3
Environment Problems in the Coastal Zone

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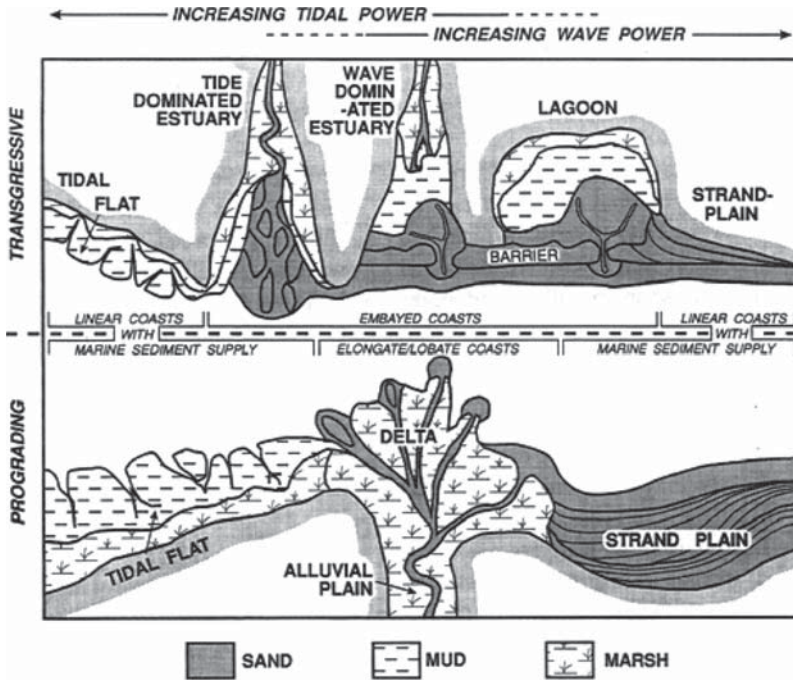
Fɪɢ. 3.1.1. Coastal depositional systems. (After Boyd et al., 1992.)

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
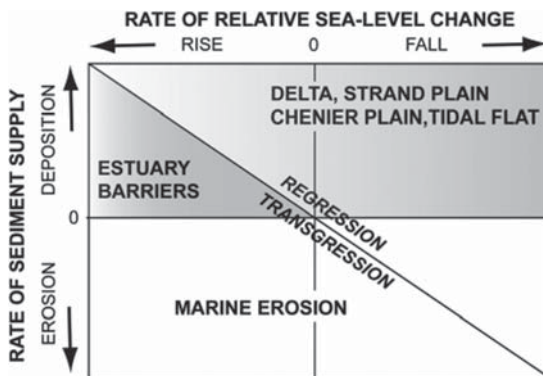

Fig. 3.1.2. Factors controlling shoreline migration. (Modified after Curray, 1964.)

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 sub-parallel 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
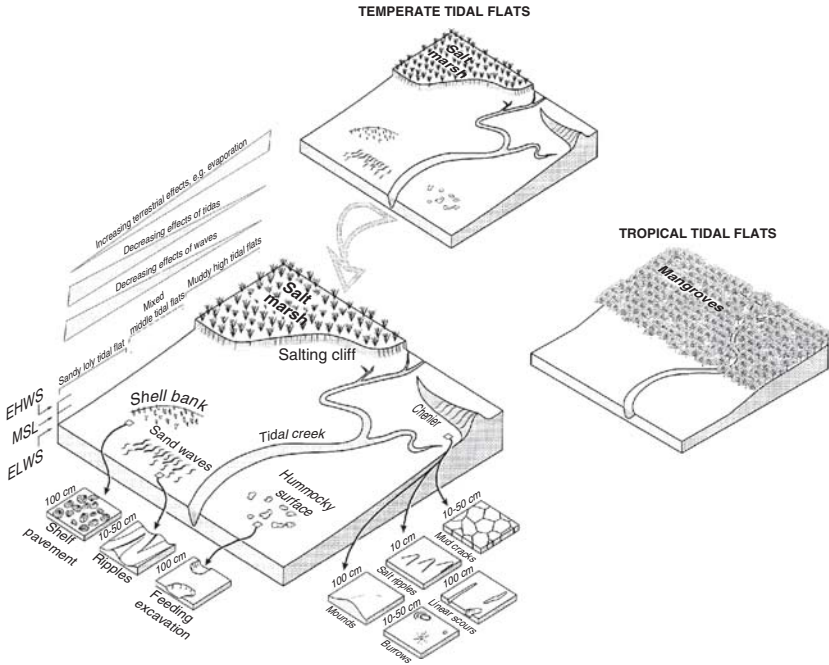
F<small>IG</small>. 3.1.4. Coastal features of a tide-dominated coast. (After Semeniuk, 2005.)

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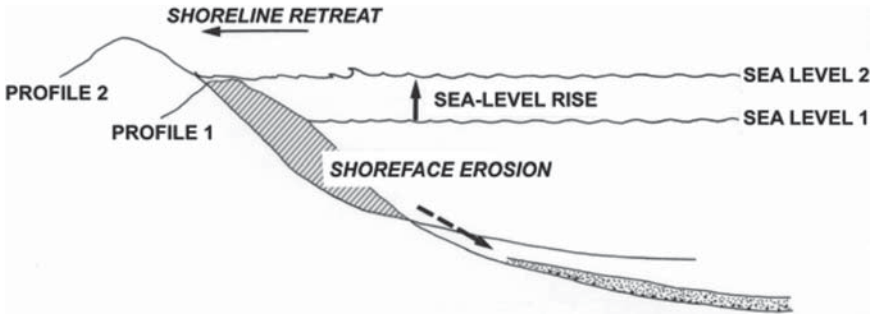
Fɪɢ. 3.1.5. Shoreface erosion due to a sea-level rise. (After Bruun 1962; Saito 1989.)

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
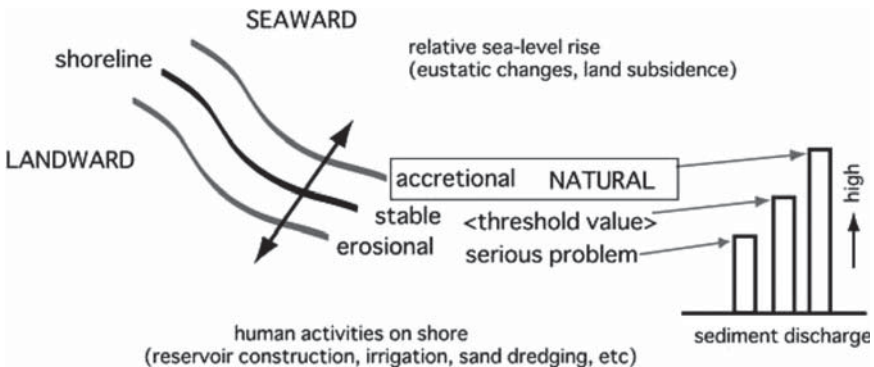

FIG. 3.1.6. Shoreline migration/retreat in relation to sediment discharge from rivers. (After Saito 2005b.)

