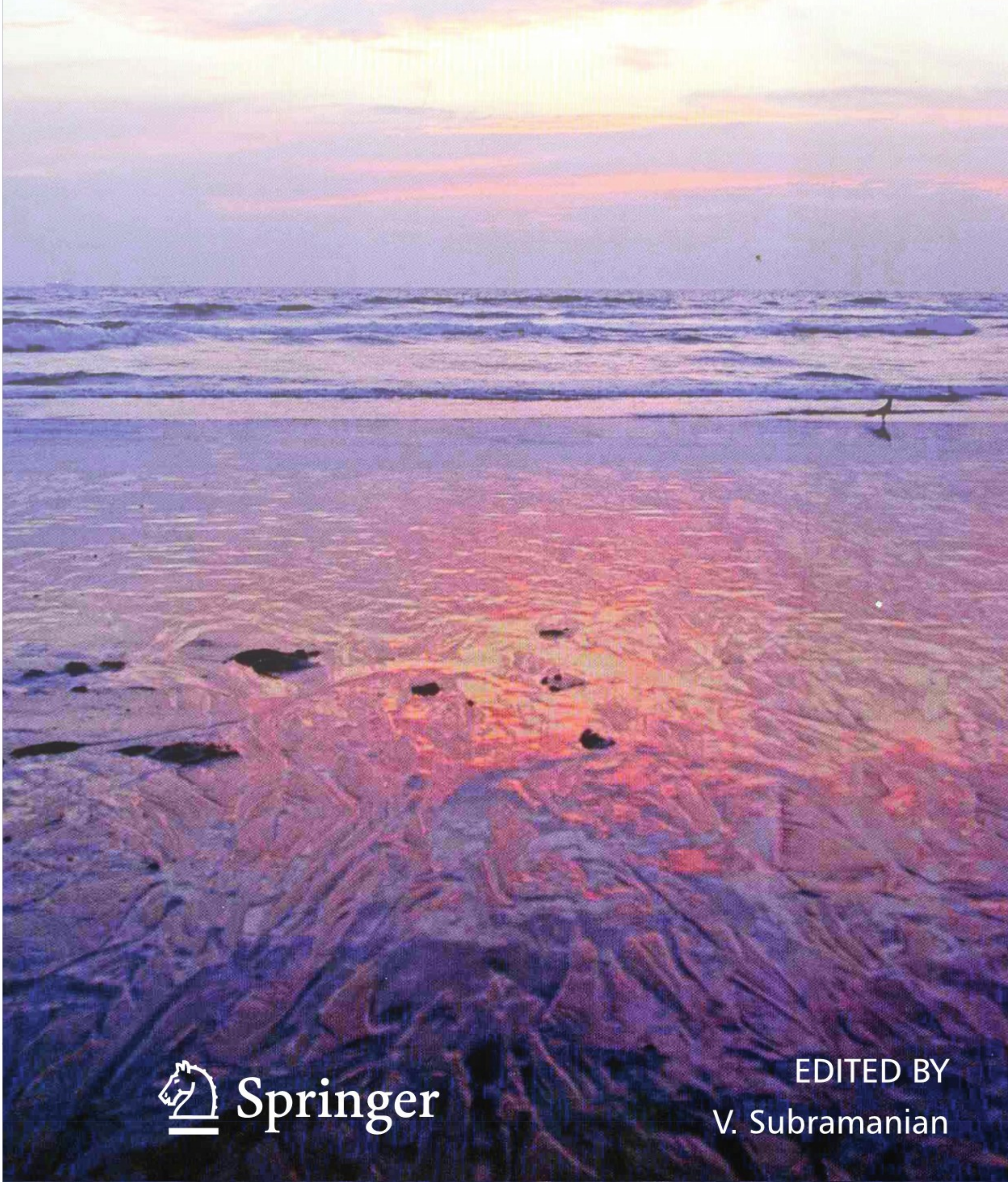
COASTAL ENVIRONMENTS:
Focus on Asian Regions



Springer

EDITED BY
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Coastal Environments: Focus on Asian Regions

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Preface

Today, globally approximately three billion people live within 200 kilometres of a coastline. By 2025, this figure is likely to double. Much of Asia's rapid population and economic growth is occurring in large coastal cities that are at high risk from sea level rise and climate change. The coastline of the Asian continent is about one fourth of the coastlines of the world. In general, with the exception of India, the bulk of Asia's population is coastal or near-coastal. Of the region's collective population of over 3.5 billion, (60%) 2.1 billion live within 400 kilometres of Asian coast. Indonesia and Vietnam are two typical examples of Asia's population shift from the hinterlands to coastal areas. Vietnam's and Japan's population is almost all coastal.

The average population density in Asian coastal areas is about 80 persons per square kilometre, that is twice the world's average population density. Thus Asian coastal areas are under threat. In a growing number of countries, coastal zone managers are adopting integrated, multidisciplinary approaches to resource management that incorporate the perspectives of all stakeholders, including governments, the private sector, non-governmental organizations (NGOs), and individuals. On the academic front, several institutions and individuals in Asia are working on practically all aspects of coastal science.

This book makes an endeavour to project some of the latest academic activities being carried out by individual experts in Asia. Topics chosen are very relevant in the context of pressures on Asian coastal population as well as those that are scientifically important for understanding the impact of climate change.

Experts who have authored individual chapters in this book are well known in their own sphere of expertise and care has been taken to project the diverse nature of academic research in Asia with a focus on Asian coasts. All manuscripts have been peer reviewed and revised before acceptance for the book. In fact one of the authors for chapter 2 (RR) is the current chairperson of SSC (Scientific Steering Committee) of LOICZ (Land Ocean Interaction in Coastal Zone) as a part of IGBP activities. The editor of this book is also the Chief Editor of the *Asian Journal of Water, Environment and Pollution* (AJWEP).

