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Ecological impact of tsunami on Nicobar Islands (Camorta, Katchal, Nancowry and Trinkat)

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Assessment of tsunami-inflicted damage to island ecosystems assumes great importance owing to the life-sustaining and livelihood support abilities of the ecosystems. Apart from damages caused to life and property, significant damages were caused to ecosystems, which will have long-lasting effects. The tsunami-induced damage to coastal ecosystems was studied in four Nicobar Islands, viz. Camorta, Katchal, Nancowry and Trinkat. The extent of damages assessed ranged from 51 to 100% for mangrove ecosystems, 41 to 100% for coral reef ecosystems and 6.5 to 27% for forest ecosystems. The severity of damages and their consequences suggest the need for a definite restoration ecology programme.

TSUNAMIS are water waves generated by the disturbance associated with seismic activity, explosive volcanism, submarine landslide, meteorite impact with the ocean, or in some cases meteorological phenomena. These waves can be generated in oceans, bays, lakes or reservoirs. The term 'tsunami' in Japanese means harbour (*tsun*) wave (*ami*)[1]. The earthquake on 26 December 2004 with its epicentre at Sumatra, Indonesia triggered a tsunami which had a major impact on the Andaman and Nicobar Islands. The massive tsunami swept through the Indian Ocean region to become arguably the largest natural disaster in living memory. Initial reports indicate that natural ecological systems such as coral reefs, mangroves and wetlands have suffered extensive damages. This calamity highlights the key protective role of coral reefs, mangroves and the importance of CRZ (Coastal Regulation Zone) Notification. Physical damages might impact the structure and function of coastal ecosystems and their ability to sustain marine life and support livelihood of coastal communities. The extent of damage caused to coastal ecosystems and communities in Camorta, Katchal, Nancowry and Trinkat Islands is studied using remote sensing and GIS tools. Ecological impacts of tsunami are not available from previous scientific literature. This communication reports first-hand assessment of ecological damages caused by the December 2004 tsunami in some Nicobar Islands.

The Nicobar Islands are situated southeast of the Bay of Bengal. There are altogether 22 large and small islands, out of which only twelve have inhabitants. The latitudes and longitudes of the four islands under study are as follows: Camorta 7°59′12″–8°14′43″N, 93°25′49″–93°34′36″E, Katchal 7°51′50″–8°01′56″N, 93°17′41″–93°28′47″E, Nancowry 7°55′04″–8°01′57″N, 93°29′23″–93°35′01″E, and Trinkat 8°01′45″–8°08′48″N, 93°37′04″–93°37′30″E. Nancowry and Camorta have a hilly terrain covered with grass, forming undulating meadows. In Camorta, Empress Peak is the highest peak, about 1.420 ft high. Katchal is one of the largest islands in the central group. It is about 61 sq miles in area. It is slightly hilly at the centre, but otherwise it is remarkably flat. Trinkat is another small flat is-

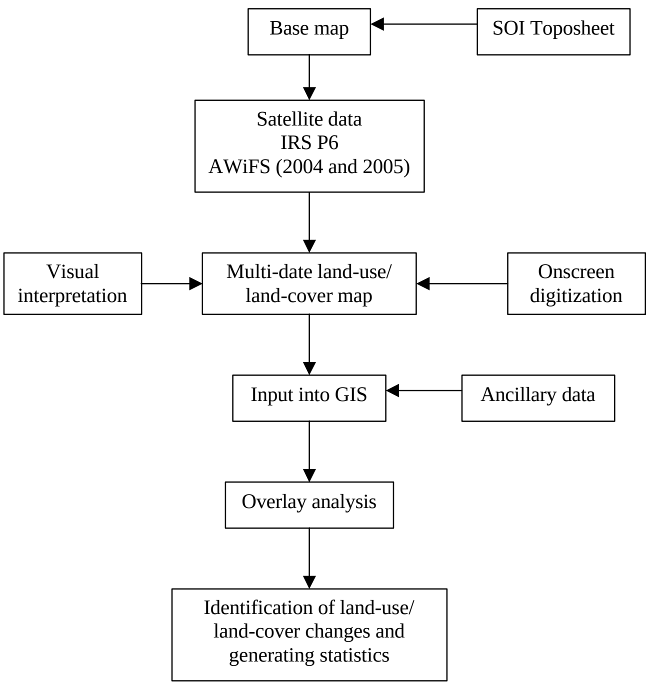

Figure 1. Methodology for land-use/land-cover mapping.

