SRI LANKA

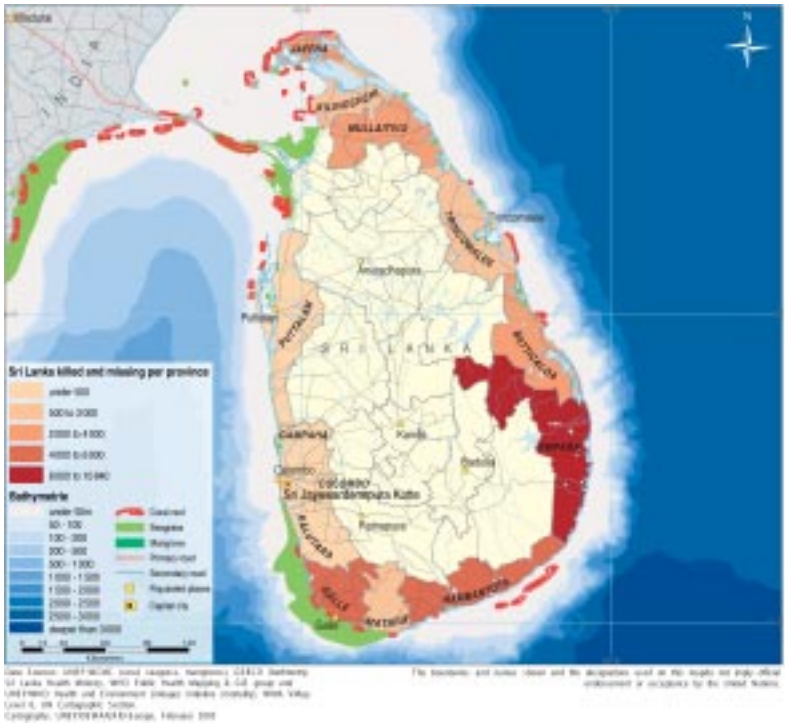
Galle, Sri Lanka (26 January 2005). A Sri Lankan man places a lit earthenware lamp in the sea at Unawatuna Beach in Galle, some 123 kilometres south of the capital, Colombo. Sri Lankans lit some 40,000 lamps in memory of those killed by the tsunami. The Sri Lankan Centre for National Operations lists 30,957 dead and 5,637 missing.

4. NATIONAL RAPID ENVIRONMENTAL ASSESSMENT – SRI LANKA

4.1 Introduction

The first tsunami wave began to impact the eastern coast of Sri Lanka about 100 minutes after the earthquake, at approximately 8:40 a.m. The wave surge was recorded at between 5 and 6.5 metres in most of the eastern and northeastern coast, and parts of the southern coast, doing most damage up to 3 metres above mean sea level. A secondary wave struck approximately 20 minutes later.

The complex interaction between water-borne energy, sea-bed and terrestrial terrain meant that the effects of the tsunami were different from place to place, but in general the eastern, north-eastern and south-eastern coast of Sri Lanka were particularly hard hit. Overall, the tsunami affected two-thirds of the coastline of Sri Lanka, over 1,000 kilometres in total. Seawater penetrated from tens to hundreds of metres inland (in places thousands of metres), and typically drained away within 30 minutes. During that time, between 31,000 and 37,000 people were killed by drowning or debris impact, and nearly 100,000 houses were destroyed along with tens of thousands of vehicles and much infrastructure. About 27,000 fatalities were fishermen, and two-thirds of the nation's fishing boats were wrecked, destroying many jobs. Farming was affected by the incursion of large amounts of salt water and marine sediment to fields and wells. Tourism was suspended in the middle of its peak season, and many coastal hotel rooms were destroyed and additional jobs lost.



A state of emergency was declared in all 12 of the affected coastal districts, and the national emergency and security services deployed rapidly. In the north and east an active role was also taken by the Liberation Tigers of Tamil Eelam (LTTE). The President moved swiftly to appoint three national task forces to lead and coordinate the response of the line agencies, these being the Task Force for Rescue and Relief (TAFRER), the Task Force for Logistics and Law and Order (TAFLOL), and the Task Force for Rebuilding the Nation (TAFREN). Many national initiatives have since been taken, ranging from the announcement that a restricted construction zone would be demarcated on the ground 100–200 metres from the coast,

Seenigama, Sri Lanka (26 January 2005). A Sri Lankan woman sits among the rubble of her house destroyed by the tsunami as aid workers help clear debris at Seenigama Village, some 90 kilometres south of the Sri Lankan capital Colombo. © Prakash Singh/AFP/Getty Images

to measures to relieve hardship such as confirmation that the salaries of civil servants killed in the disaster would continue to be paid to what would have been their retirement age and full pension rights guaranteed thereafter.

The donor community and government reacted quickly to the tsunami disaster and deployed many teams to assess various dimensions of damage, the need for restoration and recovery, and opportunities to improve the circumstances of affected peoples.

4.2 Overview of the Environmental Response

The Government of Sri Lanka, through its Ministry of Environment and Natural Resources (MENR), quickly requested urgent assistance from UNEP to work with national experts in conducting a rapid environmental assessment (REA) of the damage caused by the tsunami. Environmental issues specified for assessment included coral reefs, shore erosion, coastal land use planning, water pollution, and soil contamination. The Government further specified that its top priority for UNEP after the assessment was in developing a forward-looking plan for coastal zone management, in which lessons learned from the disaster would be adequately incorporated.

