. Sediments supplied in this way are coarse and have typical grain diameters in the range of around 1 mm. Smaller streams supply finer sediments. The other sources of sediments have marine origins. These consist of calcareous substances derived from live corals reefs and shells of marine organisms. In Sri Lanka this type of live reef is found in many areas. The reef that extends from Colombo northwards is dead.

Sand spit formation takes place at river outlets. Spit formation depends on the average littoral drift on the coast and the quantity of sediment discharged by the river to the coast. Owing to the varying sediment supply from rivers, the coastal dynamics at their outlets are unpredictable.

Waves are the main source of energy for sediment movement along Sri Lanka's coasts. Waves that reach the coast of Sri Lanka originate from two main processes. Storms in the southern and mid-Indian Ocean produce waves that radiate from the generating area. They travel large distances and reach Sri Lanka from the south. These waves have long periods and are known as the southern swell. During winter in the southern hemisphere the larger swells generated by winter storms reach this coast. This period coincides with the southwest monsoon, when the wind also blows from that direction. The wind-generated local waves, along with the strong swells, cause severe erosion problems during this time.

During the northeast monsoon, the swell is small and wind waves from the northeast monsoon are dominant. This affects only the northeast and the east coasts of Sri Lanka. During this time waves on the east coast are produced by local winds that approach from east to northeast.

Along the west coast, southwest monsoon swells and waves move sediments northwards at a high rate. During this time, monsoon-fed rivers on the west coast also have large runoff and sediment discharge. The coastal dynamics are therefore complicated and very intense. The tidal currents then help a portion of the sediments to cross the inlets of the lagoons and estuaries. Similarly, sediments along the east coast move during the northeast monsoon period. The wave forces are generally dissipated by partially or fully submerged reefs. For various reasons, coastal areas are extremely variable and complicated. Figure 5.3.16 shows the annual river discharges. The sedimentation also varies accordingly.

Human Activities

Population and Economic Growth

Over the last five centuries, following foreign occupation, the country's development has been closely linked to maritime affairs. Expanding international trade and commerce accelerated population shifts to the coast. Since independence (1948), coastal settlements have grown in size and economic importance, particularly in the south, southwest and west. Over 30% of the country's total population is living in 24% of the country's total land areas that belong to the coastal administrative divisions. Some 45% of this population is living in the urban areas. This includes the country's principal city of Colombo, the six largest of the twelve Municipal Councils, and 19 of the 39 Urban Councils.

Fishing, tourism, industry and agriculture sustain the growing economy of the coastal region. Fishing is the predominant coastal economic activity along the coasts. This marine industry provides full employment to more than 100,000 persons. The export of fish and aquatic products earns foreign currency.

Tourism in Sri Lanka has primarily focused on its scenic sandy beaches, coastal estuaries and lagoons. The numerous foreign tourists are attracted by two national wildlife parks along the coast, and by bird sanctuaries along the lagoons and estuaries.

Coconut is the major plantation along the coastal region all over the country, except in certain parts of the North where palmyra takes its place. Paddy, rubber, cinnamon and tea are the other cultivations within the coastal region, but these are a little away from the beach area.

Some industries are located along the coastal zone. Some are relevant to the fishing, tourism and agriculture fields, while others have no relevance to the coastal zone development at all.

Development of River Basins and Coastal Zone

The 103 rivers of Sri Lanka discharge their flow into the sea from all around the country. A few of them are considered large rivers, which discharge surface water with a large amount of sediment into the sea. Some large rivers supply water for generating hydroelectric power and for major irrigation schemes.

In Sri Lanka, the control of erosion due to the action of waves is the most important activity under coastal zone development. The number of harbors has been increased for fish landing, boat repair works and commercial purposes and more bare land has been converted into residential and industrial areas. Some breakwaters have been constructed for fishing. New roads have been opened in and around the coastal zone. The railway lines parallel to the coast were constructed by the British, without considering their effect on the coastal environment. Drainage facilities, sewage disposal facilities, communication facilities, schools, places of religious worship etc. are being built within the coastal zone.

Environmental Problems in the Coastal Zone

General

There are numerous activities in the coastal strip of land and in the nearshore area. Activities at any coastal location may cause instabilities, either at that locality or sometimes in distant coastal areas. Under the action of natural processes, such as waves, currents and winds, sediment moves on, off and along the beaches. If the sand supplied to a particular coastal sector is less than what is carried away, the shoreline will erode. Natural processes cause most shoreline erosion, but various human activities contribute as well. The most significant of these include sand mining from river beds and beaches, coral mining and destruction of reefs, removal of mangroves and other coastal vegetation and improper location or construction of maritime structures, such as shoreline protection works and fishery harbors.

There are also some environmental problems due to accretion. These include obstruction of outlets affecting the escape of flood waters, navigation, migration of fish and shellfish species between an estuary and a lagoon and the sea, silting of harbors, outlets for urban and industrial pollutants, intake sites for seawater required salterns and some fishery activities. Accretion is also caused by wind and aggravated by the removal of dune vegetation. In certain areas, sand blown away during the dry season is deposited on paddy lands and coconut plantations.

Changes of Coastal Features and Coastal Erosion

Coastal erosion in Sri Lanka is not unusual in terms of world trends. The danger of erosion is greatest when the monsoons are onshore. The southwest monsoon, with its fetch extending over the breadth of the Indian Ocean, generates waves with high energy. This monsoon delivers its greatest energy to the areas in the west, south and southeast. The northeast monsoon blows over a more limited fetch of the Bay of Bengal and accordingly delivers somewhat less energy to the shore. Its effects are mainly felt along the north coast and on the east coast as far the south east. The spatial variation of erosion hazards depends on an area's susceptibility to erosion, the ocean floor and coastal margin, and the supply and availability of beach material.

There are several natural defenses against erosion. Although annual monsoons regularly cause much damage in some locations, small waves and weak variable winds prevail most of time. Storms and cyclones (usually rare) affect only the sparsely populated coastal areas of the east and northwest. Corals and sandstone reefs that run parallel to most of Sri Lanka's shoreline act as natural breakwaters. Although the beaches are receding in most parts of the island, the impact of coastal erosion is most severe along the western and southwestern coasts, where development and population are also most intense. The highway and railway are routed through most of these coastal sectors.