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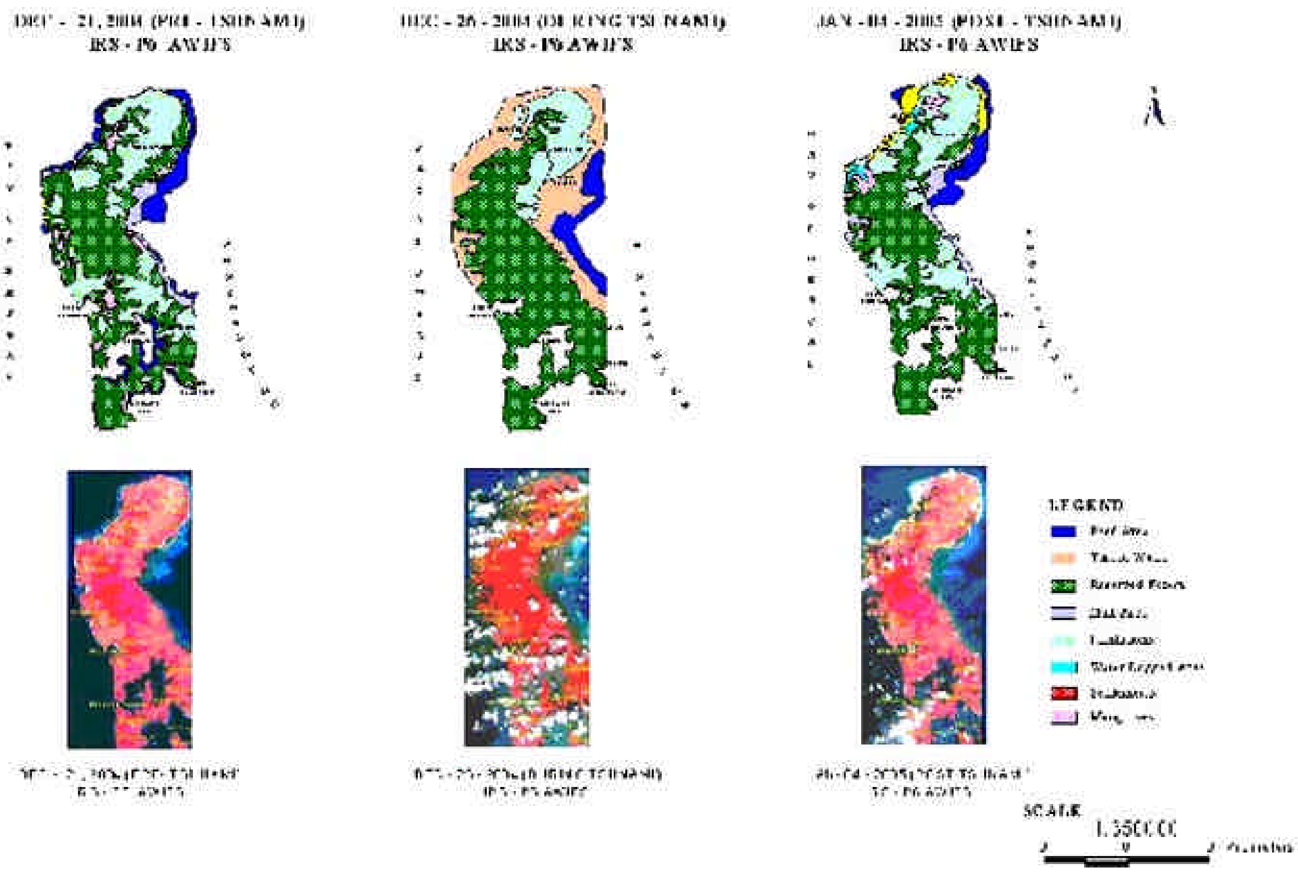

Figure 2. Comparison map of Camorta Island (pre-tsunami, tsunami and post-tsunami).

land having elevation less than 20 m for the most part. It is located at the eastern entrance to Nancowry harbour.