The UNDAC mission that was launched in Sri Lanka on 26 December 2004 included a UNEP-OCHA environmental expert, who focused on acute environmental problems with immediate and direct relevance to human lives and welfare. Based on the initial information collected, UNDP and UNEP submitted a project proposal to the UN Flash Appeal for $3,000,000 to undertake short and medium term measures for the assessment and recovery of natural resources and livelihoods.

The planning phase of the REA began with the deployment of senior UNEP staff to Sri Lanka on 5 January 2005. By 17 January 2005, the South Asia Co-operative Environment Programme (SACEP) agreed to provide logistical services in support of the UNEP REA team. Meanwhile, the MENR and Central Environmental Authority (CEA) had defined methods for the REA based on contracting teams from four universities (Moratuwa, Ruhuna, Eastern and Jaffna), supported by other sources of expertise, to undertake a field analysis of tsunami impacts on 'green' (ecosystem and biodiversity impacts) and 'brown' (pollution, debris and impacts on human settlements and infrastructure) aspects of the environment. A UNEP adviser arrived on 19 January 2005 to provide additional technical expertise to the assessment.

The REA is being prepared in coordination with various donor agencies, both bilateral (e.g. the Netherlands and Sweden) and multilateral (e.g. World Bank, ADB and JBIC). It relates to the stated needs of the Government of Sri Lanka, as well as to the work of the special Task Forces appointed by the President of Sri Lanka in the aftermath of the disaster, especially TAFREN.

An Advisory Committee comprising senior government officials and academics, and including UNEP, was appointed by MENR to oversee the REA, and approved its methods on 3 February 2005. The timeline for the REA is as follows:

(i) data collection from 7 February to 18 March 2005.
(ii) compilation of findings from 18-31 March 2005.
(iii) final report preparation from 1-18 April 2005.

The Advisory Committee is scheduled to meet on 25 February 2005 to review progress, and around 18 March 2005 to review findings.

The CEA, using funds from the Government of the Netherlands, is conducting its own parallel studies with an emphasis on solid wastes. All assessments are being conducted under the strategic oversight of the Advisory Committee chaired by MENR and including senior officials of the CEA, Department of Wild Life Conservation, Marine Pollution Prevention Authority, Ministry of Fisheries and Oceanic Resources, Coast Conservation Department, National Aquatic Resources Research and Development Agency (NARA), Forestry Department, Tourist Board, Urban Development Authority, and others including UNEP.

In terms of NGO activities, IUCN, CORDIO, Global Coral Reef Monitoring Network, and the Sri Lanka Sub Aqua Club are undertaking with NARA an assessment of impacts on coral reefs in the east, south and southwest, and of impacts on other coastal ecosystems in the south.

To date, information sharing has been effective, and this interim report is based on numerous studies addressing a range of sectors and sub-sectors, including those prepared by The Government of Sri Lanka and donor agencies, as well as others commissioned by UNEP. As a result, there are few gaps in absolute coverage, although more detail is needed and is now being collected as a basis for reconstruction planning.

4.3 Preliminary Findings: Impacts on the Natural Environment

The Coastal Zone

Sri Lanka has a coastline of approximately 1,660 kilometres (the range reported is 1,585–1,730 kilometres). The coastal zone is very diverse, and contains lagoons and estuaries, fringing and offshore reefs, mangrove swamps, seagrass beds, salt marshes, beaches, sand spits, rocky shores and dune systems. Sri Lanka's coastal zone contains very productive ecosystems that sustain a large proportion of the country's people and flora and fauna.

Priority Ecosystems and Protected Areas in Sri Lanka

website: www.unep-wcmc.org

please contact Kaveh Zahedi or Phillip Fox for further details

All data on Protected Areas, Coral Reefs, Seagrasses and Mangroves are available from UNEP-WCMC databases.
Data on population density kindly provided by CIESIN.

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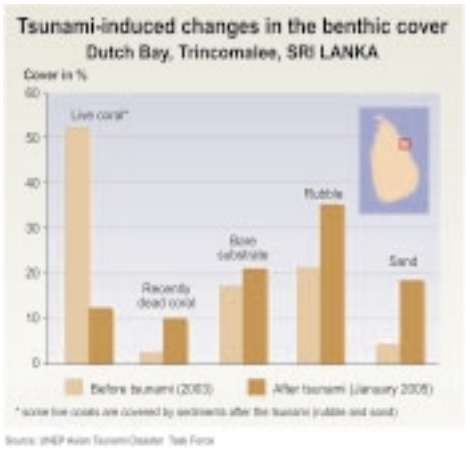
Case study – Destruction of a coral reef in Dutch Bay, Trincolamee

Trincomalee was almost exactly due east of the central part of the tsunami disturbance. Prior to the tsunami, Dutch Bay had a coral cover of about 50 per cent, mostly made up of branching *Acropora* and foliose *Montipora*, interspersed with massive Faviid and Poritid colonies. Observations after the tsunami showed that the reefs had been virtually destroyed:

- Extreme mechanical damage, with nearly half of the coral reef area ripped off, including the reef base (limestone substrate) in some places, turning the reef into fields of rubble and sand. Three quarters or more of the remainder has also been severely damaged.
- Large coral blocks and dead coral have been moved over the reef, tearing off the live coral and also the reef base. The southern reef margin has been restructured and severely eroded.
- Granite rocks and boulders 20–50 centimetres in diameter have been shifted, particularly around a rock patch near the shore.
- Virtually all remaining live corals had been damaged, and many *Acropora* colonies have been sheared. Among standing thickets, most branches were loose and moving with the swell. Many table corals had been uprooted and toppled over.
- Many massive colonies have been toppled, including some *Porites* domes over two metres in diameter, and many colonies of about 50 centimetres have shifted large distances.
- A lot of broken branches of live coral are being abraded in moving rubble beds. Many coral colonies were partially or entirely buried in rubble and sand.
- There were also signs of paling and bleaching in remaining massive colonies, most notably *Goniastrea* sp., *Porites* sp. and *Favia* sp. This may be caused by sediment stress and abrasion.
- Many soft corals were found ripped off the reef substrate and with severe tissue damage.
- There was very little evidence of litter, debris and sediment from land sources.