Erosion along Sri Lanka's land beaches is highly localized, with wide variations in erosion and accretion rates. Information based on qualitative estimates of coastal residents suggests that, on average, the coastline of Sri Lanka receded by about 1 m within a 3-year period (Table 5.3.12).

The littoral forces which are created by the actions of sea waves are high in the west coast. There is a strong net drift of sand from south to north. This has caused a net loss of coast over the last few decades. At some locations along the west coast, the erosion rate is slow due to the higher nourishment from rivers. On the northwest coast the points of erosion are isolated due to the natural reshaping of the coast by dune sand deposits. Generally no erosion takes place along the northwest coast, which shows accretion. Nourishment along the north-northeast coast is higher than erosion. On the east coast, the erosion is localized. Near Trincomalee the coast has very steep slopes and over a short distance reaches a depth of 1,000 m. The wave climate in the east coast is generally mild. This stretch of coast shows signs of slow accretion, but it is a cyclone prone area. Due to the interaction of northeast waves and the southwest swell, the coast along the southeast shows oscillations of erosion and accretion. Accretion is due to dune formation. Human impacts on this coast are minimal, due to the very low population. The south-southeast coast is very stable, consisting of large wind deposits. The erosion of the south coast and southwest coast is very high (Fig. 5.3.16).

Sand Mining and Coral Mining

Of the human activities aggravating erosion, most widespread is sand mining in river mouths, estuaries, and beaches. Demands for sand are high in and around areas where development pressure is high. Sand mining reduces the supply of sand to the sea, which leads to serious salt water intrusion, and also damage to the flood protection bunds of the rivers (Table 5.3.12).

For years, coral reefs along Sri Lanka's southwestern and east coats have been subject to large scale destruction from mining of coral for the lime required in the building construction industry. Mining reduces coral reef barriers against wave erosion, destroys the habitat of large numbers of marine fauna and flora, including economically important fish species, and can eliminate the potential for sustainable tourism. Mining of corals also occurs inland, where large deposits can be found along the southwestern coastal belt. Coral mining provides considerable employment even though it is prohibited by law. Although sand mining and coral mining are prohibited by law, the people continue doing them either because they have no other means of income or because they do not believe in or care about the adverse environmental impacts such mining has.

Habitat Degradation and Overexploitation of Resources

Several lagoons and estuaries have gradually decreased in size. This is due to the high rate of siltation and sedimentation from rivers, human activities, land filling, garbage disposal etc. New piers, jetties and bridges restrict the flow of water and promote further siltation. On the one hand estuaries and lagoons act as harbours and anchorages, disposal sites for sewage and industrial effluent. On the other, they invite recreation that requires clean water. Estuaries supply sand that significantly helps stabilize beaches, but they also supply sand for mining that can disrupt the beaches over time.

Coastal habitats (or the biological systems) are under enormous pressure because many are small and especially vulnerable to degradation. The low tides along the coasts (about 75 cm) restrict most mangroves to narrow belts along the lower reaches of rivers and narrow edges of lagoons and estuaries, so there are no large mangrove forests. Those that exist have become severely reduced by overuse, abuse, and conversion to other uses. Mangroves are widely harvested for subsistence and commercial scale operations. The economic value of such use of the mangroves, though clearly high, has not been accurately estimated. Some species are commonly used as firewood. However, extraction of firewood for domestic kilns and illicit distilleries reduces the capacity of environment to meet future needs. Conversion of mangrove areas to other uses is the greatest threat. Clearing vegetation and the changing topography and soil condition cause permanent damage. Mangrove areas are also reclaimed for housing and urban expansion. Some mangrove areas have converted to aquaculture ponds, which create a worse environment for the mangroves due to major changes in drainage. Land reclamation for coastal coconut and paddy cultivation is another major problem. The drainage system kills the mangrove environment. Chena cultivation along some parts of the east coast also damages the coastal habitats.

The coral reefs are being steadily destroyed and degraded. Most of this damage has occurred over the last 30 years. Reef mining for manufacturing lime used by the building construction industry is the single most destructive action. It has been particularly intense in the tourist and fishing areas. Efforts to stop the destruction have been discussed for years, but action has been limited. Physically damaging fishing methods (explosives, Trammel nets, the practice of breaking coral to net tropical fish) also destroy coral. Careless glass-bottom boat use, and anchor chains, clearing of coral reefs for boat passage, trampling of coral at low tide, souvenir collection and sales of specimens, and the extraction of coral and sand for aquariums or fishes for exports are other ways in which coral is damaged. Coral also dies from less visible causes, including water pollution from deposition of coconut husks within the reef lagoon.

The next worst activity is the removal of dune sand deposits. People collect sand from dune hills for building construction, which completely destroys the protective environment of the coast and coastal habitats.

Fishing Industry

The coastal zone in Sri Lanka is used for several activities. Fishing is the dominant activity all around the coast, except along the coastlines bordering natural reserves. However, the construction of breakwaters for fishing or commercial harbors can cause instability over a large area adjacent to such constructions.

Urbanization

Another widespread use of coastal land is for housing. This activity is directly related to population increases. Landlessness among fishermen leads to encroachment and the construction of temporary housing on state-owned land within the coastal zone. Settlements of this type become permanent over time. Privately owned lands in urban areas are also used for residential purposes. The erosion of the coast is not directly related to settlements on the land. However, these temporary and permanent buildings could result in altering the coastal equilibrium and long term instability in adjacent areas.

Concentration of residential areas along the coast has resulted in the construction of highways and railways connecting major cities. In the early stages these roads may have been located well away from the beaches. At present, however, the main roads are very close to the beach, due to the erosion. The cost of maintaining these roads and railway lines already forms a considerable part of the expenditure.

Drainage

The drainage of runoff from the low-lying coastal areas to the sea, through streams or canals, nearly always causes problems due to sandbar formation across the outlet. The problem is more complicated when these outlets are open only during part of the year. Sandbar formation causes salt water inflow due to overtopping waves, and flooding as soon as the first rains come. It creates general instability on the coastline.

Tourism

Recreational uses of the coast are mainly linked to tourism. Construction of structures in the littoral zone almost always cause local changes in the coastal processes, which can cause instability over a large area. The construction of tourist facilities can lead to the indirect problems of pollution and the ultimate depletion of resources.

Pollution

All the human activities within the coastal zone create various reasons to pollute its environment. People are performing various jobs to earn money because they do not have any alternatives. One problem due to the increase in population is untreated sewage. It pollutes the near shore areas and, as a result, it destroys the most desirable natural environment for the living coral reefs. Faecal pollution of beaches and coastal waters comes from temporary housing settlements near the beach, or from hotels that illegally discharge raw sewage.

