Some Aspects of Coastal Zone Management in Sri Lanka Including Impact of Tsunami: A Review

M.S. Rupasinghe and M.S.J. Perera
Department of Natural Resources, Sabaragamuwa University of Sri Lanka.

mrmahinda@yahoo.com, sandun.perera@gmail.com

ABSTRACT

2 km wide band of ocean and the adjoining strip of land extending 300 m inland along the 1,760km coastline is described as the coastal zone of Sri Lanka. It is rich in both living and non living resources including a diversity of coastal ecosystems; fringing coral reefs, sea grass beds, estuaries, lagoons, mangroves, salt marshes, sandstone reefs, sand dunes, sandy and rocky beaches, mud flats, gentle seashore vegetation and maritime grasslands. These habitats are important in restraining coastal erosion and sustaining coastal industries.

Over exploitation of resources, coastal constructions and pollution are major issues within the zone. Resources are being subjected to extractive (fisheries, sand mining), and non-extractive (tourism) pressures. Even though coastal capture fishery (edible and ornamental) resources are almost fully exploited, offshore fishery could still be expanded. Most of coastal constructions are related to fisheries and tourism industry.

Coast Conservation Department manages the zone, under the Coast Conservation Act (1981). The first Coastal Zone Management Plan developed in 1990 was revised with the assistance of Coastal Resources Management Project in 1997. Key management areas are coastal permit system and Special Area Management.

The Indian Ocean Tsunami took Sri Lanka by surprise as the island is not subjected to many coastal hazards except for localized coastal erosion and tropical cyclones. In addition to the huge humanitarian loss, it also affected coastal ecosystems. With understanding of the need for preparedness and disaster management, the Sri Lanka Disaster Management Act (2005) was enacted and several other measures were taken. It is evident that if the Coast Conservation Act and the CZMP were effectively implemented the tsunami damages could have been greatly reduced. It is also proven that the presence of natural ecosystems in coastal zone assist in minimizing impacts of coastal hazards, hence the importance of conserving them is emphasized.

Keywords: Coastal zone management, Resources, Conservation, Hazards, Tsunami, Sri Lanka.

Corresponding Author: Prof. M.S. Rupasinghe,
Head, Department of Natural Resources,
Faculty of Applied Sciences,
Sabaragamuwa University of Sri Lanka, Buttala, Sri Lanka.
Tel: +94 (0)55 2273988
Fax: +94 (0)55 2273987
E-mail: mrmahinda@yahoo.com

1. INTRODUCTION

Sri Lanka is a tropical island in the Indian Ocean with a history of continuing human occupation for over 25 centuries. The country's total population is around 19 million and with a population density of 280 persons per sq km, is one of the highest in the world. Over 40% of the people are engaged in activities directly dependent on the environment and about 25% people live in urban or semi urban areas (UNEP, 2001). Almost a third (32 %) of the country's population, two-thirds (65%) of the total urban population, two-thirds (67%) of the industrial facilities and over 80% of the tourist infrastructure are accommodated within, only one fourth (24%) of the island's land area having a coastal boundary (MoFE, 1999; Olsen et al., 1992). Projections estimate that coastal migration will continue to increase coastal population densities to even over 1,000 persons per sq. km (de Silva, 1997).

