CHAPTER 2

STATE OF THE ENVIRONMENT IN THE ASIA AND PACIFIC COASTAL ZONES AND EFFECTS OF GLOBAL CHANGE

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2.1 INTRODUCTION

Coastal zones in Asia and the Pacific are extremely diverse in their characteristics. They extend from temperate to tropical regions and are influenced by climatic conditions ranging from short-term weather events, such as monsoons and cyclones, to inter-annual variability resulting from the El Niño-Southern Oscillation (ENSO). Various geomorphological features also exist, including deltas formed by large rivers, islands, and rocky coasts. Numerous large rivers in Asia discharge huge amounts of fresh water and sediments to the sea, accounting for about 70% of the world's sediment transport flux. Coastal ecosystems, including mangroves, coral reefs, and seagrass beds, are home to rich and diverse biological resources, which support important commercial and subsistence fisheries.

Another distinguishing characteristic of the region's coastal environment is the long-standing and significant influence of human activity. The Asia and Pacific region accommodates over half of the world's population, about 60% of which exists on or near the coasts. During the Asian countries' dramatic economic development over the past 30 years, anthropogenic pressures have increased tremendously. Economic development and changes in land cover and land use in the river basins have also affected the coastal zones through discharge of wastes, including organic matter, nutrients, and hazardous chemicals, into rivers and outfalls.

In addition, global environmental changes, particularly climate change induced by global warming, will widely increase threats on the coasts. Higher air and seawater

N. Harvey (ed.), Global Change and Integrated Coastal Management, 17–38.

temperatures, sea-level rise, and changes in precipitation, tropical cyclones, and marine conditions will all exert various impacts on the health of the biophysical environment. These impacts weaken the ability of coastal systems to adapt to the existing human-induced pressures and vice versa. The result is that coastal zones in Asia and the Pacific are under multiple and interrelated stresses.

Past and ongoing changes in coastal environments are the result of natural and socioeconomic influences and should be understood by analyzing changes in those drivers. This knowledge provides a basis for estimating future trends in the coastal environment. It is also needed to supply information necessary for ensuring sustainable development of the coastal zone in the region. However, gaining a critical understanding of past and ongoing changes is challenging and involves both identifying critical driving factors and mutually correlating them.

To date, several attempts have been made in this direction, including ESCAP and ADB (2000), UNEP (2002), and the Millennium Ecosystem Assessment (2003). Following on these efforts, the International Center for the Environmental Management of Enclosed Coastal Seas (EMECS) is working to grasp the state of the coastal environment in the region, and the results will be published as a book in parallel with this volume. This work is an overview of the current understanding of the states of the environment and drivers in the Asia and Pacific region that will be presented in the EMECS book.

2.2 OVERVIEW OF THE STATE OF THE ENVIRONMENT

2.2.1 Coastal Changes

Erosion of Asian deltas

Asian coasts are characterized by large deltas, defined as a convex coastal topography formed by seaward shoreline migration. After decades of coastal erosion, however, many Asian deltas do not exhibit natural deltaic features (Table 2.1). This erosion is caused by a decrease of sediment supplied by rivers as a result of river catchment development, such as dam construction.

For example, after the Hoa Binh Dam was constructed in 1989 on the upper reaches of the Song Hong in Vietnam, sediment delivery was decreased by more than 30% from levels before dam construction. Sediment supply to the mouth of the main distributary of the Song Hong changed from about 26 million t a^{-1} in 1949 to 11 million t a^{-1} in 2000, engendering severe coastal erosion (Tanabe et al. 2003b). The Mekong River also has several dams in its drainage basin and more than ten additional dams planned or under construction. After the Manwan Dam began operation in 1993 in the upper reaches of the Mekong in China, the sediment load in Laos declined approximately 35 million t a^{-1} (MRC 2003). The Huanghe River in China, once the second largest river in the world in terms of sediment discharge, delivers less than 10% of its past sediment load because of dam construction and irrigation. This reduction created conditions that have allowed serious coastal erosion around the river mouth in the Bohai Sea.

Table 2.1 Shoreline migration of major Asian deltas during the last 2000 years. (Data source: Saito et al., 2001, Hori et al., 2002, Ta et al., 2002, Tanabe et al., 2003a, b)

	shoreline migration during the last 2000 years	average rate (m/y)
Huanghe (Yellow River)	ca. 80 km	ca. 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

Change in relative sea level

Many places face relative sea-level change, a process that combines global and local changes in mean sea level relative to the land, including land subsidence and crustal motion. From a global change viewpoint, acceleration of beach erosion attributable to the rising sea level is a salient concern. The IPCC WGI (2001) suggested that the mean sea level has risen 10–20 cm during the 20th century, possibly exacerbating coastal erosion globally. By 2100, sea level is estimated to rise 9–88 cm globally, which is up to a four-fold increase in the past trend. Consistent with global trends, Asian coasts will generally face further serious erosion in this century. This threat will be particularly severe on the coasts, where the effects of rising sea level will be compounded by those from ground subsidence and decreased sediment supply from rivers.

The northern coast of the Gulf of Thailand is an example of the impact of a relative sea-level rise on a muddy coast. Pumping up groundwater has caused land subsidence around the Bangkok area and the Chao Phraya river mouth, which have undergone more than 60 cm of subsidence between the 1960s and 1980s. This has resulted in severe coastal erosion, and the shoreline retreat amounted to 700 m until the early 1990s (Vongvisessomjai et al. 1996). That subsidence has been stabilized since 1993 by regulation of groundwater pumping. Although the shoreline has been stabilized in the river mouth areas, coastal erosion continues to propagate westward and eastward from the river mouth.

