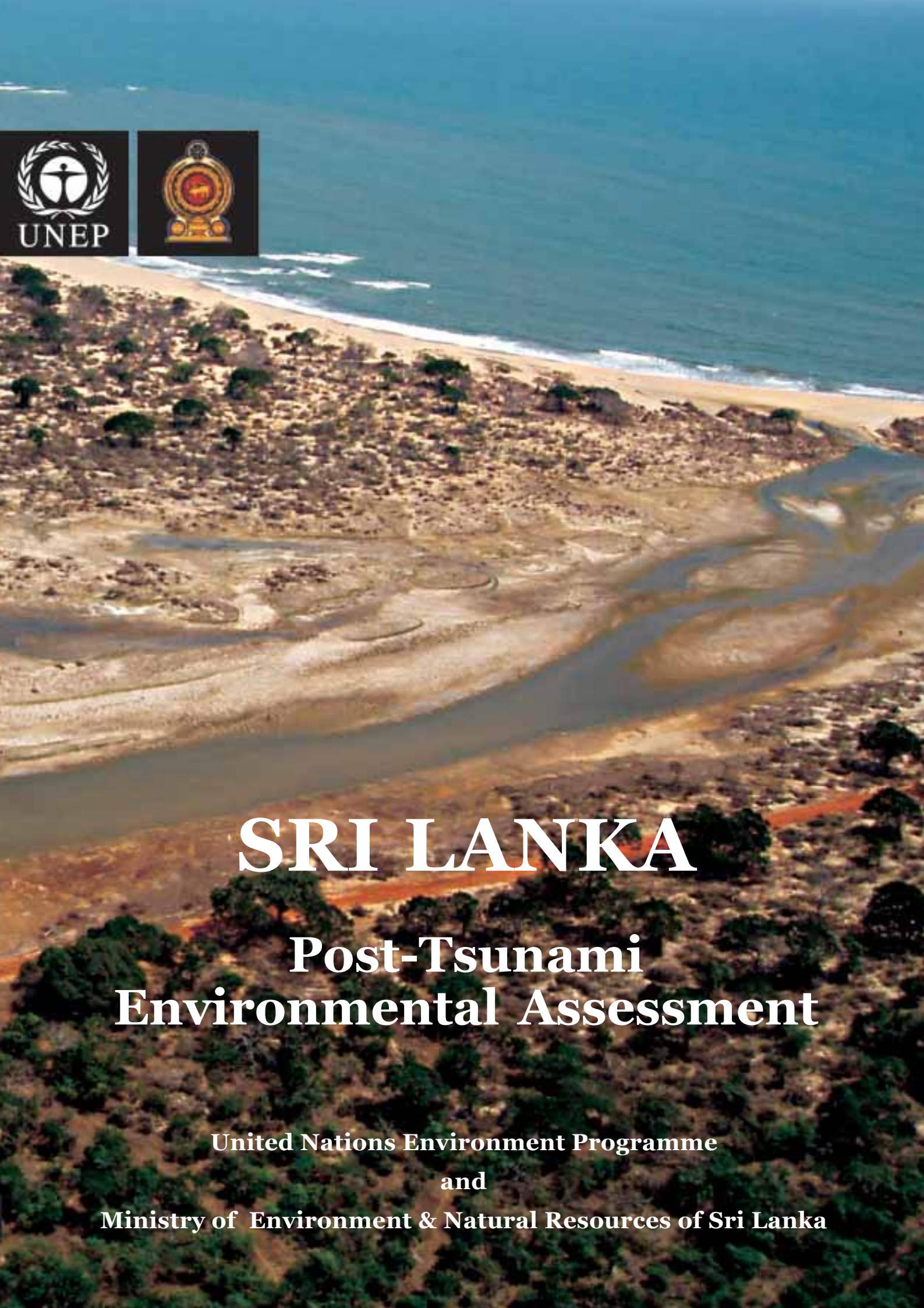

SRI LANKA

Post-Tsunami Environmental Assessment

United Nations Environment Programme

and

Ministry of Environment & Natural Resources of Sri Lanka

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Cover: Parts of Sri Lanka's coast were protected from the tsunami by high, vegetated sand dunes. In some of these places, however, the dunes were broken by river outlets, which allowed the waves to enter the interior. This aerial photograph of the coast of Yala National Park shows both of these effects. Observations like these help to make clear how the coast might be strengthened against future environmental shocks and hazards. [Picture courtesy of The Nature Conservancy.]

Sri Lanka

Post-Tsunami Environmental Assessment

United Nations Environment Programme and

Ministry of Environment & Natural Resources of Sri Lanka

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MESSAGE

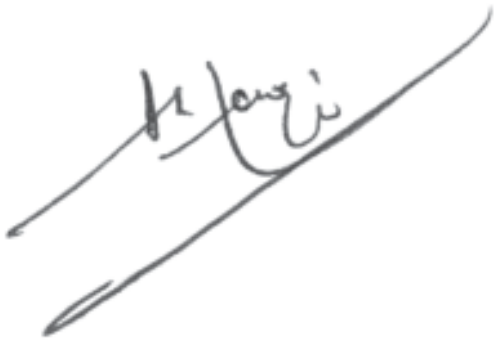
by A. H. M. Fowzie, MP
Minister of Environment and Natural Resources
Government of Sri Lanka

The Tsunami disaster of the 26th December 2004 was the worst natural calamity to have befallen Sri Lanka since historical times. It caused the loss of tens of thousands of lives, property and livelihood damage costing many millions of rupees as well as severe damage to the natural and built environment in most of the country's coastal zone. The extent of the environmental damage was immediately visible throughout the affected areas. In order to evaluate its long-term impacts, as well as to learn important lessons, and to plan and prepare for the future, it was decided to undertake a systematic assessment of the environmental damage caused by this catastrophe using universally acceptable procedures. Apart from the actual direct environmental damage observed, it also became clear that urgent action needed to be taken to integrate environmental considerations in the national recovery

and reconstruction process, to avoid further environmental deterioration and meet the already well-established pressures on natural resources.

Having recognized the nature and magnitude of the problem, the Ministry of Environment and Natural Resources sought the assistance of the United Nations Environment Programme to undertake a comprehensive assessment and to develop and implement a programme of work for environmental remediation. This assessment was done in close cooperation with all relevant national and local agencies and institutions and primarily, by Sri Lankan scientists, from our Universities and other technical institutions under the guidance and supervision of the Ministry. This report is a synthesis of their findings. The outstanding quality of the assessment is a testament to the in-country technical capacity of Sri Lanka. This assessment has not only generated valuable findings and proposals for remedial actions, but it has also contributed to further development of capacity among Sri Lankan institutions and professionals.

I would therefore like to record our sincere gratitude to all those who have contributed to this national exercise and to UNEP for its financial and technical support. I believe that we can see this disaster, if we wish to, not as a meaningless tragedy, but rather as an opportunity to encourage and enable us to achieve our sustainable development goals while ensuring environmental sustainability for current and future generations of Sri Lankans. Perhaps by this means we can manage to find something good in what was otherwise so terrible an event.



FOREWORD

by Klaus Töpfer
United Nations Under-Secretary General
Executive Director of the United Nations Environment Programme

The unprecedented scale of the tsunami disaster in December 2004 left us all speechless. This was the first natural calamity of such a size to affect densely-populated areas in modern times. Inspired by the tireless efforts of the affected countries, and by an extraordinary outpouring of international support and solidarity, the UN and other international organizations rose to meet tremendous levels of humanitarian need.

As the relief operation evolved, it became clear that key natural life-support systems had been badly damaged – some by the tsunami itself and others beforehand, undermining livelihoods and increasing vulnerability to environmental shocks. These needed to be rehabilitated, but the scale of the task was not yet known and environmental assessments would first be required. Following requests from affected countries, UNEP decided to join the efforts of UN colleagues, to provide expertise and support to the ministries of environment and other partners in the affected countries.

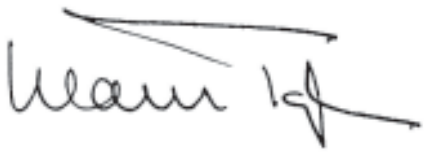
I am particularly proud of UNEP's partnership with the Government of Sri Lanka. The joint environmental assessment involved dozens of Sri Lankan scientists who visited almost every part of

the affected coast, and every site where hazardous contamination was suspected. Their detailed surveys provide a sound and credible knowledge base for restoring environments, for avoiding additional environmental harm, and for enhancing the sustainable development of communities. The report contains recommendations to focus the efforts of national and local government and communities on enhancing wise decision making, and on building capacity for environmental management.

The commitment and hard work of the Government of Sri Lanka and its partners have led to unique opportunities for environmental recovery. Sri Lanka, the "resplendent country", is among the world's richest in biodiversity, fertility, and the beauty and productivity of its landscapes and ecosystems. Sri Lankans know that their well-being depends on these environmental assets, and the country has strong human capacity and expertise in the environmental sciences. Yet there will remain a need for international assistance, to help overcome specific challenges involved in restoring coastal areas, in cleaning up polluted sites, and in planning the safe use of vulnerable coastal ecosystems.

Participation by UNEP in the environmental assessment would not have been possible without an excellent level of cooperation with a range of government institutions in Sri Lanka, and especially with the Ministry of Environment and Natural Resources (MENR) and the Central Environmental Authority. It would also have been much less productive without close partnerships with SACEP, IUCN and other international institutions, with the World Bank, Asian Development Bank and other donors, and with UNDP and other members of the UN family. The generous support of the Government of Sweden through the Swedish International Development Agency (SIDA) had a very essential role, and I would like to express my gratitude to Sweden and to all these institutions.

UNEP is firmly committed to its partnership with the Ministry of Environment and Natural Resources, and we look forward to a continued role in support of efforts for sustainable recovery. I firmly believe that the way forward lies in informed and equitable cooperation amongst stakeholders at all levels of society. Our cooperation with government, UN agencies and other institutions in Sri Lanka have helped to lay the foundations for building back safer, greener and more sustainable communities.



EXECUTIVE SUMMARY

In an immediate response to the tsunami catastrophe of 26 December 2004, the Ministry of Environment and Natural Resources (MENR) took steps to carry out a rapid environmental assessment in the tsunami-affected areas, in close cooperation with the Central Environmental Authority (CEA), and with the assistance and support of the United Nations Environment Programme (UNEP). The assessment was undertaken by Sri Lankan scientists, either independent or affiliated to Colombo, Eastern, Ruhuna, Jaffna, Moratuwa and Sri Jayawardenapura universities. It was in two parts, focussing respectively on the 'green' environment (ecosystems, biodiversity, protected areas and farmlands – MENR, 2005a) and the 'brown' environment (pollution, debris, and impacts on human settlements and infrastructure – MENR, 2005b). This document is a synthesis of the main findings of both parts of the assessment, and draws on an earlier synopsis report (MENR, 2005c) as well as the findings of other studies, which included:

- Surveys throughout the tsunami-affected areas to identify acute environmental issues with immediate implications for human lives (UNEP/OCHA, 2005), and to assess overall damage and needs (ADB *et al.*, 2005).

- Surveys in particular areas to document tsunami-related impacts on the terrestrial and marine environment and biodiversity, in the south-eastern coastal areas of Rekawa, Ussangoda and Kalametiya (IUCN, 2005a); in Ampara and Batticaloa districts (IUCN, 2005b); along the southern, south-eastern and eastern coast (NARA *et al.* 2005); and along the southern coast between Hambantota and Colombo (IWMI, 2005).

- Surveys of protected areas and special management sites to establish damage and remediation needs (DWLC, 2005; CCD, 2005).

The report reviews the main conclusions of all these studies, documenting the main features of the tsunami, the many ways in which it affected and was affected by coastal landforms, ecosystems, farmlands and settlements, and the consequences of its impact. In doing so, the report highlights key issues that have arisen in the aftermath of the disaster, including those to do with:

- **Debris and waste management**. The solid waste management system was overwhelmed by the amount of debris created by the tsunami. Emergency relief and clean-up operations displaced large amounts of debris into unsuitable locations, such as wetlands, beaches and stream channels.

- **Sustainable sourcing of drinking water**. Sea-water contamination, over-pumping and salt intrusion, and relocation of settlements to sites with marginal fresh ground-water supplies together create an emerging problem, especially in the eastern coastal districts.

- **Land drainage**. Debris and marine sand, whether deposited by the tsunami or by subsequent clean-up operations, block drainage channels in many areas, posing an acute risk of water-logging, loss of agricultural land, and the spread of mosquito-borne diseases.

- **Deforestation pressures**. Environmental considerations have been neglected in decisions made on the location of resettlement camps and new construction, and in the sourcing of building timber, resulting in clearance of forests, some of which may be in Protected Areas or their buffer zones.

- **Disaster preparedness**. There is a need for a range of measures to strengthen institutional capacity and collaboration for disaster preparedness and disaster management, including policy development and local disaster preparedness.

Drawing from these and other findings, the report contains a number of recommendations for action, upon which an indicative portfolio of proposed remediation projects is based. These recommendations will form the basis for preparing detailed proposals for investments in the context of government, UN and donor recovery and reconstruction strategies that are now being elaborated.

INTRODUCTION

Elephants (*Elephas maximus)* resting in a river near Pinnawela, Sri Lanka.

Ceylonese Tree Viper (*Trimeresurus trigonocephalus*), a Sri Lankan endemic. © Bill Love/BLUE CHAMELEON VENTURES

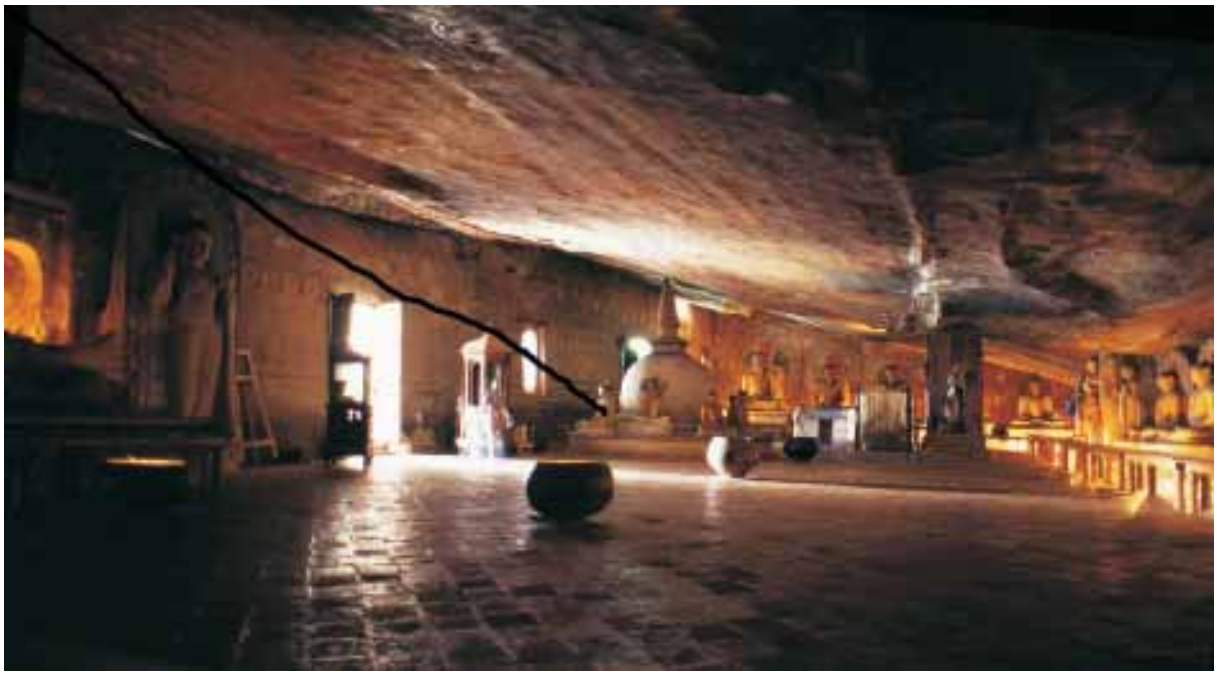
THE 'RESPLENDENT LAND'

The tropical island nation of Sri Lanka is some 65,610 km² in area, slightly larger than West Virginia, and a little smaller than the Republic of Ireland. It is located 6-10° north of the equator, a few score kilometres off the coast of south-eastern peninsular India. From the coast, the land rises to a central massif more than 1,500 m above sea level, with peaks up to 2,525 m (Mt Piduruthalagala). The climate is hot and humid, with monsoon rains in May-September and November-March. There is a wet zone in the south-west quarter of the island, where annual rainfall is 2,500-5,000 mm, the rest of the country being drier and in places even arid. The national biodiversity conservation action plan recognizes 15 biogeographical regions (MFE, 1998), within which characteristic ecosystem types include: thorn scrub, dry mixed evergreen forest, moist evergreen forest, lowland, sub-montane and highland wet evergreen forests, coastal marshes and lagoons, near-shore and off-shore coral reefs, rocky and mineral sand shores, sea-grass beds, mangroves, grasslands, and a complex network of rivers, floodplains, wetlands and freshwater bodies.

Sri Lanka is the most biologically-diverse country in Asia per unit area, and part of a global biodiversity 'hotspot' (Myers, *et al*., 2000). About half its native species are endemic (occurring nowhere else in the world), including all its fresh-water crabs, 90% of its amphibians, 25-75% of its reptiles and invertebrates (depending on taxon), around 50% of its freshwater fishes, 26% of its flowering plants, 14% of its mammals and at least as many of its non-migrant birds. Species richness is extreme (MFE, 1997, 1998; Pethiyagoda & Manamendra-Arachchi, 1998; MENR, 2003), with over 3,368 species of flowering plants, 314 ferns, 575 mosses, 190 liverworts, 896 algae, 1,920 fungi, 400 arachnids, 242 butterflies, 117 dragonflies and damselflies, 139 mosquitoes, 525 carabid beetles, 266 land snails, 78 fresh-water fishes, 250 amphibians, 92 snakes, 35 fresh-water crabs, 21 geckos, 21 skinks, 322 non-migrant birds, and 86 mammals.

The island is also critical habitat for many internationally-mobile species, including five species of endangered marine turtle (the green *Chelonia mydas*, leatherback *Dermochelys coriacea*, olive ridley *Lepidochelys olivacea*, loggerhead *Caretta caretta*, and hawksbill *Eretmochelys imbricata*), about 100 species of waterfowl, and many other migratory birds. These 'wild' biodiversity values complement Sri Lanka's plant genetic resources, with hundreds of distinct varieties of rice, pepper, cardamom, betel, grain legumes, root and tuber crops, vegetables of the Curcurbitaceae (cucumber family) and Solanaceae (potato family), and fruit crops including banana, mango and citrus. This reflects the long history of human occupancy in Sri Lanka, recorded for about 2,500 years, as does a rich tradition of using wild medicinal plants, for example in Ayurvedic medicine. Sri Lanka, then, is blessed with rich and varied natural resources, which are set amidst landscapes that are justly famous for their beauty. To protect all this, the country has established a national system of protected areas and conservation forests covering around 20% of land area.