The editor has taken care to include topics that are scientifically as well as socially relevant to sustainable coastal management in the context of their vulnerability to several natural and man-made hazards. High pressure regions such as the south Asian and southeast Asian coasts have been adequately covered in this book. Diversity of topics covered is the hallmark of this book.

February 29, 2012

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Coastal Environment of Asia

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Abstract: Asian coast is under threat from two opposing directions – nature as well as man-made. Natural disasters along coastal regions affect a very large number of countries in Asia; at the same time, due to population pressure, several types of human impact on water, soil and sediments can be seen in many countries. The coastal marine life is also endangered, of course at different levels in different regions of Asia. Researchers have evolved a system of hazard zones along coasts to delineate the regions in terms of degree of vulnerability at any given time. Due to chemical pollution, both in south and southeast Asia, the biological system is in danger of severe domino effect almost mimicking the Minamata mercury episode more than half a century ago.

Key words: Pesticides, metals, hazards, erosion, carbon.

INTRODUCTION

A coastal zone has been variously described. One possible definition from the US Commission on Marine Science, Engineering & Resource is "the coastal zone represents that part of the land affected by its proximity to the sea, and that part of the ocean affected by its proximity to the land".

The definition by the Land Ocean Interaction in the Coastal Zone (LOICZ) Science plan: "the coastal zone as extending from the coastal plains to the outer edge of the continental shelves, approximately matching the region that has been alternately flooded and exposed during the sea-level fluctuations of the late Quaternary period". This second definition is of the coastal domain from 200 m above to 200 m below sea levels which occupies 18% of the surface of the globe; it is the area where around a quarter of global primary

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productivity occurs and supplies approximately 90% of world fish catch. It is also a highly vulnerable region since where around 60% of the human population lives and two thirds of the world cities with population of over 1.6 million people are located.

On the other hand, the coastal ocean accounts for 8% of the ocean surface but contributes to less than 0.5% of the ocean volume. Around 14% of global ocean production takes place in this ocean with up to 50% of global oceanic denitrification and 80% of the global organic matter burial along with 90% of the global sedimentary mineralization and 75-90% of the global sink of suspended river load and its associated elements/pollutant and most important being the fact that in excess of 50% of present-day global carbonate deposition takes place in this region.

The coastal seas on the other hand undergo cumulative changes which, though localised, have global impact. An example is the eutrophication of coastal waters leading to changes in carbon flow and its sequestration and the effect on the global carbon cycle. The other major problem is the complexity of biological systems. Even in a localised environment, the species are numerous, the numbers are large, and there are different metabolic rates, life styles and life expectancies. Environmental changes will affect species differently and thus their effect on the biogeochemical cycles will alter. Biological systems have a slowness of response to chronic low levels of external forcing, and this buffering capacity delays or, in some cases, masks the eco-system response. There are urgent needs to be addressed at the regional and local scale. The decline in fisheries, the increasing pollution by heavy metals, PCBs and pesticides are local effects produced by anthropogenic influence. However, not enough data exist to relate these to changes in the earth system. Such effects are however keenly felt and must be dealt with scientifically to ameliorate local fallout.

PHYSICAL PROCESSES OPERATING ALONG THE COAST OF SOUTH ASIA

Coastal zones are very important for Asia because rapid industrialisation and urbanization take place along the coasts, and protein from marine fisheries makes up a significant percentage of the region's total protein consumption. Changes in the hydrological and nutrient cycles will manifest their effects in the coastal zones, and with the enclosed nature of regional seas, the impacts to the continental shelves are likely to be very significant. Also, the seas of Southeast Asia are parts of the Pacific warm pool which affects the trade winds and monsoons, and generates typhoons and hot towers which are very efficient transport mechanisms for greenhouse gases and aerosols which significantly affect global atmospheric chemistry. The role of extreme events (tropical storms, droughts and floods, earthquakes, tsunamis, volcanic eruptions, etc.) is also very important here considering their relatively high frequency of occurrence and the area's high population density.

Only in the last decade has there been a general understanding of the large-scale dynamics of the coastal circulation in the Arabian Sea and the Bay of Bengal. Large-scale currents along the outer shelf and beyond, around India, reverse seasonally with the monsoon winds. The currents form a continuum from the northern Bay of Bengal to the northern Arabian Sea.

What influences currents on the inner shelf? It is expected that large scale currents, tides, winds and river run off play important roles. Tides, winds in season (and sea-breezes), and river run-off would be the major influences nearest the coast. In the few instances of direct current measurements, the cross-shore components are tidal (towards shore on flow and away on ebb). The along-shore component would vary with season and location and could be due to the seasonal coastal currents.

Indian coastal waters are clean and well oxygenated with no detectable spread of "hot-spot" influence. The large rivers on the east coast also play a role in confining along shore pollutant transport. Their large run-offs acting as barriers to close to coast transport of pollutants and sediments. It is important to understand shelf and estuarine (of which there are a very large number of varying sizes) circulation, so that through effective modelling pertinent information is available to decision makers on movement of pollutants, sediments and offshore hazards (oil spills).

South Asian coasts have a large variety of sensitive eco-systems. Sand dunes, coral reefs, mangroves, seagrass beds and wet lands are some that deserve special mention. Some of these are the spawning grounds and nurseries of a number of commercially important fishes, gastropods and crustaceans. A critical feature of these ecosystems are the variety of bioactive molecules that they host. Recent mining of organisms from the tidal and inter-tidal zone have revealed large numbers of molecules with obvious application for human health and industrial applications. This could be the most commercially important aspect of the Coastal Zone. Molecules that show bioactivity from one ecosystem may not show the same activity, or level of activity, when mined from a different locale or different season. This feature alone should be reason enough for the protection of all such ecosystems, and not only representative isolated units in protected areas/parks.