Vulnerability of small island coasts

As with the Asian mainland, erosion poses a serious threat to small islands in the Pacific. The vulnerability of these islands is determined by the character of their coastline, the influence of large-scale environmental changes, and the condition of natural features that afford coastal protection. The coasts of most small islands in the Pacific are either cliffed or low-lying. Low-lying coasts, which are composed of sediments, are far more vulnerable to most environmental changes than are the cliffed-island coasts. Large-scale influences that can significantly increase erosion include sea-level rise and changes in wave heights and incident directions caused by El Niño.

Increased coastal erosion results from the combined effects of large-scale environmental changes, such as El Niño and sea-level rise, with loss of natural protection. Coral reefs, mangrove forests, and beach rocks protect many island coasts from destructive wave forces. Most Pacific island coasts are surrounded by coral reefs known as fringing and barrier reefs, which provide physical protection from large waves. Atolls are rings of coral reefs that enclose a shallow lagoon where a volcanic island has subsided. Many atoll reefs host islands of largely unconsolidated calcareous sand and gravel. Particularly for atolls, beach sediments are biological products, and the sediment supply is extremely limited. Where broad mangrove forests exist, they serve as a powerful protective buffer for the shoreline. However, many mangrove areas have been cleared in the past 150 years. Today, the shorelines of most low-lying coasts in the small islands are generally only lightly vegetated to allow access to the shore (Nunn and Mimura, 2005).

2.2.2 Water and Sediment Pollution

Organic pollution and eutrophication

Rapid growth of population and industrial activities has degraded environmental quality. Water pollution is the most serious problem of many countries in the region, and sewage is the major source of organic pollution in populous coastal areas. Whereas varying degrees of treatment are employed in some localities, untreated sewage is commonly disposed of either directly or indirectly. For instance in Thailand, pollutants discharged from the Chao Phraya River are the major contributor to coastal water pollution in the Upper Gulf of Thailand. The estimated biological oxygen demand (BOD) reaching the Gulf of Thailand via this river alone is 114.7 t d^{-1}. The estimate for all rivers emptying into the Gulf is 305.2 t d^{-1} (Thailand 1984).

Figure 2.1 shows BOD levels of East Asian coastal countries. It was estimated that 6 million tons of BOD are generated by coastal populations of countries neighboring the South China Sea, including Cambodia, China, Indonesia, Malaysia, Philippines, Thailand and Vietnam. Sewage treatment removes only about 11% of the generated BOD. A need to raise the volume removed by sewage treatment clearly exists, especially for large urban areas.

Eutrophication in coastal waters receiving high organic inputs from domestic and industrial effluents is common in the region. Eutrophication is associated with blooms of phytoplankton known as “red tides”. In particular, red tides have been reported frequently in Malaysia, the Philippines, Thailand, Hong Kong, and Seto Inland Sea in Japan. In Hong Kong, an eight-fold increase was reported in the number of red tides per year in Hong Kong Harbor during 1976–1986, which was attributed to the 6-fold increase in population and a concurrent 2.5-fold increase in nutrient loading (Lam and Ho 1989).

Japan’s Seto Inland Sea also suffered from severe water pollution and negative effects of eutrophication about 30–40 years ago. During the period of rapid national economic growth in the mid-1960s to mid-1970s, increased industrial activities and expansion of landfills in waterfronts caused rapid increases in water pollution, reduction of shallow water areas, and destruction of marine habitats. Concurrently, there was an increase in the frequency of red tide events (Figure 2.2)