Coral Reefs

The greatest extent of true coral reef is located in the Gulf of Mannar in the north-west, off the southern coast and the eastern coast near Trincomalee. There are extensive areas of patch reefs at Bar Reef in the north, Great and Little Basses in the south, and off the eastern shores. There are fringing, patch and platform reefs elsewhere around the country including sandstone/limestone and rocky reef habitats, covering in total about 680 square kilometres. Their diversity is high with as many as 190 species of hard corals and over 300 species of fish, including as many as 35 species of butterflyfish (*Chaetodontidae*).

The coral reefs of Sri Lanka were far from pristine prior to the *tsunami*, since in many areas they had been all but destroyed by the mining of coral rock for making lime and cement. Also, reefs had been heavily exploited for living resources while management intervention was generally inadequate. Blast fishing and purse seining were continuing, even in reef areas designated for protection such as the Pigeon Island National Park in Trincomalee, and the Bar Reef and Rumassala Marine Sanctuaries. The 1998 bleaching event also had a profound effect on the western and southern coral reefs, while the damage was less on the eastern coast, and many areas had not recovered when the tsunami struck.

Surveys by NARA, IUCN and others are continuing, or are awaiting improvements in the weather. As of mid February, coral reefs had been surveyed at five sites in the south and southwest (Kapparatota-Weligama, Polhena, Unawatuna, Hikkaduwa and Rumassala), and at one site in the east (Dutch Bay, Trincomalee). The tsunami moved enormous boulders and sections of reef, as well as thousands of tonnes of smaller fragments, sand and silt, which dislodge, abrade, crush and kill marine biota. There was also a powerful backwash carrying large quantities of waste, debris, soil and organic matter. Despite all this, damage to reefs was very patchy, ranging from total destruction in some areas to almost no impact in others, reflecting a complex interaction among the recent history and condition of the reef, with the precise way the tsunami energy was delivered to that particular environment. Some smothering was observed, but it appears primarily from re-suspended marine sediments rather than by matter intruding from the land. Litter and debris is abundant. Much of the rubble formed after the mass mortality of corals in 1998 has shifted.

Severe damage on the coast was observed where coral mining in the sea had been rampant in the past. There were signs of absorbed impact and less damage in locations with healthier vegetation and less disturbed ecosystems.

Mangroves

Mangroves are a rapidly diminishing wetland type in Sri Lanka, consisting of less than 10,000 hectares of discontinuously distributed patches along the coastline. The most extensive mangrove areas are in Puttalam district, with over 2,000 hectares. Batticaloa and Trincomalee districts also have extensive mangroves, each with over 1,000 hectares. Unfortunately, the inherent productivity of the tidal ecosystem combined with poor tenure arrangements in coastal environments that are neither land nor sea, has meant that mangroves are vulnerable to conversion by private investors, especially into prawn ponds. This has happened to a considerable degree in western Sri Lanka, where up to half of naturally-occurring mangroves are said to have been lost, but the position is unclear in eastern parts of the country where the war has inhibited both investment and monitoring.

Although mature mangroves are typically very resistant to water surges, and in many areas were apparently unaffected by the tsunami, there are limits to this resilience and in some areas large mangrove trees were uprooted and lay toppled far from the beach. Quantitative information on the extent of damage is not available at the time of writing, but an indicative sample of the impacts of the tsunami upon a range of coastal ecosystems, is provided in the case study.

Case study – Tsunami impacts on special management areas in Sri Lanka

Seven Special Area Management (SAM) sites were affected by the tsunami: Negombo, Lunawa, Maduganga, Hikkaduwa, Habaraduwa, Mawella and Kalametiya (see Table). Although detailed, quantitative data are not yet available, inspection of these sites provides an indicative sample of the impacts of the tsunami upon a range of coastal ecosystems, including lagoons, mangroves, beaches, sand dunes, reefs, canals and farmland, in the southwestern and southern coastal areas. Examples from four sites are listed below.

Environmental damage at SAM sites

SAM site	Key environmental impacts
Negombo	• The channels in the lagoon mouth have been deepened by the tsunami. • The six canals connected to the lagoon have been blocked by debris. • The beaches are polluted with debris and rubbish. • There has been little damage to coastal vegetation such as mangroves. • The sand dunes in Morawalla, Sethapaduwa and Thalahena have been damaged. In some places these dunes used to be about 15 metres high but have now been eroded. Coastal vegetation on the dunes has been affected. • A substantial amount of debris has been deposited inside the lagoon.
Lunawa	• The mouth of Lunawa lagoon was swept open by the tsunami. • The water level in the lagoon decreased. After a few days the lagoon mouth closed again. • Beaches within the SAM area are being polluted by rubbish that is being dumped there. This is especially plastic, wood and solid waste. Although some beaches are being cleaned, many beaches are polluted with debris and rubble. • The coastal vegetation has been severely damaged. Even some coconut palms have been destroyed indicating the force of the water. • Although Lunawa Lagoon is one of the most polluted lagoons in the country, the tsunami does not seem to have brought in large amounts of debris and rubbish.
Maduganga	• The physical structure of the mouth of Maduganga lagoon has not changed, but the sandbar blocking the lagoon from the sea was swept away and the southern bank was lightly damaged in places. • Due to the tsunami a large amount of debris entered the lagoon and is still inside the water body. • Several boats sunk inside the lagoon. Some of them have not been reclaimed and are still under water. • Due to the complete opening of the lagoon mouth, salinity inside the lagoon has increased. The high salinity of the water in the lagoon could result in salt water intrusion into paddy fields. • In several places the coastal vegetation has been damaged.
Mawella	• Groundwater polluted with salt water, resulting in unusable wells. • The Mawella canal and the Moreketiya lagoon are heavily polluted with debris and rubbish; there is a large amount of vegetation and organic material inside the Moreketiya lagoon. The canal is now open but blocked by debris. • The beach in the SAM area is polluted with debris and rubbish.