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.

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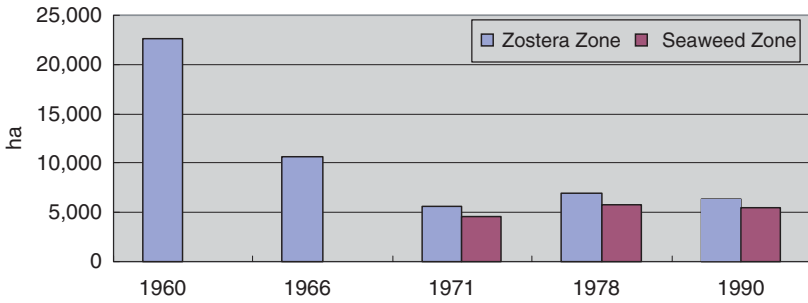
Fɪɢ. 3.2.1. Changes of areas of *Zosteria* and seaweed zones in the Seto Inland Sea. (After Okaichi and Yanagi 1997.)
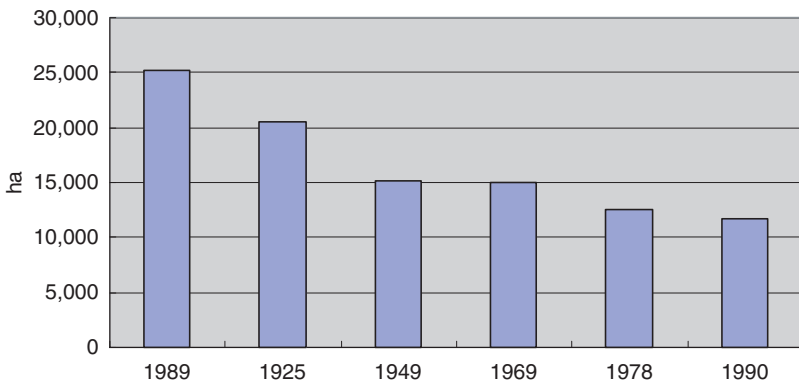

Fɪɢ. 3.2.2. Changes of areas tidal flats in the Seto Inland Sea. (After Okaichi and Yanagi 1997.)

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
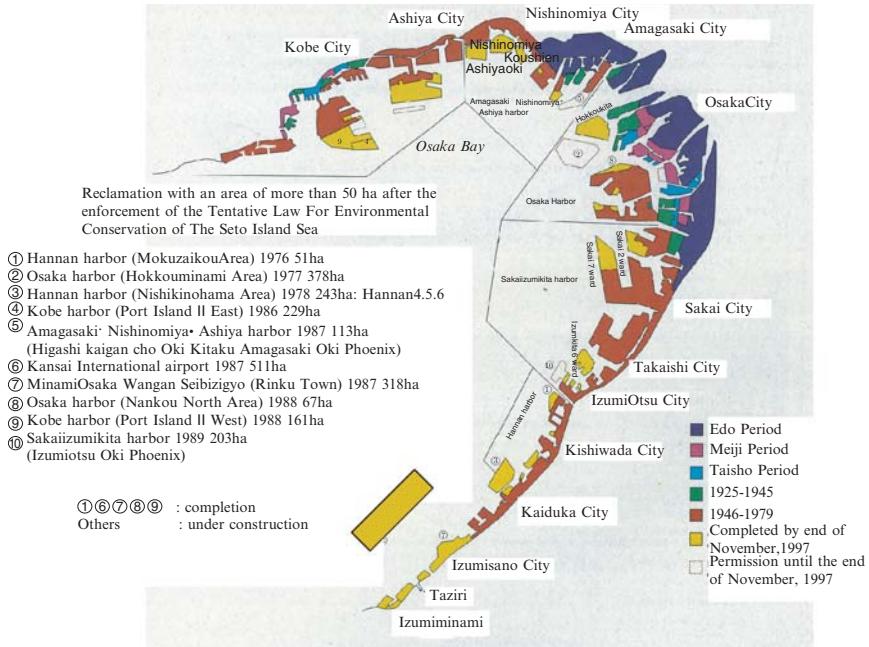
Reclamation with an area of more than 50 ha after the enforcement of the Tentative Law For Environmental Conservation of The Seto Island Sea

① Hannan harbor (MokuzaikouArea) 1976 51ha
② Osaka harbor (Hokkouminami Area) 1977 378ha
③ Hannan harbor (Nishikinohama Area) 1978 243ha: Hannan4.5.6
④ Kobe harbor (Port Island II East) 1986 229ha
⑤ Amagasaki· Nishinomiya• Ashiya harbor 1987 113ha
   (Higashi kaigan cho Oki Kitaku Amagasaki Oki Phoenix)
⑥ Kansai International airport 1987 511ha
⑦ MinamiOsaka Wangan Seibizigyo (Rinku Town) 1987 318ha
⑧ Osaka harbor (Nankou North Area) 1988 67ha
⑨ Kobe harbor (Port Island II West) 1988 161ha
⑩ Sakaiizumikita harbor 1989 203ha
   (Izumiotsu Oki Phoenix)

①⑥⑦⑧⑨ : completion
Others   : under construction

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.
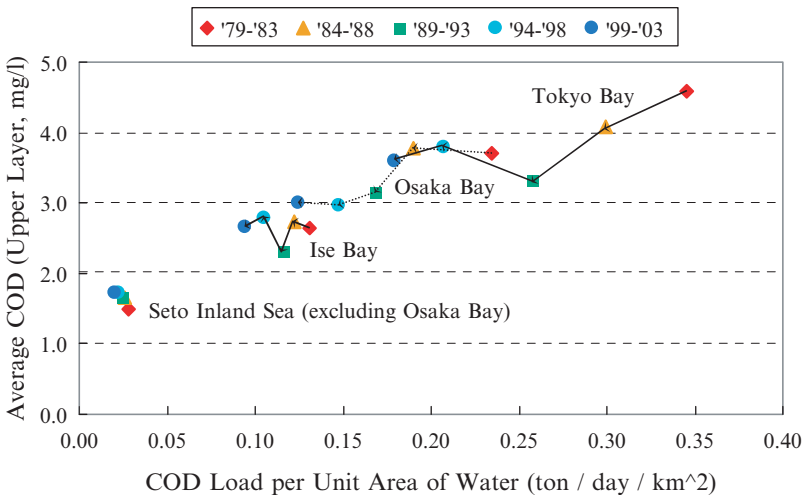

Fig. 3.2.5. Relationship between COD load and average COD concentration of sea water. (After Ministry of Environment of Japan 2005.)