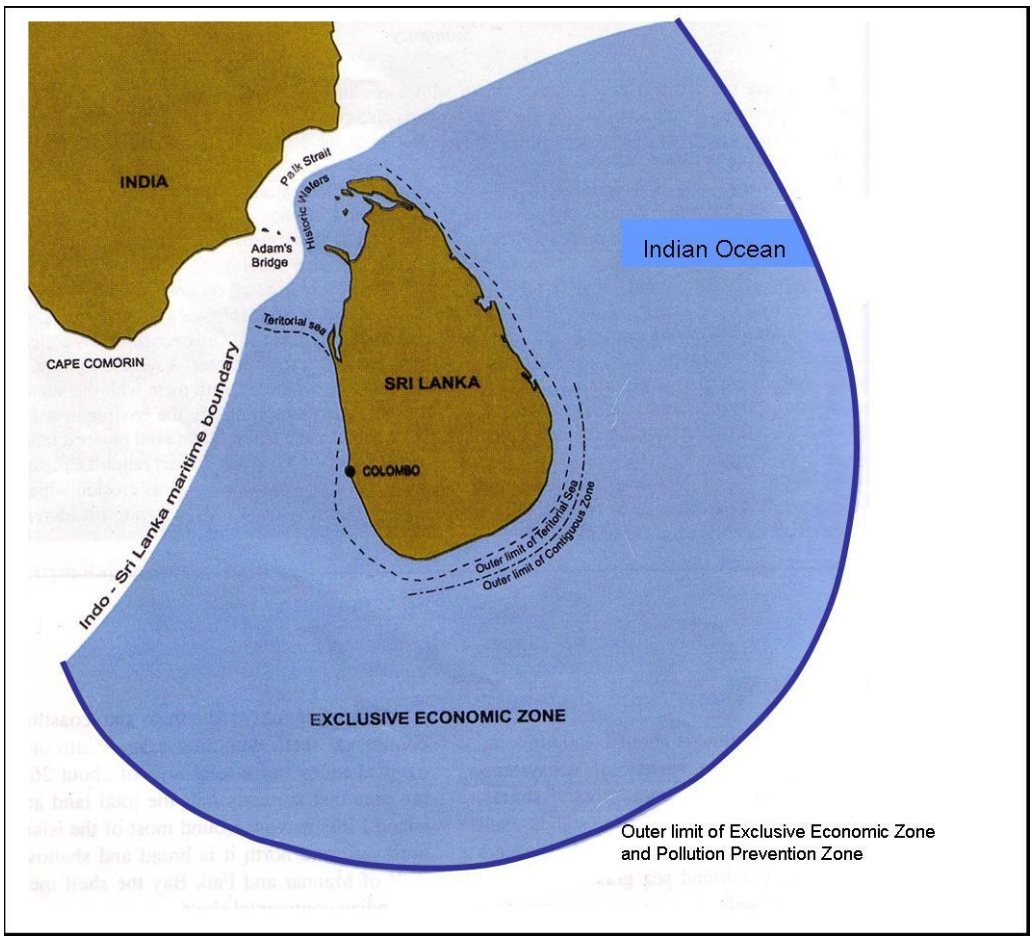

Figure 1: Coastal and maritime jurisdiction of Sri Lanka
Source: Natural resources of Sri Lanka 2000, National Science Foundation

The Coastal Zone of Sri Lanka, in the context of the Coast Conservation Act (CCA) of 1981 and amendments (MoFARD - Ministry of Fisheries and Aquatic Resources Development), is defined as the 2 km wide band of ocean and an adjoining strip of land extending 300 m inland. In the event of a water body connecting to the sea, the zone extends two kilometers inland from the mouth of the water body. The coastal zone thus, could be considered to include an area of land or water where ecological processes of both land and marine environments are inter-linked, with the influence from human activities in the region.

The length of the Sri Lankan coastline is about 1,760 km from which the Exclusive Economic Zone (EEZ) extends 200 nautical miles and covers an area of over 230,000 sq. km. Extending outwards from the coastline is the continental shelf, with an average width of about 40 nautical miles and a total area of about 26,000 sq. km. (nearly half the total land area of the island). The seas overlying the shelf are referred to as coastal. Beyond the edge of the continental shelf is the continental slope, which descends steeply to the floor of the deep ocean. The territorial limits of the island extend to 19.2 km offshore, beyond which lies the contiguous zone, under the provisions of the United Nations Environment Programme (Figure 1) (Arulpragasam, 2000).

The coastline and adjacent waters support highly productive marine ecosystems such as fringing coral reefs, shallow beds of coastal and estuarine sea grasses and an extensive system of 45 estuaries and 40 lagoons (UNEP, 2001). In addition, coastal ecosystems such as mangroves, salt marshes, sandstone reefs, sand dunes, sandy and rocky beaches, mud flats, gentle seashore vegetation and maritime grasslands occurs within sea-land interface.

The present paper reviews about the coastal resources, their depletion and other coastal issues in Sri Lanka with an emphasis on coastal hazards. The review also summarizes attempts and trends in Coastal Zone and Hazard Management in Sri Lanka.

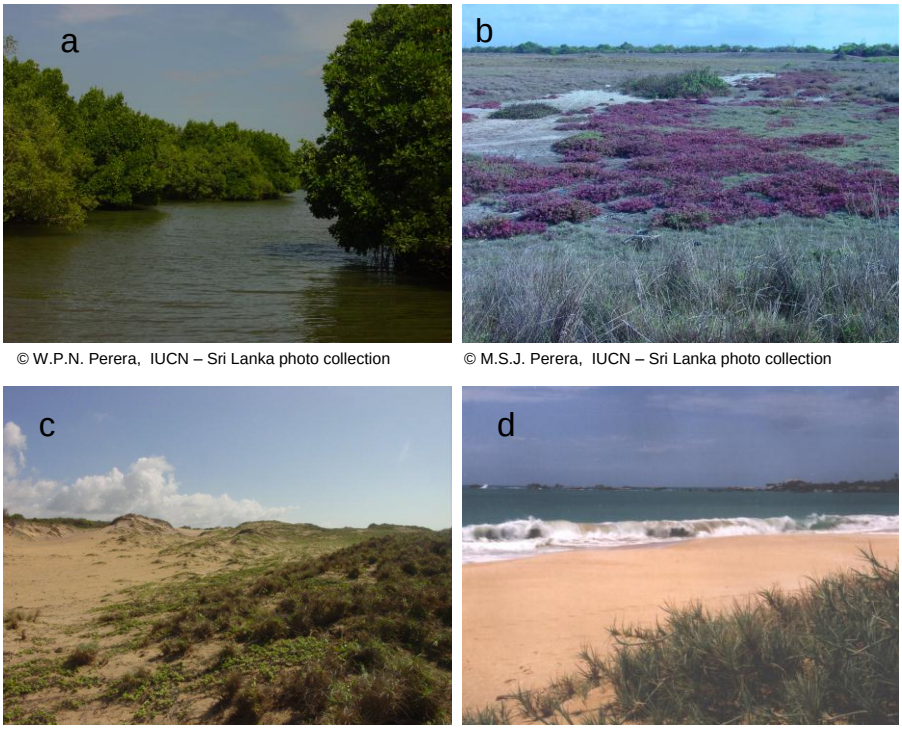

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Figure 3: Some coastal habitats found in Sri Lanka: a) Mangrove, b) Salt Marsh, c) Sand dune and d) Sandy beach

2. COASTAL RESOURCES IN SRI LANKA

The term “coastal resources” refers to anything that is useful for human, both living and non-living, found within the coastal zone. Economically, the coastal region is considered a distinctive area, where development is influenced to a large extent by access to the sea. The increase of the coastal

sector's contribution to the GDP from 35 % in 1983 to 40% by 1990s is indicative of increasing economic activity in the coastal area (Savundranayagam et al., 1994; Brown, 1997; UNEP, 2001).