Star tortoise (*Geochelone elegans*), a native of India and Sri Lanka.
Credit: IUCN-The World Conservation Union



Buddhist statues and paintings in the Cave Temples at Dambulla, Sri Lanka. ©Profimedia/Touchline Photo

The Sigiriya palace fortress in central Sri Lanka.© AFT/Getty Images

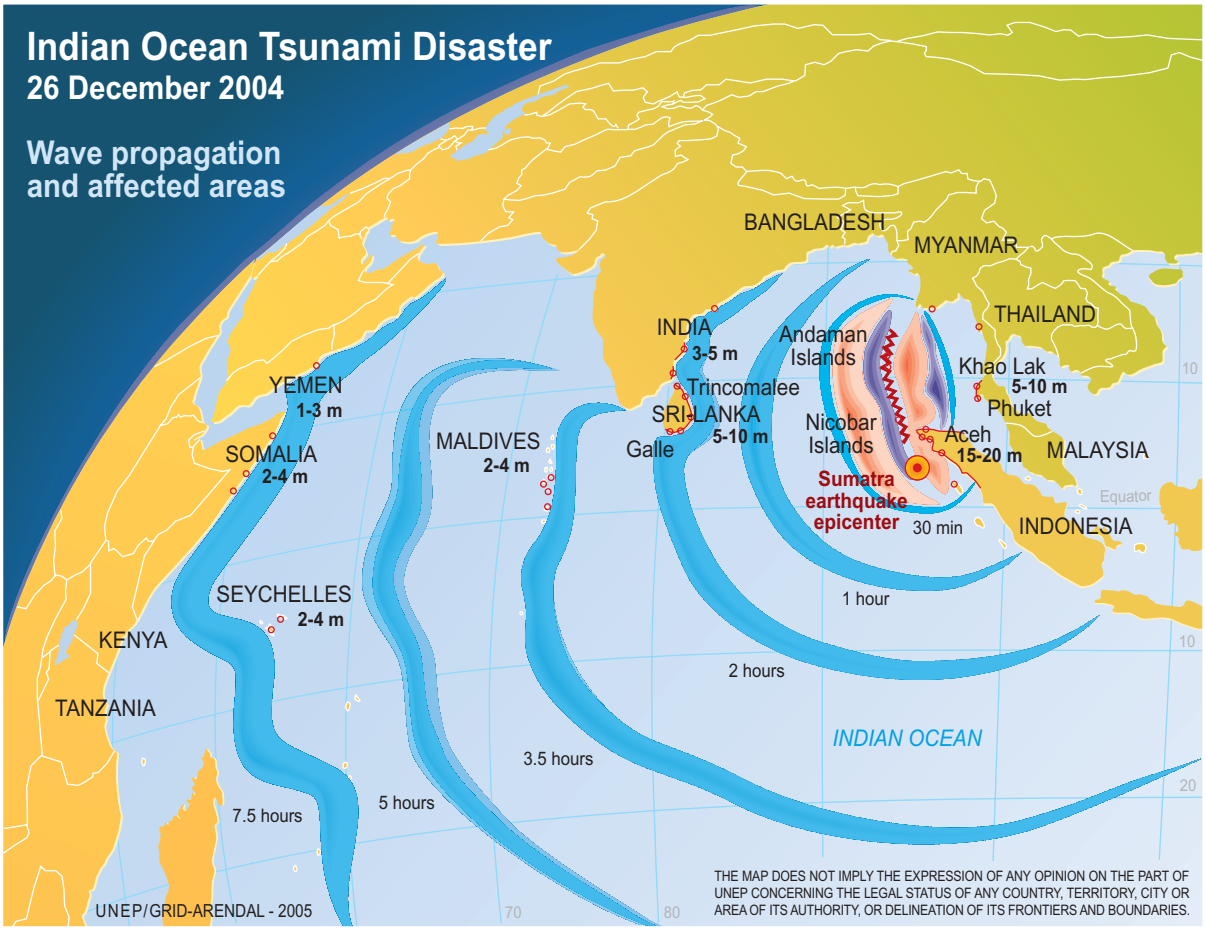
The island was settled initially late in the 6th Century BC, and a great civilization developed at the cities of Anuradhapura (from about 200 BC to 1000 AD) and Polonnaruwa (from about 1070 to 1200). The country's name, *Sri Lanka*, comes from this distant past, and means 'Resplendent Land' in Sanskrit. Its long history of civilization means that the country has a great wealth of archaeological sites, including ancient ruined cities (e.g. Polonnaruwa), spectacular fort-palaces (e.g. Sigiriya), and Ayurvedic hospitals (e.g. Ritigala). The ebb and flow of peoples and cultures has also given the country a diversity of religious sites, including Adam's Peak (sacred to Buddhists, Christians and Hindus), the Temple of the Buddha's Tooth at Kandy, and thousands of small shrines, sacred trees, decorated caves and other sites. The combination of cultural and natural features means that tourism has long been an important factor in the national economy, and one with considerable future potential. It was increasing rapidly in 2004, when overall GDP growth was around 6%, and up to the end of that year growth was expected to be about the same in 2005.

THE TIME OF THE GREAT WAVES

Then, at 0659 Sri Lanka time on 26 December 2004, a 1,200 km north-south section of the edge of the Indo-Australian tectonic plate abruptly began to subduct beneath the Eurasian plate. The speed of the rupture reached about 10,000 km/hour and the whole event lasted some ten minutes, beginning off the north-west coast of Sumatra and tearing northwards towards the Andaman and Nicobar islands. The resulting earthquake, measuring about 9.15 on the Moment Scale[1], and one of the most powerful ever recorded, displaced billions of tonnes of sea water. This in turn generated a series of surges which radiated across the Indian Ocean at a velocity of up to 800 km/hour. These began to

[1] The Moment Scale is used in place of the more familiar Richter Scale for very large earthquakes.

Origin and advance of the tsunami through the Indian Ocean region.



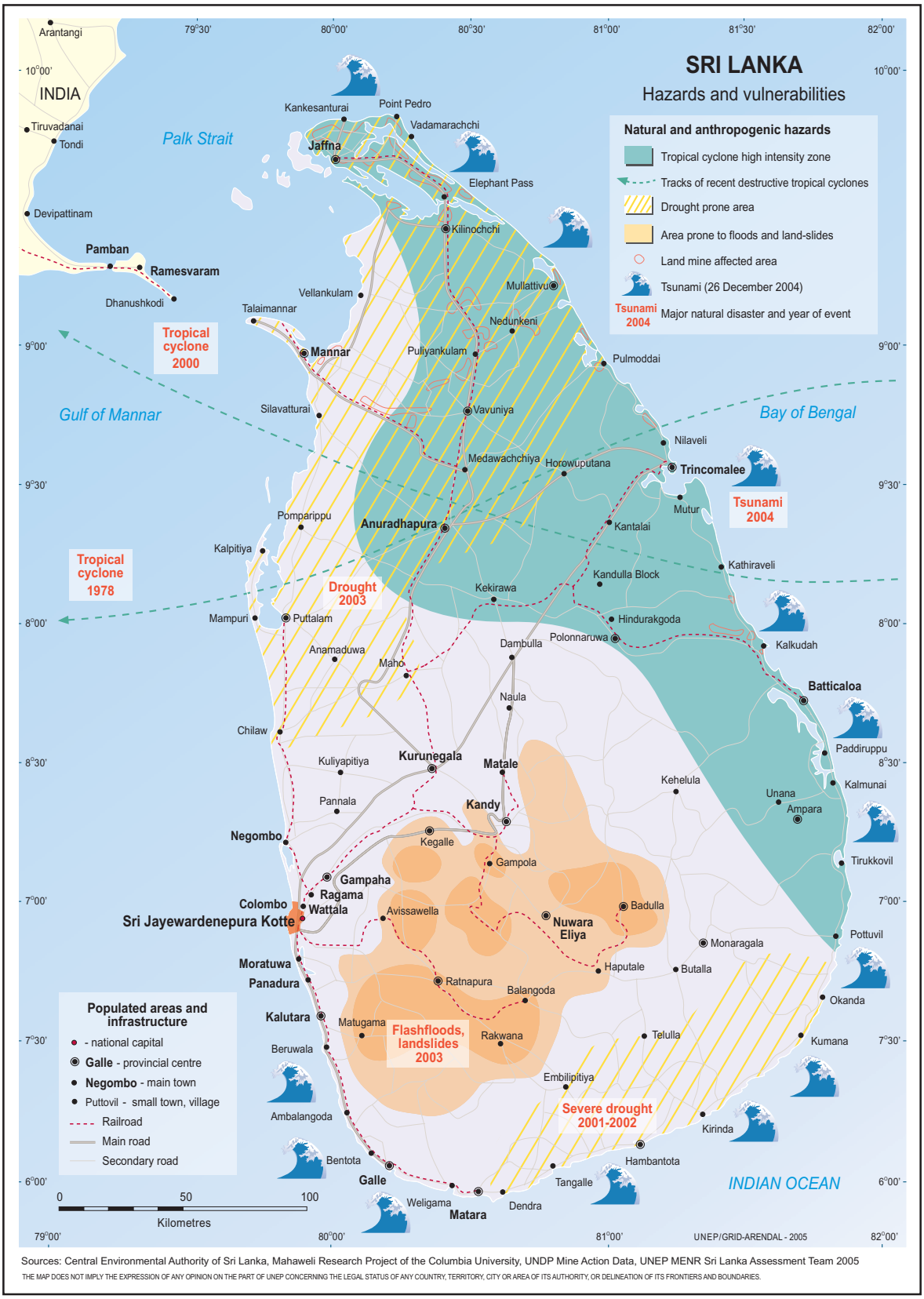
Sources: National Geographic 2005, NOAA 2005, UNEP 2005, IOC 2005

impact the eastern coast of Sri Lanka about 90 minutes later, being converted into large waves or tsunami[2] as they entered shallow water.

Sri Lanka is not a country that is particularly familiar with major natural disasters, although floods and land-slides sometimes happen in the wetter mountainous areas, there are drought-prone regions, and typhoons occasionally traverse the island. It is hard to imagine the unexpected violence of the tsunami waves, which were up to nine metres high in Sri Lanka, backed by the momentum of deep water in surging motion. Sea water penetrated from tens to hundreds, even thousands, of metres inland, destroying nearly 100,000 houses along with many vehicles and much infrastructure, and killing up to 40,000 people. It is characteristic of tsunamis that most of the people caught up in them directly are killed – so strong is the force of impact – so there were only about 15,000 injured, but to the cost should be added the tens of thousands of people orphaned, traumatized and bereft of everyone whom they cared for or who cared for them in normal times. These will be damaged for years, and perhaps for ever.

[2] Of Japanese origin, *tsunami* means 'harbour wave' and refers to a sudden wave that breaks on land following an earthquake.

Map of natural hazards and vulnerable areas in Sri Lanka.



Sources: Central Environmental Authority of Sri Lanka, Mahaweli Research Project of the Columbia University, UNDP Mine Action Data, UNEP MENR Sri Lanka Assessment Team 2005

Similar scenes unfolded across the Indian Ocean. As well as in Sri Lanka, tsunamis caused devastation along the coasts of western Indonesia, southern Thailand, western Peninsular Malaysia, southern India, Madagascar, Arabia and eastern and southern Africa, the archipelagic nations of the Maldives and Seychelles, and elsewhere. The event was the first to affect densely-populated areas on this scale in modern times, with the loss of as many as 310,000 human lives overall. News of this calamity reached the rest of the world during the days that followed. Reports of hundreds of deaths soon became thousands and then tens of thousands. An unprecedented outpouring of concern, compassion and charity then began to build up across the world. As the death toll crept into the hundreds of thousands, the giving crept into the hundreds of millions, then the billions, and the international community's disaster relief mechanisms swung fully into action. There is much to celebrate in what followed, for humanity showed the good side of what it is capable of. As area after area was found to have been destroyed, medical teams and food supplies were deployed, armies and navies, aid agencies, NGOs and UN staff turned from their normal tasks and raced to the scene to provide relief.

Lalithangani of Akurala village in Galle District lost all three of her children and her mother to the tsunami.© Shehzad Noorani/Still Pictures

Among them were some who had the responsibility to assess the situation and prioritize among the needs of people and countries, to learn lessons, and to help plan for the future. Among these, UNEP had a particular role to play, as the calamity was nothing if not an environmental phenomenon, with profound implications for how we think about and use our collective environment. It was necessary to understand how natural ecosystems and human settlements were affected by the great waves, what new hazards had been stirred up by them, and how best the pieces might be put back together so that the affected countries would emerge stronger and more resilient to natural disasters than they were before.

UN Secretary General Kofi A. Annan visits a camp for tsunami survivors at Cabeer Jumma mosque at Hambantota in early January 2005.© Yves Herman/Reuters

THE ENVIRONMENTAL ASSESSMENT

On 28 December 2004, the UNEP Asian Tsunami Disaster Task Force (ATDTF)[3] was established by the Executive Director of UNEP, with the aim of mobilising support for all affected countries to undertake rapid environmental assessments and to formulate response plans based upon them. Shortly afterwards, the Government of Sri Lanka, through its Ministry of Environment and Natural Resources (MENR), requested urgent assistance from UNEP to work with national experts in assessing environmental damage caused by the tsunami.

The aim was to assess such systems as coral reefs, shore erosion, coastal land use, water pollution, and soil contamination. The government further specified that its top priority for UNEP assistance after the assessment was in developing a forward-looking plan for coastal zone management, in which lessons learned from the disaster would be incorporated. The UNDAC mission that was launched in Sri Lanka on 26 December included a UNEP/OCHA environmental expert and focussed on acute environmental problems with immediate relevance to human lives and welfare. The planning phase of the assessment was supported from January onwards through the deployment of senior UNEP staff and a UNEP consultant, with logistical and other support provided by the South Asia Co-operative Environment Programme (SACEP).

Meanwhile the MENR and CEA defined methods for the assessment, based on contracting teams from several universities, supported by other sources of expertise, to undertake a field analysis of

[3] Chaired by PCAU, with participation by the UNEP entities DEPI, DEWA, DPDL, DTIE, GPA, IETC, ROAP, ROWA and WCMC.

tsunami impacts on both the 'green' environment (i.e. ecosystems, biodiversity, protected areas and farmlands) and the 'brown' environment (i.e. pollution, debris and impacts on human settlements and infrastructure). The 'green' assessment was undertaken by teams comprising independent scientists as well as professors, lecturers and students from Eastern University (for the eastern zone), the University of Ruhuna (for the southern and south-eastern zone), the University of Colombo (for the western zone), the University of Jaffna (for the north-eastern zone), the University of Moratuwa (for the south-western zone), and the University of Sri Jayawardenapura. The 'brown' assessment was done by teams of CEA officials and academics from the University of Moratuwa.

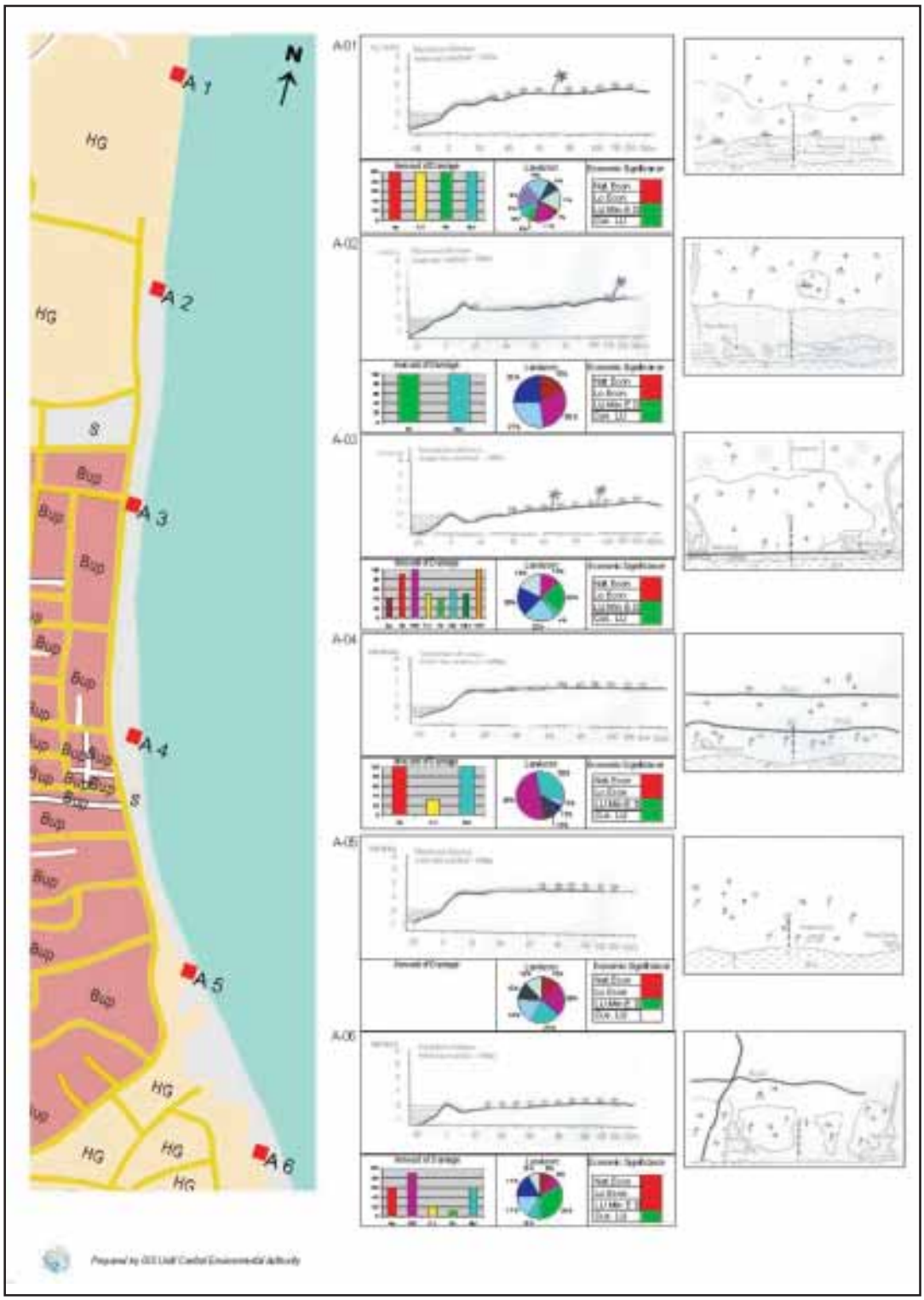
The environmental assessment was to relate both to the stated needs of the government, as well as to the work of the three special Task Forces appointed by the President of Sri Lanka in the aftermath of the disaster, especially the Task Force for Rebuilding the Nation (TAFREN). An Advisory Committee comprising senior government officials and academics was appointed by MENR to oversee the assessment (Annex 1), and approved its terms of reference, methods and time-frame on 3 February. The methods used by the two assessments were adapted to the different tasks at hand:

- Using standardized methods, the 'green' assessment teams described, at one-km intervals over the worst-affected coastline, transects perpendicular to the shore and running inland from the high tide line (MENR, 2005a). Data were collected on vulnerability, physical, ecological and social damage, land use, constraints on and options for land use, and on the precise pattern of tsunami inundation. All observations were georeferenced digitally. These profiles provided a significant sample of observation points and a set of locations where the

An assessment team after a training session at the Computer Center, University of Jaffna, including Dr J. Samarakoon (Team Leader, fourth from left in white shirt) and Dr S. Sivachandran (Area Coordinator, Northern Coastal Segment, fourth from right in pink sari).
Credit: Dr J. Samarakoon

An assessment team in training, the Batticaloa Field Assessment Group with Dr T. Jeyasingam (Area Coordinator, Eastern Coastal Segment, seated).
Credit: Dr J. Samarakoon

An example spread from the *Atlas of Tsunami Damage in Sri Lanka* prepared by the environmental assessment (MENR, 2005a, Volume 2).



complex interaction of the tsunami with topography, ecosystems and human settlements could be analysed and understood. Each also provided an observation point for overlapping 'visual encounter' descriptions of the surrounding area, providing continuous coverage of the whole 800 km stretch of worst-affected coast.

- The 'brown' assessment teams concentrated on contamination at over 750 sites where particular risks were known to exist because the tsunami affected facilities for storage or processing of potentially hazardous materials (MENR, 2005b). These included both established solid waste dumps and impromptu ones used to dispose of tsunami debris, and mass graves, as well as storage and processing facilities associated with the commercial, health, security, transport, tourism, agriculture, fisheries, mining and other sectors. The team and CEA assessed each site for type, scope and intensity of pollution, looking at faecal, oil and toxin contamination, visual, air, odour and thermal pollution, disease risks and salinization. Samples of water and soil were collected and analysed chemically. Sites were scored for the severity of impact and conclusions drawn on the urgency and feasibility of mitigation.