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.
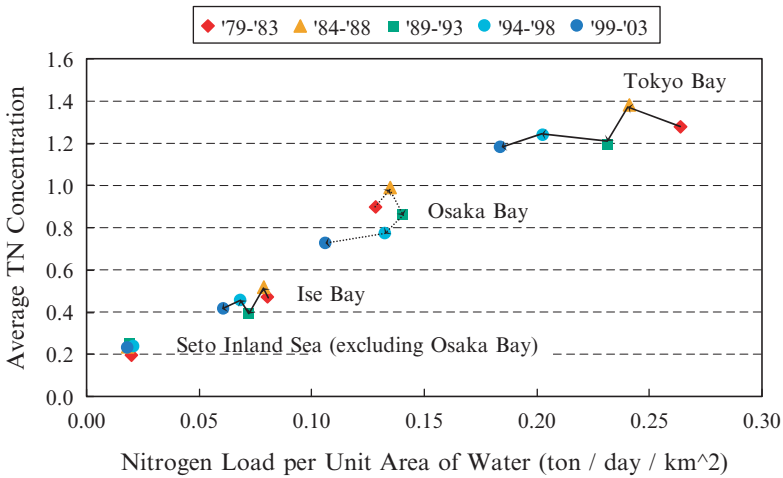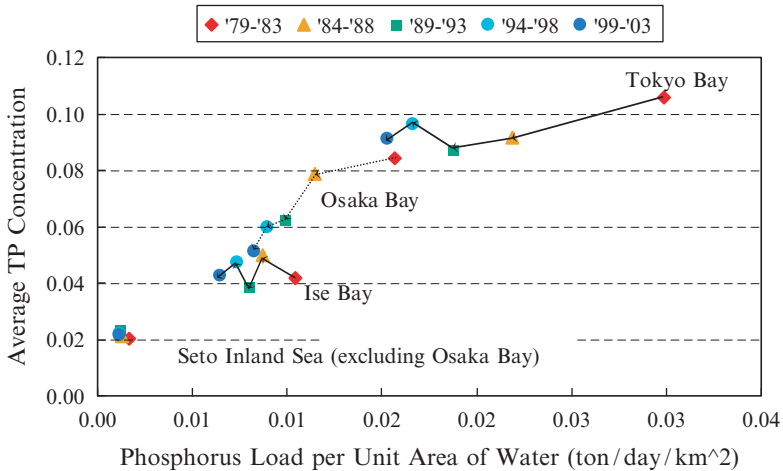

FIG. 3.2.6. Relationship between TN load and average TN concentration of sea water. (After Ministry of Environment of Japan 2005.)

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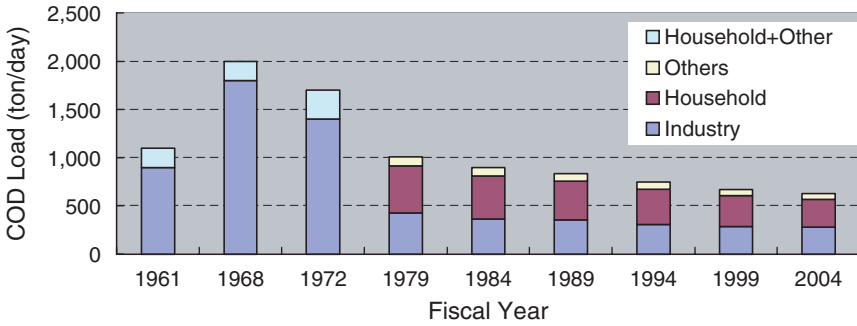
FIG. 3.2.8. Trends in the change of COD load classified into pollutant types in the the Seto Inland Sea. (After Ministry of Environment of Japan 2005.)
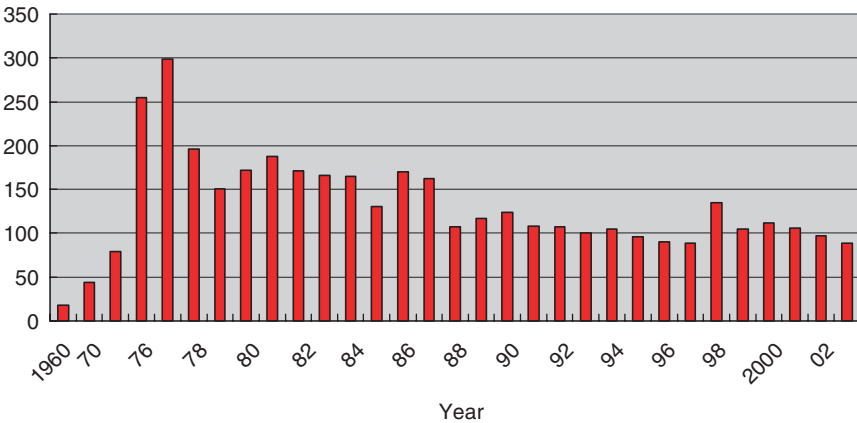

FIG. 3.2.9. Changes in the number of occurrences of red tide in the Seto Inland Sea. (After Ministry of Environment of Japan 2005.)

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
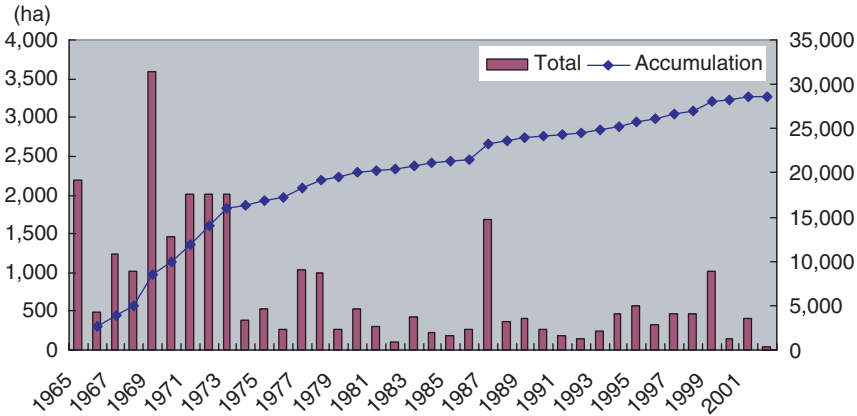
F_{IG}. 3.2.10. Trends in areas for which reclamation has been authorized. (After Ministry of Environment of Japan 2005.)

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.