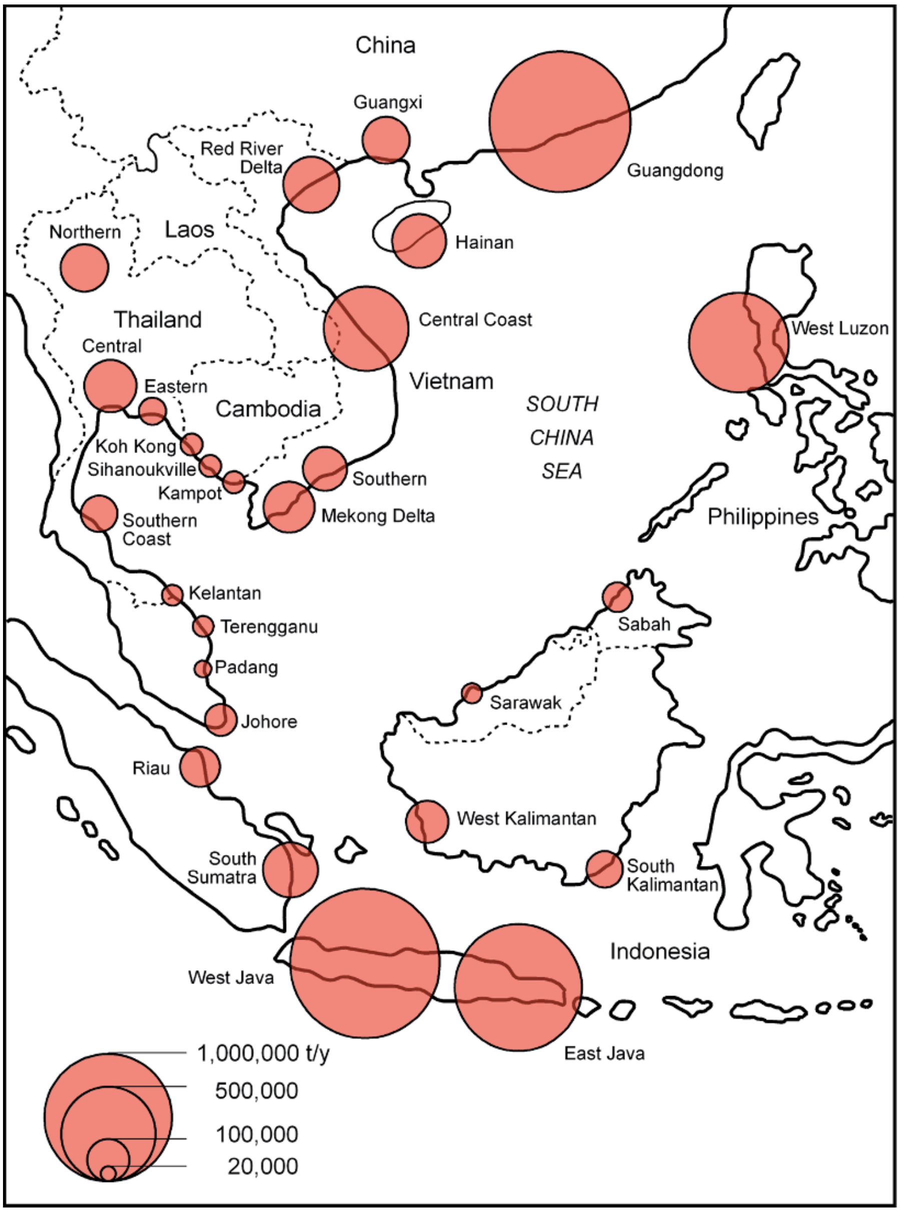

Figure 2.1. Biochemical Oxygen Demand (BOD) loading from domestic sources in East Asian Seas (*Source*: UNEP, 2000).

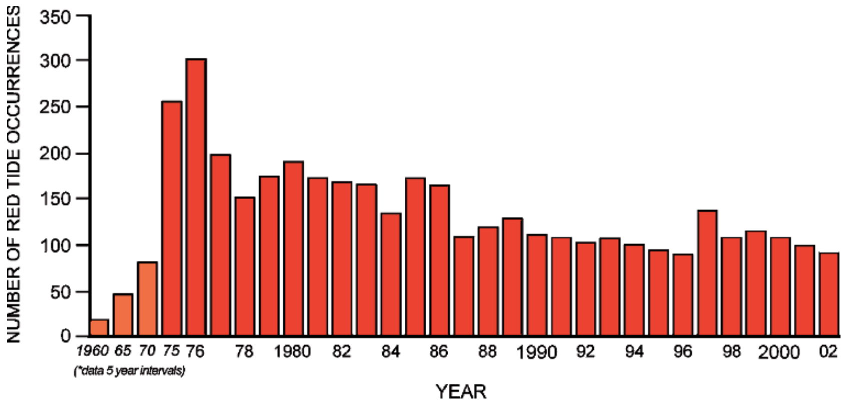

Figure 2.2. Change in the number of occurrences of red tide in the Seto Inland Sea, Japan

with notable consequences for aquaculture activities in the affected areas. For example, around 300 occurrences were recorded in 1976 causing mass mortality of caged fish cultures. In 1972, 14 million cultured yellowtails were killed by red tide, resulting in economic losses of 7.1 billion yen. In recent years, as a consequence of various environmental conservation measures, red tide bloom incidents have been reduced to around 100 events annually.

During that period of heavy pollution, the Seto Inland Sea was called “the dying sea”, but it has slowly recovered by virtue of the efforts of various groups and the support of a strong 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 an important role in environmental conservation of the area. Through total Chemical Oxygen Demand (COD) load control enforced by the law, COD discharged in the coastal zone of the Seto Inland Sea was remarkably reduced from 1,700 t d^{-1} in 1972 to 718 t d^{-1} in 1996 (Figure 2.3). Unfortunately, the achievements recorded in relation to the Seto Inland Sea are rare cases, and the region needs greater efforts to reduce the discharge of organic pollutants and nutrients in order to control the occurrence of red tide.

Hazardous chemicals

Discharge of chemicals into the sea by industrial effluents and enhanced use of agrochemicals on land is a common difficulty. An estimated 1,800 tons of pesticides were transported into the Bay of Bengal (Holmgren 1994). 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, accumulate in fatty tissues of living organisms,

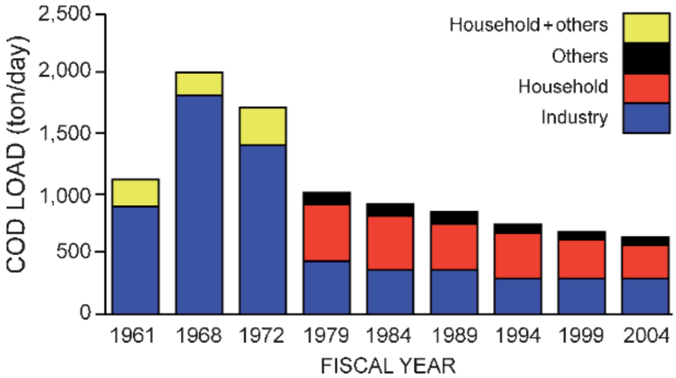

Figure 2.3. Trend in the change of total amount of Chemical Oxygen Demand (COD) load in the Seto Inland Sea, Japan

and are toxic to animals and humans. Among them, organochlorine compounds (OCs) have been recognized as endocrine disrupters, which pose serious effects on marine animals through bioaccumulation. The levels of dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCBs) in dolphins are considerably higher than other OCs because they are highly persistent, relatively lipophilic and less biodegradable (Tanabe and Tatsukawa 1991). The maximum level of DDT, ranging from 80–96 μg/g wet weight, was found in northern right whale dolphins from temperate waters. Since DDT was discharged from tropical countries, where it remains in use to control malaria, it is of interest that similar concentrations of DDT were observed in animals of tropical waters.