Considering that Indian waters are of a good quality and that pollutant sources remain relatively confined, the protection of sensitive environments, with adjacent buffer zones should be promptly notified and enforced. Losses of such areas are losses to the common good and future generations.

Sand dunes seem to be ecosystems that are most often destroyed, probably because their place in the scheme of dynamic coastal morphology, is not obvious. Suffice to say that dunes are the reserves that nature stores, dissipates energy and moves on.

Coastal Erosion is a natural process rather than a natural hazard; erosion problems occur when people build structures in the coastal zone. Any shoreline construction causes change. Stabilization of the coastal zone through engineering structures protects the property of relatively few people at a larger general expense to the public. Engineering structures designed to protect a beach may eventually destroy it. Once constructed, shoreline engineering structures produce a trend in coastal development that is difficult if not impossible to reverse. In Asia, due to the population pressure, construction and other activities take place along their vast coastal network often without suitable safety net in place so that the safety of coastal border become vulnerable from time to time. This fact is compounded by the fact that all countries now are seriously exploiting coastal regions for important energy resource namely oil and gas.

Petroleum resources are not easy to find, nor are they often located in convenient places for oil or gas to be extracted, processed and sent to be used by the community. Exploring for oil and gas under the sea bed, and the production activities which follow a successful exploration programme, all involve some risks and potential impacts on the marine environment. Clearly identifying these risks and impacts and developing detailed management plans to avoid, prevent or minimise them is a vital and integral part of planning these exploration and production activities for safe coastal health.

The coastal areas are also the place where natural disasters are also experienced. The entire Asian coast has from time to time experienced different types of natural and man-made disasters. To name a few, the Japan Tsunami and earth quake followed by nuclear plant explosion, the 2004 Tsunami of Indonesia, Thailand, India and Sri Lanka, volcanic activity in Indonesia from time to time are some of the major disasters in recent times. The recent floods in Bangkok and inland movement of sea water is a case in point where damages could be serious. The entire east coast of India, the Gujarat coast along the west coast and the islands of Lakshadweep and Andaman and Nicobar face frequent cyclonic conditions which sometimes cause large scale destruction of life and property. While it is agreed that no human interference is possible to control such an event but precautionary measures such as coastal area planning for locating coastal communities in safer areas, protecting and propagating the natural systems such as mangroves, coral reefs, shelter belt plantations, along with installation of early warning systems, timely evacuation and relief measures can minimize loss of life and property to a large extent. Most sensitive to coastal pollution is the coral reefs in many regions of the Asian coastal land mass. It is well known that coral reefs around the world are facing serious problems, as can be seen in Figs 1a and 1b.

The reef—an indicator of the health of the ocean—is facing more than 50% serious survival problems in south and southeast Asian region.

Major observed threats to the world's coral reefs include extreme climate events, unsustainable tourism practices, poison fishing for ornamental fish,

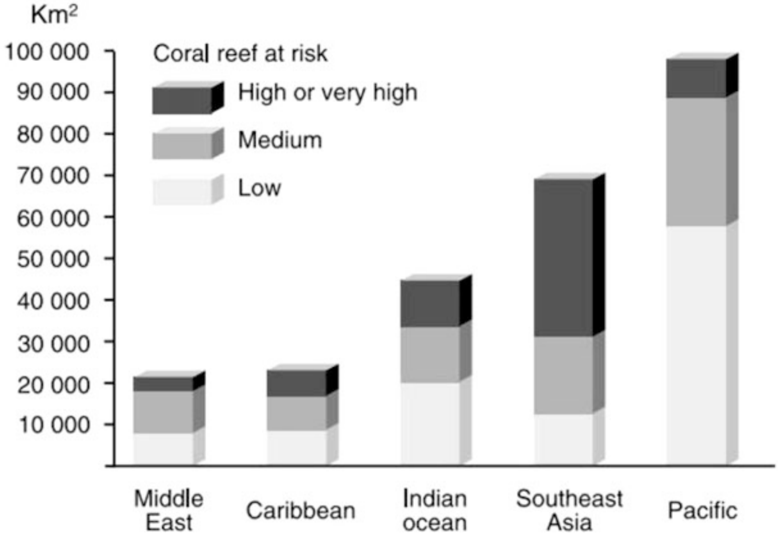

Fig. 1a: Coral reefs at risk from human activities.

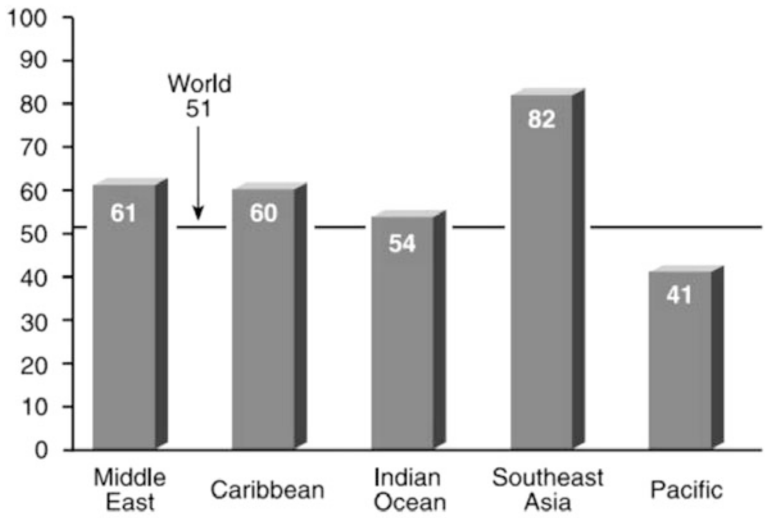

Fig. 1b: Percent of the region at risk.