The construction of beach hotels completely destroys the natural beauty of the country. Some hotels have been constructed in ecologically sensitive sites. Many of these discharge their sewage and other unwanted materials into coastal waters. Some of them have enclosed sections of the beach opposite them and restricted public access to the beach and the sea.

Coastal industries, such as paint, pulp and paper, rubber, lime, textile, distilleries, cement and cement products, fibre, and coconut husks, contribute chemical, heavy metal and organic pollutants into the lagoons and estuaries and to the beaches. These create many environmental problems for the affected areas. Oil spills from shipping and fishing craft, and cleaning of fuel tanks, are also causes of coastal pollution in Sri Lanka. A major international shipping route carries an estimated annual traffic load of over 5000 tankers about 8 km off the south and southwestern coasts.

Coastal Zone Management: Some Proposals for the Future

The Act

Overall responsibility for coastal resources management rests with the Coast Conservation Department (CCD) under the Coast Conservation Act (CCA) No.57 of 1981. All implementation and research are carried out by this department, in cooperation with other agencies and institutions. The act was amended in 1988. According to the CCA, the limit of the coastal zone in the land is located at a distance of 300 m from the high water line of the sea level. It is also located at a distance of 2 km along the area of estuaries and rivers.

The act clearly describes the legal activities to be carried out, as well as the illegal activities that are prohibited within the coastal zone to protect it in various ways. For several years efforts have been made, without success, to discourage all illegal activities. All attempts have been unsuccessful because the CCD has been unable to obtain the necessary cooperation for enforcement from local/regional political and administrative leaders. Therefore, to implement the Coastal Zone Development Plan, the leaders of the ruling government and the opposition parties, local political leaders and the administrative officers of the various departments and institutions should be of one opinion.

The Effect of Tsunami: Learning from the Recent Disaster

The worst ever natural disaster occurred in Sri Lanka in the early hours (00:58:50 hours GMT) of 26th December, 2004. The seismic sea waves, or tsunami, caused by a massive earthquake measuring 9.0 on the Richter Scale off the west coast of Northern Sumatra at 3.298N, 95.779E (at a depth of 6.2 miles below sea level), devastated the whole coastal zone of the island, except for only a few locations. It was the fourth strongest earthquake in the world. The waves travelled across the ocean at speeds as great as 960 km/h. Their height by the time they reached the shore was estimated at 20 m or more. An estimated 31,000 persons living in and around the coastal zone of Sri Lanka were killed by the tsunami. India, the Maldives and Thailand were the worst affected countries in the region. The tsunami destroyed several thousand houses, numerous permanent buildings, schools, places of religious worship, tourist hotels, highways, railways, major cities and towns, vehicles and trains, agriculture and all personal properties. Nearly 180,000 families, or approximately 800,000 persons, were displaced and homeless immediately after the disaster. The people of Sri Lanka had had no experience of earthquakes, tsunami and volcanoes because the country is not situated in and around the plate boundaries. This was the first-ever experience for the Sri Lankan people of an earthquake-related event. It was not possible to implement the development plan for the coastal zone of Sri Lanka due to the various objections of the higher level administration, as mentioned above. This would have been the best time to remove all unauthorized structures, even large hotels and other illegal activities, from the defined coastal zone to places beyond the 300 m limit.

References

Coast Conservation Department Publication (1991) Proceedings of the seminar on causes of coastal erosion in Sri Lanka, 9–11 February 1991, Colombo, p366

Cooray PG (1967) An introduction to the geology of Ceylon, Department of National Museums, Governtment Press, Colombo, p340

Dayananda HV, (1992) Shoreline erosion in Sri Lanka's coastal areas, coast conservation. Department Publication, State Printing, Colombo, p72

Madduma Bandara CM (1989) A survey of the coastal zone of Sri Lanka, coast conservation. Department Publication, State Printing, Colombo, p116

The Natural Resources, Energy and Sciences Authority of Sri Lanka (NARESA) (1991) Natural resources of Sri Lanka. Published by the Institute, p280

6 Conclusions: The Rapidly Changing Environment of the Asia and Pacific Region and its Implications for Sustainability of the Coastal Zones

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6.1 Introduction

This book presents a broad assessment of the present status of the environment in the Asia and Pacific coastal zones. Coastal zones are a precious environment, with diverse biogeochemical elements. They also represent a very important resource base for societal, economic, and cultural activities. As such, they have attracted huge movements of population and development activities, which in turn have imposed pressures on the coastal environment, inducing wide-ranging and rapid changes. The Asia and Pacific region is among those areas of the world where such changes are most active, which is why this book focuses on this particular region. In the present assessment a framework for analysis consisting of three viewpoints was used; the state of the environment, driving forces, and responses. This conclusion to the assessment uses the same framework.

6.2 The State: Pictures of a Rapidly Changing Environment

6.2.1 Changes in Coastal Features

Erosion of Asian Deltas

A notable feature of ongoing environmental change can be found in coastal geomorphology. Many large deltas, which characterize Asian coasts, have suffered from coastal erosion for decades. Recent erosion is caused by a decrease in sediment supplied by rivers, which, in turn, is attributable to development in river catchments, including dam construction. There are a number of examples of this tendency, such as the Song Hong River, Vietnam, where, after the Hoa Binh Dam was constructed in its upper reaches in 1989, sediment delivery was decreased dramatically. Sediment supply to the river mouth changed from about 26 million tons/year in 1949 to 11 million tons/year in 2000, engendering severe coastal erosion. The Huanghe River in China, which was once the second largest river in the world in terms of sediment discharge, delivers less than 10% of its former discharge because of dam construction and irrigation in its upper reaches. This reduction has caused serious coastal erosion around the river mouth in the Bohai Sea. In many parts of the Asia and Pacific region, the combined effects of development in both coastal zones and river catchments have been changing coastal geomorphology remarkably.