The ecological system of these islands is fragile. Nicobar Islands have considerable stock of marine life and are richly fringed by mangroves, coral reefs, sea grasses and seaweed ecosystems[2]. There are many varieties of fish like sardine, tuna, barracuda, mullet, mackerel, starfish and flying fish. Sharks and dolphins have been spotted. Whales have also been seen inside the Nancowry harbour. Other smaller marine animals found include turtle, octopus and crab.

Data products used in this study are SOI toposheets (1964), IRS P6 AWiFS (21 December 2004; before the tsunami), IRS P6 AWiFS (26 December 2004; during the tsunami), IRS P6 AWiFS (4 January 2005; after the tsunami) imageries and field information (GPS and socio-economic data). These data products were used to study land-use/ land-cover changes.

The methodology adopted for assessment of ecological damages in tsunami-affected islands in Nicobar was based on analysis of spatial and aspatial data (Figure 1). Application of remote sensing and GIS for studying the coastal wetland ecology of Andaman and Nicobar islands has already been reported[3]. Toposheets pertaining to Nicobar Islands were scanned and converted to image format. The images were rectified in such a manner that the spatial coordinates correspond to their geographic coordinates and then were resampled using cubic convolution method.

The projection applied in this study was geographic with spheroid Everest and datum undefined. The digital image was then registered using the resampled output of the toposheet to its corresponding geographic coordination. The registration was carried out by assigning approximately 50 Ground Control Points (GCPs) on the digital image. The land-use/land-cover classification was done following Space Application Centre guidelines[4]. The georeferenced land-use maps were digitized in ARC/INFO and were overlaid using tic coordinates of the study area. Digitized maps were edited, labelled and projected. Polyconic projections were adopted for area calculation. Changes in various coastal wetland cover and land-use changes before the tsunami (21 December 2004), during the tsunami (26 December 2004), after the tsunami (4 January 2005) and the environmental status and the extent of damage caused by the tsunami on the four selected islands were studied (Figures 2–5).

Tsunami-induced ecological damages are evident in all the four islands. There are damages to the structure and function of all the coastal ecosystems such as coral reefs, mangroves, sea grasses, estuarine mudflats, etc. The biological structure of the ecosystem could be easily disrupted as various species