Note: Reefs classified as low risk are not considered in imminent danger.
Source: Lauretta Burke et al. (1998), Reefs at Risk: A map-based indicator of threats to the world's coral reefs, World Resources Institute, Washington D.C.

overexploitation by fisheries, sedimentation, coral harvesting, dynamite fishing and pollution (not in order of priority). Figure 2 explains which activities or conditions are affecting various coral reefs throughout the world. Figure 2 also shows the percentage of reefs that are threatened by over-exploitation, coastal

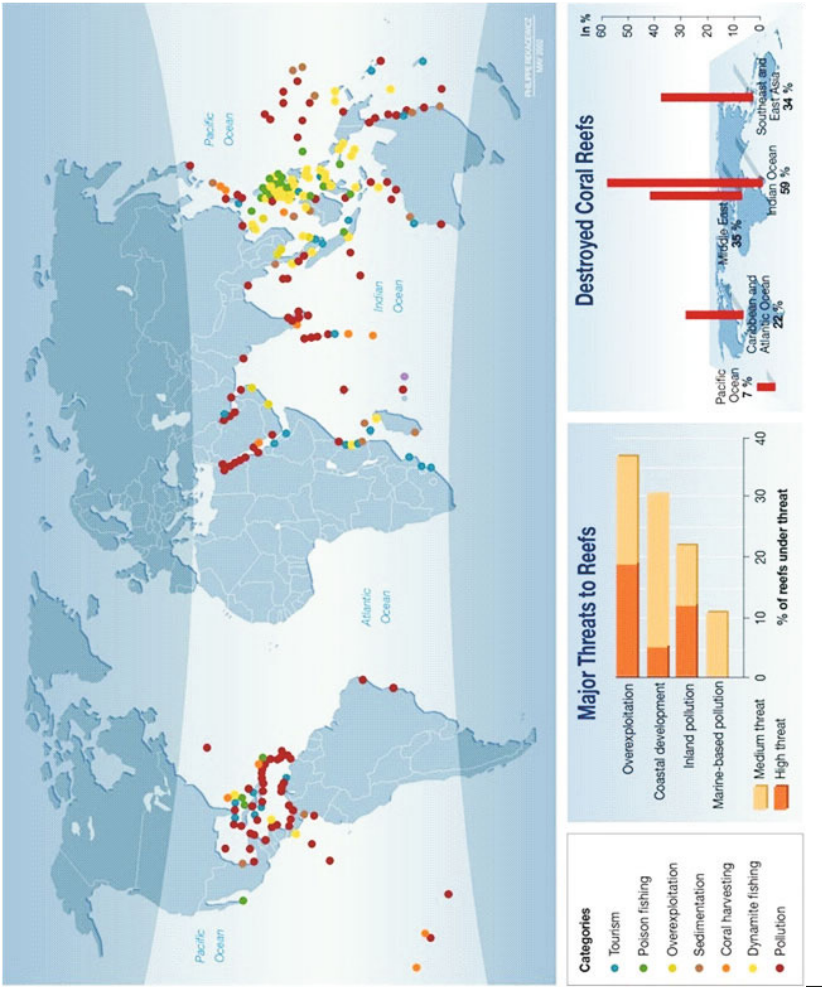

Fig. 2: Threats to the world's coral reefs.

development, inland pollution and marine pollution, and the degree to which they are under threat. Figure 1b shows the percentage of coral reefs that have been destroyed in the world's major regions. Studies in the Philippines and Indonesia estimate that the damage to coral reefs from logging-induced sedimentation greatly exceeds the economic benefits of logging, according to an UNEP report (UNEP Report, 2006).

In addition to coral reefs, the general health of coastal waters face serious threat in terms of quality due to discharge of chemicals in southeast and South Asian coasts. The fast growing economies and populations of East Asia are putting the region's marine ecosystem under increasing stress. A new study finds 90 per cent of Asia's sewage being discharged into the marine environment waters without treatment, threatening fisheries, mangrove forests, coral reefs and coastal wetlands. Sewage treatment access across Asia varies widely—from roughly 60 per cent of Japan's population to 15 per cent in Mumbai, India, to about six per cent in Karachi, Pakistan. Discharges from many big industrial plants situated along the coast is also a threat and is a "common feature" in much of South Asia. In 2001, close to 80 red tide events occurred affecting 15,000 square kilometres of coastal waters. Two thirds of the world's total sediment transport to the oceans occur in South and South East Asia, and deforestation is adding to soil erosion and sediment loads in waterways.

Coastal erosion is widespread, between a fifth to a quarter of sea grass beds in Indonesia, Malaysia, the Philippines and Thailand have been damaged as a result of impacts including clearance for commercial seaweed farms, pollution, sedimentation and dredging.