Butyltin compounds (BTs) are another typical hazardous chemical. Since the 1960s, BTs have been used worldwide for various purposes such as anti-fouling agents in paints for boats and aquaculture nets. The International Maritime Organization (IMO) prohibited the use of harmful organotins in anti-fouling paints used on ships in 2001. BTs concentrations in the marine mammals are higher for the coastal waters than for pelagic waters (Tanabe et al. 1998), and animals in 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. Regarding 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. The people around Minamata city, Japan, are known to have suffered from severe mercury pollution called "Minamata Disease" from the 1950s to the 1970s. After 22 years of controversial discussions and a judicial ruling in 2004, they still face grim human health problems. 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 in these areas face the risk of severe and irreversible health problems from eating fish and marine animals (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 discharge and loading. Oil spills cause severe pollution in ports in Bangladesh, Pakistan, and countries in Southeast Asia, and Sri Lanka's south-eastern beaches have frequently been affected by tar-balls (UNEP, 2002). The frequency and wide distribution of oil spills has led to the development of strict regulations in many countries of the Southeast Asian region. Countries in East Asia have also faced oil-spill problems. For example, accidents are quite frequent, particularly if small-scale spills are included in the accounting. In Japanese waters alone, spills of over 2 kl occur 400 times or more a year, according to annual reports by the Japan Coast Guard in the past ten years. Table 2.2 shows the list of large-scale accidents that have occurred in Japan, South Korea, China, and Taiwan over a recent 10-year period.

A large-scale accident is often devastating to coastal environments and can require a resource-intensive recovery effort. Here, we present the case of the *Sea Prince* in Korea. In July, 1995, the oil tanker *Sea Prince* loaded with 260,000 tons of crude oil from Saudi Arabia grounded on submerged rocks near Sori Island because of a typhoon. After the collision, a fire started in the engine room (Figure 2.4) and 5,035 tons of oil was spilled. Oil from the ship spread more than 200 km along the shoreline, which was characterized by rocky coasts and sandy beaches. The most seriously affected area was along Sori Island and the neighboring coasts of Busan and Ulsan. Nineteen days were required to recover 1,390 kl of the discharged oil.

Table 2.2 List of oil spills occurring around the Northwest Pacific region (Sawano, 2003)

Date (YMD)	Country	Place	Vessel	Amount	Type of oil
1992.5.1	Japan	Kushiro, Hokkaido	Shell Oil base	246 kl	Unknown
1993.9.27	S. 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	S. Korea	Jeonnam Yeocheonsi Sori Island	Sea Prince	5,035 kl	Crude/ bunker
1995.9.20	S. Korea	Busan South Hoyongie Island	No. 1 Yuilu	Unknown	Unknown
1995.11.17	S. Korea	Jeonnamyeosu Honam Oil Refinery berth	Honam Sapphire	1,402 kl	Crude
1996.9.19	S. Korea	Nine miles from Jeonnam Yoso Island	Ocean Joedo	207 kl	Heavy B-C
1997.1.2	Japan	Near Oki Island, Shimane Pref.	Nakhodka	8,660 kl *1	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

**1 – This volume is based on Sao (1998), official value announced by Japan Coast Guard was 6,240 kl.*

Figure 2.4. Firing Sea Prince near Yosu, Sori Island This photograph is quoted from Korean Ministry of Maritime Affairs and Fishery (2002)

Police and local residents cleaned contaminated areas, mostly manually. Cleanup operations along the shorelines continued for five months (Lee 2001).

2.2.3 Coastal Ecosystems

Mangroves

Mangrove forests are widely distributed throughout Asia and the Pacific islands with approximately 40% of the world's mangroves found in Asia. Large areas of mangrove forests exist in India, Bangladesh, Burma, Thailand, Vietnam, Malaysia, the Philippines, and Indonesia. Among them, 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. Mangrove forests are extremely biodiverse and act as a nursery and spawning ground for numerous species of fish, crustaceans, molluscs, and reptiles. They are also important for the daily lives and economies of local societies, providing a myriad of goods and services.

Asian countries are estimated to have lost about 26% of their mangrove area during the 20 years period from 1980 to 2000 (FAO 2003a; Kashio 2004). The annual rates of decrease are 1.6% from 1980 to 1990, and 1.4% from 1990 to 2000. Causes of mangrove degradation include conversion to shrimp ponds, felling of timber for charcoal, firewood, wood chips and pulp production, development of human settlements, ports, agriculture, 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).