Living renewable coastal resources in the form of marketable "goods" in Sri Lanka include fish, shark fin, shrimp, prawn, lobster, crab, bivalve, squid, cuttlefish, brine shrimp (*Artemia*) sea weed (*Gracillaria, Sargassum*), chank (*Xancus pyrum*), sea cucumber (beche-de-mer) and other invertebrates for the export aquarium trade (UNEP, 2001). In addition to those marketable living resources Sri Lankan coast is rich in an intrinsic biodiversity value; nationally threatened estuarine crocodiles, 5 species of globally threatened sea turtles, wading birds, sea birds and marine mammal species including globally threatened dolphins, whales and dugongs.

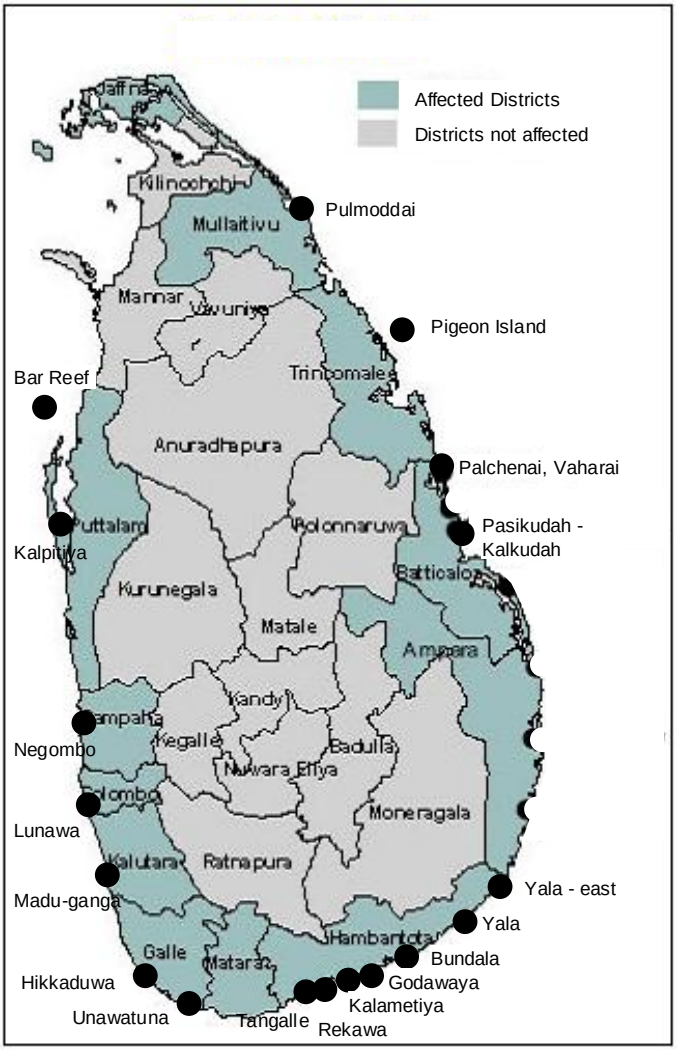

Figure 3: A map of Sri Lanka showing and sites mentioned in the text and districts affected by the Indian Ocean Tsunami

Non-living marketable coastal resources include mineral resources such as energy minerals, metallic minerals and non-metallic minerals. Among energy minerals, peat deposits that cannot as yet be economically used are estimated to be about 50 million tons. Radioactive minerals such as monazite, metallic ores such as iron ore (2.2 million tons), copper- magnetite deposits (4 million tons), mineral sands (4 million tons at Pulmoddai), ilmenite (3 million tons), rutile (6 million tons), zircon (4 million tons), high purity silica sands (6 million tons) as well as limestone, clays, deposits

of inland coral and seashells, granite, granitic gneisses, marbles, quartzites and chamockites are also found in the coastal area (Ranasinghe, 1997).

The "services" provided by coastal resources include a wide range, from flood protection, nutrient flows, nursery and breeding grounds of species harvested for commercial and ornamental purposes, and tourism, including recreational activities such as turtle, whale and dolphin watching. It is also important to note that many more coastal resources may still remain unknown since cataloguing and inventorying of resources, particularly those in the sea, have not been carried out comprehensively (UNEP, 2001).

3. RESOURCE EXPLOITATION AND DEPLETION

Diverse coastal resources are being subjected to extractive pressures such as fish capture or sand mining, as well as non-extractive pressures like aesthetic enjoyment and tourism (UNEP, 2001). Resource depletion, which occurs when, pressure of exploitation, exceeds generation rates are observed in some coastal resources, especially in the near-shore fishery industry. Excessive exploitation causes pressure directly on the resource itself by its physical overuse and/or by indirectly exerting pressure on the resource-related ecosystem, which disrupts resource generation rates.

The coastal capture fishery of edible species is the major economic activity using biological resources of the coastal area. The coastal sea is the site of activity for the capture of finfish and shellfish (mostly for domestic consumption) as well as fish and invertebrates (for the marine ornamental export trade). Bays and other near shore marine waters support the fishery of over 500 edible fish species. It has been recorded that about 70% of coastal living resources are composed of small pelagic fish like sardines, herrings, anchovies and mackerels and small demersal fish such as sciaenids and carangids (UNEP, 2001). The coastal fisheries provide nearly 97 percent of the marine fish production and 90 percent of the employment in fisheries (Arulpragasam, 2000).