The SE Asian region, that spans from Vietnam to Myanmar, contains 34% of the world's coral reefs, possibly a third of the worlds mangroves and vast areas of seagrass. But this region also contains a rapidly burgeoning human population that is creating an ever worsening marine pollution problem. Pollutants, originating from both land and sea, are responsible for significant lethal and sub-lethal effects on marine life. Pollution impacts all trophic levels, from primary producers to apex predators, and thus interferes with the structure of marine communities and consequently ecosystem functioning. Here we review the effects of sediments, eutrophication, toxics and marine litter. All are presently major concerns in Southeast Asia (SE Asia) and there is little indication that the situation is improving. Approximately 70% of SE Asia human population lives in coastal areas and intensive farming and aquaculture, rapid urbanisation and industrialisation, greater shipping traffic and fishing effort, as well as widespread deforestation and near-shore development, are contributing towards the pollution problem. As SE Asia encompasses approximately 34% of the world's reefs and between a quarter and a third of the world's mangroves, as well as the global biodiversity triangle formed by the Malay Peninsular, the Philippines, and New Guinea, the need to reduce the impacts of marine pollution in this region is all the more critical. Rapid urbanization is transforming Asia. Eighty-seven Asian cities have more than a

Oil ♥
DDT, Organochlorine, Pesticide ♣
Heavy Metals ♠
Organic, Biological Pollutants and Fertilisers ♦
Silt •

Fig. 3: The coastal region in Southeast Asia vulnerable due to several sets of human activities.

million inhabitants. By 2005, more than half the population of East Asia will live in cities. In South Asia, the urban population will overtake the rural population by 2025.

Not to be outdone, the South Asian coast is equally polluted due to discharge of a large amount and types of chemical wastes as shown in Table 1 (after Zigde, 1999).

Table 1: Pollution in South Asian coast

Sr. No.	*Input/pollutant*	*Quantum, annual*
1.	Sediments	1600 million tonnes
2.	Industrial effluents	50×10^6 m^3
3.	Sewage—largely untreated	0.41×10^9 m^3
4.	Garbage and other solids	34×10^6 tonnes
5.	Fertilizer—residue	5×10^6
6.	Synthetic detergents—residue	130,000 tonnes
7.	Pesticides—residue	65,000 tonnes
8.	Petroleum hydrocarbons (Tar balls residue)	3500 tonnes
9.	Mining rejects, dredged spoils and sand extractions	0.2×10^6 tonnes

More specifically for the Mumbai coast, the pollution load is very high as can be seen in Table 2.

Table 2: Selected contaminants entering coastal waters of Mumbai through domestic waste water

Contaminant avg.	*Concen., ppm*	*Load, kg/day*
Dissolved solids	1800	3.6×10^6
Suspended particulate matter	235	4.7×10^5
Biological Oxygen Demand	280	5.6×10^5
Nitrogen	35	7×10^4
Phosphorus	6	1.2×10^4
Manganese	0.7	1400
Iron	2.1	4100
Cobalt	0.03	20
Nickel	0.08	160
Copper	0.1	200
Zinc	2.3	4600
Lead	0.05	100

Fluvial sediment flux from Southeast Asia and Oceania accounts for 70% of the world flux although they account for only 15% of the land area draining into oceans (Silvbiski and Khittner, 2011). The South Asian region further contributes over a billion tonnes of sediments to the adjoining coastal oceans. Of importance to the region are the implications of such changes to sustainable development of marine, coastal and terrestrial resources. Key questions include: How do changes to coastal ecosystems and to catchment areas inland affect the long-term productivity of the coastal zones? How do the frequency and patterns of resource exploitation affect biodiversity, and what are the resultant consequences for ecosystem functioning? There is no doubt that the South and the Southeast Asian environment is changing at an accelerating rate, and these changes need to be monitored and analyzed so that people and institutions can devise appropriate management strategies to maintain both production and environmental amenities.

It is important hence to understand in detail the biotic control of water, gas and energy exchanges between the surface and the atmosphere, and the composition, structure and productivity of the land and coastal zones after modification. A crucial aspect of biogeochemical cycling is the transport of dissolved and suspended materials from upland areas through coastal zones to the sea.

Thus, marine pollution includes a range of threats from land-based sources, oil spills, untreated sewage, heavy siltation, eutrophication (nutrient enrichment), invasive species, persistent organic pollutants (POPs), heavy metals from mine tailings and other sources, acidification, radioactive substances, marine litter, overfishing and destruction of coastal and marine habitats. Overall, good progress has been made on reducing persistent organic pollutants (POPs), with the exception of the Arctic. Oil discharges and spills to the seas have been reduced by 63% compared to the mid-1980s, and tanker accidents have gone down by 75%, from tanker operations by 90% and from industrial discharges by some 90%, partly as a result of the shift to double-hulled tankers (UNEP, 2006; Brown et al., 2006). Some progress on reducing emissions of heavy metals is reported in some regions, while increased emissions are happening in others. Electronic waste and mine tailings are included amongst the sources of heavy metal pollution in Southeast Asia. Sedimentation has decreased in some areas due to reduced river flows as a result of terrestrial overuse for agricultural irrigation, while increasing in other regions as a result of coastal development and deforestation along rivers, water sheds and coastal areas, and clearing of mangroves (Burke et al., 2002; Brown et al., 2006; UNEP, 2006).

A major threat beyond over-exploitation of fisheries and physical destruction of marine coastal habitats by dredging, is undoubtedly the strong increase in coastal development and discharge of untreated sewage into the near-shore waters, resulting in enormous amounts of nutrients spreading into the sea and coastal zones (Brown et al., 2006; UNEP, 2006). This, together with changes in salinity, melting sea ice, increased sea temperatures and future changes in sea currents may severely affect marine life and their ability to recover from extreme climatic events.

Together with agricultural run-off to the sea or into major rivers and eventually into the ocean, nitrogen (mainly nitrate and ammonium) exports to the marine environment are projected to increase at least 14% globally by 2030 (UNEP, 2006). In Southeast Asia more than 600,000 tonnes of nitrogen are discharged annually from the major rivers. These numbers may become further exacerbated as coastal populations are depicted to increase from 77 people/km^2 to 115 people per km^2 in 2025. In Southeast Asia, the numbers are much higher and the situation more severe. Wetlands and mangroves are also declining rapidly, typically by 50-90% in most regions in the past four decades (UNEP, 2006). In addition to nitrogen, the carbon discharge by rivers to oceans in South Asia also is a serious quality issue in terms of dissolved and particulate carbon. Table 3 summarises the river-borne carbon in South Asian region. Also, it will severely exacerbate the effects of extreme weather and the productivity of coastal ecosystems to supply livelihoods and basic food to impoverished. Hence, the poor management of sewage not only presents a dire threat to health and ecosystems services, it may increase poverty, malnutrition and security for over a billion people (UNEP, 2006).