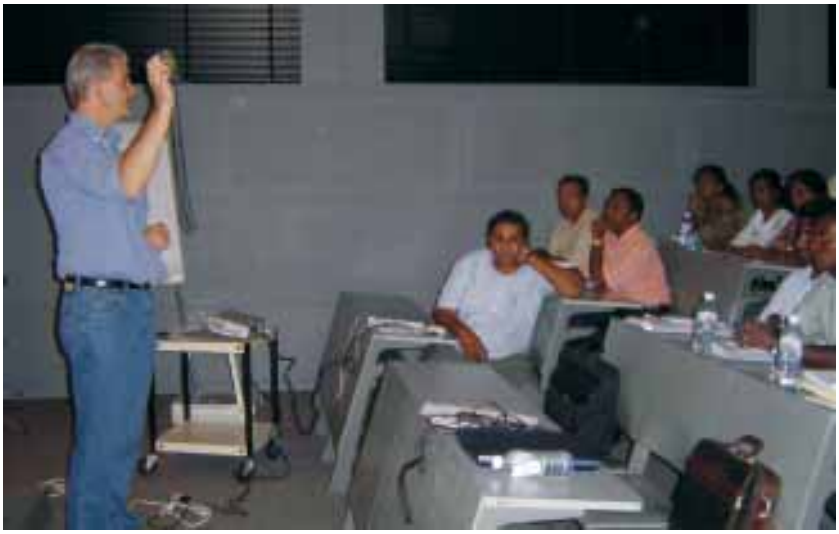
An important benefit of the assessment came from the way in which it was done, which was government-led and jointly executed by government and university teams, contributing to a new style of government-university relations. It is based on a much greater level of detail than other assessments and, particularly in the form of the *Atlas of Tsunami Damage in Sri Lanka* (MENR, 2005a, Volume 2), is informed by a systematic, georeferenced visualization of impacts across an 800 km length of affected coastline (see facing page for an example of a spread from this Atlas). It is recognized by government as the only comprehensive, science-based and official assessment of environmental issues raised by the tsunami in Sri Lanka, upon which all future environmental remediation work will be based.

The assessment aimed to produce an accurate account of the impacts of the tsunami in Sri Lanka, while also providing a foundation for planning the reconstruction and sustainable development of the affected area. Its orientation was forward-looking, since there are important lessons to be learned that should inform public and private investment both nationally and regionally if livelihoods are to be safeguarded against future environmental shocks and hazards. The tsunami has also created the opportunity for fundamental improvements in the process of economic and social development in the affected area, in which global best practices can be introduced from the beginning of rebuilding and ecological reconstruction.

Thus the assessment should be seen as one of several steps that will lead from an understanding of the disaster and its immediate consequences, through a strategic analysis, to a comprehensive plan for sustainable development in the coastal zone. It should also be seen as part of a response that informs and draws on international consensus about the consequences of global warming, early warning, environmental management and sustainable development as means by which to achieve the Millennium Development Goals.

This report is a summary of the findings of the environmental assessments (i.e. MENR, 2005a, 2005b). It was prepared during August 2005 drawing on an earlier synopsis report (MENR, 2005c), which in turn was based on the findings of the teams of Sri Lankan scientists who actually undertook the assessments and who are listed in Annex 1. Large amounts of information were also generated and shared by other institutions, and this report also draws collaboratively on such sources, which included:

- Surveys throughout the tsunami-affected areas to identify acute environmental issues with immediate implications for human lives (UNEP/OCHA, 2005), and to assess overall damage and needs (ADB *et al.*, 2005 – see Box 1).



Dr B. Maathuis (ITC, The Netherlands), demonstrating the use of a global positioning system to field assessment team members. Credit: Dr J. Samarakoon

Dr S. Epitawatte training field assessment members on map reading and preparation of site sketch maps. Credit: Dr J.Samarakoon

A field assessment team at work, with Professor M. de Silva (Area Coordinator, Southern Coastal Segment). Credit: Dr J. Samarakoon

- Surveys in particular areas to document tsunami-related impacts on the terrestrial and marine environment and biodiversity, in the south-eastern coastal areas of Rekawa, Ussangoda and Kalametiya (IUCN, 2005a); in Ampara and Batticaloa districts (IUCN, 2005b); along the southern, south-eastern and eastern coast (NARA *et al.* 2005); and along the southern coast between Hambantota and Colombo (IWMI, 2005).

- Surveys of protected areas and special management sites to establish damage and remediation needs (DWLC, 2005; CCD, 2005).

Box 1. The multi-donor needs assessment of January 2005

Among the first major, systematic efforts to assess the damage and needs created by the tsunami, and to design a recovery programme for Sri Lanka, was that undertaken jointly by the Asian Development Bank (ADB), Japan Bank for International Cooperation (JBIC), Japan International Cooperation Agency (JICA) and the World Bank in January 2005. The main report of this study was supported by 15 detailed annexes, on social impacts, environment, economic assessment, education, health, housing, agriculture and livestock, livelihood, power, water supply and sanitation, railways, roads, fisheries, tourism, and hazard risk management. The report proposed the following guiding principles to underpin the recovery strategy, urging that they be agreed upon by all key stakeholders:

- The recovery strategy shall be conflict-sensitive, and at the very least do no harm to the peace process while always attempting to foster it. All reconstruction interventions should therefore be analysed for their potential impact on the conflict.

- The strategy will be based on the principle of subsidiarity, meaning each reconstruction activity should be designed and implemented at the lowest tier of governance that is deemed competent for that particular activity. This will allow for locally appropriate solutions and enable a range of sub-national structures and organizations to channel funds.

- Affected communities should be empowered to make their own decisions during recovery. That is, all interventions must respond to clearly identified and articulated needs of local communities, and be scrutinized for their impact on gender, poverty, human rights, and the environment.

- There will be communication and transparency in decision-making and implementation. Mechanisms must be put in place to enable all affected communities, and also those not affected by the disaster, to have access to information regarding policies, entitlements, and implementation procedures, and to channel back information about their own needs and priorities to implementing authorities. Similarly, mechanisms to ensure transparency, grievance redress and accountability must also be created.

- Reconstruction processes should avoid rebuilding existing vulnerability to natural hazards. A multi-hazard risk approach should be used during the recovery phase to ensure that communities and assets are less vulnerable to impacts of future disasters.

- A coordinated approach is critical to ensure that the above principles are followed and to prevent duplication or overlap in activities.

Source: ADB *et al*. (2005)

THE TSUNAMI AND ITS EFFECTS

Satellite image showing tsunami flooding in south Kalutara District, Sri Lanka.© DigitalGlobe

PATTERNS OF WAVE BEHAVIOUR

The total duration of tsunami arrival in Sri Lanka was about two hours, from 08.00 to about 10.00 hours local time on 26 December 2004. Because of the north-south orientation of the fault that originated the earthquake-tsunami, most energy was projected on an east-west axis, and of all parts of Sri Lanka the eastern coast was directly in line to receive the first and greatest impact.

Witnesses in the coastal districts of Batticaloa (at Pasikudah-Kalkudah, Valachenai and Vaharai) and Ampara (at Akkraipattu and Kalmunai) reported that the first wave arrived during low tide at about 08.30 hours (with a range from 08.00-08.50 hours), followed by two or three other major waves (and several lesser ones) over the next 30 or so minutes (IUCN, 2005b). They described the biggest waves in various locations as ranging from 3-9 metres high at the shore, and these waves penetrated inland for distances ranging from 600 metres to nearly two km, and in places up to three km. The median depth of inland penetration at 62 sites in 38 *Grama Niladhari*[4] in Trincomalee and Ampara districts was 300 m (MENR, 2005a), with a mean of 320 m and a range of 20-1,000 m (Table 1).

The first and often reportedly the highest wave reached the eastern and northern coasts without warning, but by the time the tsunami arrived on the southern coast (e.g. at 09.20 in Matara, 09.22 in Galle, persisting for about 30 minutes), witnesses tended to report that the highest wave was the second or third and that the sea receded a long way from the shore before the highest wave came ashore (MENR, 2005b). There was considerable variation in wave behaviour, however, as it advanced along the south-eastern, southern and south-western coastlines. The median depth of wave penetration was about 130 m in Batticaloa, 110 m in Matara, 100 m in Hambantota, 70 m in Galle, and 50 m in Jaffna district.

Witnesses were inconsistent in their description of the tsunami as taking the form of a sudden rise in sea level, or else as a "bore" which rolled along accompanied by much noise and destruction. This could have been because the observers were more focused on the damage and danger than on the wave itself, but the wave form also varied greatly from place to place. This variation was probably influenced by the shape of the sea-bed, which is thought to have funnelled the waves into higher shapes in some areas.

CORAL REEFS AND SEA GRASS BEDS

The ability of intact, healthy coral reefs to absorb and dissipate over 90% of the energy from waves has been demonstrated in locations as far apart as Australia (Brander *et al.*, 2004), Central America (Roberts & Suhada, 1983), the Caribbean (Lugo-Fernandez *et al.*, 1998) and the Red Sea (Frihy *et al.*, 2004). This is also well known to traditional users of and dwellers by the sea (UNEP-WCMC, 2005).

The coral reefs of Sri Lanka were far from pristine prior to the tsunami, however, since in many areas they had been all but destroyed by the mining of coral rock for making lime and cement, and elsewhere they were still recovering from a major coral bleaching event in 1998, which was caused by unusually high water temperatures (Table 2). The reefs of Sri Lanka, then, were already stressed and weakened where they still existed (Table 3), and even in protected areas they had long been vulnerable because management capacity was too weak to prevent destructive fishing techniques from being used there (Table 4).

[4] The *Grama Niladhari* is the smallest unit of local government in Sri Lanka, equating to 60-100 households in 1-3 villages, with one appointed head.

Map showing patterns of tsunami impact and penetration in Sri Lanka.

Table 1. Landward tsunami penetration in Trincomalee and Ampara districts (from MENR, 2005a)

TRINCOMALEE DISTRICT		
Grama Niladhari Division & No.	**Place name**	**Penetration (m)**
Pulmottai - 04	Kokkilai Lagoon	200
Pullmoatai - 04	3rd Mile Post	200
Pulmoattai - 04	Kuttikaldai	300
Pulmotai - II	Behind Ilmenite Factory	200
Pullmottai - II	Pulmodai Town	300
Pulmoddai - II	Arisimaalai	100
Thiriyaai	Panmalaikudah	200
Thiriyaai	Kalrawa	300
Thiriyaai	Thiriyai-Kalrawa	200
Thiriyaai - 237	Thiriyai Junction	300
Senthoor - 237B	Senthoor	300
Senthoor - 237	Puddavaikattu	350
Jaya Nagar - 239C	Valapattukudah	200
Jaya Nagar - 239C	Karadimaalai	200
Veerancholai - 239B	Veerancholai	200
Veerancholai - 239B	Iranaikkerny	650
Kumburupiddy East -240B	Kumburupiddy	300
Kumburupiddy East -240B	Sallaipaiaru	150
Kumburupiddy East -240B	Sallaipaiaru	400
Kumburupiddy North -240A	Sallaipaiaru	300
Kumburupiddy North -240A	Thavicalmaalai	200
Kumburupiddy South - 240	Devimaalai	100
Irrakakandy - 241A	Irrakakandy	150
Vaalaiyoothu	Vaalaiyoothu	200
Nilaveli Gopalapuram	Gopalapuram	500
Nilaveli - 241	Nilaveli	500
Veloor - 241C	Veloor	400
Iqbal Nagar - 241D	Ragulthottam	700
Iqbal Nagar - 241D	Adukkuparai	400
Sampalthivu - 242	Manganai	50
Sampaltivu - 242	Sampalthivu Ward	350

Salli - 242A	Salli	150
Uppuveli - 243	Alles Garden	300
Uppuveli - 243	Uppuveli	200
Pattanatheru	NC Road	350
NC Road - 244	Pattanatheru	75
Pattanatheru	Fort Frederick Road	300
Villundy	Town Beach	60
Arunagrinagar - 244G	Inner Harbour Road	100
Orr's Hill Lower Road - 244P	Lower Road	20
AMPARA DISTRICT		
Grama Niladhari Division & No.	**Place name**	**Penetration (m)**
Sinna Muhaththuvaram - 9	Sinna Muhaththuwaram	400
Thampaddai - 2	Thampbaddai	300
Thampaddai - 2	Thampaddai	300
Thambaddai	Thambaddai	300
Thambaddai - 3	Periya Muhaththuwaram	400
Thambiluvil - 01	Thambiluvil	300
Thambiluvil - 01	Kanagaratnam	450
Thambiluvil - 02	Thambiluvil	450
Thiruk	Thirukkovil - 1	300
Thhambiluvil	Thambiluvil - 02	600
Vinayahapuram - 4	Vinayahapuram	800
Thirukkovil	Vinayahapuram	400
Korawatha	Korawatha	600
Korawatha	Korawatha	200
Omiree	Korawatha	350
Omiree	Thirupathi	400
Omiree	Omiree	1,000
Omary	Omary	600
Manelaichenai	Manelaichenai	600
Komari	Komari	80
Komari	Komari	80
Sinna Muhaththuvaram - 9	Sinna Muhaththuwaram	400

Map showing patterns of tsunami impact on ecosystems in Sri Lanka.

Sources: Central Environmental Authority of Sri Lanka, IUCN 2005, UNEP-WCMC 2005, UNEP MENR Sri Lanka Assessment Team 2005

Table 2. Impact of 1998 bleaching event on live coral cover in Sri Lankan reefs (from Rajasuriya *et al*., 2005)

Site (depth 0-3 m)	Pre-1998	1999-2000	2001-200	2003-2004
Bar Reef MS	78.5%	Close to 0%	Some colony establishment	17.7%
Hikkaduwa NP	47.2%	7.0%	12.0%	10.1%
Weligama Reef	92%	28.0%	54.0%	70.6%
Pigeon Island NP	No data	51.3%	No data	54.4%

Table 3. The 2004 (pre-tsunami) condition of Sri Lankan coral reefs (from Rajasuriya *et al*., 2005)

Reef Area (km^2)	% Reef dead	% Reef destroyed in 1998	% Reef recovered since 1998	% Reef critically endangered	% Reef threatened
680	35	40	15	10	45

Table 4. The 2004 (pre-tsunami) status of marine protected areas in Sri Lanka (from Rajasuriya *et al*., 2005)

Location	Coral status	Management	Pressures
Bar Reef Marine Sanctuary	Corals were recovering well, but fishing pressure was increasing.	Coastal Resources Management Project was developing strategies & planning management.	Extractive use was increasing, including fishing & sea cucumber & shell collection.
Hikkaduwa National Park	Corals were in poor condition due to sedimentation & high visitor pressure.	No management	Sedimentation, visitor pressure & physical damage by boats & trampling of corals.
Rumassala Marine Sanctuary	Corals were in poor condition; recent bleaching observed.	No management	Blast fishing, fish collecting & visitor pressure.
Pigeon Island National Park	Corals were in good condition.	No management	Visitor pressure & destructive fishing in vicinity.

The force of the tsunami was sufficient to move boulders and sections of reef, as well a huge weight of smaller fragments, sand and silt. There was also a powerful back-wash, carrying wastes, debris, rubble, soil and organic matter into and across the reefs.

Despite all this potential for devastation, damage to reefs was very patchy, ranging from total destruction in some areas to almost no impact in others (Tables 5, 6). This presumably reflects a complex interaction between the condition of the reef in each location, and the precise way in which tsunami energy was delivered to that particular environment. Damage to sea grass beds was minor and where present was mostly due to shifting rubble; hardly any uprooting was observed.

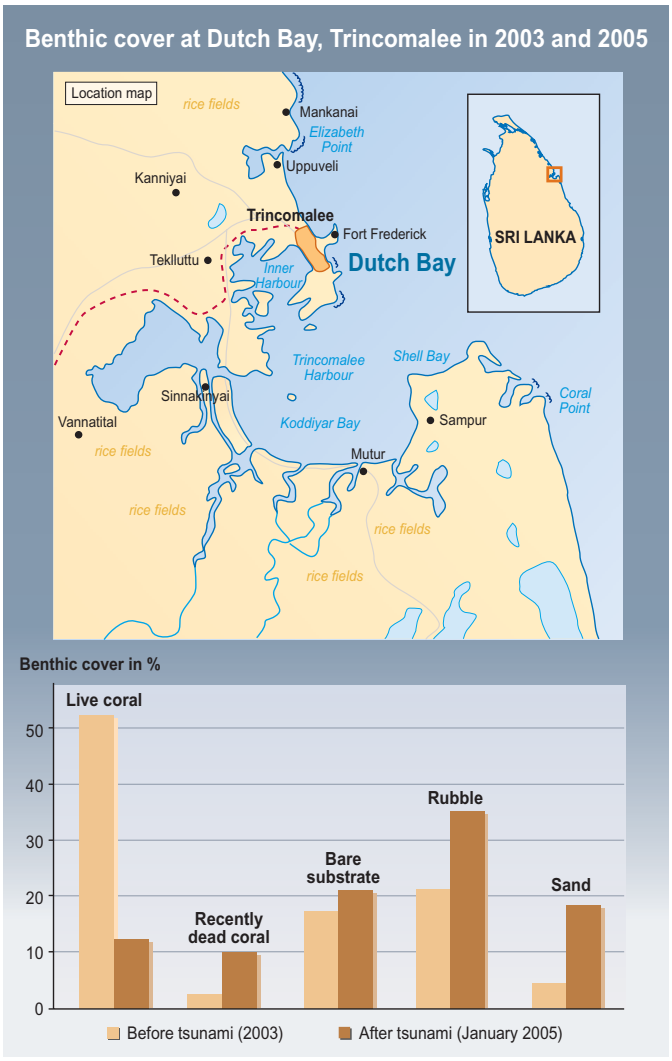
Table 5. Summary of tsunami impacts on coral reef and fish communities (from NARA *et al.*, 2005; Rajasuriya, 2005)

	Mechanical Damage		Fish Community	
Site (area)	Intensity	Extent	Impact	Comments
Polhena (southern coast)	Medium	Medium	Medium to High	Mainly loss of small reef fishes, such as damselfish (Pomacentridae), butterflyfish (Chaetodontidae) and wrasse (Labridae), where the reef substrate and habitat has been lost.
Kapparatota/ Weligama (southern coast)	High	Medium	Medium	Loss of fish life was evident where there was severe damage to coral patches. The site was degraded by destructive exploitation of resources, compounded by bleaching in 1998.
Hikkaduwa (south-western coast)	High	Medium	Low	Fish life seems little affected but live coral cover was reduced from about 15% to 12%; some debris present; sand accumulation in the reef lagoon. The site had the most abundant populations of larger fishes, such as sweetlips (Haemulidae), rabbitfish (Siganidae) and parrotfish (Scaridae), both before and after the tsunami. Butterflyfish and damselfish populations were already low after the bleaching in 1998.
Rumassala (south-western coast)	None	None	None	Very low impact, no damage to coral, some debris present. Damage due to blast fishing was evident. Fish life was reduced after the bleaching event and ongoing blast fishing continues to degrade populations
Unawatuna (south-western coast)	High	High	High	Most groups, in particular surgeonfish (Acanthuridae) and damselfish have been reduced. Many fish on this reef had been lost with coral during in 1998, and further reduced as a result of the tsunami.
Dutch Bay (eastern coast)	Extreme	Extreme	High to Extreme	Fish life reduced drastically due to extreme reef damage caused by the tsunami, especially damselfish, butterflyfish, wrasse, etc.

Table 6. Tsunami impacts on coral reefs off the eastern coast of Sri Lanka (from IUCN, 2005b)

	Mechanical Damage		Smothering		Debris		Live coral cover
Site/reef	Intensity	Extent	Intensity	Extent	Intensity	Extent	
Kalmunai	low	moderate	none	none	none	none	10-20%
Palchenai	moderate	moderate	moderate	moderate	low	low	20-30%
Sallithievu	high	moderate	moderate	high	low	moderate	15-20%

Benthic cover at Dutch Bay, Trincomalee in 2003 and 2005.



Source: NARA, IUCN, CORDIO and SLSAC 2005

A thick growth of *Rhizophora mucronata* (Rhizophoracea) in the backwaters of Negombo Lagoon, a Special Area Management site in Gampaha District, Sri Lanka. Mangroves of this type can absorb much wave energy. Credit: Dr J. Samarakoon.