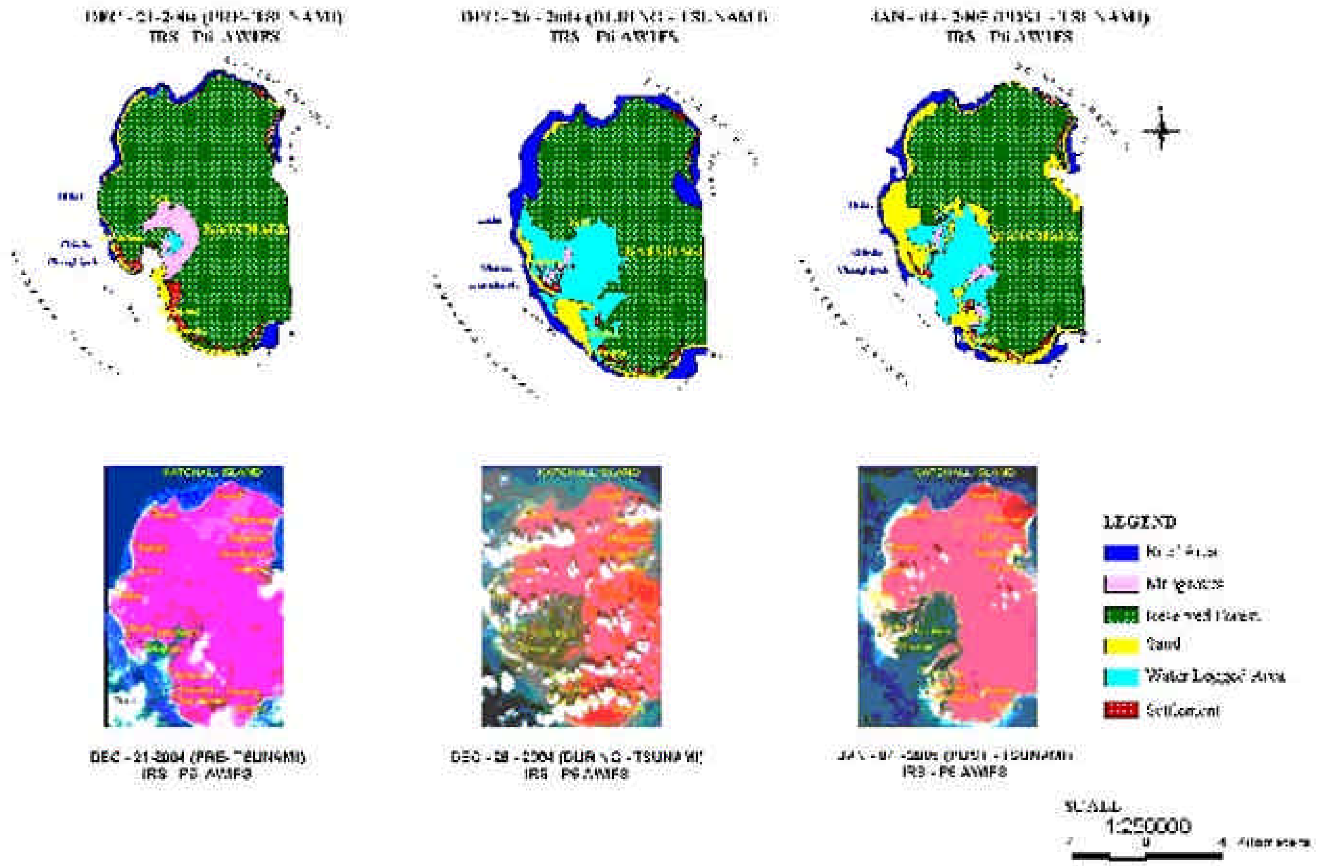

Figure 3. Comparison map of Katchal Island (pre-tsunami, tsunami and post-tsunami).

at different trophic levels were differentially removed, and with the structure altered, ecosystem functions could also be altered[5]. The tsunami-inflicted ecological damages can be studied under the following major categories.

The satellite images clearly show the coastal landscape changes in all the four islands studied. Being a low-lying island, Trinkat has suffered maximum damage. It has been cut into three pieces (Figure 5). This island has less than 20 m elevation. In the other three islands also, the low-lying coastlines have been drastically altered and the settlements in those areas are completely affected (Table 1). The inundated areas will severely affect the various ecosystems and the coastal organisms as discussed below.

The force of the tsunami will destroy all structures that it comes in contact with, including settlements, boats, etc. thus resulting in excessive debris. This debris is then dumped on the coast by the action of the waves. Coastal dumping pollutes the coastal waters. Figure 6 shows extensive littering on the beaches. This debris will slowly degrade and pollute the coastal waters and affect the active marine life inhabiting these waters. Such an effect will have long-lasting impact on the coastal ecosystems. Non-biodegradable waste such as plastics has contributed to a build-up in marine debris. Chemical changes have included salt-water intrusion, eutrophication (enrichment) of the water resulting from increased run-off, raw sewage and decomposition of flora and fauna, including unrecovered bodies. There will be slower decomposition of timber from mangroves, fishing boats and buildings. Coastal pollution will adversely affect the water quality and coastal marine life.