Table 3: Total carbon, inorganic carbon and organic carbon in Indian rivers (all in %)

River	*TC*	*TOC*	*TIC*
Sabarmati	0.69		
Mahi	1.63	0.10	1.54
Narmada	1.03	-	-
Tapti	0.71	-	-
Yamuna	0.15	0.05	0.11
Godavari	1.18	0.10	1.09
Krishna		1.55	
Ganges-Brahmaputra-Megna	0.45	0.24	0.33
Chaliyar	0.48	0.28	0.20
Kadalundi	1.09	0.90	0.19
Bharathapuzha	0.22	0.05	0.17
Chalakudi	0.44	0.11	0.33
Periyar	1.36	1.09	0.28
Muvattupuzha	2.15	1.95	0.20
Manimala	0.39	0.14	0.25
Pamba	0.24	0.12	0.12
Ackankovil	0.31	0.13	0.19
Kalada	0.27	0.10	0.16
Mandovi		1.00	
Brahmaputra (India)	1.53	1.14	0.40
Brahmaputra (Bangladesh)	2.01	1.53	0.48

POPULATION PRESSURE IN COASTAL AREAS

Population along the coast in Asia is a serious issue in terms of stress to the water body, vulnerability and food security. Figure 4 compares the population in various coastal cities in the world.

The graphic shows the proportion of the population that lives within 100 km of the coast, for each of the world's nations. It also shows the locations of selected coastal cities with a population of more than one million people. Coastal vulnerability can be thus viewed as a combined effect of man-made as well as some natural situations due to geological set up of Asia as indicated in Table 4.

The combination of wind-driven waves and the low-pressure of a tropical cyclone can produce a coastal storm surge—a huge volume of water driven ashore at high speed and of immense force that can wash away everything in its path. A massive storm surge left 300,000 people dead in the coastal wetlands

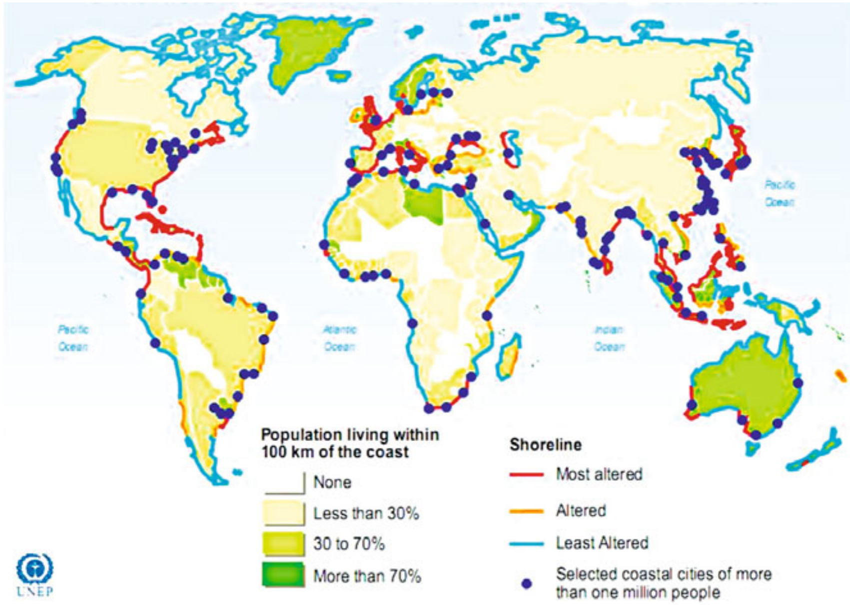

Fig. 4: Coastal population and coastal degradation.

Table 4: Relative intensity of geology-related hazards faced by some countries in Asia

Country	*Earthquakes*	*Tsunamis*	*Volcanoes*
Bangladesh	L	L	-
China	S	L	-
India	M	L	-
Indonesia	S	L	M
Iran	S	-	-
Nepal	M	-	-
Pakistan	S	-	-
The Philippines	S	L	M
Thailand	L	-	-
Viet Nam	L	-	-

S = severe M = moderate L = Low

Source: Asian Disaster Preparedness Center

of Bangladesh in 1970. About 80 tropical cyclones form every year. Their names depend on where they form: typhoons in the western North Pacific and South China Sea; hurricanes in the Atlantic, Caribbean and Gulf of Mexico, and in the eastern North and central Pacific Ocean; and tropical cyclones in the Indian Ocean and South Pacific region.

According to Neil Adger et al. (2005), natural hazards are an ongoing part of human history, and coping with them is a critical element of how resource use and human settlement have evolved. Globally, 1.2 billion people (23% of the world's population) live within 100 km of the coast, and 50% are likely to do so by 2030. These populations are exposed to specific hazards such as coastal flooding, tsunamis, hurricanes and transmission of marine-related infectious diseases. For example, today an estimated 10 million people experience coastal flooding each year due to storm surges and landfall typhoons, and 50 million could be at risk by 2080 because of climate change and increasing population densities. More and more adaptive responses will be required in coastal zones to cope with a plethora of similar hazards arising as a result of global environmental change. Coastal erosion, exacerbated by sea-level rise, also threatens vulnerable lands including deltas. In fact, many of Asia's largest cities, like the mega-cities analysed in this report, were built on such deltas and are consequently some of the most at risk to the impacts of climate change.