MANGROVES AND OTHER COASTAL FORESTS

Mangroves are dominated by trees (often of the families Rhizophoraceae, Combretaceae and Avicenniaceae) that can tolerate conditions in tidally-inundated saline mud. They are highly productive ecosystems and can yield an annual direct harvest per hectare of 100 kg of finfish, 20 kg of shrimp, 15 kg of crabmeat, 200 kg of mollusc and 40 kg of sea cucumber (Pye-Smith & Feyerabend, 1994). More than 70 other uses for mangrove products have been documented worldwide, ranging from palm-sugar and honey to tannin and water-resistant poles (Hamilton & Snedaker, 1984). Sri Lanka has short rivers with low sediment yield, and a maximum tidal amplitude of only about 75 cm, so there are few locations suitable for the development of extensive stands of mangrove vegetation. These are limited to Puttalam district, with over 2,000 ha, and Batticaloa and Trincomalee districts, each with over 1,000 ha. Elsewhere, mangroves occur only along the fringes of brackish-water lagoons, estuaries and inlets.

At Odu lagoon and Nasiva village (Valachenai), in Batticaloa district, damage to mangroves was investigated in some detail (IUCN, 2005b). Here the tsunami was about 6 metres high at the shore and penetrated up to one km inland, across a mixed landscape comprising beach, mangrove-fringed lagoon, coconut plantation, scrub forest, home gardens and the village. This complex environment evidently absorbed and dissipated much tsunami energy, and by the time the wave reached the village it was less than 40 cm high and caused no loss of life. The beach showed extensive erosion

Map showing patterns of tsunami impact on coastal landforms in Sri Lanka.

Sources: Central Environmental Authority of Sri Lanka, UNEP MENR Sri Lanka Assessment Team 2005, National Aquatic Research Agency 2005, TAFREN 2005

and about 40% of the coconut palms close to the sea were broken or uprooted, but the lagoon was little affected. Its fringing mangroves comprised a band of trees 5-6 m deep, of which the first 2-3 m (mainly *Rhizophora apiculata* and *Ceriops tagal*, both Rhizophoraceae) were severely damaged by the tsunami. The inner 3-4 m of mangrove vegetation, however, was much less damaged, and this pattern was also seen on two mangrove-dominated islets in the lagoon. The study concluded that mangrove restoration, particularly in the first 300 m on both sides of the lagoon, should be a high priority in this location in view of "their importance, both from a biodiversity and environmental security point of view".

The same study went on to observe (IUCN, 2005b:32) that "Extensive stands of mangrove appear to have played a positive role in buffering the inland landscapes from the tsunami by reducing the energy of the incoming waves and absorbing the tsunami waters into a network of mangrove creeks and channels. Agricultural lands such as rice (paddy) fields, roads, human settlements and buildings were observed to be relatively undamaged in those sections of the coastline which had continuous thick stretches of mangroves (e.g. between Akkraipattu and Batticaloa; Sallithievu and Vaharai) as compared to similar areas where such mangrove systems were absent. However large patches of deforested mangrove areas were also observed in the area, particularly in Batticaloa district (e.g. on both sides of the road from Batticaloa to Vaharai). These had been reportedly cleared for security reasons during the height of the conflict between the LTTE and government forces."

Other coastal forests proved much less able than mangroves either to survive or to moderate the impact of the tsunami. A 10-15 m shelter-belt of *Casuarina* trees in the Nawaladi area of Batticaloa Town did not succeed in protecting heavily-populated inland areas and were themselves badly damaged, with almost complete uprooting in several sections (IUCN, 2005b). Elsewhere, for example at Manalkadu in Jaffna district, planted *Casuarina equisetifolia* trees did seem to contribute to protecting the area, but mainly indirectly by helping to stabilize sand dunes which supported other features of the complex landscape in absorbing tsunami impact.

Coconut palms (*Cocos nucifera*) were resistant to physical impact and salinity effects. Although their stands are too open to contribute much to protecting inland areas from the tsunami, they did play a role in reducing beach erosion (IUCN, 2005b). The other common palm of coastal Sri Lanka, the palmyrah (*Borassus flabellifer*), proved to be more vulnerable to the tsunami than the coconut, being both more fragile and more susceptible to salt poisoning. Other trees, such as eucalypts (*Eucalyptus* spp.), neem (*Azadirachta indica*), tulip tree (*Thespesia populnea*), mango (*Mangifera indica*), tamarind (*Tamarindus indicus*), country almond (*Terminalia catappa*), banyan (*Ficus bengalensis*), cassia (*Cassia* spp.), guava (*Psidium guajava*), oleander (*Nerium oleander*), temple tree (*Plumeria obtusa*), Indian willow (*Polyalthia longifolia*) and jackfruit (*Artocarpus heterophyllus*), showed some breakage or uprooting and the survivors reacted to increased soil salinity by showing significant defoliation. Long term mortality rates are not yet known.

LAGOONS, ESTUARIES AND WETLANDS

The lagoons and estuaries of Sri Lanka are some of the country's most prominent natural features and cover some 160,000 ha in total. The lagoons are complexes of other wetland systems and often contain marshes, mangrove areas, seagrass beds, and mud flats. These ecosystems are valuable for their fish, shrimp and other products, for those that open to the sea also provide nursery functions supporting coastal fisheries. The health of lagoons and estuaries is heavily dependent on the steady flow of fresh water from the interior of the island, which determines their prevailing salinity. Hence lagoons are vulnerable to being opened to the sea in new ways, with resulting changes in salinity and hence ecology. Lagoons and estuaries in particular represent zones of tension between the influ-

Cars and trucks drive through a flooded road in the coastal area of Batticaloa, one of the districts worst impacted by the tsunami.© Shehzad Noorani/ Still Pictures

ences of freshwater from the land and saltwater from the sea; to the extent that they form and remain for long periods they result from a balance between these influences. The balance can be upset, however, and the tsunami did so temporarily in many places, inducing changes among the biota of lagoonal and wetland ecosystems as salt and marine sand has intruded and drainage channels have been changed. Nevertheless, observers have generally concluded that most lagoons have more-or-less recovered ecologically since the tsunami, except to the extent that they had accumulated sand, debris and litter (e.g. IUCN, 2005b; MENR, 2005a; Table 7).

BEACHES, SAND SPITS AND DUNES

Severe beach erosion was observed both in the east and south-west, but was patchy in its occurrence (NARA *et al*., 2005). Beaches in the east showed extensive erosion and sand migration, with some of them losing over 50% of their width and up to a metre in height (IUCN, 2005b). Much of this loss seems to have occurred due to the tsunami back-wash, so the overall pattern may have been that the tsunami deposited marine sand inland and then took beach sand back to sea. Beach vegetation was much damaged, particularly *Ipomoea* (Convolvulaceae), but clumps of *Pandanus* (Pandanaceae) and *Spinifex* (Poaceae) often remained standing. Post-tsunami observations by MENR (2005a) are summarized in Table 8 for beaches, Table 9 for sand spits, and Table 10 for sand dunes.

Table 7. Tsunami impacts on lagoons and estuaries (from IUCN, 2005b)

District		Observations
Gampaha	Negombo lagoon-estuary	Slight damage, rubble in mouth area, a few uprooted mangroves. Absorbed energy; changed wave to flood.
Colombo	Lunawa lagoon	Opened barrier at mouth. Absorbed energy; the revetment was more significant in settlement protection.
Kalutara	Kalu Ganga estuary	Slight erosion at mouth. Absorbed energy; many contributory factors connected with settlement protection.
Galle	Madu Ganga estuary	Slight mangrove uprooting, sand barrier at mouth breached. Absorbed energy; many contributory factors connected with settlement protection.
	Kosgoda lagoon	Sand barrier at mouth breached. Probably contributed to funnelling energy into settlement area and contributed to settlement damage, likely to improve fishery productivity.
	Koggala lagoon	Sand barrier at mouth breached. Minor if any role in settlement protection.
Hambantota	Rekawa lagoon	Sand barrier at mouth temporarily breached. Minor if any role in settlement protection.
	Kalametiya lagoon	Sand barrier at mouth temporarily breached. Settlement on beach front, not protected by lagoon.
Ampara	Arugam Kalapu	Sand barrier temporarily breached, some mangrove uprooting, much sand and debris deposited. Partial energy absorption, partial funnelling of wave energy; sink for debris, facilitated salt intrusion into paddy fields.
	Komari lagoon	Sand barrier temporarily breached, some mangrove uprooting, much sand and debris deposited. Partial energy absorption, partial funnelling of wave energy; sink for debris, facilitated salt intrusion into paddy fields.
Batticaloa	Batticaloa lagoon	Several openings to the sea seasonally blocked by sand barrier, most re-opened; sink for debris. Partially absorbed energy while partially funnelling energy and flood water mainly through the opening at Batticaloa (Barr Road); may have caused extensive salt intrusion with serious consequences for paddy cultivation.
	Uppar-Panichankerny estuary	Opening of sand barrier at mouth. Partial absorption and partial funnelling of energy.
Trincomalee	Sinnakarachchiya	Opening of estuary mouth. Partial absorption and funnelling of energy.
	Periyakarachchiya	Opening of estuary mouth. Partial absorption and funnelling of energy.
	Kokkilai lagoon (shared)	Opening of estuary mouth. Failed to absorb energy, extensive settlement destruction.
Mullaitivu	Kokkilai lagoon (shared)	Opening of estuary mouth. Failed to absorb energy, extensive settlement destruction.
	Nayaru	Opening of estuary mouth. Failed to absorb energy, extensive settlement destruction.
	Nanthi Kadal	Opening of estuary mouth. Failed to absorb energy, extensive settlement destruction.
Jaffna	Thondamanaru lagoon	Opening of estuary mouth. Failed to absorb energy, extensive settlement destruction.

Table 8. Tsunami impacts on beaches (from MENR, 2005a)

District	Beach	Observations
Gampaha	Lewis Place, Negombo, ca 5km	Beach scouring by diffracted or reflected wave. Beach stabilized by off-shore breakwaters, absorbed energy, protected hotels.
Colombo	Wellawatte - Mt. Lavinia, ca 2km	Beach scouring by diffracted or reflected wave. Beach partially fronted by rock reef, partial absorption of wave energy.
Kalutara	Panadura, 2-3km	Slight erosion by diffracted or reflected wave. Adjoining estuary failed to absorb energy; severe damage to settlement.
	Tangerine, 3-4km	Slight erosion by diffracted or reflected wave. Broad beach absorbed wave energy.
	Maggona, 2-3km	Slight erosion over 2-3 km by diffracted or reflected wave. Broad beach absorbed wave.
	Moragalla, >2km	Pitting, observable erosion over 2-3 km by diffracted or reflected wave. Partial energy absorption, solid, low-income housing protected.
	Kosgoda, 2-3km	Observable erosion over 2-3 km by diffracted or reflected wave. Narrow beach failed to absorb energy; Kosgoda Beach Resort destroyed.
Galle	Benthota, 2-3km	Slight erosion by diffracted or reflected wave. Partial absorption of energy, solidly built hotels not vulnerable.
	Godagala-Induruwa	Little observable erosion.
	Akurala-Seenigama, >4km	Narrow beach, backed by high revetment, observable but slight erosion. Extensive settlement and train damage, many contributory factors.
Hambantota	Hambantota	Broad beach, raised berm, slight erosion. Failed to absorb energy, extensive settlement damage.
Ampara	Arugam Bay, >2km	Broad beach, low berm, slight reshaping and erosion. Failed to absorb energy, extensive damage to settlements and agricultural land.
	Kalmunai, >5km	Broad beach, raised berm, visible erosion, scarring and pitting. Failed to absorb energy, extensive damage to settlements and agricultural land.
Batticaloa	Kalladi, >3km	Broad, flat beach, reshaping and considerable erosion, adjoining estuary mouth. Failed to absorb energy, flood and energy dissipation on settlement, extensive damage.
Mullaitivu	Nayaru, 2-3km	Broad beach, pitted and scarred by erosion, sand layers removed to expose previously buried culverts. Failed to absorb energy, extensive damage to building, including some solid structures.
	Nanthi Kadal, 2-3km	Broad beach, pitted and scarred by erosion, sand layers removed to expose previously buried culverts. Failed to absorb energy, extensive damage to buildings, including some solid structures.
Jaffna	Uduththurai	Broad beach with raised berm, slight erosion. Failed to dampen energy, extensive damage to vulnerable houses, churches survived.
	Maruthankerny	Broad beach with raised berm, slight erosion. Failed to dampen energy, extensive damage to vulnerable houses, churches survived.
	Casuarinas	Beach fronted by dead coral, backed by road on embankment, corals scattered, boat access obstructed. Absorbed energy, assisted by embankment, mainly flood damage.

Table 9. Tsunami impacts on sand spits (from MENR, 2005a)

District	Sand spit	Observations
Kalutara	Kalutara	Slightly reshaped.
Galle	Bentota	Breached, serious damage. Absorbed energy, probably protected some structures.
	Kosgoda	Breached, self-repaired. Probably absorbed energy and protected road and bridge.
Batticaloa	Vakarai	Slight erosion. Failed to absorb energy, extensive settlement damage.

Table 10. Tsunami impacts on sand dunes (from MENR, 2005a)

District	Sand dune area	Observations
Jaffna	Manalkadu	Some shifting of dunes, some shape change. Protected some houses at higher elevation, provided refuge.
	Vadamarachchi East	Little visible damage. May have accelerated wave flow and energy on the landward decline of berm and low dune combination, thereby increasing settlement damage.
Ampara	Kalmunai-Pottuvil	Little damage to dunes. Mixed role of dunes: in some stretches they provided protection, but not in others.
	Pottuvil	Wave energy penetrated at points north and south of Pottuvil Town where dunes had been denuded. Stable, vegetated dunes provided protection.
Hambantota	Panama	Breached low points of dunes and created fresh pools with new tidal inlets. No settlements.
	Yala (Protected Area)	Overtopping where dune elevation had been reduced by people. Failed to protect two hotels which had flattened dunes to provide beach access. Protected hotel situated behind intact dune.
	Karagan Lewya	Overtopped partially-mined dune. Failed to protect road traffic resulting in many deaths.
Gampaha	Palliwatte-Duwa	Dune not overtopped. Protected settlements.

COASTAL PROTECTED AREAS AND SPECIAL AREA MANAGEMENT SITES

Existing and proposed Protected Areas in coastal districts affected by the tsunami are listed in Table 11. 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 (DWLC, 2005). In Block 1 of Yala NP there were seven such places, and at one of them considerable damage was done to park facilities (with a number of human fatalities) as well as to forest and grassland, with many trees uprooted and the vegetation largely dead and brown. There were a further two sites of tsunami entry in Block 2 of the park, with damage up to 1.3 km inland in flat areas. Much of the vegetation covering Kumana wetlands in the north end of Yala was flattened and temporarily inundated, and appeared brown when surveyed.

Excluding the beach and seaward sides of dunes, about 5,000 ha or less than 1% of the Yala park area was affected by the tsunami. Natural recovery is expected as salt levels are reduced, and most ponds have already reverted to freshwater with amphibians, birds and mammals all abundant. Regeneration of vegetation, rather than succession, appears to be prevalent in affected areas. There is concern that damaged areas of the parks may be colonized by alien invasive species such as prickly-pears (*Opuntia*) and the salt-tolerant mesquite (*Prosopis juliflora*). Recovery should be monitored against this possibility, and intervention may be needed if alien invasives do start to become established.

The Coast Conservation Department (CCD) manages eight Special Area Management (SAM) sites, of which seven were affected by the tsunami: Negombo, Lunawa, Maduganga, Hikkaduwa, Habaraduwa, Mawella and Kalametiya (Table 12). These provide 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 south-western and southern coastal areas.

HUMAN SETTLEMENTS

A typical house in the coastal zone of Sri Lanka might be described as a single-floor, on-ground structure with shallow foundations, cement and burnt-brick walls, and with wooden roof supports under tiles or 'cement asbestos' roofing sheets[5] (ADB *et al.*, 2005). Most have some form of septic tank, an electricity connection and access to some form of protected or safe drinking water. There are also 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. The tsunami surge made short work of such houses within about 500 m of the coast, destroying 99,500 of them and damaging another 46,300, a total of 13% of the entire housing stock of the coastal divisions of the affected districts (ADB *et al.*, 2005).

It is hard to over-state the impact of the tsunami on everyday life in the areas that it affected. As well as killing loved ones and erasing family homes, the destruction of public buildings means the loss of mortgage contracts, deeds, wills and other legal records. Banks are faced with customers who have lost everything, and they themselves have lost many of their clients. Market places 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, have no money and cannot start rebuilding their livelihoods. Workers that 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.

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[5] There is concern at the widespread use of asbestos in construction in Sri Lanka, despite it being banned as a health hazard in many other countries. In the USA, 'cement asbestos' comprises Portland cement, sand and 5-10% asbestos as a binding agent; it has not been manufactured since 1973 and not legally installed in residential buildings since 1978 (http://www.usinspect.com/Exterior/CementAsbestos.asp).

Table 11. Protected Areas in coastal districts affected by the tsunami (from IUCN, 2005c)

Protected Areas under the Department of Wild Life Conservation (DWLC)		
District	**Name**	**Status**
Ampara	Lahugala	National Park
Ampara	Sangamam	Sanctuary
Ampara	Kudimbigala	Sanctuary
Ampara	Yala East	National Park
Batticaloa/Polonnaruwa	Triconamadu	Nature Reserve
Galle	Hikkaduwa	National Park
Galle	Honduwa Island	Sanctuary
Galle	Rocky Islets Ambalangoda	Sanctuary
Galle	Telwatte	Sanctuary
Galle	Parapaduwa Nun's Island	Sanctuary
Galle	Rumassala	Sanctuary
Galle	Madinduwa	Sanctuary
Galle	Maduganga	Ramsar site
Galle	Elweliyaya	Sanctuary
Gampaha	Muthurajawala	Sanctuary
Hambantota	Yala Strict Natural Reserve	Strict Natural Reserve
Hambantota	Bundala	National Park/Ramsar wetland
Hambantota	Katagamuwa	Sanctuary
Hambantota	Nimalawa	Sanctuary
Hambantota	Palle mallale	Sanctuary
Hambantota	Kalametiya	Sanctuary
Hambantota	Kirama	Sanctuary
Hambantota	Weerawila	Sanctuary
Hambantota	Madunagala	Sanctuary
Hambantota	Rekawa	Proposed Turtle Refuge

Table 11, continued.