From a global-change viewpoint, acceleration of beach erosion attributable to rising sea levels is a salient concern. Many places face a relative change in sea level, which combines global and local changes in mean sea level relative to the land, including land subsidence and crustal motion. The northern coast of the Gulf of Thailand is an example of the impact of a relative sea-level rise on a muddy coast. Extracting groundwater has caused land subsidence around the Bangkok area, including the river mouth of the Chao Phraya River, which underwent a more than 60 cm subsidence during the period from the 1960s to 1980s. This has resulted in severe coastal erosion; the shoreline retreat amounted to 700 m up to the early 1990s (Vongvisessomjai et al., 1996), at which time the subsidence started to stabilize thanks to regulation of groundwater pumping. Because the sea level is estimated to rise between 9 and 88 cm globally by 2100, the highest value of which is over four times greater than past trends, Asian coasts will generally face further serious erosion in this century. This threat will be particularly severe on coasts where there is the combined effect of ground subsidence and decreased sediment supply from rivers.

Coasts of Small Islands

Many island coasts have natural protection against destructive wave forces, such as coral reefs, mangrove forests and beach rocks. Most of these coasts are surrounded by coral reefs known as “fringing” and barrier reefs. Reefs provide island coasts with physical protection from large waves. Atolls are rings of coral reefs that enclose a shallow lagoon. They comprise islands of largely unconsolidated calcareous sand and gravel. Mangrove forests fringe the shoreline; if there is a broad mangrove forest, it can exert a powerful protective effect on the shoreline. However, many of these forests have been cleared over the past 150 years or so. Today, the shorelines of most low-lying coasts around the small islands are generally only lightly vegetated, in order to allow access to the shore (Nunn and Mimura 2005). Beach sediments are biological products, particularly for atolls; the sediment supply is extremely limited. In addition, changes in sea level, wave height, and incident direction caused by El Niño might seriously enhance erosion. Therefore, it is reasonable to believe that the recent tendency for coastal erosion to increase results from the combined effects of a loss of natural protection and large-scale environmental changes, such as El Niño and sea-level rise.

6.2.2 *Water and Sediment Pollution*

Organic Pollution and Eutrophication

Water pollution is among the most serious problems facing many countries in the region. Whereas varying degrees of treatment are employed in some localities, untreated sewage is commonly disposed of either directly or indirectly into the sea. It has been estimated that 6 million tons of BOD are generated by coastal populations in countries surrounding the South China Sea, including Cambodia, China, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. Sewage treatment removes only about 10% of the BOD generated.

Eutrophication in various coastal waters that receive high organic input from domestic and industrial effluent is common in the region. This eventually engenders the red tide bloom phenomena. In particular, red tides have frequently been reported in Malaysia, the Philippines, Thailand, Hong Kong, and Japan. In Hong Kong, an eightfold increase was reported in the number of red tides per year in Hong Kong Harbor during the period 1976–1986. This change was attributed to the sixfold increase in population and a concurrent 2.5-fold increase in nutrient loading (Lam and Ho 1989).

Japan's Seto Inland Sea provides an example of how people have made efforts to overcome the problem of eutrophication. About 30–40 years ago, the Sea suffered from severe water pollution and the negative effects of eutrophication. During the period of the nation's rapid economic growth in the mid-1960s to mid-1970s, increased industrial activity and expansion of landfills along the waterfronts caused rapid increases in water pollution, a reduction in shallow water areas and degradation of the marine environment and habitat. In recent years, as a consequence of various environmental conservation measures, incidents of red tide blooming have been reduced to around 100 events annually, compared to around 300 such occurrences recorded in 1976, with mass mortality of caged fish cultures.

During that period of heavy pollution, the Seto Inland Sea was called "the dying sea", but it has slowly recovered thanks to the efforts of various groups and bodies, with the strong support of a legal framework. The Law on Temporary Measures for the Environmental Conservation of the Seto Inland Sea was enacted in 1973. This law became permanent in 1978 and has played a very important role. As a result of enforcing total COD load control by law, the COD discharged in the coastal zone of the Seto Inland Sea was reduced dramatically from 1,700 t/day in 1972 to 718 t/day in 1996. Unfortunately, the achievements recorded in relation to the Seto Inland Sea are a rare case; the Asia and Pacific region needs greater efforts to reduce the discharge of organic pollutants and nutrients to control occurrences of red tide.

Hazardous Chemicals

The discharge of chemicals into the sea by industrial effluents, and enhanced use of agrochemicals on the land, are a common difficulty. Aquaculture has also contributed to the discharge of pesticides, antibiotics and hormones, as well as nutrients (ESCAP and ADB 2000). In 2001, the Stockholm Convention on Persistent Organic Pollutants (POPs) was adopted to safeguard human health and the environment. The acronym, POPs, is a collective term used to describe organic chemicals that remain in the environment for long periods, are widely distributed and that are toxic to animals and humans. Among such chemicals, organochlorine compounds (OCs) have been recognized as endocrine disrupters, which pose a serious threat to marine animals through bioaccumulation. The levels of DDT and PCBs in dolphins are considerably higher than other OCs because they are highly persistent, relatively lipophilic, and less biodegradable (Tanabe and Tatsukawa 1991).

Butyltin compounds (BTs) are another typical hazardous chemical. Since the 1960s BTs have been used worldwide, typically as antifouling agents in paints for boats and aquaculture nets. In 2001 the International Maritime Organization (IMO) prohibited the use of harmful organotins in antifouling paints used on ships. Marine animals in the waters of developed countries showed higher concentrations than those from waters surrounding developing countries, reflecting the retention of BTs used in the past in these countries. With regard to BT concentrations in fish, Asia and Oceania showed lower values than Japan, Canada, or the USA.

Marine pollution of heavy metals, such as mercury and lead, is also a concern for the region. Mercury contamination has been found in bottom sediments of many semi-enclosed bays surrounded by industrial bases and coastal waters, such as the Sea of Japan. From the 1950s to the 1970s the people around Minamata city, Japan, are known to have suffered from severe mercury pollution known as “Minamata Disease”. Recently, mercury pollution from gold mining processes was also found in the city of Manado and the Ratatok area of North Sulawesi, Indonesia. Local people face the risk of severe and irreversible health problems from eating fish and marine animals in these areas (Harada et al., 2001; Limbong et al., 2003 and 2004).

Oil Spills

Accidental oil spills have occurred frequently along oil transport routes from the Persian Gulf and at points of loading and discharge. Oil spills have been reported to cause severe pollution in ports in Bangladesh, Pakistan and countries in Southeast Asia. Sri Lanka has suffered from the frequent formation of tar-balls on its southeastern beaches (UNEP 2002). Countries in East Asia have also faced oil-spill problems. For example, accidents are quite frequent, if small-scale spills are included; in Japanese waters alone, spills of over 2 kl occur 400 times or more annually.