Mangroves, trees whose tangled roots grow above the ground in coastal swamps, are a unique habitat for wildlife like migratory birds, monkeys, lizards and turtles. Mangroves contribute directly to rural livelihoods by providing forest products – timber, poles, fuel wood and thatch for houses – and indirectly by providing spawning grounds and nutrients for fish and shellfish. Mangroves, which lie in the intertidal region between sea and land, help protect and stabilize coastlines and enrich coastal waters. They are more effective than concrete barriers in reducing erosion, trapping sediments and dissipating the energy of breaking waves. For example, villages in and around Bhitarkanika were spared much of the fury of the 1999 super cyclone due to the vast mangrove forest. Mangrove forests are themselves victims of the tsunami waves; young saplings in Nicobar Islands have been removed completely. Some of the larger trees have also been uprooted as the waters could easily enter these regions.

Land-cover estimates of the four islands showed the following changes. The mangrove areas were affected to the extent of 335.70 ha (51%) in Camorta, 339.03 ha (69%) in

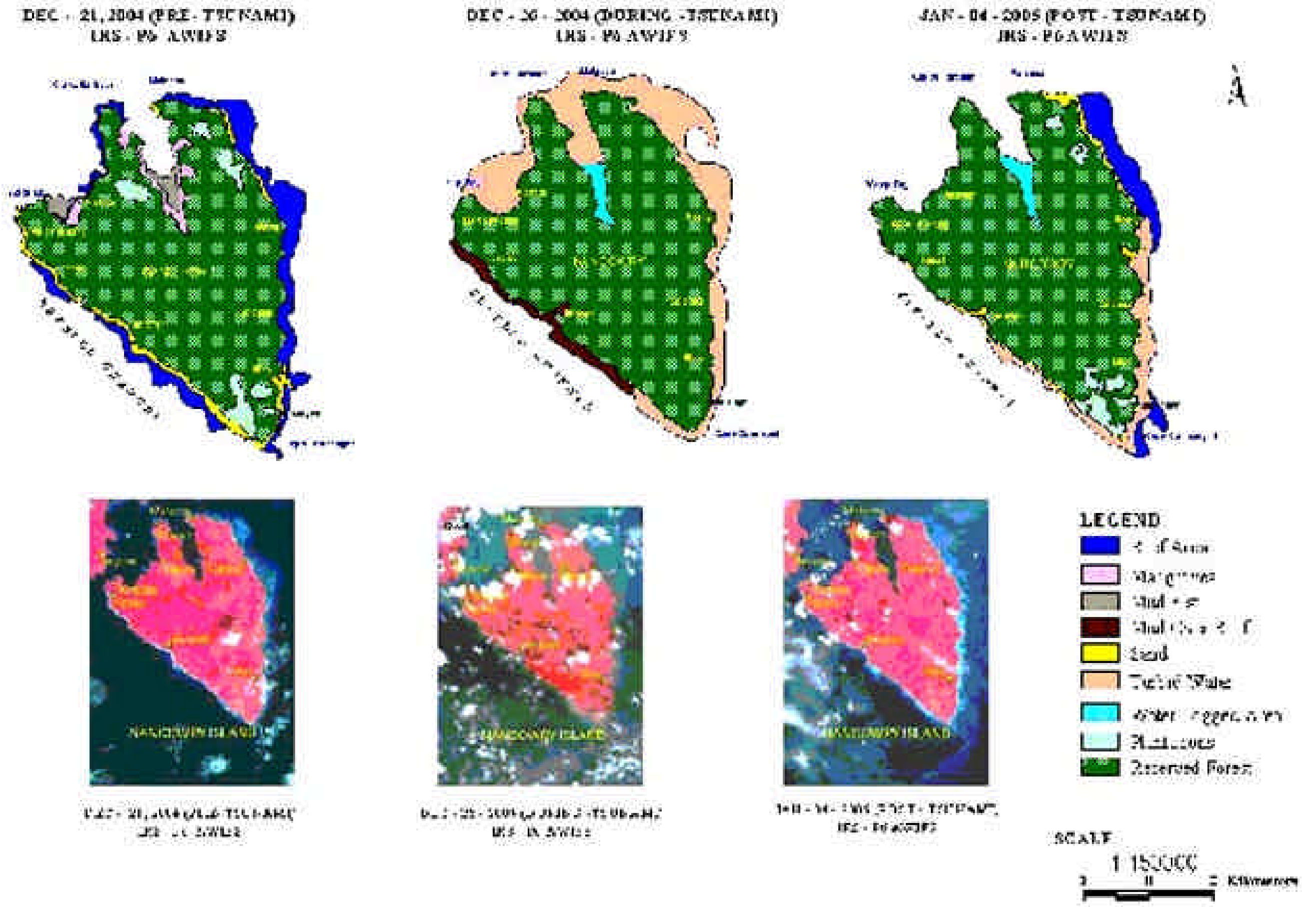

Figure 4. Comparison map of Nancowry Island (pre-tsunami, tsunami and post-tsunami).

Katchal, 152.53 ha (100%) in Nancowry and 240.06 ha (68%) in Trinkat. Such a major damage in mangrove area will severely affect the coastal productivity and destabilize coastal areas, which will accelerate shoreline erosion and increasingly affect the forest area due to salt-water intrusion into the forests. Since natural regeneration of mangroves will take considerable time (10 to 15 yrs), the impact on forest will be severe in these islands.