District	Name	Status
Hambantota	Godawaya	Proposed Turtle Refuge
Hambantota/Monaragala	Ruhuna (Yala)	National Park
Jaffna	Chundikulum	Sanctuary
Matara	Kirilakele	Sanctuary
Monaragala	Kataragama	Sanctuary
Mullaitivu	Kokilai	Sanctuary
Puttalam	Anawilundawa	Sanctuary/Ramsar wetland
Trincomalee	Pigeon Island	National Park
Trincomalee	Great Sorber Island	Sanctuary
Trincomalee	Little Sorber Island	Sanctuary
Trincomalee	Trincomalee Naval Head works	Sanctuary
Trincomalee	Seruwela-Allai	Sanctuary
Mangrove areas proposed for conservation by the Forest Department		
Galle	Hikkaduwa	Proposed conservation area
Galle	Magalle	Proposed conservation area
Galle	Balapitiya	Proposed conservation area
Gampaha	Munakarei	Proposed conservation area
Hambantota	Kalametiya	Proposed conservation area
Hambantota	Kahandamodara	Proposed conservation area
Hambantota	Rekawa	Proposed conservation area
Kalutara	Hirana I	Proposed conservation area
Kalutara	Hiarana II	Proposed conservation area
Kalutara	Kaluwamodara	Proposed conservation area
Kalutara	Megama	Proposed conservation area
Kalutara	Ittapana	Proposed conservation area
Kalutara	Ollewa	Proposed conservation area

Table 12. Tsunami impacts on Special Area Management sites (from CCD, 2005)

SAM site	Key environmental impacts
Negombo	The lagoon mouth was deepened by the tsunami, but the six canals connected to the lagoon were blocked by debris. The beaches are polluted with debris and rubbish. There was little damage to coastal vegetation such as mangroves. Sand dunes in Morawalla, Sethapaduwa and Thalahena were damaged; in some places these dunes had been up to 15m high but they have now been eroded and have lost areas of vegetation. Much debris has been deposited inside the lagoon.
Lunawa	The mouth of Lunawa lagoon was swept open and water level in the lagoon decreased. After a few days the lagoon mouth closed again. Beaches in the SAM area are being used as dumps for plastic, wood and solid waste. Some beaches are being cleaned, but others are polluted with debris and rubble. The coastal vegetation has been damaged severely; even some coconut palms have been destroyed indicating the force of the water.
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 slightly damaged in places. A large amount of debris is still inside the lagoon, including several sunken boats. Due to the opening of the lagoon mouth, salinity inside the lagoon has increased, which could cause salt-water intrusion into paddy fields. In several places the coastal vegetation has been damaged.
Hikkaduwa	Salt water has intruded into ground water and the lagoon. The coastal vegetation has been affected. Debris and rubbish have entered the lagoon. Debris and nets have been deposited on the coral reefs. Sewage lines are still intact. Two canals (Wulaguda, Mahakadewella Ella) have been polluted with debris and rubbish, as have nearby beaches.
Habaraduwa	The lagoon mouth of Kogalla is intact and does not seem to have changed. Salt water intruded into inland, wells, water bodies and paddy fields. The mangroves near Kogalla lagoon have been destroyed. Coastal vegetation and crops have been destroyed.
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.
Kalametiya	The lagoon mouth seems to be damaged. The walls of the canal that connect the sea and the lagoon have been damaged. An opening between the lagoon and the sea was created directly south of this canal. About 17 ha of paddy in Ussangoda has been destroyed by the tsunami. The lagoon has been polluted with debris and rubbish. Sand dunes have been damaged in some areas. Vegetation has been cleared widely for temporary or permanent housing.

Most houses in Kilinochchi in northern Sri Lanka were completely destroyed by the tsunami. © Shehzad Noorani/Still Pictures

Fishermen cannot pay boat builders in advance to enable them 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 increased.

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 combined to undermine standards in the built environment of Sri Lanka even at the best of times. Largely bypassed by the mainstream development process, the poor in particular have found themselves living in informal, illegal and unhealthy conditions. Such conditions had made the poor, and particularly women and children, more vulnerable both to daily stresses and to natural disasters.

Such fundamental weaknesses require systematic reforms to overcome fully, but much can be achieved by increasing local-level awareness and preparedness for emergencies. This can be done using educational and organizational methods such as those developed through UNEP's APELL programme, which it is now being implemented in the tsunami-affected Export Processing Zone at Koggala in south-western Sri Lanka (Box 2). These are in line with the overall recommendations of the World Conference on Disaster Reduction, which emphasize the need for disaster preparedness at all levels of society as a complement to more technical approaches such as the development of early warning mechanisms (Box 3).

Box 2. Awareness and Preparedness for Emergencies at Local Level (APELL)

APELL is a strategy developed by UNEP in conjunction with governments and industry. Its purpose is to minimize the harmful effects of disasters. Its implementation results in a better level of preparedness by local emergency services, and an understanding by local people of how to react to an emergency in their neighbourhood. APELL is a prevention and preparedness programme that allows for:

- building the capacity of relevant local emergency services to improve their knowledge and effective use of prevention and preparedness tools and mechanisms to properly reduce the impacts of disasters, including the environmental component of disaster management and implementing public disaster communication systems (before the disaster, during the disaster, and after the disaster);

- raising awareness of exposed communities about what types of risks they are exposed to in their community and what type of potential human and environmental impacts they can expect in order to better prepare and react in case a disaster strikes.

The APELL process is a management tool that helps local people develop the information and decision making structures they need to address the hazards facing their community. It can be useful in any situation that requires joint planning for disasters by several parties. By engaging stakeholders in a process of structured dialogue and coordination, leading to the development of a single, unified emergency response plan for the entire community. APELL is built around a 10-step process:

1. Identify the participants and establish their roles, resources, and concerns.

2. Evaluate the hazards and risks that may result in emergency situations in the community.

3. Have participants review their own emergency response plans to ensure a co-ordinated response.

4. Identify the required response tasks not covered by existing plans.

5. Match these tasks to the resources of the identified participants.

6. Make the changes necessary to improve existing plans, integrate them into an overall community plan, and gain agreement.

7. Commit the integrated community plan to writing and obtain approval from local governments.

8. Educate participating groups about the integrated plan and ensure that all emergency responders are trained.

9. Establish procedures for periodic testing, review, and updating of the plan.

10. Educate the community about the integrated plan.

See: http://www.uneptie.org/pc/apell/home.html

Box 3. The World Conference on Disaster Reduction (WCDR)

The WCDR took place in Kobé (Hyogo, Japan) in January 2005, and was a milestone in international efforts to reduce disaster risks. Called for by the UN General Assembly and hosted by the Government of Japan, it brought together some 4,000 people from governmental and non-governmental bodies around the world, with participants from 168 States, 78 observer organizations, 161 NGOs and over 560 journalists.

Structured in three segments: intergovernmental, thematic and public, the conference was a rich forum for exchanging views on many issues related to risk reduction, with the aim of reducing the loss of life and assets of populations in risk-prone areas. The *Hyogo Framework for Action* adopted by the conference provides policy direction and practical guidance for the next decade across many areas related to risk management and disaster reduction.

The WCDR drew on a review of the 1994 *Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation* and adopted the following five priorities for action:

1. Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation.

2. Identify, assess and monitor disaster risks and enhance early warning.

3. Use knowledge, innovation and education to build a culture of safety and resilience at all levels.

4. Reduce the underlying risk factors.

5. Strengthen disaster preparedness for effective response at all levels.

National governments and international organizations have already begun to implement programmes in support of the Hyogo Framework, and systems for tracking progress towards these goals are currently being developed.

See: www.unisdr.org/wcdr/thematic-sessions/WCDR-proceedings-of-the-Conference

ENVIRONMENTAL CONTAMINATION

Persistent pollutants

In parts of the east coast, the tsunami waters were described as being black in colour and carrying a thick muddy sludge. In the south-west at Matara, residents complained of itchiness after contact with wave-water, while in the south-east at Hambantota, a slimy water texture was reported (MENR, 2005b). An early inference was that marine sediments had been disturbed and delivered to land that contained an unfamiliar and possibly toxic chemistry (Senanayake, 2005). Subsequent analyses have established that contamination by arsenic has occurred in places in the tsunami-affected areas, occasionally at a concentration approaching the maximum of 0.01 mg/litre (10 parts per billion) recommended for drinking water by the World Health Organization (MENR, 2005d). Several regions, including Bangladesh, West Bengal and Nepal, possess geological formations rich in arsenic, from which the element may have leached to accumulate on the bed of the Indian Ocean. Arsenic distributed on land and in water can be taken up by plants, including agricultural crops and aquatic plankton, and further concentrated in fish and other animals which eat those plants or each other. Moreover, the disposal of tsunami debris and wastes into dumping sites could also create more concentrated sources of arsenic, and other persistent pollutants, which could then leach into ground water. Additional analyses for persistent pollutants in tsunami-affected areas would hence be desirable.

Salt

Salt has affected hundreds of hectares of paddy fields, leading to concerns that they will be unusable for many months until rains naturally reduce salinity. All dug wells in areas where the tsunami came on land, an estimated 62,000 of them, were contaminated by sea water, and often by wastewater and sewage as well (ADB *et al.*, 2005). This is an especially serious problem in Trincomalee, Ampara, Batticaloa 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 (Pearce, 2005). Wells can be pumped out and chlorinated, but in some areas aquifers have also been contaminated. An unexpected phenomenon is that of salt intrusion, caused by over-pumping of contaminated wells when there is too little rainfall to prevent it (MENR, 2005b).

DEBRIS AND WASTE DISPOSAL

The extent of debris, particularly from destroyed buildings, is very great. Calculation of the weight of an average house in Sri Lanka yields a figure of 7.5 to 15.0 tonnes of brick, cement, roofing material and contents for well-built ones, and 2.0 to 5.0 for a cruder 'fisherman's house' (UNEP, 2005). 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 4.5 tonnes per house, or 450,000 tonnes in total, to which would need to be added the weight of debris from 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., an amount that must have been at least the same again. The volume of this conservative estimate of 900,000 tonnes of debris would have been about 600,000 m^3 at standard conversion rates. By comparison, the destruction of the World Trade Centre by terrorists in September 2001 was estimated to have generated 1.2 million m^3 of rubble, and that of Banda Aceh by the tsunami in December 2004 created 7 to 10 million m^3 of debris (UNEP, 2005).

In some areas, the force of the tsunami back-wash dragged most debris into the sea and deposited it in deep water. This force scoured out the accumulated filth within many harbours, which after the tsunami revealed clean beds for the first time in years (MENR, 2005b).

Map showing patterns of tsunami impact on infrastructure in Sri Lanka.

Sources: Central Environmental Authority of Sri Lanka, TAFREN 2005, UNHCR 2005, MapAction 2005, IWMI 2005, UNEP MoE Sri Lanka Assessment Team 2005

The commercial centre of Galle in late January 2005.© Desmond Boylan/ Reuters

Piles of debris in Galle giving out a terrible smell of decomposition. © Indranil Mukkerjee/AFP/Getty Images

Managing the tangled mass of debris was an immediate challenge after the tsunami. Credit: Dr J.Samarakoon.

Making a start at clearing debris near Colombo.© Scott Barbour/Getty Images

Elsewhere, however, the extent of debris left on land, particularly from destroyed buildings, is enormous, and its disposal is proving to be a huge issue because of the sheer volume and associated costs. The CEA has instructed that solid wastes be collected and deposited in open areas such as playgrounds until proper sites for disposal are identified. A list of authorized disposal sites was provided by the CEA to IUCN for inclusion in its *Best Practice Restoration Guidelines* for Sri Lanka (IUCN, 2005c-k), numbers 4 (*Cleaning up Reefs and Beaches*) and 5 (*Solid Waste Management*). They include abandoned clay pits and coral-mining sites as well as publicly-owned areas that had already been eroded or otherwise degraded (Tables 13, 14).

Guidelines on the processing of debris and solid waste are also available from the same source (Table 15), and there is a *United Nations Post-Tsunami Waste Management Plan* (UNEP, 2005) which specifies a sequence of decision points and end points in the processing, re-use and disposal of debris and wastes (Figure 1).

Sand was transported inland in very large amounts, particularly into the rice fields and plantations of Eastern Province, in places to an average depth of about 10 cm over large areas (IUCN, 2005b). These sand deposits block drainage pathways and at some locations prevent cultivation. This problem is compounded by solid debris haphazardly disposed of along roads, in open fields, into drainage ditches, low-lying lands, waterways and beaches. This is likely to cause long-term problems by obstructing drainage of cultivated areas with the attendant risk of flooding, water-logging and loss of productive land, by clogging waterways, by blocking the migratory pathways of fishery organisms into lagoons and estuaries, and by polluting beaches. Standing water in such circumstances would also promote the breeding of mosquitoes, this contributing to the risk of malaria, dengue and filariasis.

INDIRECT IMPACTS OF RELIEF AND RECONSTRUCTION EFFORTS

Demands placed on natural resources, including land, will naturally increase during the reconstruction process. Initiatives to relocate and redevelop settlements, and to introduce new roads, railways and port developments can only increase these pressures, all heating up the market with inevitable consequences for the exploitation of natural resources. Although elasticity in the supply of building materials could be secured by increasing imports, it is reasonable to expect an increase in prices which will encourage supplies, particularly timber, to be obtained from illegal sources.

Timber is currently being imported from various sources, and mining of shore and river sand is already controlled, 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. A great increase in demand for bricks may lead to the removal of clay from productive rice 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, would help to mitigate such risks.

Meanwhile, the existing relief and reconstruction measures are being carried out under many constraints and in response to immediate pressures, and various adverse environmental consequences are likely, including:

- the disposal of massive amounts of debris into wetlands and drainage channels, resulting in interference with drainage, and water-logging and disease risks;

- the use of heavy equipment to relocate building debris, causing damage to house foundations and materials that could otherwise have been re-used or re-cycled, and the mixing of potentially hazardous materials (e.g. asbestos, marine sludge) with other items making it hard to separate and process them later;

Figure 1. Decision points and end points in managing tsunami wastes (adapted from the *UN Post-Tsunami Waste Management Plan*)

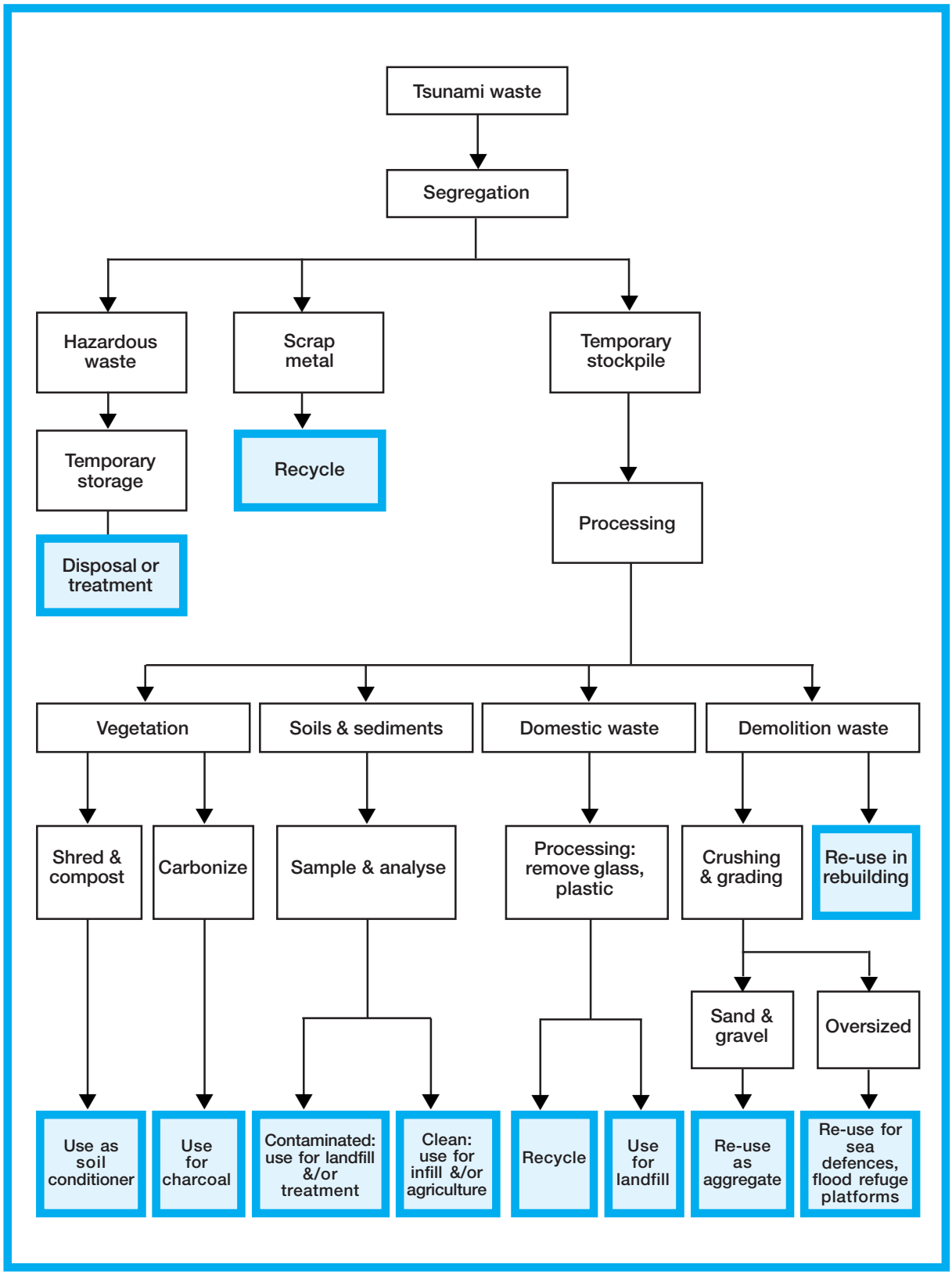


Table 13. Sites for disposal of debris and solid waste (from IUCN, 2005g)

Area	Site location
Trincomalee District	See Table 14
Western Province	Abandoned Ball-Clay pits located at Nugagoda and Naiduwa in Waskaduwa
	Roads and cavities created by Tsunami in Panadura Pradeshiya Sabha area
	Isuru Uyana 2nd phase, Etawilawatta, Kalutara – 57 perches recommended to fill
Galle District	Abandoned coral mining sites at Aluwa handewatta, Akurala South 76/A
	Abandoned coral mining sites at Sanis house, Galle Road, Akurala, Kahawa
	Abandoned coral mining sites at Beauty coral, Galle Road, Akurala, Kahawa
	Abandoned coral mining sites at Lindamula Watta, Telwatta, Godagama South
	Abandoned coral mining sites at Hirigal Watta, Daluwatumulla, Thelwatte
	Abandoned coral mining sites at Diyaheerawe, No 77 Wenamulla, Harakwala
	Abandoned coral mining sites at Diyaheerawe, Akurala South, Akurala, Kahawe
	Thekkahenawatte, Galle Road, Uduwaragoda, Kahawe
	Proposed sports ground at Sudhrma College, Matara Road, Galle
	Kaduruduwa land owned by the Southern Development Authority, Kaduruwa Watta, Akmeemana
	Land owned to Navy Training Camp at Pitiwella, Bussa
	Land closer to the Totagamuwa wijayabahu vidyalaya, Sumadura, Tatagamuwa, Hikkaduwa 7/B
	Land fill to Balapitiya Pradesheya Sabha proposed playground, 87B Andadola
	Bulugaha gedara, Galwehera, Ahungalla, Balapiriya
	In front of the Welikadamulla Sudhrmarama Temple, Welikadamulla, Balapitiya
	Madubbakagewatta, Kalahewatta, Liyanagoda, Habaraduwa
	Yaddehigewatta, Liyanagoda, Habaraduwa
	Galwakkada Handiya, Liyanagoda, Habaraduwa
	Abandoned coral mining sites at Weragoda, Hikkaduwa
	Uramulla Watta, Akurala, Hikkaduwa
	Siddhi Mawlana Takkiyar Church, Katugoda, Galle
	Telwatta Rajamaha Wiharaya, Telwatta, Hikkaduwa
	No 86/2 Kanampella, Galle
	Galle Road, Talduwa, Akurala, Kahawa, Hikkaduwa
Matara	Abandoned coral mining sites at Weligama Madina Eastern, Pilhena
	Abandoned coral mining sites at Kamburugamuwa Gadalari Watta
	Abandoned sand mining pits at Mirissa, Udupila
	Welgama Palana Junction to Kubalgama area, Kapparatota area
	Wellamadama land at Devinuwara. Closer to the PS solid waste dumping site
	Naurunna eroded area in the beach
	The land situated in between Talala Technical College and school
Devinuwara	Left side Matara-Tangalle Road, Wellawamadama existing site at Devinuwara
	Tallala, Nawurunna wellawa road eroded area at beach
Weerawila Subregion	Government land at Gonnoruwa Road, Gonnoruwa
	Abundant paddy field closer to the dam at Tangalle
Eastern Province, Ampara Subregion	Walathapitiya, Kalmunai
	Sandangani Ground (existing dumping site) Kalmunai
	Sinnal Village, Saindamarudu

Table 14. List of temporary dumping sites for solid wastes in Trincomalee District (from IUCN, 2005g)

Divisional Secretariat	Local Authority	Name of the place	Address	Remarks
Mutur	Mutur PS	Sinnapalam, Mutur Central	Sinnapalam, Mutur Central Mutur	Present solid waste pimping sites. All are low-lying areas. Solid wastes are dumped in a haphazard manner in these areas but no alternative suitable place is available to dump solid waste in Mutur
		Dakwanagar	Dakwanagar, Old Jetty, Mutur	
		Turalkili, Mutur West	Mutur West, Turalkili, Mutur	
		Akkarachchena, Mutur East	Akkarachchena, Mutur East, Mutur	
		Thanagar	Thanagar, Sinnapalam	
Kinniya	Kinniya PS	Upparu	Upparu, Kinniya	02 Acres
		Tharmarawill	Tharamarawill, Kinniya	–
Town & Gravets	Trincomalee Urban Council	Kanniya	Kanniya	Not a CEA approved site. Solid wastes are dumped in haphazard manner
	Town Gravets PS	Kanniya	Kanniya	
Kuchchaveli	Kuchchaveli PS	Not selected		
Mutur	Mutur PS	State Land	Thaquanagar Mutur	01 Acre
		Neenakeny Veddai	Neenakeny Veddai, Malainunthal, Mutur	10 Acres
		T/St. Anthonys School Play Ground	T/St. Anthonys School, Mutur	06 Acres
		Vaalaithodda Mutsanthi	Vaalaithodda Mutsanthi, Veruhal muhavaram, Mutur	06 Acres
		Mutur West Iralkuli River Site	Mutur West Iralkuli River site, Mutur	03 Acres
		T/ Almanar Vidyalaya Land	T/ Almanar Vidyalaya, Mutur	10 Acres
Kinniya	Kinniya PS	Nadathive	Nadathive, Kinniya	3.5 Acres
Town & Gravets	Trincomalee Urban Council	Kanniya*	Kanniya	–
	Town & Gravets PS	Kanniya*	Kanniya	–
Kuchahaveli	Kuchchaveli PS	Not selected		

Notes: * The DEO, Trincomalee has reported difficulty in finding suitable dumping sites in the areas of Trincomalee Urban Council and Town and Gravets PS. Also, the quantity of building debris in these two areas is relatively low and some people are intended to re-use the building debris on-site. Both the above Local Authorities have dumped building waste along with other municipal waste in the permanent dumping site at Kanniya.