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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 (NO_3, NO_2, NH_3 and PO_4), 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
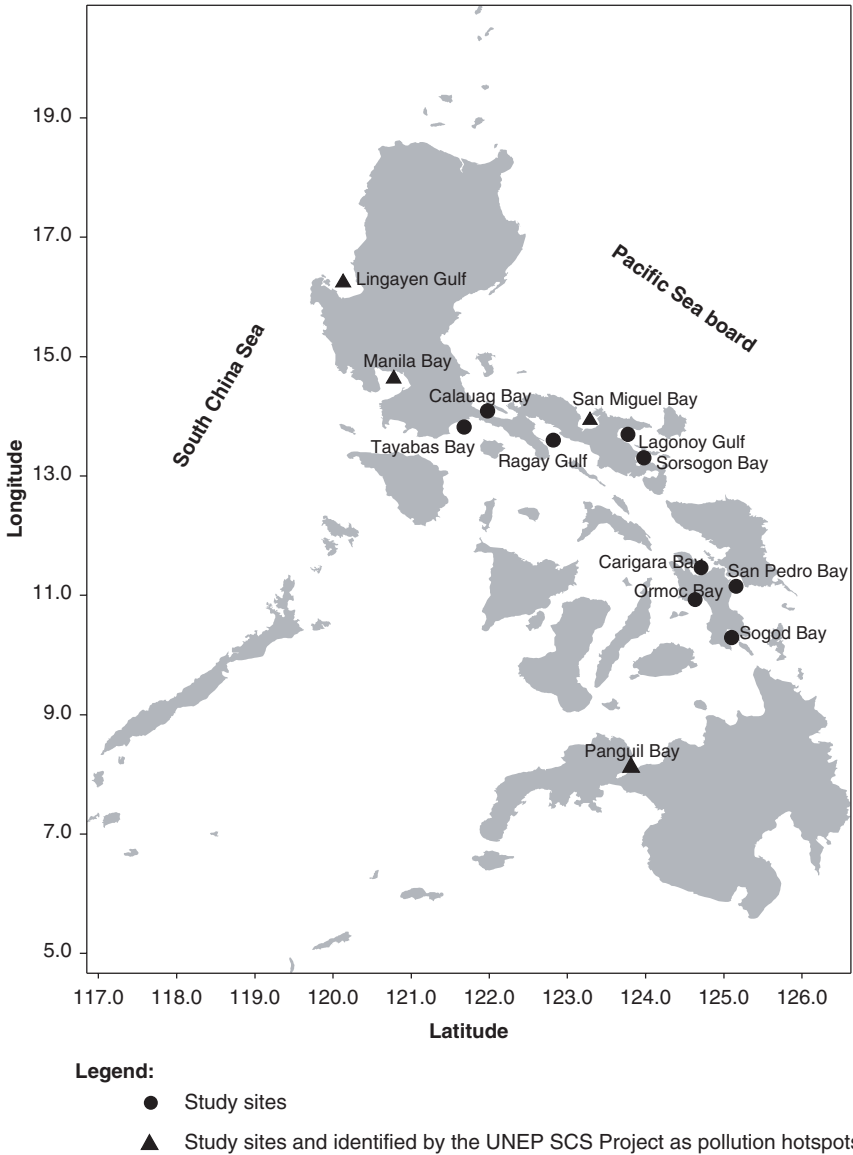
FIG. 3.2.11. UNEP SCS Project in the Philippines. Solid circles and triangles indicate study sites and study sites identified by the UNEP SCS Project as pollution hotspots.

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,
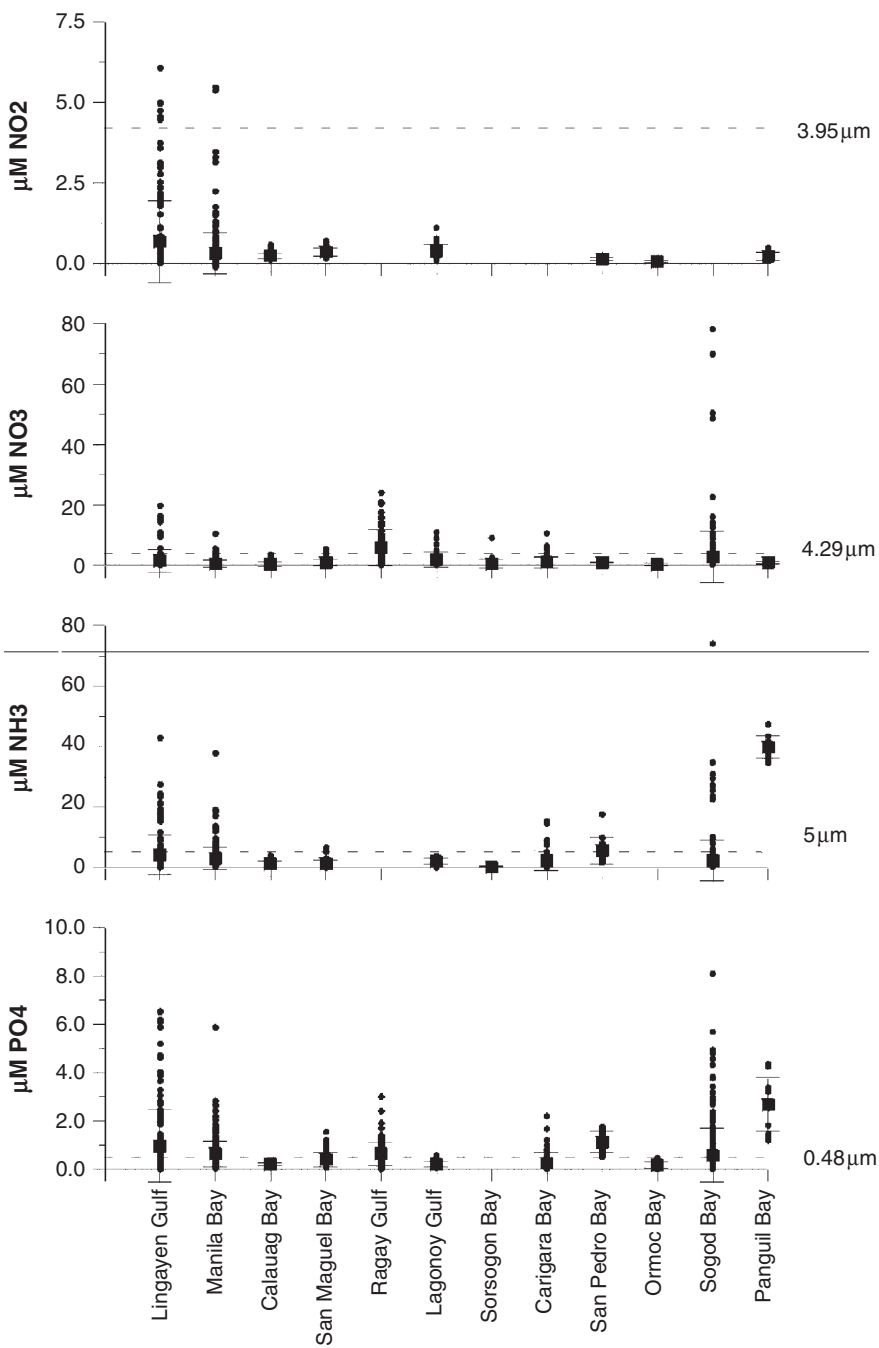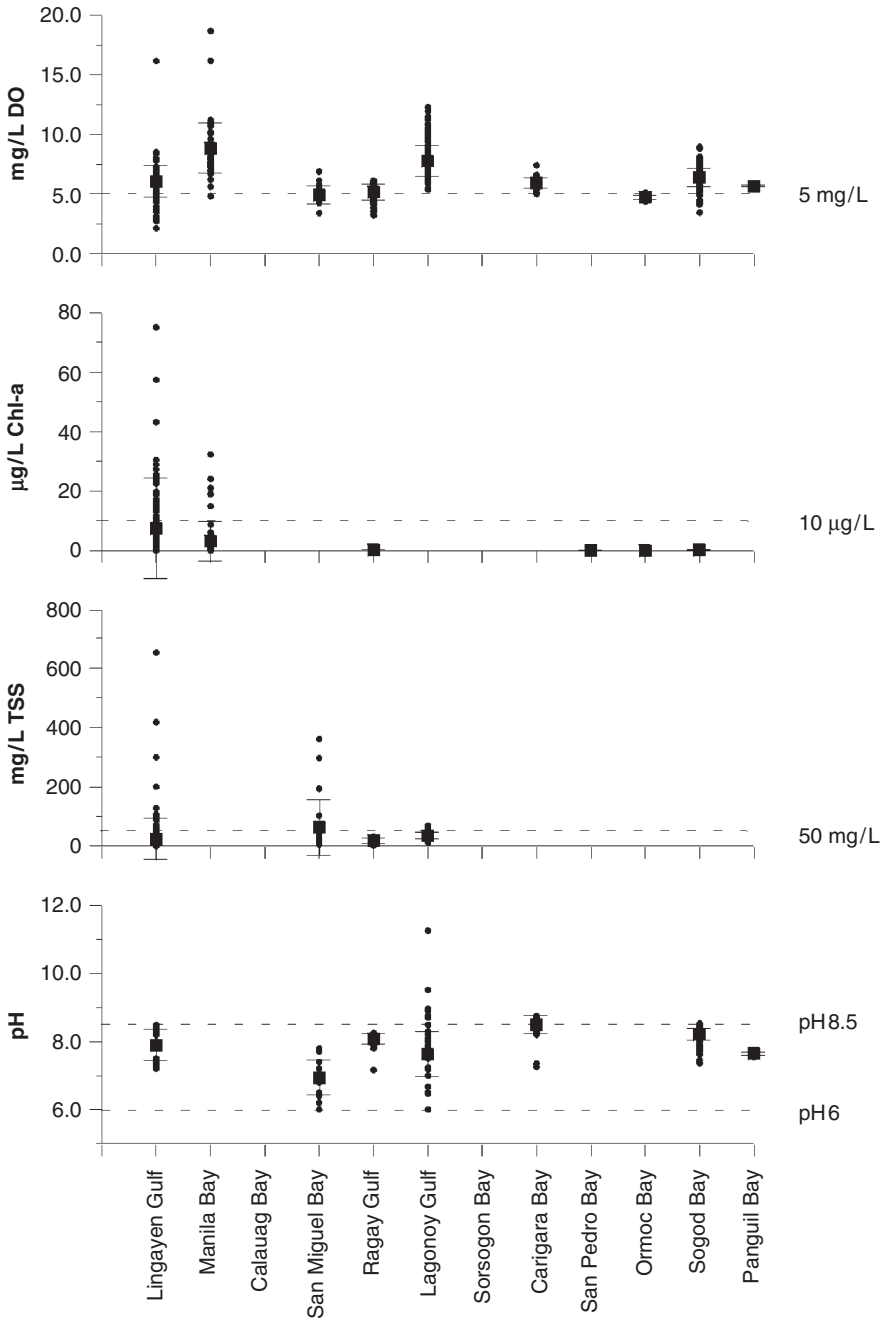
FIG. 3.2.12. (Continued)