Clearing and degradation creates serious impacts on mangrove ecosystems and neighbouring coastal areas. Destruction of mangroves directly degrades biodiversity of both flora and fauna, lowers productivity, and causes the eventual loss of fish and shrimp. Clearing mangroves also alters soil characteristics in many ways, such as through increased sediment transport and soil erosion. Importantly, mangroves serve as 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, into coastal areas, which adversely affects 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. The Asia-Pacific region has been recognized as the global centre of tropical marine biodiversity. About four-fifths of the world's coral reefs are in the region, with about half in the Pacific, one-third in the Indian Ocean, and the remainder in South Asia (ESCAP and ADB 2000). Fifty of seventy 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 the Asia-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 facilities, often causes not only direct destruction, but also indirect impacts, such as discharge of sediments and nutrients that cause high turbidity in the sea. Destructive fishing practices, such as the use of explosives and cyanide, still constitute a major problem. Growth of the live fish trade in the region has fuelled the wide use of cyanide fishing, which has severe effects on juvenile fish and coral organisms. In addition, coral reefs are often damaged physically by fishing equipment, diver interactions, and anchors. Dredging and filling for ports and fishery harbours are other causes.

In Southeast Asia, 88% of the coral reefs face a medium to very high threat from human impacts. 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, and 10% face a high risk (WRI 1999).

Global environmental changes, particularly global warming, will increasingly threaten coral reefs as demonstrated by the spread of coral bleaching in 1997–1998. Bleaching occurred globally during that period, including in the Pacific, Indian Ocean, and Caribbean regions (Figure 2.5). Although the immediate trigger for this event was increased sea temperatures related to the 1997 El Niño, long-term rises in seawater temperature potentially contributed to it (Walther et al. 2002). Damage by coral bleaching continued after the 1998 event. Most reefs damaged in 1998 have been recovering in Japan. However, 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 is also suggested that rising sea level would inundate coral reefs if the rate of sea level rise were faster than the coral reefs' upward growth rate. Healthy coral reefs are better able to keep up with rising sea level and recover from coral bleaching damage.

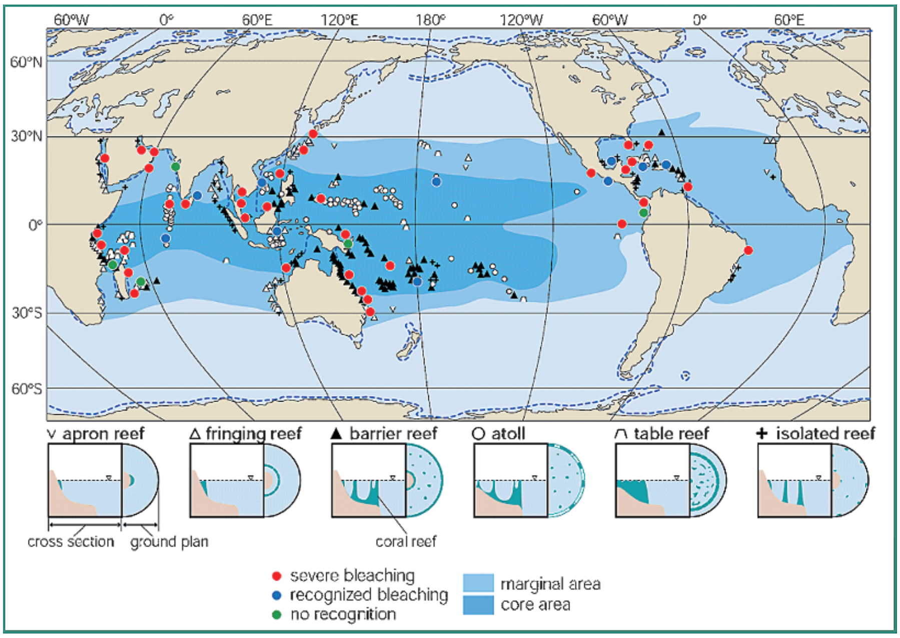

Figure 2.5. Bleaching of coral reefs reported from 1997 to 1998 (Source: Mimura and Harasawa (ed.) (2000). Revised from Wilkinson (1998) and Hori (1980))

Therefore, the combined stress of local human activities and global warming should be given attention by management.

Sea grass beds

Seagrass beds grow best in estuaries and lagoons where they are often associated with mangrove forests and coral reefs. 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. 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 to southern Japan, followed by the Red Sea and East Africa. So far, 16 species of seagrasses have been identified in Philippine waters, and 14 species have been reported from Indonesia. Australia's 30 seagrass species represents the highest diversity in the region (Fortes 1989, Kuo and Larkum 1989). Seagrass beds can also exist in other areas, although they are often less dense.

In Southeast Asia, seagrasses are under threat from the loss of mangroves, which act as a buffer that filters discharged sediments. They are also threatened by agricultural runoff, industrial wastes, and sewage discharges. In Indonesia, about 30–40% of the seagrass beds have been lost in the last 50 years, including a loss of 60% for the seagrass beds around Java. In Singapore, the patchy seagrass habitats have suffered severe damage largely through burial under landfill operations. Losses of the beds respectively amount to 20–30% and 30–50% in Thailand and the Philippines. Coastal eutrophication is a major long-term threat to seagrass ecosystems in Southeast Asia because it reduces light exposure, thereby retarding the growth of many plants.

2.2.4 Fisheries and Aquaculture

Marine fisheries

People in the Asia-Pacific region have long relied on fish and fishery products as a major protein source. According to FAO data, the region's fish catch amounted to 44.7 million tons, or 48% of the total global production, in 2002. Five Asian countries are among the top-ten producers: China, Indonesia, Japan, India, and Thailand. Therefore, the 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).