Hazards in coastal areas often become disasters through the erosion of resilience, driven by environmental change and by human loss in Bangladesh; in 1991 this resulted in over 100,000 deaths and the displacement of millions of individuals from widespread flooding. In many locations, environmental degradation such as land clearing, coastal erosion, overfishing, and coral mining has reduced the potential for economic recovery from the tsunami because of the loss of traditional income sources related to coastal ecosystems rich in biodiversity and ecological functions. An equivalent tropical typhoon that ravaged Bangladesh had reduced mortality associated with typhoons and flooding in the past decade through careful planning focused on the most vulnerable sectors of society.

COASTAL AND ENVIRONMENTAL VULNERABILITY IN ASIA

Vulnerability is an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of harmful perturbations. Quantifying vulnerability and resilience to climate change is an important exercise to predict, current and future scenario along Asian coasts. Swedish Environment Institute has formulated certain factors that are felt to be important in quantifying vulnerability:

"Sensitivity sectors—Settlement, Food, Health, Ecosystems, Water

Sensitivity Indicators: Coping and Adaptive Capacity sectors—Economics, Human Resources, Environment

Coping—Adaptive Capacity Indicators National Baseline Estimates and Projections of Sectoral Indicators, Sensitivity and Coping—Adaptive Capacity, and Vulnerability—Resilience Response Indicators to Climate Change"

Overall, the sustainability of our coast also depends on the total environmental problems on the inland regions. The significant component of coastal and regional sustainability can be quantified based on a few important aspects such as:

Environmental Systems: A country is more likely to be environmentally sustainable to the extent that its vital environmental systems are maintained at healthy levels, and to the extent to which levels are improving rather than deteriorating.

Reducing Environmental Stresses: A country is more likely to be environmentally sustainable if the levels of anthropogenic stress are low enough to engender no demonstrable harm to its environmental systems.

Reducing Human Vulnerability: A country is more likely to be environmentally sustainable to the extent that people and social systems are not vulnerable to environmental disturbances that affect basic human wellbeing; becoming less vulnerable is a sign that a society is on a track to greater sustainability.

Social and Institutional Capacity: A country is more likely to be environmentally sustainable to the extent that it has in place institutions and underlying social patterns of skills, attitudes, and networks that foster effective responses to environmental challenges.

Global Stewardship: A country is more likely to be environmentally sustainable if it cooperates with other countries to manage common environmental problems, and if it reduces negative transboundry environmental impacts on other countries to levels that cause no serious harm.

In a thought provoking article on processes that govern the environmental sustainability, the Stockholm Environment Institute has come out with a scale of 1 to 6 to quantify the relative vulnerability of our land including the coastal regions. In their publication (Ziervogel et al., 2006), they have classified many regions (see Fig. 5) on differential scale similar to earthquake scale: most vulnerable with a scale of 6 out of 6 covers such diverse regions as USA (scale of 5, may be due to extreme consumption based economy) or 2-4 (south and south east Asia including China due to population) or arctic region (scale of 6 out of 6) due to global warming effect.

Cities cover less than 1% of the planet's surface, and are home to around 50% of the world's population, and many of them see a rapid growth trend. Taken together, all cities and urban areas worldwide use 75% of the world's energy and are responsible for 75% of global greenhouse gases. The relative sensitivity of the 11 selected cities to climate change impacts is based on population, gross domestic product (GDP), and the relative importance of that city to the national economy. The adaptive capacity of the 11 cities by examining the overall willingness of the city to implement adaptation strategies were prepared by WWF (WWF, 2009).