Sea Grass

Sea grass beds constitute the most extensive coastal ecosystem in Sri Lanka. They occur along the open coast as well as within estuaries and lagoons (UNEP-WCMC, 2003). Very large beds exist around the north-western and southwestern coasts, and smaller sea grass beds are found on the leeward side of coral reefs elsewhere. Sea grass beds are important as feeding and breeding grounds for fish, as well as stabilizing submerged sand banks.

Damage to sea grass beds was minor and was mostly due to shifting rubble; hardly any uprooting was observed. Severe beach erosion was observed both in the east and southwest, but was patchy in its occurrence.

Biodiversity and Protected Areas

Sri Lanka is the most biologically-diverse country in Asia per unit area, and about half its native species are endemic. It lies on a major bird migration route and provides critical habitat to many migratory waterfowl. The island is also critical habitat for many internationally-mobile species, including five species of endangered marine turtle (the Loggerhead *Caretta caretta*, Olive Ridley *Lepidochelys olivacea*, Hawksbill *Eretmochelys imbricata*, Green *Chelonia mydas*, and Leatherback *Dermochelys coriacea*). In part to preserve this rich biodiversity, Sri Lanka has officially declared 146 National Reserves or protected areas covering about 9,926 square kilometres, or 15.3 per cent of its land area; while forest reserves of 5,182 square kilometres and proposed forest reserves of 6,211 square kilometres cover another 17.2 per cent of the land area. However, much of the biodiversity is concentrated in the wet zone, which is poorly represented in the protected area system with only one strict nature reserve, one national park, and one wildlife sanctuary.

At Yala and Bundala National Parks, vegetated coastal sand dunes completely stopped the tsunami, which was only able to enter where the dune line was broken by river outlets. At one outlet in Yala National Park considerable damage was done to park facilities (with a number of human deaths) as well as to forest and grassland, with many trees uprooted and the vegetation largely dead and brown. Two other sites in the park had damage up to 1.3 kilometres inland in flat areas. Less than 1 per cent of the park area was affected by the tsunami in total. Natural recovery is expected as salt levels are reduced, assisted by high rainfall since the tsunami. Some damaged areas of the parks may be recolonised by alien invasive species such as prickly-pears (*Opuntia*) and the salt-tolerant mesquite (*Prosopis juliflora*). There has been no documented loss of fauna in the protected areas affected by the tsunami, as most birds and the larger mammals managed to avoid being caught in it (though dead mouse deer, monitor lizards and soft-shelled terrapins have been reported from the south coast.

The Coast Conservation Department manages eight Special Area Management (SAM) sites, of which seven were affected by the tsunami. The case study provides indicative information on a range of impacts.

4.4 Preliminary Results: Impacts on the Human Environment

Human Settlements

A number of factors increased the vulnerability of human settlements to the tsunami in Sri Lanka. Among them are the historical absence of building standards, construction that was uninfluenced by a tradition of risk aversion because of a perceived absence of major natural disasters, a lack of city planning and zoning regulations, and a resulting haphazard pattern of construction. Other aggravating factors included weak local government institutions with poor response capacities for the provision of basic urban services, poor access to services by most people resulting in the need to find on-site solutions for solid waste, drinking water and sanitation, and high densities in unplanned settlements. These factors combine to undermine standards in the built environment of Sri Lanka even at the best of times. Largely

Galle, Sri Lanka (14 January 2005). Debris is seen everywhere in downtown Galle, Sri Lanka, where small shops were reduced to rubble by the 26 December Asian tsunami. © Paula Bronstein/Getty Images

bypassed by the mainstream development process, the poor in particular have found themselves living in informal, illegal and unhealthy conditions, often located in the most vulnerable zones. Such conditions make the poor, and particularly women and children, more vulnerable both to daily stresses and to natural disasters.

Around 12 per cent of all building units in Sri Lanka were located in administrative divisions along the Sri Lankan coast that were affected by the tsunami. Most houses are owner-occupier, with only 13 per cent of houses occupied by tenants. A typical house in the coastal zone of Sri Lanka has a single-floor, on-ground structure with shallow foundations, cement and burnt-brick walls, and wooden roof supports under tiles or 'cement asbestos' roofing sheets. Most had some form of septic tank, an electricity connection and access to some form of protected or safe drinking water. There were many more modest dwellings, with unfinished floors, wattle and daub, plank or palm leaf walls, and simple roofing, without in-house toilets, water and/or electricity. Within about 500 metres of the coast, the tsunami destroyed 99,500 houses and damaged another 46,300, a total of 13 per cent of the entire housing stock of the coastal divisions of the affected districts.