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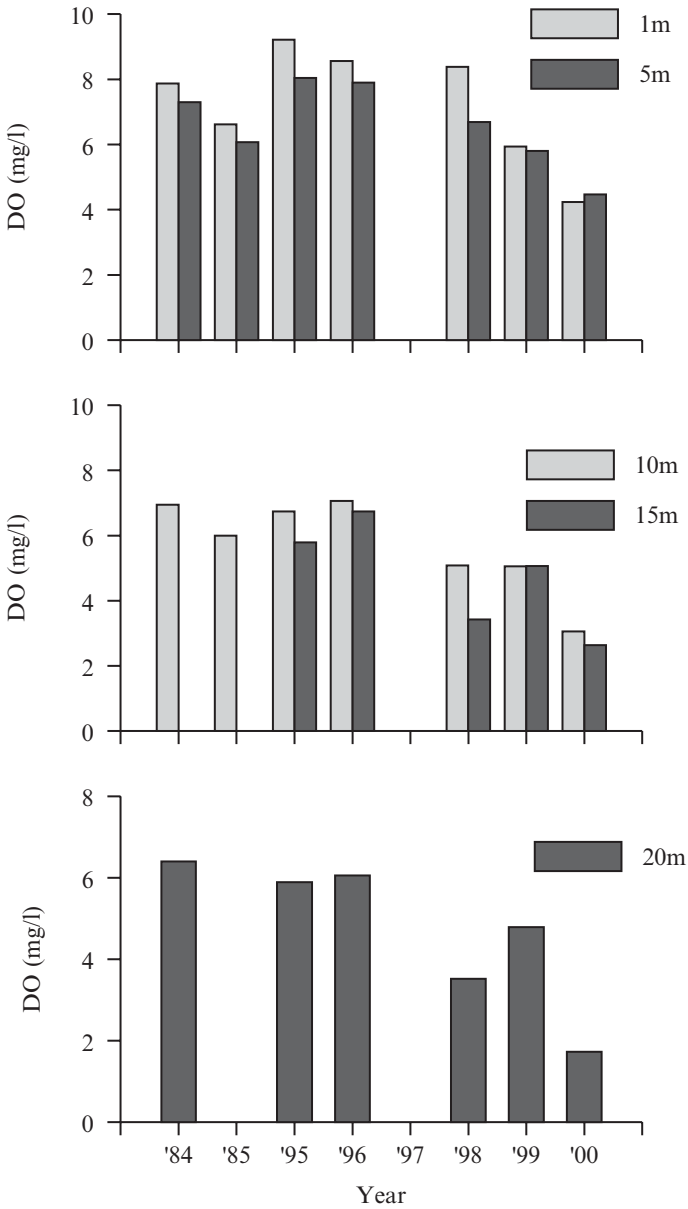
FIG. 3.2.13. Trends in the DO profiles of combined data at different stations in the Philippines. (After PRRP 1998; Jacinto 2000.)

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.

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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 envi-ronmental 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.
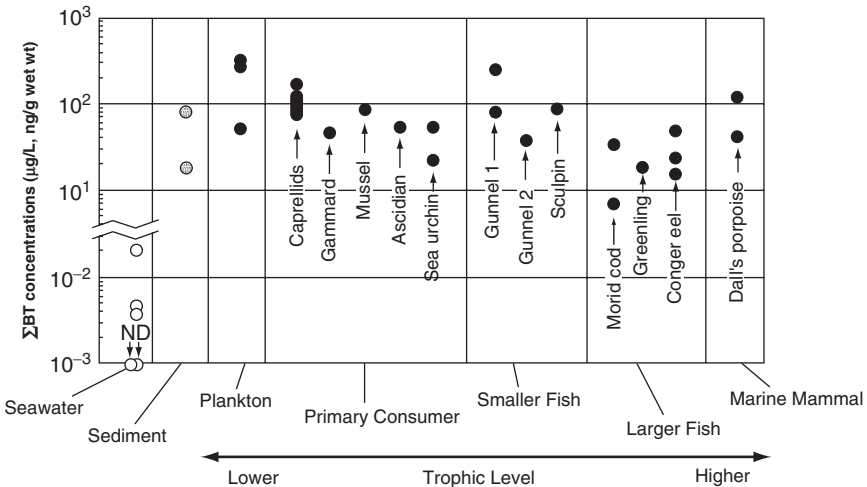

FIG. 3.2.14. Concentration of DDTs, PCBs, and HCHs in marine organisms (including marine mammals) and sea surface in the Bering Sea, the western Pacific Ocean, and the Southern Ocean. (After Tanabe et al., 1983.)