A large-scale accident is not only devastating to a coastal environment, but requires a huge amount of recovery work. For example, in July, 1995, the oil tanker *Sea Prince* loaded with 260,000 t of crude oil from Saudi Arabia grounded on submerged rocks near Sori Island, Korea because of a typhoon. This incident created an oil spill of 5,035 t. Disgorged oil from the ship spread more than 200 km along coasts comprising rocky coastlines and sandy beaches. Nineteen days were required to recover 1,390 kl of the discharged oil. Police and local residents cleaned contaminated areas, mostly manually. Cleanup operations along the shorelines continued for five months (Lee 2001).

6.2.3 Coastal Ecosystems

Mangroves

Mangrove forests are widely distributed throughout Asia and Pacific islands. Large areas of mangrove forests exist in India, Bangladesh, Myanmar, Thailand, Vietnam, Malaysia, the Philippines, and Indonesia. Of these, Indonesia has the largest area in the region, because of its long coastline, whereas the Sundarbans, located in India and Bangladesh, have the largest continuous area of mangrove forests in the world. Approximately 40% of the world's mangrove forests are found in Asia. Mangrove forests are extremely biodiverse and act as a nursery and spawning ground for numerous species of fish, crustaceans, mollusks and reptiles. They are also important for the daily lives and economies of local communities, providing a myriad of goods and services.

The total ratio of mangrove lost in Asian countries is estimated to be about 26% during the 20 years from 1980 to 2000 (FAO 2003; Kashio 2004). The annual rates of decrease were 1.6% from 1980 to1990, and 1.4% from 1990 to 2000. Causes of mangrove degradation include conversion to shrimp ponds, felling of timber, development of human settlements, ports, agriculture and industries, roads and other infrastructure, as well as excessive siltation. Shrimp culture has been the most serious cause of mangrove conversion, particularly in Southeast Asian countries such as Indonesia, Vietnam, the Philippines, Malaysia and Thailand. It is estimated that over 60% of mangrove forests have already been converted to aquaculture ponds (ESCAP and ADB 2000)

Clearance and degradation of mangrove forests have a serious impact on their ecosystems and neighboring coastal areas. Mangroves also play the role of a filter between land and ocean. Therefore, the disappearance of mangrove forests increases the discharge of land-based pollutants such as organic matter and toxic chemicals, thereby adversely affecting water quality. These impacts eventually result in the loss of productivity of inshore and near-shore fisheries and threaten coastal communities that depend on the fisheries for both commerce and subsistence.

Coral Reefs

Coral reefs are another precious ecosystem of coastal zones. They are sites of rich biodiversity, and provide resources for human use. Asia and the Pacific regions have been recognized as the global center of tropical marine biodiversity. About four fifths of the world's coral reefs are in Asia and the Pacific region; about half of these are in the Pacific, whereas one-third is in the Indian Ocean and the remainder in south Asia (ESCAP and ADB 2000). Fifty out of 70 coral genera found in the world occur in the Indian and western Pacific Oceans. Coral reefs in Southeast Asia are biologically diverse, holding an estimated 34% of the earth's coral reefs (Burke et al., 2002).

In Asia and the Pacific Region, coral reefs are threatened by a range of human activities, including coastal development, exploitation and destructive fishing practices, as well as land-based and marine-based pollution. Coastal development, including tourism sites and facilities, often causes not only direct destruction but also indirect degrading factors such as discharge of sediments and nutrients, causing high turbidity in the sea. Destructive fishing practices, such as the use of explosives and cyanide, still constitute a major problem. Cyanide is widely used, and has a severe effect on juvenile fish and coral organisms. This use is because the live fish industry has grown in the region. In addition, coral reefs are often damaged physically by fishing equipment, coral breakage and anchors. Dredging and reclamation for ports and fishery harbors are other causes.

In Southeast Asia 88% of the coral reefs face a medium to very high threat from the impact of human activities. In Indonesia and the Philippines only 30% of the coral reefs are in good or excellent condition. The reefs of the South Pacific region are under less immediate threat than those of Southeast Asia. About 40% of the Pacific reefs are classified as threatened, while 10% face a high risk (WRI 1999).

Global environmental changes, particularly global warming, will increasingly threaten the coral reefs, as demonstrated by the spread of coral bleaching in 1997–1998. Damage by coral bleaching continued even after the events of 1998. In Japan most reefs damaged in 1998 have been recovering, though bleaching occurred again in 2001 when some reefs experienced about 50% mortality. In the South Pacific severe coral bleaching occurred in 2000 and 2002, especially in Fiji, Tuvalu and Vanuatu. It has also been suggested that a rising sea level would inundate coral reefs if the speed of the rising sea level was faster than the coral reefs' upward growth rate. When coral reefs are healthy, they can more readily catch up with the rising sea level and can recover from damage caused by coral bleaching. Therefore, management should pay close attention to the combined stress of local human activities and global warming.

Sea-grass Beds

Globally, seagrass beds occupy an area of about 600,000 km^2, contributing 12% of the total carbon storage in the ocean (Duarte and Cebrian 1996). Seagrass diversity is highest in East Asia, reaching up as far as southern Japan; a second focus of diversity is in the Red Sea and East Africa. So far, 16 species of seagrasses have been identified in Philippine waters, whereas 14 species have been reported from Indonesia; Australia has the highest number, with 30 species of seagrass (Fortes 1989; Kuo and Larkum 1989). In other parts of the region seagrass beds can also exist, though they are often less dense. Because seagrass meadows support rich biodiversity, and provide primary refugia for marine organisms, most major commercial fisheries in the region are situated adjacent to seagrass beds.

In Southeast Asia seagrasses are under threat from the loss of mangroves, which act as a filter for discharged sediments. They are also threatened by industrial and agricultural runoff, industrial wastes and sewage discharges. In Indonesia about 30–40% of the seagrass beds have been lost in the last 50 years, with about 60% being destroyed around Java, while in Singapore, the patchy seagrass habitats have suffered severe damage, largely through burial under landfill operations. Losses of the beds amount to 20–30% and 30–50% in Thailand and the Philippines, respectively. Coastal eutrophication is another major long-term threat to seagrass ecosystems in Southeast Asia. This entails reduction of light, thereby retarding the growth of many plants.