Although corals occupy less than one quarter of 1% of the marine environment, coral reefs are home to more than a quarter of all known marine fish species. They provide food, livelihood and other essential services to hundreds of millions of coastal-dwellers, as critical fish habitat, popular destinations for ecotourism, or protection to coastal communities from storms and hurricanes. Coral formations act as buffers during storm surges and tidal waves. When giant tsunami waves smashed onto the shores, the massive backwash returned to sea carrying a deadly cargo that could destroy the vital coral reefs of the region. The coral in nearby shallow areas have been destroyed, crushed and shrouded in debris. The tsunami surge, which has gone through mangroves, has ripped them completely, releasing silt, sediments, nutrients and pollutants. Coral reefs are mainly affected due to siltation, which occurs as a result of the tsunami. Siltation leads to choking and death of the live coral reefs. The effect of coastal pollution, added to raw sewage released by the disaster, could further harm coral habitats and threaten already depleted fish stocks. Extensive damage to coral reef is seen in all the four islands. The extent of reef area affected is 41% at Camorta, 49% at Katchal, 53% at Nancowry and 59% at Trinkat.

On the day of the tsunami and after, extensive silt-laden turbid waters were seen all over the reef area. Such turbid waters were mapped using satellite imageries and they were observed to cover an area of 400.71 ha in Nancowry and about 552.44 ha in Trinkat. The effect decreased after ten days, but silt and mud were found to be deposited on the reef area. If the mud settled on these reefs is not removed, the coral polyps will die and never regenerate. This will lead to permanent loss of coral reef in these islands. The physical structure has been damaged by the force of the wave itself. Physical removal of flora and fauna and increased sediment load kills sediment-sensitive corals and sea grasses by smothering. The extent of this damage is not known and is likely to vary depending on local topography and hydrology.

Considerable forest and plantation areas were flooded by the tsunami. The forest areas inundated by the tsunami are