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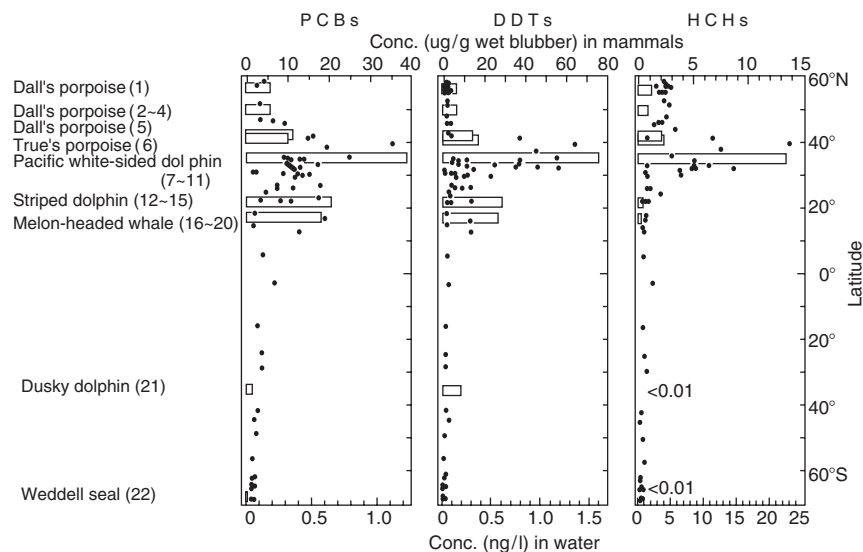
F𝚒ɢ. 3.2.15. Global comparison of the concentration of PCBs, DDTs, and HCHs in marine mammals (bar) and in surface waters (solid circles). (After Tanabe et al., 1998.)

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
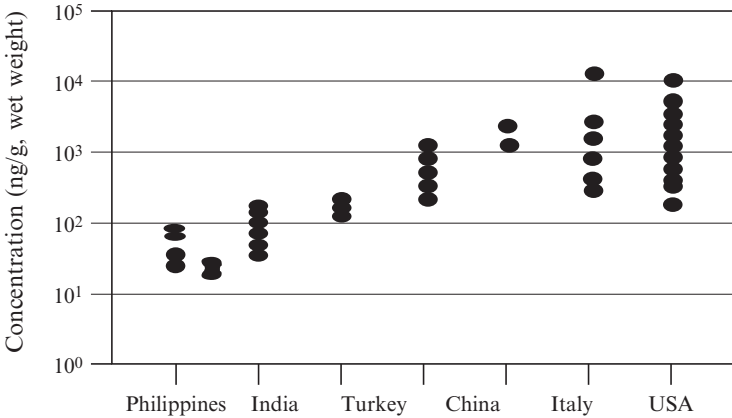
FIG. 3.2.16. Concentration of BTs of marine organisms of Otsuchi Bay along the Pacific coast of northern Japan. (After Takahashi et al., 1999.)
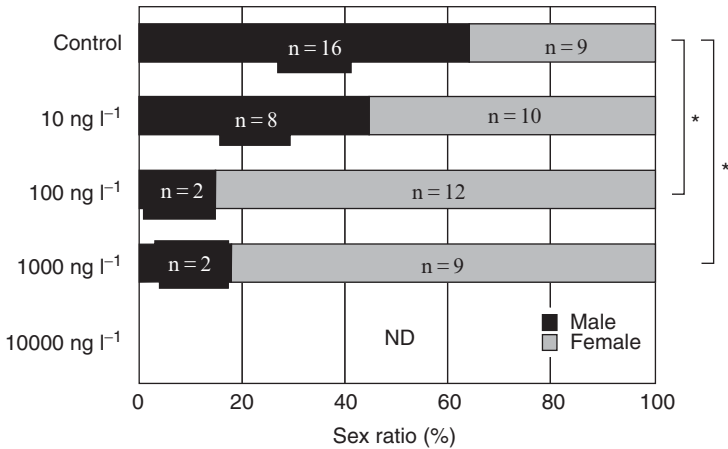
FIG. 3.2.17. Embryonic exposure to TBT for *Caprella* amphipods. (After Ohji et al., 2002–2004.)

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.

The embryonic period
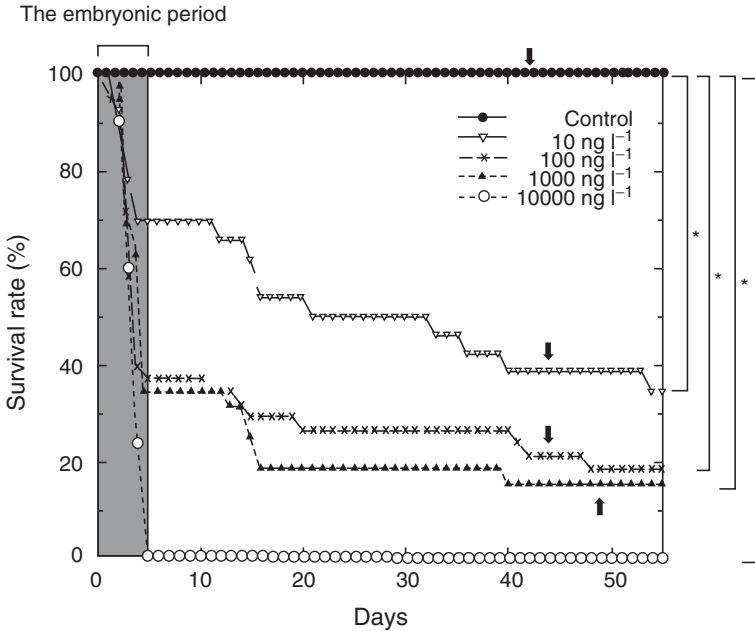

F_{IG}. 3.2.18. Changes of survival rates of *Caprella* amphipods exposed to different concentration of TBT. (After Ohji et al., 2002–2004.)

(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.

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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 macro-scopic, 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.

F ᴵ G. 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		Man-grove 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 Darus-salam	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".