6.2.4 Fisheries and Aquaculture

Marine Fisheries

People in Asia and the Pacific region have long relied on fish and fishery products as a major source of protein. According to the FAO, in 2002 the region's fish catch amounted to 44.7 million tons, or 48% of total global production. Five Asian countries are among the top-ten producers: China, Indonesia, Japan, India, and Thailand. Therefore, marine capture fishery and resources for it, are particularly important for the region. Potential resources for future landing vary among regions. Of the world's fisheries, the Indian Ocean fishery might offer the greatest potential for future development (FAO 1997).

During the period from the 1950s to the 1970s, fisheries in the region showed rapid development through structural changes in production and technologies. But fishery production in the region stagnated in the 1990s, having recorded a peak of 24.7 million tons in 1989. The main landed species from 1950 to 2002 were pelagic marine fish. The rapid increase in marine catches after the 1960s in Southeast Asia was attributed to the development of trawl fisheries. Fishery activities in Southeast Asia have increased dramatically during the past two decades, though the region now faces heavy overfishing, which has raised the question of how to maintain fishery resources for their future sustainable use.

Aquaculture Development

Aquaculture has spread throughout the Asia-Pacific region at a much higher rate than that of capture fishing production – more than four times faster than landings from capture fisheries. In addition, aquaculture's share of all fish landings increased from 21% in 1984 to 38% in 1995 (FAO 1997). Shrimp culture is the most widely expanded practice. Today Asia accounts for 87% of global aquaculture production by weight (IFPRI and WFC 2004). Freshwater culture, rather than marine culture, used to dominate the industry, but since the 1980s technological innovation has advanced rapidly in marine and brackish water aquaculture, thereby contributing to the rapid increase in production throughout the Asia–Pacific region.

Such rapid development in aquacultural production has adversely affected the coastal environment, including mangrove clearance for shrimp culture, and water pollution. An additional environmental concern associated with aquaculture is the potential hazard of the accidental release of exotic species and the spread of diseases from aquacultural facilities to the surrounding natural environment (ESCAP and ADB 2000).

6.3 The Drivers: Population Growth, Economic Development, and Global Change

6.3.1 Population Growth and Economic Development as Drivers of Environmental Change

Coastal zones in Asia and the Pacific region continue to experience tremendous and rapid changes, as described in the previous section. These have been driven by various factors, including: (i) natural forces of climatic and oceanographic phenomena; (ii) human activities, including the discharge of land-based and sea-based pollutants; and (iii) processes controlling the flow of material and energy within coastal ecosystems. Among the drivers of those changes, pressures of human activities are apparently predominant.

Coastal areas are among the most crowded and developed in the world. The overwhelming bulk of humanity is concentrated along or near coasts, which comprise just 10% of the earth's land surface. Recent data (Population Reference Bureau 2004) show that Asia-Pacific regions are home to half of the world's population; this ratio will remain at a similar level in the 21st century. More than half of all Asian people reside in the coastal zone. For example, of China's 1.3 billion people, close to 60% of the population live in coastal provinces. Furthermore, the region's coastal populations are growing faster than those of inland areas. Migration is a key factor affecting population growth in coastal zones. Indonesia and Vietnam are two typical examples of Asia's population shift. In Indonesia, 65% of people live on the main island of Java, on just 7% of country's land area. Similarly in Vietnam, where coastal populations are growing 20% faster than in the remainder of the country.

Population growth has exacerbated the trend towards an increasing number of megacities (those with 10 million inhabitants or more). In 1950, New York was the world's sole megacity. Megacities multiplied from five in 1975 to 17 in 2001, of which nine urban agglomerations were located in Asia's coastal zones. With 26.5 million inhabitants, Tokyo was the most populous city in the world in 2001. It is projected that the number of coastal megacities in Asia will increase to at least 10 of the world's top 21 by the year 2015. Tokyo, Dhaka, and Mumbai (Bombay) are all expected to hold more than 20 million inhabitants.

Asia and the Pacific regions have emerged strongly as a leading growth region. Economic activities within the region are becoming brisk, which is bringing about increased mutual dependence between the countries of the region in terms of resources and trade. Over the past 30 years the region has gradually moved from a subsistence lifestyle towards a consumer society, with rapid rates of urbanization and westernization that have occurred concomitantly with the increase in population. The ASEAN countries and coastal areas of China are undergoing rapid economic growth, and will continue to be a center of the world's economic growth.

Given the relentless and cumulative process of global environmental change driven by demographic changes, urbanization and industrial development, trade and transport demands, and lifestyle changes, the coastal zones of Asia are under increasing anthropogenic pressures (Turner et al., 1996). High concentrations of people, together with rapid economic growth in coastal regions, have produced many economic benefits. However, the combined effects of booming growth in population, and economic and technological development, are threatening the ecosystems that provide a basis for them. All coastal areas are facing an increasing range of stresses and shocks.

At the same time, human society will in turn be exposed to risks imposed by the natural environment. On December 26, 2004, the massive earthquake off the coast of Sumatra triggered a giant tsunami. This brought about a tremendous disaster in the coastal zones of countries in the Indian Ocean, with over 200,000 victims. This event revealed, in a symbolic way, just how vulnerable the coastal zones in the region are to coastal disasters. Many population centers and tourist destinations lacked disaster prevention systems such as protective structures, early warning systems and evacuation guidelines. If concentration of the population in the coastal zones proceeds without improving protection systems, the potential impacts of not only tsunami but also storm surges and high waves will be much more severe. These trends are expected to continue and intensify in the future.

6.3.2 Effects of Climate Changes and Sea-level Rise

Another major driving force in future changes in coastal environmental will be global environmental changes, in particular climate change induced by global warming. Certain effects of global warming have already been felt, although it is very difficult to separate the effects from past and current variability. As warming progresses in this century, the effects will become more profound.

The IPCC WGI (2001) indicated that the global mean surface temperature had already risen by 0.6°C ± 0.2°C during the past century. The degree of future global warming varies with the emission of greenhouse gases (GHGs) such as CO2. Therefore, it ultimately depends on how human society and its economic activities evolve in the future. The IPCC has developed future socioeconomic scenarios called SRES scenarios, which give GHG emission conditions, allowing climate models to predict climate change in this century (Nakicenovic et al., 2000). The results of those estimates are summarized in the IPCC Third Assessment Report (IPCC WG1 2001) and show that the global mean surface temperature will rise by 1.4–5.8°C by the year 2100.