PS = Pradeshiya Sabha.

Table 15. Guidelines on debris and waste processing (from IUCN, 2005g)

Type of waste	Potential use	Comments
Non-biodegradable waste		
Construction and demolition debris: e.g. tiles, aggregates, gypsum, asphalt, concrete, bricks, masonry and stone.	Reuse tiles and bricks wherever possible. Impact and use for landfill and for road bases.	The debris should not contain hazardous chemicals or by-products
Wood	Use in reconstruction or as vegetative matter (see below)	
Dirt (non-specific, including sand deposited by the tsunami)	Use as fill for potholes and eroded areas	The dirt needs to be screened to remove other waste products
Plastic (non-specific)	Send for recycling	The debris should not include hazardous chemicals
Metal (all types)	Send for recycling	Cut or crush for easy transportation
Asbestos	For careful disposal	Should be handled very carefully when wet, bagged and buried. Masks should be worn when handling asbestos.
Glass	Send for recycling	
Biodegradable waste		
Vegetative waste, paper, spoilt food items, etc.	Composting for land regeneration	Most waste should be shredded before composting in order to quicken the composting process.

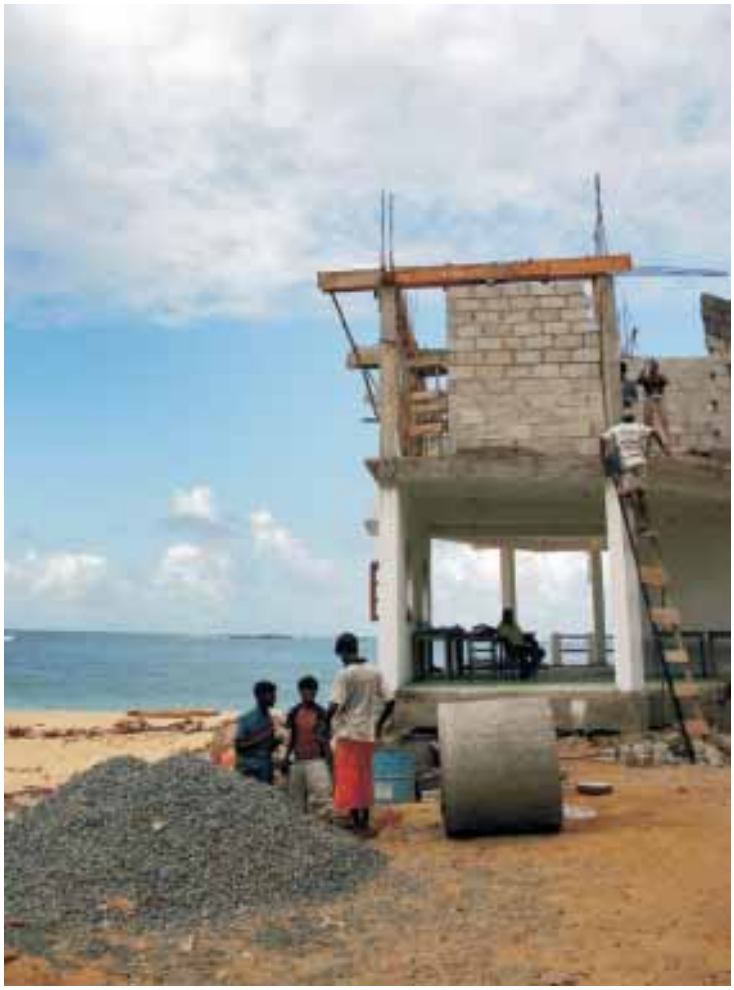
- the positioning of temporary camps for displaced people near wildlife habitats (e.g. Pottuvil, and Lahugala National Park in Ampara), which may result in human-elephant conflict, permanent roads in protected areas or buffer zones, and the further haphazard disposal of solid waste into natural areas; and

- over-pumping of wells to clear contaminated water, resulting in irreversible salinization of ground-water.

The large numbers who have been suddenly impoverished by the tsunami are likely to place unprecedented pressure on the environment, whether or not they are assisted by officially-sponsored recovery efforts. The scale of this will depend to some extent on how the recovery process is managed. In the fisheries sector, supplying new replacement boats, motors and fishing gear could increase catch rates and result in over-exploitation of the marine environment. Poor targeting, over-design of facilities and wasted investment will result in higher resource demand, depletion of natural resources and generation of wastes, all having direct and indirect impacts on the environment.

Environmental concerns are apparently not receiving adequate attention in the process of identifying locations for reconstruction and resettlement. Key issues listed by IUCN (2005c) include the following:

- That there is an urgent need to rehabilitate displaced communities and set them on the path to sustainable lives and livelihoods.
- That the government and other parties are actively seeking suitable land for construction and alternate building areas.
- That there is the danger that ecologically and economically important sites such as wetlands could be cleared to provide new sites for housing and infrastructure.
- That while many institutions are working on reconstruction and restoration, knowledge about existing zoning and protected area laws is not widely circulated, so they are not always complied with or enforced.



Workers rebuild a small tourist hotel in Unawatuna, southern Sri Lanka.
© Anuruddha Lokuhapuarachichi/Reuters

Guidelines proposed by IUCN (2005c, 2005k) emphasize the need to be aware of and to comply with existing laws and policies that relate to environmental management and protection. This includes not clearing ecologically-sensitive sites such as mangroves, scrubland and forests, not building on or filling wetlands and watershed areas, and not blocking natural water courses. It also includes integrating environmental concerns in development, for example with a rapid initial environmental examination (RIEE) prior to each reconstruction project, and consulting relevant government agencies if the proposed site is within 300 m of the mean high-tide line (consult CCD), if it is close to a forest area and/or on mangrove/wetland state land (consult the Forest Department), or if it is within or close to a Protected Area (consult DWLC and CEA). The IUCN guidelines also advocate involving affected communities in the process of reconstruction, and investing in providing new livelihoods and immediate sources of income as part of the reconstruction process.

Reconstruction work was underway in April 2005 in the village of Seenagama, Galle District.© Getty Images Publicity/ Getty Images

Rubble was still being cleared in June 2005 in Mallaitivu District. © Sena Vidanagama/AFP/Getty Images

The bulldozers move into Telwatte, Galle District, clearing sites and rearranging debris within the landscape. © Desmond Boylan/Reuters

ECONOMIC AND LIVELIHOOD CONCERNS

Sri Lanka's economy has been growing fast since 2002, and GDP growth in 2004 and 2005 was expected to be around 6% (ADB, 2005; ADB *et al.*, 2005). The tsunami, however, had an economic impact that included asset losses (direct damage), output losses (indirect damage), and fiscal costs (secondary effects). Preliminary estimates of total asset losses are about US$900 million or 4.2% of GDP. While the impact of the tsunami on the nation's output and national economy is not as great as the extent of asset losses, in the areas that were hit, the tsunami devastated lives, social infrastructure, and economic foundations.

Output losses resulting from the damage to assets and the disruption in economic activity in the affected sectors are estimated at US$331 million during 2005 and 2006, or around 1.5% of GDP. In terms of employment, an estimated 150,000-200,000 people, or 2-3% of the labour force, might have lost their jobs, including 100,000 in fisheries, 27,000 in tourism and related activities, and the rest in other informal sector activities. The tsunami is therefore expected to slow down GDP growth in 2005 by up to 1% (i.e. from 6% to 5%). This surprisingly limited impact is due to the fact that the most affected sectors of the economy, fishing and hotels and restaurants, together contribute only about 3% of GDP. The construction sector, on the other hand, is expected to offset macroeconomic losses by growing from a recent annual average of 5.5%, to 8-10% in 2005-2007.

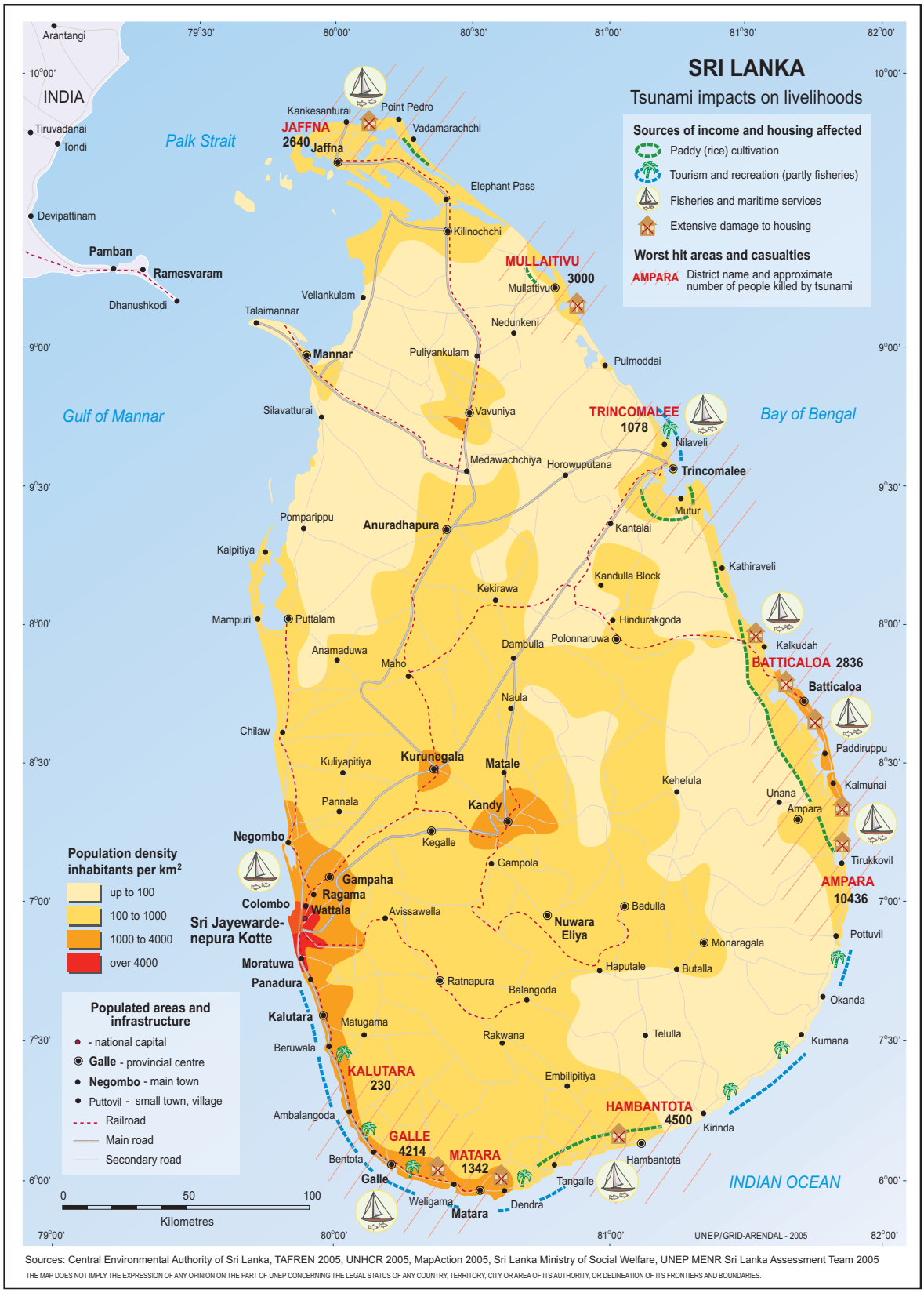
At Galle, in southern Sri Lanka, the tsunami threw most fishing boats hundreds of metres inland on the main road and into residential areas, causing great damage. ©Shehzad Noorani/Still Pictures

This macro-economic description conceals a much more sinister impact on the livelihoods of the poor, and increased poverty is potentially the most important effect of this natural disaster. 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 therefore drive around 250,000 more people below the poverty line[6], and these numbers could further increase if concerns over sanitation and health conditions, as well as other basic needs, are not properly and quickly addressed.

Of all Sri Lanka's economic sectors, 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 badly damaged, along with out-board motors, ice storage units, fishing gear and nets. Entire fishing communities were dependent upon the fleets that were in operation prior to the tsunami, and the sector is intimately integrated with rural livelihoods and income. Damage to the agriculture sector included the destruction of standing crops and home gardens, and the washing away of tree crops, while entry of sea water to productive fields may render them unusable for months. An estimated 27,000 jobs in the tourism industry were suspended by the tsunami, one third in officially-registered

[6] In Sri Lanka the poverty line as used by the Central Bank is an income of Rs 950 per person per month.

Map showing patterns of tsunami impact on livelihoods in Sri Lanka.



Sources: Central Environmental Authority of Sri Lanka, TAFREN 2005, UNHCR 2005, MapAction 2005, Sri Lanka Ministry of Social Welfare, UNEP MENR Sri Lanka Assessment Team 2005

hotels and the rest in unregistered hotels and guesthouses. Many small businesses and informal traders catered to the tourism industry, ranging from dive, souvenir, and handicraft shops to internet cafes, and these were also damaged and are now facing a sustained period with fewer customers. The main tourism season of January to March was severely disrupted.

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

Disaster survivors need immediate psychological help as well as long-term community-based mental health support (Young, 2005). One factor that may further aggravate the psychological impact of the tsunami was the practice of burying victims in mass graves, with the aim of protecting public health. This was done even though bodies do not in fact pose much risk of infectious disease, since diseases and putrefaction involve different micro-organisms (MacKenzie, 2005). The use of mass graves, without adequately documenting the identities of casualties, or sampling (e.g. of DNA), labelling and recording the location of individual cadavers, may often mean that relatives never know what happened to their loved ones. This can cause long-term distress, and can also delay the certification of death with implications for insurance claims and other legal processes.

A resident of a displaced persons camp at St John's College washes amongst the rubble.

There are lasting sources of concern among people in the tsunami-affected areas, including:

- **fear** due to a lack of trust in the sea, or in the houses where they had lived for years, or as a result of seeing what they perceive as ghosts in and around the sea;

- **poverty** because families no longer have adults who previously carried out livelihood activities;

- **vulnerability** to abuse because of a breakdown in family and community support systems; and

- **insecurity** because communities do not know what they should do in the event of another tsunami or other coastal catastrophe.

Much of this concern is rooted in the fact that affected communities often lack understanding of what they have experienced, and the media, local experts, visitors, NGOs, and others have since provided only fragmentary information. As a result, assessment teams were often besieged by questions about the tsunami, revealing confusion about its causes and consequences.

KEY ISSUES IDENTIFIED BY THE ASSESSMENTS

a) Debris and waste management. The solid waste management system in Sri Lanka is historically under-developed, and was overwhelmed by the amount of debris created by the tsunami. Emergency relief and clean-up operations displaced large amounts of debris into unsuitable locations, such as wetlands, beaches and stream channels.

b) Sustainable sourcing of drinking water. The combination of sea-water contamination, over-pumping and salt intrusion, and relocation of settlements to sites with marginal fresh ground-water supplies, all adds up to an emerging problem, especially in the eastern coastal districts, which is currently being camouflaged by the distribution of drinking water through relief agencies.

c) Land drainage. Debris and marine sand, whether deposited by the tsunami or by subsequent clean-up operations, block drainage channels in many areas, posing an acute risk of water-logging and loss of agricultural land. Standing water in such circumstances would also promote the breeding of mosquitoes, this contributing to the risk of malaria, dengue and filariasis.

d) Deforestation pressures. There is concern that environmental considerations may have been neglected in decisions made since the tsunami on the location of resettlement camps and new construction, and in the sourcing of building timber, resulting in clearance of forests, some of which may be in Protected Areas or their buffer zones.

e) **Disaster preparedness**. There is a need for a range of measures to strengthen institutional capacity and collaboration for disaster preparedness and disaster management, including policy development and local disaster preparedness.

RECOMMENDED ACTIONS

Lionel, the owner of the Welcome Trade Center, sits outside his shop, the only one still standing on 25 June 2005 in this part of Galle. © Paula Bronstein/Getty Images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Welcome

INTRODUCTION

Following the detailed analyses carried out by the 'green' and 'brown' assessment teams, informed discussions could occur between MENR and its various institutional partners. This led in turn to a number of kinds of intervention being agreed to be necessary, based on the need for urgent interventions in particular sectors, at specific sites, and more strategically at a national and regional level. These are summarized in the following sections, and are consistent with the Cairo Principles for post-tsunami rehabilitation and reconstruction, which are the basis for a forthcoming workshop in Sri Lanka and are being translated into the Sinhala and Tamil languages for nationwide dissemination (see Box 4).

Implementation of the environmental aspects of these recommendations will be overseen at a policy level by MENR, and coordination mechanisms have also been established to ensure overall harmony, especially including joint arrangements established among MENR, CEA and TAFREN. The assessment exercise has fully confirmed the abundance of national expertise, environmental knowledge and commitment that is available within Sri Lanka. The scale of the tasks that now need to be undertaken, however, reinforces the need for international assistance and support in the process of recovery and reconstruction in Sri Lanka.

URGENT INTERVENTIONS IN PARTICULAR SECTORS

Table 16 reviews the urgent interventions that were judged to be needed in response to issues detected in relation to a range of sectors and themes in post-tsunami Sri Lanka. They may be summarized as follows:

- ***Debris management*** – mobilize local government and communities to undertake immediate sorting and environmentally-friendly disposal of debris at the local level under the direction and guidance of the CEA.

- ***Environmental contamination*** – manage pollution hotspots associated with solid waste dumping and sludge disposal; sample and test marine sludge deposits for possible heavy metals and other persistent pollutants, and remove and safely dispose as appropriate.

- ***Rehabilitation of natural water bodies*** – remove debris and sludge, release stagnant, anoxic and contaminated water, and restore pre-tsunami ecological conditions to the extent possible.

- ***Restoration of land drainage*** – clear sand and debris from drainage channels, in order to prevent the loss of productive land by water-logging, and the increased transmission of mosquito-borne diseases.

- ***Sustainable recovery and reconstruction of water supplies*** – train all staff who manage water treatment and pumping units to maximize the sustainable rate of recovery of safe water supplies and to prevent over-pumping and irreversible salinization of wells and ground water; invest in the provision of drinking water supply in many affected areas.