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

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Number of species   ▢ Less than 50 ▮ 101-200 ▮ 301-500
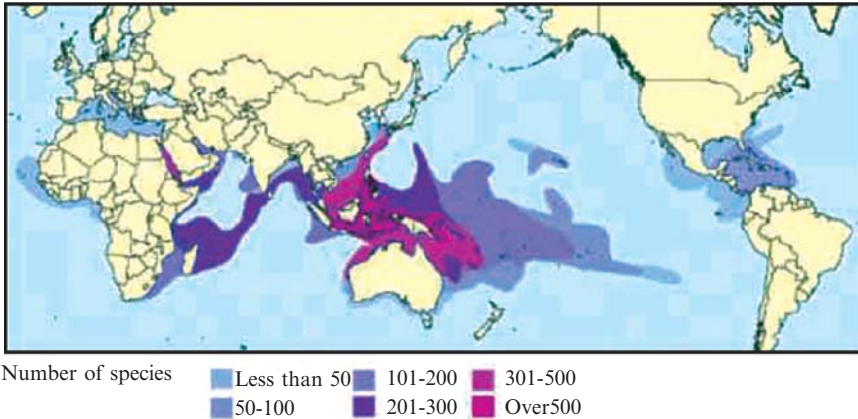   ▮ 50-100   ▮ 201-300 ▮ Over500

Fɪɢ. 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, sea-grass 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 esti-mated 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:
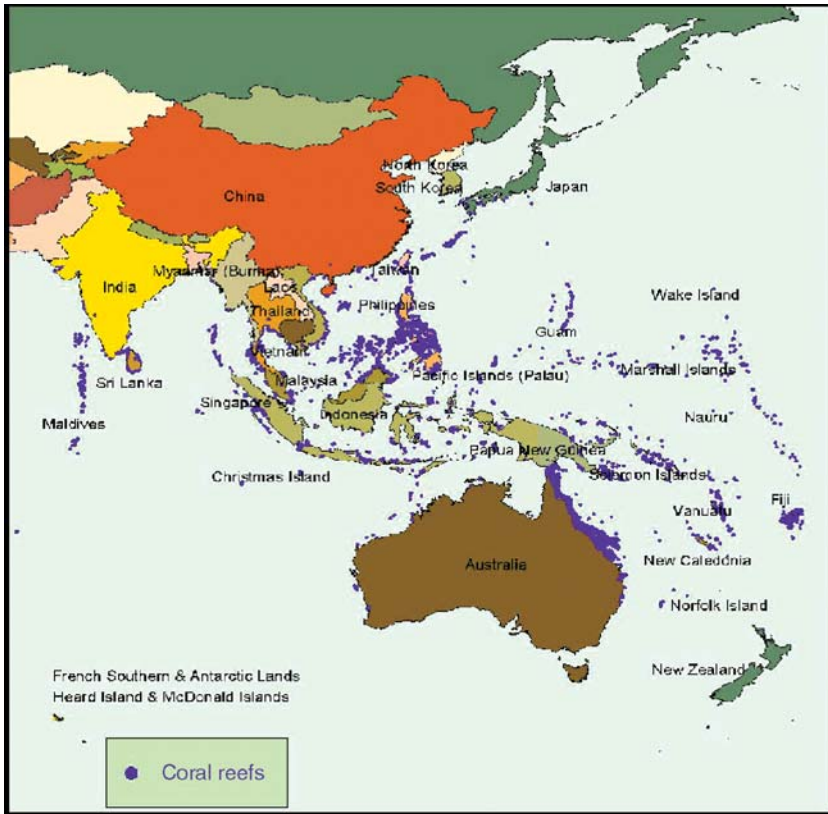
F<small>IG</small>. 3.3.4. Map of coral reefs distribution in Asia-Pacific. (www.reefbase.org.)

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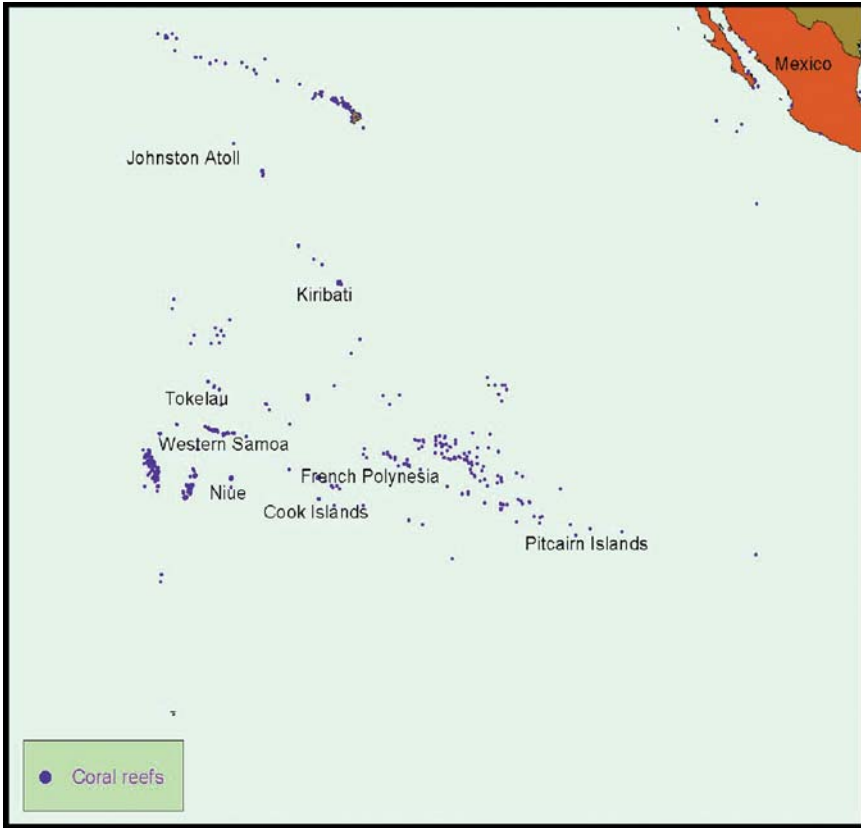
Fɪɢ. 3.3.5. Map of coral reefs distribution in Asia-Pacific (continued). (www.reefbase.org.)

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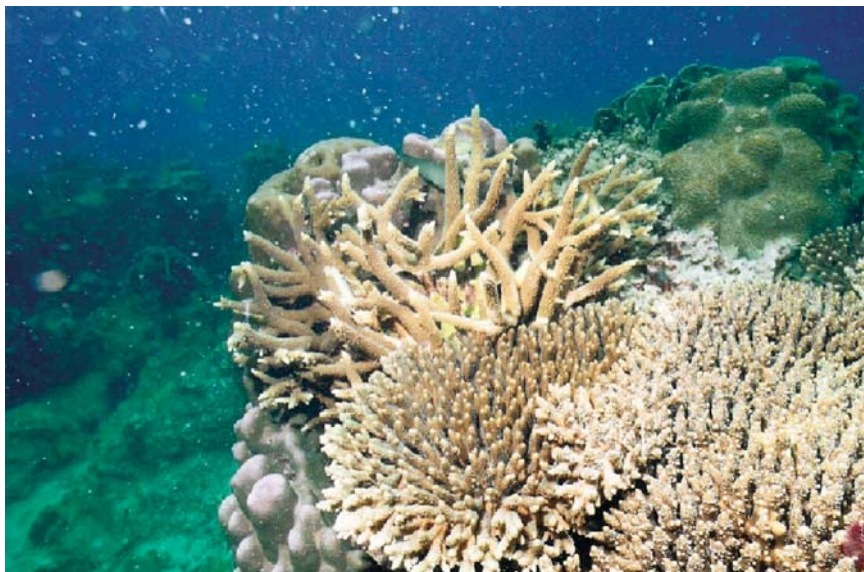
FIG. 3.3.6. A coral community at Mu Koh Chang – a newly developed area for ecotourism in the eastern part of the Gulf of Thailand.