Figure 2.6 shows the long-term trend of fisheries production in Asia, excluding China. During the 1950s to the 1970s, fisheries in the region showed rapid development through structural changes in production and technologies. Through modernization of fishing technology and the use of engines for boats, many traditional and subsistence fisheries evolved into a productive and market-oriented industry.

In the 1990s, the total fisheries production in the Asia-Pacific region fell into stagnation after having reached a peak of 29 millions tons in 1989. The largest

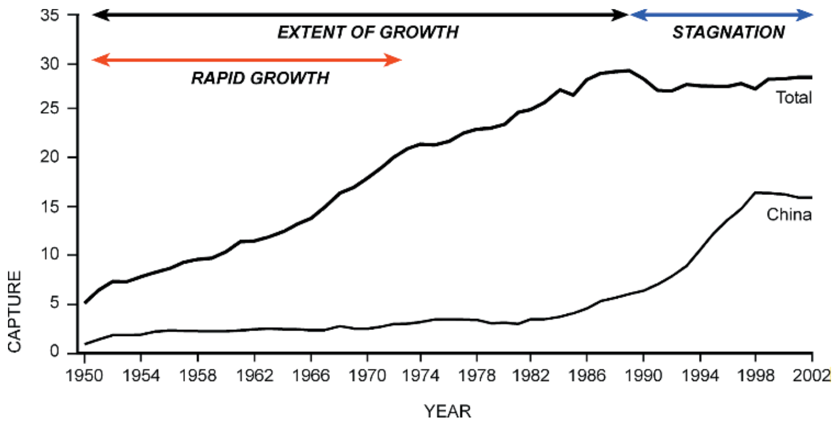

Figure 2.6. Production in capture fisheries in China and Asia excluding China between 1950 and 2002

component, the marine fisheries, had started full-scale development in the early 1960s, and reached a turning point in the late 1980s. The marine fisheries production peaked at 24.7 million tons in 1989 and fluctuated after that. The fractions of pelagic and demersal fish catches in the marine fishery have also changed. The trend in pelagic landings shows a moderate increase from about 2 million to 5.5 million tons between 1950 and 1973, followed by a period of rapid growth that reached a peak of nearly 11.7 million tons in 1988. Thereafter, the fish catch declined to 9.4 million tons by 2002 (after FAO 2003b). Simultaneously, the catch of demersal fish increased gradually from 1.5 million tons in 1950 to 5.2 million tons in 1974, then decreased to nearly 4 million tons in 1983. The rapid increase of 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. However, the region faces heavy overfishing, which has raised the question of how to maintain fishery resources for future sustainable use.

Aquaculture development

During its growth throughout the Asia-Pacific region, aquaculture production has increased at a rate four times faster than production from capture fisheries. In addition, aquaculture's share of all fish landings increased from 20.7% 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 (IFPIC and WFC 2004). Freshwater culture, rather than marine culture, used to dominate the industry. Since the 1980s, however, technological innovation has advanced rapidly in marine and brackish water aquaculture, thereby contributing to the rapid increase in production over the Asia-Pacific region.

Such rapid development in aquacultural production has adversely affected the coastal environment, including mangrove clearing 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).

2.3 POPULATION GROWTH AND ECONOMIC DEVELOPMENT AS DRIVERS OF ENVIRONMENTAL PROBLEMS

Coastal zones in Asia and the Pacific region continue to experience tremendous and rapid changes, as shown in the previous section. They have been driven by various factors, including natural forces of climatic and oceanographic phenomena, human activities, including discharge of land-based and sea-based pollutants, and processes controlling the flows of material and energy within the coastal ecosystems. Among the drivers of those changes pressures from human activities that are conducted in the coastal zones appear 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 the Asia-Pacific region is home to over half of the world's population with expectations that this ratio will remain in a similar range throughout 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 in 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 coastal populations are growing 20% faster than the remainder of the country (Hinrichsen 1998).

Population growth has exacerbated the trend of an increasing number of megacities (those with 10 million inhabitants or more), as shown in Table 2.3. In 1950, New York was the world's sole megacity. Megacities multiplied from five in 1975 to 17 in 2001. Among them, 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 21 by the year 2015. Tokyo, Dhaka, and Mumbai (Bombay) are each expected to hold more than 20 million inhabitants (United Nations Population Division 2001).

The Asia-Pacific region has emerged as a leading growth region. Concurrent with increased economic activity has been an 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 occurring concomitant with the population increase. 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.

Table 2.3 Population of cities with 10 million inhabitants or more, 1950, 1975, 2001 and 2015 (millions)

City	Population
Year of 1950	
1 New York	12.3
Year of 1975	
1 Tokyo	19.8
2 New York	15.9
3 Shanghai	11.4
4 Mexico City	10.7
5 Sao Paulo	10.3

City	Population
Year of 2001	
1 Tokyo	26.5
2 Sao Paulo	18.3
3 Mexico City	18.3
4 New York	16.8
5 Mumbai (Bombay)	16.5
6 Los Angeles	13.3
7 Calcutta	13.3
8 Dhaka	13.2
9 Delhi	13.0
10 Shanghai	12.8
11 Buenos Aires	12.1
12 Jakarta	11.4
13 Osaka	11.0
14 Beijing	10.8
15 Rio de Janeiro	10.8
16 Karachi	10.4
17 Metro Manila	10.1

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

Note: Shaded mega-cities are located in coastal zones of Asia
(Sources: United Nations Population Division, 2001) World Urbanization Prospects: The 2001 Revision)

Given the relentless and cumulative processes of 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). The high concentration of people and the rapid economic growth in coastal regions has produced many economic benefits, including improved transportation links, industrial and urban development, revenue from tourism, and food production. However, the combined effects of booming population growth 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. These trends are expected to continue and intensify in the future.