- ***Sand mining and nourishment*** – identify areas where the landward sides of large sand dunes could be harvested for sand, or wind-blown sand trapped in commercial quantities, without affecting the dunes' ability to protect the coast; areas that need nourishment must also be identified and sand pumping carried out as needed.

Box 4. The Cairo Principles for post-tsunami rehabilitation and reconstruction

In February 2005, UNEP organized a meeting in Cairo, Egypt, on coastal zone rehabilitation and management, which adopted the following 'Cairo Principles' for post-tsunami rehabilitation and reconstruction:

1. Reduce the vulnerability of coastal communities to natural hazards by establishing a regional early warning system; and applying construction setbacks, greenbelts and other no-build areas in each nation, founded on a science-based mapped "reference line".

2. Promote early resettlement with provision for safe housing; debris clearance; potable water, sanitation and drainage services and access to sustainable livelihood options.

3. Enhance the ability of the natural system to act as a bioshield to protect people and their livelihoods by conserving, managing and restoring wetlands, mangroves, spawning areas, seagrass beds and coral reefs; and by seeking alternative sustainable sources of building materials, with the aim of keeping coastal sand, coral, mangroves and rock in place.

4. Promote design that is cost-effective, appropriate and consistent with best practice and placement of infrastructure away from hazard and resource areas, and favoring innovative and soft engineering solutions to coastal erosion control.

5. Respect traditional public access and uses of the shoreline, and protect religious and cultural sites.

6. Adopt ecosystem based management measures; promote sustainable fisheries management in over-fished areas, and encourage low impact aquaculture.

7. Promote sustainable tourism that respects setback lines and carrying capacity, benefits local communities and applies adequate management practices.

8. Secure commitments from governments and international organizations to abide by these Principles and build on and strengthen existing institutional arrangements where possible.

9. Ensure public participation through capacity building and the effective utilization of all means of communication to achieve outcomes that meet the needs and realities of each situation.

10. Make full use of tools such as strategic environmental assessment, spatial planning and environmental impact assessment, to identify trade-offs and options for a sustainable future.

11. Develop mechanisms and tools to monitor and periodically communicate the outcomes of the reconstruction through indicators that reflect socio-economic change and ecosystem health.

12. Widely disseminate good practices and lessons learned as they emerge.

See: http://www.gpa.unep.org/documents/0523-5W3-Annotated%20Cairo%20Principles.doc.

- ***Ecosystem management*** – work with NGOs, local community and other responsible elements to rehabilitate damaged ecosystems with priority to Special Area Management (SAM) sites.

URGENT INTERVENTIONS AT SPECIFIC SITES

Table 17 reviews the urgent interventions that were judged to be needed at 19 sites in Ampara, Batticaloa, Galle, Hambantota, Jaffna, Matara, Mullaitivu and Trincomalee districts. They may be summarized as follows:

- Clearing debris from beaches, seashores, near-shore sea beds and coral reefs.
- Restoring access channels for fishing boats.
- Replacing and/or relocating safe anchorages.
- Identifying sites for properly-regulated sand mining.
- Identifying sites that need proper water supply and sanitation facilities.
- Regenerating and stabilizing sand dunes and the banks of drainage channels.
- Removing sand and debris from drainage pathways and farmland.
- Assessing and restoring ground-water quality.
- Identifying land suitable for resettlement, with special attention to freshwater supply, drainage, fishery livelihoods and tenure/resource conflicts.
- Restoring original ecosystems in water bodies and SAM sites.

URGENT STRATEGIC INTERVENTIONS

a) Coordinating relief and reconstruction efforts

Coordinating post-tsunami investment through a standing committee representing MENR, CEA, TAFREN and other stakeholders, with expert/donor national forums as needed, to ensure that environmental concerns are fully integrated in all decisions on national reconstruction, and to coordinate country-driven implementation of all relevant government recommendations.

b) Strengthening national policy

Through joint MENR-CEA-TAFREN leadership, strengthening national policy on the management of critical environmental issues arising from the tsunami, including policy on the environmentally-responsible disposal of debris and solid wastes, the extraction and sustainable supply of safe drinking water, the restoration of effective drainage to farmlands and urban areas, and the prevention of deforestation resulting from construction and resettlement. The policy framework should be used to develop mandatory guidelines to ensure uniform best practice.

Table 16. Sectors requiring urgent intervention (from MENR, 2005a, 2005b, 2005c)

Sector/theme	Urgent intervention required
Debris management	Mobilize local government and communities to undertake immediate sorting and safe and environmentally-responsible disposal of debris and solid wastes at the local level.
Environmental contamination	Remedy pollution hotspots associated with solid waste dumping and sludge disposal in the mineral pits at Thelwatta, Akurala, Habaraduwa and Ambalangoda, and various salterns.
Environmental contamination	Sample and test marine sludge brought on land by the tsunami for arsenic and other persistent pollutants; removal and safe disposal as appropriate.
Rehabilitation of natural water bodies	Remove debris and sludge, release stagnant, anoxic and contaminated water, and restore pre-tsunami ecological conditions.
Restoration of land drainage	Clear sand and debris from drainage channels, in order to prevent the loss of productive land by water-logging, and the rapid transmission of mosquito-borne disease.
Sustainable sourcing of water	Train all staff who manage water treatment and pumping units in all affected areas to maximize the sustainable rate of recovery of safe water supplies and to prevent over-pumping and irreversible salinization of wells and ground water.
Sand mining	Identify areas where the landward sides of large sand-dune systems could be harvested for sand, or wind-blown sand trapped in commercial quantities, without affecting the dunes' ability to protect the coast.

c) Enhancing the role of MENR in national reconstruction planning

Reconstruction will place a huge burden on the supply of building materials, yet further environmental damage may be caused if sand is sourced from coastal dunes, beaches or rivers, lime from coral reefs, or timber from Sri Lanka's residual forests. Even if these materials are imported, their production may be associated with environmental problems elsewhere. Moreover, decisions on where to place new construction, and the standards to which it is built and the arrangements that are made for sewage and garbage disposal, access and new business accommodation will all have environmental consequences within Sri Lanka. It is therefore recommended that the MENR be resourced to allow participation in all relevant decisions by its own officials, by other government officials with special knowledge acting on behalf of MENR, and/or by MENR consultants from the Sri Lankan academic, business and other communities.

d) Building institutional capacity for environmental management

Institutional capacity for environmental management is likely to be severely challenged by new demands linked to the tsunami disaster. Areas where capacity may need to be strengthened include coastal zone management planning, 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. Government plans that many of the half-million or so displaced people in Sri Lanka will be re-housed not on the sites of their original homes, but in new settlements. This is a consequence partly of people's new fear of the sea

Table 17. Sites requiring urgent intervention (from MENR, 2005a)

Location	Urgent intervention required
Valvetithurai - Point Pedro, Jaffna District	Clear shorefront of coral rubble and other debris; restore access channels for fishing boats; identify sites for building anchorages to protect fishing craft and gear without further depleting the coral reef; identify mechanisms for integrating the community into a self-managed fishing regime.
Vadamarachchi East: Maruthankerny-Vettilakerny, Jaffna District	Clear debris from nearshore sea bed; consider planting shelterbelts (e.g. of Casuarina sp, Pandanus sp.); explore the restoration of fishery livelihoods giving consideration to gender aspects and assessment of carrying capacity (both for shrimp and beach seine fishery).
Manalkadu, Jaffna District	Map sites for regulated sand mining. Revegetate and stabilize dunes. Restore drainage pathways blocked by sand drift. Stabilize banks of drainage channels. Assess groundwater quality.
Nilaveli, Trincomalee District	Restore farmland affected by salinity and sand deposition, agro-well restoration, investigations related to the water table, establishment of watershed vegetation.
Batticaloa lagoon and associated land, Batticaloa District	Define the role of the Batticaloa lagoon in sub-regional drainage, flood protection and prevention of water-logging; restore natural, shelter-belt and crop vegetation; identify resource conflicts stemming from new tidal inlets created by the tsunami.
Pasikudah-Kalkudah, Batticaloa District	Remove mines and other unexploded ordnance from coral reef areas.
Komari - Pottuvil, Ampara District	Identify land for resettlement sites in relation to freshwater supply, drainage, fishery livelihood, and tenurial and resource use conflicts.
Tangalla, Hambantota District	Restore paddy fields; prevent water-logging by restoring drainage; restore natural, shelter-belt and crop vegetation; identify options for enhancing livelihoods through environmentally-benign aquaculture.
Matara, Matara District	Restore paddy fields; prevent water-logging by restoring drainage; restore natural, shelter-belt and crop vegetation; identify options for enhancing livelihoods through environmentally-benign aquaculture.
Akurala-Seenigama, Galle District	Conduct detailed analysis of damage and contributing factors associated with coastal bathymetry.
KKS Rest House shorefront; Casuarina Beach, Aathikovilady, Supermadam (Pt. Pedro harbour area).	Clear debris from access pathways for fishing boats. Identify sites for stable sheltered anchorages while retaining optimal coral cover. Restore livelihood activity by providing appropriate number of craft and gear. Study resource sharing based upon existing customary practices.
Chundikulam, Jaffna District	Assess integrity of the district's only Protected Area.
Nayaru, Mullaitivu District	Investigate the recruitment and migratory patterns of the shrimp and fishery stock. Identify obstructions. Investigate extent of smothered seagrass beds. Rapid carrying capacity study. Highly significant shrimp fishery, substantial contribution to local livelihood, and local/regional economy.
Odu Lagoon-Nasiva (Valachenai), Batticaloa District	Restore mangroves in the first 300 metres on both sides of the lagoon.
Batticaloa-Vaharai, Batticaloa District	Restore mangroves on both sides of the road, where previously cleared for security reasons.

and a wish to live elsewhere, and partly of the closure of seaward parts of the coastal zone to habitation. The need to conduct adequate environmental impact assessments prior to the planning and construction of these settlements, and to monitor events thereafter, will exceed the capacity of the MENR and CEA to undertake this work. It is therefore recommended that the capacity of these institutions in these areas be strengthened. Such capacity building should involve an appropriate combination of training, addition of expert staff, resourcing to allow the use of national consultants, provision of appropriate equipment, hardware and software, and resourcing to support field work, data and sample analysis and reporting.

e) Building capacity for public participation in ecosystem restoration

Although central agencies such as MENR and CEA have a vital role in certain kinds of decision-making processes, there are important cost-effectiveness and sustainability advantages to be gained through decentralising other functions in natural resource and environmental management, including in waste management, ecosystem restoration and sustainable development. This strategic improvement of the planning process would respond to the fact that surveys of the tsunami-affected coastal region have confirmed that certain ecological conditions strongly modified wave impacts. In particular, coral reefs, vegetated dune systems and deep stands of mangrove forest all protected the coast, farms and settlements beyond them, while locations where such ecosystems had previously been damaged showed more intense damage. Recommendations concerning ecosystem restoration therefore emphasize the replacement, wherever possible and appropriate, of ecosystems known to help protect against big waves and similar environmental shocks. Decisions on what to do in each location would need to be made in the light of local conditions and development priorities, however, and cost-effective implementation would require beneficiary involvement and support. This would need detailed local planning and consensus-building for each section of coast, supported by government and civil society technical resources and with the full participation of local stakeholders.

It is recommended, therefore, to strengthen the capacity of local authorities (Municipal/Urban Councils and *Pradeshiya Sabha*) through the Ministry of Provincial Councils and Local Governments (MPCLG) to develop and implement such integrated local plans. This would involve facilitated discussion, learning and planning sessions at communities throughout the coastal zone to allow local authorities to work out how best to organize and mobilize the necessary labour. Officials of the MPCLG should be provided with training in the facilitation of such discussions, and also resourced to allow knowledge exchange with other informed stakeholders, studies to clarify technical issues that communities need to know about (such as the choice of appropriate species to be planted, methods of mass propagation, ways of re-establishing dunes and reefs), and the design of projects for local implementation. It is further recommended that this intervention be focussed on one or more pilot coastal areas, so that lessons can be learned and constraints identified and overcome.

It is likely to be important to remove debris from lagoons, estuaries and nearshore coastal seas and reefs, while also being feasible to replant mangroves and encourage the reformation of dunes that had been lost prior to the tsunami. Hence there are a number of sites where restoration should be encouraged, where appropriate on a 'cash-for-work' basis at the local level, to begin the process of ecosystem restoration, to support livelihoods, to build confidence and to teach lessons about what works and what does not. Such activities might include:

- Gathering mangrove propagules and planting them in locations where mangroves have previously been lost.

- Installing traps for wind-blown sand in locations where dunes had previously been lost.

- Collecting debris from reefs, lagoons and other wetlands.
- Collecting and destroying tsunami-dispersed propagules of alien invasive species.
- Replanting tsunami-damaged or cleared and abandoned lands with native vegetation to pre-empt colonization by alien invasive species.
- Establishing community marine protected areas.
- Conducting participatory environmental assessments of terrestrial ecosystems, in order to identify specific sites for ecosystem restoration.
- Monitoring changes in lagoon fish species and populations in collaboration with local fisherfolk.
- Restoring home gardens, plantations, bunds, banks, channels and other features of livelihood significance that also contribute to the complexity and resilience of the environments where people live.

f) Disseminating knowledge

Unexpected and unprepared-for disasters can be expected to impose on people at all levels and with all kinds of responsibilities the need to make decisions under conditions of stress and weak access to information. Some of these decisions may have unfortunate longer-term consequences, for example the use of mass graves, haphazard disposal of debris in drainage channels, the mixing of hazardous and other debris, and over-pumping of wells to clear contaminated or saline water. The easy availability of clear, simple, accurate guidelines in appropriate languages and formats is one important way to enhance confidence and guide people away from decisions that may have unnecessarily damaging consequences. The IUCN post-tsunami reconstruction guidelines (IUCN, 2005c-k) provide some information, but also needed are additional illustrated guidelines in appropriate languages to raise public awareness on:

- how safely to classify, separate, compost, re-use, recycle and dispose of solid waste and debris,
- how to design and construct improved housing and sanitation using safe materials (e.g. not including asbestos sheeting), and
- how to identify and correct environmental problems such as blocked land drainage, salinization, and the spread of alien invasive species.

Feelings of shock, apprehensiveness and disempowerment may be reduced through actions designed to raise awareness. Some of the information deficit could be relieved by providing information resources in the form of leaflets, but additional measures will need to focus awareness of tsunamis in particular and coastal hazards in general among affected and vulnerable communities, and among government officials at all levels. Materials should be based on scientific understanding of the causes of tsunamis and other coastal hazards, and the relevant concepts of exposure, vulnerability, risk, individual and collective responsibility, and the role of government.

g) Support priority setting by mapping coastal zone terrain

For all its convenience, the use of 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 resistance to big waves and storm surges. The 2004 tsunami penetrated onshore to a very variable extent that depended largely on vertical terrain, with flat areas without coastline defences being most extensively inundated. Hence it is recommended that a terrain map of the coastal zone be commissioned, ideally digital and at 1 m intervals up to 10 m elevation above mean sea level. If remote imagery and computer analysis cannot provide such a map at reasonable price, a physical survey using inclinometers and GPS should be undertaken instead, to map the 5 m and 10 m contours.

Even an approximate map would 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. The utility of such mapping would be further enhanced through bathymetrical surveys, especially of the embayments associated with extensive damage to the coastal built environment, and modelling of wave behaviour, which could help guide the establishment of coastal defence barriers, including breakwaters, dunes and plantations.

h) Encourage and enable regional collaboration

Various governments in the region have been working for some time on ecological restoration work in their coastal zones. These include Hainan Province of China and Tamil Nadu State of India, which have planted *Casuarina* shelterbelts as a defence against typhoons, and Bangladesh, Indonesia and Vietnam, all of which have planted substantial areas of mangroves. Other governmental and non-government institutions have also been involved in creating artificial coral reefs in the Philippines and elsewhere in the region. Valuable knowledge on what works and what does not is available as a result of this experience, which could contribute to better-informed decision making in Sri Lanka. Some of the most promising options concern coastal forests (e.g. FAO, 2005), and there is a need for exchange of information on existing and planned impact and damage assessments, rehabilitation and reconstruction activities related to forests and trees and for strengthening coordination and collaboration of national, regional and international agencies involved in forest rehabilitation and management of tsunami-affected areas. Hence there is a need for a regional partnership for information sharing, technical support and capacity building, the functions of which would be to provide access to information, to furnish technical knowledge, expertise, guidelines and tools, to support capacity building, and to strengthen partnerships, coordination arrangement and access to financial resources. It is recommended that Sri Lanka participate fully in the development of this partnership.

i) Build national consensus

Much information has become available as a result of post-tsunami assessments, with important implications for the options and priorities applicable to coastal zone planning. A knowledge-exchange process is needed to chart the future course of restoration and development in the coastal zone. Hence it is recommended that a number of Sri Lankan and other experts be gathered together as soon as possible for an extended brainstorming session, hosted jointly by MENR, CEA and TAFREN, to review the findings and recommendations of the post-tsunami environmental assessments, and to consider their implications for planning and development in the coastal zone, and build consensus around key priorities for action.

CONCLUDING OVERVIEW

In January to August 2005, concerted efforts have been made by MENR in collaboration with CEA and TAFREN, and in close association with UNEP, to ensure a unified and cohesive approach to environmental remediation in Sri Lanka. This has addressed the two main areas of remediation of damaged ecosystems and other environmental components, and integration of environmental factors in the post-tsunami recovery and reconstruction programme across several development sectors. Towards these ends the following has been achieved:

- **Environmental assessments** carried out by MENR and CEA with UNEP support, and others carried out by IUCN, NARA, ADB, World Bank, and other national and international organizations, have been collated and integrated in this report.

- **A common national platform** has been created among the three main agencies in Sri Lanka that deal with environment and development matters (i.e. MENR, CEA and TAFREN), which have been brought together under MENR leadership, to steer the implementation of the environmental remediation programme.

- **Coordination between central and local government** has been facilitated by a joint initiative of the Secretary of MENR, Chair of CEA and the Secretary of the Ministry of Public Administration, supported by UNEP, to bring the Government Agents of the 14 tsunami affected districts of Sri Lanka into the implementation process to encourage and enable a 'bottom-up' approach to the implementation effort.

- **Environmental help desks** have been established by MENR, in collaboration with CEA and with UNEP support, in Colombo and the affected districts to provide guidance in addressing on-the-ground problems that occur in the implementation process.

- **The UNDP-led Transitional Strategy** that reflects UN-wide support for Sri Lanka in the post-tsunami development and environmental remediation phase has been enriched by and harmonized with the results of the UNEP-supported environmental assessment.

- **There has been recognition by government agencies and the donor community** in Sri Lanka that the Environmental Remediation Plan developed by MENR-CEA-TAFREN with UNEP support in response to the assessment recommendations, comprises the sole environmental remediation plan of the Government of Sri Lanka.

- **The engagement of TAFREN with MENR and CEA** in planning the environmental remediation programme has ensured that the environmental programme is harmonized with the National Post-Tsunami Recovery and Reconstruction Strategy adopted at the World Bank-led Development Forum held in Sri Lanka in May 2005, at which the International community pledged US$3 billion for post-tsunami recovery and reconstruction work.

- **TAFREN's support has in turn been secured** in mobilising the various line ministries to integrate consideration of the environment into their respective post-tsunami reconstruction plans and programmes (housing, construction, fisheries, etc.).

- **As well as working closely with MENR, UNEP is represented in appropriate working groups** to ensure coordination with:

- the UN Country Team;
- the Ministry of Finance and Planning Working Group on Post-tsunami Recovery and Reconstruction;
- the Sri Lanka donors group;
- the UNDP Working Group on the Transitional Strategy;
- the MENR-CEA-TAFREN Common Platform (as invitee); and
- meetings of Government Agents of the 14 affected Districts.