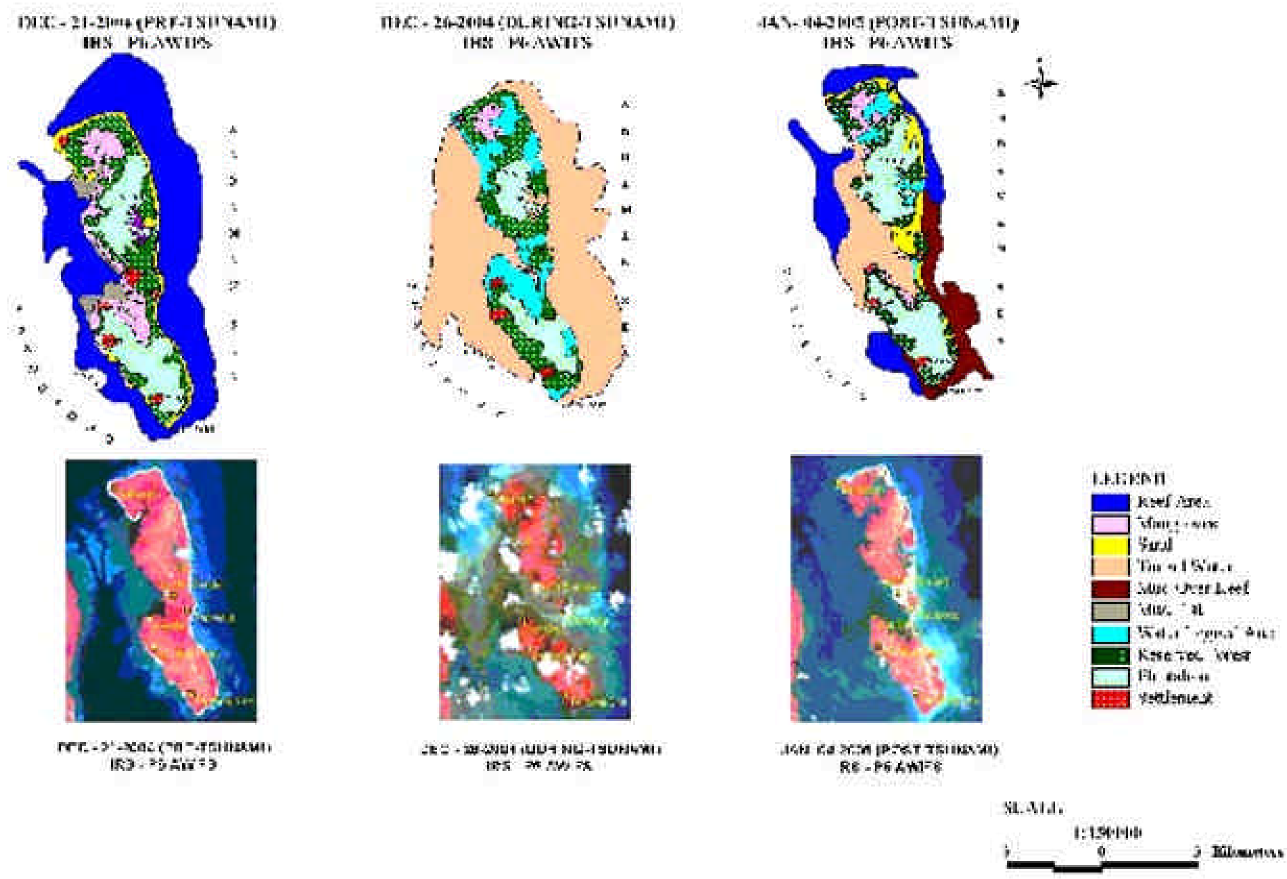

Figure 5. Comparison map of Trinkat Island (pre-tsunami, tsunami and post-tsunami).

Figure 6. Destruction of settlements by tsunami.

540.31 ha (6.5%) in Camorta, 1787 ha (18%) in Katchal, 142.49 ha (25%) in Trinkat and 148.13 ha (3%) in Nancowry. The plantation areas inundated were 362.42 ha (8%) in Camorta, 68.06 ha (27%) in Nancowry and 4.53 ha (0.69%) in Trinkat. The flooded sea water remains in the area for days and when it evaporates, it increases the soil salinity. This will affect the entire forest ecosystem, especially the micro flora of the forest ecosystem that helps in remineralization and fertilization process of this ecosystem.