In addition, the destruction of public buildings means the loss of legal records, mortgages and other details. Banks are now faced with customers who have lost everything. Small market places (*pola*) and grocery shops have been destroyed, along with means of transport, ranging from bicycles and three-wheelers, to buses and lorries. Many of the affected families and businesses, having lost their savings which were held in jewellery or cash, do not have money and cannot start rebuilding their livelihoods. Workers who should be in high demand (such as boat builders, carpenters, cement brick producers) have lost their tools, and also face a clientele that has lost everything. Fishermen cannot pay boat builders in advance to enable them in turn to buy new tools, as they need boats to start earning money. Damaged cottage cement industries too cannot satisfy demand; and sand and cement prices have already started to increase.

Waste and Debris

The extent of debris, particularly from destroyed buildings, is enormous. Calculation of the weight of an average house in Sri Lanka yields a figure of about 7,000 kilograms of brick, cement and roofing material for well-built ones and 2,000 kilograms for a cruder 'fisherman's house'. Since the latter were far more vulnerable than the former, both in terms of location and strength, an average among the almost 100,000 homes destroyed might be about 3,000 kilograms, or 300 million kilograms in total, to which would need to be added the weight of debris from 43,600 damaged houses as well as lost household goods and furnishings, shops, tens of thousands of vehicles and boats, fallen trees, destroyed roads, bridges, culverts, etc., a total that must have exceeded another 200 million kilograms in addition and perhaps far more. The disposal of these 500+ million kilograms of rubble and waste material is proving to be a huge issue because of the sheer volume and associated costs. Emergency efforts have resulted in haphazard disposal of rubble along roads, in open fields, into drainage ditches, low lying lands and waterways, including beaches. This is likely to cause long-term problems by clogging waterways and polluting beaches. Burning of debris is also evident in certain areas but impacts air quality, and the CEA has ordered it stopped. The CEA has also instructed that solid wastes be collected and deposited in open areas such as playgrounds until proper sites for disposal are identified.

Water and Agriculture

Most people in rural Sri Lanka rely on wells for their drinking water, yet all dug wells in areas where the tsunami intruded, an estimated 62,000 of them, are now contaminated by sea water, and often by wastewater and sewage as well. This is an especially serious problem in Trincomalee, Amparai, Batticaloa

Kalmunai, Sri Lanka (3 February 2005). Checking the water purification machine in Sri Lanka's eastern town of Kalmunai. A 200-member Canadian military contingent is conducting relief operations on the east coast, providing clean drinking water for 80,000 tsunami survivors. © Prakash Singh/AFP/Getty Images

and Hambantota districts. The pipe-borne water supply system in the coastal areas is also largely out of service. These factors together undermine public access both to drinking water and to water for irrigation. Wells can be pumped out and chlorinated, but in some areas aquifers have also been contaminated which must be diluted and leached back to purity over months or perhaps years of rainfall. Initial surveys show that rice fields in the eastern districts of Trincomalee and Batticoloa have been heavily damaged. These rice fields produce more than one-third of the country's total harvest. The extent of crop damage may have been underestimated in reports to date, since salt has affected several thousand rice and fruit farms, and has dried to form a crust on the soil in many areas, leading to concerns that the fields will be unusable for many months until rains naturally reduce salinity. Fortunately, the seasonal rains have been heavy since the tsunami.

Transport Infrastructure

The damage to roads is in excess of 2,500 kilometres of the national, provincial and local authority road network, representing over 5 per cent of the national roads and 2 per cent of other categories of roads. Most of these roads, however, had previously been degraded through decades of under-investment. Damage to ports, harbours and anchorages was significant, with affected harbours at Kirinda, Tangalle and Kudawella in Hambantota, at Puranawella, Mirissa, Galle and Hikkaduwa in Matara, at Beruwela and Panadura in Kalutara, and at Cod-Bay in Trincomalee. A total of 37 major anchorages and thousands of minor landing sites were damaged. Several rail corridors were affected by the tsunami: in the north-eastern corridor (China Bay to Trincomalee), tracks were damaged; in the eastern corridor (Valachchanai to Batticaloa), tracks and a bridge were damaged; and in the southern corridor the portion between Colombo and Kalutara suffered minor damage that was quickly repaired, but beyond Kalutara 40 kilometres of track was slightly damaged, 20 kilometres were moderately damaged and 4 kilometres were severely damaged. Damage also occurred to embankments, track work, bridges and culverts, signaling and communication systems, buildings and rolling stock. The most dramatic injury to the railway system occurred when the tsunami overwhelmed a passenger train on this southern portion, with the deaths of some 1,500 passengers. Sri Lanka Railways carry about 28 million passengers annually, most of them commuters, and over half are now enduring significant hardship due to the absence of rail services in the southern corridor, which are not expected to be restored before May 2005.

Hikkaduwa, Sri Lanka. The 26 December tsunami overwhelmed a passenger train in southern Sri Lanka, killing some 1,500 passengers. Over half are now enduring significant hardship due to the absence of rail services in the southern corridor, which are not expected to be restored before May 2005. © Shehzad Noorani/Still Pictures

Industrial Sites

Little damage was caused to large-scale manufacturing industry since very few industrial facilities were located in the affected area. A large number of home-based production and income generating activities have been destroyed, however, affecting in particular women and artisans, and reducing family incomes.

Medical and Psychological Impacts

Health care services lost some 44 health institutions, including a large obstetric and gynaecology teaching hospital, many district hospitals, rural clinics, and units attached to dispensaries. There were associated losses of medical officers, equipment, drug stores, district health offices and about 54 vehicles, including ambulances. Another 48 health institutions were partly damaged with loss of medical instruments, and equipment. This sudden reduction in capacity coincided with an equally sudden increase in demand for medical services among survivors locally and displaced people elsewhere.