The environmental assessments and parallel inter-institutional consensus-building processes resulted in a raft of recommendations being put forward by MENR (2005c), which were further refined into an Indicative Plan of Action for an Environmental Recovery Programme (Annex 2). The total indicative budget was for US$13,970,000, to be spent across ten themes: (1) Managing debris and waste; (2) Assessing & remediating environmental contamination; (3) Rehabilitating ecosystems; (4) Restoring land drainage; (5) Sustainable sourcing of sand; (6) Policy development & implementation; (7) Building capacity for environmental management; (8) Disseminating knowledge; (9) Disaster awareness and preparedness; and (10) Promoting public participation in ecosystem restoration. UNEP proposes to contribute selectively and strategically to some key activities within this portfolio (Table 18).

Table 18. Proposed UNEP activities in support of the Environmental Recovery Programme in Sri Lanka

Theme	Activity
1. Technical Assistance to "National Platform"	(a) Provision of international advisor to assist in driving the implementation of the recommendations. (b) Roundtable meetings in districts. (c) Support recruitment of national helpdesk advisors to the key districts.
2. Waste Management	(a) Organization of a UN Tsunami Waste Management Workshop. (b) Site assessment at 1-5 identified "hotspots". (c) Designing a proposal to address 5 - 10 selected hotspots.
3. Disaster Preparedness	Training on local-level environmental disaster preparedness (APELL).
4. City Development Strategy	Promoting participatory strategies for sustainable city development (piloted in Kalmunai).
5. Coastal Ecosystems Restoration	Small-scale demonstration projects on nature conservation, ecosystem restoration and livelihood development.
6. Environmental Coordination and Resource Mobilization	(a) UNEP will assist in integrating environmental aspects within all reconstruction activities in Sri Lanka through participation in the UN country team. (b) UNEP will help to mobilize support for the implementation of the recommendations of the assessment report.

BIBLIOGRAPHY

ADB (2005) *An initial assessment of the impact of the earthquake and tsunami of December 26, 2004 on South and Southeast Asia.* Asian Development Bank (Manila, the Philippines).

ADB, JBIC, JICA & WB (2005) *Sri Lanka 2005 Post-Tsunami Recovery Program; Preliminary Damage and Needs Assessment.* Asian Development Bank, Japan Bank for International Cooperation, Japan International Cooperation Agency and World Bank (Colombo, Sri Lanka).

Brander, R.W., Kench, P.S. & Hart, D. (2004) Spatial and temporal variations in wave characteristics across a reef platform, Warraber Island, Torres Strait, Australia. *Marine Geology 207*: 169-184.

CCD (2005) *(Environmental) Damage Assessment of the CERM SAM-Sites: Impact of the Tsunami and proposed actions.* Prepared by ARCADIS, IUCN & ECL for Coastal Resources Management Project (Coastal Environment and Resources Management [CERM] Component). Coast Conservation Department (Colombo, Sri Lanka).

DWLC (2005) *Damage Assessment of Protected Areas of the Department of Wildlife affected by Tsunami.* Department of Wild Life Conservation (Colombo, Sri Lanka).

FAO (2005) *Proceedings of a Regional Coordination Workshop on Rehabilitation of Tsunami-affected Forest Ecosystems: Strategies and New Directions.* Food and Agriculture Organization of the United Nations (Bangkok, Thailand, March 2005).

Frihy, O.E., El Ganaini, M.A., El Sayed, W.R and Iskander, M.M. (2004) The role of fringing coral reef in beach protection of Hurghada, Gulf of Suez, Red Sea of Egypt. *Ecological Engineering 22*: 17-25.

Hamilton, L.S. & Snedaker, S.C. (1984) *Handbook for Mangrove Area Management.* Environment and Policy Institute, East-West Centre (Honolulu, Hawaii, USA).

IUCN (2005a) *A Report on the Assessment of Tsunami Impacts on the Coastal Environment in Rekawa, Ussangoda and Kalametiya (RUK) Area of Southern Sri Lanka.* Prepared by C. Bambaradeniya, S. Ekanayake, S. Perera, R. Rodrigo, P. Samarawickrama & C. Asela. IUCN Sri Lanka Country Office (Colombo, Sri Lanka).

IUCN (2005b) *Rapid Environmental and Socio-Economic Assessment of Tsunami-Damage in Terrestrial and Marine Coastal Ecosystems of Ampara and Batticaloa Districts of Eastern Sri Lanka.* Prepared by C. Bambaradeniya, S. Sengupta, S., Perera, J. Tamelander, M. Meynell, M. Rust, S. Vidanage & S. Perera. IUCN Sri Lanka Country Office (Colombo, Sri Lanka).

IUCN (2005c) *Where to Reconstruct: Environmental Issues.* 'After the Tsunami' Best Practice Guidelines, No. 1. IUCN Sri Lanka (Colombo, Sri Lanka).

IUCN (2005d) *Dealing with Invasive Alien Species.* 'After the Tsunami' Best Practice Guidelines, No. 2. IUCN Sri Lanka (Colombo, Sri Lanka).

IUCN (2005e) *Materials for Reconstruction: Environmental issues.* 'After the Tsunami' Best Practice Guidelines, No. 3. IUCN Sri Lanka (Colombo, Sri Lanka).

IUCN (2005f) *Cleaning up reefs and beaches.* 'After the Tsunami' Best Practice Guidelines, No. 4. IUCN Sri Lanka (Colombo, Sri Lanka).

IUCN (2005g) *Solid Waste Management.* 'After the Tsunami' Best Practice Guidelines, No. 5. IUCN Sri Lanka (Colombo, Sri Lanka).

IUCN (2005h) *Recovery of Marine Ecosystems.* 'After the Tsunami' Best Practice Guidelines, No. 6. IUCN Sri Lanka (Colombo, Sri Lanka).

IUCN (2005i) *Restoring tourism: Environmental issues*. 'After the Tsunami' Best Practice Guidelines, No. 7. IUCN Sri Lanka (Colombo, Sri Lanka).

IUCN (2005j) *Learning to prepare for natural disasters*. 'After the Tsunami' Best Practice Guidelines, No. 8. IUCN Sri Lanka (Colombo, Sri Lanka).

IUCN (2005k) *Knowing about Environmental Policies and Legislation*. 'After the Tsunami' Best Practice Guidelines, No. 9. IUCN Sri Lanka (Colombo, Sri Lanka).

IWMI (2005) *Notes on preliminary tsunami damage rapid assessment for coastal wetlands in Sri Lanka (south coast)*. International Water Management Institute, January 2005.

Lugo-Fernandez, A., Roberts, H.H. and Wiseman, W.J. (1998). Tide effects of wave attenuation and wave set-up on a Caribbean coral reef. *Estuarine, Coastal and Shelf Science 47*: 385-393.

MacKenzie, D. (2005) Dead bodies pose no epidemic threat, say experts. NewScientist.com news service, 05 January 2005.

MFE (1997) *Designing an Optimum Protected Area System for Sri Lanka's Natural Forests*. Ministry of Forestry and Environment (Colombo, Sri Lanka).

MFE (1998) *Biodiversity Conservation in Sri Lanka: a Framework for Action*. Ministry of Forestry and Environment (Colombo, Sri Lanka).

MENR (2003) *Caring for the Environment 2003-2007 – Path to Sustainable Development*. Ministry of Environment and Natural Resources (Battaramulla, Sri Lanka).

MENR (2005a) *Rapid Assessment of Tsunami Damage to Natural Ecosystems and Associated Environments in the Coastal Zone of Sri Lanka. Volume 1: Text Report. Volume 2: Atlas of Tsunami Damage in Sri Lanka*. Ministry of Environment and Natural Resources (Battaramulla, Sri Lanka).

MENR (2005b) *Rapid Assessment of Tsunami Damage to Human Settlements and Associated Contamination Hazards in the Coastal Zone of Sri Lanka*. Ministry of Environment and Natural Resources (Battaramulla, Sri Lanka).

MENR (2005c) *Post-Tsunami Environmental Assessment in Sri Lanka: Recommendations for Environmental Recovery*. Ministry of Environment and Natural Resources (Battaramulla, Sri Lanka).

MENR (2005d) *Rapid Assessment of Tsunami Damage to Human Settlements and Associated Contamination Hazards in the Coastal Zone of Sri Lanka: hot-spots identified and their restoration*. Ministry of Environment and Natural Resources (Battaramulla, Sri Lanka).

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. and Kent, J. (2000) Biodiversity hotspots for conservation priorities. *Nature*, *403*:853-858.

NARA, IUCN, CORDIO & SLSAC (2005) *Rapid Assessment of Tsunami Damage to Coral Reefs in Sri Lanka: Interim Report, 19 January 2005*. Prepared by A. Rajasuriya, C. Karunarathna, J. Tamelander, N. Perera & M. Fernando). National Aquatic Resources Research and Development Agency, CORDIO/IUCN Regional Marine Programme, Sri Lanka Sub Aqua Club (Colombo, Sri Lanka).

Pearce, F. (2005) Tsunami's salt water may leave islands uninhabitable. NewScientist.com news service, 05 January 2005.

Pethiyagoda, R. & Manamendra-Arachchi, K. (1998) Evaluating Sri Lanka's amphibian biodiversity. *Occasional Papers of the Wildlife Heritage Trust*, *2*:1-12.

Pye-Smith, C. & Feyerabend, G.B. (1994) *The Wealth of Communities: Stories of Success in Local Environmental Management*. Earthscan (London).

Rajasuriya, A. (2005) *Report from Sri Lanka for the ICRI meeting in Seychelles, April 2005*. National Aquatic Resources Research and Development Agency (Colombo, Sri Lanka).

Rajasuriya, A., Hussein Zahir, Venkataraman, K., Zahirul Islam & Jerker Tamelander (2005) Status of coral reefs in South Asia: Bangladesh, Chagos, India, Maldives and Sri Lanka. In: *Status of Coral Reefs of the World 2004* (edited by C. Wilkinson). UNEP-WCMC (Cambridge, UK).

Roberts, H. & Suhada, J. N. (1983) Wave-current interactions on a shallow reef (Nicaragua, central America). *Coral Reefs* **1**: 209-214.

Senanayake, R. (2005) Lessons of the tsunami: beware the toxic sludge on the shoreline. *The Island*, 28 Jan 2005:8.

UNEP (2005) *UN Post-Tsunami Waste Management Plan*. UNEP (Geneva, Switzerland).

UNEP-WCMC (2005) *The role of coral reefs in mitigating wave impact*. UNEP World Conservation Monitoring Centre (Cambridge, UK).

UNEP/OCHA (2005) *Indian Ocean Tsunami Disaster of December 2004: UNDAC Rapid Environmental Assessment*. Joint UNEP/OCHA Environment Unit. http://ochaonline.un.org/ochaunep.

Young, E. (2005) Tsunami survivors need long-term psychological care. NewScientist.com news service, 05 January 2005.

ANNEXES

Annex 1. Acknowledgements

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Annex 2. Indicative Plan of Action

The Government of Sri Lanka's cross-sectorally agreed priorities for implementing the recommendations of the post-tsunami environmental assessments, also reflecting discussion and consensus between the government and the donor community.

Theme	Location & objective	Indicative budget, contributions and outstanding balance (US$ thousands)			
		Total	UNEP[1]	UNDP	Balance
1. Managing debris and waste	**Tsunami-affected areas.** Assist Local Authorities in the 14 affected coastal districts to undertake immediate sorting and environmentally- responsible disposal of debris and solid wastes at the local level by mobilizing the communities through cash for work programmes with the direction and guidance of CEA.	2,000	135	0	1,865
2. Assessing & remediating environmental contamination	**Component 1: Tsunami-affected water bodies.** Restore affected lagoons and estuaries (e.g. Karagan Lewaya, Hambantota, Shasthriwila, Panama, Arugam Bay). Sample and test marine sludge introduced to water bodies by the tsunami for heavy metals and other persistent pollutants; remove and dispose of safely as appropriate.	2,000	100	0	1,900
	Component 2: Abandoned and active mineral pits. Remedy pollution hotspots associated with solid waste dumping and sludge disposal (e.g. at Thelwatta, Akurala, Habaraduwa and Ambalangoda).	500	100	0	400
	Component 3: Regional knowledge sharing. Share information among countries on appropriate technology concerning the sampling and testing of marine sludge for persistent pollutants, and its removal and safe disposal.	75	0	0	75
	Component 4: Rehabilitating fishery harbours. Clean, rehabilitate, restore or reconstruct harbours as needed (e.g. Panadura, Beruwela, Hikkaduwa, Tangalle, Hambantota, Kirinda harbours and Arugam Bay, Kalladi Beach, Vallachchanai lagoon anchorages); correct sanitation and waste management issues.	2,500	0	0	2,500
3. Rehabilitating ecosystems	**Component 1: Special Area Management (SAM) sites.** Rehabilitate SAM sites through removal of debris and sludge, dilution of stagnant, anoxic and contaminated water, and restoration of pre-tsunami ecological conditions.	200	100	100	0
	Component 2: Protected Areas. Restore natural vegetation and eliminate alien species, restore damaged sand dunes, clear debris (e.g. Yala, Bundala).	100	0	0	100
	Component 3: Other wetland sites. Restore affected mangroves (e.g. in the first 300 meters on both sides of the Odu lagoon and on both sides of the Batticaloa-Vaharai road).	500	0	50	450

[1] In addition to these inputs, UNEP is also supporting the development and implementation of projects in tsunami-affected cities through the Cities Alliance, piloting this process in Kalmunai in eastern Sri Lanka with an initial commitment of US$50,000.

Annex 2, continued

Theme	Location & objective	Indicative budget, contributions and outstanding balance (US$ thousands)			
		Total	UNEP	UNDP	Balance
4. Restoring land drainage	**Tsunami-affected areas.** Clear sand and debris from drainage channels to prevent water-logging and impacts on farming and public health. Make new drainage as appropriate so as to minimize risk of water–logging.	300	50	0	250
5. Sustainable sourcing of sand	**Nationwide.** Identify areas where the landward sides of large sand-dune systems could be harvested for sand, or wind-blown sand could be trapped in commercial quantities, without affecting the dunes' ability to protect the coast.	30	30	0	0
6. Policy development & implementation	**Component 1: Nationwide.** MENR, CEA & TAFREN, supported by expert national consultations as needed, cooperate to ensure that environmental concerns are fully integrated in all decisions on national reconstruction, and to coordinate country-driven implementation of all relevant government recommendations.	40	20	0	20
	Component 2: Nationwide. MENR, CEA & TAFREN to develop an integrated national policy framework on the management of critical sectoral environmental issues arising from the tsunami with related Ministries, Departments and agencies at national and local levels, including: environmentally-responsible disposal of debris and solid wastes; extraction and sustainable supply of safe drinking water; restoration of effective drainage to farmlands and urban areas; prevention of deforestation from construction and resettlement. Develop mandatory guidelines to ensure uniform best practice.	60	20	0	40
	Component 3: Nationwide. Support MENR to broadbase multi-stakeholder participation including government officials, specialists, scientists, academics, business and other communities including civil society groups in policy development and implementation.	50	10	0	40
7. Building capacity for environmental management	**Nationwide.** Build capacity of MENR, CEA and District Level staff to implement all recommendations, including conducting EIA and establishing monitoring procedures prior to construction of new settlements and infrastructure, and the national component of the Early Warning and Rapid Repose Scheme through training, addition of expert staff, and resourcing to support field work, data and sample analysis and reporting.	2,000	170	0	1,830

Continued...

Annex 2, continued

Theme	Location & objective	Indicative budget, contributions and outstanding balance (US$ thousands)			
		Total	UNEP	UNDP	Balance
8. Promoting public participation in ecosystem restoration	**All affected districts and provinces.** Strengthening and resourcing local authorities through relevant government line agencies to develop and implement integrated local plans at the community, divisional and provincial levels that incorporate options for restoring ecosystems known to help protect against environmental shocks (e.g. mangroves, dunes, reefs, and wetlands) and restoring home gardens, plantations, bunds, banks, channels, and other features of livelihood significance that also help protect the environments where people live.	200	0	200	0
9. Disseminating knowledge	**Nationwide.** Produce and distribute simple, illustrated guides on how to safely handle, classify and process solid waste and debris, how to design and build improved housing and sanitation using safe materials, and how to identify and correct environmental problems such as blocked land drainage, salinization, and the spread of alien invasive species. Support to District Level actions	65	65	0	0
10. Disaster awareness and preparedness	**Nationwide.** Promotion and implementation of disaster awareness and preparedness, through capacity building at national and local levels including through UNEP's Awareness and Preparedness for Emergencies at Local Level (APELL) Programme, including demonstration(s).	100	100	0	0
11. Mapping coastal zone terrain	**Coastal zone.** Detailed mapping of coastal zone terrain (up to about the 10 m contour) to support priority setting for coastal defence activities.	3,000	0	0	3,000
12. Promoting regional collaboration	**Indian Ocean and South-east Asian regions.** Enable Sri Lanka to participate in regional partnerships that provide access to information, furnish technical knowledge, expertise, guidelines and tools, support capacity building, and strengthen coordination arrangements and access to financial resources.	150	0	0	150
13. Building national consensus	**Nationwide.** National forums for discussion on lessons learned from the tsunami and national priorities for restoration and development in the coastal zone.	100	0	0	100
	Total (US$ thousands)	13,970	900	350	12,720

Annex 3. Acronyms and abbreviations

ADB	Asian Development Bank
ATDTF	(UNEP) Asian Tsunami Disaster Task Force
CCD	Coast Conservation Department
CEA	Central Environmental Authority
CERM	Coastal Environment and Resource Management
CORDIO	Coral Reef Degradation in the Indian Ocean
DEPI	(UNEP) Division of Policy Implementation
DEWA	(UNEP) Division of Early Warning Assessment
DFID	(UK) Department for International Development
DPDL	(UNEP) Division of Policy Development and Law
DTIE	(UNEP) Division of Technology, Industry and Economics
DWLC	Department of Wild Life Conservation
EPCD	Environmental Pollution Control Division
FAO	Food and Agriculture Organization of the UN
FD	Forestry Department
GCRMN	Global Coral Reef Monitoring Network
GEF	Global Environment Facility
GDP	Gross Domestic Product
GIS	Geographical information system
GPA	(UNEP) Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
GPS	Global positioning system
HWMU	Hazardous Waste Management Unit
ICRAN	International Coral Reef Action Network
ICRC	International Committee of the Red Cross
ICRI	International Coral Reef Initiative
IETC	(UNEP) International Environmental Technology Centre
IUCN	The World Conservation Union
IWMI	International Water Management Institute
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
LTTE	Liberation Tigers of Tamil Eelam
MENR	Ministry of Environment and Natural Resources
MFOR	Ministry of Fisheries and Oceanic Resources
MOD	Ministry of Defence

Annex 3, continued

MPCLG	Ministry of Provincial Councils and Local Governments
MPPA	Marine Pollution Prevention Authority
NARA	National Aquatic Resources Research and Development Agency
NGO	Non-Governmental Organization
NREM	Natural Resources and Environmental Management
OCHA	(UN) Office for the Coordination of Humanitarian Affairs
PCAU	(UNEP) Post-Conflict Assessment Unit, Geneva
PPM	Pradeshiya Parisara Mandalay (divisional/local authority plan)
PPS	Palaath Parisara Sabha (provincial plan)
PS	Pradeshiya Sabha
REA	Rapid Environmental Assessment
RIEE	Rapid Initial Environmental Examination
ROAP	(UNEP) Regional Office for Asia and the Pacific, Bangkok
ROWA	(UNEP) Regional Office for West Asia, Bahrain
SACEP	South Asia Co-operative Environment Programme
SAM	Special Area Management
SIDA	Swedish International Development Agency
SKS	Sampath Kalaapa Sansadaya (community plan)
SLSAC	Sri Lanka Sub-Aqua Club
TAFREN	Task Force for Rebuilding the Nation
UDA	Urban Development Authority
UM	University of Moratuwa
UNDAC	United Nations Disaster Assessment and Coordination
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	US Agency for International Development
USJ	University of Sri Jayawardenapura
UXO	Unexploded ordnance
WB	World Bank
WCMC	(UNEP) World Conservation Monitoring Centre, Cambridge
WHO	World Health Organization
UNHCR	United Nations High Commission for Refugees

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