Capture fishery which was 174,500 mt in 1994 rose to 152,750 mt in 1997 and to 171,950 mt in1999 (MoFARD, 1999). Estimates of the maximum annual sustainable yield of coastal capture fishery ranges from 250,000 mt to about 300,000 mt of fish (UNEP, 2001). Therefore, the exploitation pressure is gradually reaching the maximum sustainable capacity of the coastal ecosystem.

Possible over-collection and the use of inappropriate techniques, for aquarium/ornamental fish capture, as well as inappropriate modes of transport in the export aquarium trade have also caused severe threat to reef fish populations in near shore habitats. According to UNEP (2001) although the freshwater fish export industry cultures most of its exported fish, no marine species are cultured in Sri Lanka. They are collected mostly from inshore areas where corals occur, often using the "moxy net" that damages the reef structure, while individuals are being caught from the sea by snorkelers and divers.

In the capture aquarium fishery industry, 530 mt of organisms (both collected from marine and freshwater) comprising approximately 200 species with a value of about Rs. 300 million was exported in 1996, which almost doubled to 1043 mt (with a value of Rs. 531 million) in 1998 (MoFARD, 1999; Ekaratne, 1997).

Offshore fishery resources in Sri Lanka is under-exploited and further expansion of this sector could yield much more economic gains. Offshore fishery which contributed 4,259 mt or 2.2 % to the total marine fishery in 1987, and 7.1 % in 1990, has been expanded to around 25 % in 1995 and 1996 (NARA, 1998) and to 29 % in 1997 (UNEP, 2001).

Some invertebrate species in the edible marine capture fishery have been overexploited resulting in dwindling numbers. Sea cucumber (beche-de-mer) fishery is a good example as, although 13 of the 70 species recorded in Sri Lanka are consumed in various parts of the world, only the dominant species (*Holothuria scabra*) is being selectively harvested. Unsubstantiated reports indicate that several species are now being over harvested. Lobster and crab are also exported with 1998 export quantities being 164 mt and 486 mt, respectively. The harvesting of lobster could have harmful effects on wild stocks, as gravid lobsters as well as small-sized lobsters are regularly collected in spite of bans on such collection (UNEP, 2001).

The collection of coastal non-living resources has also expanded gradually, increasing pressure on the resource and stability of the habitat. For example, garnet sand mining creates instability of the shores at Hambantota in the south east of Sri Lanka, inland coral mining and seashell mining result in ground pits that alter the habitat profile in Kalametiya and may other areas in the south east. Sand mining carried out extensively has affected the beach nourishment and the integrity of the shoreline (UNEP, 2001). The volume of sand extracted has increased from 523,780 cubes in 1984 to 625,662 cubes in 1991(CCD, 1997). Sand mining from the offshore seabed has attracted discussion in recent times for purposes of infrastructure development such as highways.

The impacts of over exploitation can have a direct effect on the related coastal resource and/or affect the resource generating process through effecting on habitat and ecosystem quality. Coastal resources may have a resilient capacity to withstand, or to rebound from, impacts by natural phenomena. This resilience may, however, be adversely affected by impacts arising from man-induced pressures as discussed above.

4. DEVELOPMENT IN THE COASTAL ECOSYSTEMS AND POLLUTION

Development in the coastal zone of Sri Lanka is primarily related to economic activities conducted in order to utilize living and non-living coastal resources. In return most of these unplanned and unsustainable developments have adverse impacts on coastal ecosystems such as mangroves, salt marshes, coral reef as well as sand dunes. Major industries that sustain on the coastal resources in Sri Lanka, which leads to coastal constructions are fisheries and tourism. In addition, housing, roads, railways and other infrastructure have excreted a pressure on the coastal ecosystems in urban areas.

Infrastructure development for the fishing industry such as the construction of harbours creates pressure on coastal ecosystems and coastal resources. Additional pressure is created by pollution from boats, anchor damage, unsustainable fisheries such as catching small sized fish, use of dynamite and other destructive practices (UNEP, 2001).

Coastal aquaculture progressed massively during past three decades having severe impacts on mangroves and coastal wetlands, due to the high profits in its initial stages. Prawn farms (Tiger prawn export industry) were established in cleared ecologically sensitive mangrove areas in the northwest exerting tremendous pressure on mangroves and degrading associated lagoons and

estuaries. It is estimated that 400 to 500 ha of mangroves or mangrove associates (NARA, 1995) have been cleared for prawn farms in North West.

Increasing tourist arrivals will continue to be a source of pressure on coastal resources, particularly because coastal tourism is showing rapid growth worldwide (Brown, 1997). The pressure on coastal habitats through hotel construction, which was low before 1960's, is now seeing a gradual increase. Tourism in Sri Lanka has primarily focused on its scenic sandy beaches and coastal estuaries and lagoons. About 85 percent of tourism revenue comes from facilities in coastal areas. Today over 75 percent of graded hotels and over 80 percent of the hotel rooms are located along the coast (NARESA/USAID, 1991). Land filling for infrastructure facilities such as roads and housing, which occur in coastal wetlands, especially in urban and sub-urban areas has also become a threat to coastal habitats.

Considerable pressure is exerted on coastal water quality by ships operating on the major international shipping route off the southern and south-western coast with an estimated annual traffic of over 5,000 tankers (NARESA/USAID, 1991). The routine dumping of engine oil into the water by fishing craft further pressurizes water quality as well as the food web functions. Occasional grounding of oil tankers, oil spills and leaks has also occurred in the recent past (UNEP, 2001).

Industrialization in the coastal zone also creates pressures on the natural ecosystem. The discharge of tannery industry waste is one of major issues discussed during recent past. Pressure on coastal ecosystems from upland or upstream sources are common, such as the seepage of chemicals, including agrochemicals, into the sediment load that eventually reaches the coastal habitats through river run-off. Pollution can therefore arise from point and non-point sources (UNEP, 2001).