2.4 EFFECTS OF CLIMATE CHANGE AND SEA-LEVEL RISE

Another major factor driving future coastal change will be global environmental changes, in particular climate change induced by global warming. Some effects of global warming have already been felt, although, it is difficult to isolate these effects in observations. As warming proceeds, however, its effects will become more profound in this century.

The IPCC WGI (2001) indicated that the global mean surface temperature has already risen by 0.6°C ± 0.2°C during the past century. The degree of global warming varies with the emission of greenhouse gases (GHGs) such as CO_2. Therefore, the future extent of warming will ultimately depend on how human society and its economic activities develop in the future. The IPCC has developed future socioeconomic scenarios called SRES scenarios, which give GHG emission conditions for climate models to predict climate change in this century (Nakicenovic et al. 2000). Results of those estimates summarized in the IPCC Third Assessment Report (IPCC WG1 2001) show that the global mean surface temperature will rise 1.4°C to 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.

Figure 2.7 shows spatial distributions of increased mean temperatures for northern winter (DJF; December–February) and northern summer (JJA; June–August) during 2081–2100, which are obtained by averaging predictions of 14 different climate models using an IPCC SRES emission scenario. This scenario shows that higher latitudes have larger warming than the lower latitudes, and that the land surface is warmed more than over the oceans. In northern winters, increased warming is projected over Eastern Asia, whereas in northern summer, stronger warming appears over the semi-arid Middle East and western China. Warming in the coastal zones is light compared with that of the inland regions because of the influence of oceans.

Projections of precipitation derived by the climate models show large variability, particularly within the region. General trends are increased precipitation in the tropics and in mid-latitudes 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

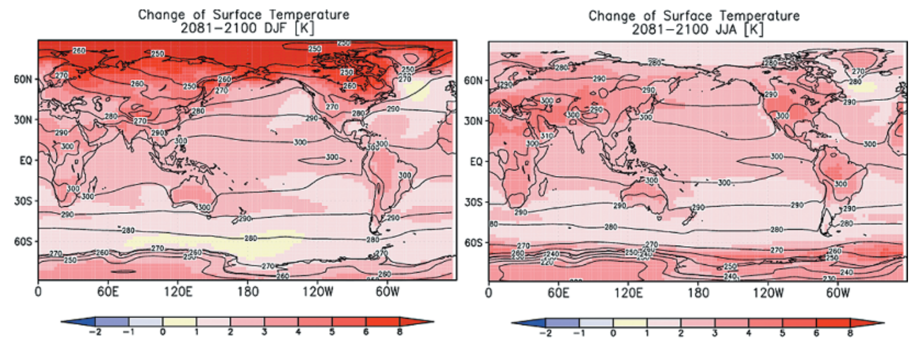

Figure 2.7. Global distribution of mean surface air temperature for northern winter (DJF; December–February) and northern summer (JJA; June–August). The present-day model climate (1981–2000) is shown by contours and its changes for 2081–2100 are by shading

(November–February) (Min et al. 2004). Global warming would also increase the amplitude and frequency of strong rainfalls.

Another concern is changes in tropical cyclones, specifically their frequency, intensity, seasonality, and geographical range. Although convincing evidence of change is not available in the observed records of tropical cyclone behaviour, the frequency of maximum-intensity tropical cyclones is expected to increase by 5–10% by around 2050. Similarly, the frequency of mean-intensity tropical cyclones is also expected to increase. Consequently, peak precipitation rates are estimated to increase by 25%. No significant change is expected as far as the geographic regions in which cyclones form; however, the formation rate may change in some regions. This formation is also strongly influenced by ENSO (Walsh 2004). These estimates indicate an increase in the frequency of floods and landslides resulting in damage to socio-economic sectors and potential impacts on the coastal zones in the region through various mechanisms.

The sea level is anticipated to rise between 9 cm and 88 cm by 2100 (IPCC WGI 2001). Because the past rate of mean sea-level rise is about 2 cm per decade in the Pacific, the estimated maximum increase is some four times greater. In addition, the changes in the sea level in the coastal zone are attributable to vertical land movement as well. This relative change to the land elevation is a salient factor affecting the coastal environment. If the relative sea-level rise becomes large, serious effects will appear 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 exacerbate existing environmental problems in each coast.

A risk assessment of coastal areas serves to illustrate the potential effects of climate change. There have been a number of country studies on the vulnerability of climate change and sea-level rise in the Asia-Pacific region. However, difficulties in gaining a comprehensive picture of future threats based on country studies prompted Mimura (2000) to perform a region-wide assessment. He investigated the impacts of sea-level rise and storm surges using global datasets on climatic, environmental, and societal information targeting the whole Asia-Pacific region. This study area extends from 30°E to 165°S and from 90°N to 60°S and includes a land area of 6.5 million km^2. The population within this area is estimated using Bos et al. (1994) to increase from 3.8 billion people in 1994 to 7.6 billion in 2100.