Sand bars and sand dunes act as a buffer against storms and tidal surges. Removal and deposition of sand dunes has been witnessed due to tsunamis. Sand dunes have helped reduce the impact of the tsunami and this has helped protect the nearby settlements from being destroyed. Changes in sediment transport pattern and loss of sea turtle nesting grounds due to removal of sand from the beaches have also been seen on the islands. The sandy areas have considerably increased in two of the four islands. The increase in the extent of sandy beaches after the tsunami was 18.7 ha in Trinkat and 1242.02 ha in Katchal, whereas decrease in sand cover is witnessed in Camorta 368.72 ha (103.43%) and Nancowry 78.98 ha (31%).

A change in the physical environment will affect the biodiversity of a region. Changes in the chemistry of the water is another factor that will affect biodiversity. For example, muddy coasts could now have become sandy coasts and vice versa. Fish populations are greatly affected due to vibrations and shock. The tsunami has affected the Indian Ocean turtle project areas and habitats, especially in Campbell Bay. Also, the effect on sea life and associated ecosystems could be massive. There is concern that marine life in Nicobar could take centuries to recover after being devastated by the tsunami.

The tsunami tidal waves have transported large volumes of sea water into inland water bodies and have also created

Table 1. Extent of area (ha) affected by the tsunami

Class	21st December 2004	4th January 2005	Change in area	Percentage area change
Camorta Island				
Mangroves	651.94	316.24	–335.70	–51
Plantation	4509.44	4147.02	–362.42	–8
Reserved forest	8311.73	7771.42	–540.31	–7
Sand	356.49	725.21	+368.72	+103
Settlements	32.82	27.04	–5.78	–17
Mud over reef	733.24	896.93	+163.69	+22
Reef area	1775.12	1035.97	–739.15	–41
Waterlogged area	–	283.12	–	–
Katchal Island				
Mangroves	576.37	177.34	–399.03	–69
Reserved forest	9801.72	8014.72	–1787.00	–18
Sand	473.82	1715.84	+1242.02	+262
Reef area	548.48	–	–	–
Waterlogged area	–	1640.60	–	–
Settlements	340.52	222.85	–117.67	–35
Nancowry Island				
Mangroves	152.53	0.00	–152.53	–100
Plantation	244.32	176.26	–68.06	–27
Reserved forest	4212.49	4064.36	–148.13	–3
Settlements	25.42	–	–	–
Sand	254.32	175.34	–78.98	–31
Reef area	829.13	381.98	–447.15	–53
Mud flat	106.39	–	–	–
Waterlogged area	–	91.07	–	–
Trinkat Island				
Mangroves	352.93	112.33	–240.60	–68
Plantation	649.10	644.57	–4.53	–1
Reserved forest	561.58	419.09	–142.49	–25
Sand	195.38	214.08	+18.70	+10
Settlements	71.52	30.09	–41.43	–58
Reef area	2432.12	986.47	–1445.65	–59
Mud over reef	–	440.01	–	–
Turbid water	–	552.44	–	–
Waterlogged area	–	126.89	–	–

large tidal pools of sea water. Based on a survey, it is seen that sea water percolates into coastal freshwater aquifers and salinizes them. Coastal freshwater aquifers are the major sources of drinking water in coastal areas.

Remote sensing and GIS techniques are useful to provide practical, robust and cost-efficient output for environmental protection and management. Remote sensing technique is useful for mapping and assessing ecological impacts caused by tsunamis, so that it is possible to take immediate remedial measures; suitable eco-friendly guidelines like CRZ can be implemented easily to save life and property. The worst damage could have been avoided by recognizing suitable limits and adhering to some simple environmental guidelines and standards.

Recommendations for further action are: removal of mud and silt from reef areas, removal of debris and other materials from beaches and mangrove areas, afforestation of deforested areas, including mangroves and resettlement of coastal population in safer zones.

Considering the extent of damage, the need of the hour is to initiate restoration of coastal ecology through an Integrated Coastal Zone Management plan.

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