5. COASTAL ZONE MANAGEMENT IN SRI LANKA

In resource management, the coastal region can be considered to represent an area of transition where terrestrial and marine environments interact to form unique environmental conditions. The coastal region therefore includes inshore waters, inter-tidal areas and extensive tracts of contiguous land (Brown, 1997).

Population growth has increased pressure on the resources of Sri Lanka's coastal zone, creating new stresses in the coastal environment. Industrial development since the late 1950s, beach based tourism development since the late 1960s and the open economic policies of the late 1970s have all placed strains on the coastal environment. By the early 1970s problems associated with coastal development had begun to arise. The need for a more management-oriented approach was first recommended in 1971 by the coast protection unit of the Colombo Port Commission. In 1978 the subject of coast conservation was transferred to the Ministry of Fisheries, by the creation of Coast Conservation Division. This division was upgraded to the status of a Government Department in 1984 (Samaranayake, 2000).

5.1. Coast Conservation Act No. 57 of 1981

Amended by Act No 64 of 1988 the Coast Conservation Act was primarily intended to conduct a survey and prepare a Coastal Zone Management Plan (CZMP) in addition to regulating development activities within the coastal zone. This Act prohibits any development activity within the coastal zone without a permit from the Director of CCD, which will be issued only if the

proposed activity is consistent with the CZMP and such activity would not have any adverse impact on the stability, productivity and environment quality of the coastal zone (Jayawardane, 2005).

5.2. Coastal Zone Management Plan (CZMP)

As required by the coast conservation act, the first CZMP was prepared and approved by the cabinet of ministers in 1990. The 1990 plan deals with the coastal problem of erosion, loss and degradation of natural coastal habitats, and also the loss and degradation of archeological, cultural and historical sites, as well as recreational and scenic areas. Objectives and policies for the management of each problem were identified along with specific management techniques. In particular, the rationale and procedures for continuing the coastal permit system are detailed. Implementing actions in this plan are regulation, direct development, research, co-ordination, education, and planning and policy development (Samaranayake, 2000).

The CZMP permitted construction activities within the coastal zone of 300m subject to the setbacks defined in it. But, law enforcement was not very effective for several reasons resulting in ad-hoc construction within the coastal zone. Difficulty in effective implementation of the Act has been compounded due to provisions in other government Acts such as Mines and Mineral Act. No 33 of 1992 and Sri Lanka Land Reclamation and Development Corporation Amending Act No. 52 of 1982 facilitating development bypassing CCA, even though Town and Country Planning Amending Act No. 57 of 1981 restrict any development within Coastal Zone except after consulting the Minister in charge of coast conservation (Jayawardane, 2005).

The CCA requires the CZMP to be revised every 4 years. The CCD with the assistance of the Coastal Resources Management Project (CRMP) reviewed the main objectives, policies and activities of the CZMP-1990. The process included several national level workshops to review set-back regulations and other local level meetings and workshops. The revised plan – CZMP-1997 was effective from 1st November 1997. New focuses are the reduction of coastal pollution and Special Area Management (Samaranayake, 2000). The CZMP was further revised in 2004 following a similar process in order to strengthen the capacity of CCD in managing the coastal zone. The Special Area Management (SAM) can be defined as a collaborative, adaptive and flexible approach to planning resource management within a defined geographic area. Initially two SAM sites were chosen in the south coast - Rekawa and Hikkaduwa, and ecological profiles as well as SAM plans have been prepared. SAM process is now being implemented by CRMP in seven sites (Kalpitiya, Negombo, Lunawa, Madu-Ganga, Hikkaduwa, Unavatuna and Tangalle), among 23 sites identified as eligible for SAM programme within the island (pers. com., CCD, 2006).

5.3. Major Milestones in Sri Lankan Coastal Zone Management

Sri Lanka have passed several milestones in the coast conservation arena during past 25 years, starting from the CCA in 1981. Few of main achievements could be listed as,

- Promulgation of laws (such as the CCA, Environment Acts, and regulations promulgated under the provisions of the Fisheries and Aquatic Resources Act)
- Preparation and implementation of National CZMP of 1990, 1997 and 2004.
- Requirement for Environmental Impact Assessments and issue of permits by the CCD for major developmental activities in the coastal zone
- Outlawing unsustainable methods of fishing, such as “light course” and dynamite fishing, as well as the capture of gravid lobsters and undersized lobsters, and coral mining.
- Increasing inputs into deep water oceanic fisheries so as not to increase pressure on coastal near-shore fishery resources

- Declaring protected areas for in-situ habitat conservation such as the Hikkaduwa, and Pigeon Island National Parks and the Bar Reef Sanctuary
- SAM Programme and the Wetland Conservation Project

In addition, Sri Lanka is a signatory in several International Conventions dealing on the management of coastal resources. They include the United Nations Convention on the Law of the Sea (UNCLOS), Conventions within the Regional Seas Programme of United Nations Environment Programme, Convention on Biological Diversity (CBD), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Convention on Wetlands of International Importance especially as Waterfowl Habitat (RAMSAR Convention), International Convention for the Prevention of Pollution from Ships (MARPOL Convention), and the Convention for the Prevention of Marine Pollution from Land-based Sources (Paris Convention) (UNEP, 2001).