By combining sea-level rise, astronomical tide, and storm surge, future scenarios of sea level were set at two points in time: 2000 and 2100. An analysis of tropical cyclones data observed from 1949 to 1989 was used to determine the highest storm surge level at each coastal segment in the region. The study assumes that global warming will not change tropical cyclones, thus storm surges, from those of the past 40 years. The study was further constrained by the accuracy of land elevation in the base maps used and the need to treat storm surge uniformly in determining the flooded area, although, storm surge flooding seldom penetrates far inland. In spite of such constraints, these results indicate the degree and scale of possible impacts from future sea-level rise and climate change for the Asia-Pacific region.

This study has revealed that, even today, the land area of the region below high tide level and storm surge level, (i.e. inundated and flooded areas) is 311,000 km^2, or 0.48% of the total land area, and 611,000 km^2, or 0.94%, respectively. The land area increase to 618,000 km^2 and 858,000 km^2 (0.98% and 1.32%) with a 1 m sea-level rise, resulting in an 247,000 km^2 increase in flooded area.

The study also showed that people in the Asia-Pacific region are already threatened by storm surges. Today, about 47 million people, or 1.21% of the total population, live in areas below high tide level, while 270 million people or 5.33% live below storm surge level. If the mean sea level rise of 1 m and the population growth estimates for 2100 are taken into account, the affected population becomes approximately 200 and 450 million people. The areas that would be severely affected are distributed in the deltas of the Mekong River, Ganges and Brahmaputra Rivers, and Yangtze River, and the southern part of Papua New Guinea. The countries and areas where more than 10% of the national population may be affected include Vietnam, Taiwan, Cambodia, Brunei, Bangladesh, and small islands in the Pacific.

2.5 CONCLUSIONS: RESPONSE BY INTEGRATED COASTAL MANAGEMENT

We have seen that coastal zones in the Asia-Pacific region continue to experience unprecedented environmental changes that are driven both by pressures of local human societies and global environmental changes. Given the plausible estimates for future growth in the region’s population and economies, in combination with progressing global warming and climate change, it appears that increasingly ominous consequences loom ahead. As the home of the world’s richest biodiversity and a vast assortment of biogeophysical processes, the coastal environment in Asia and the Pacific is a global heritage. The environment also provides a common foundation for economic, cultural, and aesthetic resources for local communities throughout the region. Therefore, relevant management of the coastal zones is of essential importance for the region’s sustainable development.

What is an appropriate response to the increasing pressures and threats facing coastal societies and the environment? We have not yet resolved this conundrum. The processes to respond to this question might consist of several components. Primarily, we must understand the past and ongoing phenomena through observations and scientific studies on coastal processes. With this understanding, we can predict future changes and their impacts in order to establish response strategies and options for management policies. Fostering practical policies and actions requires both collecting and interpreting scientific information and building the capacity to support these activities. Subsequently, we must implement appropriate responses and evaluate their effects. Responsibility for such efforts is not limited to government, and responses should be pursued at the regional, national, and even local levels of society.

In the face of the upwelling of local and global environmental problems, Integrated Coastal Management (ICM) has been proposed as a relevant framework for management of coastal zones. ICM has drawn attention globally as a policy tool that engenders a comprehensive framework to address multiple management issues. 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 (1995) successively published ICM guidelines. The common understanding behind them is that the 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 ICM at both national and regional levels. For example, in China the government has developed a framework for ICM to respond to increasing pressures of population and economic development on the coasts. Chinese Ocean Agenda 21 was developed in 1996, and the National Sea Area Use Management Law, the basis of today's coastal zone management, was enacted in 2001. Korea also has developed a framework for ICM that establishes an integrated coastal and ocean governance system strengthened by legislative actions, such as the Coastal Management Act, the Marine Pollution Prevention Act, and the Wetland Conservation Act (1999) (PEMSEA, 2003). 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 governments in the region and international organizations such as the Global Environment Facility (GEF), UNDP, and IMO. These activities signal that the concept of ICM has been widely accepted by governments and regional organizations.

In addition to national and regional efforts, countries of this region are increasingly relying on community-based management of coastal zones, which involves local government, local enterprises, self-employed individuals, and inhabitants. Community-based management recognizes that local organizations and inhabitants often relate to coastal environments as both resource users and ecosystem stewards because the community's well-being is closely linked to coastal resource condition. In some countries, this reliance is reflected in a range of traditional customs or sea tenure systems that still governs access to coastal resources at a local level. 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. 2005).

Different types of coastal management with different concepts and background are being practiced in the region. Through these practices each country and each local community will find the most relevant scheme to manage the valuable coastal resources of the Asia-Pacific region.

ACKNOWLEDGEMENTS

This overview is the main result of contributions to the book *Asian-Pacific Coasts and Their Management: States of Environment*, prepared by the International EMECS Center. I sincerely appreciate the authors of the book, who prepared relevant drafts to the sections of this paper indicated in parentheses: Tetsuo Yanagi (2.1), Yoshiki Saito (2.2.1), Piamsak Menasveta (2.2.2), Osamu Matsuda (2.2.2), Nobuyuki Miyazaki (2.2.2), Nobuhiro Sawano (2.2.2), Toyohiko Miyagi (2.2.3), Thamasak Yeemin (2.2.3), Miguel Fortes (2.2.3), Masahiro Yamao (2.2.4), Jingshan Yu (2.3.1), Haruyuki Kojima (2.3.1), Akio Kito (2.3.2), and Kwangwoo Cho (2.3.2). I also express my appreciation to the members of the book's Editorial Committee and the Secretariat of the International EMECS Center.

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