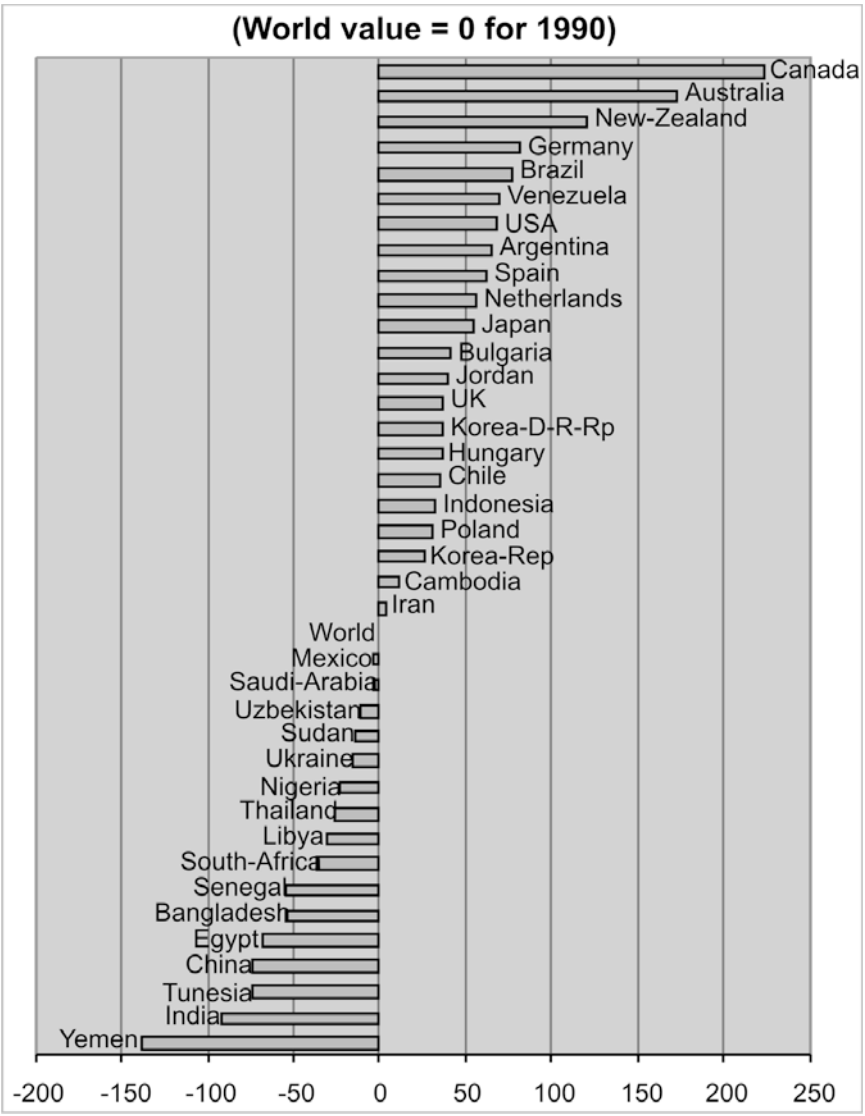

Fig. 5: World vulnerability.

Criteria compared for each city in WWF study:

1. Environmental exposure: Tropical cyclones, Storm surge, Sea level raise. Water flooding/drought
2. Socio-economic sensitivity
3. Population density (Gross Domestic Product), Contribution to GDP
4. Adaptive capacity
5. Existing examples
6. Per capita GDP

Accordingly, their study indexed cities with different degree of vulnerability on a scale of 10 (most vulnerable 10 to least vulnerable 1)

Overall vulnerability

9 Dhaka
8 Jakarta, Manila
7 Kolkata, Phnom Penh
6 Ho Chi Minh, Shanghai
5 Bangkok
4 Hong Kong, Kuala Lumpur, Singapore

Overall climate vulnerability

9 Manila
8 Dhaka, Ho Chi Minh, Shangai
7 Hong Kong
6 Jakarta, Kolkata
5 Bangkok
4 Phnom Penh, Singapore
3 Kuala Lumpur

Sensitivity Ranking: People, Assets and GDP under Threat

10 Jakarta
9 Shanghai
8 Dhaka
7 Manila, Kolkata, Bangkok
6 Hong Kong, Singapore
5 Kuala Lumpur

Inverse Adaptive Capacity

10 Dhaka, Phnom Penh
7 Jakarta, Manila, Kolkata
4 Bangkok
3 Ho Chi Minh, Kuala Lumpur
2 Shanghai
1 Hong Kong, Singapore

Asia is arguably among the regions of the world most vulnerable to climate change. Climate change and climatic variability have and will continue to impact all sectors, from national and economic security to human health, food production, infrastructure, water availability and ecosystems. The evidence of climate change in Asia is wide spread: overall temperatures have risen from 1°C to 3°C over the last 100 years, precipitation patterns have changed, the number of extreme weather events is increasing, and sea levels are rising. Because many of the largest cities in Asia are located on the coast and within major river deltas, they are even more susceptible to the impacts of climate change. In response, this report highlights the vulnerability of some of those cities—with the goal of increasing regional awareness of the impacts of climate change, providing a starting point for further research and policy discussions, and triggering action to protect people and nature in and around Asia's megacities from mega-stress in the future.

WAY FORWARD

India has initiated an exercise to map the hazard line along its coast that will assist in protecting the coastal communities and infrastructure from natural hazards such as cyclones, storm surges and tidal waves among others. The Survey of India in collaboration with the Ministry of Environment and Forests (MoEF) will map and delineate the hazard line along the coast. Based on the assessment, the coastal areas would be divided into high, medium and low erosion zones. Hazard-line mapping will cover the 5400-km coastline of Indian peninsula from West Bengal on one side to Gujarat on the other. After demarcation of the hazard line, it will give some picture as to which coastal areas are vulnerable to floods, cyclones and tsunami, which are annual phenomenon. Coastal erosion is a long-term phenomenon.

The mapping exercise, expected to be completed in four-and-half years, will benefit about sixty million people residing in the coastal areas and vulnerable to natural hazards.

On the academic front, Government of India has set up an exclusive coastal research institute in Chennai (National Centre for Sustainable Coastal Management, Ministry of Environment and Forests, Govt of India) with focus on:

1. Mapping (physical, coastal and social) vulnerability and tracking changes along the Indian coastline using the most modern geospatial technologies available in the country. This would be of immense benefit to the Ministry of Environment and Forests, to enable policy and enforcement decisions.

Mapping of shoreline changes, fishing space mapping, coastal land use, coastal structures and critically vulnerable coastal areas such as mangroves, coral reefs, sea grass ecosystems and other ecologically sensitive coastal ecosystems.

2. Enhancement of well-being of coastal livelihoods by providing energy security based on renewable systems, conservation of coastal and marine resources, addressing gender-based issues to enhance resilience, analyzing the consequences of sea level rise/climate change, changes in coastal fisheries, turning off freshwater flow to estuaries, causes and consequences in changes of human well-being.

3. Monitoring and assessment of critically vulnerable coastal areas (CVCA) through short and long term ecosystem assessment, participatory coastal and marine resources management, pollution impacts and coastal health monitoring, ecosystem services and ecological processes, cross-cutting: global change – interrelate social and natural elements and also evolve capacity building for coastal stewardship.

4. Ecology and vulnerability of islands by using disaster ecology approach for island vulnerability, provide scientific information for sustainable development of islands, pilot projects on energy and water security for the island communities.

Such a dedicated approach can become a trend setter for other Asian countries to organise their respective coastal regions in a sustainable way.

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