6. COASTAL HAZZARDS

Natural disasters in Sri Lankan coasts are commonly caused by localized coastal erosion and tropical cyclones. The devastation caused by Indian Ocean tsunami in 2004, however, took Sri Lanka by surprise warning that Sri Lanka is also vulnerable to low-frequency high impact events with extensive damage. Earthquakes have also been recorded over the past 400 years with relatively small magnitudes with no significant damage. But, any future seismic damage to Sri Lanka cannot be excluded specially due to increased seismic activity in the region with a new tectonic boundary formed below Sri Lanka (Jayawardane, 2005).

6.1. Coastal erosion

Coastal erosion has been a problem over the years especially in the south, west and northwestern coasts. At certain locations, net erosion has been recorded up to 1 m per year. Accretion rates, on the other hand, have not exceeded 0.1 m per year, except in the northeast where the rate is 0.3 m per year. The average for the entire county is a net mean rate of erosion of 0.20 to 0.35 m per year (CCD, 1997). Mainly Sri Lanka's south-western and southern coastal belt is affected by coastal erosion damaging infrastructure such as coastal railway, road system, communication and other economic activities along the coast, such as fishing and recreational activities. Damages to residential buildings, hotels and degradation of valuable land also occur on regular basis (Jayawardane, 2005). Two major factors make the western and southwestern coasts of the island particularly vulnerable; the impact of the southwest monsoon and the geology of the coastline. The latter has produced a bay and headland topography in those coastlines (Arulpragasam, 2000).

The expenditure incurred annually to mitigate shore erosion is at great cost to the national economy (Berg et al., 1998). Shoreward wave force in some areas in the southern coast has shown a statistically significant increase after post bleaching death of corals in 1998 and the subsequent collapse of the reef structure (UNEP, 2001).

Causes of coastal erosion include damming of rivers, sand mining in beaches and rivers, destruction of protective reefs through coral mining, collection of coral rubble, removal of coastal vegetation, improperly sited shore protection structures and buildings as well as the loss in river discharge due to upland water use (Jinendradasa and Ekaratne, 2000).

6.2. Tropical Cyclones

Sri Lanka's eastern and north-eastern parts are vulnerable to cyclones especially during November –December with occasional cyclone impacts in some parts of north-central and north-western provinces. Most of tropical storms developed in the south-west or south-east Bay of Bengal may become a cyclone storm (67-117km/hr) or cyclone (above 118km/hr) just after passing Sri Lanka's latitudinal region and hence Sri Lanka is less vulnerable to direct impact of a cyclone (Jayawardane, 2005). Major cyclones have occurred in the years 1907 1922, 1978 and 2000 (DMC, 2005).

http://datum.gn.apc.org/resources/slide-10jpg & slide-4.jpg

Figure 4: Damage cause by tropical cyclone in Sri Lanka, 1978

6.3. Coral bleaching

Coral reefs are an important coastal resource that constrain coastal erosion and sustain coastal fisheries. The mass coral bleaching caused by El Nino Southern Oscillation (ENSO), that occurred in April 1998, resulted in extensive (around 80%) coral death followed by serious impacts on the reef ecosystem and in changes in fish populations, species composition, reef structure, biodiversity, succession and ecosystem functions. Most of the branching and tabulate corals were completely destroyed within the depth range of 1 to 8 m. Even after two years of the bleaching, it was observed that, existing coral species have not recovered their reproductive capacities and there is little likelihood that reef ecosystems would regenerate and provide their normal services (Abeysirigunawardana and Ekaratne, 2000a, 2000b; Arulpragasam, 2000; Jinendradasa and Ekaratne, 2000).

6.4. Tsunamis

Sri Lanka's coastal belt covering the districts of Jaffna, Mullaitivu, Trincomalee, Batticaloa, Amparai, Hambantota, Matara, Galle, Kalutara, Colombo, Gampaha and Puttalam (Figure 3) were severely affected by the Indian Ocean (Boxing Day) Tsunami on December 26, 2004. The affected region in Sri Lanka harbors many key marine and coastal ecosystems such as coral reefs, mangroves, sea grass beds, coastal sand dunes, mudflats, salt marshes, and lagoons, all of which plays a vital role in sustaining living natural resources on which many people in the affected region depend. The effect of the tsunami on these ecosystems has the potential to be very severe

ecologically, which could also reduce the provision of environmental goods and services to the society and economy.

The Indian Ocean Tsunami took Sri Lanka by surprise making it the worst natural disaster ever experienced in Sri Lanka killing about 35,000 people. At least 16,000 were injured. Almost one million people suddenly became homeless, and an estimated 350,000 lost their jobs, including fishermen, other informal traders, and micro enterprise employees representing tourism as well as other small businesses, infrastructure, schools, tourist hotels, and other commercial buildings were damaged (Jayawardane, 2005, Preuss, 2005). But, in the present review paper we concentrate more on the impact of the tsunami on coastal environment, despite the damage to property and human society.

The North East coastline appeared to have borne the brunt, with the affected areas reaching 2-3 km inland. The tsunami has affected a much narrower strip in the Southern and Western coastlines, with the affected areas limited to approximately 500 meters or less and at elevations below about 2.5 to 3 meters. The damage caused by the tsunami in the Ampara and Batticaloa districts in the eastern Sri Lanka, both to human infrastructure and property as well as to natural ecosystems, was far more severe than that observed in the southern coast of Sri Lanka. However, the tsunami damage to natural and human-modified ecosystems has not been uniform everywhere. Both the extent and intensity of damage has been determined to a significant extent by site-specific factors and conditions (Bambaradeniya et al., 2005c).

There has been a very little loss of fauna recorded in the protected areas affected by the tsunami. Few wild boars (*Sus scrofa*) and a peafowl (*Pavo cristatus*) were recorded dead in Yala (pers obs. & pers. com., Park officials of Yala National Park, 2005).