Since no part of the affected coastline was connected to a sewerage network, toilets were basic, with better housing both in cities and villages dependent on septic tanks. The tsunami damaged septic tanks by flooding, breaking and dislodging them and also dislodging a large number of traditional pit latrines, polluting the environment generally and water sources in particular with human excreta. There is also concern over the adequacy and safety of sanitation facilities provided to over 150,000 people still living in about 320 welfare centres.

Victims were buried in scores of mass graves, with the aim of protecting public health, even though bodies do not in fact pose much risk of infectious disease, since diseases and putrefaction are caused by different microorganisms. Mass graves also mean that relatives will never know what happened to their loved ones, which can cause long-term distress, and the procedure can also delay the certification of death with implications for insurance claims and other legal processes.

Impacts on Livelihoods, Poverty and Gender

Increased poverty is potentially the most important effect of this natural disaster. The macroeconomic impact of the tsunami is expected to be worse in Sri Lanka than in any other affected country apart from the Maldives, but the macro-level of analysis conceals a much more sinister impact on the livelihoods of the poor. Fisheries, tourism, trade, agriculture and artisanal or cottage industries provided most of the livelihoods in the affected areas, and all have been severely impacted. The worst effects of the tsunami were experienced by people living in weakly-constructed and unplanned settlements close to the shore, women and children deprived of bread-winners, and those with marginal livelihoods as cottage artisans. A large number of home-based production and income generating activities were destroyed, affecting women in particular, and reducing family incomes. The catastrophe could drive around 250,000 more people below the poverty line, and these numbers could increase if concerns over basic needs are not properly and quickly addressed.

Fishing and related small-scale food processing were affected the most by the disaster. Of the country's 29,700 fishing boats, about two-thirds were destroyed or significantly damaged, along with outboard motors, ice storage units, fishing gear and nets. Entire fishing communities were dependent on these fleets. Damage to the agriculture sector included the destruction of standing crops and home gardens, washing away of tree crops, and entry of sea water to productive fields which may render them unusable for many months. An estimated 27,000 jobs in the tourism industry were suspended by the tsunami, one third in officially-registered hotels and the rest in unregistered hotels and guesthouses. Many small businesses and informal traders catering to the tourism industry, (e.g., dive, souvenir, handicraft shops, and internet cafes) were damaged and are now facing a sustained period with far fewer customers. The main tourism season of January to March is likely to be lost entirely.

People suddenly impoverished by these impacts are likely to place unprecedented pressure on the environment. There are reports, for example, that unusually large numbers of nesting marine turtles have been killed for meat in Sri Lanka since the tsunami, as people strive to off-set an under-supply of fish protein. The extent of such collateral damage will depend to a large extent on how the recovery process is managed. In the fisheries sector the indiscriminate replacement of boats and fishing gear with new and high-quality equipment could easily result in over-exploitation of the marine environment. Similarly, welfare, relief and reconstruction programmes, unless well managed, could lead to wasteful consumption. Poor targeting, over-design of facilities and wasted investment will result in higher resource demand, depletion of natural resources and the generation of wastes, all having direct and indirect impacts on the environment.

Mirissa, Sri Lanka (5 January 2005). A Sri Lankan man walks past the wreckage of a fishing boat tossed ashore by the tsunami in the southern coastal town on Mirissa. As many as 27,000 of the fatalities were fishermen, and two-thirds of Sri Lanka's fishing boats were wrecked, destroying livelihoods for many families. © Jimin Lai/AFP/Getty Images

Impacts of Reconstruction

Demand on natural resources, including new land and changes of land use, will naturally increase during the reconstruction process. Initiatives to impose a resettlement zone, to re-plan, re-develop and relocate cities, and to introduce new roads, railways and port developments can only aggravate these pressures. Government initiatives to undertake a series of 'mega' projects in the wake of the recovery will add to this demand, all heating up the construction market with inevitable consequences for the exploitation of natural resources. Although elasticity in the supply of building materials could be handled by increasing

imports, an increase in prices is expected, which will encourage supplies, particularly timber, to be obtained from illegal sources. Mining of shore and river sand is already controlled, to some extent, but alternatives such as washed sea sand and quarry sand are in short supply, and with increased demand people may resort to illegal sand mining. The increased demand for bricks will likely lead to the removal of clay from productive paddy lands and the felling of trees for firewood. A sustained programme to improve production techniques, introduce alternative and low cost building materials, and research on improvement of traditional building technologies will help in mitigating such risks.

4.5 Preliminary Results: Environmental Management Capacity

The main government directly agencies involved in managing ecosystem resources in Sri Lanka, comprise the Department of Wild Life Conservation (DWLC), the Forestry Department and the Marine Pollution Prevention Department in the Ministry of Natural Resources and Environment (MENR), and the Coast Conservation Department (CCD) and National Aquatic Resources Research and Development Agency (NARA) in the Ministry of Fisheries and Oceanic Resources. Additional regulatory responsibilities lie with the Central Environmental Authority (CEA). A national *Coastal Zone Management Plan* prepared in 1990 and revised in 1997 and 2004, gives strategic direction to the Coast Conservation Department, identifying needs, ways and means to protect the country's coastal resources.

Institutional capacity for environmental management was barely sufficient for routine tasks, and is likely to be severely challenged by the new demands placed on the country by the tsunami disaster. Particular areas where capacity may need to be strengthened include documentation and analysis of tsunami and other impacts on ecosystems, monitoring of the condition of ecosystems, and the assessment and management of environmental impacts associated with reconstruction and resettlement.