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	<10	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	<10	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* 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.

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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 Southeast 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 km²	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.

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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,
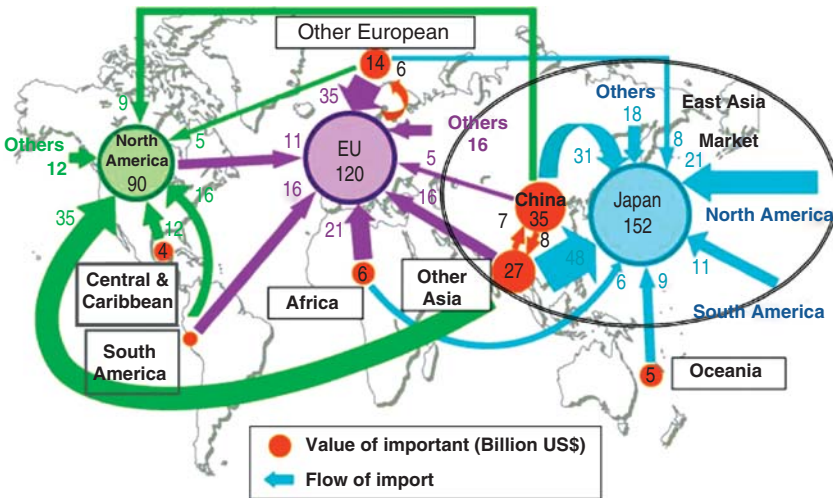

FIG. 3.4.1. Trade flow of fisheries products (1999–2001).

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
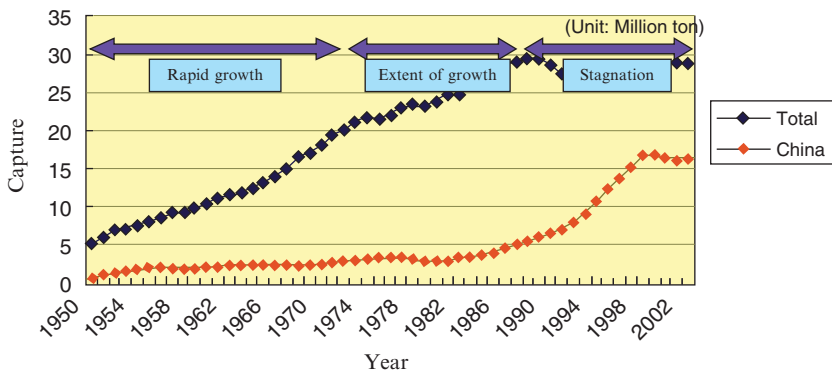

Fig. 3.4.2. Capture production in China and Asia excluding China between 1950 and 2002. (From FAO Yearbooks of Fishery Statistics, APFIC Status and aquaculture in Asia and the Pacific.)

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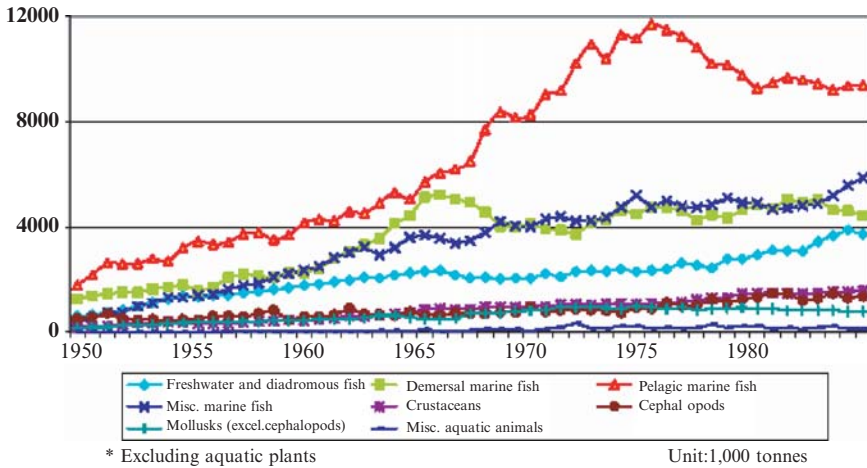
FIG. 3.4.3. Trends in capture production by species group outside China. (From FAO Yearbooks of Fishery Status and aquaculture in Asia and the Pacific.)

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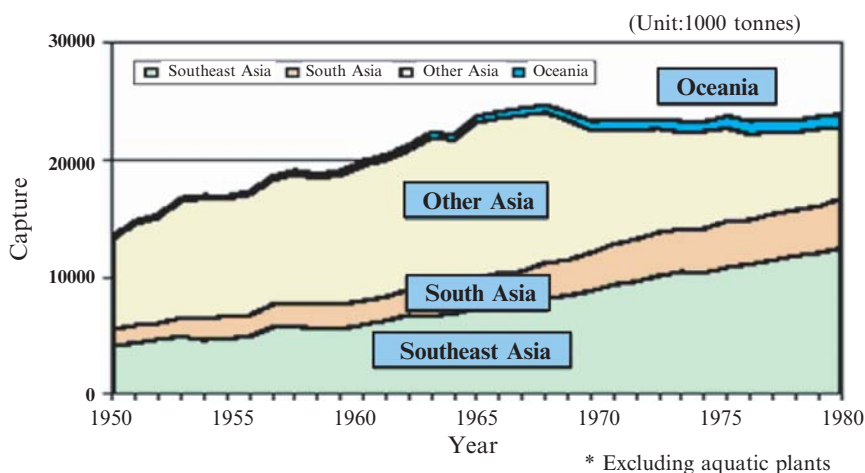
Source: FAO Yearbooks of Fishery Statistics, APFIC Status and quaculture in Asia and the Pacific

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.

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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.

Countries	Tourist arrivals (thousands)			
	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 m³/day was inadequate to handle a daily wastewater output of 20,000 m³/day. The new system introduced in November 2000 processes up to 120,000 m³/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.

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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 Yeo-cheonsi, 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 Yeo-cheonsi Sori Island	*Sea Prince*	5,035 kl	Crude/bunker
1995.9.20	South Korea	Busan South Hoy-ongie Island	*No. 1 Yuilu*	Unknown	Unknown
1995.11.17	South Korea	Jeonnamyeosu Honam Oil Refinery berth	*Honam Sap-phire*	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*	8,660 kl*	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 260,000t 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 40m/s and a wave height of about 8–10m. The center of the typhoon registered an atmospheric pressure of 940hPa and the storm area occupied an area 890km 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.

Fɪɢ. 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.)

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 Naga-hashi 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.)

F<small>IG</small>. 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)

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