Apart from fish, other dead vertebrate animals observed in Rekawa, Kalametiya and Godawaya areas in the south eastern coast include two specimens of Mouse Deer (*Tragulus meminna*), a Land monitor (*Varanus bengalenisis*) and a soft-shelled Terrapin (*Lissemys punctata*). Dead invertebrate animals observed in the affected habitats include several species of freshwater and terrestrial mollusks, as well as hermit crabs. A large number of turtle nests in Rekawa area and the Bundala National Park had been destroyed by the Tsunami waves. (Bambaradeniya et al., 2005a, 2005c; Bambaradeniya, 2005)

In contrast there has been a significant impacts on coastal habitat and floral diversity in and outside protected areas such as Yala East, Yala, Bundala, Kalametiya, Rekawa and Pigeon Island (Figure 3) (Jayawardane, 2005, Perera et al., 2005; Bambaradeniya et al., 2005b; Bambaradeniya, 2005). The gentle sea-shore vegetation consisting of creeping plants and *Pandanus* stands have been severely affected by facing the tidal surge being in the beach front. Sandy beaches, seaward slopes of mature sand dunes, and immature sand dunes have been eroded. Salt marshes, coastal grasslands and mangrove ecosystems have been affected due to large volumes of sand and marine sludge being transported and deposited by the tsunami waters. In mangrove stands, the tree line facing the waves has been subjected to moderate to severe damage. The invasive alien Prickly Pear Cactus (*Opuntia dillennii*) that occurred in patches in the beachfront habitats have been removed and transported to distant inland areas by the tsunami waves, and these propagules are established in new areas. The spread of another invasive alien plant – Mesquite (*Prosopis juliflora*), may increase rapidly over time, as it exhibits a competitive dominance under increased saline conditions (Bambaradeniya et al., 2005a).

It was also expected that the damage to the inter-tidal and sub-tidal area could have been extensive. Many coral reefs might have lost their structure and biota and might even be reduced to rubble in certain areas due to mechanical damage (Jayawardane, 2005). Large piles of coral rubble that have been accumulating on the beach were observed in Pasikudah-Kalkudah in the eastern province of Sri Lanka. These piles consist of a variety of coral types, the majority of which are branching corals in small broken pieces. Similarly in Palchenai (Vaharai) in the east coast many pieces of branching coral have been broken and are being abraded amongst the rubble. There were also occasional observations of table corals and massive coral colonies having been overturned. (Bambaradeniya et al., 2005c). There could also be significant contamination by runoff from land, with large quantities of wastes and pollutants, debris, soil and organic matter. Many marine organisms that may have survived the wave itself may later be adversely affected or killed due to deposition of debris and sand on reefs and seagrass beds (Jayawardane, 2005).

Figure 5. Tsunami impact on coastal ecosystems in Sri Lanka: a) Funneling of tsunami waves in Kalametiya lagoon, b) Beach erosion caused by tsunami in Kahanda-modara. c) Piles of dead coral rubble washed up on Pasikudah beach , d) Uprooted mangrove trees, sand and other debris deposited on salt marshes in Ambalantota, e) Impact on gentle sea shore vegetation dominated by *Pandanus* in Oruwella, Rekawa, f) Destroyed frontline mangroves in Kahanda-modara.

Greater ecological impacts are also on freshwater bodies and fishery breeding grounds in the protected areas, which have now been contaminated with saline water. Groundwater contamination and the disposal of debris was another significant environmental issue brought up due to the tsunami.

7. COASTAL HAZZARD MANAGEMENT

Hazards or disasters were previously perceived as isolated events, which need to be responded with 'emergency relief' as the standard norm. It is now recognized that disaster management is more effective if it is preceded by preparedness and the relief is followed by rehabilitation and

reconstruction (Jayawardane, 2005). Consequent to two workshops conducted in July and December 1994 to mark the International Decade for Natural Disaster Reduction and to exchange national experiences in disaster management, the government established the National Disaster Management Centre (DMC) in July 1996 under the Ministry of Social Services (Karunaratne, 2002).

Although several initiatives were taken by Sri Lankan government to mitigate the damages caused by the Indian Ocean Tsunami, they were initially reactive emphasizing relief and recovery rather than proactive with damage prevention or minimization strategies. Later the need for damage prevention strategies was emphasized and it was also discussed to develop an improved communications system to alert communities of impending dangers. The government by newspaper notices in February 2005, declared two zones of coast conservation buffer zones. Zone 1 includes western and southern coastal belt with 100m buffer zone and Zone 2 includes eastern and northern coastal belt with 200m buffer zone from the mean high water line (Jayawardane, 2005). Due to a considerable delay in settling tsunami victims lived within these buffer zones in other safer areas and protests by public and opposition political parties these limits have further been amended. It is evident that if the CCA and the guidelines in the CZMP were effectively implemented the damages caused by 2004 tsunami could have been greatly reduced. (Jayawardane, 2005).

However, 2004 tsunami has made responsible parties to act collectively for a comprehensive, long term and holistic disaster risk management framework. In May 2005, the Sri Lanka Disaster Management Act No 13 of 2005 was enacted providing a solid legislative and institutional arrangement for disaster risk management establishing a powerful National Council for Disaster Management under the President and the DMC as the lead agency for disaster risk management. In November 2005, the Ministry of Disaster Management was established to provide undiluted leadership. The Ministry declared its Road Map in December 2005 focusing on seven thematic components. They are policy, institutional mandates, and institutional development, hazard vulnerability and risk assessment, multi hazard early warning systems, preparedness and response plan, mitigation and integration of disaster risk reduction into the development process, community based disaster risk management, and public awareness, education and training. It is expected that proper implementation of this Road Map will go a long way towards safer Sri Lanka from natural disasters (Jayawardane, 2005).