The NARA Research Station was badly damaged, along with its research vessels, fleet of six rescue vessels, its radio room and its Fisheries Training Colleges and associated equipment. This will reduce its capacity to build capacity in the sustainable management of fish stocks for some time.

An early reaction of the The Government of Sri Lanka to the tsunami was to propose limiting construction and habitation near to the coast, including consideration of a possible restricted construction zone (RCZ) within 100 metres (150 metres or 200 metres in some areas) of the mean high tide line. Applying such a policy to large areas of densely-settled coastline would have profound implications for the economy, the environment, livelihoods (especially for those connected through fisheries and tourism to the sea and beach), and poverty. Plans for a Strategic Environmental Assessment to assess this matter are being developed by the MENR and CEA in concert with the Government of the Netherlands.

4.6 Conclusions and Recommendations

Protective Capacity of Ecosystems

Intact coral reefs, vegetated dune systems, deep stands of mangrove forest and other natural barriers, as a first line of defence, appear to have afforded significant protection to the coast beyond them. This is being investigated in detail by the REA assessment teams, but is consistent with the knowledge that reefs and mangroves are robust, structurally complex ecosystems that are able to absorb wave energy, and that sand dunes bound by roots are much more resistant to water and wind than is bare sand. If Sri Lanka still possessed as many natural defences as it did before its sand dunes and coral reefs had been mined, then the tsunami may have done far less damage.

Strengthening the Resilience of the Coastal Zone

An obvious conclusion from the foregoing is that the reconstruction of defensive ecosystems around the coast would be a good idea, and this is the single highest priority for the medium to long term. Some locations are not so easy to defend. Many bays suffered devastating property damage, probably because the tsunami was funnelled and strengthened by the shape of the sea bed and surrounding land, while river outlets through dune systems inevitably allowed the wave access to lagoons and inland areas. Meanwhile, the broad, flat beaches and hinterlands of the north-east offered an easy path deep inland for the tsunami surge, and it is hard to imagine how it could have been stopped entirely. A comprehensive process for strengthening the resilience and productivity of Sri Lanka's coastal zone will involve a number of measures applied in various combinations in various locations. As the coast is very heterogeneous in terms of terrain, natural ecosystems, and human pressures, there will be no one solution that can be applied in all places. Instead a number of options are available, including:

- **Relocating settlements**: some locations may be inherently indefensible except at extremely high cost, suggesting that they should be placed off-limits for construction and habitation.
- **Redesigning new construction**: buildings with open pathways for the passage of sea water, and that are well-made, seemed to be more resistant to damage during the recent tsunami than others; it is possible that adjustments to building codes may therefore be helpful where construction is to be permitted.
- **Building artificial breakwaters**: sea walls and harbour moles can break the power of waves and wind, but are expensive to build and maintain so cannot be used to protect a whole coast line; they may however be used to protect sites that are of sufficient value to justify the expense.
- **Establishing sand dunes**: natural dunes, if high and deep enough, and stabilised by vegetation, are able to stop major waves and did so in the recent tsunami incident; many areas may therefore benefit from the establishment or re-establishment of seaward dune systems.
- **Planting mangroves**: a deep enough band (>20-30 m) of mangrove vegetation can absorb considerable amounts of wave energy and protect the coast beyond, while also sustaining very productive fisheries; mangroves tend to grow in and around tidal mud-flats, estuaries and lagoons.
- **Using other vegetation types**: sea grass beds, coconut groves, *Casuarina* stands, *Pandanus* hedges, and other coastal vegetation types need to be assessed for utility in promoting resilience against disaster.
- **Establishing artificial coral reefs**: core structures, such as bundles of concrete pipes or wire cages filled with stones or rubble, may be sunk in shallow water, cabled together and anchored to resist currents; once conditioned by sea water, the structures will be colonised by reef organisms, a process of reef establishment that can be hastened by transplanting fragments of branching corals, juvenile giant clams, etc. onto the core structure.
- **Establishing marine protected areas**: experience in the Philippines and elsewhere has shown that even small areas set aside by communities and protected from fishing and other forms of damage can regenerate quickly and sustain a return to natural levels of fish diversity and productivity, which is useful both for fisherfolk and in terms of attracting recreational and educational visitors; the protected areas form a network of colonisation sites that speed up other interventions, such as the restoration of coral reefs.

None of these measures can provide a perfect defence against all extremes of natural disaster, and even intact mangroves, coral reefs and coastal dunes were damaged in places by the tsunami in Sri Lanka. Closer to the epicentre, in the Andaman-Nicobar archipelago and around northern Sumatra, such damage is reportedly extensive. Much can nevertheless be achieved through a realistic, cost-effective strategy of strengthening the coast against environmental shocks. A locally-appropriate selection from among the

options listed would need to be made by local stakeholders based on a thorough understanding of the local environment, prior to implementation by local authorities (Municipal/Urban Councils and *Pradeshiva Sabha*) supported by technical and other resources provided by the government and civil society. Ecological reconstruction initiatives would best be fully integrated within local renewal or recovery plans that also address investment in livelihoods, infrastructure, settlements, communications, government and other services.