It is noteworthy that the range of that estimate is wide because of the different socioeconomic scenarios and climate models used.

Predictions of regional climate change show that higher latitudes have greater warming than lower ones, and that the surface of the land is warmed more than over the oceans. In northern winters, increased warming is projected over Eastern Asia, whereas in summer, stronger warming appears over the semi-arid Middle East and western China. Warming in the coastal zones is small compared with inland regions, because of the presence of the oceans.

Projections of precipitation derived by climate models show a large uncertainty, particularly within the Asia-Pacific region. General trends show increased precipitation in the tropics and in the mid- and high-latitudes, and decreased precipitation in the subtropics. In East Asia precipitation might increase in the warmer season (April–September), whereas it might decrease in the colder season (November–February) (Min et al., 2004). Global warming would also increase the intensity and frequency of strong rainfall.

Another concern is changes in tropical cyclones, specifically their frequency, intensity, seasonality, and geographical range. Maximum tropical cyclone intensities will increase 5–10% by around 2050 according to the global warming, which would be accompanied by increased higher storm surges and stronger winds. Peak precipitation rates are also estimated to increase by 25%. Although there will be no significant changes in regions of formation, the formation rate will change in some regions. This formation of tropical cyclones is strongly influenced by ENSO as well (Walsh 2004). These estimates indicate more-frequent floods and landslides, with damage to socioeconomic sectors, which will have potential impacts on the coastal zones in the region through various mechanisms.

Sea level is anticipated to rise between 9 and 88 cm by 2100 (IPCC WGI, 2001). Because the past rate of mean sea-level rise is about 2 cm/decade in the Pacific, the estimated maximum increase is some four times greater. In addition, the changes in sea level in the coastal zone are attributable to vertical land movement as well; this relative change to the land elevation is the salient factor affecting the coastal environment. If the relative sea-level rise is great, then it will have serious consequences, such as inundation of coastal low-lying coastal plains and wetlands, exacerbation of flooding attributable to storm surges and river floods, accelerated coastal erosion and saltwater intrusion into rivers and aquifers. We should note that these adverse effects appear throughout the region, and will exacerbate existing environmental problems along each coast.

Mimura (2000) performed a region-wide assessment of coastal vulnerability to climate change and sea-level rise in Asia and the Pacific region, using global datasets on climatic, environmental, and societal information. The land area within the target area is about 6.5 million km^2 and the population was 3.8 billion people in 1994; the latter is estimated to increase to 7.6 billion by 2100. This study has revealed that, even today, the areas below the high tide level and storm surge level, i.e., inundated and flooded areas, are 311,000 km^2 (0.48%) and 611,000 km^2 (0.94%) of the total land area of the region, respectively. These figures increase to 618,000 km^2 and 858,000 km^2 (0.98% and 1.32%) with a 1 m sea-level rise; thus the flooded area that is increased by sea-level rise amounts to 247,000 km^2. Regarding the people affected today, about 47 million (1.21%) of the total population lives in areas below the high tide level, while 270 million people (5.33%) live below the storm surge level. These figures show that the Asia and the Pacific region is already threatened by storm surges. If the mean sea-level rise of 1 m and the population growth by 2100 are taken into account, the above population comes to about 200 and 450 million people, respectively. The areas which would be most severely affected are distributed in the deltas of the Mekong River, the Ganges, and Brahmaputra Rivers, the Yangtze River, and the southern part of Papua New Guinea.

This assessment has several limitations; the base maps used have varying accuracy in land elevation, and the area below the storm surge level is taken uniformly to determine the flooded area, whereas flooding from storm surges seldom penetrates far inland. In addition, the study ignored future changes in tropical cyclones. In spite of such limitations, these results indicate the degree and scale of the possible impacts of future sea-level rise and climate change for the Asia and the Pacific region.

6.4 Responses Toward Sustainability of the Coastal Zones

We have seen that coastal zones in Asia and the Pacific region continue to experience unprecedented environmental changes that are driven both by pressures of local human activities and global environmental changes. Given the plausible estimates of further growth in the population and economies of the region, along with progressive global warming and climate change, increasingly ominous consequences loom ahead. The coastal environment of Asia and the Pacific is part of the global heritage, a home to the world's richest biodiversity and vast assortments of biogeophysical activities. The environment also provides a common foundation for economic, academic, cultural, and aesthetic resources for local communities throughout the region. Therefore, relevant management of the coastal zones is of great importance for the region's sustainable development.

In the face of the upsurge in local and global environmental problems, ICM has become a policy tool to address multiple management issues of the coastal zones. Following Agenda 21, which was adopted at the Earth Summit (UNCED) held in 1992, major international organizations, such as the World Bank, The World Conservation Union (IUCN), UNEP, and the OECD, successively published ICM guidelines. The common understanding behind them is that coastal zones are a unique resource system that demands special management measures.

Along with the global movement, Asian countries have moved toward introducing and establishing an ICM framework. For example, China responded to increasing pressures of population and economic development on the coasts by developing a national framework for ICM. Chinese Ocean Agenda 21 was drawn up in 1996, and the National Sea Area Use Management Law was enacted in 2001. This is the basis of today's coastal zone management. Korea also has developed a framework for ICM and coastal resource use, whereby they established an integrated coastal and ocean governance system, which was strengthened by legislation, such as the enactment and amendment of the Coastal Management Act, the Marine Pollution Prevention Act, and the Wetland Conservation Act of 1999. As an initiative for collective international efforts in the East Asia region, Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) was established in 1994, with the support of governments in the region and international organizations such as the Global Environment Facility (GEF), UNDP, and IMO. These activities indicate that the concept of ICM has been widely accepted by governments and regional organizations.

At the same time, approaches to coastal management in Asia and the Pacific regions are quite diverse. In most countries, at a local level, there still exists a range of traditional customs and sometimes a sea tenure system that governs access to coastal resources. These traditional approaches have shown remarkable resilience over time. They are often flexible and responsive to local circumstances. The goal of these approaches is to sustain resources, such as fisheries, by modifying rates and patterns of harvest, depending on local resource availability. This approach is consistent with modern concepts of sustainability (Harvey et al., 2004). Because the coastal ecosystem is a resource base for the local economy, and the well being of the local population, countries in this region tend to increasingly rely on community-based management of coastal zones. This involves local government, local enterprises, self-employed individuals, and inhabitants. Given the fact that coastal assets are important, both as an economic base and as an environmental heritage, and that local organizations and inhabitants use coastal zones as users and environmental managers, this tendency towards community-based management will become a more important, and ultimately predominant, device in overcoming constraints of environmental protection and economic development in Asia and the Pacific region.