In addition to the humanitarian needs, several short-term environmental recovery needs and priorities were identified during the aftermath of tsunami. They are rubble and debris disposal, study of the role of natural resources in minimizing tsunami damage, clean up of dug wells and tube wells in affected areas, study the impacts on Protected Areas and other environmentally sensitive areas affected by the tsunami as well as a Strategic Environmental Assessment of the rehabilitation and reconstruction Programs. Most of these short term needs were fulfilled in varying degrees during the first year after the disaster, by the government with the fullest involvement of a large number of international and local non-governmental organizations, as well as community based organizations in those affected areas.

Studying long term environmental impacts on the marine ecosystems, development of sustainable waste management systems for affected areas, actions to rehabilitate the coastal ecosystems damaged by the tsunami, as well as reconstruction of damaged and destroyed buildings in National Parks were identified as medium to long term tsunami response priorities concerning on the environment. The requirement to undertake environmental impact assessments for all rehabilitation and reconstruction activities was also emphasized to ensure adverse environmental impacts are

minimized and appropriate mitigation measures are included when designing reconstruction and rehabilitation projects.

7.1. Protective function of natural landscapes and their protection importance

It has been clearly proven by post tsunami environmental assessments in Sri Lanka (Ekanayake et al., 2006; Bambaradeniya et al., 2005a; Bambaradeniya et al., 2005c; Dahdouh-Guebas et al., 2005) as well as else where (Danielsen et al., 2005; Hiraishi and Harada, 2003; Stokstad, 2005) that, the presence of healthy natural ecosystem components in coastal belt have assisted in minimizing tsunami impacts considerably. Intact mature sand dunes (i.e., old and broad dunes covered with gentle sea shore vegetation) have functioned as an effective barrier against the tsunami waves, thereby protecting inland ecosystems and human settlements. Intact *Pandanus* vegetation, as well as *Cassuarina* plantations have also served as a frontline defense by absorbing the wave energy of tsunami. Broader stands of mangroves, especially served as a protective barrier against the wave at places where, coastal wetlands like lagoons and estuaries are connected to the sea. As widely reported, extensive areas of mangroves can reduce the loss of life and damage caused by tsunamis, but narrow mangrove strips can have limited positive effects. Coastal wetlands, including mangrove swamps, salt marshes, broad estuaries and lagoons also have diffused the destructive power of sea-water and sediments brought in by the tsunami waves, thereby protecting managed landscapes such as paddy fields and settlements. In addition, it was noted that coral reefs, rocky beaches and sandstone reefs have reduced the energy of incoming waves. Moreover, it has been observed that tsunami waves have penetrated inland with a greater force in areas where natural sand dunes have been exploited and/or converted into managed landscapes such as Coconut plantations and home gardens. In areas, where near shore coral reefs have subjected to prolonged mining or destroyed by bottom set netting, etc. were also considerably damaged by tsunami waves (Ekanayake et al., 2006; Kruse, M. 2005).

In light of above evidence it was clearly proven that, sites shielded by tall mature sand dunes, and *Casuarina* plantations on at the beach front as well as broad intact mangrove stands, bordering coastal wetlands have functioned as effective barriers against the tsunami protecting inland landscapes. Therefore, while it may be a good investment to establish early warning systems for the next tsunami, it could be far more effective to restore and protect coastal landscapes as a natural defence in parallel.

8. CONCLUDING REMARKS

It has been observed that unplanned development and land use, ad-hoc human settlement and lack of implementation of existing regulations have caused severe encroachments in the coastal zone and they should be managed in order to avoid future losses of human life as well as property during coastal hazards. In the view of that the implementation of the CZMP should be strengthened with adequate enforcement of law. It is hoped that proper implementation of SAM plans and establishment of new SAM areas will improve the ecological as well as socio-economic status in sensitive coastal landscapes in the island

It is also extremely important to identify the importance of protecting natural coastal landscapes and habitats like sand dunes as well as mangroves taking lessons learnt during the 2004 Indian Ocean tsunami experience. An early warning system as well as an effective system of communication should be placed within the coastal zone, in order to facilitate quick action in a crisis like a tsunami or a tropical cyclone.

The hazard or disaster management has not been considered as a priority issue in social security in Sri Lanka till the devastating tsunami made it the worst disaster ever experienced by Sri Lankans. Therefore, even though disaster management initiatives were taken to recover from localized environmental hazards, they were not sustaining, and the focus was mainly on relief. But with the recent initiatives taken through enacting the Disaster Management Act as well as the new Ministry and the National Council for Disaster Management, with the assistance from international and local non-governmental organizations as well as the academia, Sri Lankan coastline is hoped to be well protected from future environmental hazards.

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ABBREVIATIONS

UNEP – United Nations Environment Programme
MoFE – Ministry of Forestry and Environment
CCD – Coast Conservation Department
CCA – Coast Conservation Act
MoFARD – Ministry of Fisheries and Aquatic Resources Development
EEZ – Exclusive Economic Zone
NARA – National Aquatic Resources Research and Development Agency
USAID – United States Agency for International Development
NARESA - Natural Resources, Energy and Science Authority of Sri Lanka
CZMP – Coastal Zone Management Plan for Sri Lanka
CRMP – Coastal Resources Management Project, Sri Lanka.
SAM – Special Area Management
DMC – National Disaster Management Center