Knowledge Exchange and Early Warning

As Sri Lanka reviews its coastal zone management and development plans in the light of lessons learned from the tsunami, it would be wise as well to find out as much as possible about the manner in which other tsunami-prone and typhoon-prone countries in the Asia-Pacific region undertake coastal zone planning. Various governments have been working for some time on ecological restoration in their coastal zones. These include Hainan Province of China, and Tamil Nadu State of India, which have planted *Casuarina* shelterbelt forests as a defence against typhoons, and Vietnam and Indonesia, which have planted substantial areas of mangroves. Practical knowledge on what works can be made accessible to Sri Lanka through exchange visits and study tours with these countries. Since other countries affected by the tsunami may also conclude that they need to take similar measures in their own coastal zones, sharing of relevant knowledge would increase the effectiveness of the whole regional process, with benefits for each country.

Digital Terrain Mapping in Coastal Zone Planning

Horizontal zoning based on distance from the mean high tide line has limitations as a planning tool for the coastal zone from the point of view of seeking to increase its resilience to waves and storm surges. The tsunami penetrated onshore to a very variable extent, depending largely on terrain, with flat areas without coastline defences being most extensively inundated. Hence it would be desirable to commission a detailed digital terrain map of the coastal zone, between the 50 metre terrestrial contour and the -50 metre submarine contour. This will inform choices about where certain kinds of coastline defence should be situated, and the justification for different levels of investment in different areas. The economic value of a large, low, flat area containing farmland or infrastructure, for example, might justify considerable investment in strengthening its coastline defences, whilst a narrow area bounded by steep land might not.

Reconstruction Standards

Housing represents by far the most valuable asset lost by the affected families. For most, it also represents the asset they most want to repossess with least possible delay. This will lead to intense pressure for rapid construction in the affected districts. Policies should promote safe building, and higher but affordable design standards. It should be noted that virtually no framed house will withstand a direct sideways hit from a tsunami, as the waves can deliver about a 1,000 tonne lateral force. However, consideration of building stilted houses on concrete piles could be an option. Investing in higher quality and risk reduction are as important as the need to address the potential threats of an unmanaged demand on limited natural resources that could accompany a rapid reconstruction process. The same applies to some of the social and economic infrastructure, particularly tourist hotels and related buildings which in the past have violated basic norms of environmental safety. Besides building in hazardous and ecologically sensitive locations, they have also been responsible for extensive pollution of the beaches, waterways, mangroves and estuaries through discharge of sewage, solid waste and excessive disturbance of ecosystems. Critical buildings such as schools, hospitals, and emergency response facilities should be built well away from any vulnerable locations.

Debris and Waste Management

The systematic and environmentally-friendly disposal of the construction debris is a major challenge, made worse because the local authorities in most affected areas do not provide a solid waste management service, and therefore lack relevant capacity and technical knowledge. Of those few bigger cities that do have the knowledge, none has an engineered landfill. The need therefore is to find creative and innovative responses to the problem. One step would be to encourage, and perhaps pay people, to salvage recyclable and re-saleable materials such as steel reinforcement rods, timber and bricks. This process has been initiated by people themselves in some areas and should be promoted more widely, giving families more time to salvage useful material for resale or for rebuilding their houses. Managing the large volumes of residue needs expert guidance. Engineered landfills are a possibility, and other suggestions include using building debris as base material for road construction, and in building sea walls, and dunes, an artificial coral reefs, and community refugee mounds.

Debris management and waste disposal is a significant weakness in the international response to disaster. A possible approach is to motivate, mobilize and equip local people in the immediate aftermath of disaster through the immediate delivery of goggles, masks, boots, gloves, sacks, guidance manuals in local languages, and money with which to hire able-bodied people. Mobile laboratories equipped to detect contamination by the most dangerous chemical families would also be useful in such circumstances.

Local and/or community radio stations can help to augment the flow of locally-relevant information, and pre-recorded audio tapes may provide early information content and guidance to affected people.

Mainstreaming Environmental Perspectives

Ways should be sought to achieve far greater mainstreaming of environmental considerations both in planning and implementing the reconstruction, and in the development process as a whole. There should be ongoing review of all policies, laws and institutions to ensure that adequate attention is paid to the environment at all times. While one focus would be to review national laws that govern activities in the coastal zone itself, there are other laws and regulations at national, provincial and local levels that impinge upon natural resource management, housing, construction and infrastructure development. These would need to be aligned with the policies, processes and programmes of the post-tsunami response plans, including a stronger emphasis on public participation. Such a review should be implemented as soon as possible by an inter-ministerial team with the appropriate legal support. It should be accompanied by capacity building at both the central and the local levels of society. Urgent discussions should focus on ways in which a thorough and comprehensive overhaul of Sri Lanka's capacity for environmentally and socially sustainable development can be accomplished. Some areas that could provide an immediate focus include:

- **Building capacity at MENR and CEA**. The capacity of these institutions may be exceeded by the need to conduct environmental impact assessments prior to planning and constructing new settlements, and monitoring events hereafter.
- **Building capacity at MPCLG and local authorities**. The capacity of these institutions may be exceeded by the need to integrate activities to strengthen coastal resilience within plans developed and implemented by local stakeholders.
- **Environmental education and awareness**. A process is needed to increase public understanding of the environments where communities live, so that they can be encouraged and enabled to participate in their own development, including ecological reconstruction.
- **Completion of a detailed environmental assessment**. There remains a need to analyse 1,200 sites on vulnerability, physical, ecological and social damage, land use, etc., and to use observations to model in detail wave behavior and apply lessons to the mitigation of future tsunami-like shocks.

- **Regional knowledge sharing**. The quality of Sri Lankan development planning would be enhanced through exchange among experts and institutions that have experience of ecological reconstruction, planning and construction of sustainable urban environments, use of digital terrain mapping to guide investment in coastline defence, and in waste management.

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