Faced with increasing pressures and threats to coastal societies and the environment, what, then, is an appropriate response? Though ICM is widely accepted as a major concept in management, we have not yet resolved this conundrum completely. The processes required to respond to this question might consist of several components. Primarily, we must understand both past and ongoing phenomena through observation, monitoring and scientific studies on coastal processes. As a result, we will be able to predict future changes and their impacts. On the basis of the scientific understanding on the ongoing coastal changes and future prediction, we establish response strategies and options that include management policies, institutional arrangement and applicable technologies. Subsequently, we will need to implement them and evaluate their effectiveness. To promote these steps, we must form a scientific consensus, which will need to be interpreted to foster practical policies and actions. At the same time, we must build the capacity to support these activities. A sister book titled *New Directions in Global Change Coastal Research for the Asia-Pacific Region* (Harvey 2006) also explores widely the emerging issues for future research, highlighting the understanding of coastal processes and change in the Asia-Pacific region, research related to global change, scientific information for appropriate ICM methodologies, and education.

Such efforts are not the limited responsibility of the government; they should be pursued at the regional, national and even local levels of society. In order to ensure the sustainability of the coastal zones in the Asia and Pacific region all stakeholders should work together to further harmonize the above components.

References

Burke L, Selig E, Spalding M (2002) Reefs at risk in Southeast Asia. World Resources Institute, Washington DC, 72pp

Duarte CM, Cebrian J (1996) The fate of marine autotrophic production. Limnol Oceanogr 41:1758–1766

ESCAP and ADB (2000) State of the environment in Asia and Pacific 2000, economic and social commission for Asia and the Pacific and Asian development bank.

FAO (1997) Review of the state of world fishery resources: marine fisheries. FAO Fisheries Circular 920 FIRM/C920.

FAO (2003) FAO's database on mangrove area estimates. Forest resources assessment working paper No. 62. Forest Resources Division, FAO, Rome

Fortes MD (1989) Seagrasses: a resource unknown in the ASEAN region. ICLARM Education Series 5, 46pp

International Center for Living Aquatic Resources Management, Manila, Philippines.

Harada M, Nakanishi J, Yasoda E, Pinheiro MDN, Oikawa T, Guimaraes GD, Cardoso BD, Kizaki T, Ohno H (2001) Mercury pollution in the Tapajos River basin, Amazon, mercury level of head hair and health effects. Environ Intl 27(4):285–290

Harvey N, Rice M, Stevenson L (2004) Global change coastal management synthesis report, APN, 37p

Harvey N (ed) (2006) New directions in global change coastal research for the Asia-Pacific region, Springer (in press)

International Food Policy Research Institute (IFPRI) and World Fish Center (WFC) (2004) Fish to 2020. World Fish Center, pp 1–152

IPCC WGI (2001) Climate change 2001. Scientific Basis, Cambridge University Press

Kashio M (2004) Mangrove resources and management in Southeast Asia. In: Bhandari, BB, Kashio M, Nakamura R (eds) Mangrove in Southeast Asia: status, issues and challenges. Ramsar Center Japan/IGES, Tokyo, 266pp

Kuo J, Larkum AWD (1989) Seagrass taxonomy, structure and development pp 6–73 In: Larkum AWD, McComb AJ, Shepherd SA (eds) Biology of seagrasses. Elsevier, Amsterdam, 841pp

Lam CWY, Ho KC (1989) Red tides in Tolo Harbour, Hong Kong. In: Okaichi T, Anderson DM, Nemoto T (eds) Red tides: biology, environmental science and toxicology. Elsevier Science, New York, pp 49–52

Lee B (2001) Changes of oil spill response system after Sea Prince accident. Reports of international symposium of changes on OSR system in major countries/recent movement of compensation scheme. March 1–2, 2001. Petroleum Association of Japan, Tokyo. (In Japanese)

Limbong D, Kumampung J, Rimper J, Arai T, Miyazaki N (2003) Emissions and environmental implications of mercury from artisanal gold mining in north Sulawesi, Indonesia. Sci Total Environ 302:227–236

Limbong D, Kumampung J, Ayhuan D, Arai T, Miyazaki N (2004) Coastal Mar Sci 29(1):69–74

Mimura N (2000) Distribution of vulnerability and adaptation in the Asia and Pacific region. Proceedings of the APN/SURVAS/LOICZ joint conference on the coastal impacts of climate change and adaptation in the Asia-Pacific region. APN and Ibaraki University, 21–25

Min SK, Park EH, Kwon WT (2004) Future projections of East Asian climate change from multi-AOGCM ensembles of IPCC SRES scenario simulations. J Meteor Soc Jpn 82:1187–1211

Nunn PD, Mimura N (2005) Promoting sustainability on vulnerable island coasts: a case study of the smaller Pacific Islands. In: McFadden L (ed) Managing coastal vulnerability: an integrated approach (in press)

Tanabe S, Tatsukawa R (1991) Persistent organochlorines in marine mammals. In: Jones KC (ed) Organic contaminants in the environment: environmental pathways and effects. Elsevier, Amsterdam, pp 275–289

Turner RK, Subak S, Adger WN (1996) Pressures, trends and impacts in coastal zones: interactions between socioeconomic and natural systems. Environ Manag 20:159–173

UNEP (2002) GEO 3, United Nations Environment Programme, Earthscan

United Nations Population Division, (2001) World urbanization prospects: the 2001 revision

Vongvisessomjai S, Polsi R, Manotham C, Srisaengthong D, Charulukkana S (1996) Coastal erosion in the Gulf of Thailand. In: Milliman JD, Haq BU (eds) Sea-level rise and coastal subsidence. Kluwer Academic, Dordrecht, pp 131–150

Walsh K (2004) Tropical cyclones and climate change: unresolved issues. Climate Res 27:77–83

WRI (1999) East Asia. http://www.wri.org/wri/indictrs/reefasia.html

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1. B.U. Haq (ed.): *Sequence Stratigraphy and Depositional Response to Eustatic, Tectonic and Climatic Forcing.* 1995 ISBN 0-7923-3780-8
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